

## Durability Studies on High-Strength Concrete Incorporating with Pumice Powder and Slag Sand

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**Abstract:**-The current scenario deals with the rapidly growing and emerging technology in the construction industry. The most important construction material for the construction work in the construction industry is concrete. Now a days, Concrete structures suffer serious deterioration under corrosive environment. Consequently, the safety of these concrete structures is decreased. To reduce this deterioration, the influence of Pumice powder (PP) and Slag sand (SS) as supplementing cementing materials of concrete is studied in this investigation.

The project mainly deals with the replacement of cement with Pumice powder and river sand with Slag sand. In this work, Pumice powder used as partial replacement for cement in the range 10-50 % and river sand is replaced with slag sand with 100%. The grade of concrete proposed is M60.

Durability tests such as resistance to acid attack ( $H_2SO_4$ , HCL,  $MgSO_4$ ) with 5% dilute acid solution will be used for exposure of 30 days, 60 days and 90 days and compressive strength of cubes will be tested. Weight loss due to acid exposure will also be tested.

**Keywords**-Cement, Pumice powder, Slag sand, Aggregate and Water.

### 1. Introduction

#### 1.1 General

Environmentally friendly cement-based materials is a topic of interest and cement replacement materials play an important role in the construction industry considering economical, technological and ecological points of view. Therefore, the search for alternative binders or cement replacement materials has been the subject of many publications. Concrete materials should not only possess good workability, excellent mechanical properties and durability, but also offer environmental and economic benefits. Besides cost reduction and enhancement of workability of fresh concrete, the use of pozzolans might help improve the durability of concrete such as resistance to thermal cracking, alkali-aggregate expansion, and sulfate attack. A pozzolana is defined as a natural or artificial material which contains reactive silica. Pozzolans are defined as materials that have little or no cementitious value by themselves, however, when finely divided and in the presence of moisture they will chemically react with alkalis to form cementing compounds. The silica in a pozzolana has to be amorphous, or

glassy, to be reactive. Natural pozzolans are generally derived from volcanic rocks and minerals [4]. Turkey is rich in natural pozzolan, where almost 20% of the country is covered by Tertiary and Quaternary-age volcanic rocks, and pumice can be found in several regions of the country. Pumice is a natural lightweight material of volcanic origin produced by the release of gases during the solidification of lava. The cellular structure of pumice is created by the formation of bubbles or air voids when gases contained in the molten lava flowing from volcanoes become trapped on cooling. When lightweight aggregates of pozzolanic materials were ground to very fine powder, they could possess certain cementitious properties. At the same time, when they mix with a certain amount of cement and lime, their binding property increases. In this study Pumice is chosen as a natural pozzolan because of its availability and properties and that it can be easily grinded to obtain its powder without requiring high amount of energy.

Continuous extraction of natural sand from river beds leads to many environmental problems like

bank slides, loss of vegetation on the banks of rivers, exposing the intake well of water supply schemes, disturbance to aquatic life, affecting agriculture due to lowering the underground water table etc. In order to balance this situation many alternative materials have been identified as a substitute for river sand. Some alternatives materials such as quarry rock dust, bottom ash, copper slag and foundry sand are used in concrete and mortar mixtures as a partial or full replacement of natural sand. Amongst with them, Slag sand is used to replace the river in the present study.

Current research is using of Pumice powder and Slag sand as replacements of cement and fine aggregate in the concrete.

### **1.2 Scope of study**

The purpose of this study to investigate and find the strength of concrete with replacement of cement with Pumice powder in the proportion of 0, 10, 20, 30, 40 and 50% and fine aggregate with Slag sand with 100%. 100 x 100 x 100 mm Cubes are cast and find the Compression strength for 28 days and Durability tests such as resistance to acid attack ( $H_2SO_4$ , HCL,  $MgSO_4$ ) with 5% dilute acid solution will be used for exposure of 30 days, 60 days and 90 days and compressive strength of cubes will be tested. Weight loss due to acid exposure will also be measured.

