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Study and Analysis of Geopolymeric Concrete with Fly Ash and Metakaolin for Different Mixing Design Parameters

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ABSTRACT

Fly ash (FA), metakaolin (MK) and ground granulated blast-furnace slag (GGBS) can be used to replace the binder in concrete, which in turn reduces greenhouse gas emissions i.e. carbon dioxide (CO2) . The use of the above products reduces the water demand of concrete and has no relative effect on the long-term performance of concrete; These by-products can be effectively used in the production of concrete. In this study, geopolymer concrete of M30 grade was designed to fixate using fly ash and metakaolin instead of cement. Alkaline solutions sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) were used instead of water to activate the raw materials, strengthen bonding, and mix the concrete. Low molarity metakaolin geopolymer concrete (MGPC) was formulated to provide strength as well as durability advantages over ordinary cement concrete. This paper presents the results of a comprehensive experimental program that studies the effect of various design parameters of the mix on the properties of MGPC by designing and testing 150 mm cubes and cylinders. The study result showed that the molarity of MGPC is directly related to the performance as 10M MGPC gave better results than 8M MGPC in all test results.

Keywords: Geopolymer concrete, Strengths, Thermal conductivity, Durability, Density.

1. Introduction

The geopolymeric concrete technology promoted by Davidovits guarantees the efficient use of By-products as an alternative material to Portland cement. The use of geopolymer technology can reduce CO_2 in the atmosphere. Geopolymer concrete has emerged as a building block for building materials for the lifting industry, using Flyash and Metakaolin instead of Portland cement as a binding agent. The purpose of this study, the Fly-Ash and Metakoalin compounds based on GPC compounds have two distinct and hard air curing methods at room temperatures.

The M30 grade geopolymer concrete is designed with an alkaline solution. Concrete models measuring 150 mm x 150 mm x 150 mm are designed for compressive strength, split tensile strength and flexural strength test.

The geopolymer appears as a possible alternative to Portland cement due to its strong processes and environmental protection. GPC predicts respiration rate, energy expenditure, fluid intake, and weight loss. The crude product is heated at 750 °C for 3 hours at 3M [1]. Digovitz's geopolymer cement technology ensures that the materials used are useful as an alternative to Portland cement. Using technology, concrete and property provide approximately 80% outdoor air stability. Geopolymeric cement was exhibited in residential buildings using cement flakes and methacholine [2-3]. They were treated daily in an oven at 100 °C and kept in a warm room for 28 days before chemical fertilization [4].

Four models were tested to test the behavior of aircraft panels with high pressure on wall types [5]. Recycling and waste disposal are important for environmental protection and sustainable renewable energy. However, concrete, combined with common Portland cement, has lower properties than conventional cement [6]. The physical and mechanical property of the geopolymer association was studied [7].

Research has been done to study the mechanisms and characteristics of flying ash - the shell is based on geopolymers that have been hardened in three different ways. Iron, polypropylene and polyvinyl alcohol were used and the effects of their supplementation on the behavior of compound geopolymers in terms of energy, abdominal strength and reduced dryness were studied [8]. The effect of iron and polypropylene fibers on bending and geopolymer fibers was studied. Materials emerged as a means of ameliorating geopolymer deficiencies. When using polypropylene fibers, it generally produces a reduction in high strength after the first explosion and low noise after the first explosion due to high flexibility and low power [9].

As a ceramic-like material, geopolymers have excellent destructive properties and incredible strength. To overcome this problem, adding fiber to the bending matrix is a well-known way to increase flexibility. In addition, the development of irritability depends on the effect of the grass matrix [10]. This work explored the methacholine geopolymer as an effective tool for the return of Portland cement. Studies on the effectiveness of the new geopolymer cement have shown that it can handle a wide range of processes, from liquid cement to dry cement, steel beams. The tensile strength of geopolymeric cement indicates that although these pores are large, they have better properties than Portland cement [11]. The fly ash was prepared for geopolymer concrete with bagasse ash and methacholine, replacing the fly ash in different areas, such as 10%, 20%, 30% and 40% for the main studies [12].

Geopolymers are a new type of synthetic compound when making or handling materials using a solution of alkali hydroxides and silicates. It has good mechanical properties and good use of chemicals. Compact chambers (GGBS) are an excellent source of aluminosilicate. Due to the abundance of aluminum and silk needed for the geopolymer solution [13]. Geopolymers are further organized by the reaction between chemical strength and bond strength and aluminosilicate. In recent years, as a necessary change in Portland cement, there has been a lot of research and development around the world to learn the mechanics, structure [14].

The ongoing depletion of the ozone layer and the effects of global warming have caused workers to become increasingly interested in the use of raw materials. It also has better mechanical properties and durability than conventional concrete [15]. In critical testing methods, this study studies the potential of the alkaline cationic type under the influence of the temperature of potential flangeopolymers for fine structures [16]. The work demonstrates a clear relationship between the energy and knowledge of geopolymeric materials. Cement of geopolymer cement, this effect depends on the type of cation [17]. This study examined the characteristics of cement geopolymers formed as a result of flying ash. The collapse of the rocks caused water to evaporate faster than normal Portland cement. In cold conditions up to 400 °C, 600 °C, 800 °C and 1000 °C [18]. These composite cables are suitable for routine and temporary tests. Unique curves of ordinary cement and Geo-polymer cement were imitated in the search for similar percentages of fiber. This study describes the strength of composite cement caused by the loss of cement in geopolymeric concrete plant structures [19-20].

The feasibility of using RM and RHA was investigated as common materials for geo-polymer production. the structure, microstructure and mechanical properties of the final geo-polymeric product was described. Two progressive methods of a cement-reinforced compound was studied as a beneficiation building material and therefore to develop a possible feasible method using RM and RHA geo-polymerization methods. The geopolymer binders and inactive fillers was presented, the end product is composite geopolymer. To prepare the sample geopolymer for later mechanical and microstructure samples, the precursor was poured into a cylindrical models with a width within 2 cm and a height of 5 cm, by curing in a laboratory environment (e.g., heated room with atmospheric pressure) for 14 days [21].

In the end, the samples were separated into 2 sets of standard cures, one set in ambient temperature and the other set in oven-curing at 40, 60, 80 and 100 °C. The sample was cured suitable for 1 day, 2 days and 3 days. The samples were sealed with thin plastic during curing stage. After 1 day, 2 days and 3 days of treatment all samples of different curing conditions were removed from the oven and stored in a warm room until the day of testing. Sample tests were performed to evaluate the developmental the strength of the samples. Samples were compressed at 1, 3, 7 and 28 days [22].

