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Evaluation of Options for Remodelling of Upper Jhelum Canal, Pakistan

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Abstract-The paper develops and implements remodeling approach for alluvial irrigation channels. The approach mainly includes in-depth analysis of original/existing design parameters, identification of existing condition of channel and hydraulic structures along with their problems, evaluating different options and finalizing the remodeling parameters by emphasizing hydraulic, structural and economic consideration. Upper Jhelum canal in Pakistan was selected as case study channel. The condition survey of channel was conducted which showed that it was facing multiple problems i.e. excessive silt deposition, erosion of banks, inadequate freeboard, side embayment and widened channel section. The channel was unable to run at the design discharge and therefore required remodelling. The reasons for multiple problems were diagnosed during the study. The analysis showed that the viable approach for remodeling of subject canal is at enhanced design parameters. Different options were developed by varying different hydraulic parameters and possible economical solutions were analyzed using different approaches to suggest the most suitable remodelling strategy for UJC. The existing parameters with minimum change became basis for re-designing of the channel by different approaches i.e. Lacey's regime theory, Manning's formula and Tractive force method. Sensitivity analysis was also carried out to finalize the design parameters emphasizing hydraulic, structural and economical consideration. The remodelling of UJC as per recommended parameters will ensure increased agriculture and power benefits and enhance conveyance efficiency.

Keywords-Upper Jhelum Canal, Remodelling, Alluvial Channel, Canal Problems

I. INTRODUCTION

Remodelling of irrigation channels is a process of restoring or modernization of existing system including all hydraulic structures at same/modified design parameters. Food and Agriculture Organization (FAO) [i] discussed that detailed diagnosis including the performance, present condition, original design and other deficiencies are very important for remodelling and modernization of any irrigation system. Shakir and Khan [ii] critically investigated the previous structural interventions for their viability and effectiveness for Marala Ravi Link Canal in Pakistan. The enhancement of crest level was also checked and found that it was effective in reducing sediment intake of MR Link Canal to some extent but did not make any impact in reducing the sediment entry to its offtakes including Upper Chanab Canal. The sediment management problems of Marala Barrage were also reviewed in the study. Different operational scenarios of Upper Swat Canal (USC) were investigated and quantified based on fixed frequency operation. Tariq and Latif [iii] suggested operating the channel at 8090% of the design discharge during May to July, and 7590% of the design discharge from August to April to reduce water losses due to high water allowance.

The important parameter for remodelling of irrigation channels change in concept, structure and design. It considers modification in technology, techniques and future consideration of future needs of operation and maintenance [iv]. The provision of food and fibre requirement of people is one of the challenges of this century. To fulfill these basic needs of rapidly growing population water resources and irrigation system to efficiently take water up to fields are utmost important. The Indus Basin Irrigation System (IBIS) being the largest contiguous irrigation system of the world, comprises of 12 inter river link channel, 45 canal systems, about 100,000 tertiary channels, 16 barrages and 3 major reservoirs including Mangla, Tarbela and Chashma. The IBIS commands cultural command area of 14 million hectares. Total length of primary, secondary and tertiary channels are 56128 km. IBIS utilizes 51.3 billion cubic meter (BCM) groundwater pumped through more than 800,000 tube-wells to add-on the canal supplies [v].

The importance of efficient use of irrigation water is necessarily increasing as the world population is increasing. At this stage the country would need more food and fibre to meet the needs of growing

population. This shortfall can be met either by constructing new reservoirs or irrigation water management at canal command level [vi]. Irrigation water management includes improvement of physical infrastructure for distribution of water from source to the crops and water management at the farm level [vii]. Shakir et al. [viii] suggested optimization measures for improving water management in Lower Jhelum Canal command in Pakistan which includes enhancing productivity by using crops having higher values and yields, enhancing conveyance efficiency, adopting conservation techniques including bed-furrows, laser land leveling, zero tillage and on-farm water management. The structural measures identified for improving canal management includes rationalization of canal capacities in keeping with the current water requirements and availability, rehabilitation and remodeling of canal along with its hydraulic structures, restoration of prism, raising and strengthening of canal banks and lining of distributaries and minors may lead towards optimization of irrigation system of LJC command.

FAO [ix] presented detailed methodology for modernization of medium to large irrigation canal systems for improving performance. The strategy was developed for analyzing channel optimization on the basis of Mapping System and Services for Canal Operation Techniques (MASSCOTE). During the process of remodeling and modernization, the expectations and achievements had to be kept at realistic and practical level. The most economical and easy-to-implement options were selected to start the process of modernization. Irrigation system management includes equitable and efficient distribution of water. Computation of irrigation demands and matching water supplies are also very important for successful irrigation system. In addition, irrigation system should be kept in operating condition throughout the season to achieve the desired objectives. Shakir and Nasir [x] reviewed the problems of Upper Chenab Canal in Pakistan. Water availability studies were carried out to ensure the reliability of enhanced water for irrigation, power and other benefits. It was suggested that the economical solution for remodelling of the channel was by increasing its water depth instead of enhancing the bed width. It will reduce the cost of remodelling of hydraulic structures of UCC. The opinion of users through Farmer Organizations (FO) should be considered for devising and implementation of remodelling projects [xi]. FO participation should be ensured while computing design of outlets, constructing and remodelling channels along with their commissioning for monitoring and ensuring equitable distribution.

Pakistan has one of the largest contiguous irrigation systems of the world. The rehabilitation and remodelling of irrigation canals along with their hydraulic structures have always been an ongoing process for Pakistan and other countries of the world. Some theories of designing of irrigation channels are available in literature i.e. Lacey's regime method, Tractive force method and Manning's formula. However, the topic of remodelling and rehabilitation of alluvial channels also desires practical and hands on experience of problems solving and does not much available in literature. The objectives of this study are i) to develop approach/methodology for remodeling of irrigation channels by consulting literature and practical experience and ii) to apply the developed approach to remodelling of Upper Jhelum Canal, Pakistan (case study channel).

II. Approach/Methodology for Remodeling of Irrigation Channels

The approach developed for remodelling of alluvial irrigation channels is as follows:

In-depth analysis of original/existing design approaches and parameters

Conduct condition survey to access the existing condition of channel along with hydraulic structures and access the reasons for developing problems

Develop and evaluate different options for remodeling

Selection of parameters for remodelling of irrigation channel including design discharge, longitudinal slope and water levels, bed width and depth

Design of irrigation channel by different methods and sensitivity analysis to finalize the design parameters

Finalize the remodeling approach based on hydraulic, structural and economic consideration

III. Case Study of Upper Jhelum Canal (UJC)

Upper Jhelum Canal (UJC) offtakes from Mangla head works of Jhelum River. It was designed in 1904 and commissioned in 1915 primarily as a feeder channel to supplement the supplies of Khanki headworks at Chanab River for Lower Chanab Canal system. It has total length of 142 km and original design discharge was 12800 cusecs. Its gross and culturable command areas are 642447 and 603749 acres respectively. However, the channel was redesign in 1941. It also supplies water for two Hydro power stations namely Rasul and Shadiwal having power potential of 22 and 12 MW respectively, constructed later on. UJC also fulfils the water requirements of Khanki headworks of River Chanab during low flows in river Chanab. After commissioning of Mangla Dam and Mangla Powerhouse, a new channel Bong Canal having designed capacity of 49,000 cusecs, was

constructed. The Bong canal offtakes from Mangla Powerhouse for feeding irrigation requirements of UJC and the downstream water requirements at Rasul barrage. The UJC head regulator is located at 8.4 km (RD 27+500 feet).

IV. Site Visit to Conduct Condition Survey of UJC

The site was visited during flow and closure periods of the canal to observe existing condition of the channel and hydraulic structures. Some problems observed during the site visit include but are not limited to:

Excessive silt deposition and scouring
Erosion of banks
Inadequate freeboard
Side embayment and widened channel section
Deteriorated condition of super structure of some hydraulic Structures

Excessive Silt Deposition and Scouring

The channel bed was found slightly scoured in few head reaches up to RD 244+000. However, excessive silt deposition was observed through the entire reach of the channel from RD 244+000 to 418+000 (Tail). The silt deposition was measured at some locations and found in the range of 3-5 ft. The longitudinal section of the channel shows that the head reach was constructed by cutting local soils whereas middle and tail reaches were constructed in filling of local soil. A typical photograph of excessive silt deposition of UJC is shown as Fig. 1.The channel was found widened oddly in tail reaches and became nonoperational at design discharge.

Fig. 1. Excessive silt deposition at 109.73 km of UJC

Erosion of Banks

The banks of the channel were found eroded in several reaches throughout the channel and especially in the tail reaches. Apparently banks seem to be made of local soils having less cohesive particles. Excessive bank erosions have also caused excessive water losses, less efficiency of canal system and canal breaches. The erosion of banks is also one of the problems which do not allow the canal to be operated at its design discharge. Figure 2 shows erosion of banks at typical location of UJC.

Fig. 2. Erosion of banks downstream at 99.02 km of UJC

Inadequate Freeboard

During condition survey, the water marks on the banks confirmed that recommended freeboard of 3 ft was not available in some reaches of the channel because of bank erosion, weather action, less maintenance and widened sections. It resulted in canal operation at lesser discharges compared with the design discharge. The canal has been run at even less than 50% of its design discharge since last 10 years. The freeboard was also found short at the upstream of some hydraulic structures. Fig. 3 depicts typical inadequate freeboard of UJC.

Fig. 3. Inadequate freeboard at 97.61 km of UJC

Side Embayment and Widened of Channel Section

The side embayment was observed at downstream of hydraulic structures of Upper Jhelum Canal. The channel was constructed by fluming the channel width at hydraulic structure to reduce the construction cost. The transition provided for divergence and

convergence of flowing water at downstream and upstream was found unproductive. The Fig. 4 shows the excessive side embayment and widened section of UJC resulting in non operation at its required design discharge. The currents generated downstream of these structures traveled long distances along the canal before merging into normal depth of streamline flow. The undulating flow pattern generated channel instability and side embayment.

Fig. 4. Side Embayment and Widened section at 97.61 km of UJC

Deteriorated Condition of Super Structure of Few Hydraulic Structures

The channel has more than 100 hydraulic structures including bridges, falls, level crossings, siphons, cross-regulators and head regulators of offtaking channels. Most of the hydraulic structures are as old as the canal. Silt deposition was found on the upstream (u/s) and downstream (d/s) floors of the structures. Apparently the hydraulic performance of the structures was found satisfactory. However, the superstructures including deck slab of some hydraulic structures need repair and replacement. The trend of energy dissipation arrangement of the hydraulic structures was found effective as no scouring of bed and major side embayment were observed at their downstream. As such, the present condition of piers and foundations was found satisfactory. The water marks on piers shows that 2 - 3 ft free board is available near the hydraulic structures.

Fig. 5. Damaged Deck Slab and parapet of bridge at 122.6 km of UJC

The possible reason for high silt deposition in the tail reaches and scouring in the head reaches is the entry of silt free water after the commissioning of Mangla reservoir in 1967. From historic operation of the channel, it has been observed that less discharge and less velocity have also facilitated the silt deposition and bank erosion. The reason for less discharge may be due to less availability of water or less demand for UJC. Proper maintenance of the channel and hydraulic structures have not been carried out. The operation of canal at substantially less discharge than its design discharge, deferred maintenance and monitoring seems to be the reasons for the said problems. All the above mentioned factors lead to reducing the efficiency and enhancing conveyance losses of UJC.

V. Design Discharge for Remodeling of UJC

The original design discharge of the channel was 12800 cusecs (as of 1915). The channel was redesigned for 8893 cusecs due to less availability of water in 1941 according to Manning's formula. There was no provision of supplies for two power houses namely Rasul and Shadiwal when the canal was designed in 1915 and 1941. During last 10 years, the channel has been operated at less discharge. It has been noticed that only 116 m^3/s has passed downstream khokhra (77.77 km of UJC) against the allocated discharge of 185 m^3/s during last several years. The possible reasons for less discharge are: i) the less availability of water and ii) inability of the channel (middle and tail reaches) for safely carrying the original design discharge. The current authorized head and tail discharges of the UJC are 255.7 m^3/s (9030 cusecs) and 222.8 m^3/s (7868 cucecs).

The design discharge of an irrigation channel is usually based on culturable command area (CCA) and sanctioned water allowance. The design discharge for remodeling may be enhanced by assuring the additional water through water availability studies. Pakistan Drainage Consultants (PDC) [xii] discussed that perennial irrigation channel should be atleast designed at reliability of 80% available water. The increase in CCA and commissioning of power houses necessitates updating the design discharge for the remodeling. The raising of Mangla Dam in 2009 has enhanced its live storage capacity from 4.51 to 7.39 MAF. The Mangla reservoir has 2.88 MAF additional storage available which may be used for acquiring power and agriculture benefits. The additional water may be utilized for enhancing the discharge of UJC as per Water Apportionment Accord among the provinces of Pakistan. Punjab Irrigation Department (PID) [xiii] proposed the revised capacity of UJC by computing the discharges of all offtakes, power houses and losses as follows:

Discharge for offtakes of Azad Kashmir = 1.5 m^3/s
Discharge for Rasul Power House = 102.6 m^3/s
UJC Internal (Gujrat Branch & other offtakes) = 57.7 m^3/s
Shadiwal Power House = 220.9 m^3/s
Approximate conveyance losses = 38.3 m^3/s
Total Revised Capacity of UJC = 420.51 m^3/s

VI. Evaluation of Possible Options

The possible options for remodeling are as follows:

I. To remodel the canal for existing discharge of 255.70 m^3/s at existing hydraulic parameters and fulfill the needs of Shadiwal power house and Khanki headworks at Chanab River for Lower Chanab Canal system through some alternate route including developing new channel.
II. To remodel the channel for increased discharge of 420.51 m^3/s by minimum variation of existing parameters i.e. bed and water levels, longitudinal slope, water depth and bed width

The 1st option for remodeling was analyzed technically and economically. The present condition indicates that the bed width of the channel has substantially increased from 230 to 330 ft in the middle and tail reaches and full supply has reduced from 10.2 to 5 ft. Moreover, recommended freeboard of 3 ft was not available. The width to depth (B/D) ratio of the channel has been enhanced upto 55. The channel does not provide the desired velocity and results in high conveyance losses and sediment deposition. The existing condition of the channel presents the view of a natural river. The existing dimensions and parameters of the channel including water depth, bed with, velocity and others are not considered hydraulically feasible for remodeling of UJC at 255.7 m^3/s. The development of new channel would involve cost of acquiring new land, constructing several hydraulic structures, availability of good soil and construction material (cement, sand, crush, steel etc) including engineering services which seems to be very expensive. The acquiring of land is also very complicated and time consuming process. The site visit indicated a few problems in technical design of the new channel in setting its alignment due to physical constraints including displacement of roads and other infrastructure. The cost of this option will be much higher as compared to the 1st option not considered technically and economically feasible.

The 2nd option of remodeling of the UJC at enhanced discharge seems to be feasible. The channel was originally designed for discharge more than 362.5 m^3/s (12800 Cs). The enhanced discharge is only about 15% more than the original discharge of 1904. The original design, modified design and existing dimensions of the channel are shown in Table I. Two reaches indicating entire length of UJC have been shown in Table 1 and developed on the basis of significant difference in discharge and other hydraulic parameters. The channel was originally designed in 1904 on the basis of Manning's formula. The approved L-Section shows that the basis of redesign in 1941 was again on Manning's formula by keeping the roughness coefficient (n) of soil as 0.0225.

Critical review of different design approaches including Lacey regime method, Tractive force method and Manning's formula have been carried out for their suitability of redesign of UJC. These methods proposed change in bed width, full supply depth and longitudinal slope of whole channel. The change in these parameters would require re-construction of UJC along with its hydraulic structures which will increase the remodelling cost. It would also require the cost of land acquisition and construction of diversion channel. The preliminary investigation indicated that remodeling of UJC at existing parameters along with enhanced depth would be economical solution. In this case only earthwork of banks would only be desired. However, to bring the existing bed width (260 m 330 m) to original bed width of 220 m would involve huge earthwork along with removing of earthwork. The remodeling of channel at existing bed width and longitudinal slope and by changing depth will reduce the remodeling cost to a great extent. However, the increased existing bed width of the channel does not provide stable and efficient design.

TABLE I
Design and Existing Parameters of Upper Jhelum Canal (UJC)

Design Parameters	Original Design (1904)	Design (1941)	Average Existing Parameter	
			Head Reach upto 74.4 km	Tail Reach 74.4 - 127.4 km
Discharge, Q (Cs)	12800	8893	7700	4100
Bed Width, B (ft)	228	223	240	270
Full Supply Depth, (ft)	13	10.2	9.5 - 11.5	5 - 7
Side Slope	1.5	1.5	1.5	1
Longitudinal Slope (I/slope)	6667	6667	6667	6667
Bed width to Depth (B/D) ratio	17.54	21.86	20 - 25	38 - 55

The average existing width to depth ratio (b/d) has been enhanced to 55. The increase in b/d ratio of the channel is associated with accelerated bank erosion rates, excess deposition/aggradation processes and over-widening. The re-design of the channel at such high B/D ratio does not seem to be efficient. The data of existing alluvial channels in the same region having similar topographic characteristics and discharges as of UJC, the maximum suitable range of B/D ratio of 16-23 was found. Therefore it is suggested to slightly decrease the bed width and increase the depth to get the B/D ratio within the specified range of efficient and stable design. The existing slope may also be considered as constraint to be kept same for remodeling of UJC. The hydraulic parameters computed by different design approaches for remodeling of UJC are provided in Table II.

Lacey's regime method is most extensively used method for hydraulic design of alluvial irrigation channels. Functioning of these channels depicts regime canals designed with Lacey's parameters. The suggested depth by different design approaches by allowing minimum reduction in existing bed width and keeping other existing parameters. Lacey's design parameters are recommended for remodelling of UJC as they would require less deviation from existing dimensions and its successful implementation for alluvial channel design in Pakistan. The new depth is compatible with the original design.

There are more than hundred hydraulic structures on UJC and preliminary investigation indicates that the most of the structures will safely pass the increased discharge as per new proposal. The clear waterway, fluming ratio and afflux for the structures were found satisfactory. However, the freeboard was found slightly deficient as compared to standard of 3 ft for remodelling parameters. The need of raising of deck slab of some hydraulic structures was observed to safely pass the discharge and to achieve the desired freeboard. The scouring depth was found 4 ft and 3 ft below the channel bed for the head and tail reaches respectively by taking FOS of 1.25 (for straight reach). The foundations of hydraulic structures were also found safe as being placed lower than the scouring depth. To achieve the desired bed width, a new centre line of the UJC be established and accordingly the banks should be reconstructed. The strengthening of newly constructed banks from earthen material by stone pitching along with apron are advised for the canal in filling reaches, curved portions and upstream and downstream of structures. To cater for hydraulic grade line as per new proposal, pushta may be provided in some reaches. However, a detailed study is recommended to finalize and verify the findings of preliminary investigation of this study regarding hydraulic structures and suggested parameters for remodelling. The availability of design discharge throughout the year must be ensured prior to remodelling of the channel and for sustainable solution.

TABLE II
PROPOSED HYDRAULIC PARAMETERS FOR REMODELLING OF UJC BY DIFFERENT METHODS

Design Parameters	Average Existing Parameters		Proposed Design by Lacey Method		Proposed Design by Manning Formula		Proposed Design by Tractive Force Method	
	Reach 8.4- 74.4 km	Reach 74.4 - 127.4 km	Reach 8.4- 74.4 km	Reach 74.4 - 127.4 km	Reach 8.4- 74.4 km	Reach 74.4- 127.4 km	Reach 8.4- 74.4 km	Reach 74.4- 127.4 km
Q (Cs)	7700	4100	14850	8500	14850	8500	14850	8500
B (ft)	240	270	240	230	240	230	240	230
Depth (ft)	9.5 - 11.5	5 - 7	13.55	9.47	13.7	10.1	13.9	10.3
Side Slope	1.5	1	1.5	1	1.5	1	1.5	1
Longitudinal Slope (I/slope)	6667	6667	6667	6667	6667	6667	6667	6667
B/D ratio	20 - 25	38 - 55	17.71	23.12	17.58	22.77	17.39	22.33

VII. CONCLUSIONS & RECOMMENDATIONS

1. Upper Jhelum Canal is unable to operate at its design discharge due to multiple problems and enhanced conveyance losses. Some major problems identified in the study are excessive silt deposition in middle and tail reaches, scouring in head reach, erosion of banks, inadequate freeboard, side embayment and widened channel section.
2. The existing width to depth ratio of UJC is not suitable to achieve parameters of regime channel. The option of remodelling of UJC at enhanced depth and slight decrease in bed width to achieve B/D ratio within permissible limit.
3. The enhanced discharge for remodelling of UJC has been considered suitable on the basis of preliminary study. The increased discharge favors

continuous and more benefits of power generation and agriculture.

4. It is recommended that detailed study including hydraulic evaluation of the UJC and its hydraulic structures i.e. cross regulators, bridges, inlet, syphon and falls at enhanced discharge is necessary to finalize remodelling approach. The study highlights the typical problems of alluvial channels and their solutions on the basis of practical experience in addition to following latest theories and trends. The strategies proposed for remodelling of Upper Jhelum Canal have been recommended for their application to other alluvial channels.

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A Simplified Model for Prediction of Compressive Strength of Concrete Containing Fly Ash at Various Ages

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***Abstract*-**In this research a correlation between simple and easily obtained common mix parameters have been developed to estimate the strength of the pozzolanic concrete containing Fly Ash. Experimental data from nine sources was obtained and then analyzed using multiple regressions. The parameters selected for the model development include concrete age, water to binder ratio (W/B), Fly Ash replacement, Fineness of Fly Ash, Tricalcium Silicate (C_3S) and Dicalcium Silicate (C_2S) content.The derived model was designed to predict the compressive strength $f_c^{'}$ of Fly Ash concrete up to ±30% precision. The model isdeveloped for individual ages of 7, 28, 90/91 days.

***Keywords*-**Concrete, Fly Ash, Compressive Strength, Statistical Model, Pozzolanic Reaction

I. INTRODUCTION

Fly ash doesn't have cementitious properties like cement have but due to the fineness of its particles and a greater surface area it can be used as a percentage replacement material of binder i.e. cement. When in contact with water it chemically reacts with calcium hydroxide so the amount of calcium silicate gel is increased in concrete which imparts better mechanical properties to concrete [i]. Therefore it can be said that fly ash is a valuable raw material because of its pozzolanic characteristics. Fly ash in concrete has known healthy effects on many properties of concrete that include but not limited to compressive strength, plasticity, permeability, sulphate resistance and durability [i].

Compressive strength being one of the most important property need careful estimates while performing mix designs. Different models are available to predict the strength of concrete with or without Fly Ash. Many parameters are required for reliable mix design. Compressive strength prediction models for pozzolanic concrete differs from ordinary Portland cement concrete in the sense that they need the inclusion of physical and chemical properties of pozzolans as well. Reference [ii-iii] considered only one parameter i.e. water cement ratio for concrete compressive strength estimation. Reference [iv] in his model in addition to water cement ratio incorporated effect of unit weight of concrete and its age. Reference [v] Model was complicated as they incorporated type and quantity of glassy phase for strength estimation. Reference [vi] proposed a model containing some complicated parameters like gas constant R, curing temperature and initial apparent activation energy E_0 etc.

In this research a correlation between simple and easily obtained common mix parameters have been developed to estimate the strength of the pozzolanic concrete. Pozzolanic concrete (containing Fly Ash) experimental data from nine sources [vii-xv] was obtained and then analyzed using multiple regressions. The parameters selected for the model development include concrete age, W/B ratio, FA replacement, Fineness of FAand bogue compounds (C_3S and C_2S).

II. STRENGTH PREDICTION MODELS

Reference [ii] proposed the simplest model for the strength estimation of concrete. He proposed that water cement ratio controls the strength development for a given concrete, as long as the cement type, conventional aggregates, placement conditions, curing conditions, and test conditions remained constant. He proposed equation 1, based on the concept that there is an inverse relation between the water to cement ratio and the strength of the concrete.

$$\mathbf{f_c} = \left(\frac{\mathbf{A}}{\mathbf{B}^{\frac{\mathbf{w}}{\mathbf{c}}}}\right) \qquad (1)$$

In above equation A, B = empirical constants for a mix and w/c = water to cement ratio.

Reference [iii] model for the strength estimation was also based on w/c ratio. He presented following equation

$$f_c = \frac{\alpha^{\frac{w}{c}}}{\left(\beta+\lambda\frac{w}{c}\right)^n} \quad (2)$$

Where: α, β, λ and n = the empirical constants, w/c = water to cement ratio

Reference [iv] used historical concrete mix design and strength test data in Iowa and developed statistical model to predict strength and other concrete properties. In their study researchers considered w/c ratio, unit weight of concrete and time as the strength prediction model parameters.

$$f_c = A + Bx\left(\frac{w}{b}\right) + Cuw + D\ x\ CMF + E\ x\ Log(t) - F\ x\ \left(\frac{w}{b}\right)\ x\ uw - G\ x\ uw\ x\ CMF \quad (3)$$

Where: A, B, C, D, E, F, G are Empirical constants, w/b = w/c ratio, *uw*= Unit weight of concrete, *CMF* = Cementitious materials factor and *t* = Time after hydration or age in days.

Reference [vi] considered the simplest possible geometrical and mechanical model of the structure of hardened concrete. He assumed that the strength'*s*' of the cement paste is proportional to the cross-sectional area of the solid matrix matter (i.e. cement gel), in a plane through the center of the pore, perpendicular to the direction of the applied uniaxial compressive load. Herelated the strength with w/c ratio, degree of hydration of cement 'm', where 0<m<1, and the strength of Hydrated Portland Cement gel s_o. The model proposed by Hansen is presented in Equation 4.

$$s = \left[1 - 1.22\left(\frac{\left(\frac{w}{c}\right)-0.36m}{\left(\frac{w}{c}\right)-0.32}\right)^{0.66}\right] x\ s_\circ \quad (4)$$

Above equation was then converted into more simplified form in equation 5.

$$s = A\ x\ \left(\frac{c}{w}\right) + E \quad (5)$$

Where: *s* = strength of concrete (MPa), c = cement constant of concrete (kg/m^3), w = free water content of concrete (kg/m^3), and A, E = constants for given materials, age and curing conditions of concrete.

Reference [xvi] derived an estimation equation that can express coefficient α, which indicates the activity of FA as a binder, in the form of a function of age, FA content, and Blaine specific surface area of FA. He found that addition of FA as fine aggregate replacement increases early strength, however when replaced as cement it reduced the early strength of concrete. Proposed equation 6 is presented below.

$$f_c(t) = \left(\frac{t}{a+bt}\right)\left(\frac{\alpha_1\alpha_2 FA + C}{W}\right) + B \quad (6)$$

Where f_c' (t) = compressive strength at t days (N/mm^2), t = age (days), a and b = experiment constants, α_1 = function of FA/C, α_2 = function of specific surface area by Blaine, FA= fly ash content (kg/m^3), C = cement content (kg/m^3), W= unit water content (kg/m^3), and B = constant.

Reference [xvii] proposed prediction model shown in equation 7 using apparent activation energy to estimate the variation of compressive strength of fly ash concrete with aging.

$$\frac{S}{S_{28}} = R_u\left\{1 - \frac{1}{\sqrt{1 + A\left[e^{-\frac{E_0}{RT}}e^{-\alpha t} + e^{-\frac{E_0}{RT}}e^{-\alpha t_0}(t - t_0)\right]}}\right\} \quad (7)$$

Where *S* = compressive strength, S_{28}= 28-day f_c', R_u= limiting relative f_c', A & α = constant, R = gas constant, T = curing temperature (K), E_0= initial apparent activation energy (J/mol), t = age (days), and t_0= age (days) when the strength development is assumed to begin.

Reference [v] proposed a model based on type and quantity of glassy phase and chemical composition of FA. They prepared the model for 10% to 50% of FA replacement and for ages of 28, 91 and 365 days.

$$CS = c_1\left(\frac{K}{A}\times 10\right)^{c_2} + c_2\,(CaO)^{c_4} + c_5\,(LOI)^{c_6} + c_7\left(\frac{Fineness}{1000}\right)^{c_8} \quad (8)$$

Where CS = compressive strength and c_1-c_8= coefficients determined by the least square technique.

Reference [xi] used chemical composition like glass content and the fineness of fly ash and lime mortar and related them to the compressive strength.

Reference [viii] proposed a model that incorporated the fineness and loss on ignition (LOI) of Ordinary Portland Cement or the fly ash concrete. He discovered that the fineness and loss on ignition have a good correlation with concrete compressive strength.

Reference [xxiv] did a statistical analysis and found the compressive strength of concrete mixes at any age with the help of rate of strength gain constant (*A*) and grade of strength constant (B).

$$f_t = A\ln(t) + B \qquad B = 0.005\,(f_c)^{2.20} \qquad A = 1.4035\ln(B) + 2.9956 \quad (9)$$

Where, (ft) is the compressive strength at age (t) days and (A) and (B) are constants.

Reference [xxv] found the compressive strength with his model using regression analysis

$$R_c = b_1X_1 + b_2X_2 + b_3X_3 \quad (10)$$

Where R_c compressive strength of concrete, X_1 is age of specimen, X_2 is the fly ash and X_3 is the unit weight of

the samples. The coefficients b_1, b_2 and b_3 are obtained from multiple linear regression analysis

Reference [xxvi] measured compressive strength of concrete using Support Vector Machines (SVM), they found that the influence of FA characteristic parameters in the compressive strength of concrete was trivial. Also the Blaine reveals little influence.

A. Advantages of the Proposed Model Over Existing Ones

Model presented in this work not only complies with the essential strength parameters but also incorporate simple parameters that can be obtained with specified mix proportions of concrete and the chemical composition of the FA and cement. In this research a correlation between simple and easily obtained common mix parameters has been developed to estimate the strength of the pozzolanic concrete.

III. Model Development

In this research pozzolanic concrete (here Fly Ash) data is obtained from different research works and journals and then analyzed using multiple regressions. The parameters selected for the model development include age, W/B ratio, FAreplacement, Fineness of FA and bogue compounds (C_3S and C_2S). The bogue compounds were calculated using simple equations as follows.

$$C_3S = 4.071 \times CaO - 7.6 \times SiO_2 - 6.718 \times Al_2O_3 - 1.43 \times Fe_2O_3 - 2.852 \times SO_3 \quad (11)$$

$$C_2S = 2.867 \times SiO_2 - 0.7544 \times C_3S \quad (12)$$

The parameters are ought to be the same for each data. Furthermore the statistical models developed in the present research have been checked, using individual data from other studies, for its validation. The data used for checking ought to have same limitations for the data parameters.

A. Limitation of Parameters Used

As the data used in the present study is obtained from different sources, so it has been taken into account that the data should not differ too much. Hence certain criteria wereset, so that the range of parameters used for the design of model remains closely correlated. Following are the limitations that are followed for the strength prediction model.

I.	Age	3-90 days
II.	W/B	0.28-0.70
III.	FAreplacement	5-55%
IV.	Fineness of FA	240-500 m^2/kg
V.	Concrete f_c'	NSC

B. Model Development Methodology

The statistical analysis is an iterative process and need special considerations for the model development. The process involves several stages in which the impact of several parameters, their correlations with each other and with concrete strength, was evaluated. So for the model development data has to be assembled carefully.

The process was completed in two stages. In first stage the data was assembled form different work of authors from References [vii-xv] and all the anomalies were reviewed and the discrepancies were removed, if any. All the missing data was calculated or assumed when required, and the outliers were eliminated. The data used for the analysis is provided in appendix A-1 for the interest of readers. In second step the parameters that appeared to relate significantly with the strength of concrete were selected.

The variables selected for the model designing were tested to formulate an appropriate prediction model form. Only those variables were kept that significantly affect the f_c' of concrete. The compressive strength was found to correlate well with the power relationships.

The iteration process was done for the preparation of a better prediction model. This was done by considering several power relationships between the responses i.e. f_c' and the variables. Only the best correlations were kept and implied. As it was an iteration process so it requires multiple revisions for the formation of ultimate model. Software MINITAB was used for analysis of data.

C. Final Equation for Strength Estimation

The model was developed for separate ages of 7, 28, 90/91 days. The coefficients are presented in appendix A-2.

Several models were attempted for the input parameters in MINITAB software as described earlier. Separate Model developed for the measurement of compressive strength of FA concrete at specified age 7, 28, 90 is given below.

$$f'_{c\,(age)} = \left[\alpha_2 \frac{1}{B^{0.33}} + \alpha_3 C^{0.33} + \alpha_4 \frac{1}{D} + \alpha_5 e^{E^2} + \alpha_6 e^{\left[\frac{F}{1000}\right]}\right]^2 \quad (13)$$

In above equation, B = W/B ratio, C = C_3S %, D = C_2S %, E = % FA replacement and F= FA Blaine's fineness in m^2/kg

Coefficients of variables α_1, α_2, α_3, α_4, α_5 and α_6 were obtained through the software Minitab with the iteration process. They are presented in appendix A-2

D. Parameters Affecting the Proposed Model

The factors that affect significantly the proposed model were found to be Age in days, W/B ratio, C_3S %, C_2S % and FA Blaine's fineness. So they only these parameters were used for the formation of the final model.

E. Model Examination

Accuracy of developed equation was checked by employing following technique.

In first step graph was prepared for the experimental and model values of the compressive strength of concrete.

In second step deviation of results from mean value was calculated. Total four graphs were prepared. Graphs shown in Fig. 1-3 were drawn to check the accuracy of equation 13. Fig. 1 was drawn for 7days age whereas graphs shown in Figures 2 and 3 were drawn for 28 days and 90days concrete strength.

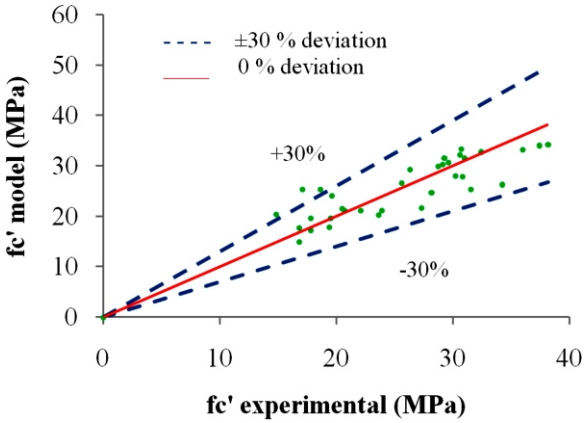

Fig.1. Exp. & Mod. Values for Final Separate Model (for 7 days)[A-1]

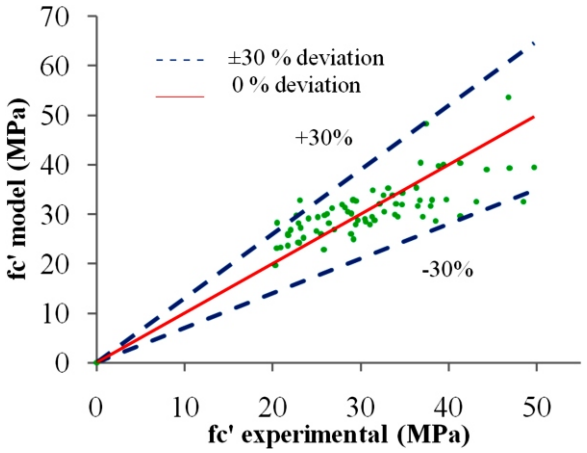

Fig. 2. Exp. & Mod. Values for Final Separate Model (for 28 days)[A-1]

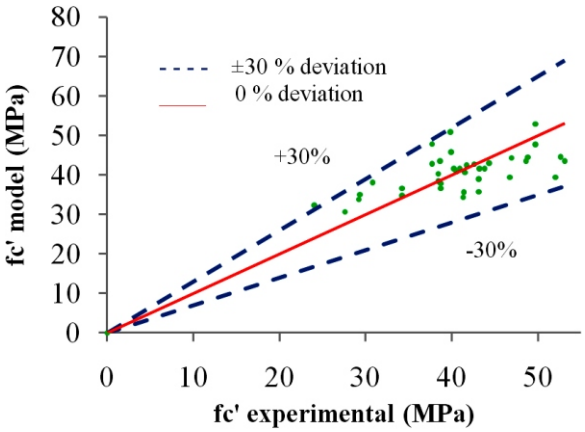

Fig. 3. Exp. & Mod. values for Final Separate Model (for 90/91 days) [A-1]

It was observed that in all figures data is confined within the allowable limits of ±30 %.

IV. Validation of the Developed Model

Developed model was verified by selecting data other than that used for development of model. The data for validation is taken from References [xx-xxiii]. The data used for the validation of the proposed model is provided in appendix A-3.

For validation of model graphs were drawn between experimental and model values. Figures 4 -8 were drawn to validate separate model developed for specified strengths. After the validation of models it was observed that the data from the other researchers used in the model given in equation 13 fits within the limits of ±25%. This shows that the proposed models work effectively.

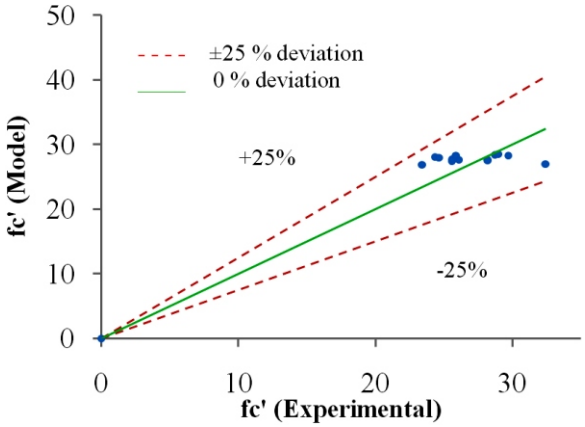

Fig. 4. Exp. & Mod. Values data for validation of Separate Model for 7 days [A-5] Source: Reference [xxii]

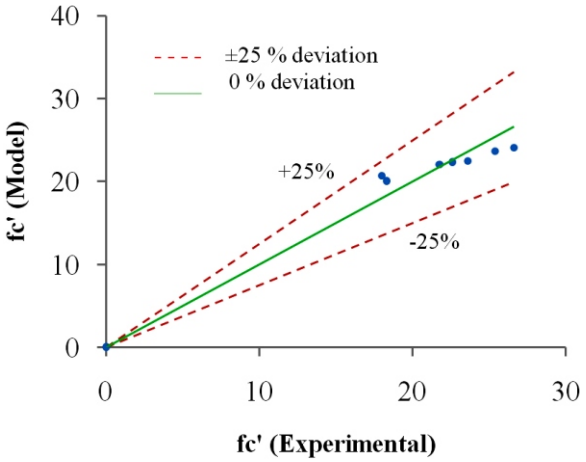

Fig. 5. Exp. & Mod. values data for validation of Separate Model for 7 days [A-5] Source: Reference [xvii]

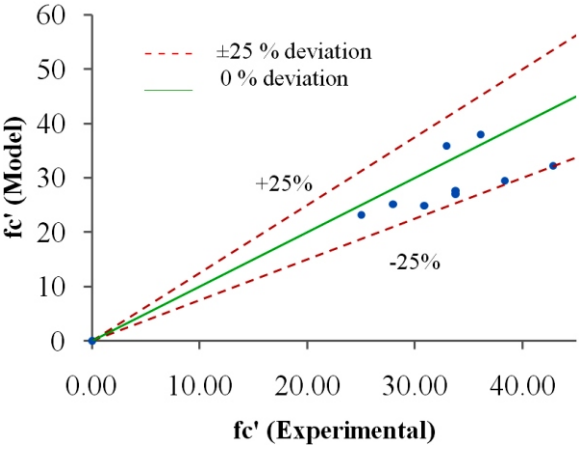

Fig. 6. Exp. & Mod. Values for validation of Separate Model for 28 days [A-5] Source: Reference [xvii]

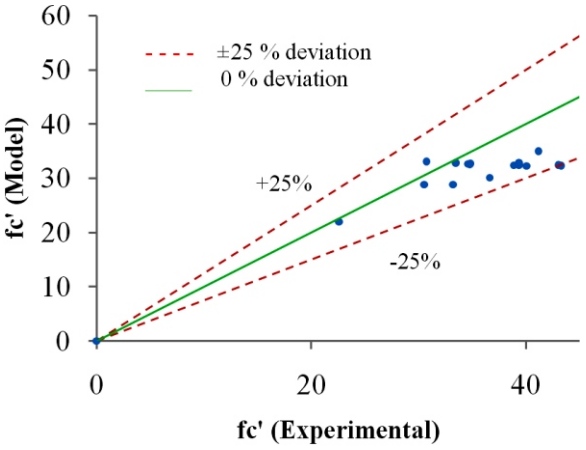

Fig. 7. Exp. & Mod. values for validation of Separate Model for 28 days [A-5] Source: Reference [xx]

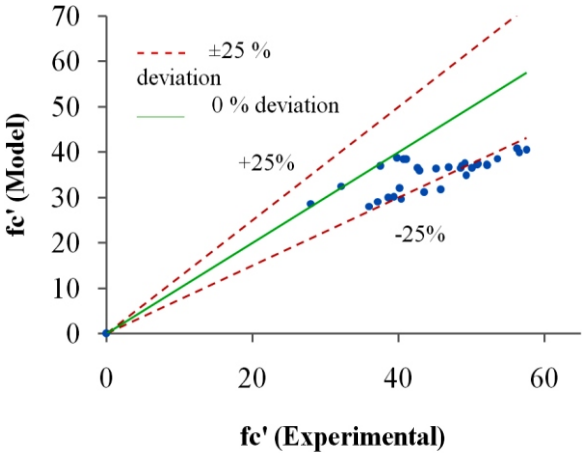

Fig. 8. Exp. & Mod. Values for validation of Separate Model for 90/91 days [A-5] References [xvii], [xx], [xxii]

V. Conclusions

1. The final model proposed for the prediction of f_c' includes simple parameters that can be obtained easily from concrete mix proportions and chemical and physical properties of the concrete mix and FA content.
2. The coefficients of key parameters used in the formulation of model show similar trends as observed in the literature.
3. The derived model was designed to predict the f_c' of Fly Ash concrete upto ±30% precision. But through the validation of the model it was observed that the model behaves well for validation data. The graphs for validation show that the model fits within ±25% precision level nicely.
4. The proposed model is based on multivariable regression analysis so for the development of model ANN (artificial neural network) is recommended.

Notations

NSC ----- Normal Strength Concrete
f_c' -----Concrete Compressive Strength
FA ----- Fly Ash
w/c ----- Water to Cement Ratio
B ----- Binder Content
W ----- Water Content in concrete
W/B ----- Water to Binder Ratio
C_3S ----- Tricalcium Silicate
C_2S ----- Dicalcium Silicate

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A- 1

WHOLE DATA USED FOR THE MODEL FORMULATION

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
Source Data From Reference [xii]																
32.5	3	0.50	0	0	0	0	0	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.00	0
35.5	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	235.1
29.2	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	235.1
27	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	235.1
30.8	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	384.9
29	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	384.9
27.8	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	384.9
36.7	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	523.9
35.6	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	523.9
34.2	3	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	523.9
34.20	7	0.50	0	0	0	0	0	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.00	0
30.80	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	235.1
29.60	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	235.1

*The standard cement chemical composition was used as per ASTM C 150 where found missing in researcher's data.