### **Literature Review**

**Bhupati Kannur & H. S. Chore**[1] studied the Properties of low-fines self-consolidating concrete by adding industrial by-products such as fly ash and sugarcane bagasse ash as cement replacing materials at 20, 30, 40 and 50%; and 10, 20, 30 and 40%, respectively.. The durability of mixes is determined by water absorption, water penetration, and rapid chloride penetration tests (RCPT). The compressive and flexural strengths of the mixes which are not less than 30 and 3.8 MPa can be used for rural roads and those showing mix values above 40 and 4.5 MPa, can be effectively used for the construction of urban roads as per Indian Road Congress specifications. The maximum water absorption among all the mixes is 3.56% and the maximum water penetration is 35 mm. The RCPT values at 90 days curing are found to be in the range of 788–1393 coulombs.

**V.Sathish, P. Dhanabal, P. Narendra Reddy and A.Anil** [2] investigated various properties of concrete by replacement of cement with pumice stone powder. In this work pumice stone powder was partially replaced with cement in different percentages like 10%, 20%, 30%, 40%. Pumice powder, generated by the stone processing industry, is an inert by-product possessing excellent cementitious characteristics. This study is focused on the strength properties of pumice powder in pozzolan concrete. The results indicate that the fresh and hardened properties of the modified mix with pumice stone powder as improved considerably. The use of pumice powder as a substitute for cement in the concrete mixture also has the ability to improve the compressive, and tensile strength of concrete.

**T. Shanmugapriya, K. Sathish Raja and C. Balaji** [3] The main aim of this study is to check the strength and durability characteristics of HPC using M-Sand along with 5% silica fume. The natural sand was replaced by M-Sand in different proportions of 0%, 20%, 40%, 60%, 80% and 100%. The compressive strength, flexural strength, splitting tensile and modulus of elasticity were studied. Similarly, the durability properties like sorptivity and Rapid Chloride Permeability test were also conducted. The results indicated that a marginal increase in strength and durability properties of high-performance concrete by addition of manufactured sand as a complete replacement of natural sand.

**Gaveesh H R, Umashankar Y, Yogananda M V, R Manjunath**[4]. In the present study, granulated blast furnace slag (GBS) which is a by-product of steel manufacturing plant is used by replacing partially and completely for manufactured sand (about 0%, 25%, 50%, 75%, and 100%). Characterizations of all materials were carried out to know the properties and behavior in solid concrete blocks during its fresh and hardened state. Dimensionality, Compressive strength, Water absorption and Block density tests were carried on hardened concrete blocks. Tests reveals that increase in percentage of GBS in the manufacturing of concrete blocks as a replacement to M-sand beyond 50% leads to gradual decrease in compressive strength and block density.

Meanwhile, increase in the percentage of GBS results in increase in water absorption.

**Chandrasekhar Reddy Kamasani and Sateesh Reddy Siddamreddy**[5] The study used to partially replace cement with BA powder at proportions 0, 5, 10, 15, 20 and 25% and coarse aggregates are replaced with FA aggregates made with FA and cement using a cold-bonded technique at proportions 0–25%. FA aggregates were made at 10:90, 15:85, 20:80 and 25:75 proportions of cement and Fine Aggregate. The FA aggregates at the best proportion 15:85 was selected as a coarse aggregate by conducting tests like specific gravity, crushing value, impact value and water absorption tests. The addition of 30% content decreases porosity by 21% and increases strength significantly at 28 days. Microstructure evolution is carried out to identify material behaviour.

**Hesam Madani, Mohammad Naser Norouzfzar, Jamshid Rostami**[6]. The analyses show that combined use of silica fume and high volume of pumice could provide highly environmentally-friendly concrete. For instance, the mixture with 60% pumice and 9% silica fume (124 kg/m<sup>3</sup> cement) had a 365 days compressive strength of 75 MPa with low level of global warming potential (GWP). In conclusion, the obtained results reveal that use of silica fume as a complementary to pumice is a sustainable solution to produce durable concretes with appropriate characteristics at both early and later ages, especially for those with high volume of pumice. In this regard, utilizing at least 3% silica fume is recommended to provide excellent performance in enhancing the durability and mechanical characteristics.

