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Experimental Study of Fire Behavior of Polyvinyl Chloride (PVC) on Masonry Brick Prism

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Abstract-- Heating equipment, cooking equipment, electrical and lighting equipment, smoking materials, and intentional fire starting are the five most prevalent causes of fires in commercial buildings, according to the National Fire Protection Association (NFPA). The most essential factor is the construction materials, which can cause or avoid a fire. The focus of the research should be on passive fire safety as well as aggressive fire safety to prevent flames from spreading. The purpose of this article was to investigate the fire resistance of structural masonry prism using PVC (polyvinyl chloride) wall panels due to its high fire resistance and also we can use it as an interior finishing material. All organic polymers are combustible: if enough heat is applied to them, they will thermally break down and their thermal decomposition products will burn. When the source of heat or flame is removed, however, PVC usually does not burn. Because PVC contains 56.8% chlorine in its basic polymer weight, and chlorine is one of the few components that confer strong fire characteristics to a polymer. PVC can still be specified for applications at 130°F (54.4°C), the material can withstand significantly less pressure at elevated temperatures (those above 73°F or 22.8°C) Structural materials.

Masonry prisms are built for compressive strength testing according to the ASTM C1388 Standard Test methods to research the fire behavior of polyvinyl chloride (PVC) as a wall assembly in structures by using compressive strength testing machine. For the making of one masonry prisms of dimensions, 9''x 9''x12''there are 8 bricks required of mortar ratio of 1:4. And using this ratio we make 9 masonry prisms for 3 trials. The research shows that, even when exposed to high temperatures, brick/masonry prism strength had a significant impact on the structural stability and fire resistance time of the panels (under load). The PVC encasement was found to improve the thermal insulation characteristic, which is one of the fire resistance performance requirements.

Keywords-- Masonry Prism; Compressive Strength; PVC wall panel, Fire resistance, Brick masonry.

I. INTRODUCTION

Fire has been regarded as one of the Earth's elemental powers since ancient times [1]. Depending on where it's used, it may be both harmful and constructive. The alluring flame of fire may captivate, its heat and light can help people survive, and its elemental force ushers in modern civilization; nevertheless, in an uncontrolled stage, fire can bring terrible disaster and even death [2]. Although data show that fire death rates per million populations have been falling in general over the previous decades [3], there has been an increase in the fire death rate per million populations in countries such as the United States, Denmark, Japan, and the Czech Republic [4]. Fire starts when a substance is ignited and continues until the flame has spread to all flammable surfaces. The most significant factor is the construction materials, which can cause or avoid a fire [5]. Fire safety regulation, which aims to eliminate fire-related dangers, has a significant influence on building architecture, aesthetics, functionality, and cost [6].
To avoid flames from spreading, put an emphasis on both passive and active fire protection. [7]. It should be moved towards building materials for fire safety purposes for this reason. Some aspects have to be considered to produce an aesthetically pleasing and long-lasting interior environment. Environmental influences (heat, water, moisture, noise, light, and so on), mechanical effects, and aesthetic needs are all examples of these. "Finishing layer" is the layer that was designed to give these functions. The finishing layer must be attractive, long-lasting, and strong [8]. When it comes to finishing materials, PVC helps to prevent fires from starting and spreading due to its flame-retardant properties [9] [10]. Polyvinyl chloride (PVC) is a kind of plastic that is utilized for several uses owing to its flexibility and inexpensive costs, such as wall panels and pipes. Various flame retardants and smoke suppressants for PVC materials have been developed during the previous decade. [11]. In many applications, PVC is replacing traditional building materials such as wood, metal, concrete, and clay. It is the most significant polymer

for the construction industry because of its versatility, economic efficiency, and track record of usage [12]. There are numerous benefits of PVC such as its durability, easy installation, robust and lightweight, cost-effective, safe material, fire-resistant, a good insulator, and versatility [13]. As the fire starts when a substance is ignited and spreads to all flammable surfaces. For this, PVC wall panels can be used for wall coverings on brick or concrete structures [14].

Clay bricks, fly ash bricks, concrete blocks, line-based blocks, stones, and other masonry units are examples [15]. Because of its abundance, low cost, high sound, and heat insulation characteristics, and availability of trained labor, brick masonry is a typical building material in Pakistan [16]. In Pakistan, masonry is often utilized as infill walls in reinforced concrete structures. Material characteristics of masonry are required for masonry analysis and design [17]. Bricks are made by molding clay into a rectangular shape, drying it, and then burning it. PVC is a widely used commercial plastic because of its low cost and outstanding qualities, such as high electrical insulation, abrasion resistance, low humidity diffusion, exceptional resistance to water, bases, acids, alcohols, and oils, and minimal creep deformation, and mechanical stability [18]. PVC, a flame retardant has a thermal conductivity of 0.12- 0.25 m·K, considered a thermal insulation material because its low thermal conductivity (k) is usually lower than 0.5 W/(m·K) which indicates the great performance and durability on the wall [19]. It is the most essential polymer for the construction industry because of its versatility, economic efficiency, and track record of usage [20]. PVC has several advantages, including durability, ease of installation, strength, lightweight, cost-effectiveness, safety, fire resistance, a good insulator, and flexibility [21] [22] [23] [24].

