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A Critical Analysis of Pumice Stone Powder Influence on the Performance of Engineered Cementitious Composite

Muppalla Venkata Sai Surya Pratap Chowdary[1], Vennam Swathi[2], SS.asadi[3]
[1,2,3]Department of Civil Engineering, Vignan's Foundation for Science, Technology and Research (Deemed to be University), Vadlamudi, Guntur 522213, Andhra Pradesh, India

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Abstract:

Engineered Cementitious Composite (ECC) is a high tensile construction composite. This is using worldwide as an alternative of other composites due to its characteristics. This has properties such as early strength, self-healing and strain hardening nature, etc. The materials which are involving in the preparation are responsible for that but high cement content may lead to global warming due to emission of co2 into the environment. To avoid this, Pumice stone powder of 0%, 5%, 10%, 15%, 20%, and 25% was investigated. The properties of ECC with fly ash to cement ratio (F/C) is 1.6 was studied. The specimens were cased and cured for7, 14, and 28 days to study the mechanical characteristics and impact on early strength. Flowability of ECC increased with increasing of pumice stone powder.7 days cured specimens showed the decrease in the strength with increasing dosage of pumice stone due to slow pozzolanic action. Later the strength increased with increasing curing period and the optimum at 10% pumice stone powder.
Keywords: *Engineered Cementitious Composite, Pumice stone powder, Cement, early strength, Fresh properties, Mechanical characteristics*

1. Introduction

Engineered Cementitious Composite (ECC) is a high ductile construction composite. The materials which are using in the preparation of this composite such as cement, Poly vinyl alcohol fibers (PVA), fly ash, water, Polycarboxylate ether, and Silica sand, etc are responsible for its characteristics. The tensile strain of this composite will increase more than 3% with the utilization PVA fibers and this is greater than conventional and fiber reinforced concrete [1, 2]. These fibers are also responsible for the ductility and bridging of cracks while subjected to heavy loads. The cracks which forms in the conventional concrete at loading condition that can expand due to the utilization of coarse aggregates. That was excluded by past researchers with introducing novel composite (ECC) [3, 4]. But it consists of high cement content and that responsible for the co_2emissions. Pozzolanic materials such as Metakaolin, fly ash, silica fume etc can reduce this problem [5, 6]. In this investigation, Pumice stone powder was used in place of cement and studied the influence on fresh and mechanical characteristics of ECC.

2. Objectives

The following objectives were framed to study impact of Pumice powder on characteristics of ECC.

- Determination of Flowability of composite
- Analysis on early strength of composite
- Performance at optimum percentages of pumice stone for cement replacement

3. Experimental investigation

3.1 Materials

In the present work, following materials were used.

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3.1.1 Cement

Cement is one of the worldwide using construction ingredients. This occupies the major portion in the ECC after fly ash dosage. This is one of the binding materials that hold ingredients in the composite. This was used based on IS 12269-1987[6]. The properties of Ordinary Portland Cement (OPC) used in this investigation were mentioned in table-1.

Table-1: Characteristics of OPC

Characteristics	values
Specific gravity	3.14
Consistency	32
Initial setting time	40min
Final setting time	430min
Fineness	5%

3.1.2 Fly ash

Fly ash is one of the pozzolanic materials. The combination of fly ash with cement can reduce the impact of cement on the environment and also improves the performance of ECC. Class-F category fly ash based on ASTM 2012a [7] was used. The chemical characteristics of fly ash were mentioned in table-2.

3.1.3 Pumice powder

Pumice powder was used to reduce the cement content in ECC. This is one of the pozzolanic materials and is formed by crushing of pumice stones. The chemical composition of this composite is mentioned in table-2.

Table-2: Chemical composition of fly ash and pumice powder

Chemical composition	Fly ash (%)	Pumice powder (%)
Sio_2	59.07	78.5
Al_2o_3	25.63	15.8
Fe_2o_3	4.57	1.4
Cao	2.78	0.65
Mgo	1.22	0.05
Tio_2	0.83	0.2
others	5.9	3.60

3.1.4 Silica sand

Silica sand as fine aggregate with the maximum grain size of 200µm and mean size 100µm was used in this investigation. This type of fine aggregate is more suitable for ECC due to that responsible for self-consolidations observed from past researchers [7-9].

3.1.5 Polyvinyl alcohol (PVA) fibers

PVA fibers were utilized in the preparation of ECC. Normally oiled fibers are using in the construction field but the cost more compare to Unolied fibers. To reduce the cost of construction, Unolied fibers were preferred in this investigation. These fibers had 6mm length and tensile strength of 1600MPa.