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
28.70	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	235.1
32.40	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	384.9
30.60	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	384.9
29.30	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	384.9
38.20	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	523.9
37.40	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	523.9
36.00	7	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	523.9
43.10	28	0.50	0	0	0	0	0	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.00	0
39.70	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	235.1
38.10	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	235.1
36.80	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	235.1
41.30	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	384.9
39.40	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	384.9
38.80	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	384.9
49.70	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	523.9
46.90	28	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	523.9
44.30	28	0.	45.	23.5	4.91	18.	1.	19.	5.10	3.51	63.	2.	61.0	8.82	0.15	523.9

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m²/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
		50	98	5		67	47	13			29	83	0			
46.70	90	0.50	0	0	0	0	0	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.00	0
43.10	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	235.1
41.40	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	235.1
40.50	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	235.1
44.30	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	384.9
42.60	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	384.9
41.70	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	384.9
52.60	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.05	523.9
48.80	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.10	523.9
46.90	90	0.50	45.98	23.55	4.91	18.67	1.47	19.13	5.10	3.51	63.29	2.83	61.00	8.82	0.15	523.9
Source Data From Reference [xiv]																
30.70	7	0.37	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
29.10	7	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.26	270
17.10	7	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.40	270
30.20	7	0.44	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
26.30	7	0.44	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
19.60	7	0.50	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.26	270
14.80	7	0.48	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.40	270
25.60	7	0.47	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
18.60	7	0.53	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
46.80	28	0.33	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
37.40	28	0.37	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
33.10	28	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.26	270
23.10	28	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.40	270
36.30	28	0.44	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
33.60	28	0.44	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
25.90	28	0.50	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.26	270
20.50	28	0.48	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.40	270
32.60	28	0.47	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
22.70	28	0.53	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
49.70	91	0.33	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
39.80	91	0.37	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
37.70	91	0.	61.	25.5	4.2	1.4	0.	20.	5.2	2.3	64.	2.	55.0	19.0	0.26	270

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
		39	4			4	16	9			4	9	0	0		
38.70	91	0.44	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
38.40	91	0.44	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.14	270
29.20	91	0.50	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.26	270
34.20	91	0.47	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
Source Data From Reference [ix]																
16.70	3	0.48	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.33	314
30.70	3	0.37	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.14	270
29.10	3	0.39	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.26	270
17.20	3	0.39	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.40	270
30.20	3	0.45	0	0	0	0	0	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.00	0
26.40	3	0.44	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.14	270
19.70	3	0.51	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.26	270
14.80	3	0.48	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.40	270
25.60	3	0.47	0	0	0	0	0	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.00	0
18.70	3	0.54	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.14	270
41.30	91	0.48	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.33	314

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
43.10	91	0.39	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.40	314
27.60	91	0.53	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.40	314
30.80	91	0.42	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.43	314
24.00	91	0.52	48.9	23.9	3.4	15.3	0.3	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.43	314
49.70	91	0.33	0	0	0	0	0	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.00	0
39.90	91	0.37	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.14	270
37.70	91	0.39	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.26	270
38.70	91	0.45	0	0	0	0	0	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.00	0
38.40	91	0.44	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.14	270
29.30	91	0.51	61.4	5.5	4.2	1.44	0.16	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.26	270
34.20	91	0.47	0	0	0	0	0	20.33	4.36	2.99	62.92	3.23	59.90	13.90	0.00	0
Source Data From Reference [x]																
17.80	7	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
19.50	7	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
19.40	7	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
16.80	7	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
23.90	7	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
22.10	7	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
20.70	7	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
34.70	28	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
27.90	28	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
31.60	28	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
31.50	28	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
29.10	28	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
36.70	28	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
43.80	91	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
40.20	91	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
43.20	91	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
40.90	91	0.33	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
38.60	91	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
53.10	91	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
48.60	91	0.28	47.1	23	20.4	1.21	0.67	22.52	3.9	2.99	63.15	2.8	47.40	28.89	0.56	289
Source Data From Reference [xiv]																
17.80	7	0.71	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
27.30	7	0.50	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.31	370
28.20	7	0.48	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.31	370
16.80	7	0.45	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.55	370
23.60	7	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.50	370
25.80	28	0.71	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.00	0
20.30	28	0.71	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.31	370
38.50	28	0.50	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.31	370
41.30	28	0.48	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.31	370
29.20	28	0.45	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.55	370
34.20	28	0.39	61.4	25.5	4.2	1.44	0.16	20.9	5.2	2.3	64.4	2.9	55.00	19.00	0.50	370
Source Data From Reference [xv]																
20.00	3	0.50	0	0	0	0	0	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.00	0
25.00	3	0.44	39	20.8	11.6	13.6	3.65	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.40	930
31.50	7	0.50	0	0	0	0	0	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.00	0
20.50	7	0.46	40.1	21	11.8	12.7	2.25	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.40	300
31.00	7	0.44	39	20.8	11.6	13.6	3.65	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.40	930
48.50	28	0.50	0	0	0	0	0	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.00	0

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
30.50	28	0.46	40.1	21	11.8	12.7	2.25	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.40	300
52.00	90	0.50	0	0	0	0	0	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.00	0
41.50	90	0.46	40.1	21	11.8	12.7	2.25	20.80	5.20	3.80	64.30	2.00	57.61	16.17	0.40	300
Source Data From Reference [xxiii]																
21.73	28	0.70	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
26.37	28	0.62	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
28.51	28	0.55	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
33.99	28	0.51	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
22.04	28	0.54	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.33	393
24.08	28	0.50	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.27	393
26.16	28	0.49	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.23	393
28.23	28	0.47	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.18	393
29.46	28	0.45	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.15	393
21.76	28	0.71	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
22.92	28	0.62	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
28.93	28	0.56	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
32.13	28	0.51	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
34.73	28	0.46	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
23.17	28	0.54	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.30	393
25.14	28	0.50	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.25	393
26.75	28	0.47	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.21	393
29.14	28	0.44	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.17	393
31.36	28	0.41	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.14	393
20.88	28	0.83	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
23.03	28	0.78	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
28.90	28	0.70	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
31.04	28	0.63	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
37.05	28	0.58	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
20.46	28	0.64	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.36	393
23.48	28	0.60	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.30	393
26.96	28	0.57	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.25	393
29.67	28	0.53	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.20	393
33.85	28	0.51	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.16	393
21.73	28	0.	0	0	0	0	0	20.	5.2	2.3	64.	2.	55.0	19.0	0.00	0

f_c' (MPa)	Age (days)	W/B	Fly Ash					Cement*					Bogue Compounds		%FA Replacement/100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
		81						9			4	9		0		
25.49	28	0.70	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
29.39	28	0.63	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
31.29	28	0.58	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
36.46	28	0.52	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0
22.85	28	0.62	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.33	393
24.96	28	0.57	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.27	393
30.55	28	0.53	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.23	393
32.66	28	0.49	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.19	393
37.93	28	0.47	43	19.9	23.7	5.7	2.7	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.16	393

A-2

TABLE FOR COEFFICIENTS OF INDEPENDENT VARIABLES OF FINAL MODEL USING SOFTWARE ANALYSIS

α	Predictor Non-constant	Coefficients for Final Model using Control & FA mixes		
		b	c	d
		Separate model for specific ages		
		7 Days	28 Days	90/91 Day
α_2	$\frac{1}{\left(\frac{W}{B}\right)^{0.23}}$	4.74	4.48	5.33
α_3	$\left(C_2S(\%)\right)^{0.232}$	0.588	0.075	-0.361

α_4	$\frac{1}{\ln(C_2S(\%))}$	1.05	2.28	2.06
α_5	$e^{\left(\frac{FA\%}{100}\right)^2}$	-4.67	-2.14	-1.79
α_6	$e^{\left[\frac{FA_{Blaine}\left(\frac{m^2}{kg}\right)}{1000}\right]}$	0.68	-0.285	0.597

A-3

WHOLE DATA FOR THE VALIDATION OF THE PROPOSED MODELS

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
Data Source from Reference [xx]																
16.34	3	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
16.64	3	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
31.85	3	0.30	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	310.00
10.90	3	0.40	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	287.00
20.22	3	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
26.14	3	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
24.01	7	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
18.60	7	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
38.00	7	0.30	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	310.00
14.40	7	0.40	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	287.00

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
25,36	7	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
34.30	7	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
33.25	28	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
30.55	28	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
57.00	28	0.30	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	310.00
22.60	28	0.40	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	287.00
36.60	28	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
45.85	28	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
40.75	90	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
41.10	90	0.29	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	310.00
60.20	90	0.30	50.20	28.60	13.2	2.6	0.6	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	310.00
28.01	90	0.40	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.70	287.00
42.65	90	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
54.55	90	0.39	44.9	25.20	7.50	2.40	0.28	20.80	4.90	3.10	63.30	3.00	53.71	19.12	0.50	287.00
Source Data from Reference [xxi]																
14.57	3	0.66	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
17.91	3	0.57	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
20.74	7	0.66	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
24.76	7	0.57	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
28.51	28	0.66	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
32.43	28	0.57	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
34.82	91	0.66	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
36.91	91	0.57	0	0	0	0	0	20.9	5.2	2.3	64.4	2.9	55.0	19.00	0.00	0.00
Source Data from Reference [xxii]																
24.36	7	0.49	55.1	21.10	5.20	6.70	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	362.00
26.09	7	0.49	53.4	22.00	6.30	6.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	319.00
25.59	7	0.49	50.9	25.30	8.40	2.40	0.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	290.00
25.66	7	0.49	57.6	29.00	5.20	0.30	0.20	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	312.00
24.68	7	0.49	52.2	27.40	9.20	4.40	0.45	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	351.00
25.91	7	0.49	50.9	28.90	5.40	1.40	0.40	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00
23.45	7	0.49	46.2	31.30	8.50	1.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	237.00
28.72	7	0.49	38.4	13.00	20.60	14.60	3.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	392.00
29.71	7	0.49	39.5	19.50	5.70	24.70	1.80	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m²/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
29.00	7	0.49	36	19.80	5.00	27.20	3.15	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	401.00
28.23	7	0.49	50.5	17.20	5.90	15.80	1.00	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	300.00
32.45	7	1.49	0	0	0	0	0	21	4.60	3.00	64.10	2.70	58.5	16.11	0.00	0.00
38.85	28	0.49	55.1	21.10	5.20	6.70	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	362.00
34.80	28	0.49	53.4	22.00	6.30	6.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	319.00
33.50	28	0.49	50.9	25.30	8.40	2.40	0.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	290.00
34.63	28	0.49	57.6	29.00	5.20	0.30	0.20	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	312.00
34.73	28	0.49	52.2	27.40	9.20	4.40	0.45	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	351.00
39.37	28	0.49	50.9	28.90	5.40	1.40	0.40	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00
30.69	28	0.49	46.2	31.30	8.50	1.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	237.00
40.08	28	0.49	38.4	13.00	20.60	14.60	3.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	392.00
42.99	28	0.49	39.5	19.50	5.70	24.70	1.80	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00
43.24	28	0.49	36	19.80	5.00	27.20	3.15	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	401.00
39.37	28	0.49	50.5	17.20	5.90	15.80	1.00	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	300.00
41.13	28	0.49	0	0	0	0	0	21	4.60	3.00	64.10	2.70	58.5	16.11	0.00	0.00
52.21	90	0.49	55.1	21.10	5.20	6.70	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	362.00

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m²/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
46.93	90	0.49	53.4	22.00	6.30	6.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	319.00
45.17	90	0.49	50.9	25.30	8.40	2.40	0.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	290.00
48.51	90	0.49	57.6	29.00	5.20	0.30	0.20	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	312.00
48.58	90	0.49	52.2	27.40	9.20	4.40	0.45	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	351.00
50.80	90	0.49	50.9	28.90	5.40	1.40	0.40	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00
42.89	90	0.49	46.2	31.30	8.50	1.80	0.50	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	237.00
50.90	90	0.49	38.4	13.00	20.60	14.60	3.30	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	392.00
52.03	90	0.49	39.5	19.50	5.70	24.70	1.80	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	377.00
49.04	90	0.49	36	19.80	5.00	27.20	3.15	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	401.00
50.10	90	0.49	50.5	17.20	5.90	15.80	1.00	21	4.60	3.00	64.10	2.70	58.5	16.11	0.20	300.00
49.22	90	0.49	0	0	0	0	0	21	4.60	3.00	64.10	2.70	58.5	16.11	0.00	0.00
Source Data from Reference [xvii]																
15	3.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	331.80
13	3.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	331.80
19	3.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	331.80
16	3.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	331.80
15	3.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	331.80

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
13	3.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	331.80
34	3.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	331.80
32	3.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	331.80
29	3.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	331.80
24	3.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	331.80
40	3.00	0.35	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	331.80
34	3.00	0.35	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	331.80
27	3.00	0.35	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	331.80
43	3.00	0.32	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	331.80
40	3.00	0.32	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	331.80
29	3.00	0.32	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	331.80
24	7.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	332.80
22	7.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	333.80
18	7.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	334.80
27	7.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	335.80
25	7.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	336.80

fc' (MPa)	Age (days)	W/B	Fly Ash SiO_2	Fly Ash Ai_2O_3	Fly Ash Fe_2O_3	Fly Ash CaO	Fly Ash SO_3	Cement SiO_2	Cement Ai_2O_3	Cement Fe_2O_3	Cement CaO	Cement SO_3	Bogue Compounds C_3S %	Bogue Compounds C_2S %	% FA Replacement / 100	FA Blaine m^2/kg
23	7.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	337.80
18	7.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	338.80
33	28.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	339.80
34	28.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	340.80
28	28.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	341.80
25	28.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	342.80
36	28.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	343.80
38	28.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	344.80
34	28.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	345.80
31	28.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	346.80
50	28.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	347.80
50	28.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	348.80
48	28.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	349.80
43	28.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	350.80
39	90.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	351.80
40	90.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	352.80

fc' (MPa)	Age (days)	W/B	Fly Ash					Cement					Bogue Compounds		% FA Replacement / 100	FA Blaine m^2/kg
			SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	SiO_2	Ai_2O_3	Fe_2O_3	CaO	SO_3	C_3S %	C_2S %		
37	90.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	353.80
36	90.00	0.60	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	354.80
40	90.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	355.80
46	90.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	356.80
44	90.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	357.80
39	90.00	0.55	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	358.80
56	90.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.00	359.80
58	90.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.10	360.80
57	90.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.20	361.80
54	90.00	0.40	55.10	34.90	3.70	3.60	0.20	22.52	3.90	2.99	63.15	2.80	47.5	28.75	0.30	362.80

A- 5

EXPERIMENTAL VS MODEL VALUES OF SEPARATED MODEL FOR VALIDATION

VALIDATION DATA FOR SEPERATE MODELS																
7 DAYS DATA				28 DAYS DATA						90/91 DAYS DATA					
Mehta (1985)		Han et al. (2003)		Atis (2005)		Mehta (1985)		Han et al. (2003)		Mehta (1985)		Han et al. (2003)		Atis (2005)	
f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod.	f_c' exp.	f_c' mod
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.36	25.79	23.6	28.74	33.25	28.43	38.85	30.92	32.90	35.84	52.21	37.40	38.6	41.71	40.75	43.26
26.09	25.00	21.8	22.91	30.55	27.60	34.80	30.13	33.80	27.59	46.93	36.52	40.3	34.33	41.10	42.43
25.59	24.40	18	20.38	22.60	19.77	33.50	29.48	28.00	25.12	45.17	35.83	37.2	32.44	28.01	35.04
25.66	24.51	26.6	30.73	36.60	27.20	34.63	29.52	25.00	23.19	48.51	35.92	36	31.38	42.65	36.94
24.68	25.47	25.4	24.70	45.85	27.55	34.73	30.52	36.10	37.97	48.58	37.00	40.2	43.36	-	-
25.91	25.97	22.6	22.06	-	-	39.37	30.99	38.30	29.46	50.80	37.54	45.8	35.83	-	-
23.45	23.50	18.3	19.41	-	-	30.69	28.52	33.80	26.90	42.89	34.78	43.5	33.89	-	-
28.72	27.42	-	-	-	-	40.08	32.76	30.90	24.91	50.90	39.30	39.3	32.81	-	-
29.71	27.20	-	-	-	-	42.99	32.61	49.70	46.88	52.03	39.09	56.3	50.12	-	-
29.00	27.98	-	-	-	-	43.24	33.49	50.30	37.36	49.04	40.00	57.5	42.00	-	-
28.23	25.03	-	-	-	-	39.37	30.31	48.00	34.47	50.10	36.63	56.5	39.90	-	-
32.45	30.36	-	-	-	-	41.13	34.83	42.80	32.21	49.22	40.40	53.5	38.72	-	-

Identification of Seamless Connection in Merged Images using Evolutionary Artificial Neural Network (EANN)

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***Abstract*-**Recently various software have been invented in order to make the job of image manipulation more comfortable and effective. Using software images are merged in such a way that ocular review cannot differentiate the resulting forgeries from authentic images. This paper proposes a model for the identification of such merged images. Proposed methodology for identification is the connection of two stagesfeature extraction using principle component analysis and the use of classifier based on the evolutionary artificial neural network (EANN). The behavioral aspects of EANN phenotype was evaluated under changing parameters. The results obtained after experimentation were promising.

I. NOMENCLATURE

ANN	Artificial Neural Network
EANN	Evolutionary Artificial Neural Network
BNN	Biological Neural Network
PCA	Principal Component Analysis
GA	Genetic Algorithm

II. INTRODUCTION

In this era of modern technology image manipulation is one of the most common practices. Using various sophisticated software like Photoshop images are fused in such a way that an individual is remarkably unable to identify whether image is merged or not. Image forging is carried out commonly for deceitfulness.

Certain factors in images are added with the best intensions to make a merged image more believable and more likely to be imprinted on individual memories [i]. Although image merging has a lot of social, political and religious issues associated with it [ii]. A great deal of manipulated images are used for different purposes, black mailing is one of the major problem of the day especially on social media sites like Facebook and Tweeter [iii-iv]. Various countries like France and Britain have taken action against the prevalence of forged images; they claim that these unreal images are harmful to individual's psyche, that is why majority of countries have imposed restriction upon uploading of such images on social media sites [ii]. Besides these restrictions they are unable to control the spreading of manipulated images worldwide. There should be some efficient technique to classify manipulated images before it creates a fuss in social media and effect individuals psyche. This paper proposes a model for the classification of forged images.

Literature review shows that high performance image classification can be exercised with the help of feature extracting schemes and by using machine learning algorithms [v-vi]. The main problem in developing merged image identification system is to select relevant feature extracting scheme and classification system that can achieve any desired goals. Feature extraction is essential in identification process because images are too complex to be processed by any classification system [vii]. Features are extracted from images using various schemes including Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT) and Principle component analysis (PCA) to name a few. However, FFT is a good technique for frequency analysis while DWT is desirable to reduce dimensionality of data and for the data analysis in both frequency and spatial domain [vii]. Ideally the set of features used in classification should be independent of one another. Individual can use PCA which is an effective technique [viii], to obtain independent features and to eliminate redundant information [ix]. Feature measurements of images are passed to classifier that evaluate the features of images and affiliate to which category they belong e.g. in the case of email, classifiers colligate whether email is spam or not. There are several classifiers such as decision trees, neural networks, naïve Bayesian classifier for decision support system [x]. For highly accurate classification most of the classification systems used today are Artificial Neural Network (ANN) [xi-xii], but according to Xin Yao better intelligent system can be created if evolutionary algorithms (EAs) and ANNs are used in combination [xiii] known as Evolutionary artificial neural network EANN.

In this paper the main subject addressed is to identify the forged images using PCA and EANN as feature extracting scheme and classification algorithm respectively. Here EANN is used as classifier whose accuracy of identification strongly depend on the quality of training data as well as the structure and training algorithm chosen [xiv]. The training data chosen for identification purpose are the features extracted from images using PCA while Genetic Algorithm (GA) is used to train the ANN forming EANN. Individual can find Neuro Evolution ANN application in nonlinear control problem, robot controlling cancer detection, spam email image identification, face recognition, image authentication, image segmentation, image compression and several other aspects of image processing [xii], [xv-xxix].

Rest of the paper is organized as follows: Section III provides a brief background of EANN and its operation, followed by the EANN architecture used for merged image identification process. Section IV describes the methodology used to classify merged and original images. It includes the creation of database and feature extraction process in detail. Section V and VI provides a detailed discussion on the training and testing of EANN. Section VII, includes the EANN training and testing results. Finally, a brief summary and conclusion are in Section VIII.

III. Evolutionary Artificial Neural Network (EANN)

EANN is a computational classification system based on the functionality and structure of biological neural network (BNN). According to Xin Yao EANN originates when one of the evolutionary algorithms such as evolution strategies (ES), evolutionary programing (EP) and genetic algorithm (GA) are used to train an artificial neural network [xxx]. In this paper GA, working as genotype, is used to find the optimum connecting weights (genes) for fixed ANN topology known as phenotype. In EANN genotype is a long string created only from weights of ANNsynaptic connections. EANN phenotype comprise of nodes having same functionality as neuron in biological neural network (BNN). Fig. 1 shows the computational node in EANN phenotype, nodes have several inputs and function associated with them; these inputs can be from neighboring nodes or from program inputs and associated function of each node is a sigmoid function. Subsequent subsection put some light on EANN functionality and architecture.

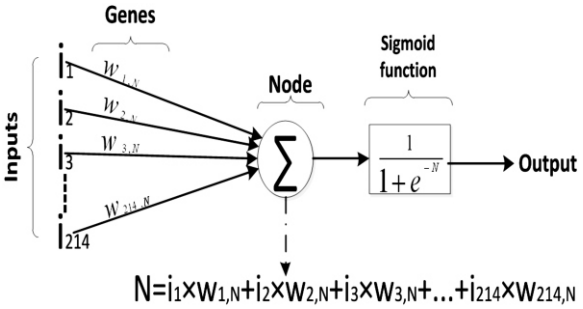


Fig.1.Computational Neuron Architecture

A. EANN Algorithm Functionality

For having a good grasp on how EANN operates, the fundamental parts in Fig. 2 which accounts for the EANN operation are described in detail as follow

1) Initialization

In the initialization, all the weights (genes) in the EANN phenotype (architecture) are joined to make a string called genotype. Random numbers are assigned for each gene (weight) between -1 and 1. This generated string (parent) is then used as a member of initial population as shown in Fig. 3.

2) Mutation

Mutation is to alter individual genes to produce a new individual child. Number of mutants are chosen in accordance to evolutionary strategy $(1 + \lambda)$-ES, which states that λ mutants can be generated from a parent. Mutants compete with the parent for fitness; the fittest mutant turn into a parent of the next generation. Figure 4 shows four mutants (offspring's) that are generated from parent genotype of Fig. 3. Mutation results in $(1 + \lambda)$ population size. Mutation is expressed as follow

Number of genes to be mutated = Total genes×Mutation rate

3) Selection

Selection determines which of the individual will survive in a generation. Set of examples are provided as input to EANN and output is calculated for all population size. Selection is based on maximum successful matches of EANN output with the individual target values. Selected genotype will be the fittest among all population size and will survive.

The process of mutation selection and fitness evaluation in each generation continue by evolving the genotype until desired behavior of phenotype is obtained.

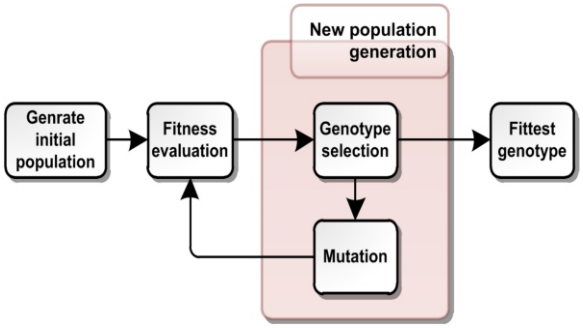


Fig. 2. Procedure of EANN

-0.8015	0.1799	0.0754	-0.4833	-0.7488	-0.7443	-0.3211	...	0.4824

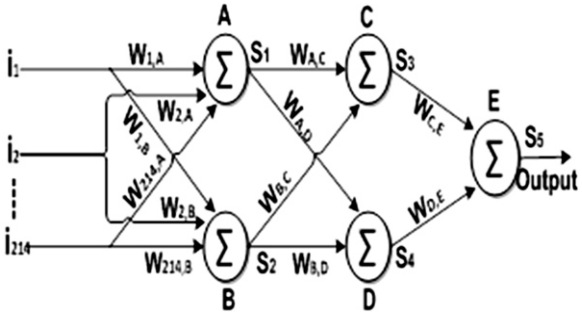
Fig. 3. Parent genotype

-0.5977	0.1799	0.6132	-0.4833	-0.7488	-0.7443	-0.3211	...	0.4824
-0.8015	0.1799	0.0754	-0.7810	-0.7488	-0.7443	-0.3211	...	0.3368
-0.8015	0.1799	0.4746	-0.4833	-0.7488	-0.7443	-0.3211	...	0.5845
-0.8015	0.1799	0.0754	-0.4833	-0.3358	-0.5216	-0.3211	...	0.4824

Fig. 4. Offspring Genotype, colored genes indicate mutation

B. EANN Architecture

EANN phenotype is made up of nodes analogous to neurons in BNN. Nodes in the EANN phenotype works the same as it does in ordinary ANN. Nodes take numerous weighted inputs, sum them and pass the activity 'S' through sigmoid function which produces an output which is always between zero and one. A typical computational node and its function are shown in Fig. 1. EANN phenotype is a collection of such computational nodes. The EANN Architecture chosen for the process of identification is shown in Fig. 5. It has 214 inputs i.e. I_1, i_2, i_3,…, I_214 representing features of single image, weights 'w' in the EANN phenotype representing the genes in its genotype, 2 input nodes viz. 'A' and 'B', 1 hidden layer containing 2 nodes namely 'C' and 'D' and 1 output node 'E'. Output node shows the desired behavior of EANN phenotype i.e.output '1' and '0'will indicate original image and merged image respectively.



$$A = i_1 \times W_{1,A} + i_2 \times W_{2,A} + i_3 \times W_{2,A} + \cdots + i_{214} W_{214,A}$$

$$S1 = \frac{1}{1+e^{-A}}$$

$$B = i_1 \times W_{1,B} + i_2 \times W_{2,B} + i_3 \times W_{2,B} + \cdots + i_{214} W_{214,B}$$

$$S2 = \frac{1}{1+e^{-B}}$$

$$C = S_1 \times W_{A,C} + S_2 \times W_{B,C} \qquad S3 = \frac{1}{1+e^{-C}}$$

$$D = S_1 \times W_{A,D} + S_2 \times W_{B,D} \qquad S4 = \frac{1}{1+e^{-D}}$$

$$E = S_3 \times W_{C,E} + S_4 \times W_{D,E} \qquad S5 = \frac{1}{1+e^{-E}}$$

Fig. 5. EANN phenotype

IV. METHODOLOGY

The procedure of merged image identification is carried out using machine learning algorithm such as EANN described previously. First, features are extracted from all the images in the database using PCA and are stored in a single text file. Secondly, EANN is trained with training data to learn to distinguish between merged and original images. Finally, the network is tested with "unknown" images to assure how considerably EANN has learned to identify merged and original images. The overall process of merged image identification is shown in Fig. 6.

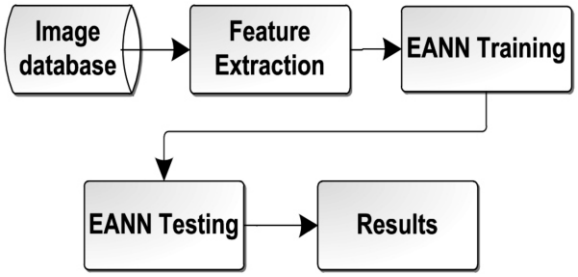


Fig. 6. Methodology of merged image identification using EANN

A. Database Creation

Two databases areused in this paper. One is online database comprise of 100 authentic and 100 forged color images having dimensions of 384×256, taken from internet named as database 1 while self-created database 2 possesses 214 merged and 214 original

images having dimensions 480×640 taken from Samsung Galaxy s4 Camera. Photos in database2 are merged with the help of Photoshop editing software. The merging of photos in Photoshop commence as follow.

Open any two images individually you want to merge in Photoshop, make selection using lasso tool or quick select. After selecting lasso tool drag the cursor over the part of pic individual want to merge. Select Refine edge (make changes in dialogue box according to individual need), output what individual have done to new layer with mask. Move the new layer image to background image and adjust its size, apply transformation. Click 'Merge Layers' and save it. All the merged images in database are created in same fashion. The overall process of image merging via Photoshop is shown in Fig. 7.

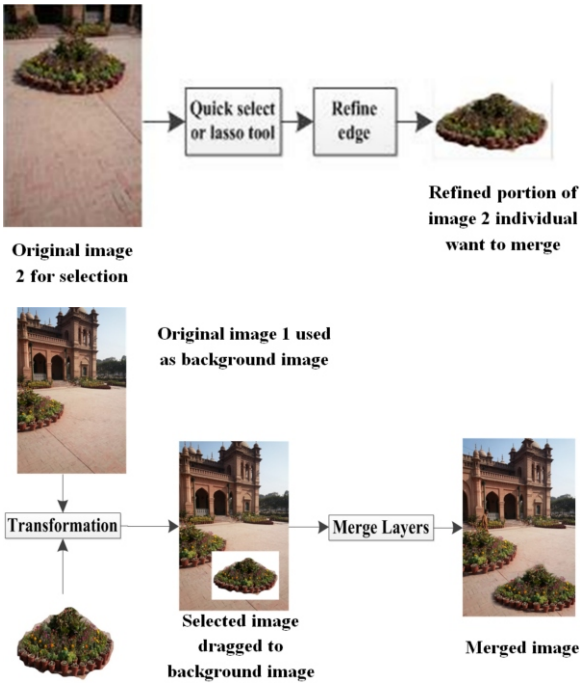


Fig. 7. Merging of photos using Photoshop

B. Feature Extraction

The process of merged images identification commence with the extraction of features from images. As the image is too immense to be processed by the EANN algorithm, PCA is employed to eliminate the redundant information from images.

PCA is a statistical technique that transforms the image to new set of coordinates called the principle component [xxxi]. Principle components are the directions where the data is more spread out i.e. where it has high variance. Fig. 8 and Fig. 9 shows the process of obtaining the principle components.

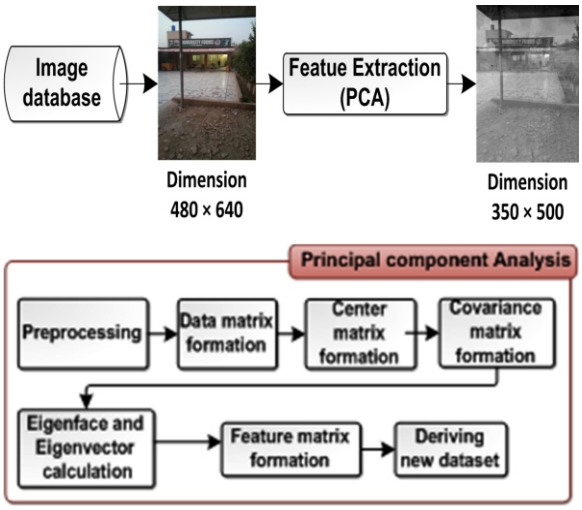


Fig. 8. Block diagram for feature extraction using PCA

-1.07E+08	-3.33E+07	7.39E+07	3.48E+06	-5.44E+06	⋯	2.44E+07

Fig. 9. Sample final data obtained in the end of feature extracting process

The process begins with preprocessing of all Images in the databases. Preprocessing reshape all the 480×640 and 383×256 dimension images of both database into 1*175000 and 1*98304 dimension vectors. These preprocessed images are arranged in data matrix (D), each column of data matrix D represent reshaped image vectors called observation (N), having M unknown variables, Eq. (1) represents nth observation of data matrix D. For instance the data matrix formed from original images or merged images in database1 have N=214 and M=175000 while N=100 and M=98304 in case of data matrix formed from database2.Aim of data matrix formulation is to reduce M=175000 or M=98304 variables to L=213 or L=99 variables for each observation in the data matrix. Mean of data matrix D is found from Eq. (2) and stored in vector M. After calculating mean, a new matrix CM known as center matrix is calculated using Eq. (3) by subtracting image mean M from the data matrix D. Covariance matrix of the center matrix is then foundusing Eq. (4) by multiplying center matrix and its transpose. Principal component variances i.e. eigenvalues of covariance matrix of center matrix is found using 'princomp' command in MATLAB which returns a 214×214 or 100×100 in case of database 1 and database 2 respectively, of size equal to number of observations. Applying Eq. (5), Eigen faces can be found by the multiplication of center matrix with eigenvalues matrix 'v'. The unnecessary components that have small eigenvalues are discarded and feature vector is formed from remaining eigenvectors as seen by Eq. (5). New data set is formed in terms of these eigenvectors which are used as basis vector given by Eq. (6)

$$D_n=(D_1,D_2 \dots , D_M)^T \quad (1)$$

Where n=1,2,…,N=428

$$M(m)=\frac{1}{N}\sum_{n=1}^{N} D(m,n) \quad (2)$$

Where m=1,2,…,M

$$CM=D - M*I \quad (3)$$

Where,(I) is identity matrix

$$Cov(CM)=CM.CM^T \quad (4)$$

$$Eigenfaces= CM\times V \quad (5)$$

$$Feature\ vector=(eig_1,eig_2 \dots ,Eig_L) \quad (6)$$

Where L=213 or L=99

$$Final\ dataset=feture\ vector^T \times CM \quad (7)$$

Final data set has dimension of 213*428and 200 * 99 data matrix in case of database 1 and database 2 respectively, implying that the value of M for all the 428 or 200 observation has been reduced from 175000 or 98304 variables to just 213 or 99 variables, these 213 or 99 variables in single observation represents the features of an image. Finally, the final data sets are stored in text files, before storing it, few changes are made to final data matrixes, so that the text files are compatible with inputs of EANN and these changes are described in the subsequent paragraph.

For EANN compatible input preparation, transpose of final data matrix is necessitated which results in 428×213 or 200×99data matrix. Each row of resulting matrixes depicts features of single image. Tags known as target values are inserted at 214thand 100thcolumn for image classification, tags '0' and '1' indicates merged and original image respectively. This new matrix of size 428× 214and 200× 100is stored in a text file. The text file is divided into two dataset known as training and testing data sets respectively. Text file prepared from database 1 contain 50% of the data for training and 50% for testing while text file obtained from database 2 contain 90% of data for training and 10% of data for testing. These data sets will be used in the training and testing of EANN. Figure 10 shows the sample input text file obtained from data base provided as input to EANN algorithm.

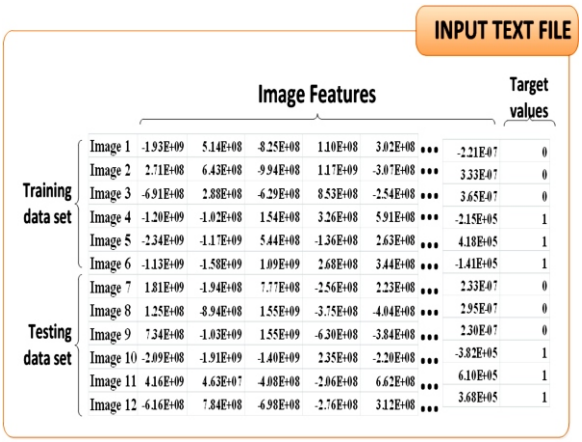


Fig. 10. Sample input text file obtained from database1 provided as input to EANN

V. EANN TRAINING

EANN is trained on training data set created previously to learn to distinguish between merged and original image. For training EANN text file similar to that shown in Fig. 8, is read by the MATLAB EANN training program. Each line in text file can be considered as string (chromosome). To make this string binary, the data has been normalized between 0 and 1.A parent genotype similar to a genotype shown in Fig. 3 is constructed in which genes are assigned random numbers between -1 and 1. Parent genotype is mutated with 10% mutation rate, mutation results in 4 offspring's analogous to Figure4, thus a population size of 5 (1+4) i.e. having 1 parent and 4 offspring's has been created. Initially EANN phenotype is constructed using the parent genotype. During the first iteration training dataset is given to EANN phenotype and outputs are calculated for individual imagesin training data set and compared with their respective target values. During next iteration one of the offspring genotype is used to construct EANN phenotype and trained with training data. The process is repeated for all the remaining offspring genotypes. Five count for five genotypes has been initialized, that count successful match of outputs with individual target values. At the termination of first generation all the five counts are compared with one another, the genotype having maximum count will survive and turn into a parent of the next generation. The max count indicates the fittest genotype among the initial population. The process of mutation and selection continue for 1 million generations. The genotype which survives after 1 million generation will be used in testing the behavior of EANN phenotype to examine how substantially EANN has learned to distinguish between merged and original image.

VI. EANN Testing

The purpose of EANN training was to find compatible connecting weights known as the fittest genotype which survived for 1 million generation. The fittest genotype obtained from the training EANN was used to construct fixed EANN phenotype shown in Figure 5. EANN that has been trained with training data set is now tested with testing data set to figure out how well the EANN has learned. Outputs for the entire individuals in the testing data set are calculated and compared with their respective target values; hence performance of system is evaluated. Accompanying section include the results obtained from training and testing of EANN phenotype with training and testing data respectively.

VII. EANN Training and Testing Results

EANN phenotype was trained and tested with different characteristics of phenotype i.e. EANN training and testing algorithm was simulated number of times with different seed values, increasing network size but with fixed mutation rate and same training and testing data set. During each run behavior of phenotype was checked and efficiency was calculated, the results of the experiment are tabulated in Table I.

In the end of experiment 1 it was observed that keeping the network size "2×2" and seed value "0" the efficiency of EANN phenotype was reached up to 82 % but does not exceed this limit while in experiment 2 the accuracy of identification reached up to 100% on keeping the network size "2×2" and seed value 1.

TABLE I
Experimental Results for Two-fold Training and Testing

Seed Value	Network Size	Training result	Training result efficiency	Testing result	Testing result efficiency
0	2 x 2	184	85.98%	176	**82.24%**
1	2 x 2	150	70.09%	153	71.49%
2	2 x 2	187	87.38%	172	80.37%
0	3 x 3	182	85.04%	174	81.30%
1	3 x 3	178	83.17%	146	68.22%
2	3 x 3	162	75.70%	125	58.41%
0	4 x 4	168	78.50%	152	71.02%
1	4 x 4	141	65.88%	147	68.69%
2	4 x 4	156	72.89%	141	65.88%

TABLE II
Experimental Results for Ten-fold Training and Testing

Seed Value	Network Size	Training result	Training result efficiency	Testing result	Testing result efficiency
0	2 x 2	161	89.4%	18	90%
1	2 x 2	166	92.2%	20	**100%**
2	2 x 2	143	79.4%	15	75%
0	3 x 3	143	79.4%	14	70%
1	3 x 3	161	89.4%	18	90%
2	3 x 3	151	83.8%	17	85%
0	4 x 4	159	88.3%	18	90%
1	4 x 4	164	91.1%	18	90%
2	4 x 4	138	76.6%	15	75%

VIII. Conclusion

In this paper, original and merged images are identified with the help of Principle Component Analysis and EANN, which are used for feature extraction and machine learning approach respectively. Since, the images are too immense to be given as an input to EANN, so for dimensionality reduction the feature vectors of images are used. The results obtained from EANN for image identification are promising. Current EANN is being trained and tested with a target of 214 or 100 images. Best results are obtained by keeping the number of nodes in each layer small. Experimentation showed that identification accuracy has reached up to 100% by employing features extracted using PCA technique.

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Ductility of Reinforced Concrete Columns Confined with Stapled strips

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***Abstract*-**Response of three 150×150×450mm short reinforced concrete (RC) columns confined with different types of confining steel was investigated. Standard stirrups, strips and stapled strips, each having same cross-sectional area, were employed as confining steel around four corner column bars. Experimental work was aimed at probing into the affect of stapled strip confinement on post elastic behavior and ductility level under cyclic axial load. Ductility ratios, strength enhancement factor and core concrete strengths were compared to study the affect of confinement. Results indicate that strength enhancement in RC columns due to strip and stapled strip confinement was not remarkable as compared to stirrup confined column. It was found that as compared to stirrup confined column, stapled strip confinement enhanced the ductility of RC column by 183% and observed axial capacity of stapled strip confined columns was 41% higher than the strip confined columns.

***Keywords*-**Columns, Confinement, Strength, Stirrups, Stapled Strips

I. INTRODUCTION

Confinement of concrete increases both axial strength and ductility of RC columns[1] At peak loads after spalling of concrete cover the strength and ductility of the member will depend upon the confinement of concrete core [i]. Knowledge of behavior of confined concrete helps in calculating the most suitable quantity of confining steel. Confinement also enhances the moment capacity of columns. Affect of confinement on concrete was first time studied by Richart et al[2] and he found that improvement in strength of concrete when confined with lateral fluid pressure is same as when concrete was confined with spirals. It was found that [ii]:-

1. Confinement compensates the strength loss which results due to spalling of concrete cover.
2. Confinement increases the capacity of concrete to carry on large deformations without considerable strength loss.

On the bases of tests researchers suggested that confinement can be improved by [ii-vi]:-

1. Reducing transverse reinforcement spacing
2. Addition of overlapping hoops and ties
3. Uniformly distributing the column bars around perimeter
4. Increasing the ratio between total volumes of transverse reinforcement and the volume of concrete core
5. Increasing yield strength of transverse reinforcement
6. Replacing rectangular ties and cross hoops with spirals or circular ties or strips

The emphasis of this paper is on RC column response in terms of compressive strength and post elastic behavior in terms of stress strain relations. Ductility ratios of concrete columns confined with stirrups, strips and stapled strip have also been calculated and compared. Interestingly it was concluded that by using stapled strip confinement ductility of RC columns can be improved significantly.

II. EXPERIMENTAL PROGRAM

Three RC and one plain concrete column each 150×150×450mm were tested under cyclic axial load. Structural detailing of RC columns is shown in Figures 1 and 2. Center to center spacing of stirrups as per ACI code recommendation comes out to be 37mm, resulting in clear spacing of 31mm. Strips and stapled strips were also placed at 31mm clears spacing. In all RC columns clear cover to longitudinal bars was 13mm. Type of confining steel used in RC columns and end anchorage conditions of stirrups and strips are summarized in Table I. Nomenclature is explained in the bottom of the table. In second column of this table, 25-S means that 25×1.28mm stapled strips were used as confining steel and 25-H means, 25×1.28mm strips were provided with 135° hooked at the end.

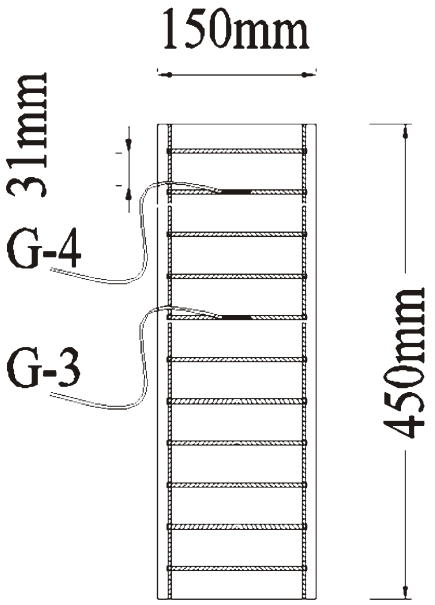

Fig. 1. Structural detailing of stirrup confined columns

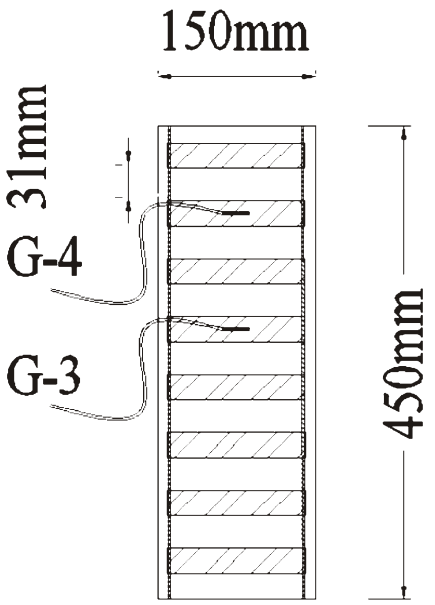

Fig. 2. Structural detailing of stapled strip confined columns

TABLE I
TYPE OF CONFINING STEEL AND END ANCHORAGE CONDITION

Column No	Type of confinement	Detail of confining steel	End anchorage condition of legs
1	*25-#S	25×1.28 mm strips	Stapled
2	25-H	25×1.28 mm strips	135° seismic hooks
3	@BAR-H	6.35mm diameter deformed bars	135° seismic hooks
4	Plain	Confinement was not provided	

*-25×1.28mm Strip,#-Stapled,@ Round stirrups

Column no 1 and 2 were confined with stapled strips and strips respectively. Figure 3 shows a typical stapled strip used as confining steel. Figure 4 shows the end anchorage condition of strips. Column no 3 was confined with 6.35mm diameter round stirrups. Both stirrup and strips were anchored at ends with 135° seismic hooks.

Fig. 3. End anchorage condition of hooked strip

Fig. 4. End anchorage condition of stapled strip

Material Properties

Strength of concrete cylinders at the time of testing of RC columns was 27.6 MPa. Grade 40 (276 MPa), 6.35mm diameter bars were used for stirrups as well as for longitudinal steel. Strips and 35×40mm wide staples (to be used in stapled strips) were cut from the same 1.28mm thick mild steel plate.

Tension test was performed on the coupons cut from plates as per Standard Test Methods for Tension Testing of Metallic Materials "E8M-04". Yield strength and ultimate strength of tested coupons were 286 MPa and 309 MPa respectively

III. Instrumentation and Test Methodology

Axial deformation in columns was measured with two gauges installed on opposite faces. Axial deformation in stirrups as well as on strips was measured using electrical resistant strain gauges (ERSG) pasted onto mid of stirrup/strip/stapled strip with M100 glue conforming to ASTM D1002 and 638. In each column, gauges were fixed on two stirrups. G-1 and G-2 gauges were used to measure axial deformation of columns. ERS gauge, G-3 was applied on strip placed in middle height of column and G-4 was pasted on upper half portion. Top and bottom surface of all the columns were capped with plaster of Paris if required. A mild steel 35mm wide and 2mm thick collar was also fixed externally on top and bottom of the column to avoid crushing of concrete in this region. Samples were tested in universal testing machine and loading rate was controlled manually.

Load was applied in cycles at ASTM C-39 recommended loading rate of 0.15-0.35 MPa/sec and was automatically recorded using 1814KN capacity load cell connected to data acquisition system. Initially load cycles applied were load controlled. After reaching the maximum capacity when first few cracks began to appear, load was applied using displacement controlled criteria. Instrument setup is shown in Fig. 5 and 6. Response of all gauges and load cell was automatically recorded using data acquisition system.

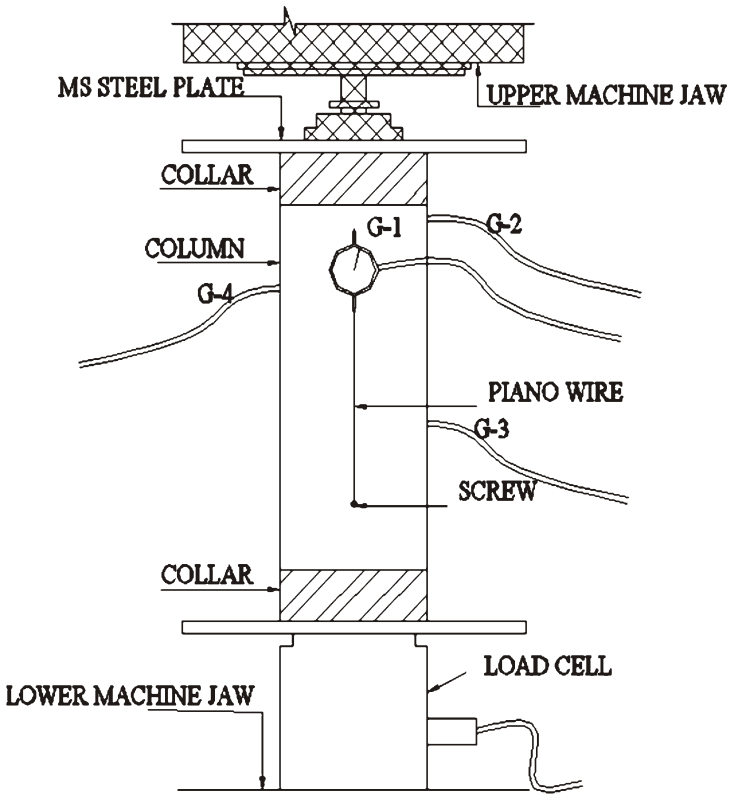

Fig. 5. Instrument setup for axial test

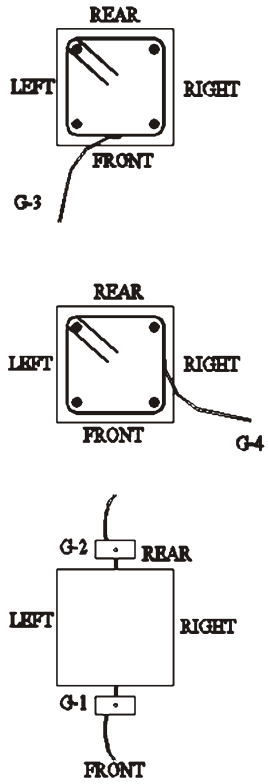

Fig. 6. Location of gauge 1,2,3 and 4

IV. Test Results and Observations

Tested columns are shown in Fig. 7 (a, b and c). As shown in Fig. 7(a) stirrups legs did not open at peak load even after cover spalling. At peak load after initiation of concrete crushing due to loss of bond, seismic hooks tend to open up resulting in loss of anchorage of stirrups. A damaged strip confined column, showing failure of strip confinement at anchorage is presented in Fig. 7 (b). Loss of both

strength and ductility as compared to stirrups confinement is obvious Fig. 8. Fig. 7 (c) depicts excellent response of stapled strip confined columns. Staples did not open and provided excellent support to core concrete that improved ductility of columns.

In order to further probe into the response of column theoretical axial capacity of columns, concrete contribution and core concrete contribution towards column strength were calculated for all columns, using equations 1, 2 and 3 respectively. The results were compared experimental results.

A. BAR-H confinement *B*. 18-H confinement *C*. 18-S confinement

Fig. 7. Response of columns towards different confining steel.

