Influence of Aggregate Characteristics on the Compressive Strength of Normal Weight Concrete

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Abstract-Experimental investigations on the properties of concrete have been performed around the globe and their correlation is interpreted in relevant design codes. The structural behavior of cement concrete significantly relies on the material resources, properties of the aggregates constituting the concrete and the local construction practice. These factors vary from place to place. Therefore, the compressive strength of concrete prepared from the aggregates available in one locality may not be directly applicable to the other areas. The purpose of this study is to evaluate the Influence of locally available coarse aggregates on the compressive strength of normal weight concrete (NWC) prepared under local environmental conditions of district Khairpur Mir's, Sindh, Pakistan. The coarse aggregates were collected from five different quarries in the vicinity of Khairpur Mir's, Pakistan. In total, 180 cubes were tested. 10 different batches were formed in order to arrange individual characterization of concrete. Each batch was contained of 18 cubes and each quarry contains 2 batches making a total of 36 cube with four different ratios for each quarry. Dry density and compressive strength of concrete was calculated and a comparison is provided as a guideline for the future construction work in the local community.

Keywords-Quarry, Aggregates, Khairpur Mir's, Cement Concrete, Compressive Strength

I. Introduction

Concrete prepared with Portland cement is considered as the most resourceful and multipurpose construction material in the civil engineering industry. Global production of concrete is about 12 billion tons a year [i] corresponding to almost 1 m^3per person per year [ii]. Yearly cement production levels are about 3 billion tons [i]. However, the relatively unreliable durability of concrete exposed to adverse circumstances for long term is always a hot issue under discussion for researchers. Since up to 80% of the total concrete volume comprises of aggregates, therefore, the properties of aggregates such as the shape, texture, grading influence workability, finish ability, bleeding and segregation of fresh concrete have important influence on the behavior of concrete.

During last few decades, the use of large-sized coarse aggregates has been considerably increased in concrete engineering for economic and environmental reasons. There is a growing research interest to understand the effect of maximum aggregate size on the characteristics of normal weight concrete (NWC) and high strength concrete (HSC) due to the uncertainty of the interfacialbond stress transition between the aggregates and matrix which are regarded as the weakest link in concrete [iii]. Following this, improper mix proportions and diversity in grading may result in durability complications. Concrete strength is determined depending upon the curing conditionseither through the bond between the cement paste and coarse aggregate and/or by the interlocking characteristics of aggregates. Irregular surfaced cubical aggregates are considered as finest solution to achieve an optimal bond between aggregates and cement, and provide high values of strength [iii].

Several researchers studied the influence of various types of aggregates on the strength of structural concrete. Reference [iv] studied the effect of aggregate size on the softening branch of concrete by conducting the uniaxial, bi-axial and tri-axial compression tests and found that the concrete made with large sized aggregates showed more ductile behavior in the post-peak branch. Their resultscould be applied only on NWC. According to [v] studied the effects of aggregate size on the softening response and brittleness of HSC by performing three point bending tests. The results showed thatin HSC without silica fume, the fracture energy increased with the largest sized aggregates. Reference [vi] performed numerical investigations and concluded that the heterogeneity of disordered materials has a strong influence on the shape of the stress-strain curves and the loading bearing capacity of concrete prisms. Their results showed that the relatively heterogeneous specimen emitted more acoustic emission events prior to the macro-fracture as compared to homogeneous specimen. Furthermore, a higher stress drop was observed correspondent to the higher event rate in relatively homogeneous specimens. According to [vii] carried out tests on concrete containing spherical aggregates of different sizes to study the effect of the aggregate size on the performance of concrete. The study revealed that the aggregate size was inversely proportional to the tensile strength. However, the compressive strength increased slightly with the increase in the size of aggregate.

The structural behavior of concrete is considerably guided by taking into account of various factors including the source from where aggregates are collected, the estimation of properties of aggregates and the description of material sources. The knowledge of these factors can produce a handy information about locally prepared concrete to be used as a reference in future works.Indeed, the properties of concrete and the experimental testing conditionsare significantly responsible for the resultant structural performance of concrete.The experimental conditions take account of the stiffness of the testing machine, the boundary conditions, and thegeometry of samples, the strain rate, and the loading method. Concrete characteristics include variables such as the mechanical and physical properties of the cement and aggregates and the water cement (w/c) ratio. Since these parameters are different from place to place, thus the strength of the prepared concrete varies place to place.

This study intends to provide a conceptual framework for the use of aggregates based on their physical and mechanical properties for their use in local construction and evaluates the strength of structural concrete prepared with locally available aggregates of different quarries in Khairpur Mir's district under different curing time periods. The effects of the shape, texture and grading characteristics of aggregates on concrete strength were also studied. Field investigations were performed to the quarries and crushing plants of Khairpur for characterization. The gravels collected from quarries were utilized for laboratory examination. Packing density concepts and surface area concept were used for concrete proportioning. The location of quarries is shown in Fig. 1.