The solution of sodium and potassium hydroxide (14 M each) were prepared separately. The prepared solution was left for 24 h before sodium silicate was added. The mixture of sodium hydroxide / potassium hydroxide and sodium silicate solution was left for 1 day and then used for the geopolymerization process. High temperatures are required for the polymerization process and, to determine the optimal temperature curing, Mix 4 was heated at different temperatures for 72 h.. After demoulding, all samples (Mix 1, Mix 2, Mix 3, Mix 4 and Mix 5) were taken to an oven for heat curing at 100 °C for 72 hours, The samples were left in the chamber until the day of the test. A mixed mixture with portland cement (M30) was prepared for comparison with geo-polymeric cement [23].

The reality of geopolymerization was investigated and provides general principles for the use of geopolymers. Metakaolinite (MK) was produced by calibration for 6 h at 900°C. The compressive strength is increased at moderate levels of the thermal response but the mechanical performance does not directly of the reactivity of raw materials. The reaction rate was increased with the temperature increasing the material from 20 °C to 50 °C during the phase I and phase II periods. The deconstruction of the raw material was slow at 20°C and delayed in the subsequent polymerization process. [24]

Three test mixtures with different potassium hydroxide molarities such as 8M, 10M and 12M were used. In addition, a ratio of 1.50 was fixed for potassium silicate as potassium hydroxide. Samples of 100 mm mixed cubes are provided and stored in ovens for 24 high temperature ranges of 60°C, 70°C and 80°C. All cubes were tested for compressive strength using a Compression Testing Machine (CTM). The loading rate during the test was 2.5 kN/s. The strength of the cement cubes was tested on days 7 and 21. At a temperature of 70˚C for a period of two hours, the experiments showed the highest regulatory energy for a 12M molar of an alkaline KOH solution [25].

The geopolymerization kinetics of alkaline-methacholine systems and the effect of various synthesis temperatures, as well as the total amount of changes in the silicon surface and mechanical properties are being studied. The total amount of unstructured silicon, NRS, (in methacholine and sodium silicate) was calculated in samples cured at 30, 60 and 90 °C. All samples were ground and mixed with 12.5 g of Geopolymer with 250 mL of 2 M KOH solution [26]. The mechanical properties of metakaolin-based geopolymer mortars formed under different curing conditions at temperatures from 10 to 80 ° C and at different curing times. The composition of geopolymers material was tested based on history and different types of geopolymer products were prepared at room temperature as a mixture of the best mechanical properties after twenty-eight days. Geopolymer samples were synthesized by machine mixing the metakaolin and activator solution in a planetary mixture of 5 min. Then quartz sand was added to this geopolymer paste with some additional water to obtain better workability of the mortar [27].

This work examines the bonding strength of MK-based GPCs using test output. Types of tests include bar type, different geopolymer mixtures obtained using different proportion of alkaline alkaline activators, and concrete types (with and without steel bar). The model was designed to predict the bond strength and the steel structure embedded in plane and fiber reinforced geopolymers. A solution of sodium silicate and sodium hydroxide (NaOH) was used to form an alkaline solution. The NaOH reaction was performed by deform the solid NaOH with a 97% purity level in distilled water one-day before use. The concentration of the NaOH solution was 20 M [28]. The requirements of various parameters such as strength, water absorption, electrical conductivity, fiber level and monomer ratios were analyzed and the amount and rate of geopolymerization and structural analyzes were made. To prepare the samples, the mixture was first, fine and coarse aggregates were dry mixed for two or more minutes. After that, MK was added to the mixture and the mixture was stirred for 3 - 3 minutes. PP fiber and alkaline activator solution were added immediately after the preparation of the premix MKs forming

the desired gel. This gel should be mixed vigorously for about 2-3 minutes to form alumina and silicate monomers. Mixing was continued to obtain a homogeneous mixture. The finished geopolymer cement was then poured into a mold without being too hard, and after 24 hours it was removed from the substitute and cured at 20 ± 2 °C and 70 hours of low humidity. ± 10% [29]. The geopolymer cement was produced using only metakaolin flash, evaluate their performance in new and challenging environments, the pure NaOH and water were added in glass solution of water and the souttion was cured up to 20 °C in 24 hours. Cement geopolymer was prepared in two stages. First, the metakaolin and aggregate were mixed and the mixing solution was stirred continuously while stirring until the same dark orange colored mixture was obtained [30].

During the mixing process, RA and water additive were first mixed together for 5 minutes, then adding sand and binders and the water mixture continued for another 5 minutes. Alkaline activator solution and RWR then add and mix continuously for another 2-3 minutes. To assess the compressive behavior during the experimental mixture, forty-two cylinder speciman with dimensions of 100 mm (width) and 200 mm (height) were designed. Three experiments were performed on one set of sample. Samples were removed from replacement after 24 h and placed for another 24 h at 80 °C before putting into a standard curing condition (20 °C and RH> 95%) [31]. A mixture of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions were used as the activator solution. The concentrated sodium hydroxide solution was prepared by mixing 97-98% pure NaOH pellets with tap water. The densities of sodium hydroxide solution and the amount of alkaline solution are approximately 1.15 and 1.5 g/cm^3. The curing temperature and curing time of all mixtures was 50 °C of 48 h [32]. It has been shown that the alkali solution/fly ash ratio in the range of 0.30-0.40 improves the strength and microstructure of the cement geopolymer. Three treatment regimens were used: 24 hours at 60 °C, 12 hours at 70 °C, and 24 hours at 75 °C [33].

The efficiency of kaolin and fly ash was 100% and 89% respectively passing through a 45 μm sieve. The solid-liquid ratio of the metakaolin-based geopolymer paste was 0.8, while the average ratio of the fly ash-based geopolymer was 3.0. Along with many trail models studied, these two ratios closely match in optimum strength and workability. The geopolymeric precursor (metakaolin or fly ash) and alkaline silicate solutions were hand-mixed with the mixture for 10 minutes and another 5 minutes before pouring into cubic model. The dimensions of the cubic geopolymer models are 25 mm × 25 mm × 25 mm. Samples were then collected to remove any air bubbles by swelling [34]. Ms is the weight of the SiO_2 / Na_2O ratio in the alkaline activator solution. SH concentrations of mortar and concrete mixtures activated with SH solutions rated as 10, 12, 14 and 16 M. The activator / binder ratio was also evaluated [35].