II. DATA AND METHODOLOGY

The data received from these evaluations pertains to the behavior of the material inside the test equipment, and, unusually, such information may be used to compute the material's performance in its end-use environment. As a result, such measurements are referred to as "apparatus bound." The development of a variety of measurement methodologies for essential fire qualities such as ignitability, flame spread, heat release, smoke production, and poisonous gas generation has substantially improved the situation in recent years. All of the new tests offer data in engineering units that may be utilized in computations and mathematical models, allowing the designer, regulator, or specifier to pick and choose which tests to perform.

2.1. Methodology

A masonry prism is a test specimen made out of masonry units and mortar that may be used to determine the characteristics of masonry assemblages. ASTM A 447 Standard Test Methods for Compressive Strength of Masonry Prisms is used to build prisms for compressive strength testing. We need bricks, cement, sand, water, temperature sensors, a weighing scale, wire, glue, petrol, PVC wall panels, and a compressive strength machine to build masonry prisms with dimensions of 9"x 9"x12" for testing fire behavior of polyvinyl chloride PVC wall panels on a brick wall. One masonry prism requires 8 bricks of mortar ratio of 1:4 (which means one 0.0625cft cement and 0.3125cft sand), water (W stands for water, while C stands for cement

Fig. 1 Mold of size 6"x6"x6"

W=0.7xC.
So, W=0.7x0.0625,
This further implies that
W=0.04375cft

And using this ratio we make 9 masonry prisms for 3 trials. In one trial, take 3 prisms for experiment and 2 masonry prisms are exposed to fire at 55-degree temperature in which one is covered with PVC wall panels and the other one is a simple plastered one. Add some fuel (like petrol) which causes the fire. Set the temperature sensors for the exact value of the temperature burning.

Fire both prisms for approximately 20 minutes until the PVC panels detach from the wall for the accurate measurement of results. When the PVC wall panel detaches from the wall, remove the fire from the prisms. Now take time to cool down the masonry prisms, then carry all (3) prisms to a compressive strength machine.

Test one by one all masonry prisms and test them in the compressive strength machine. Note the readings of every prism. Similarly, repeat this experiment two more times for accurate value and take the average value. Contrary to this, perform a small test for the comparison of results. Take 3 accurate sizes of brick i-e 4.5''x3''x9'' and fire 2 bricks one covered with PVC and other one is simple. Then test 3 bricks, one is before the fire and the other one is exposed to fire directly and indirectly (covered with PVC panel). Note the readings and draw the table. Apart from this, collect the burned PVC panel and send it to the chemistry department to examine the chemical properties of burned PVC panel that it might be dangerous or not, or it may release hazardous gases or not.

2.2 Materials

Fig. 2 Collection of Bricks

Bricks are collected to make masonry prisms used in the experiment.

Fig. 3 Chenab Sand

Chenab sand is used for the binding purpose to build masonry prisms.

Fig. 4 Sample of PVC Panels

PVC panels are used as the finishing material on masonry prism when the experiment is performed to check the fire resistance capacity

Fig. 5 Temperature Sensor

The temperature sensor is used to detect temperature while experimenting.

2.3 Construction

Fig. 6 Preparation of Mortar

With the help of Chenab sand and water mortar is prepared with the ratio of 1:4.

Fig. 7 Working on masonry prism

Masonry prisms are constructed in process with the help of bricks and mortar.

Fig. 8 Construction of masonry prism

The construction of 9 masonry prisms is in the process to perform an experiment

Fig.9 Final Masonry prism

The final look of masonry prisms with or without plaster walls to experiment.

III. SITE LOCATION

The site is located in the backyard of the Department of Building and Architectural Engineering (B&AED), Bahaudin Zakariya University Multan (BZU). Multan city is located in the southern region of Punjab (province of Pakistan).

3.1 Site Characteristics

The selection of the site depends on the suitability of the environment to facilitate the combustion process.

It was made sure that fuel, oxygen, and appropriate heat is available at the site to ensure the proper combustion of the material.