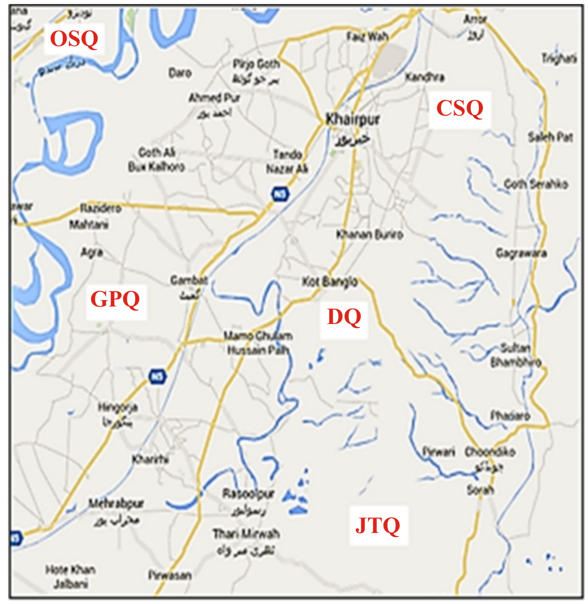


Fig. 1. The Locations of the sites from where the aggregates were collected

II. EXPERIMENTAL PROGRAMME

The coarse aggregates selected from five different quarries named as Obhan Shah Quarry (OSQ), Chattan Shah Quarry (CSQ), Goal Pahari Quarry (GPQ), Darak Quarry (DQ) and Jara Takar Quarry (JTQ). The main source of all the quarries are enormous sedimentary rocks. These rocks are blasted before performing crushing, screening and washing. Along with concrete preparation, other major utilizations of such aggregates are earth works, preparation of asphalt and rip-rap for stabilization. The other basic contents generated due to the interaction with water are removed. The high temperature of the area also destabilizes the rock to weathered condition.

A. Materials and Properties

The size of coarse aggregates selected for this study ranges between 5-20 mm. In total, 180 cubes were tested. 10 different batches were formed in order to individual characterization of concrete. Each batch contains 18 cubes and each quarry contains 2 batches making a total of 36 cube with four different ratios for each quarry. The Ordinary Portland cement (ASTM type I) with a specific gravity of 3140kg/m^3 and fineness of 351 m^2/kg is used. Potable drinking water is used in concrete mixtures. Aggregates are classified as fine and coarse aggregates and the detailed properties are given in Table I. The local mining sand was used as fine aggregate with the maximum size of 4.75 mm. The other properties of fine aggregates are: specific gravity 2.60, fineness modulus 2.51 and bulk density 1460 Kg/m^3. Fig. 2 shows the gradation of the different types of coarse aggregates and local mining sand.

TABLE I
DETAILS OF ALL THE AGGREGATES COLLECTED FROM DIFFERENT QUARRIES

Crushed stones								
Properties	**OSQ**	**CSQ**	**GPQ**	**DQ**	**JTQ**	**Allowable limits**	**Suitability**	**Remarks**
Color	Grey	Grey	Grey	Grey	Grey	-	-	-
Maximum Size (mm)	20	20	20	20	20	-	-	-
Bulk Specific gravity	2.65	2.66	2.6	2.61	2.59	2.5-3.0	2.5-3.0	-
Compacted bulk density (Kg/m^3)	2365	2350	2375	2385	2355	2400	2400	-
Flakiness Index	42.0	41.5	42.2	33.0	36.8	Max. 15%	Max. 15%	High
Elongation Index	4.32	4.8	5.35	8.95	10.1	Max. 25%	Max. 25%	Low
Water absorption (%)	0.30	0.3	0.42	0.38	0.58	0.1-2.0%	0.1-2.0%	Medium
Crushing value (%)	20.2	20.4	24.5	26.2	23.8	Max. 27%	Max. 30%	Medium
Impact Value (%)	14.8	15.6	16.4	17.7	16.8	Max. 23%	Max. 27%	Medium
LA Abrasion Value (%)	24.4	25.8	26.8	30.8	28.5	Max. 30%	Max. 35%	Medium