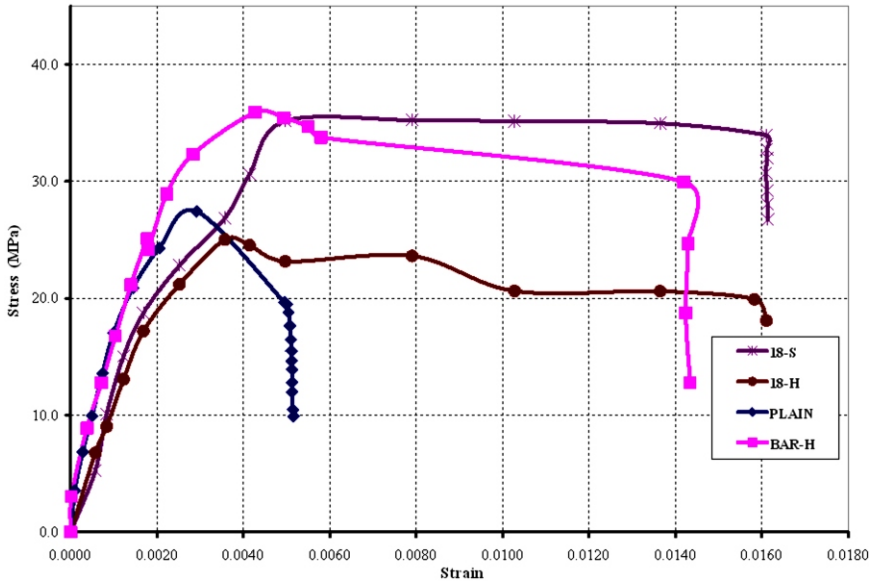

Fig. 8. Stress strain relationship of RC columns.

Axial capacity of the column "P_o" was computed using relation [ix]:-

$$P_o = \alpha f'_c \left(A_g - A_s\right) + A_s f_y \quad (1)$$

Value of α varies between 0.85 and 0.9 for large size samples 3 and in this tested program, value of α was "1".

A_g = Gross area of column

A_s = Area of longitudinal steel

f_y = Yield strength of steel

f'_c = concrete strength in this case it is the strength of cylinder at the time of testing

Computed concrete contribution to the column strength under pure concentric loading P_{oconc} is given as [ix]:-

$$P_{oconc} = \alpha f'_c \left(A_g - A_s\right) \quad (2)$$

Computed core concrete contribution under concentric loading was obtained using this relation[8]:-.

$$P_{ocore} = \alpha f'_c \left(A_{core} - A_s\right) \quad (3)$$

A_{core} = Area of core

P_{test} = Maximum column load applied in the test.

$$P_{c\,max} = P_{test} - A_s f_y \quad (4)$$

Comparison of test results and computed values are presented in Table II.

TABLE II
SUMMARY OF TEST RESULTS

Column No (1)	Type of confinement (2)	Po (kN) (3)	$P_{o\,cocn}$ (kN) (4)	P_{ocore} (kN) (5)	P_{test} (kN) (6)	P_{cmax} (kN) (7)	P_{test}/P_o (8)	P_{cmax}/P_{ocore} (9)
1	18-S	652.1	617.2	427.5	792.8	666.19	1.22	1.56
2	18-H	652.1	617.2	427.5	563.0	436.42	0.86	1.02
3	BAR-H	652.1	617.2	427.5	807.6	680.94	1.24	1.59

A. Axial Capacity of Columns

The ratio P_{test}/P_o compares the tested capacity of columns with the computed one. For strip confined column the ratio 0.86 shows that capacity of column was 14 % less than expected, due to poor response of strip confinement. This can be further confirmed by comparing the stress strain relation plots of all columns in figure 8. There is not any major difference in strength enhancement as for as columns no 1 and 3 are concerned. By stapling the strips the axial capacity of columns was improved by 41 %.

B. Core Concrete Strength

After cover is spalled off, behavior of column largely depends on the performance of core concrete. Core concrete response affects the ductility of column and is largely affected by the degree of confinement. Effect of type of confinement and end anchorage condition on behavior of core concrete was studied with the help of ratio P_{cmax}/P_{ocore}. Due to poor response of strips against lateral concrete pressure P_{cmax} was 36% less than stirrup confined columns. However by using stapled strips as confining steel the enhancement in P_{cmax} as compared to strip confined columns was 53%.

C. Strength Enhancement Factor

Strength enhancement factor is another term that can be used to evaluate the contribution of confining steel towards over all column capacity. Strength enhancement factor "Ks" is defined as the ratio of maximum confined concrete strength to cylindrical strength of concrete and mathematically it was calculated as [vii].

$$K_s = f_{cc}/0.85 f'_c \quad (5)$$

The strength enhancement factor for the columns is given in Table III and a graphical representation is given in Fig. 9. Ks for stirrup confined columns and stapled strip confined columns is same with out any major difference. However as was observed in axial capacity, stapled strip confined columns show 41 % improvement in strength enhancement factor.

TABLE III
STRENGTH ENHANCEMENT FACTOR AND DUCTILITY RATIO AT 0.004 STRAINS

Column No	Type of confinement	f_{cc} (Mpa)	$\varepsilon_{0.85}$	K_s	μ_e
1	18-S	35.24	0.0103	1.50	4.03
2	18-H	25.02	0.0027	1.07	2.57
3	BAR-H	35.89	0.0040	1.53	1.42

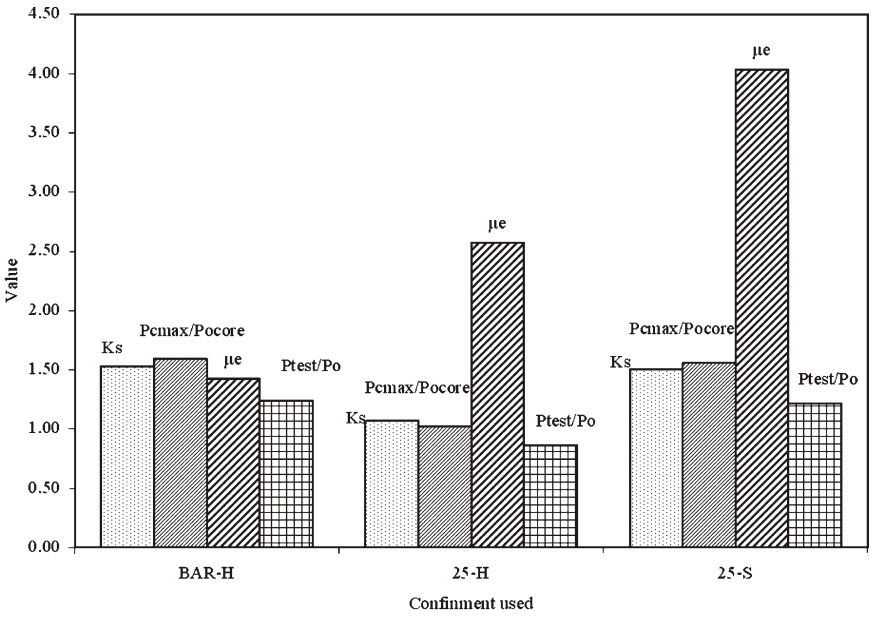

Fig. 9. Response of columns in terms of K_s, P_{cmax}/P_{ocor} μ_e and P_{test}/P_o

D. Ductility Ratio

Effect of confinement on ductility was evaluated by calculating the ductility ratio μ_e defined as ratio of core concrete strain to an assumed strain of (0.004) [viii]:-

$\mu_e = \varepsilon_{0.85}$ /0.004

$\varepsilon_{0.85}$ = Core concrete strain corresponding to the stress at $0.85f'_c$

Although there was not any remarkable increase in strength of strip or stapled strip confined columns as compared to stirrup confined columns but the increase in ductility was significant. Ductility ratio of stapled strip confined column was 183% more than stirrup confine columns and 57% more than strip confined columns. Strip confined columns did not show any strength enhancement but amazingly depicted 80% improvement in ductility ratio.

V. Conclusions

Stapled strip confinement as employed in this experimental program depicted an amazing increase in ductility of RC columns. Following conclusions were drawn from this effort:-

1. Core concrete contribution towards over all columns axial capacity, in stapled strip confined columns was 53% higher than strip confined columns.
2. Increase in axial capacity of stapled strip confined columns as compared to strip confined columns was 41%.
3. Strip confined column did no show any improvement in axial capacity. However stapled strip confinement augmented the axial strength of RC column to the level of stirrup confined columns.
4. Ductility ratio of stapled strip confined column was 183% more than stirrup confine columns and 57% more than strip confined columns.
5. Strip confined column did not show any strength enhancement but amazingly as compared to stirrup confined column it depicted 80% improvement in ductility ratio.

VI. Acknowledgment

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Parametric Optimization for Laser Marking Performance via Taguchi Approach

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Abstract-This paper parametrically optimizes the laser marking process for marking stainless steel AISI 316L for marking's quality and time using Taguchi method wherein the rationale is to ensure the compatibility of the process with material being processed. Four parameters namely "laser frequency", "number of layers removed", "laser power" and "scanning speed" are investigated herein. Main effect for means and signal to noise ratio have been done to study & optimize the effects of variables on stated performance measures respectively. The process is mathematically formulated via linear regression model. It is found that among the factors studied herein, major contributing factor for marking time is "number of layers removed" whereas "scanning speed" effects surface roughness the most. Optimum levels for minimizing marking time are determined to be: level 1 for "laser frequency" and "number of layers removed", level 2 for "laser power" and level 3 for "scanning speed". On the other hand, for minimization of surface roughness, optimum levels are found to be: level 1 for "laser frequency", "number of layers removed" and "laser power" and level 3 for "scanning speed". The mathematical model developed herein is found to be statistically significant at 95% confidence level with contributions of model terms to be 98.92% for marking time and 96.84% for surface roughness. The developed models are validated by the confirmatory run wherein good agreement between predicted and experimental values is obtained.

Keywords-Laser Marking, Taguchi Method, Surface Roughness

I. INTRODUCTION

Laser beam marking process uses a highly focused laser light that falls on the surface of the work part to engrave or mark the object. The process has wide applications in various types of food industries for engraving number and dates on food packages as well as for marking and printing logos and bar codes on printed circuit boards, electronic components and other products for the purpose of product identification and traceability [i-iii]. The process provides higher flexibility, accuracy, ease of automation and reproducibility as compared to other conventional marking techniques such as hot stamping, mechanical scribing or inkjet [i]. The non-contact nature of the process allows wide variety of materials such as plastics, wood, metal and ceramics to be used as work piece that furthers the usefulness of the process [ii, iv].

The principle of operation is based on ablation wherein the interaction between material and the laser beam, which comes from a laser system and passes through a focusing lens (convex lens), leads to the vaporization and melting of work material. As a result, the material is removed from the work piece in layers via ablation mechanism [i, v]. Fig. 1 shows the principle of operation for a laser marking machine.

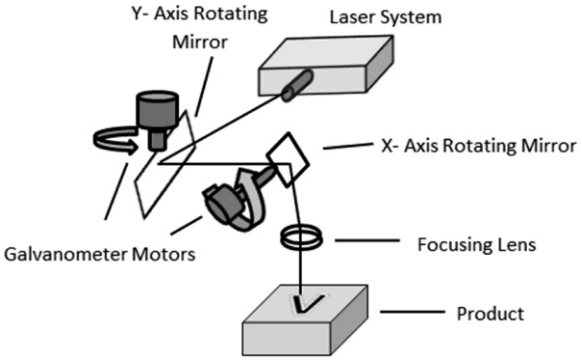

Fig. 1. Principle of operation for a laser marking machine [i]

Several studies have been done on the parametric optimization in order to improve the quality of marked parts [v-x]. Results of these studies show that process parameters can be adjusted to optimize the process for number of applications. Some researchers [vii] have used Artificial Neural Networking (ANN) while optimizing the process whereas others have used Taguchi method to improve the quality of marked parts [v]. No considerable work, however, could be found for the optimization for marking time. Considering, that the marking time is related to the cost dynamics of the process it is imperative that a study is undertaken to

minimize the marking time yet maximizing the quality of the engraving. This would ensure the compatibility of the process with material being processed. The rationale behind this research is thus to ensure the compatibility of the process with material being processed.

This paper reports on the optimization of laser marking process for enhanced surface quality and operation time reduction for the case of Stainless Steel AISI 316L that has good heat and corrosion resistance properties [xi]. It is mostly used in shafts, pumps and equipment for processing chemical foods [xii]. Taguchi method is used herein while investigating four process parameters namely "pulse frequency", "number of layers removed", "laser power" and "scanning speed". "Pulse frequency" is defined as number of pulses emitted from laser system per unit time, "number of layers removed" refer to the total number of layers ablated in the process after multiple passes, "laser power" is the average power of the pulsed laser and "scanning speed" is the distance per unit time covered by the laser head as it scans the selected area during machining. [xiii-xiv]. Main effect plot for means and signal to noise ratio are used to analyze and optimize the process respectively while regression modeling is done to understand the relations between the process parameters.

II. Materials and Experimental Setup

A. Work piece Details

A 6.35 mm (1/4-inch) thick plate of Stainless Steel (AISI 316L) is employed for the presented work. The material's chemical composition is given in Table I.

TABLE I
CHEMICAL COMPOSITION OF STAINLESS STEEL (AISI 316L)

AISI 316L		
Element	**% Wt. (Actual)**	**% Wt. (Standard) [xi]**
Cr	17	16 - 18
Ni	10.50	10.0 - 14.0
Mn	1.20	0 - 2.0
Si	1.00	0 - 1.0
S	0.02	0 - 0.03
C	0.06	0 - 0.03
P	0.03	0 - 0.045
Mo	2.50	2.0 - 3.0
Fe	Balance	Balance

A. Marking Details

Marking is done on the work piece using laser marking machine (TruMark station 5000, TRUMPF, Germany) with Ultraviolet (UV) laser as the beam. The machine used for experimentation is shown in Fig. 2.

Fig. 2. Laser marking machine used for the marking operation on the work piece

C. Experimental Conditions

A convex lens with focal length of 163 mm is used in the way of laser beam to focus the laser beam on the work piece with an input voltage of 230 volts. A mix hatching mode scanning strategy is adopted herein because in multi-layer machining cycles, surface roughness is reported to be reduced by changing the scanning direction [xv], In this mode, the laser head moves in different directions (i.e. angles) in successive passes of machining cycle to remove the layers. In the work presented herein, angles of the hatching pattern are fixed (as opposed to random hatching) so that in each experiment a similar hatching pattern can be re-produced.The hatched lines make angles of 45°, 90°, 135° and 180°. Hatching mode with scanning directions is shown in Fig. 3.

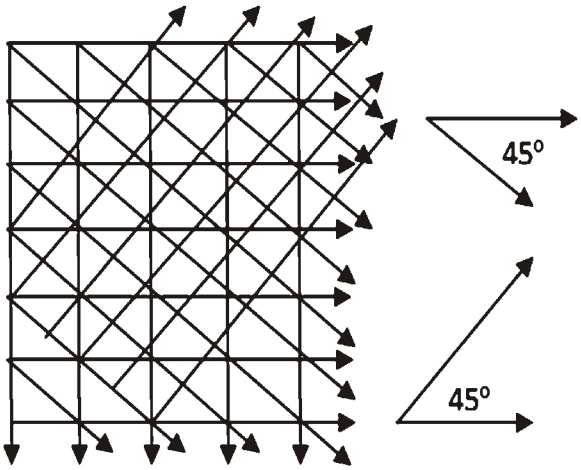

Fig. 3. Mix hatching pattern with scanning directions

Three replications are done to ensure repeatability of experiments as is the general approach [xvi-xvii] with average values reported herein.

D. Design of Experiments

Taguchi's orthogonal array L9 is used herein to optimize the effects of four process parameters. The column namely "Working Range" shows the overall range of parameters' values whereas three levels are taken for each process parameter. For each parameter investigated, level 1 is the minimum value whereas level 3 is the maximum value of the chosen value set. Table II lists process parameters with units and values of the levels selected herein.

TABLE II
PROCESS PARAMETERS AND LEVELS

Process Parameters	Units	Symbol of Units	Working Range	Level 1	Level 2	Level 3
F_p	Hertz	Hz	25-75	25	50	75
N_r	-	-	10-30	10	20	30
P	Watt	W	65-95	65	80	95
S_s	Micro-second	µ-sec	70-130	70	100	130

The work piece after marking operation is shown in Fig. 4.

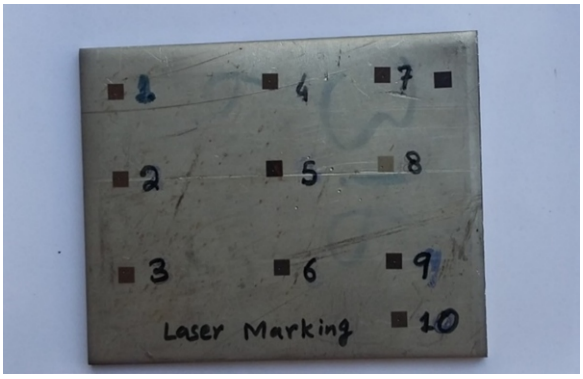

Fig. 4. Workpiece after marking operation.

III. MEASUREMENT & PROCEDURES

Marking time is noted for each experiment by using a stop watch while surface roughness data is taken by measuring R_a using profilometer[1] (Fig. 5). Three readings are taken with a cut-off length of 0.8 mm and an evaluation length of 4.0 mm and the average is reported herein.

Fig. 5. Profilometer employed for the measurement of surface roughness (Ra).

IV. RESULTS, ANALYSIS[2] AND DISCUSSION

A. Making Time and Surface Roughness

Table III lists the average results of marking time (T_m) and surface roughness (Ra) for all the nine experiments.

TABLE III
TAGUCHI ORTHOGONAL ARRAY AND EXPERIMENT RESULTS FOR MARKING TIME AND SURFACE ROUGHNESS

Exp. No.	Process Parameters				Performance Measures	
	F_p	N_r	P	S_s	T_m	Ra
1	25	10	65	70	37.17	3.87
2	25	20	80	100	53.32	4.31
3	25	30	95	130	65.69	4.82
4	50	10	80	130	23.23	3.45
5	50	20	95	70	74.34	7.82
6	50	30	65	100	81.48	5.13
7	75	10	95	100	37.56	5.80
8	75	20	65	130	40.46	2.86
9	75	30	80	70	96.51	7.53

[1]Surface Profilometer: Surtronic S25, Taylor Hobson Ltd, United Kingdom
[2]Minitab 16.0 is used for the analysis

B. Main Effect Plots for Means

The effects of individual parameters on marking time and surface roughness are calculated by using data means. The values of data means for marking time and surface roughness are given in the Table IV and Table V respectively.

TABLE IV
RESPONSE TABLE (MEANS) FOR MARKING TIME

Process Parameters	Level 1	Level 2	Level 3	Delta	Rank
F_p	52.06	59.68	58.18	7.62	3
N_r	32.65	56.04	81.23	48.57	1
P	53.04	57.69	59.20	6.16	4
S_s	69.34	57.45	43.13	26.21	2

Table IV shows that process parameters F_p, N_r and P have a direct relation with the marking time while S_s has an inverse relation with marking time. Delta shows the intensity of the effect of process parameters on the response (marking time), it is calculated by the difference between the maximum and minimum values of data means for each variable, while ranking has been done on the basis of the higher delta values for each process parameter [xviii]. N_r is, hence, found to have an effect on the marking time the most followed by S_s.

TABLE V
RESPONSE TABLE (MEANS) FOR SURFACE ROUGHNESS

Process Parameters	Level 1	Level 2	Level 3	Delta	Rank
F_p	4.33	5.47	5.40	1.14	4
N_r	4.37	4.99	5.83	1.46	3
P	3.95	5.10	6.15	2.20	2
S_s	6.41	5.08	3.71	2.70	1

The case of surface roughness is depicted in Table V. Here S_s affects the surface roughness of the work part the most whereas F_p is found to have a minimal effect on the surface roughness. Fig. 6 presents the main effects plot for means for marking time whereas Fig. 7 shows the same for surface roughness.

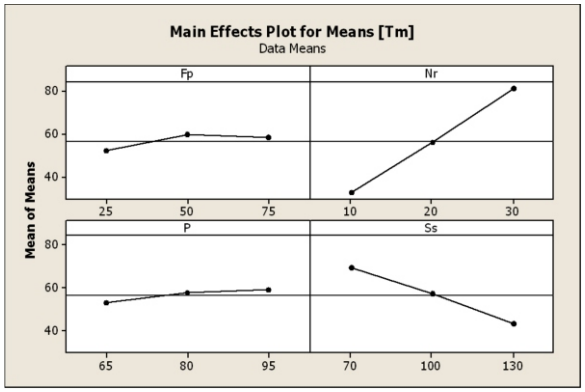

Fig. 6. Main effect plot (means) for marking time.

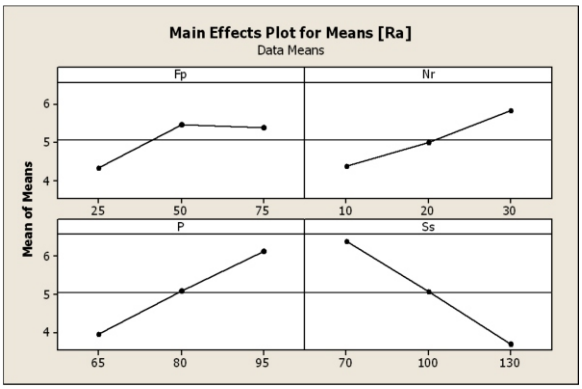

Fig. 7. Main effect plot (means) for surface roughness.

The major contributing factor for marking time is number of layers removed followed by scanning speed. The results can be explained; here the number of removed layers represent the number of complete hatched patterns. Higher the number of complete hatched patterns, the thicker the marked impression. Each hatched pattern takes some time for its completion i.e the time for the complete movement of the laser beam. Therefore, higher the number of removed layers, greater will be the marking time for the laser process. Second important factor for marking time is scanning speed. Scanning speed is the speed of the laser beam during its hatching mode. It is clear that lower the scanning speed, more is the time that the laser beam needs to machine the surface [xiii].

For surface roughness, scanning speed is the most contributing factor for surface roughness followed by laser power. The influence of scanning speed in coordination with laser power on surface roughness could be explained on the basis that a focused laser beam provides energy for vaporization of the unwanted material in order to generate a marked impression in laser marking machine. Laser beam is result of light amplification of monochromatic lights. The higher the intensity of laser, higher would be the power and hence thicker will be the marked impression [i, xix]. Therefore, power of the laser beam increases the surface roughness but it may not affect the surface roughness as much when movement of the laser beam i.e scanning speed is fast. On the other hand, when movement is slow, surface quality deteriorates.

C. Main Effect Plot for Signal to noise Ratio (SNR)

The type of the Signal to Noise Ratio analysis used herein is "smaller the better" for both "marking time" and "surface roughness". This indicates that the smallest values of both marking time and surface roughness are preferable. The formula for measuring "smaller the better" signal to noise ratio (SNR) is given in the Eq (1) [xvii].

$$\text{SNR} = \eta = -10\log_{10}[\frac{1}{n}\sum_{i=1}^{n} y_i{}^2] \quad (1)$$

Where SNR is represented by η and y_i is the ith reading [xvii].

Table VI and Table VII list the average SNR values for marking time and surface roughness using the above equation.

TABLE VI
RESPONSE TABLE (SIGNAL TO NOISE RATIOS) FOR MARKING TIME

Parameters	Level 1	Level 2	Level 3	Optimum Level
F_p	-34.10	-34.32	-34.44	-34.10
N_r	-30.07	-34.70	-38.09	-30.07
P	-33.92	-33.85	-35.09	-33.85
S_s	-36.17	-34.75	-31.94	-31.94

TABLE VII
RESPONSE TABLE (SIGNAL TO NOISE RATIOS) FOR SURFACE ROUGHNESS

Parameters	Level 1	Level 2	Level 3	Optimum Level
F_p	-12.70	-14.27	-13.98	-12.70
N_r	-12.59	-13.23	-15.13	-12.59
P	-11.69	-13.66	-15.60	-11.69
S_s	-15.72	-14.05	-11.18	-11.18

Results from the response tables using signal to noise ratios (Table VI and Table VII) have been used to plot the marking time (Fig. 8) and surface roughness (Fig. 9).

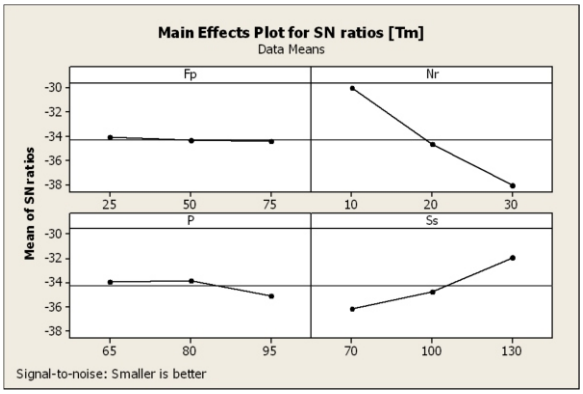

Fig. 8. Main effect plot (Signal to noise) for marking time.

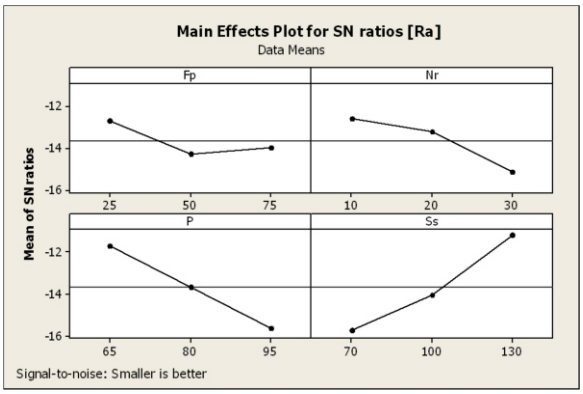

Fig. 9. Main effect plot (signal to noise) for surface roughness

Since Taguchi approach is built on the basis that selection of appropriate levels of the process parameters would weaken the effects of noise factors [xviii] so the point is to select the level of process parameter with highest SNR. Correspondingly, for marking time, level 1 of the first two process parameters (F_p and N_r) is regarded as the optimum level, for P it is level 2 whereas level 3 is the optimum level for the last process parameter S_s. For surface roughness on the other hand, level 1 is the optimum level for F_p, N_r and P whereas level 3 is the optimum level for S_s.

D. Mathematical Modelling

General linear regression analysis has been used in order to formulate the process. The regression equation for the marking time has been given in Eq (2).

$$T_m = 29.2122 + 0.1223F_p + 2.4287N_r + 0.2053P - 1.4369S_s \quad (2)$$

To determine the statistical significance of the developed model and to quantify contribution made by each individual process parameter, analysis of variance (ANOVA) has been done for the regression model for marking time as shown in Table VIII. The contribution of regression terms account to 98.92% against the error contribution of only 1.08%. Moreover, P-value for the regression modeling comes out to be 0.000348 which is less than the selected α value of 0.05 that thus validates the statistical significance of the model with 95% confidence level.

TABLE VIII
ANOVA FOR REGRESSION ANALYSIS OF MARKING TIME

Source	DoF	Sum of Squares (SS)	Mean Squares (MS)	Variance Ratio (F)	P	Cont. (%)
Regression	4	4682.80	1170.70	91.452	0.0003	98.92
F_p	1	56.12	56.12	4.384	0.1043	1.18
N_r	1	3539.05	3539.05	276.461	0.0000	74.76
P	1	56.92	56.92	4.446	0.1026	1.20
S_s	1	1030.71	1030.71	80.516	0.0008	21.77
Error	4	51.21	12.80			1.08
Total	8	4734.01				

For surface roughness, the regression analysis provides the mathematical formulation as given be Eq (3).

$$Ra = 1.19444 + 0.0212667\,F_p + 0.0726667\,N_r + 0.0731111\,P - 0.0449444\,S_s \quad (3)$$

Here too analysis of variance (ANOVA) has been done for the regression model for surface roughness (Table IX) to determine the statistical significance of the developed model and to quantify contribution made by each individual process parameter. A P-value lower than selected α of 0.05 shows the statistical significance of the regression model at 95% confidence level. The contribution of regression terms account to 96.84% against the error contribution of only 3.16%.

TABLE IX
ANOVA FOR REGRESSION ANALYSIS OF SURFACE ROUGHNESS

Source	DoF	Sum of Squares (SS)	Mean Squares (MS)	Variance Ratio (F)	P	Cont. (%)
Regression	4	22.9884	5.7471	30.6244	0.0029	96.84
F_p	1	1.6960	1.6960	9.0375	0.0396	7.14
N_r	1	3.1683	3.1683	16.8827	0.014	13.35
P	1	7.2161	7.2161	38.4521	0.003	30.4
S_s	1	10.9080	10.9080	58.1253	0.001	45.95
Error	4	0.7507	0.1877			3.16
Total	8	23.7390				100

E. Confirmatory Experiment

In order to validate the conclusions drawn from the regression analysis, the confirmatory runs involve prediction and verification of the performance measures under optimal levels of process variables. Confirmatory experiments were performed with the optimum levels of process parameters and results were compared to the predicted values. Results of confirmatory experiments for marking time, surface roughness are shown in Table X. The confirmatory runs show very good agreement (error 2.23% for marking time and 3.7% for surface roughness) between predictedand experimental results. The results of the confirmatory run validate the parametric optimization obtained for the laser marking process with parameters investigated herein.

TABLE X
CONFIRMATORY TESTS FOR MARKING TIME AND SURFACE ROUGHNESS

Performance Measures	Test conditions (optimum parameters)	Experimental value	Predicted value	Relative error
Marking time	$F_{p1}\ N_{r1}\ P_2\ S_{s3}$	11.81	12.08	2.23%
Surface Roughness	$F_{p1}\ N_{r1}\ P_1\ S_{s3}$	1.30	1.35	3.70%

V. CONCLUSIONS

Laser marking process has been investigated for optimization of process parameters for marking time and surface roughness of stainless steel AISI 316L using Taguchi method. Four process parameters i.e. "laser frequency", "number of layers removed", "laser power" and "scanning speed" are investigated in this study. Main effect plot for means and signal to noise ratios have been done to analyze the process while regression modeling is used to formulate the process. Following conclusions can be drawn from the research study:

For marking time, number of layers removed is found to be the major contributing process parameter followed by scanning speed.

For surface roughness, scanning speed is found to be the major contributing factor for surface roughness followed by laser power and number of layers removed whilst pulse frequency is found to be the least contributing factor.

Signal to noise ratio results show that

- Marking time is minimized at the optimum level of process parameters which for F_p (laser frequency) and N_r (number of layers removed) is level 1, for P (laser power) it is level 2 and for S_s (scanning speed) it is level 3.
- Surface roughness is minimized at the optimum level of process parameters which for F_p (laser frequency), N_r (number of layers removed) and P (laser power) is level 1 whereas for S_s (scanning speed) it is level 3.

Mathematical modelling provides useful mathematical relations among the process parameters for marking time and surface

Roughness. The model is found to be statistically significant at 95%confidence level with error contributing to only 1.08% for the model developed for marking time and 3.16% for the model developed for surface roughness.

Confirmatory tests are conducted to validate the mathematical formulations. A good agreement (2.23% error for marking time and 3.70% error for surface roughness) was found between the experimental and predicted results.

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NOMENCLATURE

F_p = Laser frequency
N_r = Number of layers removed
P = Laser power
S_S = Scanning speed
T_m = Marking time
Ra = Surface roughness

Effective ASCII-HEX Steganography for Secure Cloud

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Abstract-There are many reasons of cloud computing popularity some of the most important are; backup and rescue, cost effective, nearly limitless storage, automatic software amalgamation, easy access to information and many more. Pay-as-you-go model is followed to provide everything as a service. Data is secured by using standard security policies available at cloud end. In spite of its many benefits, as mentioned above, cloud computing has also some security issues. Provider as well as customer has to provide and collect data in a secure manner. Both of these issues plus efficient transmitting of data over cloud are very critical issues and needed to be resolved. There is need of security during the travel time of sensitive data over the network that can be processed or stored by the customer. Security to the customer's data at the provider end can be provided by using current security algorithms, which are not known by the customer. There is reliability problem due to existence of multiple boundaries in the cloud resource access. ASCII and HEX security with steganography is used to propose an algorithm that stores the encrypted data/cipher text in an image file which will be then sent to the cloud end. This is done by using CDM (Common Deployment Model). In future, an algorithm should be proposed and implemented for the security of virtual images in the cloud computing.

Keywords-Pay-As-You-Go Model, Cryptography, Steganography, CDM,ASCII-HEX, Cloud Computing

I. INTRODUCTION

In the history of computing, various models of computing have been developed to make the computing robust, efficient, intelligent and effective. Peer to Peer computing and client server computing has been developed for better interaction and communication of client. Distributed computing plays a big role to achieve high availability and accuracy of data. Grid computing is also a major development. Internet is continuously changing and growing from the start of its development. IT (information technology) is spreading everywhere. Above mentioned model gives us many advantages and services but there are some issues which cannot be handled by them. There are also services which cannot be provided by them. There is need to solve these issues and provide large and different variety of services capable of full utilization of computing resources. A new infrastructure deployment model is cloud computing to provide variety of services and resources on demand basis. These resources can be shared and pooled. It can also provide security and privacy to different clients on demand basis.

Classification of various services can be done into different categories. Online software services are provided to the customers using cloud computing so that customers don't have to install application in their system and this type of delivery model is called SaaS (software as a service). Different applications can be developed by using PaaS (platform as a service) delivery model. There are also other delivery models like IaaS (infrastructure as service) which can provide infrastructure environment and networking components, Taas (testing as a service) to provide testing environment and testing applications, and XaaS (everything as a service). For better deployment of these services, different models are used. Community, public, private, and hybrid clouds are types of these deployment models. In [xvi], cryptography and separation models are used to protect cloud computing and to make it more secure. Availability model and tunnels are also used for cloud security. All these models use same standard so they are not efficient and effective for better security of cloud computing.

This paper introduces mainly common security algorithms which are used to make cloud secure and efficient. Section 2, discusses the problem statement while section 3 covers the types of steganography and cryptography used in cloud computing. Section 4, discusses the architecture of CDM and its working. Proposed algorithm, working of encryption and decryption process is described in section 5. Section 6, summarizes the work of the paper and plans on the future work.

II. PROBLEM STATEMENT

The cloud environment uses various security measures and parameters to store the customer's data with high level of security. According to [xviii, xix, xx], customer wants to secure his personal and sensitive data on cloud but there are some privacy and trust

management issues which needs to be resolved. Sometimes the services of single cloud are not sufficient to fulfill the needs of cloud's customer. This issue can be resolved by combining the services of two or more cloud computing providers. The cloud provider always maintain the security of cloud environment with an efficient mechanism at the cloud end so that the client does not have information or knowledge about the security levels of cloud environment [xiv, xv]. How the data is being stored and moved over a medium in a cloud is also hidden from customer.

In this paper, we introduce an algorithm that is used to provide the security to the customer's data from unauthorized access. This algorithm uses combination of Hex (Hexa-decimal) and ASCII (American standard code for information interchange). Encryption process is performed to generate some different keys for security of data. By using these keys, decryption of data can also be done.

Data can be converted from readable form to a scrambled code and again from scrambled code to readable form through cryptography and the main components of cryptography are encryption and decryption [ix]. Cipher text is sent from sender to receiver as well as from receiver to sender to achieve authentication, confidentiality and integrity [x]. Original data remains same before encryption and after decryption process. Before decryption and after encryption process, the data is in the form of cipher text which is called intermediate representation of data. The process of hiding or merging one type of data into another type of data is steganography. There are different techniques to achieve steganography which use image, audio and video or any other form of objects [xii]. The proposed algorithm uses steganography and cryptography for high security of data and from its unauthorized access using ASCII and HEX code. In encryption, Queries are executed with monetary data. Linear secret sharing techniques are performed for evaluation of computational burden and organization acquirement. But particular portion in the cloud can be delimited by using this algorithm [i]. By using OTP (one time authentication/password), data and enterprise application can be secured. There exists a problem in this procedure like stealing of password or authentication key by unauthorized person. Rubbing encryption algorithm is used to find difference among several cloud based OTP techniques. Security of password from attacks is main goal of this algorithm [ii]. There are many security algorithms to remove vulnerabilities existing in cloud computing like illegal access, virtualization and IP level vulnerabilities. But, these algorithms do not provide appropriate solution from cloud site to customer site. As only one level of security is provided, which is not enough to secure the cloud, so dynamic algorithm gives solution and protect different levels of cloud [iii]. When accessing cloud services, mobile devices handle security and confidentiality as per their capability of storage, memory, operating system and processing power. Scalability and processing issues are needed to be resolved when applying digital credential based validation/authentication technique [iv]. In Mesh AMI (advanced metering infrastructure) attacks cannot be prevented using this technique. According to [v], this issue can be resolved by extending the framework to gateway conscious multipath routing. DOS (Denial of Service) attacks can be prevented by implementing IPC (IP Chowk) model and this model is very effective compared to many other models and techniques when using trace back, filtering and many other parameters. IP Chowk model is not recommended for large networks as compared to Hash function technique which is very suitable to implement [vi]. There is graph security problem while using virtualization as it does not prevent users from sharing and accessing the physical server and creates many problems of security among provider and user of cloud [vii]. According to [viii], there is very important role of governmental IT as maximum availability and reliability can be achieved by governmental IT. But there is need to maintain suitable strategies, procedures and there is also need to identify and measure tangible and intangible threats. Proposed algorithm's main goal is to achieve maximum security over the data of customer by ASCII-HEX key based steganography. Images are used for this purpose.

III. Literature Review

Maximum security can be achieved by using ASCII-BCD [xi], ASCII-HEX steganography. There are many type of this technique of data hiding.

A. Types of Steganography

Text Steganography: Text steganography can be achieved by using word shifting, line shift and feature coding. Working of these coding techniques is alteration of the text or by alteration of some certain characteristics of textual elements [xiii].

1) Image Steganography

Steganography can also be done by using images to cover the objects and this method is also very popular for steganography. There are many different file formats for digital images and different algorithms also exist for these file formats [xvii]. Encrypt and scatter, masking and filtering, redundant pattern encoding and LSB (Least significant bit) insertion are types of these algorithms.

2) Audio Steganography

This type of steganography works by embedding sensitive data into digitized audio signal. In this way slight alteration of binary sequence of the corresponding audio file is done. In this steganography,

Phase and LSB coding, and spread spectrum methods are used.

3) Video Steganography

Steganography can also be done in video files. Collection of images and sounds produce these video files and many techniques which are used for images and audio files can also be applied on video files. This type of steganography is useful for hiding large amount of data [xxi].

4) Protocol Steganography

In protocol steganography covert channels and network control protocols are used, and information is embedded within messages.

B. Types of Cryptography

Cryptography is used to provide security. In cryptography plain text is secured by encrypting the message with key. This key secures the message from intruders who can read the message and decrypt it to get the message back. Encryption and decryption of the message cannot be done without the key [xxii].

1) Secret key Cryptography

It is very traditional and also known as symmetric cryptography. Encryption and decryption of message is done by a single key. It is also very useful for authentication. Set of rules are followed by sender for better encryption of text and transmission of the cipher text to the receiver. Same set of rules are also followed by receiver to decrypt the message. The main problem is distribution of keys as it is necessary that sender and receiver have the keys. Generally, stream cipher and block cipher are categories of this secret key cryptography. The key is continuously changing because of feedback mechanism. This scheme encrypts one block at a time with same key for each block.

2) Public key Cryptography

Complementary assignment of two keys (one public, one private) to the individuals involved in a transaction is done by public key cryptography for securely exchanging messages. One of the key is called public key and it can be shared by the owner while other key is not shareable and is called private key.

IV. Related Work

Pay-as-you-go model is followed to provide everything as a service. Various deployment models are used for better deployment of services within restricted boundary. There is need of high security to secure valuable data of customers, stored and maintained at the server. Many security measures are imposed over the data of customer to achieve maximum security and reliability. There are many levels of security. The customer's data enters into various level of access from customer end to provider end for accessing a cloud utility. Different algorithms are used to safe the data at the cloud end but, they are not effective.

TABLE 1
Proposed Model Vs Previous Model

Attribute	Proposed Technique	Previous Technique
Cypher length	Smaller	Bigger
Effective	More Effective	Less Affective
Complexity	More Complex to break its code due to more keys	Less Complex to break due to less keys
Memory	Takes less memory	More memory
Processing	Takes less processing	Takes more processing
Composition	ASCII and HEX	Binary (1,0)

In [xi] this problem has been overcome by implementation of ASCII-BCD based steganography in order to achieve maximum security level and to overcome the problems of traditional algorithms. Encryption and decryption process uses two types of keys. Encryption and decryption process also has two phases to provide two cipher text; alphabets cipher and digits cipher. Conversion of characters of text into ASCII and then into BCD is done to generate complete cipher text which is placed on the image.

In Fig. 1, CDM is used which is used for the support of maximum security at client side. After encryption the cipher text is placed into image.In proposed algorithm's, encryption and decryption process, conversion of ASCII is done into HEX. When customer requests for the data from the cloud, a reverse process of an encryption with keys occurs. We have compared our model with the previous models [xii], and Table I is illustrating the comparison.

V. Proposed Work

The data coming from input section is placed into a matrix to get positions of characters in data to generate key 0.

Then this data is converted to ASCII form for encryption purpose. To achieve higher level of security, data is again converted from ASCII to Hex and matrix of HEX data is made and positions of HEX characters are extracted to make key 1.

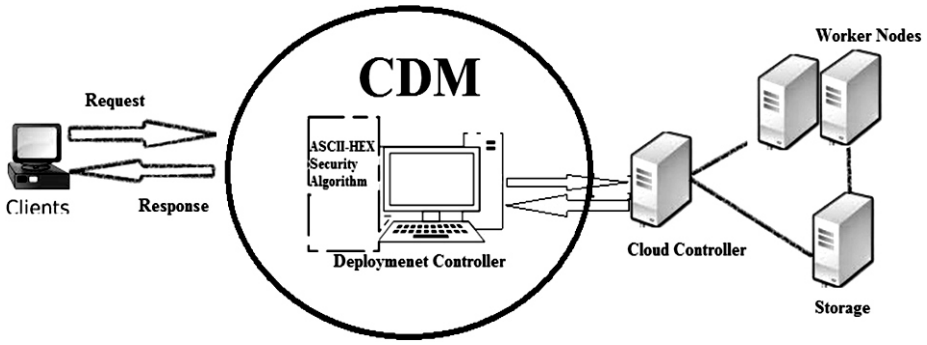

Fig. 1. Working of Cloud and CDM

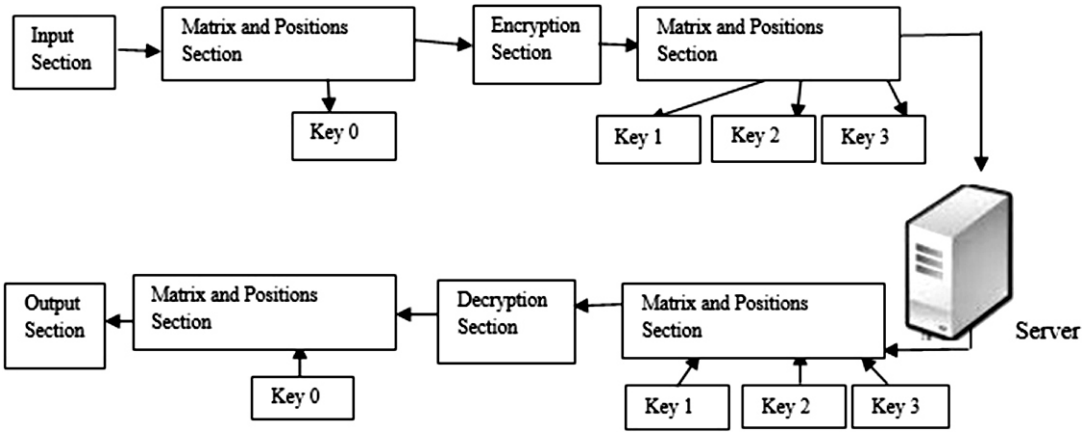

Fig. 2. Proposed Algorithm's Conceptual Diagram

HEX conversion gives us the data in the form of; 1-8 digits and A-F alphabets. Separate matrix of alphabets and digits is made and the positions of alphabets of HEX give us key 2 and key 3.The encrypted text is then placed into an image starting from some specific pixel and the position of that pixel will work as private key and this image is sent to server for storage purpose.When a customer requests for data, data is read from the image using private key. By using key 2 and key 3, alphabets and digits of HEX data is extracted while key 1 is used to get real Hex form of data for decryption purpose. By using Key 0, we get original position of data and send it to output section. Fig. 2 is the conceptual diagram of the proposed algorithm.

A. Encryption

We use image based steganography for encryption processof the proposed algorithm to highly secure customer's data as shown in Fig. 3. Image of any format can be used to secure and hide the customer's data. Encryption of a sample word is shown below. The sample word is 'known'. When 'k' from 'known' is put into matrix it gets position (01*01). 107 ASCII value is equivalent to character k. After converting 107ASCII to 3-bit Hex, 06b is generated. This Hex value is put into Hex matrix and its position is obtained. Matrix of digits and matrix of alphabets is generated to get their positions. Same process is done for remaining characters of input file until it encounters space or EOF. Encryption of word 'known' gives us cypher text 'befe06060607706' which will be put into image. The pixel position of image where first character is placed is our private key. In this case let's say 072. 2 indicates 2nd column of the image pixel's coordination and 7 indicates 7th row of the image pixel's coordination. Other keys are shown in Fig. 4.

The input file of customer's data is transformed to matrix form to get the position of characters in the data. These positions are stored and act as a key (Key1). 3-bit ASCII based characters are generated from the text characters.3-bit Hex code is generated by reading and converting 3-bit ASCII data file character by character. There are some special characters whose ASCII to HEX conversion is not available. If there is any of those special character whose HEX conversion is not available then its ASCII will be moved into HEX data. Three bit ASCII digits of those special character are treated as HEX digits. The positions of digits is taken from the hex data file and stored as a second key

(Key 2). The position of alphabets is taken and stored as a third key (Key 3). When there will be any space between characters then both of the matrixes will be placed in the buffer and this cypher text will be placed on image; alphabet characters first and digit characters second. Again the process will start for remaining data until the end of file (EOF). If there is not EOF then next character will be read from input data file. When EOF is encountered then this image will be sent to cloud storage server for storage purposes. This image is used latterly for decryption purposes.