Blending was performed at two different stages; 100 rpm for 2 minutes and 200 rpm for 4 minutes to determine their homogeneity and avoid bubbles and agglomeration into the sample.. The paste was then poured into 20 x 20 x 20 mm cubic molds and placed in the oven at 50 °C for 24 hours and then stored at room temperature for one day. Curing was performed by storing cubic geopolymer samples in distilled water for 1 to 28 days [36]. The binders (cement or fly ash) and liqied components (water or alkaline water) are mixed in a pan mixture for 5 minutes. The cement and aggregates or the fly ash and aggregates dry mixed for 3 minutes. Then add water or alkaline liquid was added and wet mixing for 4 minutes. The mixture was poured into different moulds in three equal portions. Each group was vibrated for 15 to 30 seconds. After treatment, the OPC and geopolymer samples were stored in a controlled environment stored at relative humidity of 50% and temperature of 28°C [37]. The specimen was cut to a position of approximately (1 × 1 × 1) cm after 14 days of treatment. [38]

The alkaline activator solution was obtained and stored in a warm room temperature for 24 hours to make stability. The sample geopolymer was produced at room temperature and an alkaline solution containing metakaolin according to different/liquid cell values was continued to be mixed until the homogenization of the mixture was completed. The final samples were placed in the process chamber at a temperature of 70 °C for 24 hours to allow for the reinforcing and stabilizing properties of the geopolymer pastes [39]. Particle and bond analysis is examined for both geopolymer bonds and sample grains to match the structure with geopolymer chemistry, bond, mineralogy and microstructure. 13 M NaOH solution and sodium silicate solution were mixed in 1:2 ratio of the solution prepared [40].

2. Testing methodology

The all dry components, including coarse aggregate, fine aggregate, and MK, are mixed in a mixer for about 5 minutes. All liquids, such as water, sodium hydroxide, and sodium silicate solutions, are then gradually added and stirred until a homogeneous mixture is obtained. The concrete mixture was then left in rollers with a diameter of 150 mm and a height of 300 mm and shaken through a shaking table. The filled molds were allowed to process at room temperature (26 ± 2°C, relative humidity 20% ± 4%) by exposing the top surface of the mold to air temperature. Samples were collected after 24 hours and processed at room temperature until the day of the test (7 and 28 days). For the reference cement concrete mixes, the samples were rinsed 24 hours after mixing and immersed before testing.

3. Experimental program

3.1. Materials

3.1.1. Geopolymer binder

MK was used in this work as an aluminosilicate material. Locally available was as kaolin was calcined at 750℃ during 3 hours to obtaining the MK. The chemical composition of MK is showed in Table 1.

3.1.2. Aggregates

In this study, the three aggregates were used, the largest 10 mm unit, the ground unit (maximum size less than 4.75 mm), and Narmada sand (locally available). The physical characteristics of the aggregates used in this study are shown in Table 2.

Table 1 Chemical composition of MK in percent

Sl. No.	Oxide Composition	Value (%)
1	Calcium oxide (CaO)	1.287
2	Silicon oxide (SiO_2)	50.995
3	Aluminum oxide (Al_2O_3)	42.631
4	Ferrous oxide (Fe_2O_3)	2.114
5	Sulfur trioxide (SO_3)	0.439
6	Potassium oxide (K_2O)	0.337
7	Titanium oxide (TiO_2)	1.713
8	Phosphorus pentoxide (P_2O_5)	0.051
9	Magnesium oxide (MgO)	0.127
10	Sodium oxide (Na_2O)	0.284
11	Manganese oxide (MnO)	0.006
12	Zinc oxide (ZnO)	0.004
13	Strontium oxide (SrO)	0.012

Table 2 Aggregates

Sl. No.	Aggregate Size	Fineness modulus	Specific gravity (Saturated surface dry)
1	Coarse aggregate (Maximum size of aggregate = 10 mm)	6.08	2.60
2	Crushed aggregate (Maximum size of aggregate =4.75 mm)	4.75	2.63
3	Narmada sand (locally available)	1.88	2.50

3.1.3. Experimentation

The samples used in this test were obtained sequentially, such as 150 mm x 150 mm x 150 mm at each time point, the specimens for 8M and 10M were taken for 7 days, 28 days for testing of compressive strength, split tensile strength and flexural strength test. For the test, it was observed that the 10M sample produced good compressive strength compared to the 8M sample using an alkaline ratio of 1: 2.5 to 1: 3.

4. Test results and discussion

The M30 grade geopolymer concrete was used with for 8M and 10M solution with 1:2.5 and 1.3 alkaline liquid ratios for different mix design. Concrete models were measuring with dimension of 150 mm x 150 mm x 150 mm for compressive strength, split tensile strength and flexural strength test for 7 days and 28 days with variation in % geopolymers (NaOH:Na2SiO3).

Table 3 and 4 showed the results of compressive strength test of mix with 8M and 10M solution (1:2.5) respectively. Table 5 and 6 showed the results of compressive strength test of mix with 8M and 10M solution (1:3) respectively. Table 7 and 8 showed the results of split tensile strength test of mix with 8M and 10M solution (1:2.5) respectively. Table 9 and 10 showed the results of split tensile strength test of mix with 8M and 10m solution (1:3) respectively. Table 11 and 12 showed the results of flexural strength test of mix with 8M and 10M solution (1:2.5) respectively. Table 13 and 14 showed the results of flexural strength test of mix with 8M and 10M solution (1:3) respectively. Variation of 7 and 28 days compressive strength with variation in Mix for 8M and 10M for solution (1:2.5) and Mix for 8M and 10M for solution (1:3) shown in Fig.1-4 respectively. Variation of 7 and 28 days split tensile strength with variation in Mix for 8M and 10M for solution (1:2.5) and Mix for 8M and 10m solution (1:3)) shown in Fig.5-8 respectively. Variation of 7 and 28 days flexural strength with variation in Mix for 8M and 10M for solution (1:2.5) and Mix for 8M and 10M for solution (1:3) shown in Fig.10-12 respectively.

4.1 Thermal conductivity

During the measurements, the initial temperature of the samples was maintained between 25-27℃ and the relative humidity was between 52-67%. To study the effects of temperature drops on models, initially the temperature of the measuring head was 12℃ higher than the environmental temperature. In the second measurement, the measuring head was 45℃ higher than that of the base plate.

4.2 Durability

After curing, the initial weight of the cement samples was recorded, and then they were added to two different proportions of chemical and sulfate to measure the results of the stability properties of the cement geopolymer. the changes in weight and compressive strengths studied. The duration of the exhibition is seven days and twenty-eight days. In addition, the compressive strength of the dry samples was tested on machine drying after 7 and 28 days, which was the onset of the initial compressive strength.

4.3 Density

The weight of the GP sample was determined immediately after the samples were molded and after 7 and 28-day follow-up. The density of geopolymer mixes tends to be higher when fresh (ie wet conditions) with densities ranging from 2380 to 2475 kg/m^3. Density reduction is observed after 7 days of setting, which is 2.7% -4.8% less than fresh density. Dry density at 28 days is observed and finds better density, but it reduces at the 7 days curing age. The 28-day dry density ranges from 2215 to 2295 kg/m3, which is lower than the average wet density by 4.8% -6.3%. Generally, density for geopolymer mixes tends to decrease with cure time due to excess water evaporation.