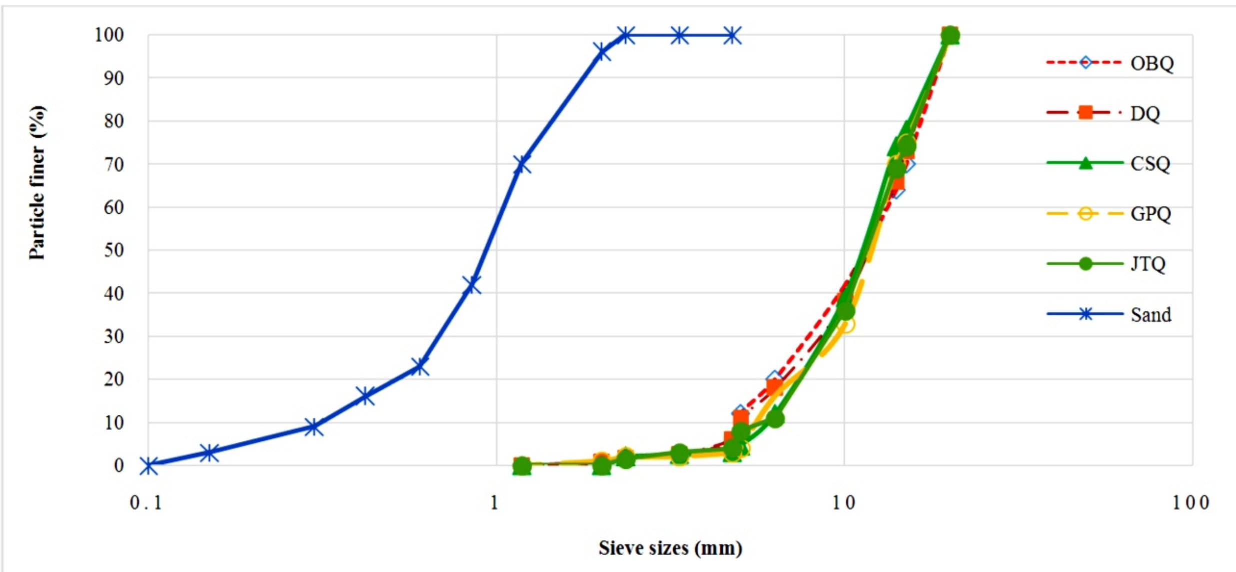


Fig. 2. Gradation of the aggregates (Coarse and Sand)

B. *Mix Proportioning*

The mix proportions were selected according to the requirement of different types of aggregates. The ACI mix design approach was used to design the normal weight concrete. The concrete fabrications are divided into ten different batches, two batches from each type coarse aggregate. The two different w/c ratios (0.50 and 0.55) and mix proportions (1:2:4 and 1:1.5:3) were selected to divide the specimens. The distribution of the specimens into different batches with different types of aggregates and w/c ratio is shown in Table II.

C. *Test methods and curing duration*

The cement and aggregates were blended in a mixer for two minutes. A mixture of 70% mixing water was added to the mixture and mixing was continued for another 3 minutes. The remaining water was further added and mixed for another 5 minutes prior to slump test. Later, the slump test was conducted. After slump test, the concrete specimens were cast in steel moulds of 100 mm cubes to calculate compressive strength. Specimens were compacted using vibrating table. The concrete specimens were demoulded one day after casting. An average result of mechanical properties was obtained after testing three specimens. For determining the effect of the curing duration on the compressive strength of concretes, the specimens were properly cured, and are as follows:

a) Continuous moist curing (C1): specimens were immersed in water at a temperature of

24±3°C for 7 days.

b) Continuous moist curing (C2): specimens were immersed in water at a temperature of 24±3°C for 14 days.

c) Continuous moist curing (C3): specimens were immersed in water at a temperature of 24±3°C for 28 days.

TABLE II
DETAILS OF ALL BATCHES OF SPECIMENS (CASTED AND TESTED)

S. No	Batch	Mix ratio	W/c ratio	Quarry	No: of specimens
1	B-1 (A)	1:2:4	0.50	OS	9
2	B-1 (B)	1:2:4	0.55	OS	9
3	B-2 (A)	1:1.5:3	0.50	OS	9
4	B-2 (B)	1:1.5:3	0.55	OS	9
5	B-3 (A)	1:2:4	0.50	CS	9
6	B-3 (B)	1:2:4	0.55	CS	9
7	B-4 (A)	1:1.5:3	0.50	CS	9
8	B-4 (B)	1:1.5:3	0.55	CS	9
9	B-5 (A)	1:2:4	0.50	GP	9
10	B-5 (B)	1:2:4	0.55	GP	9
11	B-6 (A)	1:1.5:3	0.50	GP	9
12	B-6 (B)	1:1.5:3	0.55	GP	9
13	B-7 (A)	1:2:4	0.50	D	9
14	B-7 (B)	1:2:4	0.55	D	9
15	B-8 (A)	1:1.5:3	0.50	D	9
16	B-8 (B)	1:1.5:3	0.55	D	9
17	B-9 (A)	1:2:4	0.50	JT	9
18	B-9 (B)	1:2:4	0.55	JT	9
19	B-10 (A)	1:1.5:3	0.50	JT	9
20	B-10 (B)	1:1.5:3	0.55	JT	9

III. RESULTS

A. *Slump*

Table III shows the slump values of all the mixes with different w/c ratios. The substitution of higher water content in the mix proportion of 1:2:4 was resulted in higher slump value as compared to the other mixes. This shows that by increasing the amount of coarse aggregates and w/c ratio in the concrete mixture, the slump value also increases.

B. *Density*

All types of selected coarse aggregates have closer values of the specific gravity and bulk density, Table I, hence the density of the concrete was not affected. Two types of density tests were conducted for all types of mixes. The demoulded density was measured immediately after demoulding the samples, whereas the oven dry density was measured after 28 days. It was observed that the dry density of the concrete specimens was found almost similar for all types of the concrete mixes.