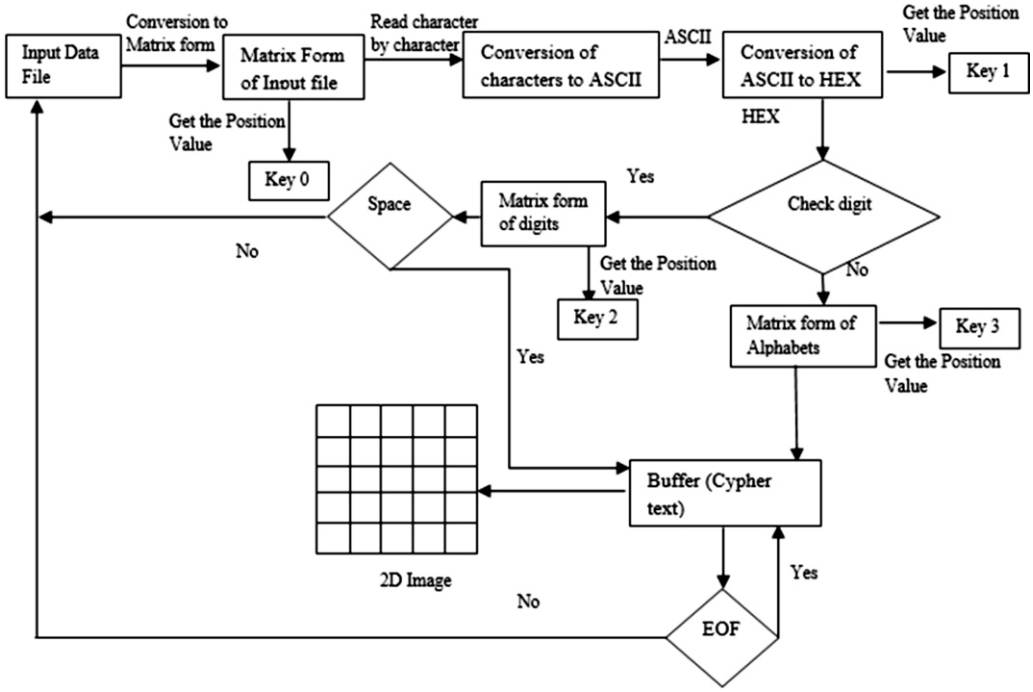

Fig. 3. Encryption Process Diagram

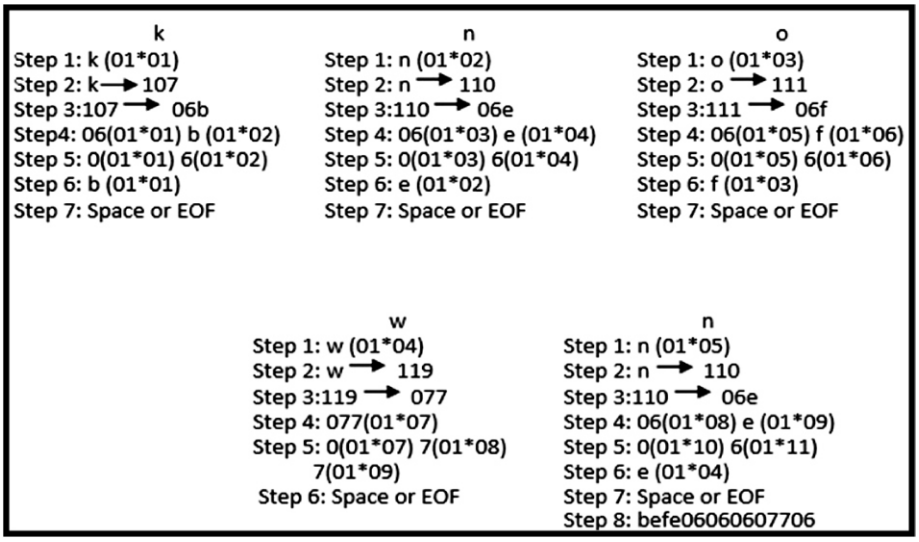

Fig. 4. Encryption Process Example

B. Decryption

We have stored the customer information in an image using our proposed algorithm and this image is stored on cloud. When customer needs its important data which is stored in the form of image on the cloud, cloud does some work, verifies the customer and its requirement. It selects the required image and sends it to the client or customer.

Here CDM uses two types of keys to decrypt it; first type is shared keys which are used for both

encryption and decryption while second type is private. The private key is used to identify the required pixel from where decryption process starts.

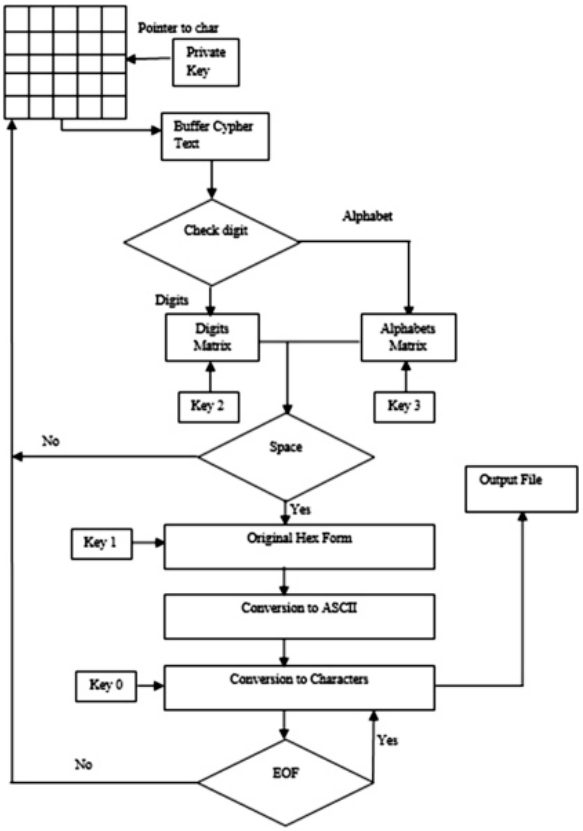

Fig. 5. Decryption Process Example

After getting the cypher text, the alphabets are placed on their positions in the alphabets matrix using key 3. Same process will be done for digits until it encounters space. Original HEX form is obtained using key 1 and decryption of HEX to ASCII is done. If some 3-bit HEX digits cannot be converted into ASCII then they are moved as it is into ASCII file because they are special characters. Then these ASCII characters are converted into original text and their positions are obtained using key 0. This process continues until the EOF. This decryption process of the image is described diagrammatically in the Fig. 5.

Cypher Text: **befe06060607706**

Private Key: Pixel Location of Image Let's say 072. 2 indicates 2nd column of the image pixel's coordination and 7 indicates 7th row of the image pixel's coordination. Using Key 3, 2 and 1, alphabet, digit and HEX matrix are generated. Conversion of three bit HEX data to ASCII and using key 0 original data is obtained.

Step1: b(01*01) e(01*02) f(01*03) e(01*04)
Step 2:0(01*01) 6(01*02) 0(01*03) 6(01*04) 0(01*05) 6(01*06) 0(01*07) 7(01*08) 7(01*09) 0(01*10) 6(01*11)
Step 3:06(01*01) b(01*02) 06(01*03) e(01*04) 06(01*05) f(01*06) 077(01*07) 06(01*08) e(01*09) 06b 06e 06f 077 06e.
Step 4: 107 110 111 119 110k(01*01) n(01*02) o(01*03) w(01*04) n(01*05)

Result: **known**

VI. Conclusion and Future Work

There are many deployment models which are used to provide services. These services are used within a limited boundary. Pay as you go model is used by cloud computing which provides services to the cloud customers. There is the need of high security to secure valuable data of customers, stored and maintained at the server. Many security measures are imposed over the data of customer to achieve maximum security and reliability. There are many levels of security and various security algorithms are used for security of sensitive data at the provider or cloud end but, they never ponder about the security methods in various layers existing between the customer and cloud. ASCII-HEX based steganography is implemented in order to achieve maximum security level and to overcome the problems of traditional algorithms. Encryption and decryption process of proposed algorithm uses two types of keys.Encryption and decryption process also have two phases to provide two cipher text; alphabets cipher and digits cipher. Alphabets and digits are generated from HEX values and these Hex values are generated using ASCII characters. These two types of ciphers are stored into image for storage purpose. Maximum security of the data at the customer's end is achieved by using CDM. After the customer's request of data, decryption process is performed at cloud end with the help of keys. Proposed algorithm's main goal to achieve maximum security of sensitive data with less complexity and processing. In future maximum reliability can be achieved using virtual images in this algorithm.

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Imperiling Urban Environment through Varying Air Pollution Rein in Measures and Mass Transit Policies - A Case Study of Lahore

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***Abstract*-**Gargantuan expansion of big cities has increased motor vehicular tremendously. Lahore, a primitive green city is now gripped with swelling motor vehicular air pollution. Mass public transport, a back bone of city transportation network, due to erroneous running significantly contributes toward motor vehicular air pollution. Policy initiatives of the Government to curb motor vehicular air pollution are merely focused upon reduction of air pollution at source by the use of technology and clean fuel programmes. The policies for introduction of mass transit remained imprecise which lead to rise in transportation demand and increase in surfeit emission; Half-baked policies normally stem out to get political popularity which imperils urban environment. The paper highlights inconsistent policy measures and unsound air pollution control strategies adopted in big cities of Pakistan. Furthermore it gives guidance for sustainable mass transit policy measures.

***Keywords*-**PEPA, Mass Transit, NEQs, KCR

I. Introduction

Urban population is increasing in the World. By 2050, 6.4 billion people, about two-thirds of humanity likely to become urban residents. In 2008, the world crossed a significant point when half of its population started living in urban areas. By 2030 this number will grow to around 5 billion people, and in Africa and Asia urban populations will double between 2000 and 2030 [i].

Gargantuan growth of cities surges usage of motor vehicles tremendously. The plying of these vehicles on the urban roads poses a threat to urban environment. Shanghai Manual [ii] reveals that urban transport represents one of the fastest growing sources of greenhouse gas. According to UNEP [iii], transport is the second largest sector contributing to global carbon dioxide (CO2) emissions from fossil fuel combustion emissions that contribute to global climate change.

Urban environment can only be protected by taming fastest source of greenhouse gases. A sustainable transportation system with supporting policies can help to improve urban environment meaningfully. Sustainability is looked at from a threefold perspective, namely, economic, social and environmental. It goes without saying that sustainability is inextricably linked with the transportation system.

II. Overview of Air Pollution in Pakistan

Air pollution is one of major environmental issues in Pakistan. Surveys pertain to air quality; show that air pollution level in big cities of Pakistan is either crossed the safe limit or reached at threshold level [iv]. There are two main sources of air pollution in Pakistan. These are stationary sources like industrial pollution and mobile sources which include motor vehicle's Exhaust. Situation of suspended particles and carbon monoxide due to emission of motor vehicles in cities is alarming. Air pollution level is increasing remorselessly in urban environment. Unrelenting level of air pollution put health of urbanites at stake.

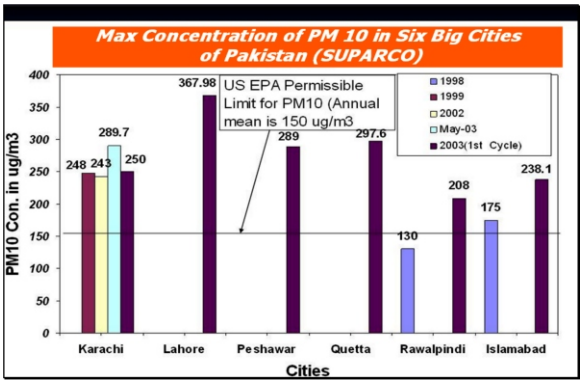

Fig. 1. Air Pollution Level in Major Cities of Pakistan [iv]

Fig. 1. Shows that air pollution situation of Lahore is relatively grimmer as compare to other major cities of Pakistan.

III. Motor Vehicles Situation in Pakistan

A. Scenario of Karachi

Karachi is a centralized city where 70 percent of business services and about half of the retail trade is located in central business district. A 50 percent of employment, whole sale trade and transport sector is in CBD [v]. Gigantic expansions of city, spatial fabrication, economic growth and urbanization have increased travel demand. Resultantly causes high growth of vehicles. In 2002, total registered vehicles and cars were growing at twice the growth rate of the population. Vehicles fleet was dominated by cars and motor cycles which account for 92 percent of vehicles as compared to 6 percent for the para-transit vehicles and 2 percent for public transport vehicles. This rapid rise in personal vehicles ownership and lack of economic instrument, such as charged parking and road pricing have led to erroneous congestion especially in central part of city which increases average commute travel time in Karachi by over 45 minutes. [v]

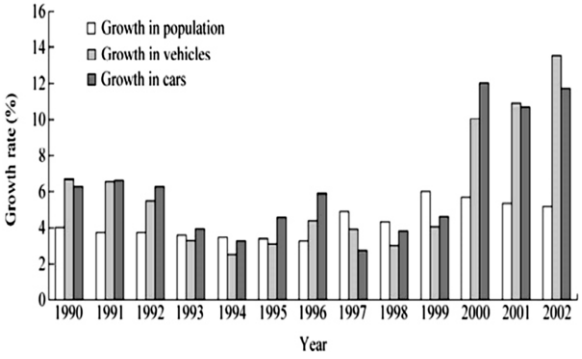

Fig. 2. Growth Trend of Vehicles and Cars Versus Population in Karachi [v]

Fig 2 shows growth of vehicles with growth of population. It indicates that highest growth in vehicles with respect to population is in year 2002 which may because of increase in travel demand and the absence of planned mass transit system.

Reference [v] Traffic Engineering Bureau of Karachi has carried out two traffic surveys in the city. Result of these surveys show that although trips made by the private vehicles are increasing but buses/mini buses still continue to give over 50 percent of the travel demand.

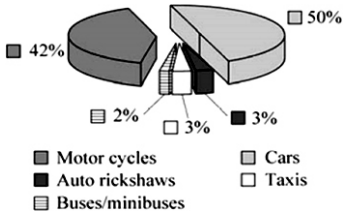

Fig. 3. Share of Passengers Vehicles Fleet in 2003 [v]

In 2007, Karachi was the only mega city in the World without rail base transit system. Karachi circular railway (KCR) which was acted as suburban railway system, started its operation in 1964. KCR proved a reliable alternative to the available public transport for middle class people. But after 1978, heavy subsidies, negligence in maintaining infrastructure and delays in schedule timing, caused declining of rider-ship and popularity. Ultimately, operation of KCR was ceased in 1999 due to heavy losses. Recently, it has been revitalized but no statistics released about passengers ridership.

B. Situation of Rawalpindi

Like other big cities in Pakistan, Rawalpindi is also experiencing high growth of motor vehicles. The growth rate by end of 2008 was 6.05 percent. It is significantly higher than the data of the previous decade (where a progressive rise in vehicles numbers was recorded). However it is in line with growth trends of Pakistan. Statistics of earlier years show that largest growth observed in cars. Growth and modal split of motorized vehicles shown below

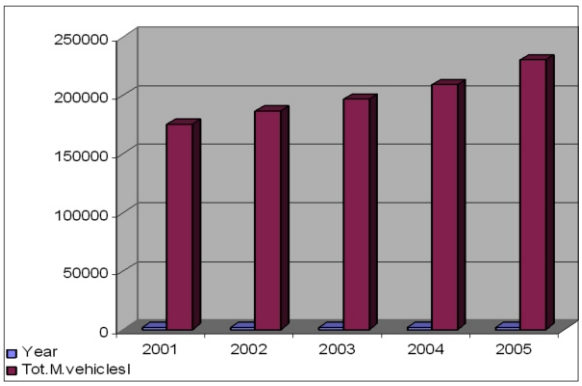

Fig. 4. Growth of Motor Vehicles in Rawalpindi [vi]

Fig. 4 shows growth of motorized vehicles in Rawalpindi. It indicates that rise in number of vehicles is gradual

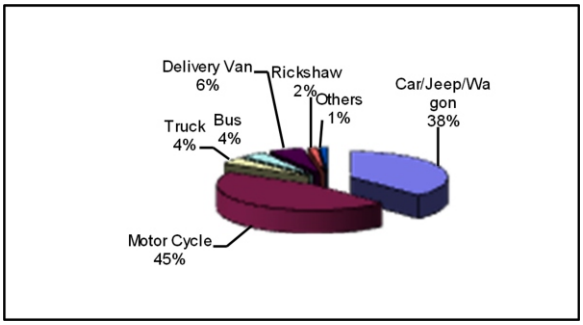

Fig. 5. Modal Share of Vehicles in 2005 [vi]

Fig. 5 shows percent share of key modes in overall volume of traffic.

C. Growth of Vehicles in Case study Area

Motor vehicular air pollution is major source of air pollution in Lahore. Road network, consisting of arterial and collector roads developed in Lahore, is comparable to any other historical city. Present shape of road network in the city is primarily radial which suits for efficient operation and coverage of public transport but due to absence of adequate number of distributors/rings/inter radials, there is unnecessary traffic pressure on primary network. Reference [vii] distribution of overall traffic assigned to the existing road network shows that 35 percent of total traffic is passenger car and jeep, whereas 30 percent constitutes motor cycles. Non-motorized vehicles are 15 percent and public transport is 8 percent of total traffic. Comparative analysis of different studies indicates that overall traffic has increased by 1.5 times with an average annual growth rate of 3.75 percent. Comparison of northern and southern sections of Lahore indicates that growth trends in bicycle and animal driven vehicles in north is steady whereas negative growth of these modes observed in the south.

City experiences high usage of personal vehicles in wake of ailing Public Transport. Growth of traffic at key roads of Lahore highlighted below

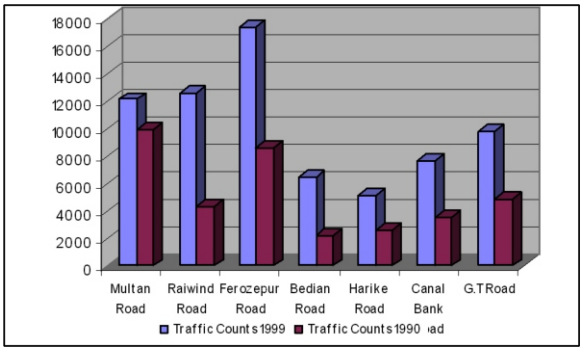

Fig. 6. Traffic Growth at Major Roads of the City Source [vii]

Fig. 6 shows decade growth of vehicles at key roads of Lahore

Mass transit of city comprises upon bus and wagon transit. Due to poor traffic management these vehicles contribute heavily towards air pollution.

Three pollutants, when compare with WHO standards indicate alarming echelon of air pollution in Lahore.

TABLE I
AIR POLLUTION SITUATION IN LAHORE [viii]

Name of Spot	NOX PPb	PM_{10} ($\mu g/m^3$)	CO ppm
WHO Standards	75	150	9
Yateem Khana Chowk	175	1123	3
Chearing Cross	328	1100	5.2
Bank Square	208	1050	19
Qurtaba Chowk	105	1030	22

Table I shows that there is a high gap between WHO permitted limits and observed level of air pollution in Lahore. Moreover, relatively high gap observed in values of Pm_{10}.

Despite a modest growth of 26 during 2000-2003, mass transit couldn't reduce pollution level in Lahore significantly. Pollution level at only one point where these buses have largely been induced, reflects no letup in pollution scenario.

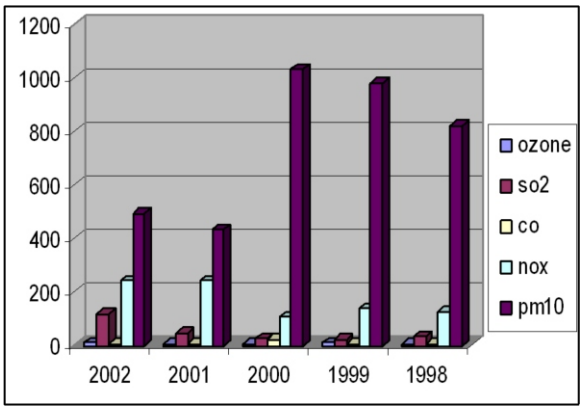

Fig.7. Air Pollution Level at Qurtaba Chowk [viii]

A comprehensive study on Transportation system in Lahore concluded that with existing network and do nothing situation average velocity in 2010 may decreases and PCU/h will increase alarmingly [ix].

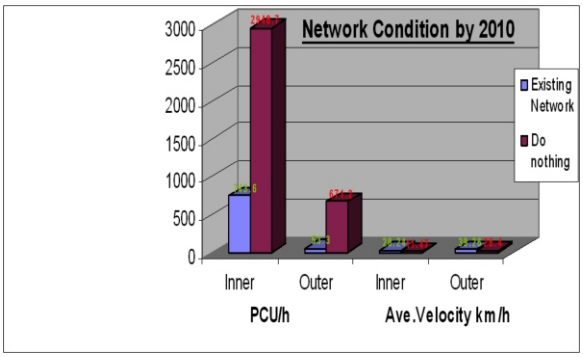

Fig. 8. Network Condition by Year 2010 [ix][adopted]

Fig. 9 shows pcu/h on inner and out network of Lahore in light of do nothing scenario.

To reduce vehicular emission management strategies for bus transit is imperative for city. Lesson from other cities of Asia suggest that construction of flyovers and modernized infrastructure does not guaranteed reduction in congestion and air pollution.

Trying to solve traffic congestion by building infrastructure simply does not work. Cities like Bangkok and Manila tried to solve their rather serious and economically costly traffic congestion problem by building flyovers, expressways and rail based mass transit systems along main corridor routes. For people

in these cities, traffic congestion remains a daily commuting nightmare [x].

IV. Remedial Initiatives by Government of Pakistan

The Government of Pakistan has made significant progress in planning and responding the environmental challenges over the last two decades. National Conservation Strategy (NCS) 1992 was a major step taken by the Government of the Pakistan in terms of enacting environmental policy and practice.

A. National Conservation Policy 1992 [xi]

The objective of NCS is to identify key environmental issues and their prioritization. NCS has 68 specific programs in 14 core theme areas. The core theme areas set out for priority implementation are

Maintaining soils in crop lands
Increasing irrigation efficiency
Protecting watersheds
Supporting forestry and plantations
Restoring range lands and improving livestock
Protecting water-bodies and sustaining fisheries
Conserving bio-diversity
Increasing energy efficiency
Developing and deploying renewables
Preventing and abating pollution
Managing urban waste
Supporting institutions for common resources
integrating population and environment programs

Program related to air pollution include shifting of industry, large manufacturing units, setting up vehicles tune up centers and compressed natural gas stations. Due to economic and technical constraints and lack of potential only limited success has been achieved in resolving industry related programs. However, progress regarding setting up of tune up centers and CNG stations is significant.

B. Pakistan Environmental Protection Act (PEPA) 1997 [xii]

The Existing laws relevant to motor vehicular air pollution listed below

Pakistan Penal Code 1860 (Section 278)
West Pakistan motor vehicles ordinance 1965
Motor vehicles rules 1969
City Development Act 1973
Constitution of Islamic Republic of Pakistan
(Article 9 and concurrent list-24)
Pakistan Environment Protection Act 1997
National Highway Safety Ordinance 2000
Punjab Local Government Ordinance,2001

Among all above PEPA is comprehensive and closely associated with urban issues. It paves the way for establishment of federal and provincial environment protection agencies and approval of National Environmental Quality Standards (NEQS). Sections of Pakistan Environmental Protection Act relevant to urban air pollution summarized below

Section 3 establishes the Pakistan Environmental Protection Council. ("Council").Section 4 enumerates its functions including those of approval of National Environmental Quality Standards and power to direct the Pakistan Environment Protection Agency(Established under section 5 as the implementation organ for this legislation with specified task listed under section 6) or any Government Agency to, inter alia, prepare and implement environmental protection projects.

The Agency's tasks under section 6 include preparation, revision and establishment of the NEQS (with council's Approval), enforcement of NEQS and establishment of standards for quality of ambient air, water and land, after consultation with Provincial Environmental Protection Agency (Provincial Agency) concerned. While agency can set different standards for discharge of emissions from different sources and for different areas and conditions(section 6(1)(g)(i), if such standards are less stringent than the NEQS, prior approval of Council has to be obtained

Section 7 empowers agency to undertake its functions whereas section 8 establishes and empowers Provincial Agencies for the same purpose

Section 11 expressly prohibits any emission of any effluent or waste or air pollutant or noise in excess of NEQS or, where applicable, the standards established under section 6(1) g(i).Contravention leads to levying by the Federal Government of pollution charge calculated and collected as per prescribed procedure. The specific extension of same standard to motor vehicles takes place in section 15 which further says that in order to maintain this standard, the agency may direct any motor vehicles or class of vehicles to install prescribed pollution control devices or other equipment or undergo testing or maintenance use a particular fuel, which motor vehicles or class of vehicles shall be prohibited from operating till such direction has been complied with

Penalties for contravention or failure to comply with provisions of section 11 and section 15: punishable with fine of up to Rs.100000 with an additional fine of up to Rs. 1000 per day for any continuing offence or failure to comply with. Any monetary benefit as result of the commission of the offence may also be recovered through a commensurate fine. Repeated contraventions may also lead to ,inter alia ,imprisonment up to two years

Prohibitions of certain discharges or emissions.

Section 15 : regulation of motor vehicles

Section 17 : penalties (extend to Rs. 100000/- with an additional fine of Rs. 1000/- every day)

C. National Environmental Action Plan [xiii]

For long time National Conservation Strategy remained defacto environmental policy of Pakistan. All actions to address environmental degradation and to promote sustainable utilization of natural resources were taken under fourteen core areas. The course of action was followed under National Environmental Action Program (NEAP) which approved in 2001.Thus narrowing down focus of government policy to four core areas namely, clean air, clean water, waste management and reservation management. A comprehensive program launched to support implementation of NEAP. The main objective of NEAP is to safeguard health and to promote sustainable livelihood by enhancing quality of life of people. It targeted to establish bridge between government agencies and civil society.

1) Components of Plan

The NEAP component plan targeted three sources of air pollution in collaboration with UNDP Pakistan. These include pollution caused by industry, indoor burning and vehicular emission. The program adopted six pronged approach by focusing on environmental governance, ecosystem management, energy conservation, dry land management and grass root initiatives.

2) Pollution Control

The purpose of the program is to improve human health by curtailing industrial pollution, vehicular pollution, indoor pollution and quality of drinking water. Sub-objectives of program are

1. Capacity enhancement of industry and EPAs to cut short industrial pollution.
2. Decrease greenhouse gases emission and vehicular emission to improve environment.
3. Enhance technical capacity of Town Municipal Administrations to bring improvement in health, education and income generation of poor.
4. Protection of drinking water in urban and rural areas.
5. Improvement in health and environmental conditions of households.

3) Fraction of Pollution Control Program

Pollution control program is further divided into secondary programs. Details of these secondary programs are as under

Industrial Pollution

Target of this program is to get clean production, improve environmental management and institutional capacity building for small and medium-sized enterprises and development at regional level.

Vehicular Pollution

Motor vehicles contribute 90% of total emitted hydrocarbons (HC), aldehydes and carbon monoxide (CO). Furthermore 75% of sulphur dioxides (SOx) and nitrogen oxides (NOx) generate through motor vehicles. The main focus of program is to help reduce pollution caused by automobile emissions.

Water Quality Protection

In the year 2000, contamination of ground water caused an outbreak of bone deformity disease. The outbreak required a vigorous monitoring especially about drinking water. The program thus primarily focused upon strengthening institutional capacities to develop program related to issues of drinking water.

Indoor Pollution

The focus area is to curtail indoor pollution in order to bring improvement in health and environmental condition

Hazardous Waste Management

The program includes measures relate to capacity building to prevent generation of wastes and improvement of contaminated sites. This includes hospital waste management. Despite NEAP regarding environmental issues and institutional frame work, the Government is cognizant of the fact that further efforts and actions need to bring actual improvement in state of environment and natural resources.

D. National Environmental Policy 2005

The National Environmental Policy aims to protect environment was announced in 2005. It focused on improvement of quality of life through protection; conservation and restoration of environment. The policy introduces a new paradigm to integrate environmental consideration in decision making. Guidance on sectoral and cross sectoral areas with highlighted instruments of implementation and monitoring made policy more open and smooth for implementation and capacity building of government institutes.

Sectoral Guidelines

Sectoral guidelines cover nine areas of environmental management and strategies, these include

Water Supply and Management
Air Quality and Noise
Waste Management
Forestry
Biodiversity and protected areas
Climate change and Ozone Depletion
Energy Efficiency and Renewables
Agriculture and Live Stock
Multilateral environmental agreements

Cross Sectoral Guidelines

Cross sectoral Guidelines cover sectors where sustainability is reliant upon environmental regulations. These include

- Poverty and Environment
- Population and Environment
- Gender and Environment
- Health and Environment
- Trade and Environment
- Environment and local Governance
- Natural Disaster Management

E. Ambient Air Quality Improvement Program

Government is quite concerned about degradation of air quality especially in major cities and has taken some significant measures to

- Establish National Environmental Quality Standards and review motor vehicles examination system in country.
- Devise a phase out plan of lead and sulphur by providing clean fuels.
- Through incentive measures 150000 petrol vehicles converted to CNG and efforts have been made to convert diesel engine to CNG fuel. Fifteen tune up stations set up and revolving loan of US $ 3million reserved to encourage establishment of more tune up stations.
- Safe guard environment at federal and provincial level a special squad of traffic police constituted.
- Steps for enforcement of industrial emission standards.

Clean Fuels Program

Clean fuels program tailored to convert vehicles on clean fuels. Under umbrella of this program 0.2 million cars have made to switch over to CNG fuel. With assistance of Canadian International Development Agency (CIDA), rickshaws have been converted to CNG on experimental basis in several parts of country.

V. Initiatives Taken by Government of the Punjab to Curb Air Pollution

Efforts of Government to curb air pollution remained focused on shifting obnoxious industries outside municipal limits and penalizing high polluted vehicles. However, after realizing gravity of situation and financial support from National Government, Government of the Punjab has taken key steps towards environmental conservation. Detail of initiatives taken by Government of the Punjab for protection of urban environment is given below

A. Ban on Two Stroke Rickshaws

After establishing fact that two-stroke rickshaws are major contributor to air and noise pollution, the Punjab Government put ban on issuance of fitness certificates on two-stroke motor cab rickshaw after 1st January 2005 .It was announced to phase out two-stroke rickshaw from major cities of the Punjab, namely, Lahore, Multan, Gujranwala, Faisalabad and Rawalpindi by 31st December 2007. Furthermore, a ban has been imposed on induction of two-stroke rickshaw as public service vehicle with effect from 31st July 2005 in major cities of Punjab. Accordingly directions issued to manufacturers M/s Saigals Qingqi private limited and M/s Sohrab industries private limited to stop manufacturing of two-stroke motor cycle rickshaws by 31st December 2007.

B. Chief Minister's Green Fund Program

Under this program incentives have been provided to prospective owners of four-stroke CNG rickshaw. This program initiated through Bank of Punjab from 15th Jun 2005.This scheme provides interest free loan to prospective buyers to purchase four-stroke CNG rickshaw. Only on payment of 10-25 percent of total cost, rickshaw hands over to owner and remaining amount will be collected in easy installments.

C. Modern Vehicle Testing Station

Government is planning to set up modern vehicle testing stations and strengthening of institutions of motor vehicles examination. In this context Secretary Transport directed by the chief minister to finalize matter in light of recommendations of ENERCON and concerned institutes.

D. Motor Transport Management Information System

A project called motor transport management information system for integrated computerization of MVE (motor vehicles examination), Fitness certificate /route permit and emission control motoring is to be started in near future. The prime objective of program is to get coordination among four departments, namely, traffic police, Excise and Taxation, Transport and Environment Protection by bringing them online through wireless system.

E. Establishment of An Urban Unit In Planning and Development Department

The Govt. of the Punjab has established the urban sector policy and management unit to make strategic interventions which improve urban environment, standards and quality of life. This urban unit with assistance of World Bank will launch an integrated traffic management system pilot project on Ferozepur road at cost of Rs. 550 million. The project would be implemented on 16 Km stretch between Mozang chungi and Khaira distributary. The work on project will commence from mozang chungi side. Under this project service lanes will improve, bus stops will

redesign and separate lanes for more than 500 buses to ply will introduce. Signals on roads will be computerized and equipped with cameras and traffic will control through newly recruited trained policemen. According to Director of Urban Unit the World Bank consultants are of the view that road is capable of taking traffic load and problems can solve by better coordination between departments and agencies responsible for traffic management. [x]

F. Ban on Old Poorly Maintained Wagons

Govt. of the Punjab after obtaining expert technical opinion that conversion of old wagons to CNG is not possible imposed a ban on old wagons. Subsequently model condition of 10 years imposed w.e.f 30th Jun2006.

G. Induction of Dedicated CNG Buses

Government the Punjab decided to recommend Federal Government to allow duty-free import of 4000 dedicated CNG buses (exempt import duty for two years). Further Government will provide subsidy or financial support to operator of CNG buses by sharing 20 percent of cost.

V. Mass Transit Development in Pakistan

After British rule little attention has paid on the development of mass transit infrastructure. Except Karachi Circular Railway, urban mass transit system of the country comprised on bus transit only. But with the growing demand of the public transport Govt. initiated different studies for introduction of railways and bus rapid transit. Different studies and development of mass transit are as under.

A. Karachi Mass Transit Study (KMTS)

Karachi mass transit study was commissioned in 1987 in amid of growing motor vehicles and declining progress trend in the share of mass transit system. The objective of Karachi mass transit study was development of programs for improvement of public transport system. After initial study it realized that Karachi needed mass transit system to fulfill growing demand. Furthermore project on build operate transfer basis was feasible. To undertake transport relevant mega project 'Karachi Mass Transit Authority' created under auspices of Government of Sindh .The mandate of the Authority was to develop and undertake implementation of mega projects. The plan prepared by Karachi Mass Transit Authority outlined five corridors of high demand in 1990.The routes identified by Karachi Mass Transit Authority revised in light of the directive of Ministry of Environment and Heritage Foundation. After deliberation and agreed on priority corridor I, Government invited Expression of Interest. Agreements were also signed but construction could not start on Priority-I (15.2 Km).The project could not gain its financial close to start physical construction. The deadline set for the system to become operational was the end of year 2000. There were some political reason and irrational decision about choice of the mode. The study concluded that inclusion of light rail transit was not feasible. Despite the fact, decision makers decided to move forward with option of rail transit. Consequently, no investment received as consultant of project was given his consent that rail not feasible at that time. Salient points of the whole study were as under

It recommended immediate action to address deficiencies of buses and minibuses

It identified transit way technology for city of Karachi (Transit ways give exclusive ways for public transport)

It called construction of 87 transit way after tested computerized network transit way alignment of 190 Km in four alternative area wide networks. The entire 87 Km should need to in place by the year 2001.

It addressed the need for year 2000 and serves requirements upto 2010.

Inclusion of light rail transit was not feasible

B. Bus Rapid Transit System in Karachi

Karachi mass transit study concluded that introduction of light rail transit was not a feasible option as bus ways could perform best, cost least and have adequate capacity. Light rail is relatively costly with very high capital cost and high fares.

A rail line will impose 2.5 times the cost per ride of the same route as bus-way [xiv]

In light of the results of Karachi mass transit study a new project called Karachi Mega City Sustainable Development Project with help of Asian development Bank is being launched. The Asian Development bank has allocated US $223 for bus rapid transit system. The system would facilitate transportation of at least 20000 passengers on persons per hour per direction basis. The project consists on construction of eleven corridors which may build in four tranche of Mega City Project. Under tranche-1, the entire three corridor project is planned to complete within a record period of 24 month. Detail of three corridors under tranche-1(plan to undertake in 2008) is as under

Corridors UnderTranche-1
Route I (32 Km)
Surjani Town to Quaid's Mausoleum
Route II (14 Km)
Quaid's Mausoleum to Karachi University
Route III (4 Km)
Orangi Town extension
Corridors Under Tranche-2
Route IV (21.5 Km)
Nagan chowrangi to Landhi
Route V & VI (2.7 Km)

Rashidabad extension and Upmore extension
Corridors Under Tranche-3
Route VII (4.7 Km)
Gulistan-i-Jauhar to University road
Route VIII (10.4 Km)
KDA to Metropole via shahrah-i-Faisal
Route IX (2.3 Km)
From shahra-i-Quaidin
Route X (18 Km)
Korangi to shahra-i-Faisal
Route XI (4.8 Km)
In Defense Housing Authority

Buses plying under BRTS will environment friendly dedicated CNG buses with capacity of 160 passengers. Budget allocated for all three phases of tranche-1 is US $ 223 million. BRT system in Karachi is likely to incur a construction cost of about US $ 2.57 million per Km including cost of stations, all equipment and cost of buses.

C. Development of Mass Transit in Lahore

Govt. policies about mass transit system remained inconsistent and vague. During 1970's,for only two million people, a sufficient fleet of double decker buses (which were less polluted, low fuelled and high transit capabilities) were available and government endured to focus on the development bus transit. In later years rather than expanding role of mob carrying transit government relied on tiny fleet of Bus transit (each comprise on 75 seats). To cope with the growing demand of transport, government had allowed to operate privately owned (15 seater) wagons. These wagons with low transit capabilities had caused a huge damage to environment of city. Furthermore, that transit system, being an uncomfortable, less transit capable, highly overloaded forced people to have their own riding. Thus results in uncontrollable rise of Para transit. By counting high vehicular emission and growing concern about congestion in city, the Government redefined its role. Incentives to bus transit operators were introduced and a ban imposed on allotment of routes to wagon transit. The developed situation, again swapped the Government policy of bus transit but that time in private control. Government policy had been focusing merely on single mode since long, despite feasibility and scope of other mass transit system. Master Plan for Greater Lahore asserted the need of circular railway around city, keeping in view the future spiralling demand of motor vehicles and environmental concerns. But the Govt. did not pay heed to the assertion, even after expiry of planning period. In 1991, a comprehensive study on transportation system of Lahore was carried out with cooperation of Japanese International Cooperation Agency (JICA). It was again asserted in the report that Light Rail Transit (LRT) and Heavy Rail Transit (HRT) were highly feasible for city. Introduction of LRT not only would save energy but also helped in maintaining the environmental balance. Furthermore, growing motor vehicles and increasing congestion had forced the Government to reconsider the option to introduce of rail transit in the city. In connection to it, in 2007, the Government had hired a Hong Kong based company to carry out feasibility study of light transit in Lahore.

D. Lahore Light Rail Mass Transit (LLRMT)

LLRMT was a two-phased 97 Km long project. MVA Asia have proposed four rail lines in the city to share traffic burden. Funding for the project was committed by the Asian Development Bank (ADB). Proposed capacity of LLRMT is to move 35000 passengers per hour in city. Two phases of the project have been proposed. In phase I, two tracks have to be built, a north- south bound route (called as green line) and an east- west bound route (called as orange line). The proposed length of the green line is 27 Km. Out of which 11.6 Km long green line route be under ground while 15.4 Km long would be overhead. Twelve underground and ten overhead stations have to be built on green line route. The cost of the green line is US $ 2.4 billion (US $ 88 million/Km). Initially, the project has planned to finish by 2012 but finally, the completion year for the green line set as 2011. It has been estimated that 227000 people will benefited from the green line. The Authority has selected green line route from Shadra to Hamza Town via Ravi Road, Lower Mall, The Mall Road, Fatima Jinnah Road, Qartaba Chowk and Ferozepur Road Area. Passengers of LLRMT would be charged Rs.125/- to 140/- to travel from one end to other.

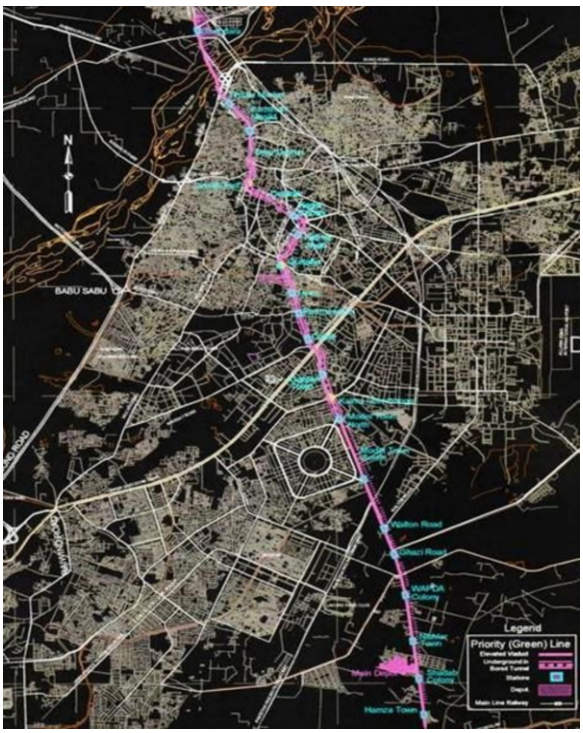

Fig. 9. Route Map of LLRMT Priority Line [xv]

Fig. 10 shows underground and elevated corridors of priority line to be completed by the year 2010.

The route of the orange line has been planned from Pakistan mint to sabzazar via Shahnoor, Awan Town, Hinjarwal, Niazbeg Thokar etc. The total length of orange line is 27 Km. Out of which 6.9 Km long track would be under ground while 20.2 Km long would be overhead. Six underground and twenty overhead stations have planned to develop. The total cost of orange line was US $ 1.9 billion (US $70.37 million per Km) and completion year set as 2015. About 245000 people annually would benefit from orange line. Completion of the phase II is set as 2020. Two more tracks have to be built. Routes of these tracks are called as blue line and purple line respectively. The blue line 24 Km long have planned to start from Chouburji and end at college road. Whereas purple line 19 Km long will start from Bhatti Chowk and end at Allama Iqbal International Airport. Train stations on elevated routes would be designed like overhead bridges while underground routes would have two entrance ways and two exit ways.

Due to change of government and allegation of corruption, LLRMT project could not be initiated, despite availability funding from Asian Development Bank.

Government of the Punjab (GoPb), recently negotiated the project with Chinese investor company "NORNICO" who showed willingness to provide 85% of the contract amount. According to the contract NORINCO has to design and build LRMTS; whereas LTC to engage an operator for subsequent operation of the system. The previously carried out feasibility and initiation of the project, was put at stake by a chaotic construction of a flyover at Kalma Chowk Lahore. The flyover has been located on the green line proposed LRMTS.

Reference [xvi] Fate of this project is under risk, as GoPb has constructed a flyover at Kalma Chowk. Semi Government Consultant Company was responsible for the design & construction of the Kalma Chowk flyover. LRMTS Green Line alignment and design had been completely ignored. The construction had been done on ad-hoc basis due to inability of the Consultant to understand and incorporate the complex LRMTS Green Line (GL) alignment and station design. The most serious problem is the location of flyover pillars which incurs re-design of the GL underground Kalma Chowk station.

Another similar mistaken action, has now subjected the construction of green line to another review. The situation is further made worst buy the recently started construction of Canal / Muslim Town/ Wahdat road junction flyover. This will have the same impact on GL Cana station as did the Kalma Chowk flyover. Future LRMTS Green Line would need another review and re-design effort by some International Consultant [xvi].

E. Metro Bus Lahore (Bus Rapid Transit System)

In 2011 the Government of Punjab appointed "Ulasim", a Turkish based company of the Istanbul Metropolitan Municipality, for preparing the preliminary design of Metro Bus System (MBS). The Metro bus operates on 27 Km long corridor starting from Gajjumata to Shahdara. The corridor has the following salient features

It operates in centre of the road at 10 m wide dedicated corridor

There are twenty seven (27) bus stations each after 1 Km with two curb-side platforms serving opposite bound Buses.

Each Platform can accommodate simultaneous stopping of three articulated buses.

Corridor from Qaddafi Stadium to Data Darbar (8.3 Km's) made elevated to avoid conflict of Metro buses with normal traffic in the congested areas..

Metrobus system now operates with 64 articulated buses.

The maximum speed of the Metrobus is 50 Km/h with headway of 2-3 minutes.

Intelligent System is equipped with Automated Fare Collection (AFC) System, Bus Scheduling System (BSS), Vehicle Tracking System (VTS), Passenger Information System (PIS)

LRMTS network, which was developed by JICA based on identification of potential mass transit corridors and their priority of implementation, built primarily on forecasted passenger demand, has identified the following four lines:

1) Green Line - Ferozepur Road/Mall Road/Ravi Road/Shahdara

2) Orange Line - Raiwind Road/Multan Road/ Mcleod Road/ Railway Station/GT Road

3) Blue Line - Township/Gulberg Boulevard/Jail Road

4) Purple Line - Bhatti Gate/Allama Iqbal Road/Airport

An international group have submitted to Transport Department an unsolicited bid to build and operate a monorail system along the Green Line alignment on BOT basis. The technical specifications of the proposed systems have been scrutinized and now confirmed. But no decision yet taken regarding 'monorail' system in Lahore.

A Korean group of investors have also expressed interest in providing BRT system along the Green and Orange lines corridors on BOT basis. Government has requested the Korean investors to prepare detailed feasibility study which covers detail of technology, financing and implementation plan for the two BRT lines along both Green & Orange Lines corridors.

The imprecise stance of Government finally lasted when it decided to extend the metro bus project along

orange and blue lines in Lahore. But rather than to focus on its extension and completion, Govt. decided to introduce it in other big cities of Punjab without assessing its impact on environment and overall transportation of the city. The work on Metro bus of the twin city (Rawalpindi-Islamabad) has been started. The transit system of Lahore which is being run on only one corridor is now turned into a half-baked scheme which could have crucial connectivity problem with existing public transport. Furthermore, there require a root rationalization of all routes in wake of Metro bus. In 2014, the Government again intends to introduce the rail transit along orange line already as proposed by LLRMT feasibility with cooperation of a Chinese company.

The inconsistent behaviour of the Government leads to increase transport demand sharply. The transport demand recently estimated by Japanese International Co-operation Agency (JICA) is 12 million trips, which includes 4 million short walking trips and 8 million motorized trips, on a usual weekday. The number of vehicles registered in Lahore increased sharply from 95 vehicles in 2001 to 238 vehicles in 2008; per 1000 population [xvii].

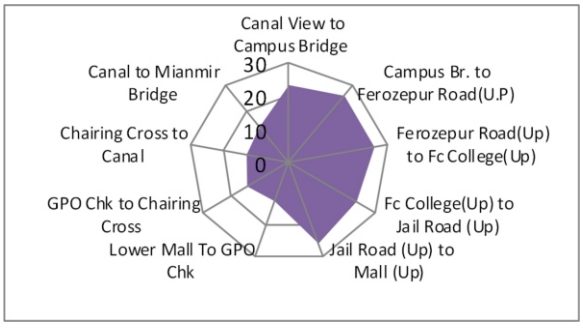

Fig. 10. Percentage of Surfeit Emission due to Erroneous Running of Mass Transit in Lahore

Furthermore, the existing mass transit due to erroneous running generates up to 26% additional emission at different corridors of Lahore [xviii]. Surfeit emission at different corridors of Lahore highlighted in Fig. 10.

F. Results and Discussion

The growth of motor vehicles in big cities of Pakistan particularly in Lahore is unprecedented which has led to pollute environment.

Policy and initiatives taken by the Federal Government to curb urban air pollution has focused upon reduction of motor vehicular emission at source by the use of technology and clean fuel programs. It rarely focused upon control of air pollution through mass transit system.

Government policy for introduction of mass transit remained imprecise which has increased transportation demand and up surged surfeit emission due to erroneous running of existing mass transit system.

The Planned Metro bus expansion has put to stagnation as the Govt. finally decided to introduce rail transit at orange line. Incongruously, it decided to extend its operation to other big cities of Punjab.

Routes alignment or rationalization of public transport needs to be carried out in the wake of metro bus operation. Up to 26% surfeit emission resulted due to erroneous running of existing mass transit.

The construction of the green line would need another review and re-design effort by some International consultant due to disorder construction of two flyovers as finally decision for rail transit has taken.

Inconsistent policies of governments towards mass transit system have jeopardized fragile environment of the city.

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Mapping of Liquefaction Susceptible Sands of Punjab Province in Pakistan

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***Abstract*-**Liquefaction is hazardous for existing and new developments because the saturated loose sands lose their bearing capacity under shaking due to earthquake. In Pakistan, lesser database is available about the presence of liquefiable sands and local codes are also silent about its origination/mapping especially in Punjab Province. Historically, Punjab has been facing low to high intensity earthquakes. The developments on liquefiable sands faced numerous losses of lives and property after earthquakes in recent decades. An attempt has been made to evaluate liquefaction susceptibility of sand deposits in different districts of Punjab for future record in terms of mapping. There are lots of procedures available for analysis, identification and quantification of liquefaction potential of sands. The analysis is done based on two of the most recognized techniques i.e. Standard Penetration Test (SPT) parameter and grain size characteristic. Analysis resultant parameters like cyclic resistance ratio (CRR) and cyclic stress ratio (CSR) are plotted on the base curves available in literature about liquefiable sands. Based on analysis, a map is proposed for liquefiable sands in Punjab.