4.4 Workability

The workability of the mixes was evaluated based on the slump test. The M1 mix with a low sodium silicate to NaOH (solids) ratio of 2.5 had zero drop. However, increasing the ratio of sodium silicate to NaOH (solids) 3 produced more workable mix for M2 with a drop of about 30 mm, while further increasing the ratio of sodium silicate to NaOH to 4 resulted in a mixture less workable with 20 mm drop for M3. Therefore, in general, increasing the sodium silicate to NaOH ratio improves the workability due to the increase of H2O/Na_2O (eg M1 and M2) and the workability decreases during M3. However, a further increase in sodium silicate to NaOH (solids) beyond a certain threshold (ie 3) resulted in a more viscous and cohesive mixture (due to the high amounts of sodium silicate).

Table 3 Results of compressive strength test of mix with 8M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	20.42	31.07
M2	100% F.A	Failure	
M3	100% Metakaolin	30.68	31.73
M4	87.50%MK+12.50%F.A	32.21	32.97
M5	75.00%MK+25.00%F.A	29.81	30.88
M6	62.50%MK+37.50%F.A	29.11	29.69
M7	50.00%MK+50.00%F.A	25.52	28.88
M8	37.50%MK+62.50%F.A	23.65	28.45
M9	25.00%MK+75.00%F.A	22.70	27.40
M10	12.50%MK+87.50%F.A	21.38	26.84

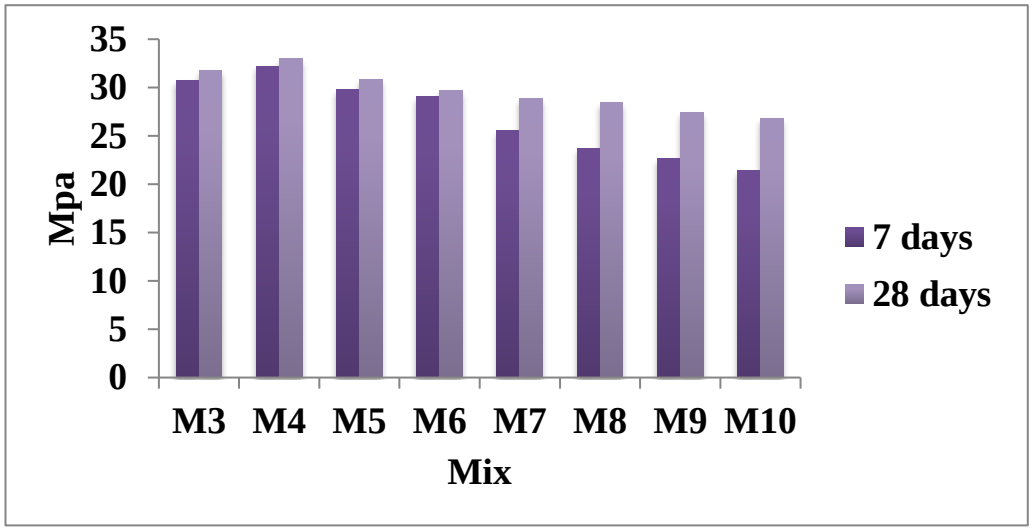

Fig.1 Variation of 7 and 28 days compressive strength with variation in Mix for 8M solution (1:2.5)

Table 4 Results of compressive strength test of mix with 10M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	20.47	31.55
M2	100% F.A	Failure	
M3	100% Metakaolin	31.48	32.81
M4	87.50%MK+12.50%F.A	33.43	35.09
M5	75.00%MK+25.00%F.A	31.55	31.97
M6	62.50%MK+37.50%F.A	29.65	30.73
M7	50.00%MK+50.00%F.A	26.96	29.80
M8	37.50%MK+62.50%F.A	24.14	28.94
M9	25.00%MK+75.00%F.A	23.68	28.43
M10	12.50%MK+87.50%F.A	22.27	28.19

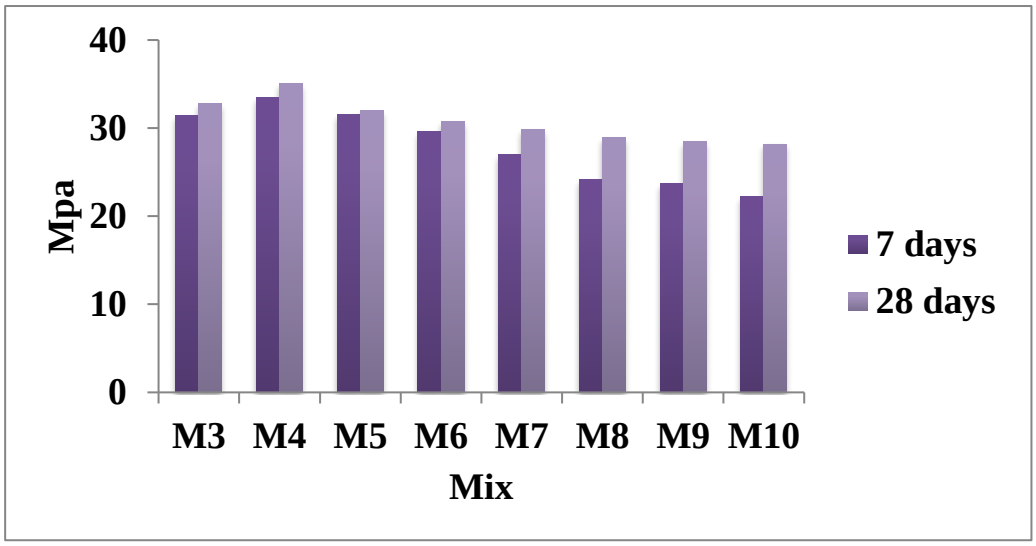

Fig.2 Variation of 7 and 28 days compressive strength with variation in Mix for 10M solution (1:2.5)

Table 5 Results of compressive strength test of mix with 8M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	20.55	31.65
M2	100% F.A	Failure	
M3	100% Metakaolin	32.02	34.48
M4	87.50%MK+12.50%F.A	33.16	35.81
M5	75.00%MK+25.00%F.A	31.30	32.30
M6	62.50%MK+37.50%F.A	29.36	31.42
M7	50.00%MK+50.00%F.A	25.64	30.88
M8	37.50%MK+62.50%F.A	23.66	29.84
M9	25.00%MK+75.00%F.A	22.35	28.88
M10	12.50%MK+87.50%F.A	22.15	28.47