3.1.6 Water

Locally available water was used in this investigation that free from impurities. The PH of 6.5 was obtained and that is within the limits to avoid the impacts by alkaline or acidic nature water. Super plasticizers are used along with water in mixing for better workability.

3.1.7 Superplasticizers

Polycarboxylate ether was used as Super plasticizer based on ASTM C494 [8]. This type of superplasticizers different from others due to long parallel chains and that can improve the flow ability and more suitable for high strength composite especially ECC.

3.2Mix proportions

The following mix proportions were considered to study the impact of pumice stone powder on the performance of ECC.

Table-3: Mix proportions of ECC mixtures

Mix no	Constituents(Kg/m^3)						
	Cement	Fly	Pumice	Water	Silica	Polyvinyl	Polycarboxylate ether

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		as h	pow der		san d	alcoho l fibers	
1	467	74 7	-	319	428	26	4.35
2	444	74 7	23	319	428	26	4.35
3	420	74 7	47	319	428	26	4.35
4	397	74 7	70	319	428	26	4.35
5	374	74 7	93	319	428	26	4.35
6	350	74 7	117	319	428	26	4.35

Here, the mix composition was shown based on research work and limited to 25% with 5% increment. The dosage of water and superplasticizers maintained as constant and prepared 6 ECC Mix proportions. These mixtures were used to analyze the impact of pumice powder on fresh, mechanical characteristics of ECC.

3.3 Mixing process and casting of specimens

The Pan mixer with 120 litre capacity was considered for mixing of ECC. The materials cement and fly ash mixed for 3 minutes and later pumice powder, silica sand, PVA fibers were added. For this, Polycarboxylate ether, water added and mixed for 2min.The mixing process is adjusted due to local material conditions. These mixtures poured in casting moulds of 70mm×70mm×70mm cube, Ø150mm×300 mm cylinder and 500mm×100mm×100mm prisms. After that day, specimens were de mounded and shown in figure-1. The specimens were casted according to order from Mix-1to Mix-6. All the specimens were placed in the curing tank for 7, 14, and 28days. The mechanical strength of different ECC mixtures was determined.

Figure-1.Demoulded ECC specimens

4. Results and discussions

The influence of pumice powder on characteristics of ECC was determined and mentioned below.

4.1. Fresh properties

Flowability test was conducted to study the workability of ECC Mixtures and that was shown in table-4.

Table-4: Workability of ECC mixtures

Mix no	Slump flow	Flow time(sec)
1	705	1.32
2	707	1.28
3	711	1.29
4	712	1.27
5	714	1.25
6	719	1.26

The deformability factor = $\frac{(\text{Slump flow} - \text{Bottom diameter of the slump cone})}{\text{Bottom diameter of the slump } cone}$ <2.75 for good consolidation [3, 9]

The slump flow increased with the increasing dosage of pumice powder and flow time decreased. All the ECC mixtures showed good self-consolidation.

4.2. Compressive strength

The specimens were tested after curing of 7, 14, and 28days based on IS: 516-2013 [10]. Total 18 cubes were considered for analysis the compressive strength of ECC mixtures. The strength of composite was shown in the following figure-2.

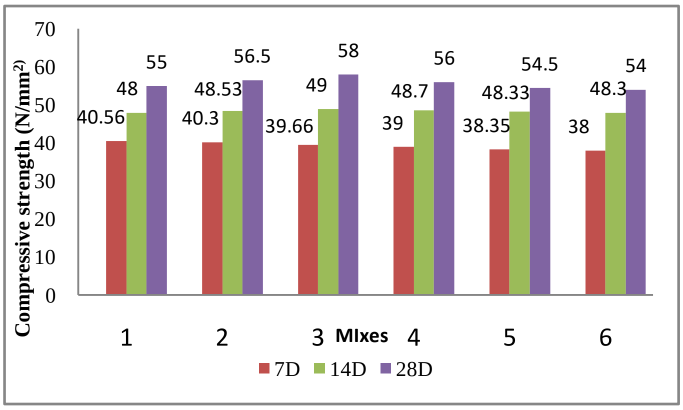

Figure-2.Compressive strength of mixtures

The compressive strength of Mix-1 represents the reference mix. It decreased from Mix-1 to Mix-6 gradually due to the addition of pumice powder for 7days cured specimens. The slow pozzolanic reaction of pumice powder is responsible for that in ECC. The strength at 14, 28 days showed optimum for mix-3 compared to other mixes. The increased curing period increased the strength and that optimum for ECC mixtures at 10% replacement of pumice powder.