***Keywords*-**Sands, Liquefaction, Standard Penetration Test, Map, Grain Size Characteristics, Punjab, Pakistan

I. INTRODUCTION

Liquefaction is a phenomenon which mostly occurs in granular soils under saturated and poor drainage conditions. These granular soils are like sands or silty sands[i]. During seismic loadings, the volume of loose sands decreases resulting increase in pore water pressure. Due to rise in pore water pressure, shear strength decreases and subsequently reduction of effective stress occur [ii]. Evaluation of liquefaction potential for a soil deposit can be determined by a combination of factors like properties of that soil, environmental conditions and earthquake characteristics. Although, we cannot determine some factors directly but for liquefaction evaluation procedure, the effects of these factors can be incorporated. Two methods are commonly available to evaluate the liquefaction potential of soils i.e. through field Standard Penetration Test (SPT) and laboratory gradation parameters. The liquefaction potential of soil is normally referred interns of Cyclic stress ratio (CSR), Cyclic resistance ratio (CRR) and respective Factor of Safety (FOS). The details of these methods are discussed below.

After massive damages due to severe earthquakes of Alaska and Niigata Japan in 1964, two methods of liquefaction assessment were developed one from SPT data proposed by [iii] also named as "simplified procedure" and other from laboratory gradation parameters by [iv]. Since, then the "Simplified procedure" was continuously improved by different researchers like [v],[vi],[vii] Fig. 1 shows the latest status of the procedure.

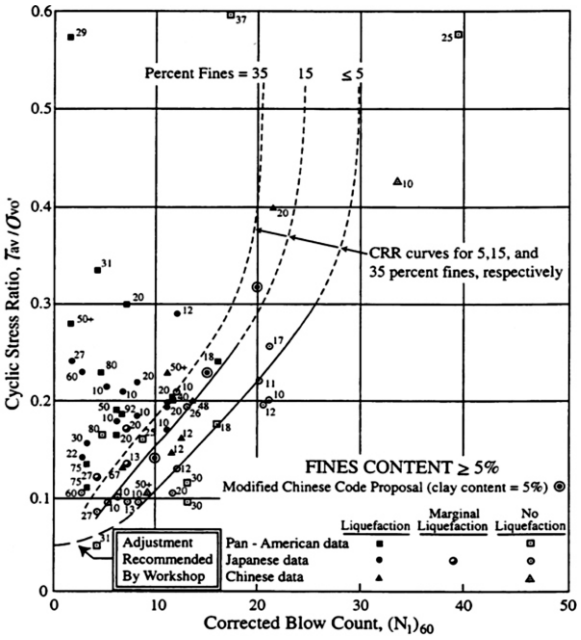

Fig. 1. Simplified base curves for determination of CRR from SPT (Seed et. al 1985)

To prepare liquefaction maps of soils is a common practice in developed countries for its possible consideration during development on such soils. The maps developed for liquefaction susceptibility differentiates the zone of low or high liquefaction potential. Mapping of liquefaction susceptibility is raised in order to identify that how the liquefaction hazard is different from one place to another on the

basis of different earthquake characteristics.

Distribution of different geologic strata, depth of ground water table, bore hole logs and predicted levels of shaking during future earthquakes are parameters which are used for development of these maps.

Although the liquefaction susceptibility mapping for the areas are increasing around the world, but the method for the development of such kinds of maps has remained the same. The basic parameter used in most of the previous and existing liquefaction susceptibility maps is geotechnical engineering data and surface geology.

One of the available maps of liquefaction susceptibility of San Francisco Bay Area of USA is shown in Fig. 2. In this map, interpretation of Liquefaction susceptibility has been done on the basis of geotechnical engineering data and surface geology. References [viii], [ix], [x], [xi]& [xi] also used geotechnical engineering data / geological data for liquefaction susceptibility mapping in past.

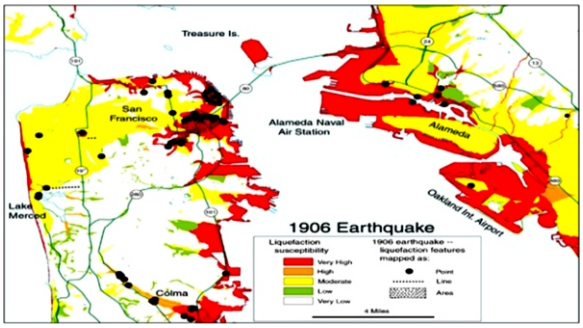

Fig. 2. Liquefaction susceptibility map of San Fransico Bay area USA

Almost no work has been done regarding mapping of liquefaction susceptible sands of Punjab Province in Pakistan. In this research, a basic liquefaction map has been developed after identification and analysis of sands prone to liquefaction. The purpose of this research was to provide the basic guidelines to the geotechnical and structural engineers for carrying out design in the liquefaction susceptible areas.

II. Materials and Methods

Identification of liquefaction prone soils in Punjab was carried out initially. For that purpose detailed literatures / documents in form of geotechnical engineering reports / geological formations were collected / consulted from different organizations like Soil Survey of Pakistan, Geological Survey of Pakistan, Communication and Works Department Government of Punjab, NESPAK, Berkley Associates, etc. The basic base in identification of potentially liquefiable soil areas was seismic zoning map of Pakistan as shown in Fig. 3.

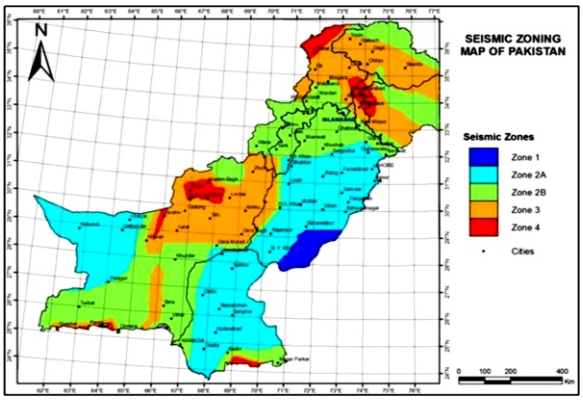

Fig. 3. Seismic Zoning Map of Pakistan

The geotechnical engineering reports/geological formations of all districts of Punjab were evaluated based on the criteria of gradation parameters and Standard penetration tests data. After identification of liquefiable soils, the in-situ geotechnical parameters like SPT blows (N) were further corrected to $(N_1)_{60}$ as recommended [xiii] and analyzed to determine the liquefaction properties like CRR (Cyclic Resistance Ratio) which is a measure of liquefaction resistance of soil, CSR (Cyclic Stress Ratio) which is induced by earthquake and respective factors of safety. These factors were calculated from mathematical expressions/equations described from Eq. (1) to Eq. (7).

$$CSR = 0.65 a_{max} / g r_d \sigma_v / \sigma'_v \quad (1)$$

0.65 = Reduction factor converting the (single/one time) peak cyclic to the "equivalent uniform shear stress

a_{max} = The peak ground acceleration in units of g.

r_d = Stress reduction factor accounting for the flexibility of the soil profile.

σ_v = Total vertical overburden stress.

σ'_v = Effective vertical overburden stress.

Stress reduction factor assumes a linear relationship of r_d versus depth as shown in Eq. 2 [xiv]

$$r_d = 1 - 0.012z \quad (2)$$

z = Depth in meters below the ground surface where the liquefaction analysis is being performed

The N-value is the blow counts for the last 30 cm of penetration and 50 times is the maximum value. However, for harder soil penetration cases, there often happens that penetration depth does not reach 30 cm or counts need more than 50 times for 30 cm penetration. For practical use of N-values for earthquake engineering purpose, the corrected N-value of "N_{SPT}" is used.

The measured SPT blow count (N_{SPT}) is first normalized for the overburden stress at the depth of the

test and corrected to a standardized value of $(N_1)_{60}$. Equation (3) is used for the calculation of corrected SPT $(N_1)_{60}$ using the recommended correction factors.

$$(N_1)_{60} = N_{SPT} \times C_N \times C_E \times C_B \times C_R \times C_S \quad (3)$$

C_N = Correction applied for overburden
C_R = Correction applied for rod length
C_B = Correction applied for borehole diameter
C_E = Correction applied for hammer energy
C_S = Correction applied for sampler whether it is with or without liner

$$CRR = 1/[34 - (N_1)_{60}] - (N_1)_{60}/135 + 50/[(10(N_1)_{60} + 45)]^2 - 1/200 \quad (4)$$

Equation (4) for the calculation of CRR is valid for $(N_1)_{60} < 30$ and earthquake magnitude of 7.5 (ii). For $(N_1)_{60} > 30$, Clean granular soils are too dense to liquefy and are classed as non-liquefiable. If the magnitude of earthquake is other than 7.5 then CRR value is further corrected using a factor named as Magnitude Scaling Factor (MSF) and its mathematical expression is shown as Eq. (6) [ii]

$$CRR = CRR_{7.5} \text{ x } MSF \quad (5)$$

$$MSF = 10^{2.24} \text{ x } (M_w)^{2.56} \quad (6)$$

M_w is the anticipated earthquake magnitude

$$FOS = CRR/CSR \text{ x } MSF \quad (7)$$

An Excel spreadsheet based on "simplified procedure" was developed to calculate these liquefaction properties in steps mentioned by [xv].

Then the calculated values of $(N_1)_{60}$ and factors of safety were checked against the limits defined by researchers. The soils having $(N_1)_{60} < 30$ the soils were considered liquefiable and for soils having value of $(N_1)_{60} > 30$, considered as non-liquefiable [xvi]. After calculation of $(N_1)_{60}$, CRR and CSR values at a particular depth of given soil stratum, factor of safety against liquefaction was calculated [iii]. For the soils having factor of safety less than or slightly greater than 1.0 i.e. 1.2 (xvii), the soils were declared liquefiable.

Then the calculated parameters like $(N_1)_{60}$, CRR, CSR and factor of safety were plotted against depth to interpret the behavior of liquefaction susceptible sands of Punjab. Also, the parameters like CRR, CSR and $(N_1)_{60}$ were plotted on the curves (ii) to show the compatibility of this research with previous researchers. Correlations between $(N_1)_{60}$, CSR and CRR were also proposed.

Liquefiable soils identified at different sites were also verified through gradation parameters obtained from geotechnical engineering reports. Based on the findings of research, the mappings of liquefiable soils for the province of Punjab were made using ARC GIS software.

III. Results and Discussion

For the identification of liquefiable soil areas; geological data, geotechnical reports/ data from various Government and Non-Government organizations were reviewed. Initially the surface soils data present in all districts of Punjab were evaluated based on the criteria of gradation parameters and Standard penetration tests data. After initial evaluation the methodology explained by [iii] and [iv] as shown in Fig. 4 was adopted.

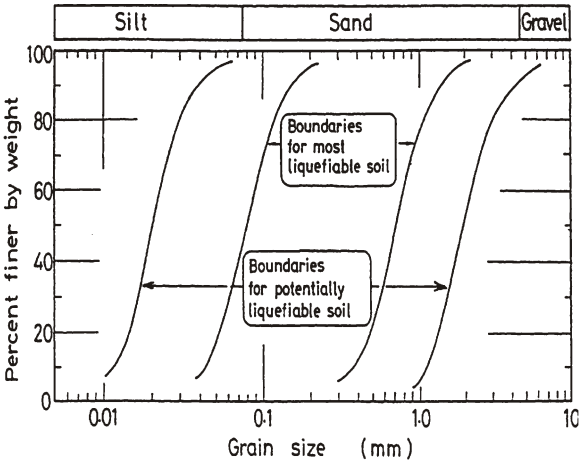

Fig. 4. Liquefaction soil boundaries based on gradations (Tsuchida 1970)

Characterizations of districts in Punjab Province are listed in Table I based on basic geological surface data obtained from Soil Survey of Pakistan & Geological Survey of Pakistan. It was observed that tehsils Attock, Haroonabad, Minchanabad, Bahawalnagr, Daryakhan, Wazirabad, Karorlaliesam, Malikwal, Muzafargarh, Liaqatpur, Sargodha, Bahalwal and Sialkot tehsils of these districts have distinguishable alluvial sands deposits. Liquefaction susceptible sands were also observed at different other districts of Punjab at scattered locations particularly along the fine major river routes. Presence of loose sands at the top strata and shallow depth of ground water table was the criteria for preliminary scrutiny. In order to further scrutinize the initial data formation for the analysis only tehsils having distinguishable formations of alluvial sands (with liquefaction susceptibility) were only selected as summarized in Table I.

TABLE I
SUMMARY OF DISTRICTS IN PUNJAB WITH RESPECT TO SOILS FORMATIONS

Sr.	District Name	Dominant soils formations in most parts of districts	Liquefaction susceptible tehsils in districts used in analysis
1	Attock	Alluvial sands	Nartopa
2	Bahawalnagar	Alluvial sands	Haroonabad, Minchanabad, Bahawalnagar.
3	Bahawalpur	Loams	-
4	Bhakkar	Alluvial sands	Daryakhan
5	Chakwal	Pothohar Belt with Expansive Soils	-
6	Chiniot	Clayey stratum	-
7	Dera Ghazi Khan	Expansive Soils (xviii)	-
8	Faisalabad	Clayey stratum	-
9	Gujranwala	Clayey stratum with Alluvial Sands and Expansive Soils (xviii)	Wazirabad
10	Gujrat	Clayey stratum	-
11	Hafizabad	Clayey stratum	-
12	Jhang	Clayey stratum	-
13	Jehlum	Clayey stratum	-
14	Kasur	Clayey stratum	-
15	Khanewal	Clayey stratum	-
16	Khushab	Clayey stratum with Expensive Soils	-
17	Lahore	Clayey stratum	-
18	Layyah	Alluvial sands	Karorlaliesan
19	Lodhran	Clayey stratum	-
20	Mandi Bhahuddin	Alluvial sands	Malikwal
21	Mianwali	Clayey stratum	-
22	Multan	Clayey stratum	-
23	Muzafargarh	Clayey stratum with Alluvial Sands	Muzafargarh
24	Narowal	Clayey stratum	-
25	Nankanasab	Clayey stratum	-
26	Okara	Clayey stratum	-
27	Pakpattan	Clayey stratum	-
28	Rahimyarkhan	Clayey stratum with Alluvial Sands	Liaqatpur
29	Rajanpur	Clayey stratum	-
30	Rawalpindi	Pothohar Belt	-
31	Sahiwal	Clayey stratum	-
32	Sargodha	Clayey stratum with Alluvial Sands	Sargodha, Bhera
33	Sheikhupura	Clayey stratum	-
34	Sialkot	Clayey stratum with Alluvial Sands	Sialkot
35	Toba Tek Singh	Clayey stratum	-
36	Vehari	Clayey stratum	-

The database in forms of geotechnical testing reports were collected from different organizations in these thirteen identified tehsils of Punjab Province for the verification of the presence of liquefaction soils. The summary of which is presented in Table II.

TABLE II
PROJECT NAME WITH THEIR SOURCE OF COLLECTION

Sr.	Tehsil	Title of geotechnical engineering report	Reference
1	Minchinabad	Govt. Boys High School	
2	Haroonabad	Govt. Islamia Rizvia	
3	Bahawalnagar	Distt. Jail Residences	
4	Bahawalnagar	Separate Emergency Block in DHQ	
5	Muzaffargarh	Executive Engineer Residence	
6	Liaqatpur	Riverine Post	
6A	Liaqatpur	Govt. Boys High School	
6B	Liaqatpur	Govt. Girls Primary School	
7	Layyah	Police Station	Building Research Station(BRS), Communication &Works Department, Lahore, Govt. of Punjab
8	Layyah	Police Station	
9	Bhakkar	Govt. Boys Degree College	
10	Bhakkar	Govt. Boys Degree College	
11	Attock	Govt. Girls Elementary School	
12	Attock	Govt. Girls Elementary School	
13	Attock	Govt. Girls Elementary School	
14	Sargodha	Govt. Degree College for Girls	
15	Sargodha	Govt. Degree College for Girls	
16	Sargodha	Govt. Degree College for Girls	
17	Bhera	Govt. Degree College for girls	
18	Bhera	Govt. Degree College for Girls	
19	Mandi bahauddin	Construction of Judicial Complex	
20	Mandi bahauddin	Construction of Judicial Complex	
21	Mandi bahauddin	Construction of Judicial complex	
22	Marala	Lucky Hydropower	Barqaab Consulting Services (Pvt.) Ltd. Lahore
23	Wazirabad	New Khanki Barrage	Berkley Associates Lahore

From the database of geotechnical investigation reports of projects tabulated in Table II the SPT profiles and gradation parameters have been extracted for further analysis. A liquefaction phenomenon was observed in sandy soils. Fig. 5 presents the grain size analysis of soils encountered in regions reported in Table II.

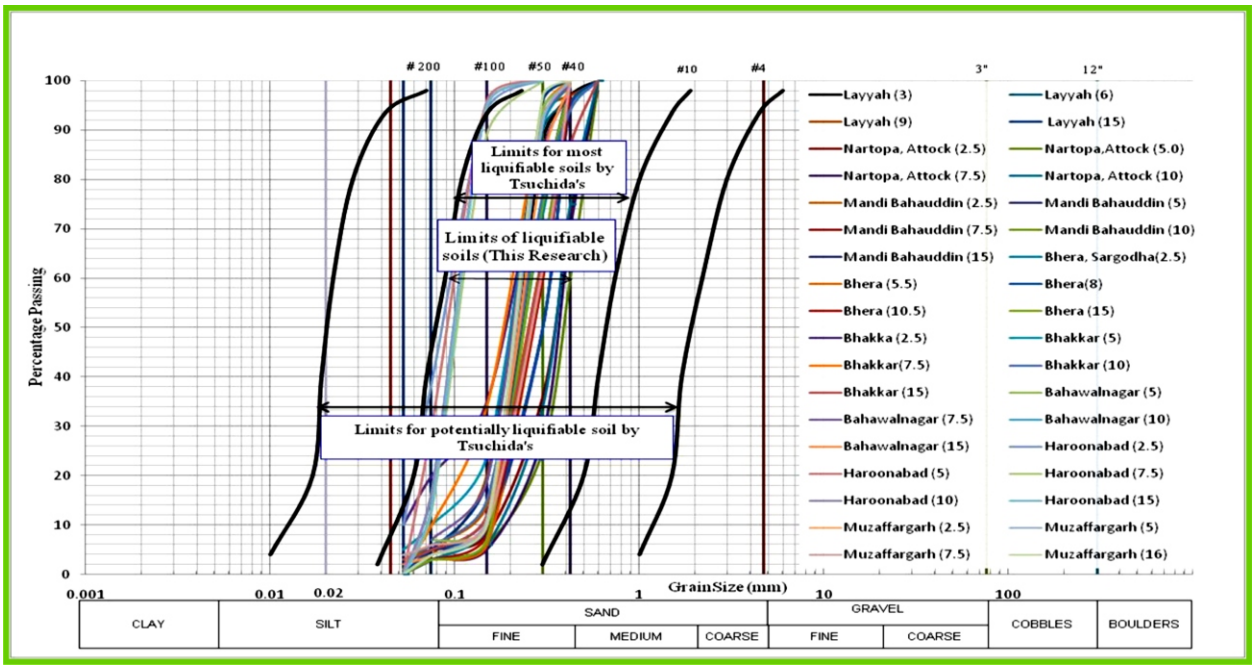

Fig. 5. Gradations profiles of soils

It can be seen in Fig. 5 that most of the soils are medium to fine sands in nature. Sands are more susceptible to liquefaction. The gradations of sands found in all the tehsils fall well within the boundaries of the liquefiable soils proposed [iv].

Hence, based on the analysis of gradations curves the soils encountered in all tehsils are categorized as liquefiable. The SPT profile with depth for all twenty three projects is shown in Fig. 6.

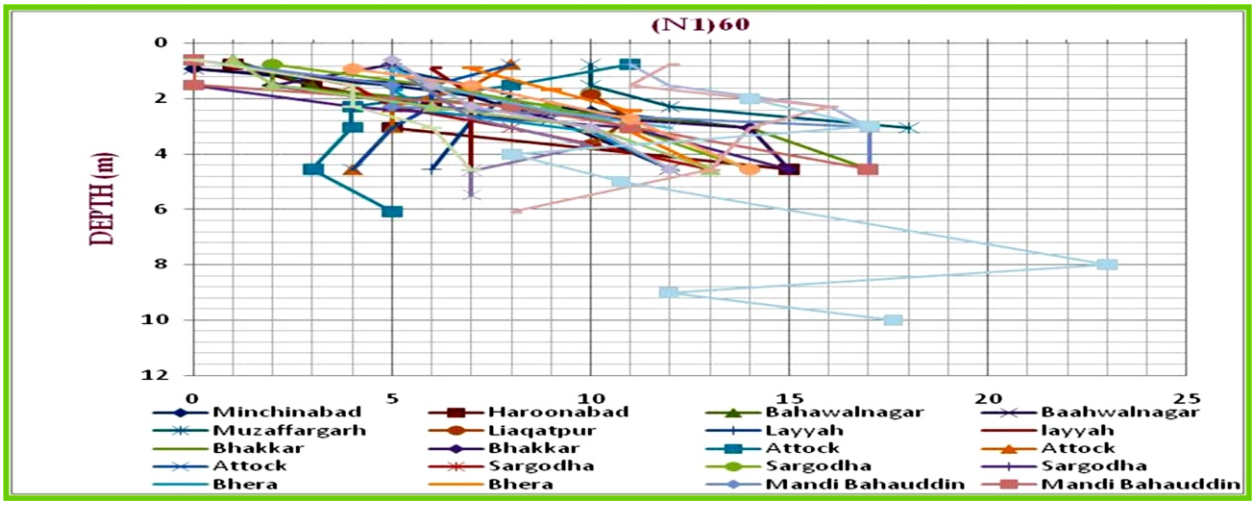

Fig. 6. SPT blows profile with depth

It can be seen from Fig. 6 that the value of $(N_1)_{60}$ is less than 20 in almost all the soils up to an average depth of 6 m. Hence, the soils showing $(N_1)_{60}$ < 30 are declared as liquefiable soils [ii]. CRR and CSR were determined using SPT blows against moment magnitude (Mw) of 7.5 intensity and maximum value of Peak Ground Acceleration (PGA) for a particular zone as reported in Seismic code of Pakistan (SP-2007). Moment magnitude of intensity 7.5 and maximum value of Peak Ground Acceleration (PGA) is taken to consider the critical condition for analysis. Figs.7 & 8 show the profiles of CRR and CSR with depth.

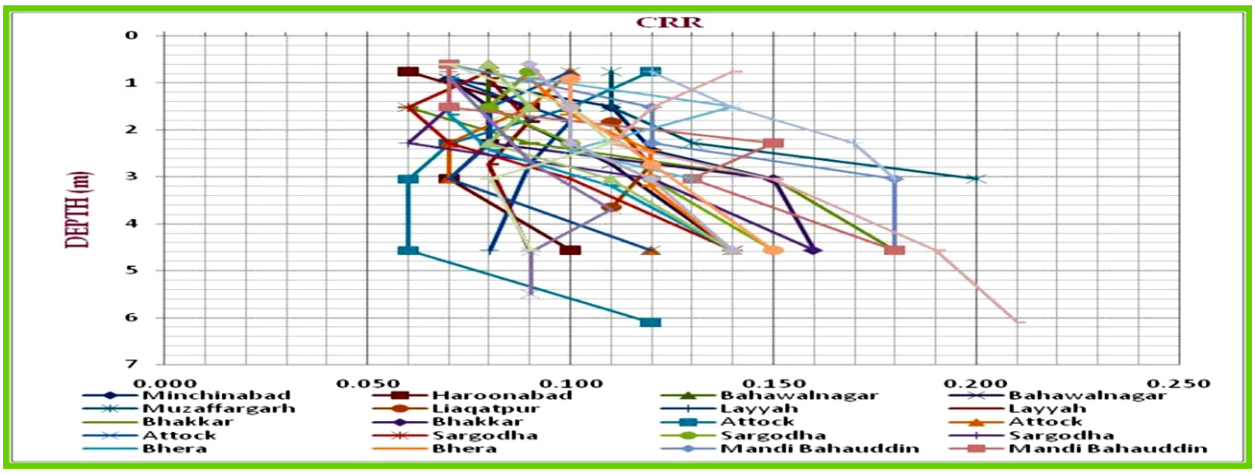

Fig. 7. CRR profiles with depth

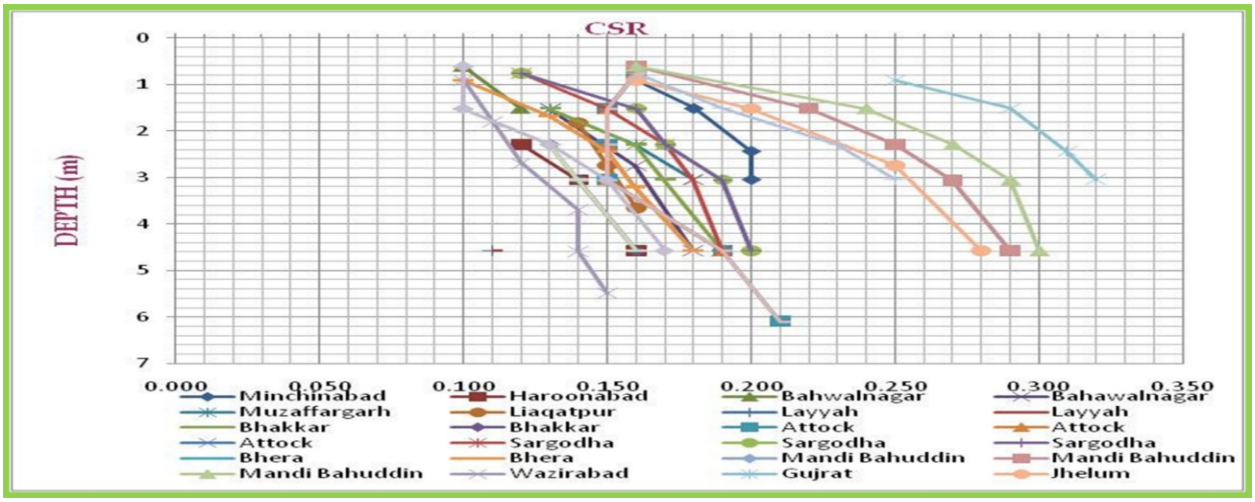

Fig. 8. CSR profiles with depth

It is eminent from Fig. 7 that CRR increases with the depth. The typical range of CRR observed in all location varies from 0.06 to 0.2. The CSR shows an increase with depth in typical range of 0.1 to 0.3 as shown in Fig. 8. The corresponding FOS profiles with depth are presented in Fig. 9.

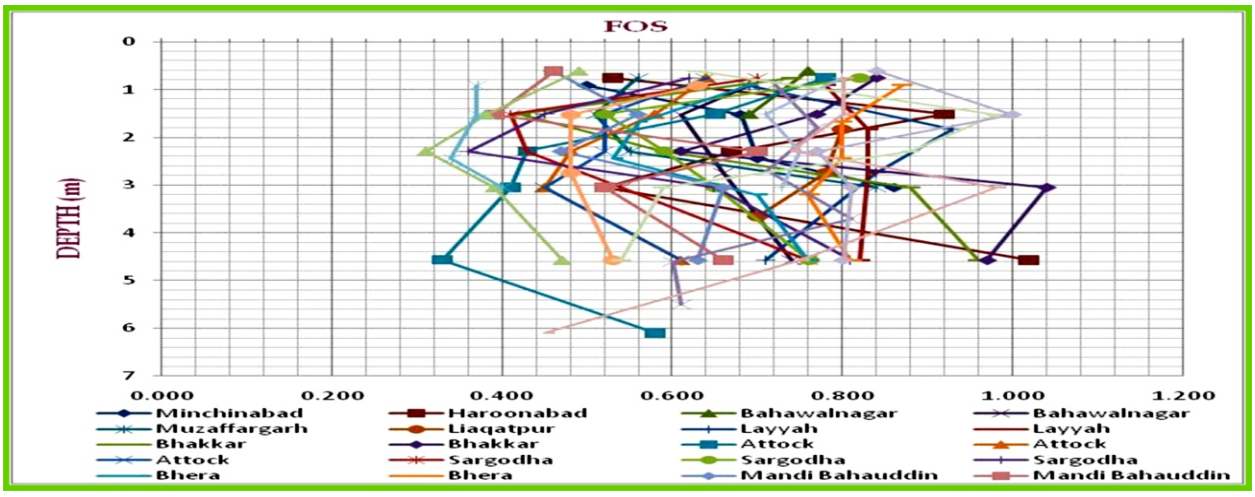

Fig. 9. FOS profiles with depth

In almost all the locations the Factor of Safety (FOS) ranges well below 1 as shown in Fig. 9. For further evaluation of the liquefaction susceptibility in soils i.e. $(N_1)_{60}$, CRR and CSR were also plotted on the original curve proposed by [iii] with future subsequent modifications as shown in Fig. 10.

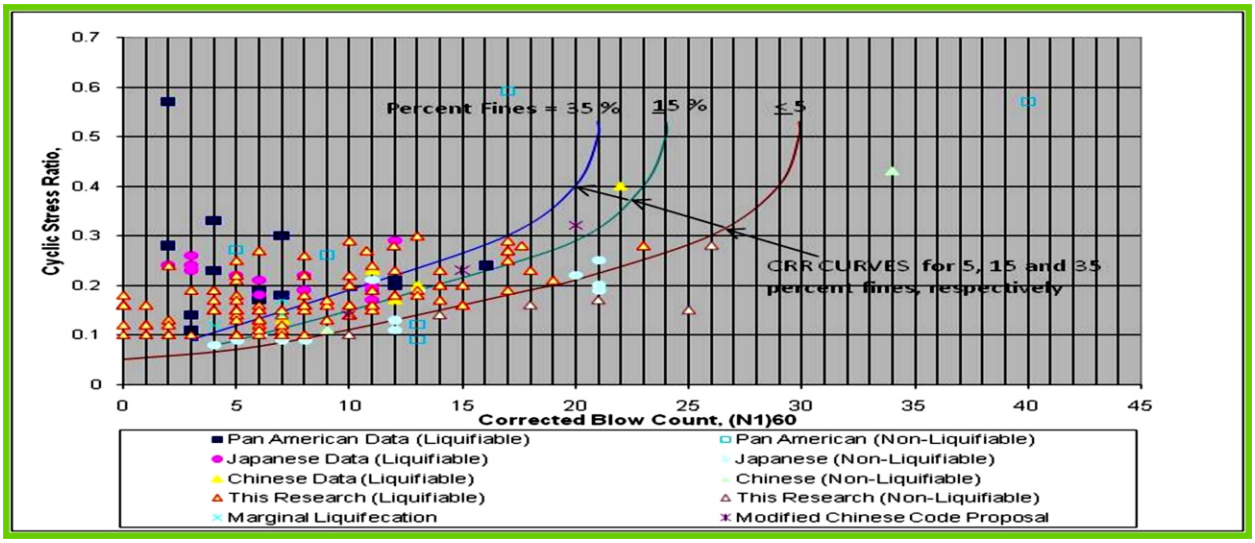

Fig. 10. CSR & CRR and $(N_1)_{60}$ plotted on Seed & Idriss Curve

The sands under study has been observed typically well within the typical zones of liquefiable soils as depicted in Fig. 10. Hence, the in-situ geotechnical engineering data of all 23 projects of all thirteen tehsils under study proved as liquefiable sands.

There are number of relationships reported in literature between CRR, CSR and $(N_1)_{60}$ for different type of soils. Two strong correlations between CRR, CSR and $(N_1)_{60}$ have also been obtained during data analysis of the subject study as shown in Figs. 11 & 12.

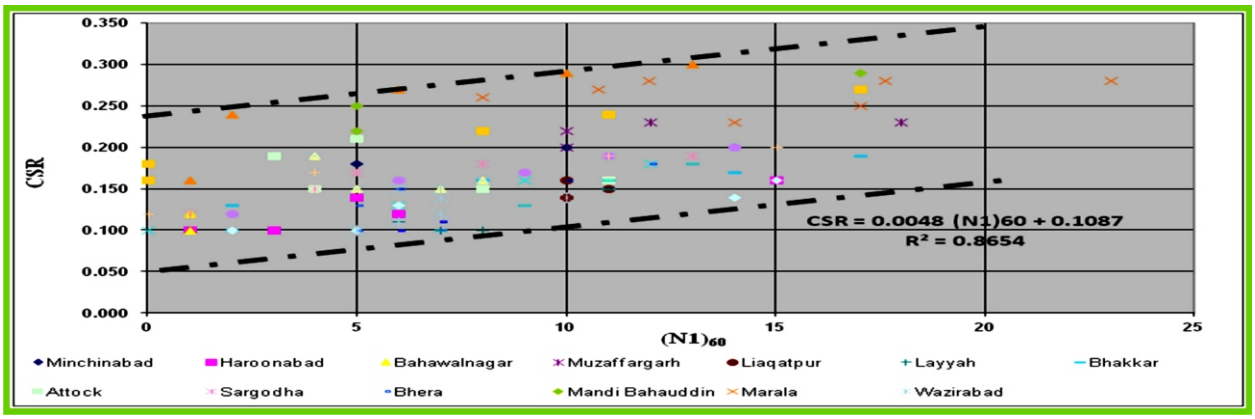

Fig. 11. Correlation between CSR and $(N_1)_{60}$

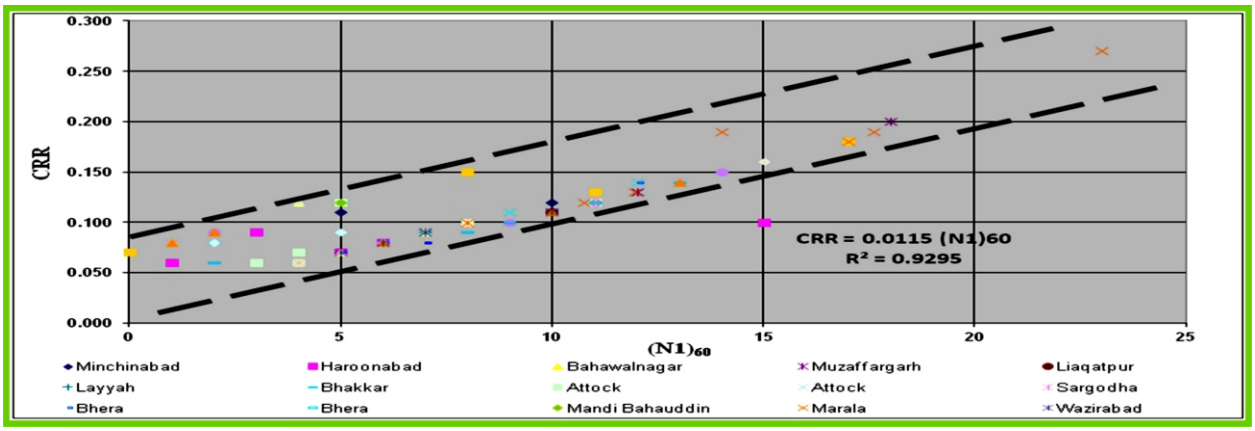

Fig. 12. Correlation between CRR and $(N_1)_{60}$

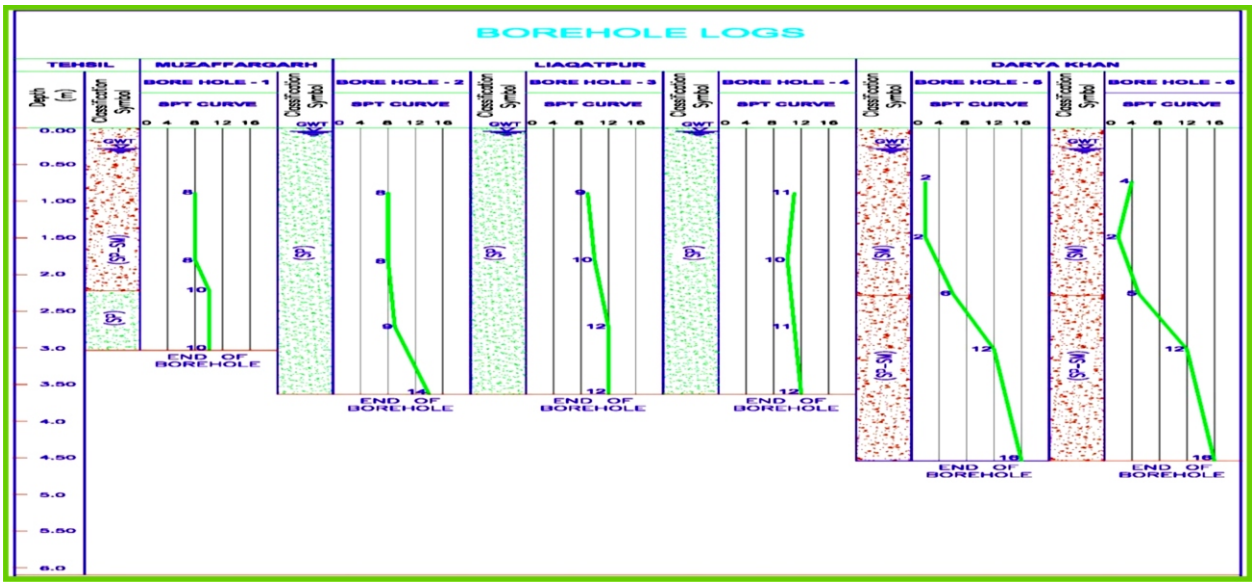

Fig. 13. Typical Bore Hole Log plot of different liquefiable tehsils

Both correlations reported in Figs.11&12 have strong coefficient of determination. The correlations between CRR, CSR and $(N_1)_{60}$ reported in Figs.11 & 12 are helpful for the direct determination of CSR and CRR after carrying out only SPT test at site. Further validations of correlations are recommended. Boreholes 2D plots of liquefiable tehsils like Muzaffargarh, Liaqatpur and Darya Khan has been plotted side by side as shown in Fig. 13 which shows higher water table and presence of poorly graded sands / silty sands in the upper strata.

Also the SPT-N values are less than 15 even at a depth of 3m. A map of Punjab province was developed using ARC GIS software as shown in Fig.14. On the map using coordinates districts, tehsils and locations of the projects were marked. Based on $(N_1)_{60}$ the magnitude of liquefaction on the map was subdivided into two parts as proposed [ii].

$(N_1)_{60}$ = 0 20 High liquefiable soils
$(N_1)_{60}$ = 21-30 Intermediate liquefiable soils

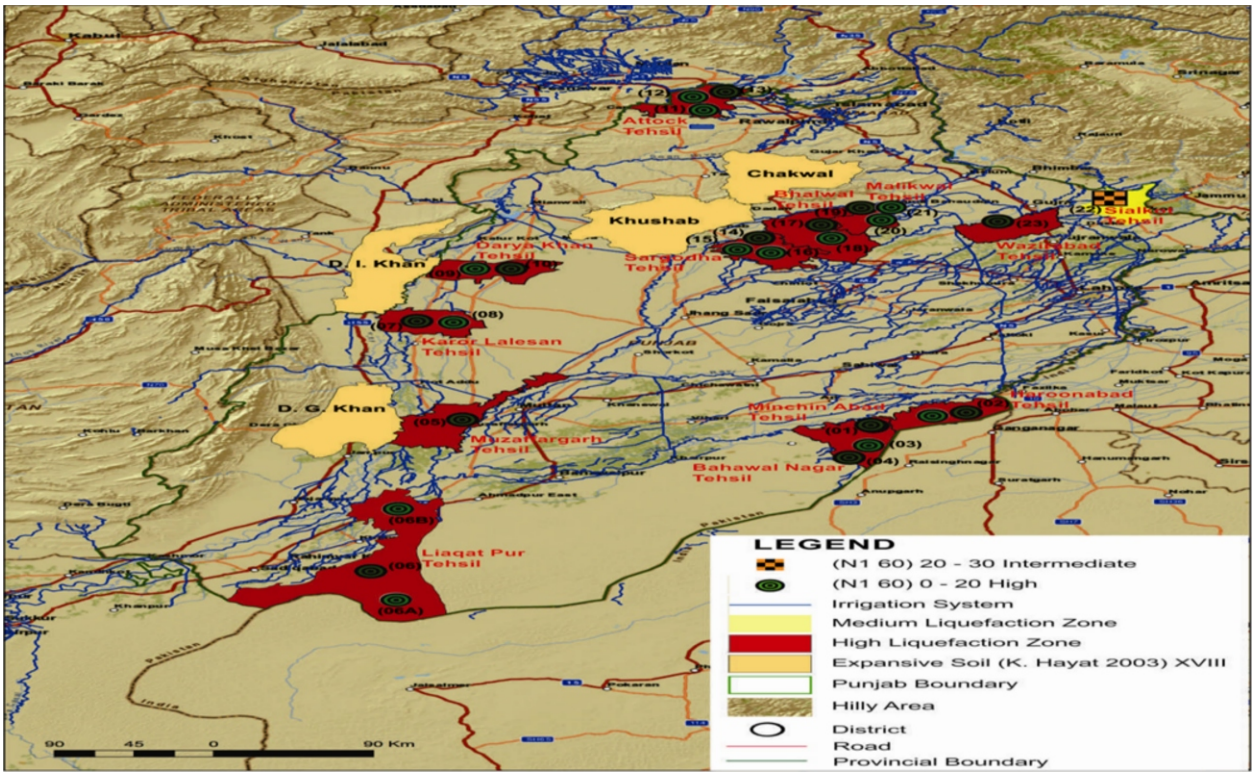

Fig. 14. Map of Punjab showing liquefiable soils

IV. Conclusions

The main object of mapping is to introduce the trend adopted worldwide in the practice of Pakistan. Further, it has been one of the key considerations to propose the idea through the subject research to local government and non government organizations dealing in codes of practice, researchers and professionals engaged in the practice of engineering to be adopted for identification of liquefiable soils. Following conclusions can be drawn from the above findings:

High liquefiable sands zones in Punjab are identified in Liaqatpur, Bhawalnagar, Muzzafargarh, Layyah and Minchanabad tehsils in southern Punjab. Attock tehsil in northern Punjab. Malikwal, Waziarabad, Bhalwal and Sargodha tehsils in eastern Punjab. Darya Khan tehsil in western Punjab.

Medium liquefiable sands zones in Punjab province are as following Marala tehsil in eastern Punjab.

Any geotechnical / structural engineering investigation or development works carried out in liquefiable susceptible zones identified above need to incorporate special considerations in design of footings.

V. Acknowledgements

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Estimation of Potential Rainfall Recharge in the Pothwar Area

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***Abstract*-**Groundwater recharge is a complex phenomenon to understand and describe because it cannot be seen with open eyes. We have to depend on some theoretical assumptions to understand this complicated hidden natural underground water movement process. There are many factors affecting and controlling the water movement in soil profile. Groundwater use in district Chakwal is of a fundamental importance to meet the rapidly expanding drinking and agricultural water requirements. The main factors contributing to groundwater recharge in Chakwal are rainfall, evapotranspiration and geology. Due to the semi-arid climatic conditions of the area, this resource is almost the only key to economic development. There are a number of dug wells in the area where water is getting stored during rainy season. Sources and processes of recharge in humid areas are different compared with semi-arid areas. Due to the main source of available water in the area, the potential groundwater recharge estimation could be good exercise to visualize the amount of rainwater entering the ground. For groundwater recharge estimation there are a number of simple and advanced techniques available. In the present study simple methods were used to estimate potential recharge due to available limited resources. Rainfall runoff, gravimetric and water table fluctuation methods were used to quantify rainfall recharge during the monsoon season. The average potential recharge estimated was 60% of the rainfall of 148 mm. Rainfall runoff and gravimetric methods were found to be comparable for short period potential recharge estimation while water table fluctuation method gives actual recharge and require longer period data. Potential recharge values were higher for area having grassland type vegetation and low for area covering shrubs and thick vegetation.

***Keywords*-**Semi Arid, Plateau, Gravimetric, Rainfall Runoff, Water Table Fluctuation

I. INTRODUCTION

The Pothwar Upland commonly called the Pothwar Plateau, lies on the South of Northern Mountains. It is bounded by river Jhelum on the East, Indus on the West, Kalla Chitta Range and Margalla Hills on the North and Salt Range on the South. District Chakwal is surrounded by Mianwali, Rawalpindi, Attock, Jhelum and Khushab districts as shown in Fig. 1. The area is full of diverse wildlife and pictorial scenes. At present, the area is under water stress conditions due to low rainfall and extensive deforestation. There are a number of famous lakes like Kallar Kahar, Uchali, Khabeki and Jhallar having problems of water quality and storage area. Chakwal is a rural barani district with hilly terrain having a very small industrial sector. Due to high spatial and temporal variation of rainfall in arid region great difficulties arise in raising crops/plants due to uncertain water-supplies [i]. The total runoff potential of Pothwar Plateau is about 3.50 million-acre-feet (MAF) and only 0.10 MAF is being harvested [ii]. However, a large amount of water (about 3.40 MAF) is being lost as surface runoff annually. This is not only the loss of precious resource, but also causes erosion of fertile top-soil which results in decreased soil fertility and productivity, siltation of water storage reservoirs and conveyance system as well as floods in the downstream areas [iii]. Most of the soils in District Chakwal range from silt loam to loam with pH ranging from 7 to 9. Chakwal lies within the monsoon range. There are two rainy seasons in this area, The first caused by the monsoon winds originating from the Bay of Bengal, begins from 15th July and continues up to around the 15th September. The second season caused by the Mediterranean winds (Western disturbances) begins from December and continues upto the monsoon season. Occasionally Western Disturbances coincide with monsoon causing prolonged large areas. The average rainfall is 558-635 mm and Choa Saidan Shah Subdivision has the maximum rainfall in the district.

Due to undulating features of Chakwal the rainfall runoff takes place quickly causing soil erosion. The farmers were unhappy with this phenomenon. To control these problems, the Government of Punjab established an institution named Soil and Water Conservation Research Institute (SAWCRI) and Barani Agriculture Research Institute (BARI) based

at Chakwal with SAWCRI substations at Rawalpindi, Jhelum, and Hafizabad districts. SAWCRI is working well with the co-operation of farmers to reduce the soil loss by placing stone structures in the way of runoff. These hurdles divert the direction of runoff and reduce its speed causing minimum soil erosion. SAWCRI is also working on rainwater harvesting and BARI is endeavoring to enhance agricultural production under barani conditions.

II. Review

Groundwater recharge can be defined as the quantity of rainfall reaching the water table. Groundwater recharge can be quantified either by change in the soil moisture status or water table fluctuations. For this purpose accurate measurement of seepage, net pumping leakage from nearby aquifer, water content and pressure variations on the water table is required. [iv-vi] used water table elevations to describe the recharge. However, only a few investigations attempted to describe recharge by soil moisture data [vii]. [viii] showed that the two quantities might differ, due to either the influence of the unsaturated zone or non-acceptance by the aquifer of the potential value. Losses from irrigation systems frequently provide contribution, which exceeds that from rainfall. [ix] presented a water balance model to estimate groundwater recharge in Rechna Doab. [x] presented a method for calculation of groundwater recharge from rainfall in the Indus Plains of Pakistan. [xi] while working on development of ground water model for SCARP-1, considered contribution of rainfall to ground water recharge in the surface water balance of field. A certain fraction of the seasonal rainfall was assumed to drain out as surface run off and rest either recharge the aquifer or increase the moisture content of soil profile and ultimately evaporate. What remained on surface was assumed to have evaporated. Subtraction of evaporation and evapotranspiration losses from effective precipitation resulted in the quantity of rainfall contribution to ground water recharge. It has been estimated and prepared by various agencies (WAPDA, 1980) that 10 percent of the total rainfall over an area contributes towards the ground water reservoir. An exercise on the same line was carried out by WAPDA (1982) for 52.5 percent cropping intensity (actual for 1980-81) for SCARP-1 and losses for rainfall was estimated to be about 35 percent.