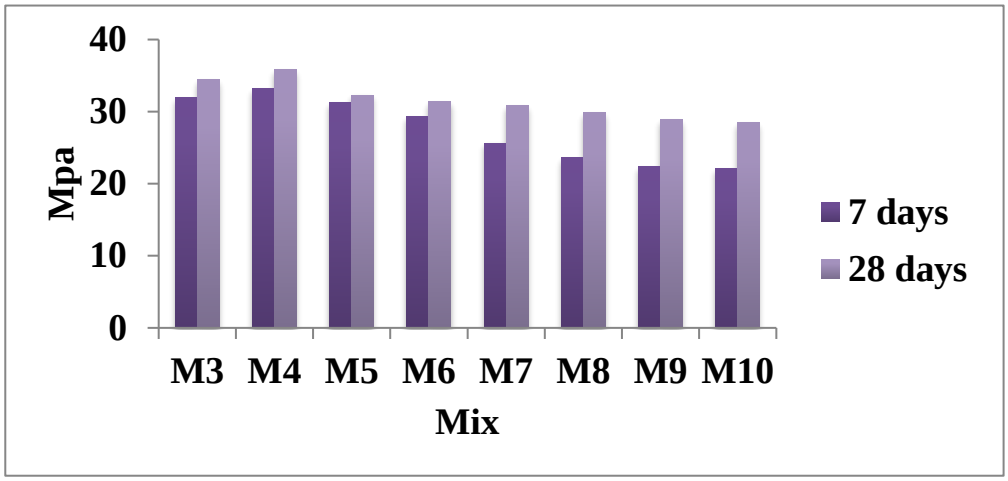

Fig.3 Variation of 7 and 28 days compressive strength with variation in Mix for 8M solution (1:3)

Table 6 Results of compressive strength test of mix with 10M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	29.93	30.15
M2	100% F.A	Failure	
M3	100% Metakaolin	32.85	35.57
M4	87.50%MK+12.50%F.A	34.09	36.74
M5	75.00%MK+25.00%F.A	32.84	33.38
M6	62.50%MK+37.50%F.A	31.79	32.19
M7	50.00%MK+50.00%F.A	29.91	31.40
M8	37.50%MK+62.50%F.A	25.53	31.11
M9	25.00%MK+75.00%F.A	24.15	30.16
M10	12.50%MK+87.50%F.A	23.48	29.67

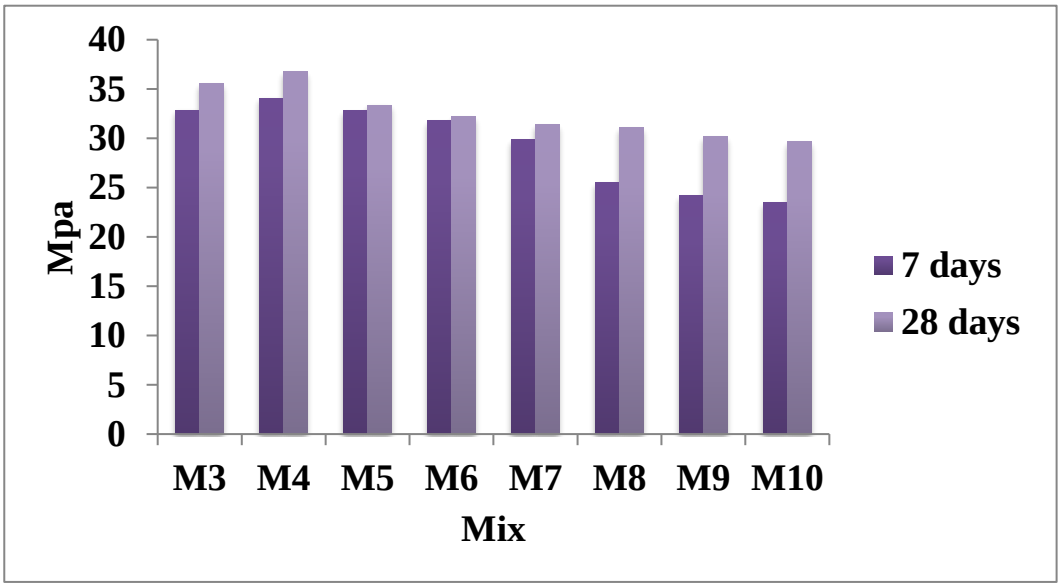

Fig.4 Variation of 7 and 28 days compressive strength with variation in Mix for 10M solution (1:3)

Table7 Results of split tensile strength test of mix with 8M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	3.44	3.52
M2	100% F.A	0.22	0.29
M3	100% Metakaolin	1.63	1.73
M4	87.50%MK+12.50%F.A	2.99	3.15
M5	75.00%MK+25.00%F.A	2.75	3.03
M6	62.50%MK+37.50%F.A	2.26	2.82

M7	50.00%MK+50.00%F.A	1.97	2.56
M8	37.50%MK+62.50%F.A	1.59	2.09
M9	25.00%MK+75.00%F.A	0.76	1.59
M10	12.50%MK+87.50%F.A	0.20	0.29

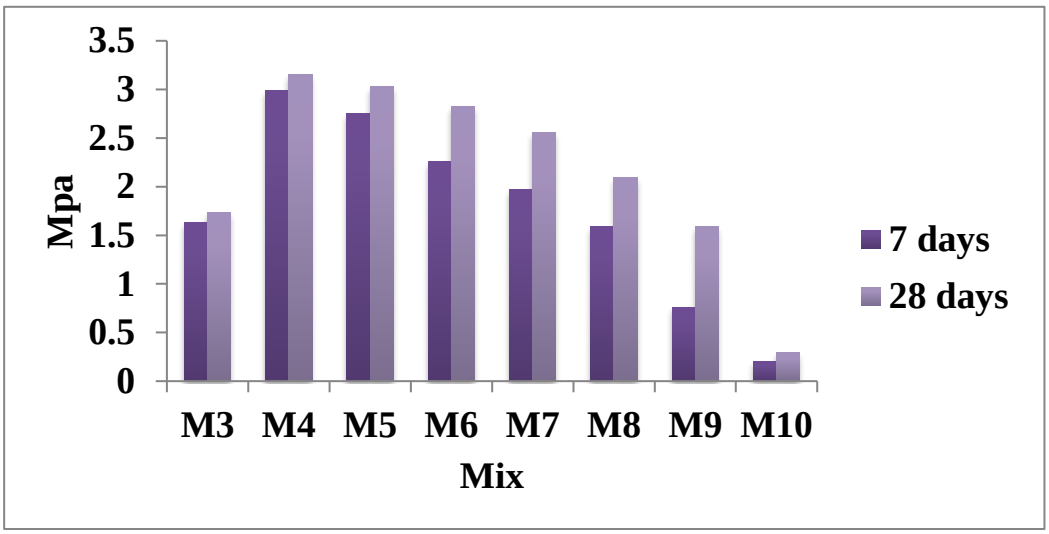

Fig.5 Variation of 7 and 28 days split tensile strength with variation in Mix for 8M solution (1:2.5)