**Quang Tran a , Pratanu Ghosh** [7] This study explored thirty-seven various concrete mixtures, which includes ordinary Portland cement (OPC) and other binary and ternary mixtures integrating the ultrafine VPP as a major supplementary cementitious material (SCM) along with other cementitious materials namely fly ash, slag, silica fume and metakaolin. The research was conducted to evaluate two performance parameters namely the compressive strength and the durability due to chloride-induced corrosion. Two different nondestructive testing instruments, namely 4-point Wenner Probe and Merlin meter were utilized to investigate the surface resistivity (SR),

the bulk resistivity (BR) and the charge passed within a very short time. These are important hardened concrete properties related to the corrosion resistance of reinforced concrete structures. The results indicated that the binary and ternary-based VPP mixtures have remarkably higher compressive strength and very low permeability compared to OPC and other SCM based binary mixtures from early ages to long-term period (up to 91 days).

### 3. Methodology

The blends were created with the goal of giving concrete its maximum strength. The mix proportions of the different materials used in the concrete mixes are provided based on the IS 10262-2009 Code approach.

#### 3.1 MATERIALS USED

##### A. CEMENT

Owing to its own usage as an essential ingredient in concrete, mortar, stucco, and the majority of non-specialty grout, the kind of cement used is ordinary Portland cement which is most often used globally. Portland cement from the outside was the cement type used in this investigation. The physical parameters of Portland cement are displayed in Table 1. The 53 Grade Ordinary Portland Cement from Penna, a locally accessible brand, was the cement used throughout the experiment. It was lump-free and brand-new.

**Table 1: Cement's Physical Characteristics**

S.No	Property	Test result
1	Normal consistency	29%
2	Specific gravity	3.11
3	Initial setting time	65min
4	Final setting time	550min
5	Soundness	3mm
6	Fineness (sieve)	95%

##### B. Natural Sand:

As a fine aggregate, locally - sourced natural sand with a maximum size of 4.75 mm was used, which complies with IS 383-1970 grading zone II. Through sieve analysis, the fineness modulus and grain size distribution of river sand was calculated. The table

lists the physical properties of fine aggregate, which may be purchased from nearby vendors.

**Table 2: Fine aggregate physical characteristics**

S.No	Property	Test result
1	Specific gravity	2.64
2	Fineness modulus	2.52
3	Zone	II
4	Water absorption	1%

### C. Pumice Powder

A naturally occurring lightweight aggregate known as pumice stone is created when molten volcanic material suddenly cools. Viscous magma that is primarily siliceous and rich in dissolved volatile components, particularly water vapour, erupts from volcanoes during eruptions to produce pumice. Pumice can be utilised as a lightweight aggregate since it is both light and robust. When molten lava erupted from a deep location beneath the earth's crust, gas was able to escape, which is why they were so light. Due of its small weight and porous texture, pumice can float for a long time—sometimes years—before it ultimately gets wet. The bulk density of pumice, a light-colored, froth-like volcanic glass, ranges from 500 to 900 kg/m<sup>3</sup>.

**Table 3. Properties of Pumice stone powder**

TEST	RESULT
Moisture	0.98 %
Silicon Di Oxide	63.87 %
Aluminium Trioxide	11.47 %
Calcium Oxide	2.37 %
Magnesium Oxide	1.00 %
Sodium Oxide	6.81 %
Potassium Oxide	0.94 %
PH (5% Aq. Suspension)	8.20
Bulk Density	1.05 g/cc
Water Absorption	30 ml/100g



**Fig 1.Pumice powder**

### D. Slag Sand:

Slag Sand is an alternate material to River Sand. Natural resources are being disrupted sensitively as a result of the rapid extraction of river sand, which is being employed widely in the building sector as per with cement. Natural sand gives less compressive strength when compared with slag sand. The bonding strength varies due to the kind of stones used. When the truck changes the fineness modulus is changed so the mix has to be changed often and then. Slag sand is obtained at the end from the iron and steel industry. It is formed by quenching molten iron in a blast furnace slag in water or steam and then drying and finally grinding it to a fine powder. It is a non-metallic product. Slag sand has a major constituent CaO which increases compressive Strength. The major advantage of Slag sand is it limits the increase of temperature and makes the heat of hydration reaction a bit slower. For this study, slag sand was transported from JSW Industry Anantapur. Physical properties of Slag sand shown in below table.

**Table 4: Physical Properties of Slag Sand.**

S.No	Preliminary Tests	Results
1	Specific Gravity	2.65
2.	Zone	II

### E. Water:

Concrete must be mixed with clean water that has no dangerous quantities of oils, acids, alkalis, organic compounds, or other deleterious chemicals. The presence of these contaminants in the water may affect cement setting time, concrete strength, and reinforcing corrosion. In

this investigation, we used portable tap water from the college campus water plant that met the IS456-2000 standards for casting concrete and curing the specimens.