There is no wide spread irrigation system in Chakwal. The only major rivulets and seasonal channels that run through Chakwal are the Soan and the Soj Nullah. A number of small dams have been constructed in the district through which some irrigation takes place. There are large numbers of storm channels which are mostly active during rainy season. Chakwal area is a barani area, so there is a need to develop groundwater resources to fulfill the irrigation and domestic water requirements. Due to this reason it is necessary to see the ground water storage pattern after the monsoon season and to quantify the rainfall recharge occurring actively in every monsoon season. The objective of the present study was to estimate potential rainfall recharge using different methods.

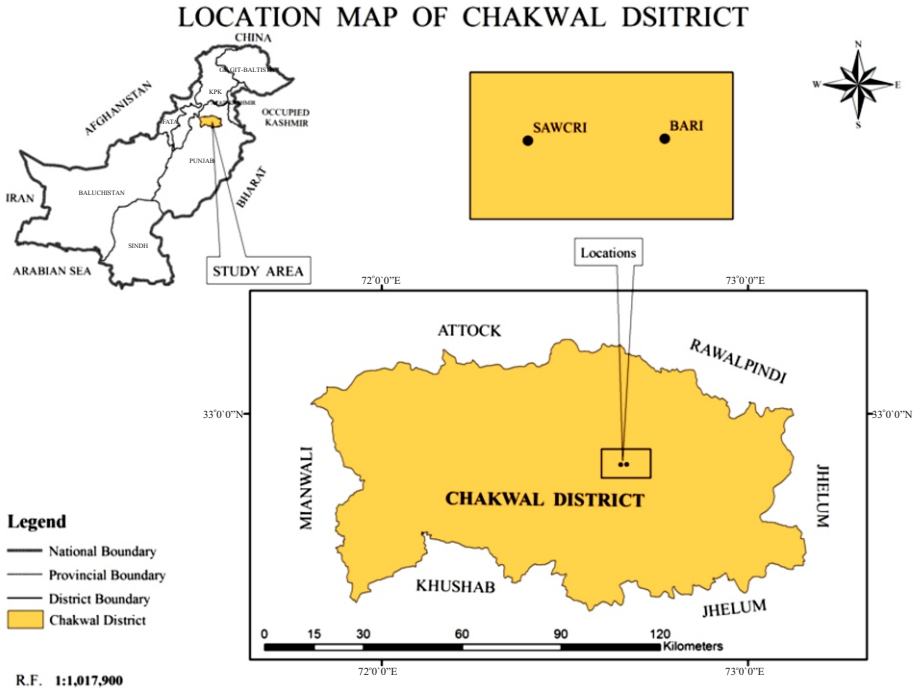

Fig.1. Map of study area

III. Materials and Methods

The study was conducted during the monsoon season (June to July, 2006) over an area of 65 hectares at the Barani Agricultural Research Institute (BARI) Chakwal to carry out the different field activities. Rainfall and the water table variation in the area are from 400 mm to 750 mm and 35feet to 90 feet respectively (BARI). The data required (Soil Texture, rainfall data, runoff data) for this study was taken from the meteorological station of Soil and Water Conservation Research Institute (SAWCRI) Chakwal. The following methods were used for the estimation of rainfall recharge:

1. Gravimetric Method
2. Rainfall Runoff Method (Also called Water Balance Method)
3. Water Table Fluctuation Method

A. Data Collection

1) Hydraulic Conductivity

To determine the hydraulic conductivity of the selected field, the soil samples were collected at different locations and constant head permeater apparatus was used for analysis.

2) Soil Moisture Data

Soil moisture data was used in gravimetric method. For soil moisture data, the soil samples were collected for forty days on daily basis at the depth difference of 0.5 to 5 feet and the samples were analyzed in the SAWCRI lab.

3) Specific Yield

Specific yield data was used in water table fluctuation method. Pumping test analysis was performed to determine the specific yield of the wells. For this purpose two open wells in the study area were selected and draw down was noted during the pumping test. Water table fluctuation was also noted by considering an open well as observation well. To calculate the rainfall recharge, the change in water table depth before and after rainfall was multiplied with specific yield of the well as given below;

$$R = \Delta H * S_Y \quad (1)$$

Whereas

R	Rainfall recharge (mm)
ΔH	Change in water table depth (mm)
S_Y	Specific yield of the well

To quantify the soil erosion and rainfall runoff in district Chakwal, SAWCRI has laid a network of runoff plots. There are twenty plots with each of size 10 m^2. .The study was divided in five field slopes ranging from 1% to 5% with four field conditions as;

T_1	Control	T_2	Ground nut
T_3	Moong	T_4	Millet

When rainfall occurred the runoff of different quantities was generated in each plot, due to different slope and vegetative cover. This runoff was collected in collection drums buried at the plots outlets. The recharge was calculated by using the following relationship,

$$\text{Recharge} = \text{Precipitation} - \text{Runoff} - \text{Evaporation} \quad (2)$$

IV. Results and Discussion

During the study period there were three rainfall events as shown in Fig. 2. Water table fluctuation during the study is shown in Fig.3. The soil texture up to the depth of 0-15 cm was loam and 15-90 cm the soil texture was clay loam so the soil under consideration was clay loam. The average bulk density of the soil was 1.35 g/cm^3 and the saturated hydraulic conductivity was 0.01 cm/min. It is clear from the Fig. 4 that the maximum recharge occurred by rainfall of 60 mm. The maximum recharge was estimated by rainfall runoff method. The recharge estimated by the water table fluctuation is the actual recharge which is very less as compared to potential recharge. The results of gravimetric method and rainfall runoff method are comparable whereas the results of water table fluctuation method are not comparable because the water table data taking period was very short and there is always a lag between rainfall event and actual recharge.

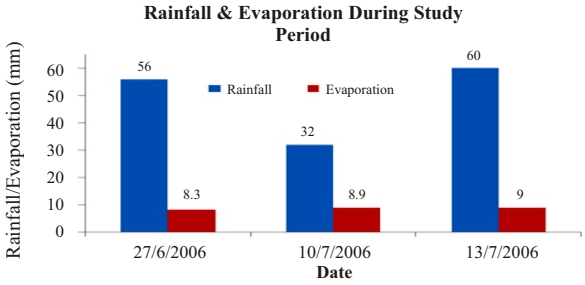

Fig.2. Rainfall during the study period

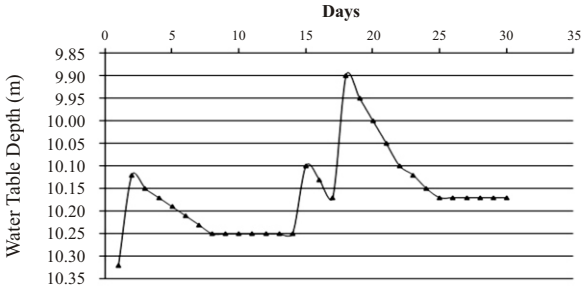

Fig.3. Water table fluctuation in dug well during the study period

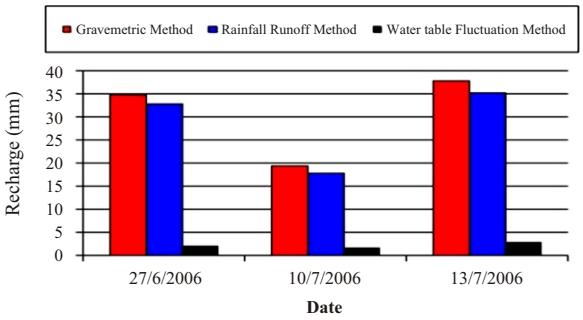

Fig. 4. Recharge comparison of three methods

V. Conclusions and Reccomendations

There were three rainfall events during the study period with a total rainfall of 148 mm.

The soil texture was clay loam. The bulk density and hydraulic conductivity determined were 1.35 gm/cm^3 and 16.6 cm/day respectively.

The Rainfall-runoff method and Gravimetric method are the best approaches for Potential recharge estimation while water table fluctuation method is good for actual recharge estimation.

Potential recharge values were higher for area having grassland type vegetation and low for area covering shrubs and thick vegetation.

Study should be conducted for longer period covering multiple rainfall events and the results for shorter period data should be used carefully.

Remote sensing and GIS data used with detailed water balance models may give better results of recharge estimation.

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Assessment of Quality Assurance practices in Pakistani Software Industry

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Abstract-The growth of software industry in Pakistan in recent years is very impressive. However, to sustain this growth and deliver high quality software, software development organizations need to follow rigorous quality assurance practices. This defines the primary purpose of this research, which is to assess the current quality assurance practices in the Pakistani software industry in order to identify areas where improvements can be made. Major aspects of software quality assurance, namely testing methodologies and techniques, test automation and tools, test management, quality metrics, and quality assurance training and education, were taken into consideration. The results of the research show that currently the use of quality assurance related activities is not widespread. This is specifically true of small software development organizations. However, it is encouraging to see that they are very much inclined in incorporating such practices.

Keywords-Software Quality Assurance, Software Testing, Software Quality, Pakistan

I. INTRODUCTION

The software industry has shown a decent growth in the last two decades. A study on the value of software development shows that in software development industry, investment increased from $82 billion to $149 billion from 1995 to 1999 [i]. Charette stated in his report that $1trillion was spent on IT hardware, software and services during 2005 [ii]. Beside this growth, the software industry still needs improvement to produce such products that meet quality standards, time pressure and budget restriction [iii]. Information technology (IT) in today's world is very important, but IT has the challenge to develop successful products with well-known methodologies [iii-vi]. These software products not only affect the business but influence human lives as well [vii-viii]. Therefore, a focus on the assurance of quality software is becoming more and more important.

Software Quality Assurance (SQA) comprises a set of techniques that ensure the software engineering processes to produce a quality product [ix]. Software development organizations give less importance to quality assurance as it is the first option to cut back when deadlines are missed [ix]. The literature suggests that errors missed in the early stage of software development may have a rippling effects, and are time consuming and expensive to correct at the end of the project [x]. Ewsui-mensah [xi] shows that 52.7% of the software projects completed are 189% over budgeted. In 2005, US economy suffered at least $25billion and as much as $75billion was lost due to project failures [ii]. Hardgrave et. al. suggest that the software development needs improvement with methodologies, but these methodologies are not the solution of all software development problems [vi]. As Gill stated in his study, the project fails if the quality management process is not effective no matter how advanced the tools and techniques are [xii].

Feldman [xiii] defines quality assurance as "*providing guarantee and reliability that the product works correctly*". Merriam Webster [xiv] describes quality assurance as "*a set of services that inspires confidence and certainty*". Software quality assurance team is defined as "*professionals founded to promote the quality assurance profession through proliferation and advancement of high professional standards*" [iii]. Pyhajarvi and Rautiainen [xv] define the role of quality assurance team as exploring errors and assuring that these errors are resolved before the release of the product, unless management decides not to fix these defects.

This study aims at understanding the level of Software Quality Assurance (SQA) techniques and practices that are being followed by the software development organizations in Pakistan. This research will help to identify the best practices and the weaknesses in the quality assurance techniques currently used in the Pakistani software industry. Apart from this, this study will also help to find out whether the existing training courses of quality assurance taught in universities and private institutions of Pakistan cover the required types of techniques and skills that are useful for the present industry.

The rest of the paper is organized as follow:

section II explains survey methodology, section III presents the findings and analyses, section IV discusses the findings and section V concludes the paper with future directions of the research.

II. Research Methodology

The data was collected though a survey questionnaire from various software development organizations across Pakistan. The questionnaire consists of 24 questions related to software quality assurance. Two approaches were used for the distribution of questionnaire. The nearby organizations were approached in-person where hard copies of the questionnaire were distributed. A web based version was also designed and the link of the survey was emailed to the participants. About 150 organizations were contacted but only 42 participants participated in the survey.

The questionnaire was divided into five categories. In addition, an introductory section was also added to find the organization structure, size in term of employees, level of experience and the way they develop the software. The five categories under focus were: software testing methodologies and techniques, test automation and testing tools, test management, quality metrics, quality assurance training and education.

As the respondents were allowed to select multiple answers for some of the questions, the results show more than 100% bar for these questions.

III. Survey Findings and Analysis

A. Organization Profile

Out of 42 responders of survey, almost half (42.8%) of the responded were the developers, 21.4% claimed to be testers, 16.6% were project managers, 19% were team leaders and the rest were system analysts and C.E.O's (as shown in Table I). 47.6% of the respondent stated that they have a master degree, 19% have MS/M.Phil, 23.8% have Bachelor, and 7.1% have PhD degree.

TABLE I
Respondents by Their Position

Current position	Response	%
Developer	18	42.8
Tester	9	21.4
Team leader	8	19
Project manager	7	16.6
C.E.O	2	4.7
System Analyst	1	2.3

Most of the organizations were small in size, 33.3% had number of employees less than 10 and 23.8% had 10-20 employees. Some of the organization were large 7.1% (>500) (Table II). Some of these have a significant amount of experience in the field of software development: 47.6% respondents stated to have 2 to 5 years of experience, 23.8% with 1 year, 16.6% with 2 year, 7.1% respondent claimed to 5 to 10, and 4.7% have more than 10 years.

TABLE II
Organization Size

Size of the company	Response	%
Less than 10	14	33.3
10 to 20	10	23.8
20 to 50	7	16.6
50 to 100	5	11.9
100 t0 500	3	7.1
More than 500	3	7.1
Total	31	100

As far as the development method of the organization is concerned, a mix response was noted. 33.3% respondents state that they are following agile methods while 26.1% say they are using some kind of phase oriented method. 66.6% of the organization claimed that they have a separate team for quality assurance, while 33.4% say that they do not have any dedicated team for quality assurance. In term of budget allocated to quality assurance process, 30.9% participants indicate that they allocate less than 10% budget (cost/time) to quality assurance process whereas 40.4% of the organizations assign 10-25% of the resources. This result shows that in most organizations quality assurance process is under estimated.

B. Testing Methodologies and Techniques

In this section the adaptation of software testing methodologies and techniques were considered. Regarding different testing techniques adaptation, 57.1% of the organizations claim that they are doing black box testing (also called functional testing) while 45.2% state that they are doing white box testing (also called structural testing). Method like inspection and other static techniques are not as common. The use of automated testing is also less popular due to the lack of expertise in automated testing tools. Only, 4.7 % of the organizations stated that they do not use any kind of testing techniques, but instead they do “ad hoc” testing.

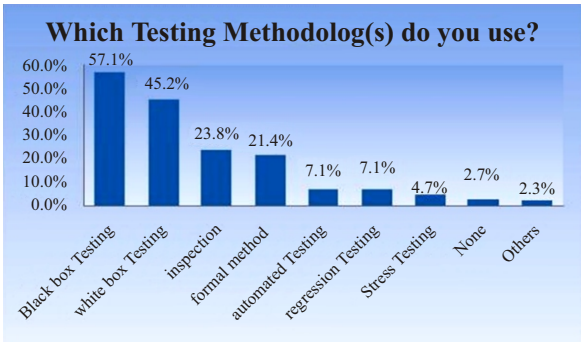

Fig. I. Testing Methodologies

1) Black box Testing Vs White box Testing

The survey result shows that black box testing is more popular in the organizations than white box testing (i.e. 57.1% follow black box while 45.2% perform white box testing). Boundary value analysis (45.8%) is the most common test case design techniques for those organizations that perform black box testing, followed by state transition testing and equivalence partitioning (33.33% each). Only 20.8% are using decision table testing.

For white box testing branch coverage (47.3%) is most frequently used as coverage criterion. Other common white box testing techniques are condition coverage (36.8%), path coverage (36.8%) and statement coverage (26.3%).

2) Static Vs Dynamic Testing

To test the software by execution it is called dynamic testing. White box, black box and ad hoc testing are parts of dynamic testing [xvi]. The survey result shows that dynamic testing is more popular than static testing techniques. This may be because of static review techniques such as Inspection, Desk check etc. require more time.

3) Brriers to adopting a testing methodology

This section investigated the views of the respondents on the barriers in adopting testing methodology in organization. The summary of the responses are presented in Table III. It can be seen that 45.2% of the respondents state that cost is the major factor preventing their organization from adopting testing methodologies. Lack of expertise (30.9%) is the second major factor that hampered the use of testing methodologies. Only 11.9% of the participants believe that there is no barrier.

The two large problems identified are cost and lack of expertise. The possible reasons for these problems are the small budget and size of the projects and may be the professional in software testing and software quality assurance are not sufficiently trained.

TABLE III
BARRIERS TO ADOPTING A TESTING METHODOLOGY

Barrier	Response	%
Costly to use	45.2%	1
Lack of expertise	30.9%	2
Lack of support tools	11.9%	3
Difficult to use	7.1%	4
Do not think there is any barrier	11.9%	3
Other	2.3%	5

C. TestAutomation and Testing Tools

It was observed that the use of automated testing and testing tools are not much common in the software industry. 35.7% of the respondents state that no automated testing is performed in their organizations. While 23.8% claim that less than 10% of the testing process is automated. 40.4% responded that they do not use any testing tool, while 26.1% say that testing tools are used in some project. Only 19% of the organizations are using testing tool in every project for testing.

The major issue in using testing tool is cost (47.6%) while 28.5% participant reported that testing tools are time consuming to use and 9.5% think that there is no barrier to use testing tool. Table IV summarizes the responses.

TABLE IV
BARRIERS TO ADOPTING A TESTING TOOLS

Barrier	Response	Rank
Costly to use	47.6%	1
Difficult to use	16.6%	3
Time consuming to use	28.5%	2
Do not think it is useful	14.2%	4
Do not know of any testing tool	7.1%	6
Do not know there is any barrier	9.5%	5
Other	4.7%	7

D. Test Management

In order to produce high quality software, testing process must be performed efficiently [xvii]. All the documentation should be well planned and up-to-date. Test cases and defect tracking should be well planned to achieve the goals of an effective testing process. To avoid duplication test cases should be written down. However, only 14.2% of the organizations are using standardized forms for test case documentation. 50% indicate that they do not use any kind of documentation for test cases. These results are shown in Fig. II.

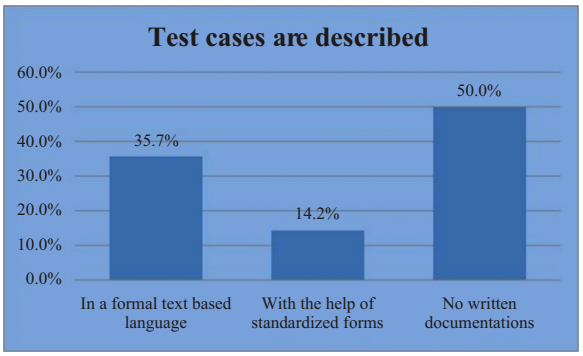

Fig. II. Documentation of Test Cases

A research suggests that organization must take data protection seriously [xviii]. However, still 30.9% of survey responses indicate that they test with original data from production. Only 16.6% of survey participants claim that they comprehensively document their testing. Testing documentation requires time and many other resources which need to be properly managed. The responses reveal that currently there is a lack of good testing management process in most of the organizations.

E. Quality Metrics

The usage of quality metrics to measure the quality of software in industry is discussed in this section. The survey result indicates that defect counting is the most popular method for quality metrics. This may be because of the simplicity of the process. About 64.2% of the organizations are using some kind of defect counting methods while only 14.2% indicate they are using number of test cases executed with in a period of time as a metrics.

It is sometime difficult for the organization to decide when to stop the testing process. Metrics such as 'no bug found per certain number of requirement any more' are most popular when determining criteria to stop the testing process. 47.6% of the organizations are using this criterion while 23.8% assign fixed resources (cost/time) to testing and stop the testing process when these resources are over. This shows lack of organized and systematic procedures to decide how testing should be done. This may be due to the small size of Pakistani software organizations. This shows that testing is not given the importance it deserves within software development process.

F. Quality Assurance Training and Education

This section was aimed at finding out the extent to which formal software quality assurance training has been facilitated by software organizations to train their employees. This also aimed at exploring the type of training that quality assurance personal in Pakistani software industry are receiving (i.e. universities education, in-house training, commercial training courses, or self-study).

Survey result indicates that only 21.4% of the respondents have knowledge of testing from courses offered in the universities while 73.8% of the respondents indicate that they have not received any kind of testing training or have studied testing by themselves (through self study). About half (54.7%) of the organizations favor to give training to their testing staff. This indicates that software organizations in Pakistan are aware of the importance of software testing for producing quality software's.

When asked about the major hurdles in delivering testing training 61.9% of the participants indicate that cost is the major barrier in providing training, followed by tight schedule (38%), and only 14.2% reported that there is no barrier. The responses from the survey are presented in Table V.

TABLE V
BARRIERS TO PROVIDE TRAINING TO SOFTWARE TESTING STAFF

Barrier	Response	Rank
Cost	61.9%	1
Time	38%	2
Course	9.5%	4
Do not know there is any barrier	14.2%	3
Other	2.3%	5

IV. DISCUSSION

If sample is not representative of the population then one cannot make specific generalizations of the population [xix]. Presently, the small sample size was not strongly supported in order to either prove or disprove research question. However, the survey provides a view of the current quality assurance methods in Pakistan.

In Pakistani software organization cost is the most evident barrier to the use of automated testing tools (Table IV), software testing methodologies and technique (Table IV), and providing training to software testing staff (Table V). This may be due to the low budget of the project and the small size of the organizations. Lack of expertise ranked second in the list of barriers to use software testing methodologies and technique. This shows that there could be many software testers who are not properly trained.

There is also lack of good testing management techniques. This may be due to less allocation of recourses (time/cost) to the quality assurance process. As 71.3% of the participant said that they allocate less than 25% of the project recourse to quality assurance process. Another possible reason is documentation. As reported (section III (D)) 50% of the respondent do not use any kind of documentation. A significant amount

of the organization is not using proper stopping criteria to quit the quality assurance process. While it is encouraging that more than half of the organizations are using some kind of method to measure the quality of their products.

The organizations using agile methods for development testing is mostly done by the developers. While a mix response is recorded from organization using phase oriented style of development i.e. testing is done by developers in some organization while in other organization testing is done by trained testers. Although automated testing is gaining popularity among software testers, however in Pakistan most of the organizations are not using automated testing. As reported in (Table IV) the major factor to not using automated testing tool is cost and time.

Overall from the survey result the current state of quality assurance process is lacking some key components. Some of the findings are encouraging to see. The software organization is aware of the importance of good quality. Therefore more than half of the organization are providing training program to their testing staff. Most of the organizations are hiring separate employees for quality assurance process. This research has mentioned various factors lacking from the software industry. Adaptation of these factors to improve quality of the software product is primary concern. However, the capability of the organization to adopt these practices is still undiscovered and can be researched in future studies.

V. Conclusions and Future Work

This paper analyzed the software quality assurance method carried in Pakistan in 2013. While the sample data was smaller than ideal, but the results highlight some trends of the current practices of quality assurance.

As a second stage of the survey, it is suggested to increase the sample collection to facilitate a more dynamic statistical analysis of the data. Since not all the organizations contacted took part in survey will be contacted again to known their reason for not participating as well as will be encouraged to be a future participant. In future, a comparative study between Pakistan and other South Asian countries could also be managed in this sector. This would indicate the competitiveness of Pakistan among its neighbor's countries.

From the survey finding it is clear that, education and training in software quality assurance is not sufficiently addressed in formal education systems of Pakistan. A review of the current curriculum of the software engineering in the universities is also suggested.

The implication of this survey is clear. To find the best relationship between quality assurance methods and software quality, ensuring that quality assurance methods are required for the highest quality software which is much more important as software is intruding more into the daily life. Despite limitations, the findings of this survey will be helpful in this process.

Acknowledgment

The work described in this paper was not possible without the support of the software development organizations who took part in the survey. Their assistance and support in this survey is highly valuable.

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Characterizing Snowmelt Regime of the River Swat - A Case Study

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Abstract-Snowmelt generates 70 to 80% of runoff of Indus River and its tributaries. Forecasting snowmelt generated flow is important for water management, reservoir operation and channel diversion. River Swat being not direct contributor to the existing reservoirs remained out of focus for characterizing its snowmelt regime. Thirty years (1971-2000) data of upper Swat catchment above Kalam gauging station was acquired from WAPDA. Normal monthly values over the period and average monthly values of each year were determined for stream flow, precipitation and temperature together with average monthly values of weighted and maximum temperature. Snowmelt regime was ascertained from plot of normal values of flow, precipitation and temperature. Using temperature index approach, average monthly flow over the snowmelt months (April, May and June) in terms of mm depth over the catchment was regressed on all the temperature indices using exponential, power and third degree polynomial functions. T_{max} was found the best index for snowmelt with R^2 as 0.902 for the third degree polynomial function. Runoff coefficient (ROC) for the total precipitation was conceptualized and through iteration was found as $T_{max}/100$. The optimized value of ROC was used to segregate rain induced and snowmelt induced runoff. The segregated snowmelt induced runoff was again regressed on T_{max} using the same function which slightly improved R^2 to 0.916. The model was tested for four years of data and forecasted flow was found reasonable in the context of simplicity of the approach.

Keywords-Snowmelt, Reservoir Operation, Normal Montlhly, Average Monthly

I. INTRODUCTION

Water is lifeline of agriculture which is mainstay of the economy of Pakistan. The country has the biggest contiguous irrigation system in the world known as Indus Basin Irrigation System (IBIS), which has it's across border catchments extended to India, and China. Despite having the biggest irrigation system, Pakistan, which once had surplus water, is now rapidly becoming water deficit country. Major portion of the water resources of the country originate from glacial and snow melt in high altitude mountainous catchments. Forecasting flow generated by these catchments is critical to water resources management, water distribution, operational regulation of reservoirs and, planning and management for hydel power generation. For forecasting flow, numerous advanced models are available, but their judicious utility requires comprehensive meteorological data on temporal and spatial scale. Whereas, these catchments, apart from being hard, rugged and high altitude mountainous terrains, are in some cases inaccessible due to security reasons.

Inhospitable mountainous terrain and harsh climatic environment further adds to data collection problems. As such limited data are available that too spatially and/or temporally ill representative of the catchments. Flow forecasting capability from the limited available data and a better understanding of snowmelt-runoff generating physical processes and hydrological regimes of these catchments is, therefore, either missing or limited on temporal and/or spatial scale [i-iii].

The IBIS has several tributaries, which originate from moderate to high altitude mountainous terrains and the river Swat is one of its major tributaries. After originating from Hindukush and having confluence with the river Kabul at Charsada, it drains into the Indus at Attock, from where it will feed the proposed Kalabagh dam. Areservoir, called Munda dam, is being constructed at the River Swat below Chakdarra. Water from the river is also diverted for various hydel power projects in Malakand Agency. Since the river was not an active contributor to the existing reservoirs, study of its flow regime never remained an immediate requirement of the concerned authorities. In the perspective of the under construction and proposed dams, thorough study of the river has become imperative. Moreover, study of Swat sub-basin is critical to the entire IBIS as the flow generated from upper Swat basin involves all the three physical processes, such as glacial melt, seasonal pack melt and runoff from instant precipitation, which are common to the entire IBIS. Characterization of flow regime of the Swat basin will also help towards improving flow forecasting capability of the entire IBIS as it can be considered its representative in terms of physical processes involved.

Objectives of this study are, therefore, to have a better understanding of snowmelt regime and runoff generating processes of mountainous watershed of upper Swat and to investigate linkage of river flow with the available climatic data. The critical objective is to determine whether climatological measurements made at limited weather stations at the base of mountainous watershed provide a suitable representation of basins' meteorological variables for forecasting river flow and to develop a deterministic model for that purpose.

The study area encompasses a watershed of River Swat, which originates from Hindukush range and after passing through Kalam and Mangora it drains near Charsada into the river Kabul, which has its confluence with the river Indus at Attock. Normal annual precipitation as recorded at the Kalam gauging station is 910 mm. The dominant source of precipitation is monsoon and westerlies which contribute 55% and 45% respectively [iv]. Flow is generated from instant precipitation, melting of seasonal snow-pack and glaciers [i]. There are two gauging and weather stations, one at Kalam and the other at Chakdarra. The watershed area above the former gauging station (that pertains to this study) is 2025 sq km, having a mean elevation of 3300 meters with 0.3 percent area above 5000 meters. The sub-basin falls between longitude of 72° 10' to 72° 50' N and latitude of 35° 25' to 35° 55' E. The Kalam sub-basin was chosen because of lying at glacier and snow melt outlet of upper Swat catchment.

II. Techniques and Methods

Different techniques and data processing methods used by the researchers for snowmelt-streamflow relationships of different watersheds have been reviewed in detail containing their pros and cons followed by study site data and processing. Regression analysis of flow on different temperature indices is then carried out. For segregation of snowmelt from direct runoff, a runoff coefficient is conceptualized and applied. At the end before drawing conclusions, forecasted flow is evaluated with the gauged flow to find reasonable correlation.

A. Snowmelt Study Approaches

Snow melt estimation is made either by energy balance approach or by using most representative climatic parameters. In energy balance approach, heat energy input to, or output from, snow through various processes such as net radiation flux, heat gained from air, sensible heat flux through evaporation, condensation or sublimation, rainwater heat flux, ground surface heat flux and change in internal energy is involved. In the index method approach, one or more climatic variables are used in empirical expression to determine snow cover energy exchange and resulting snow melt. Most commonly used climatic parameters for this purpose include air temperature, solar radiation, wind speed, and vapor pressure.

The heat energy balance analysis is the most reliable approach for calculating snowmelt. However comprehensive data for heat balance analysis are rarely available. The heat balance approach thus has inherent limitations. The most commonly data recorded on traditional weather stations are precipitation, daily maximum and minimum temperature, humidity and wind speed. Even on the traditional weather stations the routine data are some times missing [i].

That situation demands most readily available indices that best represent basin values from point measurements in time and space and that best serve to describe the snowmelt process. Temperature index is widely used for that purpose. Incorporation of all energy balance variables obviously improves model output; however average temperature alone has also been reported to be the best predictor, if other parameters are not available [v]. Moreover temperature best represents energy fluxes, and is easily measurable and normally available record [vi] and, therefore, is commonly used as snowmelt index [vi]. Rather it is considered the best snowmelt index as it well reflects various other snowmelt operators such as radiation, humidity, air circulation and snow covered area, because the temperature is either directly, or inversely, related to all those operators. The output of temperature index approach is also comparable to that of energy balance approach, which requires detailed evaluation of multiple variables [vii], [ii].

For temperature index approach, snowmelt rate is considered proportional to air temperature with proportionality factor called the snowmelt factor. Normally daily mean temperature is used for that purpose which is considered average of T_{max} and T_{min}. Daily mean temperature may be misleading where T_{min} drops much below 0 °C, giving mean temperature value less than zero. Under these circumstances, no positive temperature would be available while snowmelt might be going on over some part of the day with above zero temperature, thus giving undue weightage to T_{min}. Due to these reasons, only T_{max} is sometimes used for the purpose and has been reported to be accurate as compared to daily mean temperature [viii], but that procedure entirely excludes effect of T_{min}. A compromising way has been proposed wherein higher weightage is given to T_{max} as compared to T_{min} as given by the equation below [ii].

$$T_{wt} = (2T_{max} + T_{min})/3$$

where T_{wt} is weighted index of temperature.

Correlation of the extent of winter snow-pack and winter precipitation with annual stream discharge of the Kunhar sub-basin of the upper Jhelum basin was

Investigated [iii]. It was found that a strong correlation exists between point measurement of annual maximum of snow-pack water equivalent and of the total winter precipitation (at Kunhar sub-basin) with total annual discharge. Significant correlation was also found between total winter snowfall and annual discharge [iii]. The investigation showed altitude not appearing a strong operator in determining usefulness of snow measurements which was made at the valley bottom. On carrying out multiple regression analysis of point measurements of snow accumulation at various stations with discharge at downstream gauging station, and found significant improvement. It was therefore concluded that despite steep vertical and horizontal gradients of snow accumulation, accessible valley sites in Kunhar basin appeared to be as useful as the remote high elevation sites for gaining an index of basin wide snow accumulation, provided the data were available for more than one site. A limited data was dealt in the study not exceeding more than eight years in any case [iii].

The impact of rainfall on runoff characteristics of glacierized catchments in the Himalayan region was studied [ix]. It was concluded that the monsoonal cloud cover reduced snowmelt in July and August owing to decline in radiation energy input and snowmelt production is not offset by runoff production from liquid precipitation during the monsoon. It was inferred that liquid precipitation falling over glacier, analogous to channel precipitation, joins supraglacial melt-water channels and is ultimately routed to the glacier portal through the glacial drainage network without major losses. As such, runoff coefficients of 1.0 and 0.7 were used for glacierized and non glacierized areas respectively for computing total runoff from the basin. The relationship between daily average temperature and daily total discharge from May-October was also studied. The relationship was found poor with R^2 value of 0.54 which improved to 0.62 with rainfall corrected discharge [ix].

In a detailed study, regression analysis between climatic variables (temperature and precipitation) and stream flow data of fifteen sub-basins of the river Indus was carried out [i]. It was concluded that these sub-basins have different hydrological characteristics depending on their mean altitude, relief and exposure to moisture bearing winds. On the basis of the analysis, summer volumes of these basins were categorized into three major categories:

Thermal control in the current summer: These are the high elevation catchments where summer runoff is generated by melting of glacier and permanent snow predominantly by summer energy input such as in river Hunza, Shigar and Shyok.

Winter and spring precipitation controlled regime: It includes catchments where summer runoff is predominantly controlled by preceding winter and spring season precipitation such as River Astore, Kunhar, Swat and upper Indus.

Current precipitation controlled regimes: These include southern foothill catchments where runoff depends directly on current rainfall such as river Brando, Siran and Khan Khawar.

It was further shown that precipitation measurements at standard valley weather stations can be used as a basis for forecasting volume of flow in winter and spring precipitation controlled regimes [i].

B. Data Source and Processing Technique

Flow and precipitation records of IBIS are maintained by the Surface Hydrology Wing of the Water and Power Development Authority (WAPDA). The authority made available flow, precipitation and temperature data pertaining to Kalam sub-basin from 1971 to 2000. The raw data was in the form of daily values of maximum and minimum temperatures, daily precipitation and daily flow records at Kalam gauging station. The daily maximum and minimum temperature data were converted into mean daily temperatures, from which monthly averages were calculated for each month of the data years. Similarly monthly averages of stream flow and precipitation were determined. From the average monthly values of temperature, precipitation and stream flow, normal monthly values from 30 years data record were calculated and plotted to determine overall data trends. For regression analysis, average monthly values of temperature, precipitation and stream flow for snowmelt months of April, May and June over the period of 1971-1995 were used and the data for the remaining years were used for testing the results thereof.

III. Results and Discussion

Normal monthly temperature, precipitation and stream flow (in terms of mm depth over the catchment) as distributed over the year are presented in Fig. 1. As is evident from the figure, that the flow hydrograph starts rising in the beginning of March, concurrent with the peak normal precipitation, and attains its peak somewhere in June, almost concurrent with, but slightly lagged behind peak normal monthly temperature. Although, the start of flow rise coincides with peak precipitation, but then onward both have entirely opposite trends flow persistently continues rising and precipitation persistently continues declining.

On the other hand, temperature rise starts in the mid of January without any influence on flow regime. That means the rise of temperature in January, without any significant influence on flow regime, merely causes ripening of snow i.e. bringing the temperature of snow profile from below zero to zero Celsius conducive to snowmelt [ii]. A little rising trend in flow at the end of February seems due to its coincidence with

peak precipitation. Over the month of March, there is a significant rise in flow but that period also coincides with the period of maximum precipitation, which seems contributing to the flow rise. Pertinent to mention is that proportion of liquid precipitation of the total precipitation might have increased by that time due to rise in temperature. Flow as well as temperature exhibit rise in March, while peak precipitation period still prevails. The peak precipitation seems either have contributed to the flow, or have triggered rain induced snowmelt [x] as temperature rise at the start of snowmelt season is likely to cause only snow ripening instead of snowmelt [ii].

That means snowmelt is unlikely in the early season. Thus the flow rise in the beginning of March may not necessarily be due to commencement of snowmelt but may have substantially been contributed by total precipitation, which by that time might have acquired significant proportion of liquid precipitation at least at low altitude causing its reflection in the stream. All that shows snowmelt does not have necessarily started in March as the initial rise of flow appears to be due to high liquid precipitation in that month or due to rain induced snowmelt.

At the other end of the season, peak of flow coincides with temperature but does not sustain with it, i.e. flow decline starts earlier than the temperature decline. That seems to be due to altitudinal status of the catchment. Mean altitude of the Upper Swat catchment as already stated, is 3400 meter with only 0.14% above 5000 meter [i] which characterize it as the seasonal snowpack dominant catchment. Summer flow is, therefore, contributed mostly by seasonal snowpack-melt with little contribution from glaciers. Seasonal snowpack at medium altitude is likely to exhaust earlier than the catchment dominated by glaciers. Therefore, the flow hydrograph could not maintain its peak with the sustained maximum temperature due to the catchment having exhausted seasonal snowpack.

From March to June, there is almost linear and smooth rise in flow with the corresponding smooth rise in temperature, despite corresponding decline in precipitation, which indicates that snowmelt in upper Swat basin may be relied on from April to June. Further evidence of that will be demonstrated in the further analysis in the coming paragraphs.

Normal annual precipitation and normal annual flow with yearly fluctuations over thirty years period (1970 -2000) are shown in Fig. 2. The Figure indicates that the total annual flow directly responds to the total annual precipitation, but 30 years normal flow and precipitation exhibit significant difference.

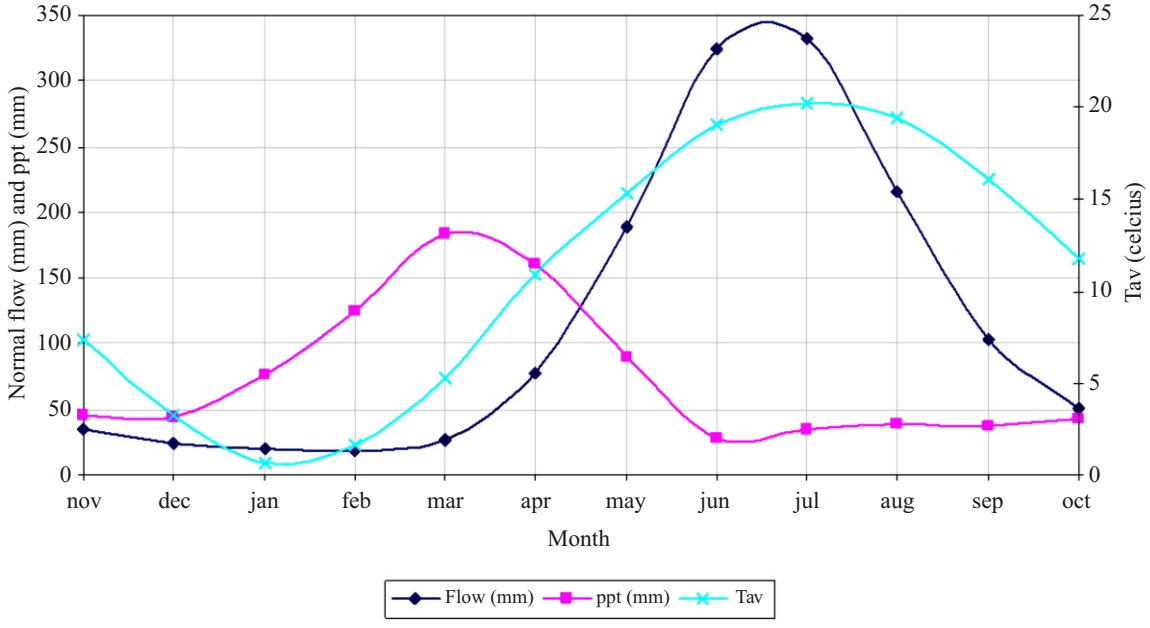


Fig. 1. Normal monthly temperature, precipitation, and flow (in terms of mm depth over the catchment) as measured at Kalam gauging and weather station Swat over 1971-2000.

The upper Swat river flow as recorded at Kalam (in terms of mm depth over the catchment) is 1339 mm against the recorded precipitation which is only 910 mm, meaning thereby that the recorded precipitation grossly underestimate catchment precipitation. The reason is obviously spatial distribution of precipitation over the catchment. In mountainous watersheds, both spatial and altitudinal precipitation distribution are always significant because of high relief, altitudinal variation and air currents turbulence. Snow or rain, therefore, indicates neither same pattern of variation with altitude, nor linear relationship exists for that. For

some basins precipitation increases with altitude continuously, while for others, it first increases to certain altitude and then starts declining [ii]. Since the instant flow regime pertains to snowmelt which comes from relatively high altitude, that means precipitation (obviously in snow form) at high altitude would have been more than that recorded at the bottom of the valley.

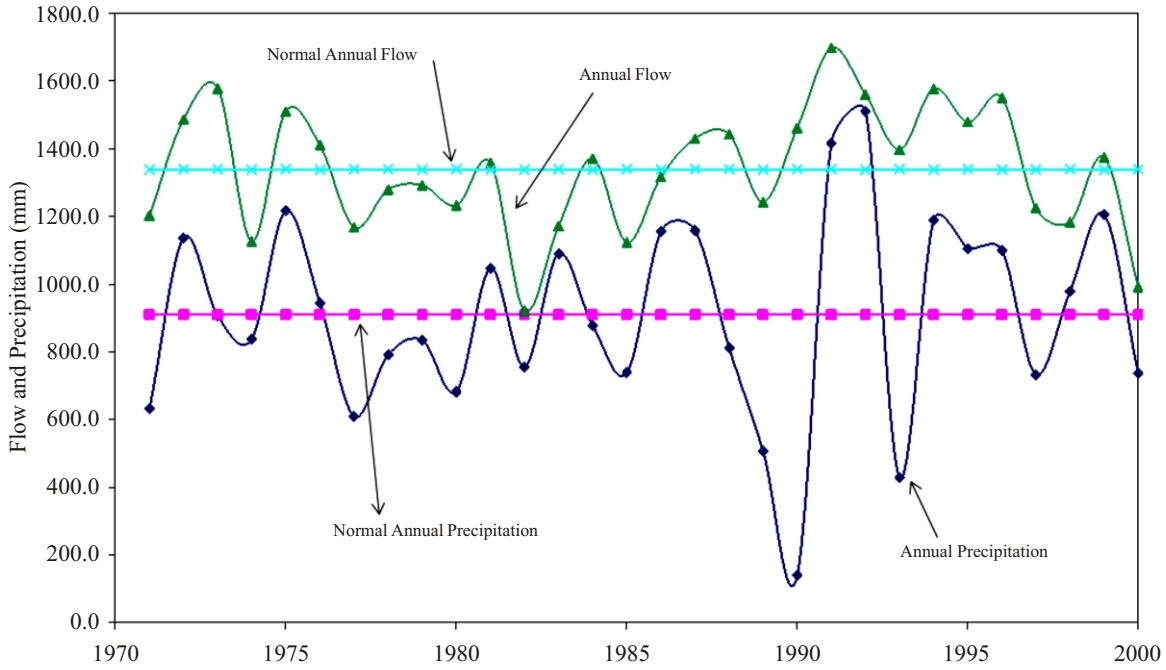


Fig. 2. Annual and normal annual flow and precipitation of 30 years (1971-2000)

An alternate explanation might be that the excess flow might have been coming as ground flow leakage from adjacent basins. Both the factors might be working simultaneously, but spatial distribution and the vertical precipitation gradient seem significant in the instant case, owing to the gauging station located at the bottom of the valley near the outlet of the catchment. Horizontal spatial distribution as well as the vertical precipitation gradient is therefore considered responsible for difference in recorded precipitation data and the river flow. That variation is required to be taken into account in the flow forecasting models.

Regression Analysis

For regression analysis, all the three temperatures based indices *i.e.* average monthly temperature (T_{av}) based on the daily maximum and minimum readings, average monthly maximum temperature (T_{max}) and weighted monthly temperature (T_{wtd}= $(2T_{max}+T_{min})/3$) were used. Keeping in view the snowmelt season as discussed before, monthly average flow (mm depth over the catchment) records for April, May and June of each year over the period 1971 to 1995 were regressed on each of the three temperature indices. It is pertinent to mention that when the data including any of the months before or after April, May and June were included, coefficient of determination was found persistently less than that pertaining to the said three months. As such the data pertaining to the said three months were used for regression. For regression of flow on the temperature index, 2nd degree polynomial, 3rd degree polynomial, power function and exponential functions were fitted to the data. Results of the regression analysis of these functions regressed on temperature indices are presented in Table I.

TABLE I
RESULTS OF 25 YEARS RIVER FLOW REGRESSED ON CATCHMENTS TEMPERATURE BASED SNOWMELT INDICES

variable	Function fitted with flow depth (mm) as dependent variable and corresponding R^2			
	2nd degree polynomial function	3rd degree polynomial function	Exponen-tial function	Power function
T_{av}	0.8697	0.8912	0.8774	0.8786
T_{wtd}	0.8874	0.8955	0.8817	0.8787
T_{max}	0.8993	0.9016	0.8734	0.8659

The results of regression analysis demonstrate that the temperature index in its all the three forms ($T_{av,}$ $T_{wtd,}$ T_{max}) yields comparable results when stream flow is

regressed on any one of its forms. Regarding the regression function fitted, the polynomial function was found giving the best and further the third degree polynomial function came out with the highest value of coefficient of determination (R^2 = 0.9016). The function giving the highest value of R^2 was selected as the best representing the river flow verses average maximum monthly temperature and is given below:

$$Y= -0.086 X^3+6.907X^2-149.4X+1027.4$$

where

Y= monthly river flow as mm depth over the catchment.

X= average maximum monthly temperature (^oC).

The graphic presentation of the best fitted third degree polynomial expression for monthly flow regressed on mean monthly maximum temperature is shown as solid blue line in Fig. 4. The fitted line, of course, includes runoff due to snowmelt as well as precipitation. The figure also shows scatter plot of the corresponding precipitation data for the sake of background input reference.

After regression of flow data on the temperature index (mean monthly maximum temperature in our case), the most critical question was to segregate direct runoff resulting from liquid precipitation to that from melting of solid precipitation (snowmelt). It is evident from the figure that in the beginning of the season precipitation is high which gradually and almost linearly decreases towards end of the season. In the beginning of snowmelt season a substantial proportion, or all of the recorded precipitation, would be in solid form (snow) due to low temperature especially at high altitudinal bands. As the temperature increases with advancement of melt season, the proportion of solid precipitation goes on gradually decreasing, and it is more than likely that at the peak melt season almost the entire precipitation would be in liquid form at almost all the altitudinal bands. especially in the catchment under consideration having moderately high altitude. Now the following factors operate for determining runoff coefficient (ROC) from liquid precipitation.