Table 8 Results of split tensile strength test of mix with 10M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	3.44	3.52
M2	100% F.A	0.25	0.49
M3	100% Metakaolin	2.93	3.49
M4	87.50%MK+12.50%F.A	3.34	3.59
M5	75.00%MK+25.00%F.A	2.99	3.15
M6	62.50%MK+37.50%F.A	2.53	2.86
M7	50.00%MK+50.00%F.A	2.38	2.48
M8	37.50%MK+62.50%F.A	2.15	2.38
M9	25.00%MK+75.00%F.A	1.78	2.09
M10	12.50%MK+87.50%F.A	1.53	1.89

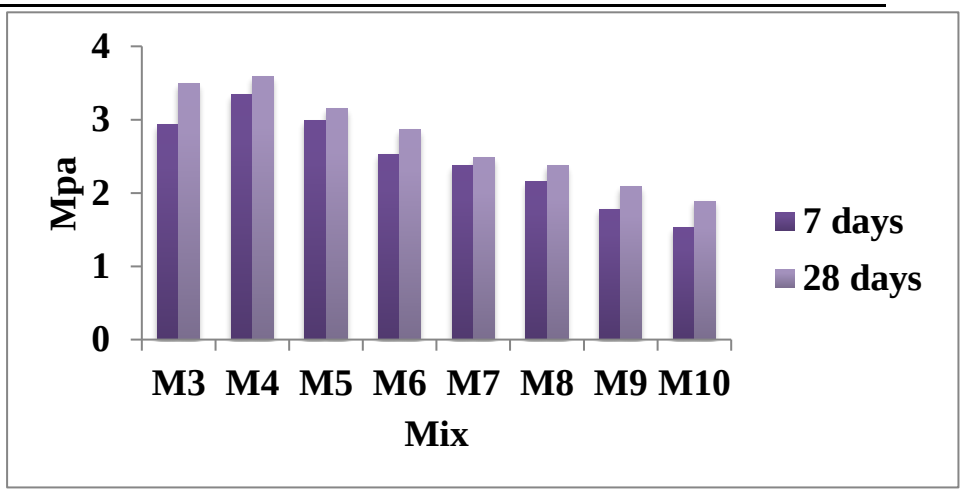

Fig.6 Variation of 7 and 28 days split tensile strength with variation in Mix for 10M solution (1:2.5)

Table 9 Results of split tensile strength test of mix with 8M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	3.44	3.52
M2	100% F.A	0.26	0.34
M3	100% Metakaolin	1.79	2.99
M4	87.50%MK+12.50%F.A	2.27	3.14
M5	75.00%MK+25.00%F.A	2.08	3.34
M6	62.50%MK+37.50%F.A	1.88	2.74
M7	50.00%MK+50.00%F.A	1.49	2.26
M8	37.50%MK+62.50%F.A	1.43	1.66
M9	25.00%MK+75.00%F.A	1.00	1.18
M10	12.50%MK+87.50%F.A	0.20	0.31

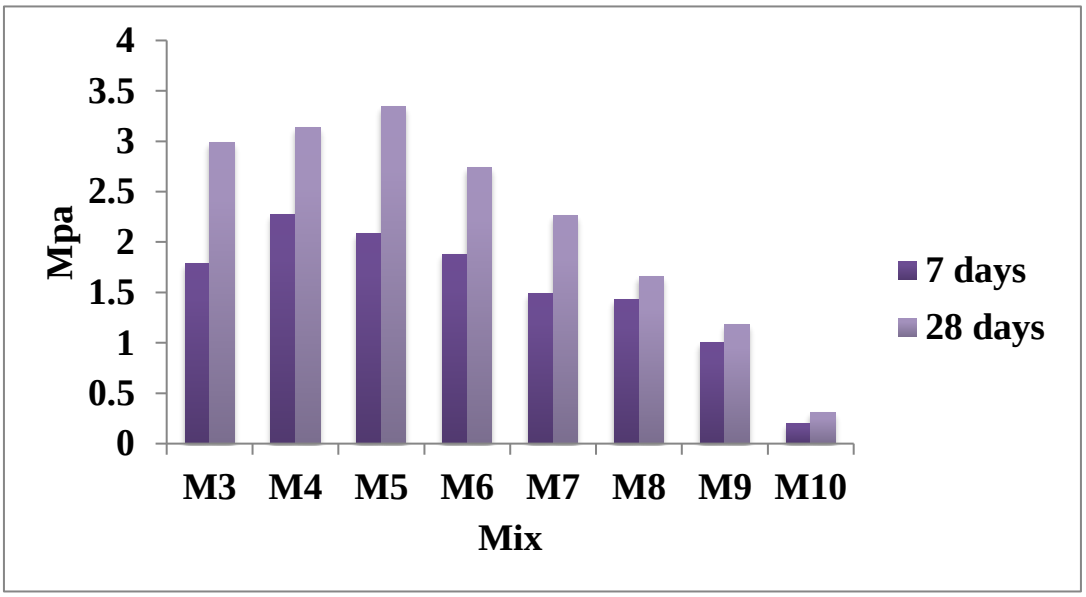

Fig.7 Variation of 7 and 28 days split tensile strength with variation in Mix for 8M solution (1:3)

Table 10 Results of split tensile strength test of mix with 10M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	3.44	3.52
M2	100% F.A	0.38	0.75
M3	100% Metakaolin	2.77	3.44
M4	87.50%MK+12.50%F.A	3.46	4.03
M5	75.00%MK+25.00%F.A	2.91	3.14
M6	62.50%MK+37.50%F.A	2.89	2.99
M7	50.00%MK+50.00%F.A	2.14	2.55
M8	37.50%MK+62.50%F.A	1.88	2.56
M9	25.00%MK+75.00%F.A	1.79	2.39
M10	12.50%MK+87.50%F.A	1.54	2.02