**F. Super plasticizer:**

In order to make high-strength concrete, superplasticizers (SP) are added to fresh concrete to enhance its workability and enable the water content to be dropped. Fosrac Conplast SP 430 Dis is the material utilized in this investigation.

**3.2. MIX PROPORTIONS**

To attain M60 grade strength, the concrete was designed in accordance with IS 10262- 2009, and a water-to-cement ratio of 0.28 was employed. Six distinct mixes of Concrete with varying proportions containing Pumice powder (0%,10%,20%,30%,40%,50%) and Slag sand of 100% were tested to analyze the strength characteristics in terms of Compressive Strength. These cubes are immersed in acid solution for curing for 30 days,60 days and 90 days. After that the dry weight is noted and again find the compression strength by using UTM machine to find the durability strength of concrete. The table shows the designed proportions of the basic ingredients in concrete.

**Table.5. Mix proportions of different mixes**

S. No	Material	Composition
1.	Cement	340 kg/m <sup>3</sup>
2.	Fine aggregate	610 kg/m <sup>3</sup>
3.	Coarse aggregate	1240 kg/m <sup>3</sup>
4.	W/C ratio	0.5

**A. Casting of specimen**

As the largest size of aggregate exceeded 2 cm, the size of test specimen used was 100 x 100 x 100 mm cubes, as proposed by the IS Code.For casting the specimens, standard C.I metal moulds have been used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before concrete is poured into the mould. Thoroughly mixed concrete is filled in to mould.

**B.CURING**

After casting work is over moulded specimens are stored in room temperature for 24 hours. After this period specimens are taken out from moulds carefully without damaging the surfaces. These specimens are exposed to environment after demoulding for some time to remove water content. Then these specimens are placed in different curing solutions for further tests to be conduct. Specimens are kept for curing in water for 28 days. Acidic solutions (5%HCL,5%Mg<sub>2</sub>SO<sub>4</sub> and 5% H<sub>2</sub>SO<sub>4</sub>) are to be checked in regular intervals to maintain the pH value. Specimens are kept curing in these solutions for 30 days, 60 days and 90 days.

**4.Results & Discussions**

**4.1. GENERAL**

Listed below is a discussion of the properties that were evaluated while concrete was in its fresh condition and its hardened state, along with the experimental findings that were made

**4.2. FRESH PROPERTIES OF CONCRETE:**

The workability test is connected to the test of newly laid concrete. To determine the workability of concrete, four different types of tests are often employed. The four distinct test types are the flow test, the Vee bee test, compacting factor test, and the slump test. The slump test and the compacting factor were chosen as the workability tests for this investigation. Concrete's fluidity and consistency are indicated by its slump value. It measures how easily concrete can be shaped. Higher slump values indicate more workable concrete, whereas lower slump values indicate less workable concrete.

The findings demonstrate that, with compare to the slump of the control mix, the mix's slump values were enhanced by the inclusion of Pumice powder and slag sand. When the amount of used pumice powder was raised by 10%, the range of enhanced slump value rise from 76mm to 99mm. From this,with increase in ash content,The value of the slump gradually increased. Similarly, the results obtained from the compaction factor test also follow the same trend as the slump test.

**4.3. HARDENED PROPERTIES OF CONCRETE**

From the explanation above, it is clear that adding Pumice powder as an additive has a reasonable influence on the different properties of concrete

when it is still fresh. Therefore, it is crucial to consider whether these effects will lead to changes in the varying characteristics of concrete during its hardened condition. The experimental program was carried out as a consequence.