ROC will increase with increase in temperature due to greater proportion coming up in liquid form.

ROC will decrease with increase in temperature due to decline in snow covered area as liquid precipitation on snow surface is considered equivalent to channel precipitation [ix].

Now the above three variables are simultaneously affecting the ROC in somewhat opposite directions; two of those are causing a decrease in ROC whereas the third one causing an increase. What will be the net affect is uncertain. The ROC will obviously be determined by the fraction of liquid precipitation, but as yet the fraction of total precipitation in liquid form is not known. However, the parameters (overall precipitation and temperature) affecting the runoff coefficient are likely to counteract, but neither in equal nor in known proportion. Which parameter would have more effect on runoff coefficient, remains the most critical question. To decide the runoff coefficient for segregation of snowmelt and direct runoff was thus a bit tedious job. Under these conditions, a trade off might work. As such, for segregation of snowmelt runoff from liquid precipitation induced direct run off, it was assumed that runoff coefficient was directly proportional to temperature index (average T_{max} in the instant case). That is based on the concept that with rise in temperature fraction of liquid precipitation out of total precipitation goes on increasing in a pattern as conceptually elaborated in the Fig. 3.

The Figure is based on average T_{max} and precipitation over the snowmelt months of April, May and June. As depicted in the diagram, at low temperature (start of the melt season) total precipitation is high and liquid precipitation is low or zero. With rise in temperature, total precipitation is decreasing at higher rate and so is its solid precipitation part, but liquid precipitation is increasing at lower rate due to overall decrease in total precipitation. That makes liquid precipitation line almost parallel to temperature line. However, liquid precipitation is unknown yet, but the line almost parallel to it, temperature line, is known. That concept tempted these authors to assume runoff coefficient proportional to temperature for the catchment under consideration. Thus runoff coefficient may be taken as directly proportional to temperature index. Taking that assumption into account, we assumed runoff coefficient as:

$$ROC = K * T_{max} (\text{monthly average})$$

where

ROC= runoff coefficient

T_{max}= average maximum monthly temperature

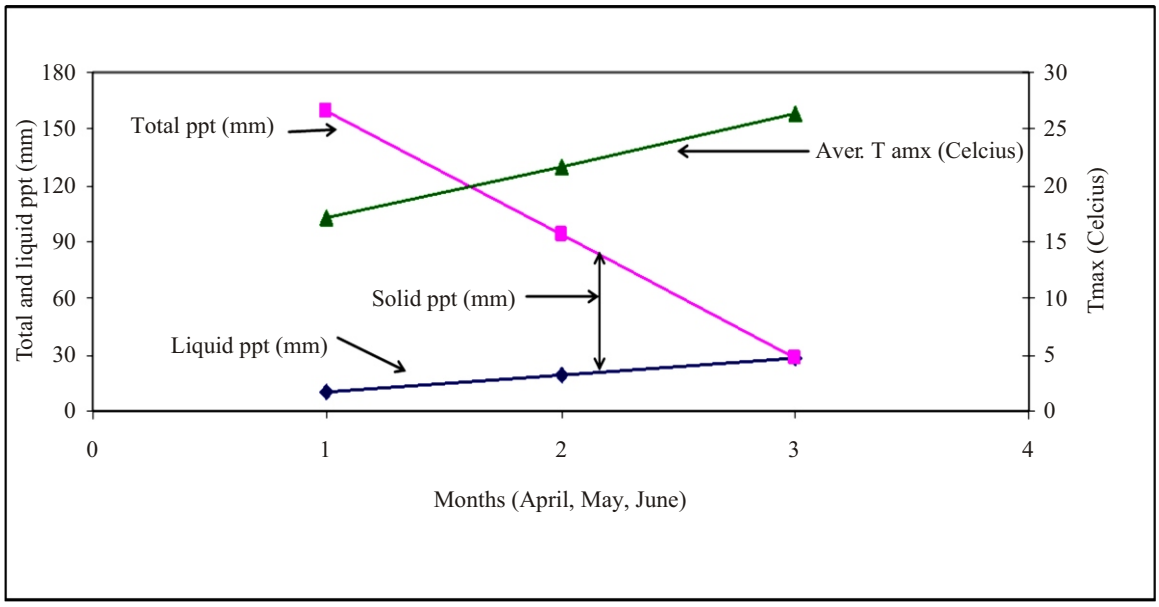


Fig. 3. Conceptual segregation of total precipitation into liquid and solid parts and variation with temperature

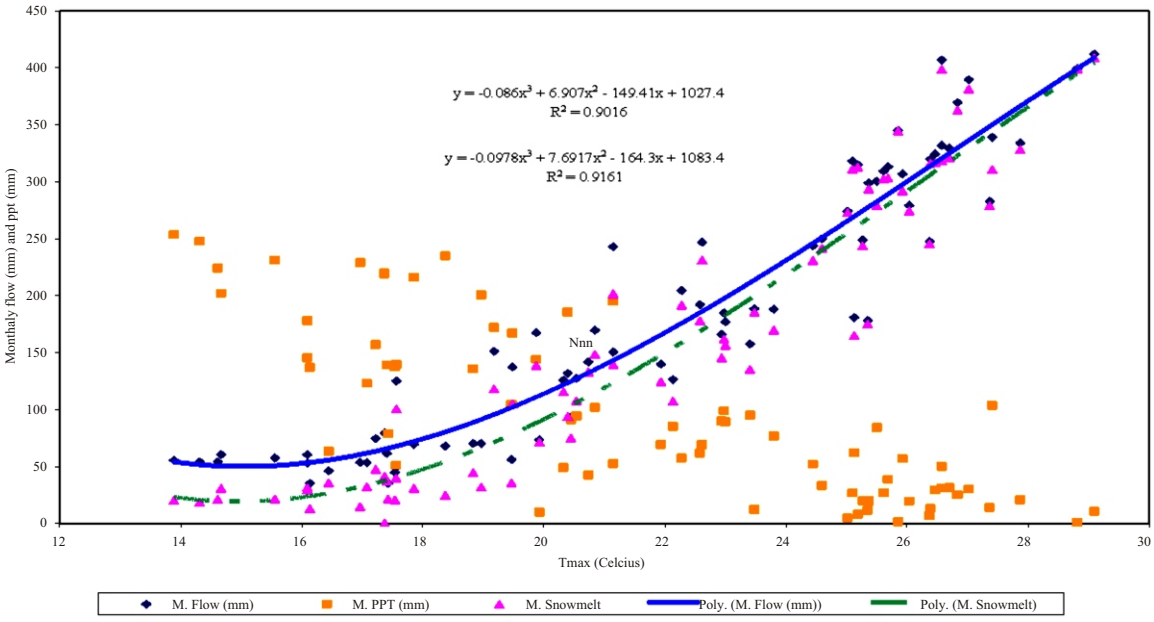


Fig. 4. River monthly flow and snowmelt (in terms of mm depth over catchment) vs. Average maximum monthly temperature (1971 to 95)

Using the so optimized value of K, which came out 1/100 in our case, direct runoff from total precipitation was deducted from stream flow and the resulting snowmelt was determined as per formula below:

Snowmelt = Total flow Precipitation x ROC

where, ROC = K x T_{max}

The snow melt runoff so derived was again regressed on the maximum mean monthly temperature index. It was assumed that by applying the runoff coefficient and subtracting the resulting runoff from stream flow should reduce the river flow scatter around the regression line and should accordingly improve the coefficient of determination (R^2). At the same time the optimized runoff coefficient should not bring the winter minimum flow to zero level, in any of the data years. Accordingly through iteration, the fraction of temperature index (T_{max}/100) was considered as runoff coefficient for which the derived snowmelt gave best fit against the temperature index. The best fit line so

derived is shown as a dotted green line in Fig. 4. As is also shown in the figure that with the incorporation of the so assumed runoff coefficient, R^2 value of the third degree polynomial function improved from 0.9016 to 0.9161. This improvement in the value of R^2 appears very nominal, but it happens so when R^2 is in the range of 0.90, where an analogy of law of diminishing returns applies. Even if it is considered no improvement in the R^2 value of the fitted function, that does not discredit the method used for segregation of the snowmelt runoff from stream flow.

The trend of the segregation is as expected. In the beginning of the snowmelt season, precipitation is high and although liquid precipitation proportion will be less but overall liquid precipitation amount will be high, as such the corresponding direct runoff is high. As the season advances, precipitation goes on decreasing and difference between snowmelt and direct runoff goes on decreasing and ultimately entire runoff becomes snowmelt runoff.

The model so developed for snowmelt runoff was used, incorporating direct runoff contribution from liquid precipitation accordingly, for flow forecasting and compared it with available flow data for years 1996 to 1999. The actual and forecasted flows are shown in the Figures 5-8.

The forecasted vs. actual flow results for the three summer months of April to June appear promising. These results are required to be seen in the perspective that a single climatic parameter, i.e. temperature index, was used for snowmelt forecasting, whereas snowmelt, in fact depends on multiple climatic parameters such as solar radiation, wind and humidity apart from air temperature. But, the record of all those climatic variables is lacking in the high altitude mountainous basins and one has to rely on the only available climatic variable i.e. temperature index.

The values of the unavailable climatic variable do not vary as smoothly as the temperature index and day to day drastic variation of other parameters and especially of wind speed may cause a lot of day to day variation in snowmelt factor. Thus a lot of scatter in snowmelt may go unaccounted for when only a single climatic variable is taken for snowmelt prediction. Nevertheless, the results indicate that the temperature index can be relied on for snowmelt prediction when other data is lacking for application of comprehensive snowmelt model.

Figure 5. Forecasted flow vs measured flow over April, May and June 1996

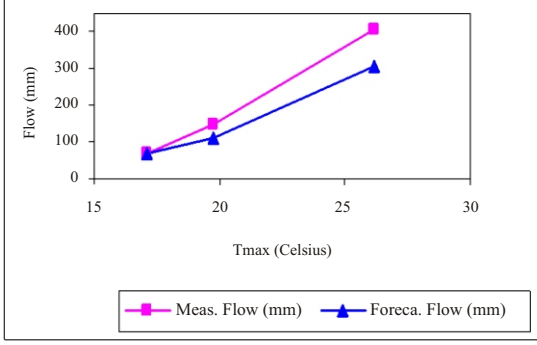


Figure 6. Forecasted flow vs measured flow over April, May and June 1997

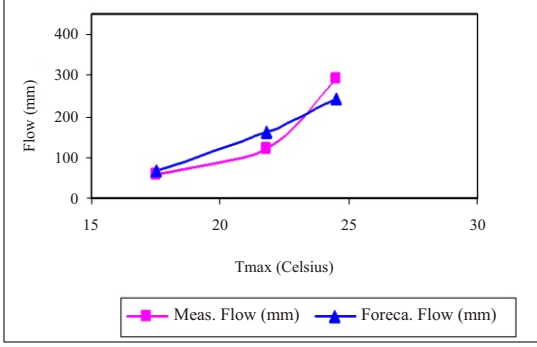


Figure 7. Forecasted flow vs measured flow over April, May and June 1998

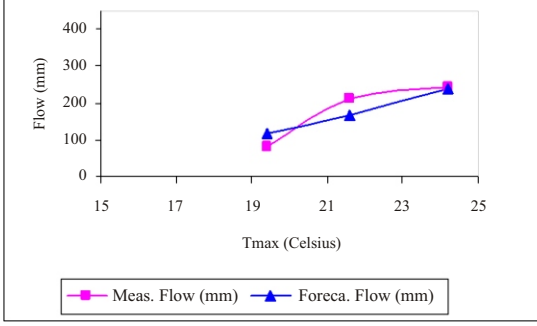
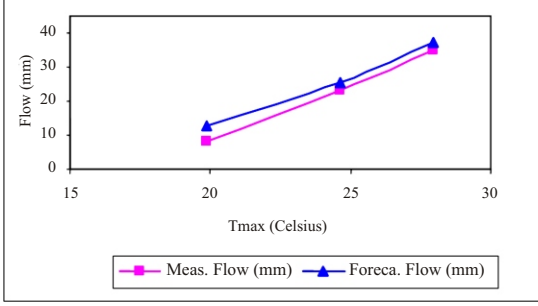


Figure 8. Forecasted flow vs. Measured flow over April, May and June 1999



IV. CONCLUSIONS

That the snowmelt season in upper Swat catchment is normally expanded over three summer months of April, May and June.

That the temperature index, if other climatic variables and snow accumulation parameters are not available, can give reasonable estimation of snowmelt.

That the snowmelt have significant correlation with all the three temperature indices, but maximum temperature index comparatively better describe snowmelt at least in the catchment under consideration.

That the precipitation data recorded at the valley bottom, though underestimate overall precipitation (liquid plus solid precipitation), can be useful for segregation of snowmelt and direct runoff.

That the runoff coefficient for mixed precipitation (liquid plus solid precipitation) is directly related to some fraction of temperature index. In the instant case it was found hundredth of average maximum monthly temperature.

That regression analysis of twenty five years snowmelt data on mean monthly maximum temperature yielded a good third degree polynomial fit with R^2=0.916.

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Aerodynamic Analysis of S Series Wind Turbine Airfoils by using X Foil Technique

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Abstract-In order to attain supreme energy from wind turbine economically, blade profile enactment must be acquired. For extracting extreme power from wind, it is necessary to develop rotor models of wind turbine which have high rotation rates and power coefficients. Maximum power can also be haul out by using suitable airfoils at root and tip sections of wind turbine blades. In this research four different S-series airfoils have been selected to study their behavior for maximum power extraction from wind. The wind conditions during the research were ascertained from the wind speeds over Kallar Kahar Pakistan. In order to study the wind turbine operation, the extremely important parameters are lift and drag forces. Therefore an endeavor to study lift force and drag force at various sections of wind turbine blade is shown in current research. In order to acquire the utmost power from wind turbine, highest value of sliding ratio is prerequisite. At various wind speeds, performance of several blade profiles was analyzed and for every wind speed, the appropriate blade profile is ascertained grounded on the utmost sliding ratio. For every airfoil, prime angle of attack is resolute at numerous wind speeds.

Keywords-Airfoils, Angle of Attack, Sliding Ratio, Wind Speed, Tip Speed Ratio, Reynolds Number

I. INTRODUCTION

One of the crucial inputs for the development of any country is energy. State of development of a country can be described by a mutual factor which is energy supply per unit capita. Pakistan is a third world country with 188 million population [i]. Energy supply per capita of Pakistan is 0.48 tons of oil equivalent (TOE) annually in association to world's average of 1.90 TOE [ii]. Unfortunately the energy production for the last decade is static, whilst for next five years,annual growthrate in demand is estimated 7.4 %. Almost 68 % inhabitants of Pakistan resides in rural regions while 37 % has no electricity facility. Their life standard can be enhanced by facilitating least amount of electricity.

At present, Pakistan has 22812 MW installed electrical generation capacity, 67 % of which comes from fossil fuels, 29.7 % from hydel resources and the rest from nuclear energy [iii-iv]. Hydroelectricity is cheaper and has less pollution effects but gradual decrease in its contribution is being observed from 70% in 1960s to 33% currently [v]. Electricity prices and air pollution has been increased due to this trend.

Environment corrosion, fossil fuels expenses and huge gap between demand and supply are the factors which necessitate reliable, environment friendly and cost effective energy resources. Now a days, world focus on development of renewable energy resources has been increased [vi]. Wind energy has supreme future scenarios among the entire sorts of sustainable and renewable energy resources. Furthermore, wind energy has attract the world as it originates all over the world and it is valuable renewable energy because it has no effect on greenhouse due to any radiation [vii]. World's capacity of wind power generation has touched to 282,275 MW at the end of 2013 [viii]. Wind is a low density power source. Maximum conversion of wind energy efficiency into mechanical energy leads to make it economically feasible. For achieving this goal, rotor aerodynamics is the key factor.

Syed et al was used two dimensional CFD RANS equations for S809 and S826 wind turbine blade airfoils at low Reynolds number and 11 m/s [ix]. Hoogedoorn et al had also been carried out two dimensional CFD RANS computations for NACA 0008 and NACA 0012 at high Reynolds numbers [x]. Wang et al was applied URANS approach on NACA 0012 air foil at free stream velocity 14 m/s [xi]. The literature indicates that high wind speed range is the main focus of most researchers but no one emphasis on range of low wind speed.

Pakistan is now focusing on renewable energy resources. Alternative energy development board (AEDB) Pakistan has made short and long term policies. Main aim of short term policy is to produce 650 MW of wind power in near future and to enter this power into national grid [xii]. Major aims of long term policy includes to make sure 10 percentage share of renewable energy in total power production of Pakistan at the end of 2015 and to produce 9.7 GW electricity from wind and solar energy at the end of 2030 [xii].

Main objective of this research is to find the most suitable HAWT wind turbine airfoil for the wind

conditions of Sardhi, Kallar Kahar, Pakistan at Latitude 32.70° N and Longitude 72.73° E [xiii]. At 50m height, Kallar Kahar has 293W/m^2 total wind power density which makes it an exceptional site for wind power generation prospects according to international wind power classification [xiii]. Profili software is used for determination of aerodynamic load on selected airfoils.

II. Contemporary Research

In order to enhance wind turbine efficiency, highest power produced by wind turbine is required. In current research, wind flow is analyzed around blades of wind turbine to determine power. National Renewable Energy Laboratory developed blade profiles are selected for current research. When associating different airfoils, drag and lift coefficients for every airfoil are determined at various angles of attack. Drag and lift forces are measured by dimensionless drag and lift coefficients and depend upon airfoil shape and α (angle of attack). Equations 1 and 2 can express lift and drag forces calculations [xiv] as

$$L = (½)\,\rho A V^2 C_L \quad (1)$$

$$D = (½)\,\rho A V^2 C_D \quad (2)$$

Equation 3 can expressslide ratio [15] as

$$\varepsilon = L/D = C_L / C_D \quad (3)$$

III. Methodology

Cross sections of wind turbine blades use profiles of airfoils to produce mechanical power. Determination of blade dimensions depends upon the airfoil characteristics, maximum required power and strength. Well tested airfoil families have been used to design modern horizontal axis wind turbines. Thin airfoil is used to design blade tip for high sliding ratio and for structural support, thick airfoil is used for root area. Air foil characteristics should be determined before the discussion of wind turbine power production [xv]. NREL generated, 2D S-series profiles are used for aerodynamic simulations with the help of RANS equations. Performances of blades are tested at selected range of winds as mentioned in Pakistan metrological department report for Sardhi Kallar Kahar, Pakistan [xiii] and for each wind speed, appropriate profile will be determined on the basis of maximum power produce by wind turbine blade. For optimum blade shape, Wilson et al has calculated the power coefficient C_P for turbines by considering the drag and finite number of blades [xv]. The results fit accessible records within 0.5% accuracy for sliding ratio from twenty five to infinity, tip speed ratios from four to twenty and one to three number of blades (B) [xv].

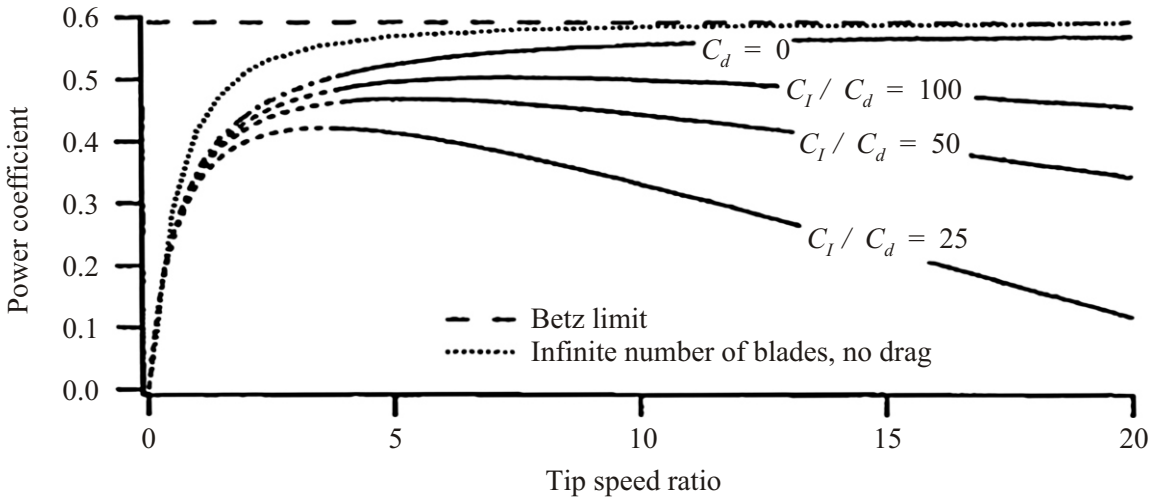


Fig. 1. Power coefficient of three bladed wind turbine rotor as a function of sliding ratio [15].

For three bladed wind turbine rotor, the sliding ratio effect on power coefficient is presented in Fig. 1. It is clear in figure that as the airfoil drag increases then reduction in power occurs significantly. Equation 4 can express power coefficient as [xv]

$$C_P = (16/27) * \lambda / ((\lambda + (1.32 + ((\lambda - 8)/20)^2)/B^2)) - (0.57 \lambda^2 / (\varepsilon*(\lambda + (1/2B))) \quad (4)$$

TABLE I
SELECTED RANGE OF REYNOLDS NUMBER FOR CURRENT RESEARCH AT VARIOUS WIND SPEEDS AT 50 M ALTITUDE AND ONE METER WING CHORD

No.	Wind Speed (m/s)	Reynolds Number
1	5	341000
2	6	409000
3	7	477000
4	8	546000
5	9	614000
6	10	682000
7	11	750000

Round off values of Reynolds number have been taken and best suited altitude 50 m, for Sardhi Kallar Kahar Pakistan [xiii] has been taken with one meter wing chord. For this research, C_L and C_D are measured at selected range of wind speeds [xiii]. Following S series profiles are used in the current study for simulation purpose, as shown in table II.

TABLE II
SELECTED S SERIES AIRFOILS

No.	S series airfoils
1	818
2	825
3	826
4	828

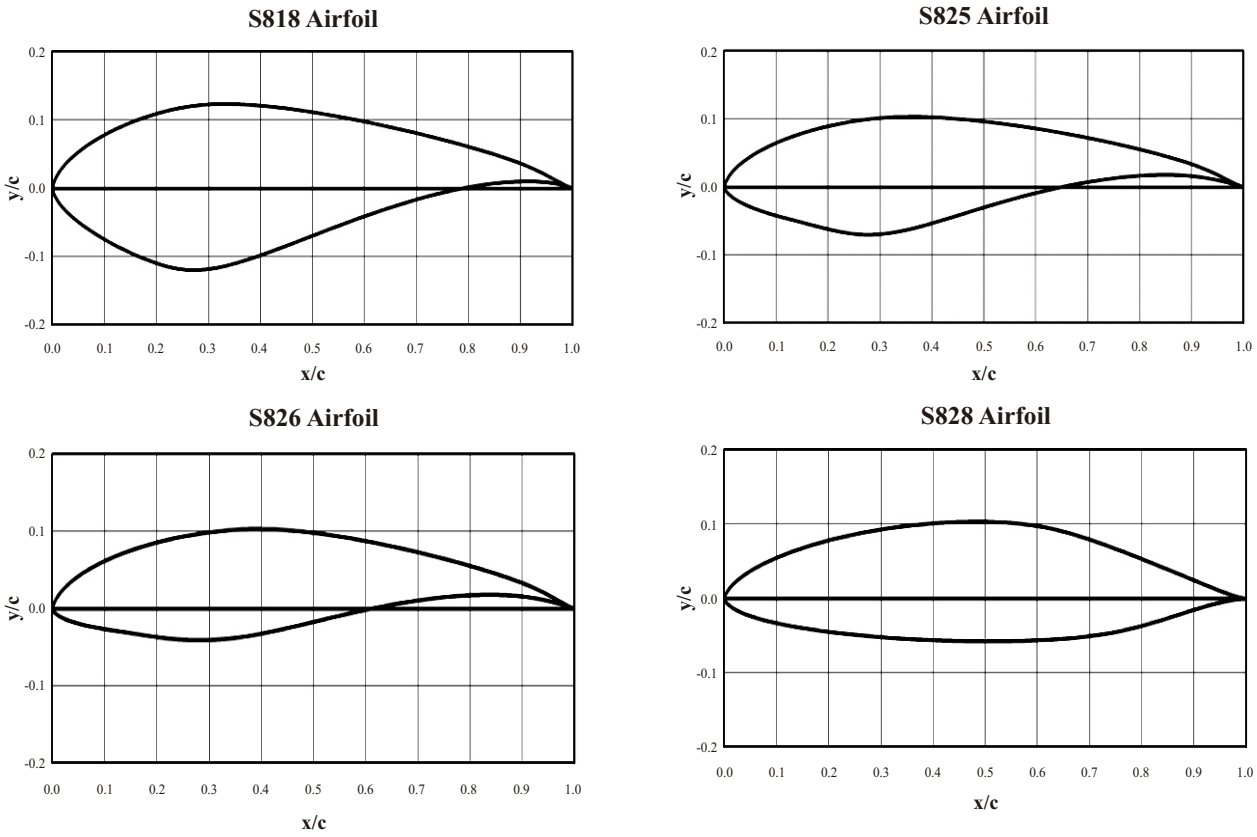


Fig. 2. Selected range of S series airfoils

Flow field simulation of these airfoils has been done by using Profili software package. Effect of forces on surrounding boundary and surfaces is also determined by Profili. Note that due to low velocity range, there is always a subsonic flow in current research. Selected range of angle of attack is from -5° to 13°. Polars of selected airfoils have been determined within boundary conditions as a function of Reynolds number with a step difference of 0.5. Flow considerations around boundaries and surfaces of airfoils are also observed. Basically X-Foil technique is used in Profili. For data acquisition, linear interpolation and extrapolation techniques are also used. Trapezoidal and elliptical wings are also designed by using

selected range of airfoils. Number of ribs for half wing is taken 10 while lower and upper skin thicknesses are taken 1.50 mm each and chord length is taken 1 meter. Thickness of airfoil at root and tip sections of wind turbine blade can be increased or decreased by considering rotor design. Normally root region of blade is made thicker for structural support [xvi].

IV. Results and Discussion

At various wind flow velocities, airfoil simulations were carried out. The velocity range, tabulated in table I, is selected for this research because wind speed in Kallar Kahar region lies within this array. Angle of attack range for simulation is taken from -5° to 13° which lies within the standard operative range of wind turbine design. Main goal of this research is to locate the suitable angle of attack at which wind turbine blades can develop maximum power based on highest value of sliding ratio. Trailing edge angle, maximum thickness, thickness distribution, leading edge radius and mean camber line of airfoil, as shown in Fig. 3, are the factors which affect the aerodynamic performance of that airfoil.

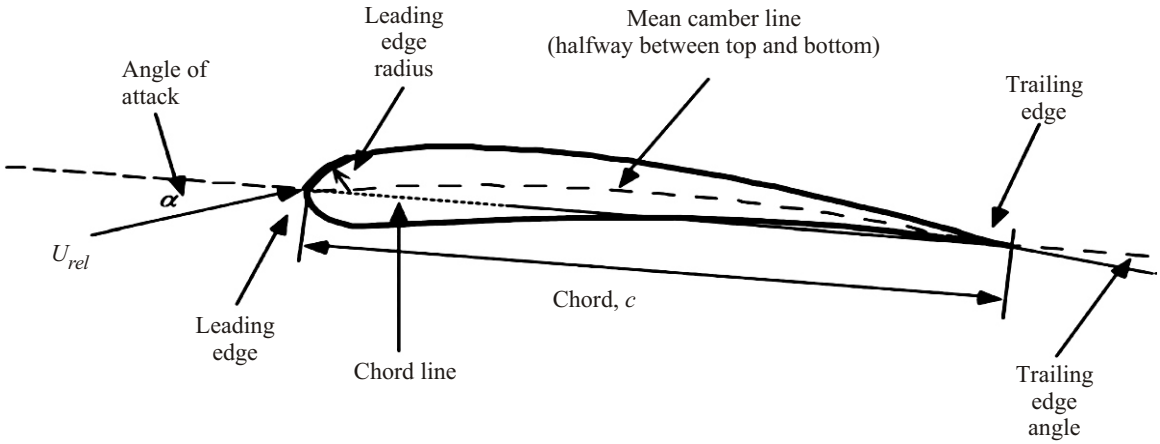


Fig. 3. Basic terms of airfoil [xv]

Figures 4a to 4g, represent the sliding ratio results of selected S-series airfoils against angle of attack at defined range of velocities. It has been observed for all airfoils that sliding ratio value increases with the increase of wind speed. For a constant velocity, data shows that as angle of attack increases then sliding ratio first increases and after reaching to a peak value, it starts decreasing to low values for all airfoils. All airfoils have different angle of attack for maximum value of sliding ratio. If cambered airfoil is used then the possibility of increasing the lift coefficient and decreasing the drag coefficient is enhanced at low angle of attack. Due to highest camber, S818, S825 and S826 have high values of sliding ratio while S828 has low values of sliding ratio among selected airfoils. S818, S825 and S826 are almost symmetric airfoils and due to this symmetry, the pressure difference between the suction surface and pressure surface remains trivial at zero angle of attack. In order to find the best angle of attack for all profiles, combined effect of sliding ratio value curves of each airfoil for all wind speeds is shown in Figures 5a to 5d.

It has been observed that at similar operating angle of attack, sliding ratio value increases with the increase in wind speed. In figure 6, appropriate range of angle of attack for designated airfoils is revealed. It is determined that to attain maximum power from a wind turbine, 6° to 10° is the appropriate range of AOA. For S 828, the best angle of attack with respect to its high sliding ratio value lies from 6° to 7° because its maximum thickness remains from 40% to 50% of the chord length. While for S 818, S 825 and S 826, range of appropriate angle of attack is from 6° to 10° because all of them are symmetric airfoils and their maximum thickness befalls from 20% to 40% of the chord length. The appropriate values of angle of attack as displayed in figure 6, can be utilized to establish a 3D blade profile that comprises of different airfoils and each airfoil has a twist angle equal to its appropriate angle of attack. At each wind speed, best airfoil can also be chosen by considering the maximum sliding ratio effect at appropriate angle of attack.

Average wind speed in Sardhi, Kallar Kahar Pakistan at 50 meter height is approximately 7 m/s [xiii]. Data in figure 6 shows that S 825 and S 826 have maximum value at 7 m/s and so that they are able to produce maximum power at this speed. So it has been recommended to use these airfoils for wind turbine blades which operate at this wind speed in selected site. Results also display that suitable airfoil in selected conditions changes with the variation of angle of attack. For example, at 7 m/s and 7° angle of attack, appropriate airfoil is S 825 while at same speed and 10°, appropriate airfoil is S 818.

It is observed from data in figures 4-6, there is a prominent influence of angle of attack on determining of appropriate airfoil and there is no effect of wind speed in the selection of suitable profile. There should be required a broad study to find appropriate airfoil at each value of angle of attack.

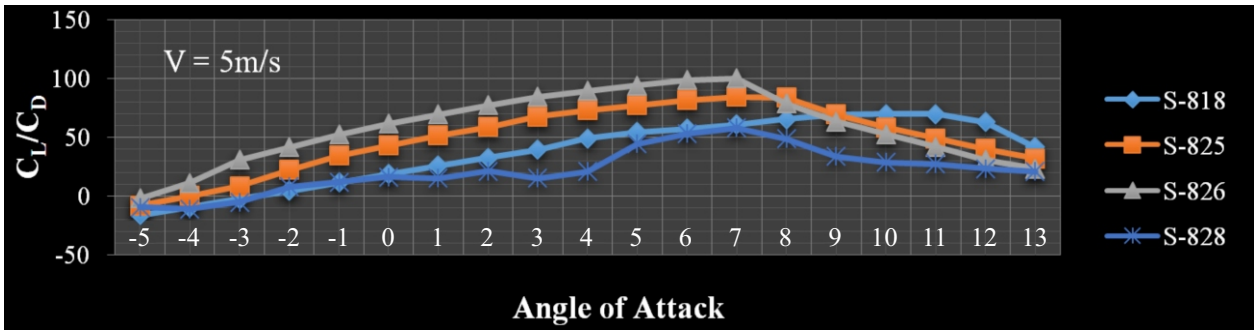


Fig. 4a. Values of sliding ratio at 5 m/s

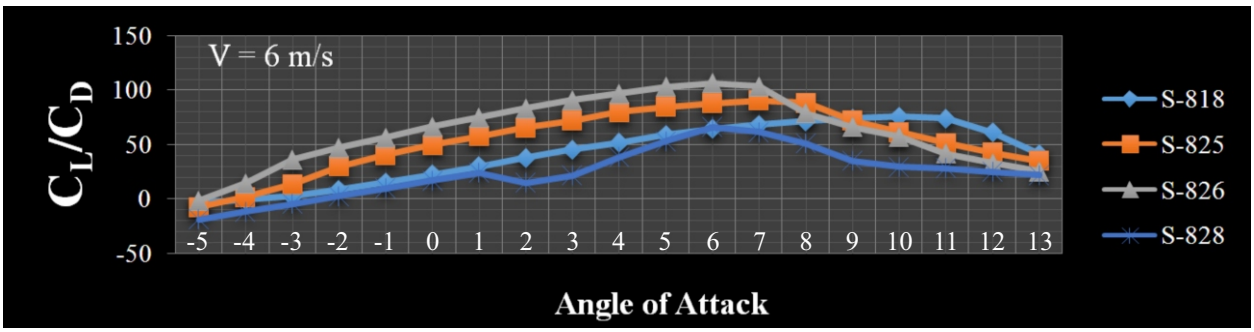


Fig. 4b. Values of sliding ratio at 6 m/s

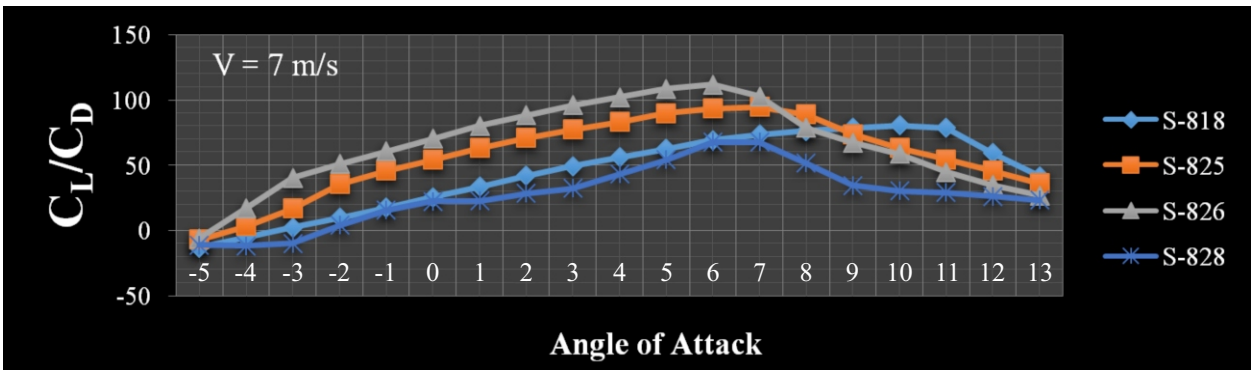


Fig. 4c. Values of sliding ratio at 7 m/s

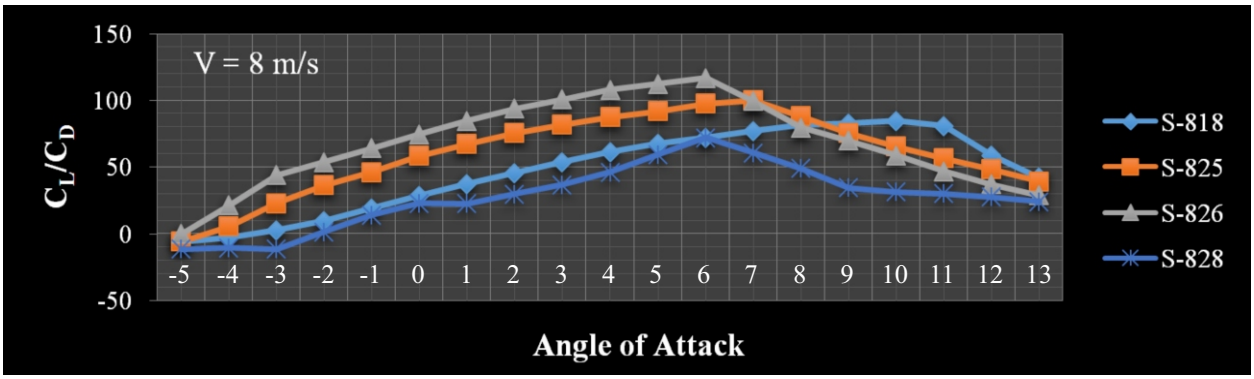


Fig. 4d. Values of sliding ratio at 8 m/s

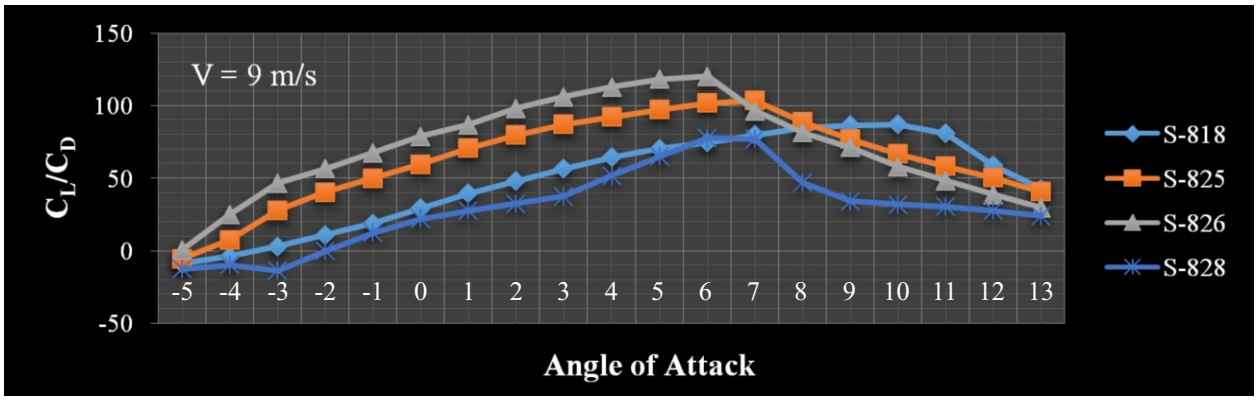


Fig. 4e. Values of sliding ratio at 9 m/s

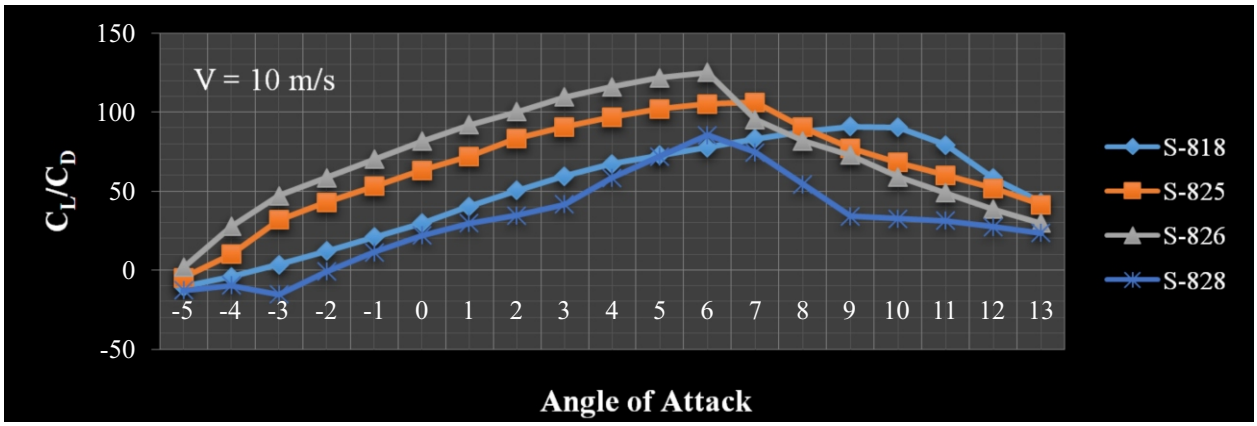


Fig. 4f. Values of sliding ratio at 10 m/s

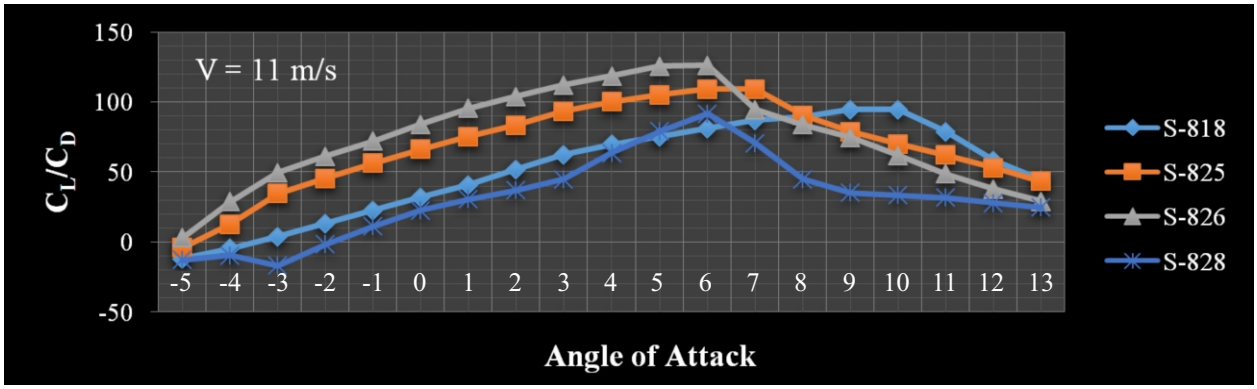
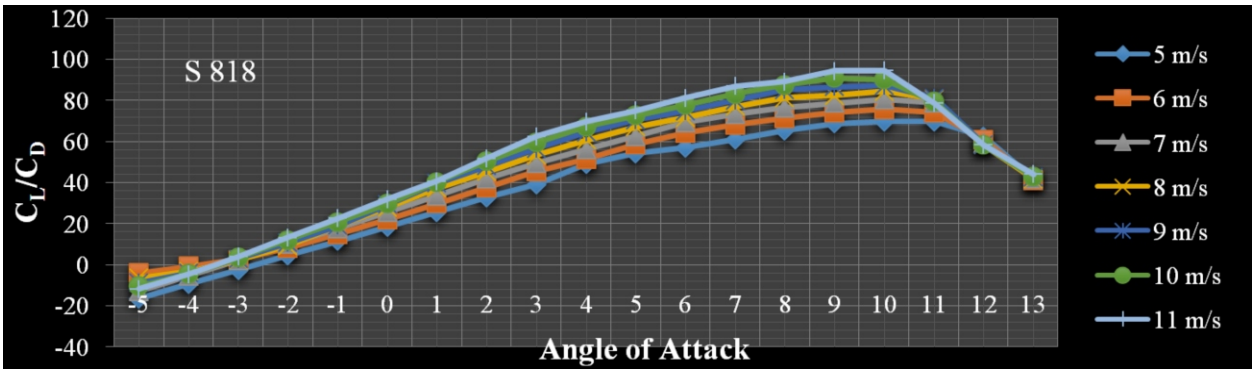
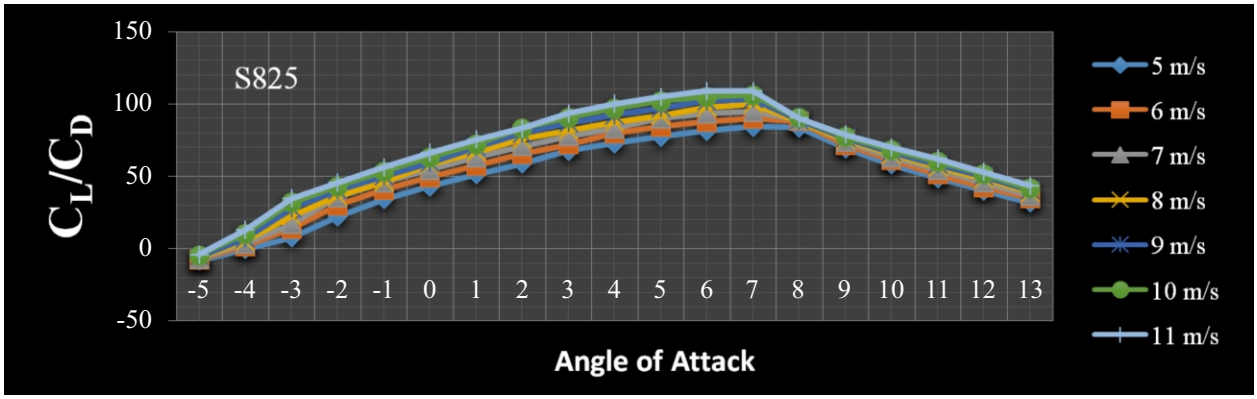


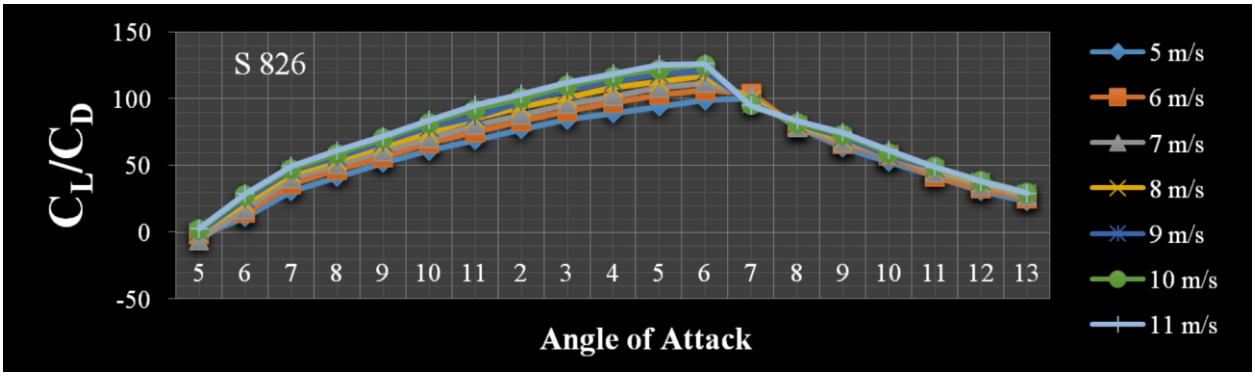
Fig. 4g. Values of sliding ratio at 11 m/s