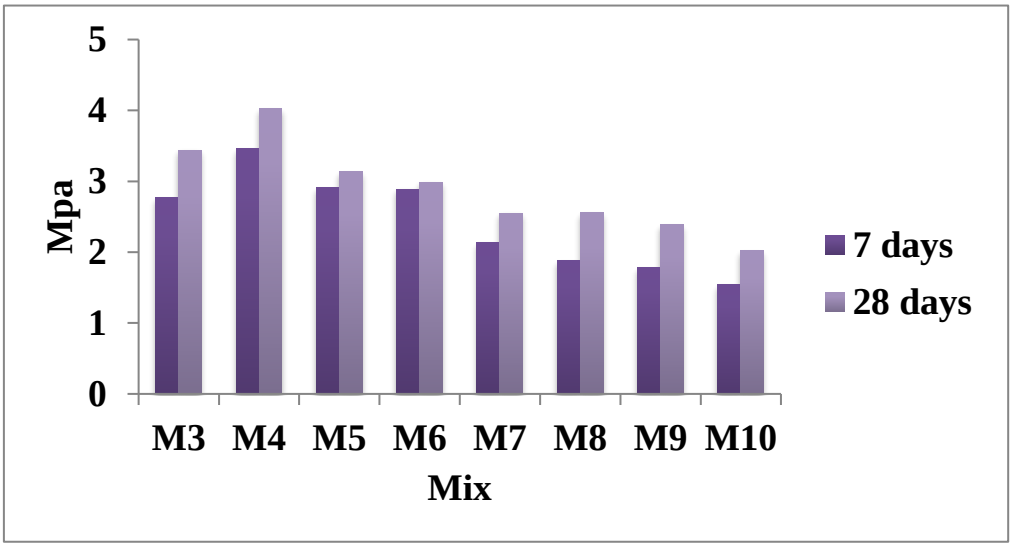

Fig.8 Variation of 7 and 28 days split tensile strength with variation in Mix for 10M solution (1:3)

Table 11 Results of flexural strength test of mix with 8M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	1.55	4.67
M2	100% F.A	0.07	0.40
M3	100% Metakaolin	0.59	3.14
M4	87.50%MK+12.50%F.A	0.97	3.47
M5	75.00%MK+25.00%F.A	0.91	3.08
M6	62.50%MK+37.50%F.A	0.85	2.75
M7	50.00%MK+50.00%F.A	0.59	2.14
M8	37.50%MK+62.50%F.A	0.55	1.78
M9	25.00%MK+75.00%F.A	0.52	1.58
M10	12.50%MK+87.50%F.A	0.34	1.19

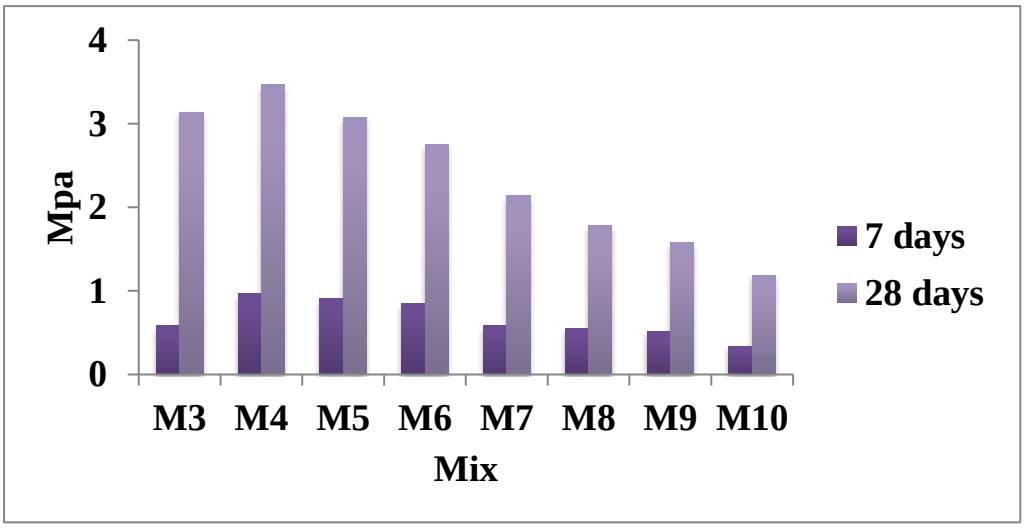

Fig.9 Variation of 7 and 28 days flexural strength with variation in Mix for 8M solution (1:2.5)

Table 12 Results of flexural strength test of mix with 10M solution (1:2.5)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	1.55	4.67
M2	100% F.A	0.10	0.47
M3	100% Metakaolin	1.00	2.54
M4	87.50%MK+12.50%F.A	1.19	3.69
M5	75.00%MK+25.00%F.A	0.91	3.13
M6	62.50%MK+37.50%F.A	1.04	3.11
M7	50.00%MK+50.00%F.A	0.97	2.53

M8	37.50%MK+62.50%F.A	0.91	2.21
M9	25.00%MK+75.00%F.A	0.87	1.78
M10	12.50%MK+87.50%F.A	0.85	1.31

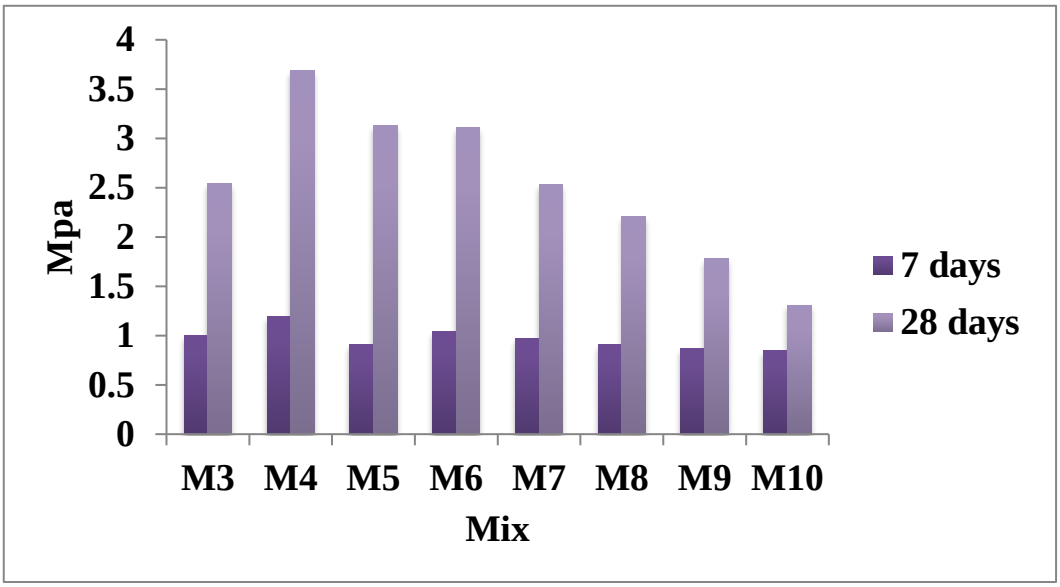

Fig.10 Variation of 7 and 28 days flexural strength with variation in Mix for 10M solution (1:2.5)