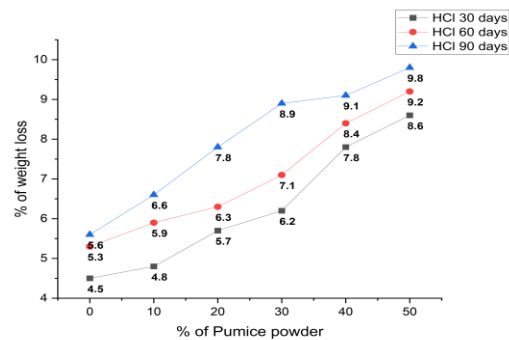
**Weight loss of specimen with acid curing**

The weight of concrete specimen was taken before and after immersing the specimen in water, sulphate, chloride and  $MgSO_4$ . The detailed results of mass loss are provided below. The result reveals that there is no weight change of all specimens immersed in water. The significant change in weight is noted when specimens are immersed in 5%  $H_2SO_4$ , 5% HCl and 5%  $MgSO_4$ . At 30 days, Weight loss is less in  $MgSO_4$  when compared with HCl and  $H_2SO_4$ . After further days of curing, it was shown that more weight loss occurs in specimen curing in  $H_2SO_4$  and HCl than  $MgSO_4$ . Concrete with Pumice Powder and Slag Sand has lower values compared to control mix because of the denser structure which reduces salts penetration. It was also agreed that higher amount of sulphate ions, gypsum and ettringite are influenced by more hydration product which provides growth in weight of specimen which containing slag sand in 5%  $H_2SO_4$  and 5% HCl. Under combined sulphate and chloride, there is significant mass increase from 28 days up to 90 days and CT concrete is more affected and this is mainly attributed by formation of more ettringite and gypsum. Incorporation of Pumice Powder and Slag Sand reduces the hydration process, moreover reduces the penetration of salt in concrete thus no significant increase in weight. This assure that incorporation of Pumice Powder in concrete could reduce the permeability of corrosive species which cause corrosion in reinforced structures and failure of structure. It is concluded that, addition of PP and SS increase the overall performance of concrete thus it is adequate under 5% HCl and 5%  $H_2SO_4$  and 5%  $MgSO_4$ .

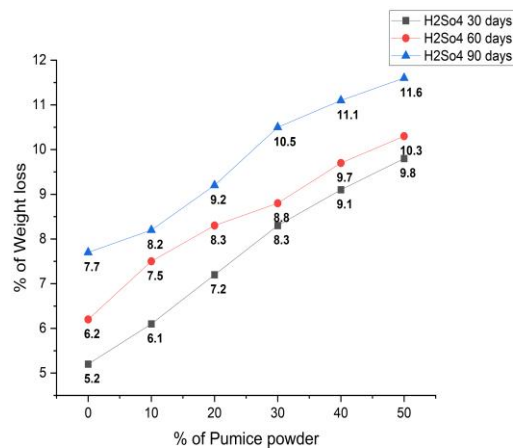


**Fig 6-Curing of specimen in acid solution**

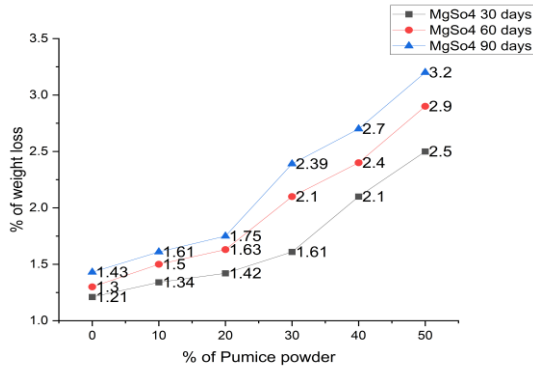
The Variation of mixes with % of weight loss are presented in the below figure No's  
 Comparison of weight loss with specimen cured in HCl acid solution



**FigNo:1 Comparison of weight loss with specimen cured in  $H_2SO_4$  acid solution**



**FigNo:2 Comparison of weight loss with specimen cured in  $MgSO_4$  acid solution**



FigNo:3 Compression strength of concrete immersed in Normal water

The compressive strength for the dried samples was determined after immersion test. The compressive strength of 28 days immersed samples in portable water are presented in Fig 12. The results demonstrate that the performance of concrete samples containing pumice powder of 10% is higher than the CT at 28 days when immersed in water, this indicates that the pozzolanic reaction initiated the growth of strength in concrete. It was noted, under presence of pumice powder and slag sand the pozzolanic reaction took place after 28 days and kept on increasing with concrete age.