TABLE III
SLUMP VALUES OF ALL MIXES

S. No	Batch	Mix ratio	w/c ratio	Quarry	Slump (mm)
1	B-1 (A)	1:2:4	0.50	OS	31
2	B-1 (B)	1:2:4	0.55	OS	35
3	B-2 (A)	1:1.5:3	0.50	OS	27
4	B-2 (B)	1:1.5:3	0.55	OS	25
5	B-3 (A)	1:2:4	0.50	CS	32
6	B-3 (B)	1:2:4	0.55	CS	34
7	B-4 (A)	1:1.5:3	0.50	CS	28
8	B-4 (B)	1:1.5:3	0.55	CS	26

S. No	Batch	Mix ratio	w/c ratio	Quarry	Slump (mm)
9	B-5 (A)	1:2:4	0.50	GP	33
10	B-5 (B)	1:2:4	0.55	GP	36
11	B-6 (A)	1:1.5:3	0.50	GP	26
12	B-6 (B)	1:1.5:3	0.55	GP	29
13	B-7 (A)	1:2:4	0.50	D	30
14	B-7 (B)	1:2:4	0.55	D	38
15	B-8 (A)	1:1.5:3	0.50	D	29
16	B-8 (B)	1:1.5:3	0.55	D	30
17	B-9 (A)	1:2:4	0.50	JT	31
18	B-9 (B)	1:2:4	0.55	JT	38
19	B-10 (A)	1:1.5:3	0.50	JT	29
20	B-10 (B)	1:1.5:3	0.55	JT	27

TABLE IV
DENSITIES OF THE SELECTED MIX PROPORTIONS

S. No	Batch	Mix ratio	Demoulded density (Kg/m3)	Ovendry density (Kg/m3)
1	B-1 (A)	1:2:4	2375	2335
2	B-1 (B)	1:2:4	2380	2345
3	B-2 (A)	1:1.5:3	2360	2325
4	B-2 (B)	1:1.5:3	2355	2332
5	B-3 (A)	1:2:4	2374	2334
6	B-3 (B)	1:2:4	2382	2347
7	B-4 (A)	1:1.5:3	2362	2327
8	B-4 (B)	1:1.5:3	2356	2337
9	B-5 (A)	1:2:4	2373	2330
10	B-5 (B)	1:2:4	2381	2345
11	B-6 (A)	1:1.5:3	2361	2325
12	B-6 (B)	1:1.5:3	2354	2335
13	B-7 (A)	1:2:4	2374	2334
14	B-7 (B)	1:2:4	2382	2342
15	B-8 (A)	1:1.5:3	2361	2330
16	B-8 (B)	1:1.5:3	2352	2332
17	B-9 (A)	1:2:4	2371	2335
18	B-9 (B)	1:2:4	2385	2349
19	B-10 (A)	1:1.5:3	2366	2330
20	B-10 (B)	1:1.5:3	2360	2331

C. Tests for Compressive Strength

The aggregates collected from different quarries had different crushing strength properties. After investigating the properties of the aggregates, a slight variation in properties was found. Consequently, all obtained concretes followed the similar trend in the result increment. The water-cement ratio and the cement content affect the response of the concrete to applied stress. The explanation can be based on two opposing effects caused by incorporation of air into concrete. Firstly, it increased the porosity of the matrix; entrained air has an adverse effect on the strength of the composite material. Secondly, it improves the workability and compatibility of the mixture; entrained air tends to improve the strength of the interfacial transition zone (especially in mixtures with very low water and cement contents) and thus improves the strength of concrete. In concrete mixtures with low cement content, it was observed that when having air entrainment accompanied by a significant reduction in the water content, the beneficial effect on the interfacial transition zone compensates the adverse effect of air entrainment on the strength of the matrix. In Table IV, column C1 shows the specimen cured for 7 days in water, column C2 shows specimen cured for 14 days in water and column C3 shows specimen cured for 28 days. The compressive strengths of all the prepared concretes (both batches) are mentioned in Table V.

The relationship of the both batches of concrete prepared from CSQ at the selected number of days is shown in Fig. 3. The maximum value of compressive strength obtained for CSQ concrete was 38.2 MPa at 1:2:4 mix proportion and 0.50 w/c ratio. The Batch 3A achieved 42% and 92% of the 28-day compressive strength at 7 and 14 days, respectively. This quarry aggregates were of reddish color and had good characteristic strength of aggregates.This quarry provided best result as compared to the other quarries.

It is a fact that the aggregate plays a progressively more important role in concrete behavior as strength increases. In normal-strength concrete, failure in compression almost exclusively involves debonding of the cement paste from the aggregate particles, will be called the matrix-aggregate interface. In contrast, in high-strength concrete, the aggregate particles as well as the interface undergo failure, clearly contributing to overall strength. As the strength of the cement paste constituent of concrete increases, there is greater compatibility of stiffness and strength between the normally stiffer and stronger coarse aggregate and the surrounding mortar. Therefore, it can be said that the bond between the CSQ aggregates and the cement paste was stronger; therefore,the CSQ concrete showed higher compressive strength as compared to all other mixtures. It is a fact that, in HSC, higher strength coarse aggregates typically yield higher compressive strengths, while in NEC, coarse aggregate strength has little effect on compressive strength [viii].