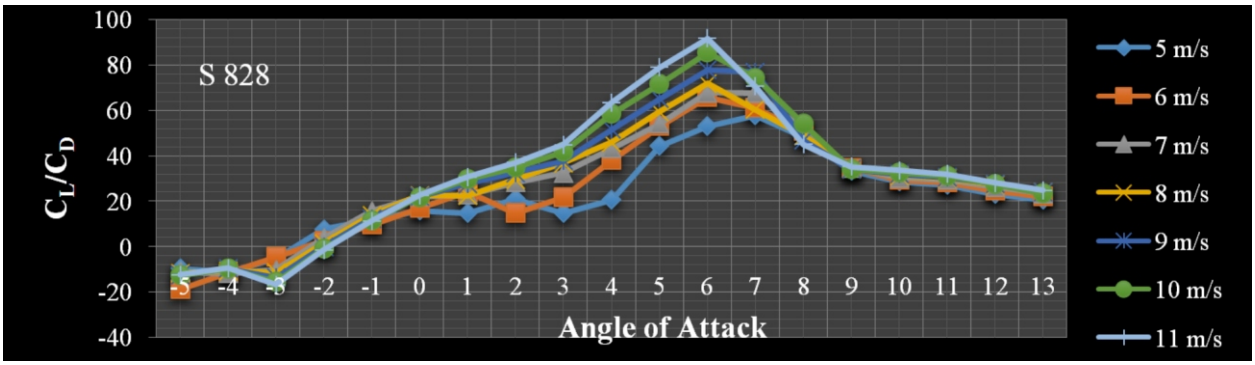
(a) S818



(b) S825



(c) S826



(d) S828

Fig. 5. Values of sliding ratio for each selected airfoil at various wind speeds

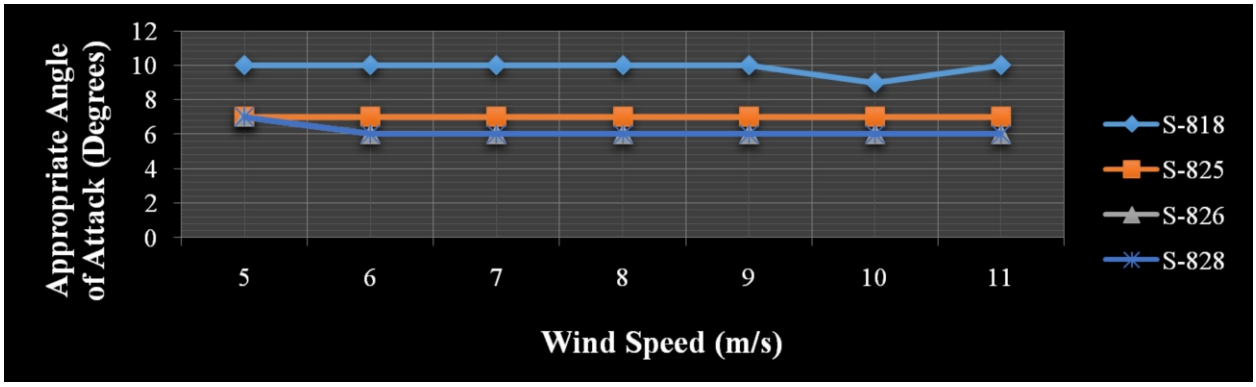


Fig. 6. Appropriate angle of attack for selected airfoils at various wind speeds

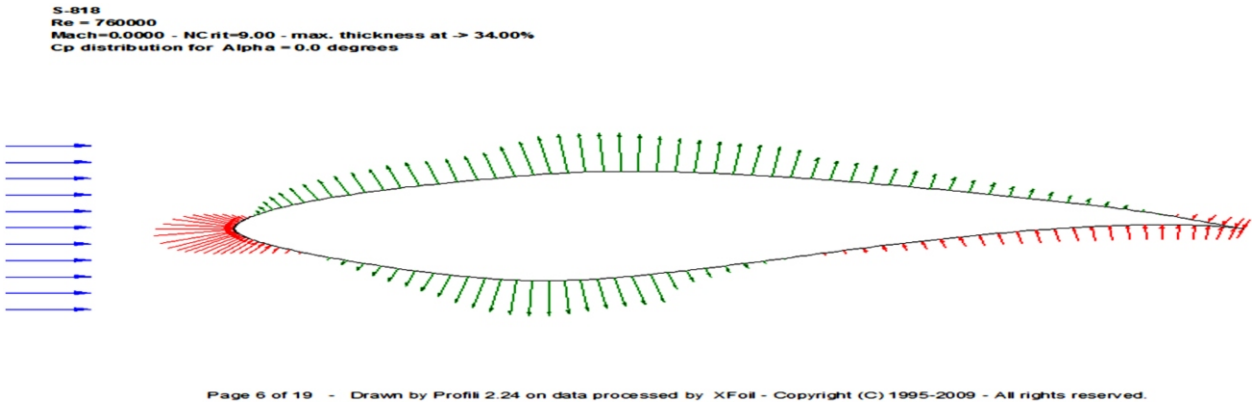


Fig. 7. C_p distribution for S 818 at 0^o angle of attack and 11 m/s

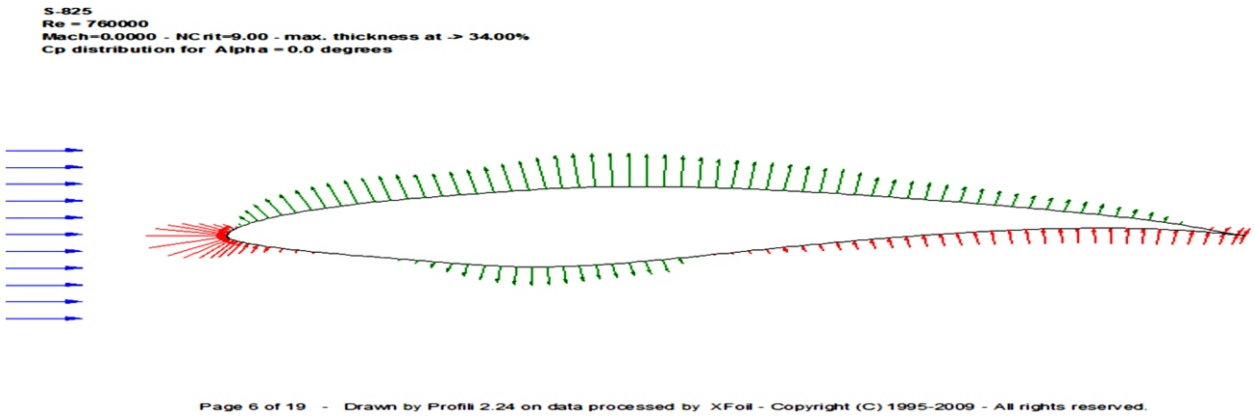


Fig. 8. C_p distribution for S 825 at 0^o angle of attack and 11 m/s

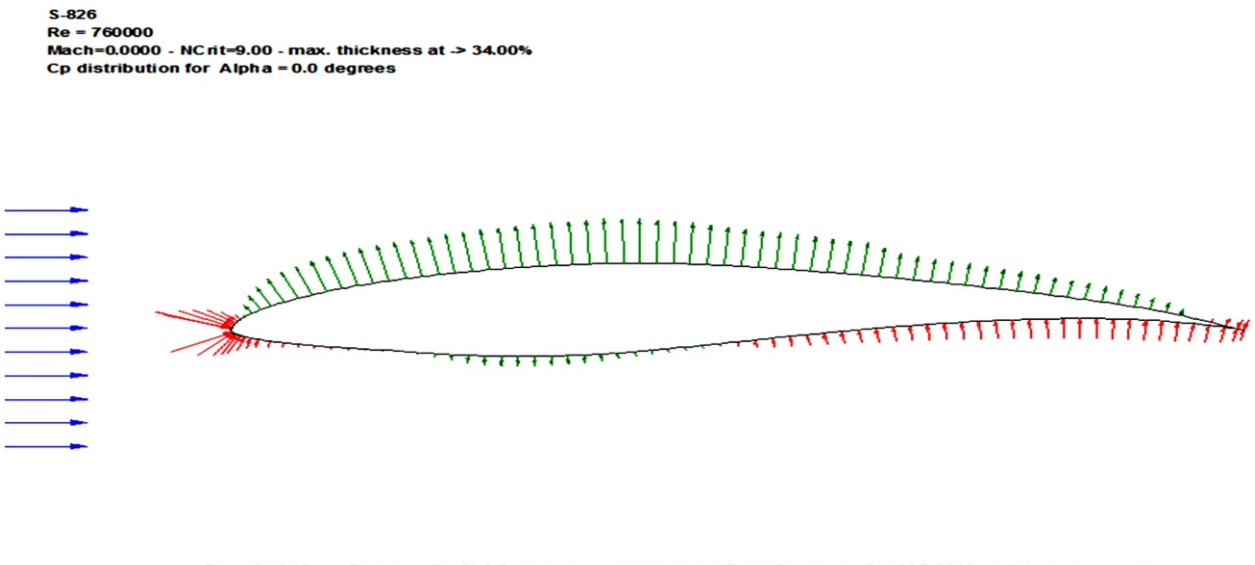


Fig. 9. C_p distribution for S 826 at 0^o angle of attack and 11 m/s

C_P distribution over S 818, S 825 and S 826 airfoils are shown in figures 7, 8 and 9. From all three figures, results show that there is a positive lift force on the lower surface of all profiles because pressure distribution is positive here. But at 2-4% of chord length in middle region, negative lift value occurs. Pressure rise is observed from minimum to maximum at trailing edge. This region is defined as adverse pressure gradient. Pressure adjacent the trailing edge is linked to profile thickness. Pressure is somewhat positive for thick airfoils but $C_P$is zero for infinitely thin airfoils. Stagnation point (C_P = 1) ensues nearby leading edge and at this region flow velocity is zero.

As shown in Figures 7, 8 and 9, as air flow starts to accelerate over the profile, data shows low values of pressure at that stage so C_P suddenly gets zero value and then to negative value. When flow decelerates, rise in pressure and drop in C_P values occurs. Due to these variations, rotation in airfoil occurs.

Note that pressure on upper surface is always less than the lower airfoil surface. Pressure coefficient turn into more negative value with the increase in wind speed.When flow reaches trailing edge, it decelerates on upper surface and combines with lower surface flow.

V. Conclusion

High efficiency of airfoil is directly related to high sliding ratio values. Data observation shows that selection of appropriate airfoil mainly depends on angle of attack. Choice of optimum profile does not depend upon the wind speed. Optimum range of angle of attack is from 6^o to 10^o for selected airfoils. At this range, maximum value of sliding ratio and maximum power from wind attains from all airfoils. It has been observed that sliding ratio value declines when angle of attack rises from appropriate range.

For extracting peak power from wind, airfoils whose thickness ranges from 20% to 40% of chord length, should be operated from 6^o to 10^o of angle of attack while those airfoils whose thickness occurs from 40% to 50% of chord length should be operated from 6^o to 7^o of angle of attack. Finally conclusion obtained from data is that most efficient airfoils from selected range are S 825 and S 826 and they are highly recommended for wind turbine working at selected range of wind speeds [13].

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Towards a Semantic Web Stack Applicable for Both RDF and Topic Maps: A Survey

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***Abstract*-**Semantic Web extends the World Wide Web by transforming the Web into more machines processable, and intelligent. Semantic Web enables users to share contents beyond the limits of applications and websites. To successfully implement Semantic Web, technologies are developed to effectively represent, navigate, and create metadata relationship among the information. As synthetic sugar, both RDF and Topic Maps have come up as the leading technologies for successfully for realizing the vision of Semantic Web into reality. Semantic Web Stack is a layered model representing architecture of the Semantic Web. The layered model integrates and defines relationships among the technologies and languages essential for the Semantic Web. Semantic Web Stack is developed originally for the RDF exclusively and has no direct support for the Topic Maps. However, each layer of the model is equally comparable and applicable to the Topic Maps paradigm. This paper investigates and analyzes the Semantic Web Stack for determining its applicability for the Topic Maps. We have come up with the conclusion that the stack has potential for accommodating Topic Maps equally but subjected to little more efforts from the research communities.

***Keywords*-**Semantic Web, Resource Description Framework (RDF), Topic Maps, Semantic Web Stack

I. INTRODUCTION

Resource Description Framework (RDF) and Topic Maps are the two standards developed by the different standard making organizations for fulfilling the vision of Semantic Web. Semantic Web extends the current web in such a way that the problem of finding precise information at the right time and place will be possible due to its advanced techniques of inferencing, intelligence and machine based searching.

RDF is a W3C standard for representing metadata relationship between web resources. RDF paves the way for software applications to interchange web resources semantically, enhances interoperability between software applications and enables machines for automatic processing of web resources. ARDF model expresses meanings by consisting of statements (triples) where each statement relates web resources by using the analogy of a subject, a predicate, and an object, corresponding to subject, verb, and object of an elementary sentence [i]. Topic Maps is a ISO standard for discovering, linking, filtering and retrieving relevant information on the Web. Topic Maps models web resources in the form of topics, associations between the topics, and occurrences of the topics and associations.

The advent of standards encouraged researchers for contributing extensive research efforts utilizing both of them in parallel for fostering the growth of Semantic Web, resulting into the division of Semantic Web into two separate islands. A plethora of supporting technologies including ontology modelling languages, query languages, interchange formats, and storages are devised for RDF and Topic Maps technologies. The technologies developed for RDF are divided into multiple layers where layer consumes services and offers services to one another. The cumulative efforts resulted into a layered model called Semantic Web Stack, which was first proposed by Tim Berners-Lee (i.e. inventor of the World Wide Web) [ii]. Semantic Web Stack is the general architecture of the Semantic Web. The layered approach provides a number of advantages including dividing the overall process into smaller and simpler components that are easier to develop, facilitate standardization of technologies belonging to individual layers, preventing changes in one layer affecting the other layers, allowing different technologies to work with each other, providing simplicity to enhance understandability and debugging, and accommodating addition of further layers.

Topic Maps, on the other hand, was originally developed for the representation of back of the book index construction [iii]. The original idea of Topic Maps was further extended by the researchers and used it for wider applications like to represent exchange and convey knowledge on the Semantic Web [i]. A Topic Map represents networks of nodes instead of tree hierarchy consisting of topics associations, occurrences, and scope [iv]. To compete with RDF, a comparable technological layered stack is proposed for Topic Maps consisting ontology modelling languages,

and query languages providing almost the same functionalities provided by technologies in the Semantic Web Stack. However, RDF related technologies comparatively provides a rich set of features and succeeded in gaining attention of the wider Semantic Web research community as compared to Topic Maps by reaching acceptable levels of maturity. To help Topic Maps to preventing from getting wiped and save the invested efforts, the Semantic Web Stack should extend support for Topic Maps.

This research paper is aimed to provide a comprehensive study by analysing the Semantic Web Stack, covering all of its possible aspects, and presenting its pros and cons. It also attempts to find out how this model can be used for Topic Maps. Main contributions of this paper include:

The key contribution is the detailed analysis of the Semantic Web Stack and its strength of supporting Topic Maps paradigm.

The topic is almost unique in its integrity and opens new area of research. No prior work exists in the literature addressing the same problem in a comprehensive manner.

To organize and classify the available literature about the topic in an attractive manner to catch and boost interest of the new researchers in the area and take them into new avenues of research.

The paper is expected to provide a compact platform for researchers for finding new research dimensions and discovering solutions for the existing ones.

II. Semantic Web

The World Wide Web (WWW) has new ways of accessing electronically available information. The WWW, at present, contains billions static web pages, accessed by millions of users around the globe. However, this tremendous quantity of information has given birth to the increasingly difficult problems of finding, accessing, presenting and maintaining the information needed by different users. Furthermore, today's web suffers with information overload problem which can significantly affect its very usefulness [v]. A reason is synthetic nature of the today's web, where information is presented primarily in natural language and computer presents the information only while the interpretation and identification of pertinent information is delegated to users. Thus, a considerable gap has came out between the information available for automated tools aimed at solving the problems stated above and the information maintained in human interpretable form.

According to Oxford dictionary [vi] the word "semantic" is concerned with the meaning of words, phrases, and sentences. Semantic Web distinguished as the next generation of the Web advocates that information will not only aim for human readers but for machine processing as well, which will enable intelligent information services (i.e. intelligent search agents, semantic search-engines, and intelligent information filtering etc.) to provide greater functionality and interoperability as compared to the current isolated services [vii]. Tim Berners-Lee, inventor of the WWW, URIs, HTTP, and HTML toasted the idea of Semantic Web in his historical article "The Semantic Web" and characterized Semantic Web as an extension of the World Wide Web which will enable giving well-defined meanings to information and make the exchange of machine-readable information easy and efficient [viii]. The Semantic Web is a network of information which enables people and computers to work in cooperation through giving well defined meanings to information. Semantic Web provides a platform where data sources using ontologies, semantic rule, web services, and web processes can be integrated. Information are linked up making it easy for machine processing for different purposes such as effective searching, integration, automation, and reuse across various applications [ix]. Thus, Semantic Web enhances machine abilities to solve a well defined problem by performing well-defined operations on existing well defined data.

Semantic Web turns the Web of information (current web) into web of knowledge (future web, knowledge-based web) as shown in Fig. 1 to provide qualitatively new levels of services through unambiguous representation of the underlying data, programs, pages, and any other web resources using semantics. Enabling automated services to understand content on the Web will improve their human assistance capabilities in providing more accurate filtering, categorization, and search of information sources [x-xi]. Therefore, Semantic Web can be thought as an infrastructure for which applications can be developed not an application by itself [ix].

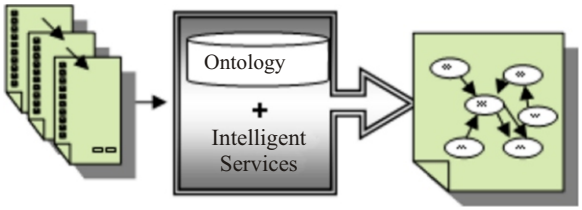

Fig. 1. From the current web to the web of future [viii, xii]

W3C (World Wide Web Consortium) [xiii] assumes to achieve full potential of the Web; it should be turned into a place where information can be shared and processed by automated tools as well as by people. A typical example of Semantic Web application will be

automated travel agent which will come up to the user with suitable travel or vacation suggestions under certain restrictions and preferences. To derive suggestions, software agent (automated travel agent) will not only use the already determined sources of information but will search the Web in a similar way as a human user might do when planning a vacation [xiv]. But the problem is that web pages are mainly concerned with presentation to and utilization by human users [xv]. Annotations are used to identify contents of a web page. Annotations are typically in the form of natural language strings or tags which are interpretable and understandable to human beings but not to automated tools (e.g. software agents). To solve this problem and give machine accessible semantics to annotations, Semantic Web uses a number of technologies including ontologies [xiv]. Ontologies are metadata and getting the status of backbone of Semantic Web [xii]. Ontologies provide a generic presentation of domain knowledge and a commonly agreed understanding of a domain to help people and machine communicate efficiently. Therefore, success and proliferation of Semantic Web mainly depends on the cheap and fast construction of web ontologies [xvi].

III. Semantic Web Stack

The basic idea behind the development of Semantic Web Stack by Tim Berners-Lee was to integrate all these technologies and languages into a model through which the realization of the Semantic Web becomes possible. Semantic Web development continues in step wise fashion and each step constructs a layer on top of another. Building a layer on top of another, generally, follows two principles. First is downward compatibility, where an agent fully aware of one layer would be able to interpret and use information written at lower levels. Second is upward partial understandability, where an agent fully aware of one layer should be able to take partial advantage of information at higher levels [xvii].

Generally, Semantic Web Stack model can be divided into three layers as shown in Fig. 2. The bottom layer consists of URIs, Unicode character scheme, XML and XML schema, providing base for the Semantic Web and is already implemented for writing structured web document with user-defined vocabularies. The middle layer is especially for the implementation of Semantic Web core techniques and technologies for developing Semantic Web applications and consists of RDF, RDF Schema, ontology languages, and query languages. The top layer consists of the technologies including logic frame work, trust and proofs etc., which are not standardized but providing enhancement to the lower layers by allowing writing of application specific declarative knowledge, representation of proofs in web language from lower layers and proof validation, and gaining users' trust for its operations and information provided. Users interact with the Semantic Web through applications user interfaces built on top of the top layer. Since the model is developed and presented by the W3C working group, therefore, no information about Topic Maps standard is included in the model. However, the Topic Maps standard and its relevant technologies are comparable to the technologies belonging to each layer of the RDF standard depicted in the Semantic Web Stack [xviii].

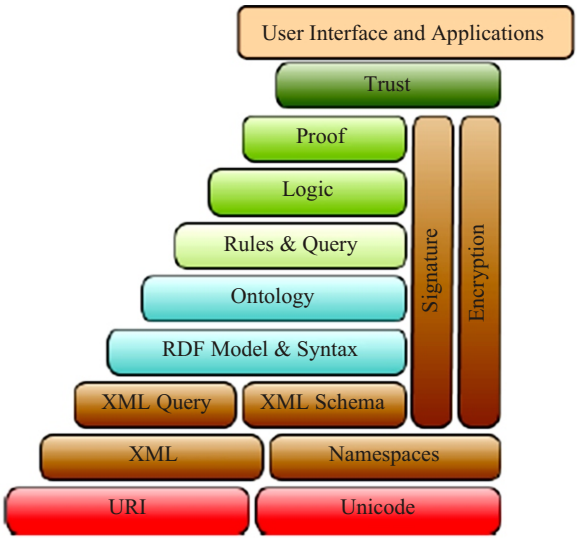

Fig. 2. The Semantic Web Stack

A. *URI/IRI and Unicode*

Uniform Resource Identifier (URI) or International Resource Identifier (IRI) and Unicode character scheme are the technologies belonging to the bottom layer of the Semantic Web Stack inherited from the Web. A URI is the general form of URL used for accessing a web page in today's web. However, instead of restricting URIs for representing web pages addresses, they have broad spectrum of applicability for identifying any abstract or physical resource on the Web. A URI has the potential of identifying diverse and small object such as email address, mobile number, locations, ISBN, and author of a book. Since RDF establishes a metadata relationship between web resources and resources they can be identified on the Web using the notion of subject, predicate, and object (SPO), therefore, it becomes potentially impossible for URL technology to indentify small and diverse objects and their interrelationships. On the other hand, URIs provides effective support for addressing small and complicated resources and their metadata relationships precisely which goes beyond the scope of URLs.

Along with URI, an encoding scheme called Unicode is used at the same layer. Unicode provides support for representing any type of text in any language in the world uniquely in the computer.

Unicode has the capability to record more than one millions characters and supports approximately one hundred scripts. Unicode system is standardized and used in connection with several new and emerging technologies such as XML, Java, and .NET platform etc. Statement <?xml version="1.0" encoding="UTF-8"?> is included at the top of each RDF document signifying the encoding scheme used. UTF-8 is the mostly used and implemented character encoding scheme, which makes the Semantic Web a universal platform. Unicode in combination with URI extends support for identifying any type of resource in the Semantic Web regardless of its text and scripting language.

B. XML, Namespaces and XML Schema

The layer at the top of URI and Unicode layer accommodate XML, XML Schema, and Namespace technologies for representing low level semantics. In Semantic Web, resources will be divided into pieces and structured in such a way that there will be metadata relationship between resources. HTML provides constructs for formatting web pages and hypertext documents but cannot encode information about resources divided into pieces and structurally related with each other.

1) Extensible Markup Language (XML)

XML is a general purpose markup language for creating special-purpose markup languages, which is simpler to parse and process than SGML. In Semantic Web paradigm, XML will structure the data in such a way that the contents of web resources will be easily accessible to the machine. XML includes features for describing each piece of information, and implementing nesting structures and properties of objects in an easily understandable pattern. The pieces of information can be stored, structured and associated with other web resources using XML [xix]. XML enables users to create XML document with the liberty of defining their own tags according to their choices and needs, storing in plain text file, running on any platform. For example, if someone wants to create a XML document for representing information about name and email address of an object would have contents as follows:

```
<?xml version="1.0"encoding= "UTF8"?>
<email>
<to>Chief Editor
</to>
<em-address>kareem1@yahoo.com</em-address>
<from>Alam</from>
<Em-address>fakhrealam@uom.edu.pk
</em-address>
<subject>about my paper</subject>
<body>Reviewers had suggested some changes which are now accommodated in the paper</body>
</Email>
```

When a document is created using XML editor, it would contain the definitions of data along with their structural relationships [xix]. The self-made tags created by the users are checked by the XML parser for integrity and validity. An XML document can be easily stored in the form of a text file which can be transferred to any other platform, system, and program. XML documents can be used with and retrieved from different types of databases such as relational, object oriented and XML's own storage servers etc. Representing XML documents in plain text format improve XML's interoperability by running on multiple platforms and programs extensibility by easily integrating new programs on top of the older programs. Other features of XML include language independence, reuse with HTML, and exchangeable structure using DTDs and XML Schema.

2) Namespace

Programmers can define elements in an XML document according to their choices and needs which could arise naming conflict in situations when different XML documents are merged from various applications of the same type [xx]. XML namespaces are devised to resolve such problems, because namespaces uniquely and universally identifies each element and attribute. Using the namespaces feature, a XML documents can be easily and quickly created by merging and reusing code from different XML documents, which can further transferred and reused with other XML documents. A namespace prefix representing the namespace has to be embedded at the start of each element and attribute definition to distinguish it from other similar elements and attributes.

The general syntax of namespace declaration is: *xmlns:prefix="URI"*, where xmlns is the reserved word, prefix is any valid namespace identifier for representing namespace resource designated by the unique URI.. To define a default namespace for a document, the prefix part can be omitted and declaration can be restricted to *xmlns="URI"*. In declaration of namespace statement, *xmlns:xhtml= http://www.w3.org/1999/xhtml* the prefix xhtml means that this document is defined inside the XHTML namespaces and can be mapped into it. The default namespace can also be described for the above statement as *xmlns=http://www.w3.org/1999/xhtml*. The type of statement with no explicit prefix definition will be considered to be in the XHTML namespace. When an attribute is declared with no explicit namespace prefix would mean that the attribute does not belong to any namespace. Therefore it can be concluded that the attributes do not necessarily depend on the default namespace.

XML data model has been proven much better and

sophisticated than other data models such as relational and object oriented. Therefore, several types of query languages such as Xquery and XQL have been developed to query its resources [xxi]. The XML query languages provide simple and stylish interface to users due to which they can choose query style of their own choice. XQuery is the powerful XML based query language developed for Semantic Web Stack, which can easily relate web resources, documents, and databases of the Semantic Web. XQuery provides the potential for reading XML files, selecting a particular value, arranging data in an order, and returning final results in another XML document format.

3) XML Schema

XML schema is the extension of XML DTD with tremendous advancements in features and functionalities including support for data types and namespaces, and extensible to future additions [xxii]. XML Schema describes information about the basic structure and internal format of a XML document. XML Schema language, also called XML Schema Definition (XSD), provides potentials for defining and expressing elements and attributes, childs of elements and attributes along with number and order, data types of elements and attributes as well as their fixed values etc. in a XML document. The validity of a XML document can be verified by computer programs using XML Schema documents. The programmer can take help from the schema document to create accurate and valid XML documents which can be further used by computer programs.

C. RDF and RDF Schema

XML has the expressive power to express and encode any type of resource if proper grammar is defined for the resource [xiv]. Similarly, XML has strong parsing capability to parse any type of data using its parser libraries to determine its usability and validity for other applications due to its support for syntactic interoperability. However, XML fails in mapping an unknown data with a known data and establishing a semantic relationship between them. To overcome the limitations of XML and increase supporting and sharing semantic/metadata between heterogeneous web resources in Semantic Web, RDF technology is developed for creating data models on top of the XML data models.. RDF technology produces data models, implementing and establishing semantically enhanced metadata relationships between different types of web resources. RDF model increases applications' interoperability by exchanging previously machine dependent web resources between applications and automatic processing of web resources.

1) RDF

RDF is a W3C recommendation providing a standard for metadata for describing data about web resources. Although RDF provides much better and rich syntax and semantics as compared to the XML, but still consumes the services from XML by working in collaboration with XML. The RDF framework has sophisticated features of expressive power and syntactic interoperability over XML, but the feature distinguishing RDF from XML is its semantic interoperability [vii]. The main reason of this property of RDF model is due to its independent object-attribute structure, no need of objects translation, defining relationships between similar domains, mapping two different RDF descriptions, and the availability of knowledge representation techniques. These features empower RDF to interchange data at much higher level as compared to XML parser. A major reason of RDF propagation is its inherent flexibility to represent the full spectrum from highly structured data similar to a relational database to unstructured data as it may be found in social networks [xxiii]. However, to fulfill Semantic Web needs requires availability of universally shared knowledge representation language. Although the need is not practically satisfied as yet with a single technology but using technologies such as RDF, its schema and ontology languages in combination can provide considerable solution.

Recent years have witnessed a tremendous increase in the publically available RDF datasets semantically related and interoperable with each other, whose example is LOD (Linked Open Data) cloud a remarkable collection of interlinked RDF datasets [xxiv]. To achieve semantically interoperability, RDF model is serialized into XML syntax called RDF/XML. RDF/XML syntax can merge and integrate distributed and heterogeneous resources on the Semantic Web. In addition to RDF/XML, RDF model can be represented in other interchange formats as well such as Notation-3 (N3) which is more simple and easy to read and write, and provides logic and inference mechanism as compared to RDF/XML.

2) RDF Schema

RDF describes relationship between web resources using subject, predicate and object notion, however, web resources may also contain vocabularies which could belong to other resources [xi]. RDF framework provides constructs from its own vocabulary for mapping relationship between web resources using, and fails to map relationships if web resources are semantically related by using constructs from other resources. To describe such type of semantic relationships between vocabularies, a schema language for RDF called RDF Schema is used which can itself be expressed as a RDF model. The RDF Schema language works above RDF in the Semantic Web Stack and extends the original RDF model with some special semantic mechanisms to add numerous constructs for defining classes of resources and the properties specific to those resources. In other words, RDF Schema language extends the expressiveness of

RDF frameworks by providing a set of novel constructs [xxiv].

In database paradigm, schema language only works to impose restrictions on DBMS and define the internal storage structure for databases such as tables, fields and relationship structure and size. RDF schema, on the other hand, provides constructs for defining concepts, concepts' properties, values of the properties, and the relationship between all these concepts, properties and values. With the help of RDF schema, users can not only determine what the data is about but also all others related information to this data. While describing all vocabularies, RDF schema divides vocabularies into the form of classes, the property belongs to particular classes, sub classes and into the instances of classes. RDF schema also imposes constraints on RDF and its properties that are expressed in a particular domain.

D. Ontology

The widespread increases in the size of web contents have created serious limitations in the hypertext system. The finding, sharing, interpreting and integrating of the required information from multiple sources are difficult with using the technologies provided by the current web such as keyword based search etc. However, some techniques have been developed in the current web, also called Web 2.0, for solving these problems, but they are able to solve specific problems such as information integration and sharing according to specific situations and users. Furthermore the general problem of finding and integrating information by the machines automatically according to users' demands and preferences cannot be solved by these techniques. Semantic Web aim to solve the problems by sharing information among wider communities and processing the information automatically using the Semantic Web tools [xxv].

The expressive power of RDF and RDF schema also fails while dealing with complex type of resources and their semantic relationships [xii]. Ontologies are deemed as supporting technology for Semantic Web to help in solving the problem of semantic annotations between different types of web contents. Gruber formerly defined the notion of ontology in 1993 as "explicit specification of conceptualization" [xxvi]. Typical web ontology consists of taxonomy and a set of inference rules. The taxonomy defines hierarchy of classes of objects and relationships among them. A large number of relationships among objects of the classes can be described by assigning properties to classes which can be inherited by the subclasses. Using ontologies, effective reasoning can be possible, better syntax can be written, precise meaning will be assigned to the knowledge, and the appropriate expressions can be possible quickly.

The origin of ontology goes back to the philosophy and can be defined in a different ways because of their potential applications in many fields. In the Semantic Web, ontology gives formal meanings to the web contents which are further interpreted and transferred into semantic annotation. The success of Semantic Web depends on the existence of multiple distributed ontologies enabling users to annotate their data for improving shared machine readable content [xi]. Knowledge which consists of multiple concepts in a specific domain can formally be represented and related with the help of ontology. With the use of ontology, different types of shared vocabularies and taxonomies, from which a specific domain is created and which consist of multiple concepts/objects along with their properties and relations with other concepts and objects, can be easily retrieved [xxvii]. Ontology can be used in almost each field of computer science for the proper organization of information. For the proper organization of information in the Semantic Web, an ontology language called Web Ontology Language (OWL) is developed.

1) Web Ontology Language (OWL)

RDF and RDF Schema describes vocabularies by using constructs for supertype and subtype relationships, classes and their instances, and superimposing restrictions for domains and ranges of properties [xvii, xxviii]. However, the power of RDF Schema becomes unsuccessful in implementing special types of features and restrictions such as range restrictions for classes, disjointness of classes, defining compound class properties using boolean and set theory (union, intersection, complement), and describing cardinality restrictions. To the problems unbearable for RDF and RDF Schema, an advance ontological language is developed by the Semantic Web community called OWL, which works one level above the RDF/RDFs in the Semantic Web Stack.

The Web Ontology Language (OWL) is a W3C standard used to create ontologies for the World Wide Web. OWL (i.e. successor of the web ontology language DAML + OIL) is a description logic (i.e. SHOIN(D)) based ontology language with an RDF/XML syntax [xxviii]. OWL includes constructs for describing much richer semantics, integrations, and interoperability between web resources as compared to RDF Schema. OWL can be effectively used in computer programs because of its machine oriented methods for checking the validity and consistency of knowledge and making implicit knowledge explicit. The documents created using OWL are called ontologies, which can be published and shared on the World Wide Web. The OWL overcomes the weakness of RDF Schema by adding more vocabularies for describing classes and properties including disjointness, equality, symmetric, and transitive etc. as well as restriction on classes and their properties. The syntax of OWL is based on XML and has three

sub-languages: OWL Lite, OWL DL, and OWL Full. Every Lite ontology is also a DL ontology and every DL ontology is also a Full ontology [xxix].

OWL Lite is easier to learn and implement as compared to Full and DL, and is especially designed for situations where users' requirements are limited to implementing simple constraints features and a classification hierarchy [xxx]. OWL Lite is an extension of RDF and includes features for more specific or intersection based class definition, creating class individuals, describing equality or difference between class, characterizing inter-class relationships, and characterizing properties as inverse and transitive etc . OWL Lite is effective if used for simple domains such as if users' want to implement cardinality constraints of only 1 and 0 values. It is very simple to provide tool support for OWL Lite for enabling quick migration of thesauri and other taxonomies [xxvi]. However, the available tools for supporting OWL Lite are complex and can be used with OWL DL as well.

OWL DL provides all of the OWL language constructs for helping users to gain maximum expressiveness without losing computability. DL stands for description logic, which represents a decidable fragment of first order logic and included in OWL DL for obtaining required computational properties and reasoning capabilities. OWL DL is mature enough for providing foundation to the OWL for creating knowledge based ontologies [xxvi, xxviii]. OWL DL implements several types of restrictions on OWL and RDFs syntax to obtain processing efficiency for reasoning. However, due to the rapid change and restriction imposed on RDF document before converting it into OWL DL documents, full compatibility has been lost between OWL DL and RDF.

OWL Full is fully compatible with RDF Schema and can represent resources on the Web both syntactically and semantically as RDF and RDF schema [xxvi, xv]. OWL Full helps users who want maximum expressiveness and syntactic freedom of RDF with no computational guarantee. In OWL full, constraints regarding classes, subclasses, properties, individuals can be represented in ontology more efficiently and expressively such as a class can depict simultaneously a collection of individuals and a single individual in its own right. OWL Full borrows some of the semantics from the other species of OWL (i.e. OWL Lite and OWL DL). With the help of OWL full, one can build an ontology which can extend the meaning of already built RDF and OWL vocabulary.

E. Rules and Query

Rules and query languages are defined in layer at top of the RDF and Ontology layer in the Semantic Web Stack. Rules languages add more inference mechanism web ontology languages and query languages are used to retrieve data from the RDF model. Rule languages address the logic problems related to description and inference mechanisms which cannot be satisfied by the existing RDF and OWL technologies [xxxi]. The rule language used in the Semantic Web Stack is called Semantic Web Rules Language (SWRL) and the query language used is called SPARQL.

Semantic Web Rule Language (SWRL), standardized by W3C in 2004, is result of the combination of OWL DL and OWL Lite sublanguages of the OWL with the Unary/Binary Datalog RuleML sublanguage of the Rule Markup Language [xxxi]. Rule langue is need for several reasons including reusing of the existing rule sets, improving OWL expressivity, and providing ease in reading and writing rules. SWRL has high level abstract syntax for Horn-like rules and expresses all of the rules in terms of OWL concepts, properties, and individuals. The main features of SWRL include its strong support for several popular tools such as SWRL Tab, KAON2 and Pellet.

Query languages help Semantic Web Stack for enabling users to retrieve data from RDF model. SPARQL is the Semantic Web query language, which can be used for retrieving data from RDF graphs stored in triple format. SPAQRL was first standardized in 2008 by W3C and its extension SPARQL 1.1 is also standardized recently [xxxii]. Data in a RDF model is stored in triple format which reflects a certain graph pattern. , data is stored in the form of triple format which is based on certain graph patterns. Graph patterns in RDF models can be queried using SPARQL queries for retrieving results to the users if triple patterns in the models matches with the queries. Information retrieved by a SPARQL query could be in the form of URIs, blank nodes, and plain and typed literals. A reason of SPARQL inclusion in Semantic Web Stack could be the ability to transfer SPARQL query to another query format such as RDBMS query language (i.e. SQL) or XML query language (i.e. XQuery) etc.

F. Logic, Proof and Trust

In Semantic Web Stack, there are also some unrealized technologies such as Logic, Proof and Trust, working above on the standardized technologies such as XML, RDF and OWL. The basic vision of the Semantic Web highly requires logic and knowledge to be essential parts of the Semantic Web Stack. Logic provides detailed explanation for query answering, shows precise knowledge, and delivers easy to understand formal semantics. The OWL sublanguages OWL Lite and OWL DL come with first order logic and descriptive logic respectively, having inference capability to deduce complex knowledge from the ontologies. However, a powerful logical language is necessary for the Semantic Web to enhance reasoning and inferencing capabilities with the aid of logic either from a single ontology or ontologies in combination.

Proof layer in the Semantic Web Stack is included by Tim Berners-Lee to access cognitive and meta information [xxxiii]. The basic reason would be when a client submits a request to the server for a particular resource along with proofs, the server will reply to the client based on proof. Generally, meta information about a resource are considered as a proof of its contents and the proof of one resource can also become the proof of another resource when the information from one resource is incorporated with another one. Proof can also be used for the presentation of graphical data and natural languages, due to which humans can easily deduce answers and solve problems by using proof as a template. Due to these reasons, the importance of proof becomes a practical reality in the Semantic Web.

In Semantic Web Stack, proof is enhanced with Trust because only proofs cannot provide much confidence for people to publish their data on the Semantic Web [xxxiv]. The proof depends on statements due to which a true assumption is not possible for the user and in some situations, at a particular time; it becomes impossible for the people to understand it. With the help of Trust, RDF data in the Semantic Web will be secured more by digital signature techniques from their respective web authors. This type of trust will work globally and the users and Semantic Web agents will reach to more precise RDF statements with full confidence.

G. User Interface and Applications

The top layer of Semantic Web Stack is the user interface and applications through which people will interact with RDF model though applications [xxxv]. To embed the semantic structure in the current web, there is need for applications which integrate data and improve the search mechanism to a more specialized and intelligent level. Applications generally show the characteristics of RDF data in the Semantic Web. With the help of these applications, distributed and heterogeneous information resources can be accessed visually. Applications based on RDF can also store and organize knowledge in a better way and manage large repositories in an efficient way.

The applications can provide adaptive and customized views by analyzing users' current task/activity and can generate response to the users according to the context identified. Specialized browsers based on these applications are used for visualization and navigation within specific domains due to which users can easily and quickly explore inside the domain and build-up their own thinking of conceptual associations and problem solving paths. In short, due to these applications, the RDF and Topic Maps based information can be efficiently manipulated, the structure of knowledge/resources can be maintained precisely, and both knowledge and information layer can be easily searched, navigated and visualized.

IV. Semantic Web Stack for Topic Maps

Semantic Web Stack is developed by the W3C RDF data models exclusively and containing no information about handling Topic Maps. However, Topic Maps is a parallel technology to RDF, performing almost the same functions and in the similar way as RDF do. Like RDF, several techniques and technologies are developed for Topic Maps to help in realizing the vision of Semantic Web. Each of the technology developed for Topic Maps is equivalent to corresponding technologies in the Semantic Web Stack. Fig. 3 shows layer wise comparison of the technologies for both of the standards. Table I presents layer wise comparison of the technologies capabilities for both of the standards.

A. Serialization/Interchange Formats

Serialization is the process in which data in one format is semantically converted into another format for the storage and transmission purpose. It is due to the serialization that different types of data formats can be stored and run on different hardware platform regardless of their underlying architecture, thus, promoting interoperability. XML provides persistent method for the interchange of data on the web to be stored or communicated regardless of the programming languages in a human readable format [i]. A number of serialization formats are defined for mapping RDF models including RDF/XML and N3 etc., whereas, the serialization formats developed for Topic Maps to function at lower layer of the Semantic Web Stack are XTM and LTM. The Topic Maps serialization formats can work on the same layer of the Semantic Web Stack where RDF serialization formats functions. The serialization formats provided for both of technologies can be either XML based or non-XML based [i].

XTM is a XML based serialization format for Topic Maps, which utilizes XML for storage and URL for relating and referencing. XTM is more simple, flexible, and easy to interpret as compared to other format and improves knowledge accessibility across applications. XTM is inherently implemented in web browsers, making knowledge representation and navigation on the Web considerably easy LTM is non-XML based serialization format for Topic Maps which can work on Semantic Web Stack similarly XTM. LTM enables creating Topic Maps documents in simple textual format in any text editor, which could be either processed by Topic Maps software or converted into XML format for further processings. However, LTM representation of Topic Maps information is simple, efficient, and takes less space as compared to XTM. LTM representations of a Topic Map data model can be

easily converted into XTM format but have lower expressive power than XTM. Furthermore, LTM interchange format is suitable for representing small Topic Maps such as email, presentations, discussions and personal use.

B. *Data Modeling and Ontology*

Topic Maps data model can work on the same layer on which RDF model works in the Semantic Web Stack. A Topic Maps data model describes semantic relationship between web resources in the similar way RDF technologies perform. Like its counterpart, the Topic Maps data modeling and ontology technologies will enable machine dependent web resources to be interchanged and processed automatically by applications to work in interoperable way.

In Semantic Web, RDF Schema and OWL technologies provide much richer semantics and constraints for RDF data models. Topic Maps Constraint Language (TMCL) standardized by the ISO no.19756 defines schema for Topic Maps [xxxvi, xxxvii]. For Topic Maps, TMCL technology provides increased semantic interoperability and constraints for Semantic Web. In relational database, the schema is used to show the relation between tables, field size, arrange data in a graphical structure, and to impose some types of constraints on data. In Topic Maps paradigm, schema language is also used to implement some types of constraints on information. These constraints include simple and best user interface to properly document the structure of Topic Maps and to verify the information in a consistent and meaningful way. The mechanism used to implement constraints in TMCL is so simple, precise and clear that the job can be automatically validated in machine readable form. These validations can be performed by a mechanism called semantic validate, which verify every document and report errors when the condition is not according to the context and will remain silent when the constraints are fulfilled. Several types of constraint languages are available to implement constraints on Topic Maps. Among them XTche language, AsTMa! Language, and OSL language are more popular.

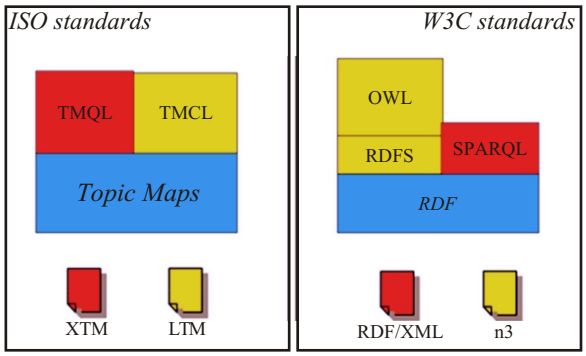

Fig. 3. Layer wise technologies comparison of RDF and Topic Maps

TABLE I
LAYER WISE TECHNOLOGIES CAPABILITIES FOR RDF AND TOPIC MAPS

Layers	Characteristics		RDF	TMs
Serialization/ Interchange Layer	XML Based		✓	✓
	Non-XML Based		✓	✓
Data Modelling and Ontology Layer	Data Modelling Language	Statements Declaration	✓	✓
	Schema Language	Schema Definition	✓	✓
	Ontology Development Language	Restrictions	✓	✓
		Concepts	✓	✓
		Properties	✓	✓
		Occurrences	✓	✓
Query Language Layer	Implementation		✓	✓
	Accuracy		✓	✓
	Scalability		✓	✓
	SQL Resemblance		✓	✓

C. *Query Language*

Topic Maps Query Language (TMQL) can be implemented on the Semantic Web Stack to retrieve data from Topic Maps data model (TMDL), in the similar way as SPARQL retrieves from a RDF data model and OWL ontology. This query language was standardized by the ISO and is easy to learn and implement on the Semantic Web paradigm due to its similarity with SQL and XML. Semantic Web information, regardless of its huge size and rapidly changing nature, can be accessed with the help of TMQL.

D. *Concluding Remarks*

The Semantic Web Stack is a model developed by W3C for accommodating technologies developed exclusively for semantically annotating RDF data models only and there is no such model developed for Topic Maps until now. However, the technologies developed for Topic Maps data modeling can be exactly layered up as technologies prescribed for RDF data models. Like RDF technology, the Topic Maps data modeling and ontology development technologies builds a layer over the serialization/interchange formats, and query languages builds a layer over the data modeling and ontology development technologies layer. The performance, expressibility, accuracy, reliability, and usability of the technologies developed for both of the paradigm are almost the same. Therefore, instead of creating a separate Semantic Web Stack for Topic Maps, the existing W3C Stack should be extended with introduction of new set of protocols and logic capabilities applicable equally to RDF and Topic Maps paradigms.

V. CONCLUSION

Semantic Web vision is a response to the limitation of the current web which aims to make web content machine processable by adding metadata annotations using the technologies of RDF and Topic Maps. The basic idea behind the development of RDF and Topic Maps was to extend and present the current web as a useful and flexible medium where users can easily dig out information as per their requirements. RDF and Topic Maps make information machine processable by enriching them with semantics and reasoning capabilities. The Semantic Web Stack developed by Tim Berners-Lee is a model which shows the basic architecture of Semantic Web. The model consists of multiple layers and the basic purpose is to integrate all the technologies and languages into a single model for the realization of the Semantic Web. Semantic Web Stack was developed for RDF only and has no direct support for Topic Maps. However, each of its layers can be comparable and applicable to the Topic Maps paradigm. Semantic Web Stack is a model developed by W3C keeping in view RDF and its succeeding OWL, whereas, Topic Maps are least considered for complying with the standard requirements defined in the model.

In this paper, we presented a comprehensive study of RDF Semantic Web Stack covering each layer of this model and compared it with Topic Maps tools and techniques. The on-hand knowledge about the available techniques in the Semantic Web Stack for RDF and their equivalent in Topic Maps is presented wisely to elaborate their capabilities and are compared and analyzed in a format to give insight knowledge to the people to help them in selecting one suitable for their needs. During investigation, it has been found that Semantic Web Stack is rich enough and fruitful to fulfill the varied needs of users in Topic Maps as well, but requiring certain more efforts. Therefore, instead of developing a separate model for Topic Maps, the existing Semantic Web Stack model has the potential to accommodate Topic Maps technology.

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