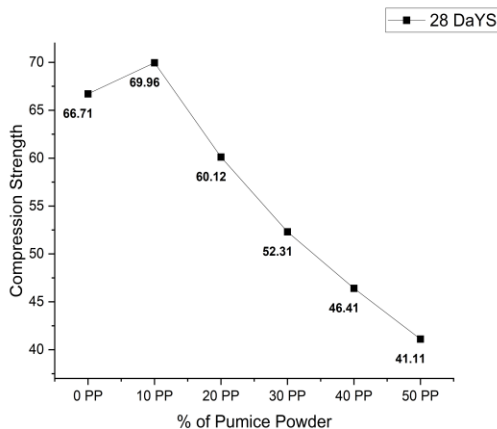


Fig 4 Compression strength for water curing

**Compressive Strength of the Specimens Immersed in 5% H<sub>2</sub>SO<sub>4</sub> Curing**

The compressive strength of samples immersed in 5% hydrogen sulphate curing for different exposure time are presented in Figure.

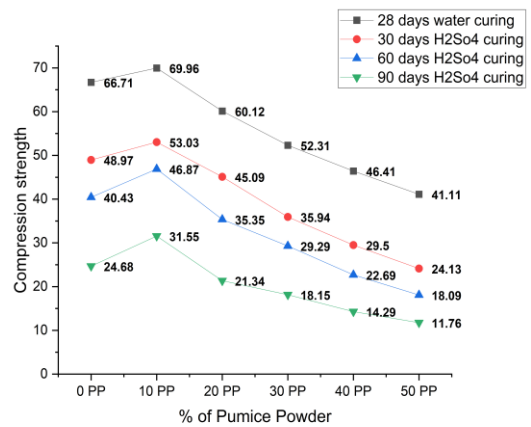


Fig 5. Compression strength for H<sub>2</sub>SO<sub>4</sub> Exposure

**Compressive strength of specimen immersed in MgSo4 solution**

Concrete samples under 5% MgSO<sub>4</sub> exposure condition show that the performance of concrete samples containing pumice powder and slag sand was found to be comparable with concrete of control mix at 28 days of immersion. It was noted that concrete samples with and without pumice and scoria after exposure to sulphate solution there is no significant damage caused for short-term exposure. The compressive strength of was found to be almost significant to the control mix cured in water to the specimen cured in MgSo<sub>4</sub> for 30days respectively. There is a minimum weight loss in the specimen for long term curing and the results are shown in below.

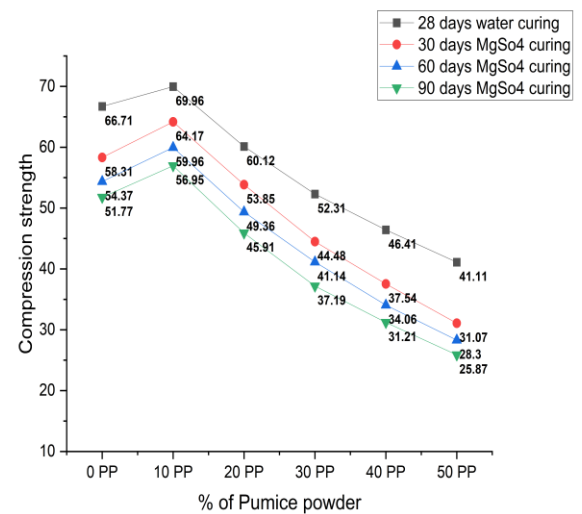


Fig 6. Compression strength for MgSo<sub>4</sub> Exposure

Compressive strength of specimen immersed in HCL solution The compressive strength of samples immersed in 5% hydrogen chlorate curing for different exposure time are presented in Figure.