TABLE V
DETAILS OF ALL BATCHES OF SPECIMENS (CASTED AND TESTED)

S. No	Batch	Quarry	Ratio	w/c ratio	C1 (7 days)	C2 (14 days)	C3 (28 days)
1	B-1 (A)	OS	1:2:4	0.50	18.5	23.2	32.0
2	B-1 (B)	OS	1:2:4	0.55	17.0	18.3	24.0
3	B-2 (A)	OS	1:1.5:3	0.50	18.6	23.0	27.0
4	B-2 (B)	OS	1:1.5:3	0.55	19.4	21.4	25.0
5	B-3 (A)	CS	1:2:4	0.50	16.0	36.0	38.2
6	B-3 (B)	CS	1:2:4	0.55	16.1	19.0	27.0
7	B-4 (A)	CS	1:1.5:3	0.50	24.0	24.4	31.3
8	B-4 (B)	CS	1:1.5:3	0.55	19.0	20.5	27.0
9	B-5 (A)	GP	1:2:4	0.50	37.0	37.6	38.0
10	B-5 (B)	GP	1:2:4	0.55	18.0	21.0	31.2
11	B-6 (A)	GP	1:1.5:3	0.50	14.5	25.2	27.5
12	B-6 (B)	GP	1:1.5:3	0.55	19.0	21.0	25.2
13	B-7 (A)	D	1:2:4	0.50	19.4	26.1	35.0
14	B-7 (B)	D	1:2:4	0.55	21.0	25.0	30.0
15	B-8 (A)	D	1:1.5:3	0.50	23.0	27.5	32.0
16	B-8 (B)	D	1:1.5:3	0.55	17.5	20.3	29.0
17	B-9 (A)	JT	1:2:4	0.50	25.4	26.0	29.0
18	B-9 (B)	JT	1:2:4	0.55	19.4	22.5	25.7
19	B-10 (A)	JT	1:1.5:3	0.50	24.0	28.3	31.8
20	B-10 (B)	JT	1:1.5:3	0.55	19.0	21.3	25.8

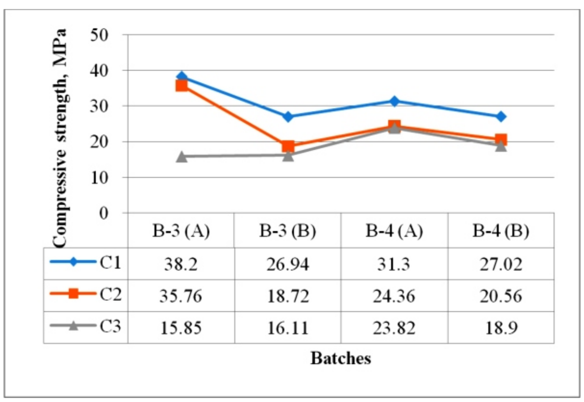
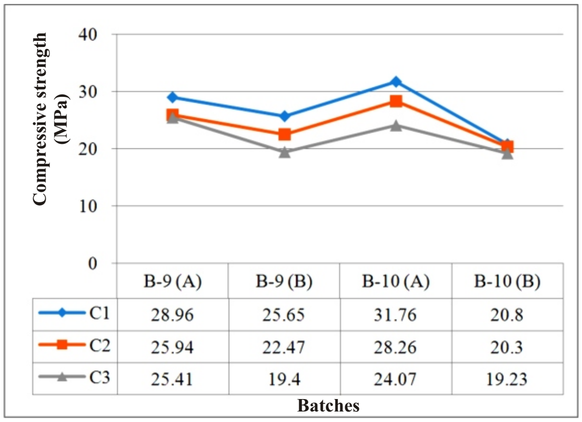


Fig. 3. Compressive strength of both batches of CSC

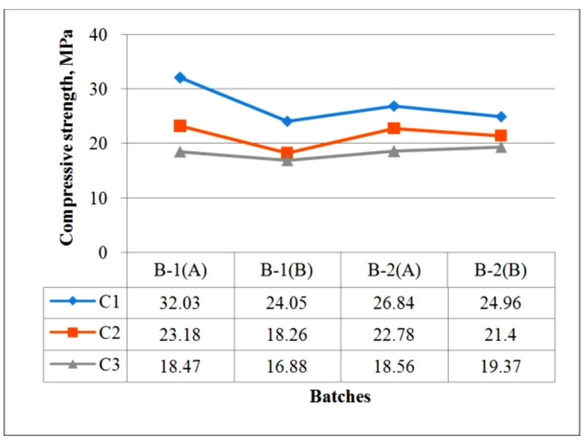
The lowest value of compressive strength was obtained for the concrete prepared from JTQ; which resulted in a 28-days compressive strength of 20.8 MPa with the mix proportion of 1:1.5:3 and 0.55 w/c ratio. Two main reasons of strength reduction were found in this concrete. First, this concrete has very high w/c ratio and secondly, the properties of the aggregates used in this concrete were very low (Table I). This quarry aggregates have mixed color (red, pink and white) which showed that the aggregates adopted from this quarry have not undergone for a proper gradation. Originally, flaky and elongated type of aggregates were obtained. This indicates that the aggregates of this quarry possess low strength as compared to the other quarries, particularly CSQ. Another reason is that, these aggregates had weaker bond with the cement paste which resulted in reduction in concrete strength. Micro cracks tend to propagate through the aggregate particles. Thus, aggregate strength becomes an important factor in high-strength concrete. Due to the poor nature of the aggregates, Batch 9A showed almost same compressive strength at all ages. The relationship of the both batches of JTC concrete were shown in Fig. 4.