Table 13 Results of flexural strength test of mix with 8M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	1.55	4.67
M2	100% F.A	0.22	0.46
M3	100% Metakaolin	0.64	1.30
M4	87.50%MK+12.50%F.A	0.77	1.97
M5	75.00%MK+25.00%F.A	1.71	4.02
M6	62.50%MK+37.50%F.A	1.59	3.17
M7	50.00%MK+50.00%F.A	1.05	2.86
M8	37.50%MK+62.50%F.A	0.83	2.36
M9	25.00%MK+75.00%F.A	0.68	1.34
M10	12.50%MK+87.50%F.A	0.31	0.97

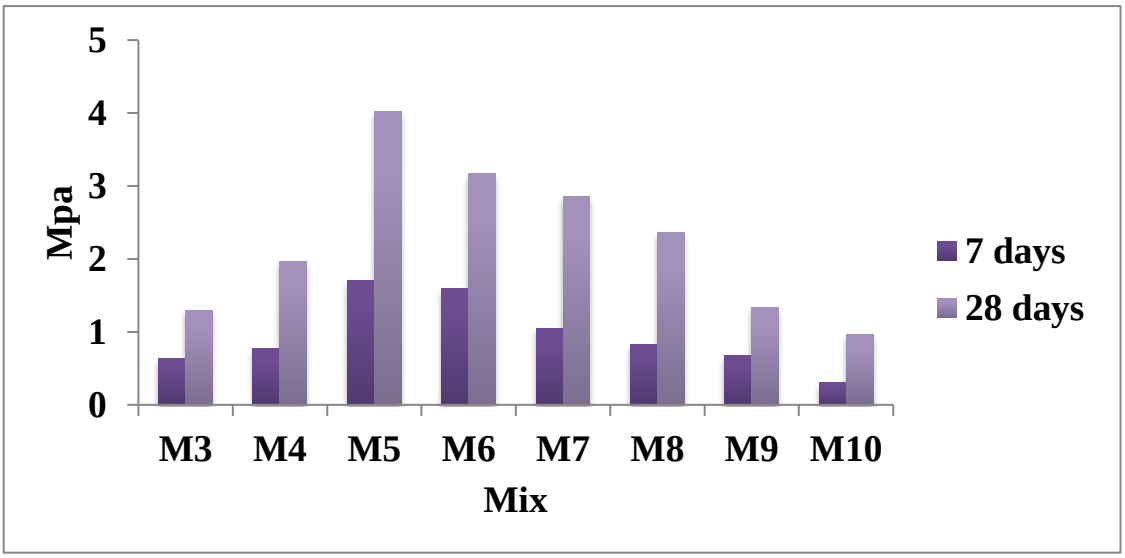

Fig.11 Variation of 7 and 28 days flexural strength with variation in Mix for 8M solution (1:3)

Table 14 Results of flexural strength test of mix with 10M solution (1:3)

Sl. No	Mix	7 days (N/mm^2)	28 days (N/mm^2)
M1	C.C	1.55	4.67
M2	100% F.A	0.01	0.59
M3	100% Metakaolin	0.67	2.68
M4	87.50%MK+12.50%F.A	0.80	3.16
M5	75.00%MK+25.00%F.A	1.57	4.06
M6	62.50%MK+37.50%F.A	1.51	3.17
M7	50.00%MK+50.00%F.A	0.86	2.56
M8	37.50%MK+62.50%F.A	0.77	2.20
M9	25.00%MK+75.00%F.A	0.52	1.42
M10	12.50%MK+87.50%F.A	0.44	1.17

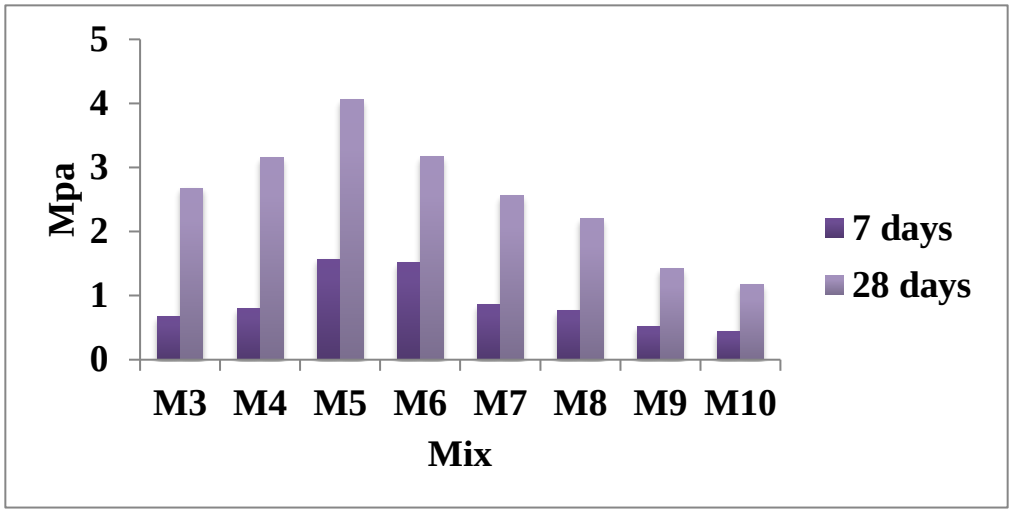

Fig.12 Variation of 7 and 28 days flexural strength with variation in Mix for 10M solution (1:3)

5. Conclusions

In this article, research has presented the effects of mixed design parameter (sodium silicate in sodium hydroxide, the ratio of alkali to solid MK, internal measurements and the effect of water on pollutants) on new and dry GPC structures in the MK region. The most suitable mixtures were classified as 87.50% MK + 12.50% FA. Strength properties were found for GPC with 10 Molar NaOH yielding better results than 8 Molar Solutions. The proportion of concrete and alkaline water increased from 1:2.5 to 1:3. The divided tensile strength of concrete hardness was added to a 10M solution in a 1:3 alkaline water ratio. Alkaline water ratio of flexural strength increased in 10M solution by 1:3.

During the measurement, the initial temperature of the samples was maintained between 25–27°C and the relative humidity between 52–67%. Furthermore, the compressive strength of the dried samples was tested 7 and 28 days after machine drying, which was the onset of the initial compressive strength. Dry density is observed at 28 days and gains greater density, but decreases at 7 days of age. The 28-day dry density ranges from 2215 to 2295 kg/m3, which is 4.8% -6.3% less than the average wet density. Generally, the density of the geopolymer mixture decreases with curing time due to evaporation of excess water.

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