IV. PROPERTIES OF MATERIALS

The properties of the materials are given below:

4.1 Cement

Properties of cement are according to ASTM C150

Cement	Properties
Specific Gravity	3.15
Normal Consistency (%)	32
Initial Setting time	½ hour
Final setting time	10 hours

4.2 Sand

The properties of Chenab sand are given below [22]

Sand	Properties
Fineness Modulus	2.56
Specific gravity	2.48
Bulk density	1650kg/m^3

4.3 Bricks

Properties of brick are given below (ASTM C62-Table 1):

Table I: PROPERTIES OF BRICK

Type of brick	Brick Size (mm) 229x114.3x76.2
Compressive Strength psi(MPa)	14.2
Water Absorption (%)	25
Saturation Coefficient	0.9

4.4 PVC Panel

Following are the properties of PVC wall panels (ASTM D4216 Table 2) through which we can pursue the experiments [23]

TABLE II PVC PANEL PROPERTIES

Properties	Unit of measurement	Polyvinyl Chloride (PVC)
Physical Properties		
Density	g/cm³	1.36 - 1.40
Mechanical Properties		
Tensile Strength	Psi	8000-9000
Flexural Strength	Psi	7000-13000
Compressive Strength	Psi	9500
Thermal Properties		
Heat Deflection Temperature	˚C	92
Melting Temperature	˚C	100-260

4.5 Mix Proportion

Masonry bricks were utilized in this experiment. The following are the total numbers of specimens (ASTM C62 Table 3):

TABLE III COMPRESSIVE STRENGTH OF BRICKS

Type of brick	Cement Mortar Ratio	No. of Prisms Made
First Class Brick	1:4	3
First Class Brick	1:4	3
First Class Brick	1:4	3
Total		**9**

4.6 Experiment

Fig. 10 Prisms prepared for the experiment

Prisms are prepared for the experiment for checking the fire resistance capacity of masonry prisms with or without PVC wall panels.

Fig. 11 Experiment

The experiment is being performed here by the participants with the help of petrol and a lighter.

Fig. 12 Fire Testing

Testing the fire behavior of masonry prisms with or without PVC wall panels and measuring the temperature with the help of a temperature sensor.

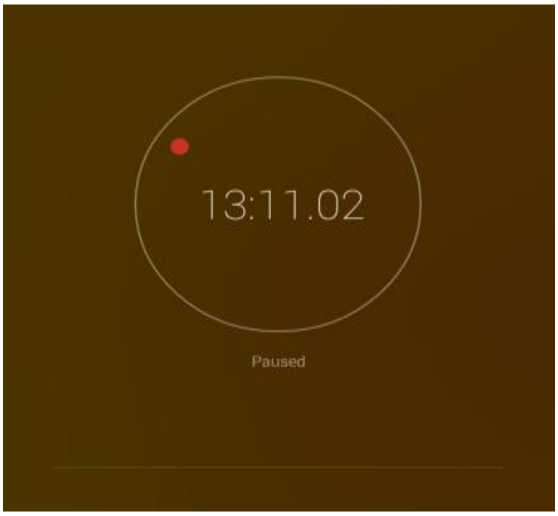

Fig. 13 Stop Watch Reading

While performing the experiment stopwatch is used to calculate the exact timing at the point where the PVC panel was completely burned and the masonry prism is exposed to fire and that duration is around 13:11:02

V. COMPRESSIVE STRENGTH TEST OF PRISMS

The compressive strength of Prism specimens was tested using a universal testing machine (UTM) with a capacity of 1000kN. The prisms were positioned in the center of the UTM loading platform and were subjected to axial compression with no eccentricity. The load is steadily raised until the specimens are crushed. The specimen's ultimate compression strength was determined by the load at which it failed. The testing method was carried out following the applicable ASTM C39 Code of Practices [24] [25].

Fig. 14 Compressive Strength testing of fire untouched prism

Fig.15 Compressive Strength test of prism without PVC wall panel

Fig. 16 Compressive Strength testing of prism without PVC wall panel 2

Fig.17 Compressive Strength testing of the prism with PVC wall panel

VI. RESULTS AND DISCUSSIONS

Compressive strength results of the masonry prisms represented graphically are shown in Table 6.1 & Fig.6.1.