	B-9 (A)	B-9 (B)	B-10 (A)	B-10 (B)
C1	28.96	25.65	31.76	20.8
C2	25.94	22.47	28.26	20.3
C3	25.41	19.4	24.07	19.23

Fig. 4. Compressive strength of both batches of JTQ

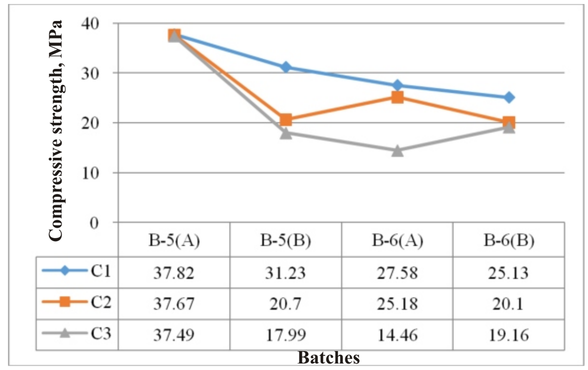
The aggregates obtained from rest of the three quarries showed 10-14% lower strength as compared to the CS concrete. It might be due to the poor properties of the aggregates as compared to the CSQ aggregates. All the batches prepared by OSQ aggregates showed a proper trend of gaining compressive strength at all ages. This indicates that the quality of the aggregates is better than the JTQ aggregates, but these aggregates are less stiff than CSQ aggregates. The relationship of the compressive strength of both batches prepared by OSQ is shown in Fig. 5.



	B-1(A)	B-1(B)	B-2(A)	B-2(B)
C1	32.03	24.05	26.84	24.96
C2	23.18	18.26	22.78	21.4
C3	18.47	16.88	18.56	19.37

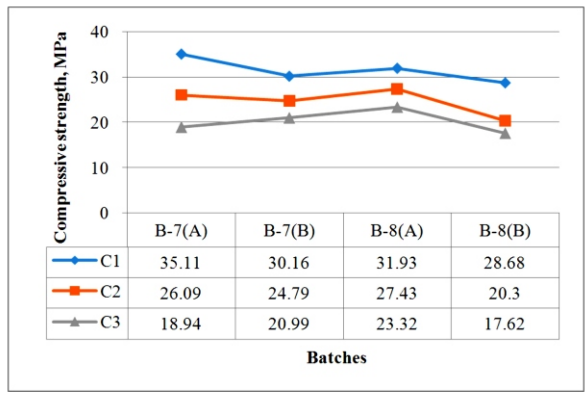
Fig. 5. Compressive strength of both batches of OSQ

Figs. 6 and 7show the compressive strength of the both batches of concrete prepared from GPQ and DQaggregates, respectively. It was observed from the test results that the mixture B-5 (A) concrete achieved its higher compressive strength at 7 days curing. It might be due to lower water cement ratio and strength achieved was almost same to the 28-day compressive strength of batch 3A. But in the rest three batches the trend was totally different. The 7-day compressive strength was on average of about 60-65% of the 28-day compressive strength. The batches 5B, 6A, 6B, 7A, 7B, 8A and 8B on average showed 27% lower compressive strength as compared to batch 3A. This was due to the poor performance of the aggregates, so that the GP aggregates might not be able to make a proper bond with the cement paste due to that it showed lower compressive strength results.



	B-5(A)	B-5(B)	B-6(A)	B-6(B)
C1	37.82	31.23	27.58	25.13
C2	37.67	20.7	25.18	20.1
C3	37.49	17.99	14.46	19.16

Fig. 6. Compressive strength of both batches of GPQ



	B-7(A)	B-7(B)	B-8(A)	B-8(B)
C1	35.11	30.16	31.93	28.68
C2	26.09	24.79	27.43	20.3
C3	18.94	20.99	23.32	17.62

Fig. 7. Compressive strength of both batches of DQ

Despite having almost similar properties of the aggregates and variable strength parameters, CSQ concrete showed higher compressive strengths.This shows that this quarry have regular size aggregates with uniform gradations. Whereas, other quarries like, GP, and DQ have shown acceptable compressive strength.

From results it was observed that the JTQ have a very low compressive strength due to poor quality stones (aggregates) with undefined shape and size and of improper gradation. It was noticed that the strength of concrete was mainly dependent of the type of aggregates. It is very important to investigate the geological characteristics of quarries including rocks, stones and their aggregates.

Results show that the most commonly used quarry in the region namely OSQ, has not given competitive results as compared to other quarries of this region. And same is the case with JTQ. In the continuation with above CS and GP quarry have given better compressive strengths. The relationship of the compressive strengths of all the batches with the number of days is parented in Figs. 8, 9 and 10 at 7, 14 and 28 days, respectively.