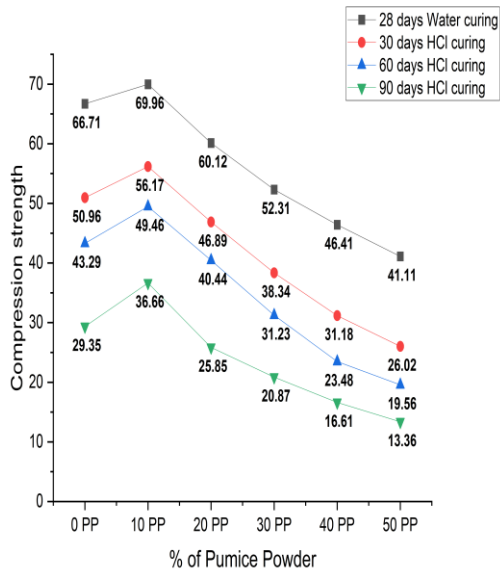


Fig 7. Compression strength for MgSO<sub>4</sub> Exposure

Comparison between H<sub>2</sub>SO<sub>4</sub>, HCL and MgSO<sub>4</sub>

a) For 30 days Exposure

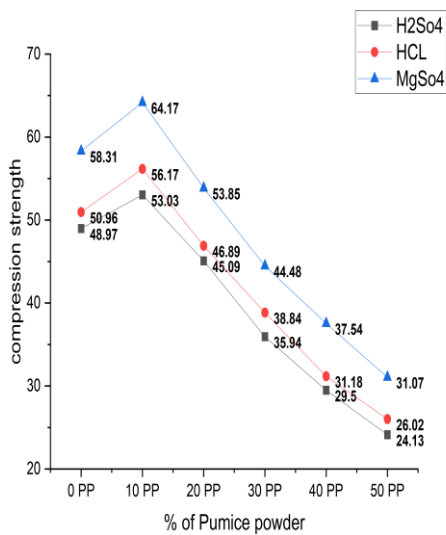


Fig 8. Compression strength for 30 days

From above shown graph, it is clear that the compression strength is high in MgSO<sub>4</sub> when compared with HCL and H<sub>2</sub>SO<sub>4</sub> for 30 days Exposure.

b) For 60 days Exposure

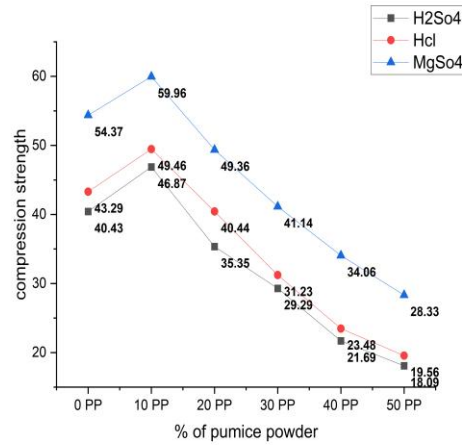


Fig 9. Compression strength for 60 days Exposure

From above shown graph, it is clear that the compression strength is high in MgSO<sub>4</sub> when compared with HCL and H<sub>2</sub>SO<sub>4</sub> for 60 days Exposure.

c) For 90 days Exposure

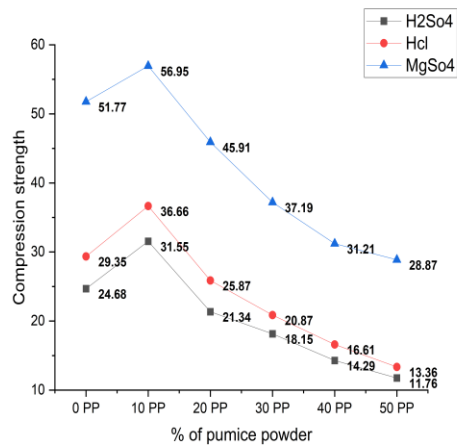


Fig 10. Compression strength for 90 days Exposure

The concrete containing pumice powder of 10% and slag sand of 100% have more compression strength in acid attack of 30 days, 60 days and 90 days. By this, we can state that the durability strength is high when concrete having pumice powder and slag sand.

### 5. Conclusion

The main aim of this study is to determine the compressive strength and durability of cubes in which cement is replaced with pumice powder and river sand with slag sand in different proportions. Durability tests such as resistance to acid attack ( $H_2SO_4$ , HCL,  $MgSO_4$ ) with 5% dilute acid solution will be used for exposure of 30 days, 60 days and 90 days and compressive strength of cubes will be tested. Weight loss due to acid exposure was also measured.

1. Replacing cement with pumice powder up to 10% increases the compressive strength and durability considerably.
2. Pumice Powder and slag sand are cheaper than the cement and sand as they are waste material it is economical to use in the concrete for sustainability.
3. Durability of concrete increases by replacement of cement with pumice powder.
4. From our experimental work carried out as the strength of concrete when replaced with 10% cement is increased and the strength of concrete when replaced with 20% cement is decreased. Hence it is recommending the use of pumice powder between 10- 20% as cement replacement for optimum results.

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