4.3 split tensile strength

The split-tensile strength of specimens which cured for 7, 14, and 28days were determined based on IS 5816-1999 [11].The 18 cylinders were considered for the analysis of split-tensile strength of mixtures. The strength of the composite was shown in figure-3.

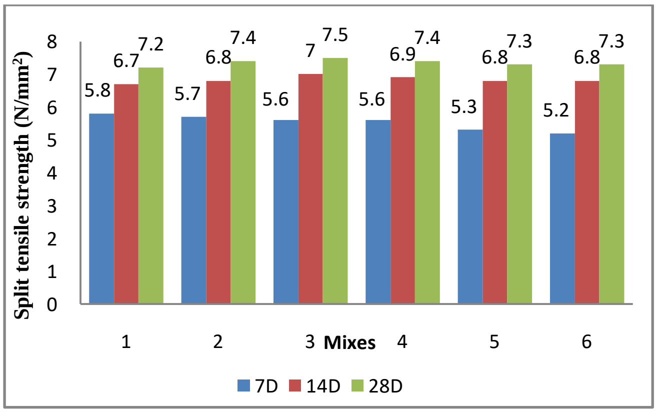

Figure-3.Split tensile strength of mixtures

The Split tensile strength decreased from Mix-1 to Mix-6 gradually due to the addition of pumice powder for 7days cured specimens. The strength at 14, 28 days showed optimum for mix-3 compared to other mixes. The increased curing period increased the strength and that optimum for ECC mixtures at 10% replacement of pumice powder.

4.4Flexural strength

The Flexural strength of specimens which cured for 7, 14, and 28days were tested based on IS: 516-1959 [12].The 18 prisms were considered for the analysis of Flexural strength of mixtures. The strength of the composite was shown in figure-4.

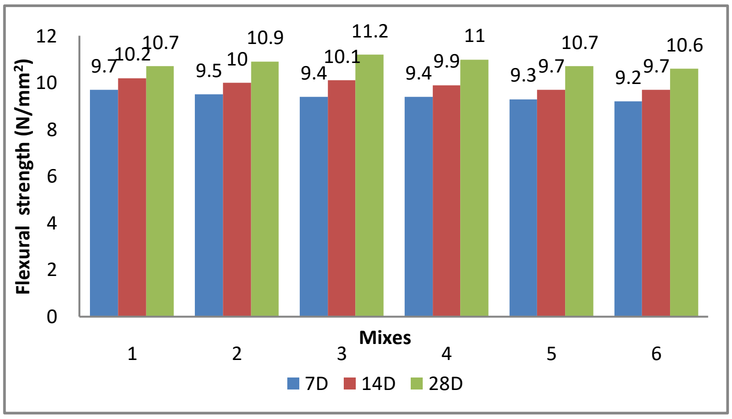

Figure-4.Flexural strength of mixtures

The Flexural strength decreased from Mix-1 to Mix-6 gradually due to the addition of pumice powder for 7days cured specimens. The strength at 14, 28 days showed optimum at 10% replacement of pumice powder compared to other mixes. The increased curing period increased the strength and that optimum for mix-3 ECC.

5. Conclusions

In this present study, the impact of pumice powder on the performance of ECC has been investigated. Based on this study, below conclusions were framed.

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i. The flowability of composite mixes was increased with the addition of pumice powder. From Mix-1 to Mix-6 the flow time gradually decreased. The flowability increased by 1.98% and flow time decreased by 4.54% from Mix-1to Mix-6 respectively.
ii. The compressive strength of mixes decreased from Mix-1 to Mix-6 with the addition of pumice powder due to slow pozzolanic reaction. Later that increased with the addition of pumice powder and maximum at 10% replacement at 28 days curing period. The increase in strength happened from 14days of curing of specimens.
iii. The split tensile strength of mixes also decreased from Mix-1 to Mix-6 at 7days of curing. Later that increased for 14 days, 28 days cured specimens and maximized at 10% of pumice powder utilization in ECC.
iv. The flexural strength of mixes decreased from Mix-1 to Mix-6 with replacement of cement by pumice stone powder for 7days cured specimens. That was increased with curing period and the 14 and 28 days cured Mix-3 specimens showed the optimum strength.

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