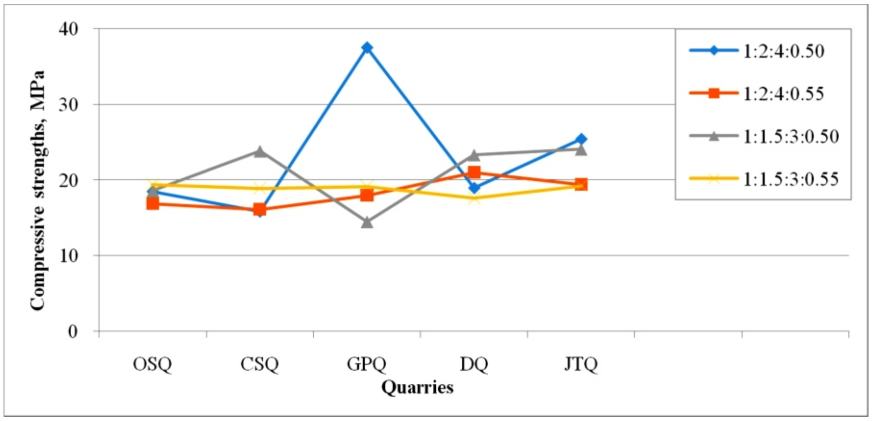


Fig. 8. Compressive strengths of all batches at 7 days

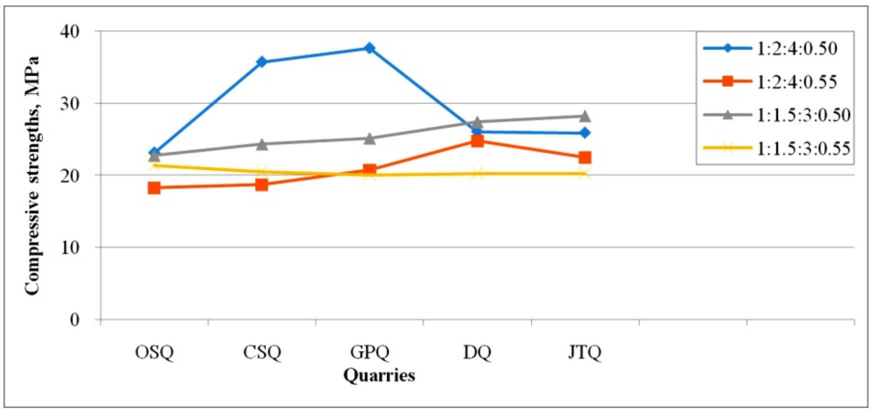


Fig. 9. Compressive strengths of all batches at 14 days

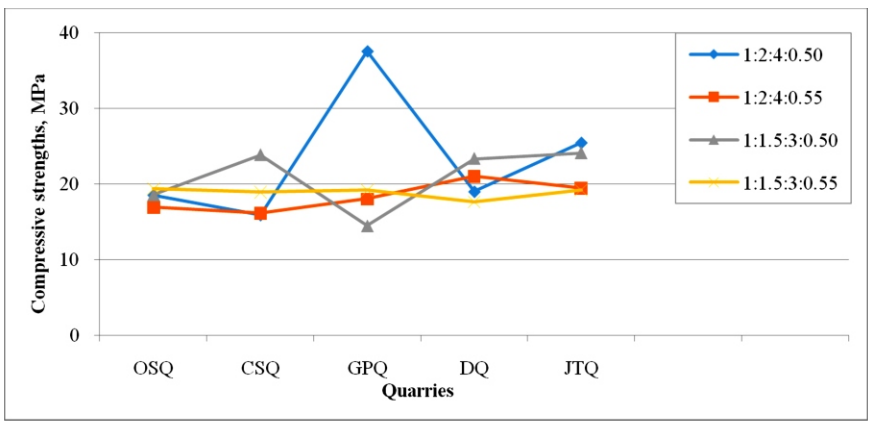


Fig. 10. Compressive strengths of all batches at 28 days

IV. DISCUSSION

Properties of the concretes mostly depend on the characteristics of the aggregates. It was observed that except CSQ aggregates, the rest of the aggregates showed lower compressive strength. This was due to characteristic properties of the aggregates. The first condition is the shape and the surface texture of the aggregates. Shape and surface texture of the coarse aggregates play a major role on the behavior of fresh and hardened concrete. Flaky, elongated, angular, and rough particles have high voids and require more sand to fill voids and to provide workable concrete, thus increasing the demand for water. Poorly shaped aggregates may also increase segregation. Reference [ix] reported that the flaky and elongated particles tend to produce harsh mixtures and affect finish ability. According to [x], state that flat and elongated particles should be limited to a maximum of 15 percent by weight of total aggregate. In the present study, the aggregates selected were rough and flaky except the CSQ.That is the main reason of these aggregates showing higher strength.

Aggregate porosity may affect durability as freezing of water in pores in aggregate particles can cause surface popouts. However, it the relationship between absorption and freeze-thaw behavior has not proven to be reliable [xi, xii]. Nevertheless, absorption can be used as an initial indicator of soundness. Furthermore, aggregates with low absorption tend to reduce shrinkage and creep. This might be another reason because the CSQ aggregates have lowest water absorption compared to all other aggregates (Table I).