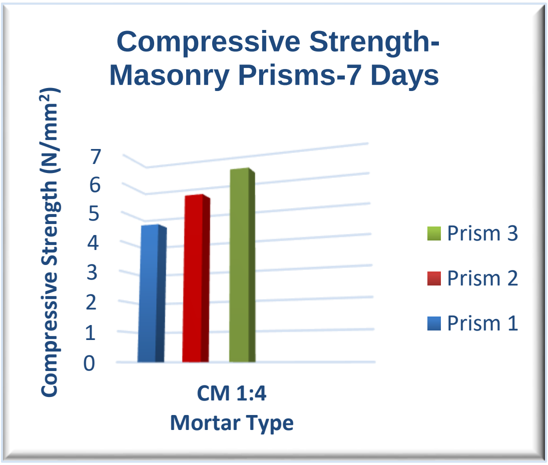

Fig 18: Compressive Strength-Masonry Prisms-7 Days

Table IV Compressive Strength-Masonry Prisms-7 Days

Sr.	**Brick Type**	**Specimen Identification**	**Area (mm^2)**	**Compressive Strength (N/mm^2)**
1	First-class brick	Plaster Wall before Fire **(Prism 1)**	52258	4.59
2	First-class brick	Plaster Wall after Fire **(Prism 2)**	52258	5.5
3	First-class brick	PVC wall after fire **(Prism 3)**	52258	6.25

TABLE V MEANTIME AND TEMPERATURE-MASONRY PRISMS-7 DAYS

Sr.	Brick Type	Specimen Identifica-tion	Mean Temp˚C	Mean Time Seconds: one-100th of a second
1.	First-class brick	Plaster Wall after Fire (Prism 2)	54	13:11:02
2.	First-class brick	PVC wall after fire (Prism 3)	54	13:11:02

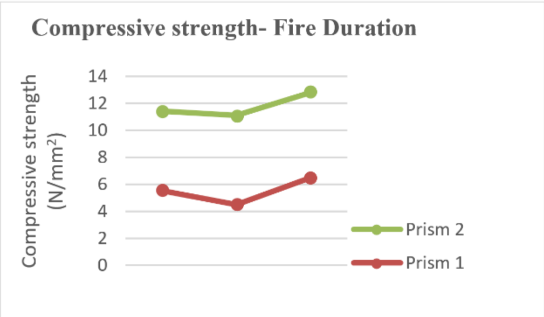

Figure 19: Compressive Strength-Masonry Prisms-Fire Duration (seconds)

The compressive strength of the plastered masonry prism before the fire was approx. 240.3 KN or 34.8 psi and of compressive strength of the plastered masonry prism after the fire is approx. 288.57 KN or 41.8 psi. Whereas compressive strength of masonry prism using PVC wall panel gave the highest value I-e 327 KN or 47.414 psi after the fire, which is higher than notes earlier. Therefore, we concluded that brick absorbs more heat and gains more strength as compared to the strength of the masonry prism before the fire.

Fatigue failure occurs on masonry prisms through progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably below the normal strength.

However, if the results were otherwise and plastered masonry prism after fire gains more heat than compressive strength will also high and at the same time, continuous absorption of heat in masonry prisms will lose its strength after reaching its elastic limit. From the above data obtained from the experiment, we obtained the information that PVC wall panels resist fire and allow heat which only increases the strength of the brick/masonry prism. In trials, the fire span was approx. 20 minutes. During this span, the plastered wall catches the fire but the PVC wall panel continuously resisted and extinguished the fire. Because of the numerous unfavorable remarks made about PVC in the occurrence of any big fire tragedy, the function of PVC in flames is presently a contentious subject. Much small-scale smoke and poisonous gas experiments are also used by critics to determine the role of PVC in these fires. The goals of this study are to synthesize current technical knowledge of real-world fire behavior and apply that information to interpret existing data for PVC in large- and small-scale fire experiments, also provide a feeling of technical realism to the challenges at hand.

VII. CONCLUSIONS

PVC is less flammable than other polymeric materials, natural or manmade, and it will not generally continue to burn unless there is a substantial amount of fire exposure. PVC has a lower heat release rate than most flammable materials, and it has been proven that heat release rate determines the severity of a fire. This implies that when PVC burns, it produces less heat and heats up more slowly than other materials. PVC produces smoke in small-scale testing that is comparable to that of many other materials, and the smoke created in full-scale flames is often lower since PVC materials burn more slowly than most others. PVC materials have smoke toxicity that is comparable to that of most commercial materials. When fire safety is a priority, PVC is one of the safest materials to use.

PVC's flammability is a key factor in deciding whether or not to use it in a variety of applications. It is more resistant to fire and burning than other organic polymers due to its comparatively high chlorine concentration (56.8%). In the case of flexible PVC, the plasticizers that let it bend subtract from its fire resistance in most cases. Flame-retardant (FR) and smoke-suppressant (SS) additives are frequently used in cable testing to fulfill standards such as oxygen index, heat release, smoke evolution, and amount of burning. PVC compositions may fulfill many severe FR standards by using synergistic mixtures of FR and SS additives.

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