Relative density or specific gravity also plays major role in the concrete but it is not necessarily related to aggregate behavior. However, it has been found that some aggregates have compounds of shale, sandstone, and chert that have somewhat low specific gravity may display poor performance. The CS quarry aggregates showed the higher specific gravity (Table I) compared to all other aggregates, therefore higher compressive strength was achieved as expected.

Another advantage is that the in lower strength concretes, the weakest link almost exclusively occurs at the matrix-aggregate interface and the mechanism of progressive micro cracking consists of mortar cracks bridging between nearby bond cracks. The observed behavior is that the high strength concrete are more homogeneous material. When the matrix is more compact and the voids are less in number, there is greater compatibility between the strength and elastic properties of the coarse aggregate and the mortar. Improved compatibility also lowers the stress at the matrix aggregate interface, reducing the likelihood of interfacial failure. Thus, microcracks are more likely to propagate through the aggregate, and therefore, the extent of micro cracking is reduced as concrete strength increases.

Therefore, it can be said that the bond behavior of CS quarry was much better than the aggregates of other quarries. CS aggregates have higher specific gravity and are free of lumps and voids. Thus, the interfacial bond between the aggregates was stronger. The failure may be due to aggregate itself rather than mortar joint failure.

VI. CONCLUSIONS

The following conclusions have been drawn from this research. The great variation in the compressive strength of concrete using aggregates of different quarries were observed.

The maximum 28-days compressive strength was found for CSQ concrete as 38.2 Mpa as mentioned in batch no.3A with 1:2:4 mix proportion and 0.50 w/c ratio.

The lowest 28-days compressive strength observed as 20.8 Mpa for JTQ concrete, as mentioned in batch no.10B, with 1:1.5:3 mix proportion and 0.55 w/c ratio.

Compressive strength of concrete can be increased by using various aggregates of different quarries, keeping the w/c ratio unchanged as shown in B-5A and 1:2:4:0.50 ratio is used, whereas aggregates from GPQ, good results were obtained with a compressive strength of 37.82 MPa when cured it for 28 days which nearly equals to the result of CSQ concrete.

This study will guide the local construction industry to use the aggregates of CSQ and GPQ for production of concrete in the region and as the strength of OSQand JTQas compared to others, therefore, better quarries could be adopted with reference to this study.

REFERENCES

[i] P. K. Mehta and P. J. Monterio,"Concrete: microstructure, properties, and materials":*3rd Ed. ASA: McGraw-Hill* New York: 2006.

[ii] S. N. Roma, T. Ngo, P. Mendis, and H. B. Mahmud, "High-strength rice husk ash concrete incorporating quarry dust as a partial substitution for sand", *Construction and Building Materials*, vol. 25, pp. 3123-3130, 2011.

[iii] S. N. R. Shah, M. Aslam, S. A. Shah, and Raja Oad, "Behaviour of Normal Concrete Using Superplasticizer under Different Curing Regimes", *Pakistan Journal of Engineering and Applied Sciences,* vol. 15, pp. 87-94, 2014.

[iv] B. A. Radovani, "Grain size of adopted aggregate influence on strain-softening of concrete", *Engineering Fracture Mechanics*, vol. 35(4), pp. 709-718, 1990.

[v] C. Tasdemir, M. A. Tasdemir, F. D. Lydon and B. I. G. Barr, "Effects of silica fume and aggregate size on the brittleness of concrete", *Cement and Concrete Research*, vol. 26(1), pp. 63-68, 1996.

[vi] C. A. Tang, P. Lin, H. Y Liu, and Z. Z. Liang, "On failure modes and strength characterization of brittle disordered materials under uniaxial compression and tension", *Key engineering materials*, vol. 183, pp. 637-642, 2000.

[vii] T. Akçaoğlu, M. Tokyay, and T. Çelik," Effect of coarse aggregate size and matrix quality on ITZ and failure behavior of concrete under uniaxial compression",*Cement and Concrete Composites*, vol. 26(6), pp. 633-638, 2004.

[Viii] A. S. Ezeldin, and Aitcin, P.-C. (1991) "Effect of Coarse Aggregate on the Behavior of Normal and High-Strength Concretes," Cement, Concrete, and Aggregates, CCAGDP, V. 13, No.2, pp. 121-124.

[Ix] F. E. Legg, Jr., Aggregates, Chapter 2, Concrete Construction Handbook, ed. Dobrowolski, J. McGraw-Hill, 1998. 4th ed.

[X] P. K. Mehta, and P. J. Monteiro, Concrete: Structure, Properties, and Materials, Prentice-Hall, Englewood Cliffs, N.J., 2nd ed, 1993.

[Xi] S. Popovics, Strength and Related Properties of Concrete. A Quantitative Approach, John Wiley and Sons, 1998.

[xii] M. Aslam, P. Shafigh, M. Z. Jumaat., "Structural Lightweight Aggregate Concrete by Incorporating Solid Wastes as Coarse Lightweight Aggregate", Applied Mechanics and Materials Vol. 749 (2015) pp. 337-342.