Flowability and Compressive Strength of Lime Stone Calcinated Clay Cement based ECC

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Abstract. This article helps to determine the exact flowable behaviour and compressive strength of Lime stone calcinated clay cement based Engineered cementitious composite. To make more sustainable and flowable ECC, cement is replaced with lime stone calcinated clay cement and PVA fibres are replaced with polypropylene fibres. Incorporation of fibres improves the toughness of casted specimen. Compressive strength test was performed to investigate the hardened property of ECC. In addition, flow table test was done to investigate the green properties of LC3 based ECC. Experimental studies showed higher flowability of the LC3 based ECC with PP fibre was at low fibre content. This research article recommends the use of LC3 based ECC with the pp fibre in case of self-compactable ECC with little modifications. Looking forward, further attempts could provide quite beneficial to the literature.

Keywords: LC3 based cement, ECC, metakaolin, Lime stone powder, fly ash.

1. Introduction

ECC is the most happening material in construction industry. This research establishes a relatively advanced area which has developed from Engineered cementitious composite. Engineered cementitious composite (ECC) itself also called as ductile concrete (or) bendable concrete (or) flexible concrete. Absence of coarse aggregate requires the larger amount of cement content. High amount of cement could produce much more carbon emissions rather than normal concrete. One of the major topics to be investigated in this particular field is use of different supplementary materials to improve the properties of ECC as well as to decrease the carbon emissions. Hence, supplementary materials are introduced in the ECC. Out of many few supplementary materials that can be used instead of OPC are Ground granulated blast furnace, Fly ash and Metakaolin etc… Generally, ECC comprises of OPC, Fly ash, silica fume, silica sand and PVA fibres. One of the best applications with PP based ECC is thin sheet with super fine river sand. Acoustic emission analysis method was used to evaluate the specimens at four different stages i.e., crack initiation stage, steady cracking stage, ultimate load stage and bearing capacity failure stage.[1]

Limestone powder helps to accelerate the cement hydration and easily reacts with aluminates. It actually protects from the expansive reactions produced by aluminates. So that, it can be prevented from cracking and stress.[2] Usage of more lime stone powder can make concrete coarser after ages.[3] A number of studies have investigated the use of different amounts of fly ash and its effectiveness. It has been found that the more amount of fly ash has a capability to reduce the compressive strength and enhance the deformability and also helps to reduce the crack width.[4]For the effective utilization of PVA fibres in ECC, Fibres were oiled to reduce the bonding between fibres and matrix. Thus, it makes the PVA based ECC high tensile toughness and ductile in nature.[5–7] It is also capable of absorbing...
good amount of energy and acts as seismic resistant. [8,9] PVA fibres cost and oiling of PVA fibres could make the ECC much costlier than the conventional concrete. One of the accessible ways of tackling this problem is the replacement of PVA fibres with PP fibres which are low cost. It has been mentioned that PP fibres has slightly better performance in compressive toughness and flexural strength when subjected to both static and dynamic loads.[10]

In this article PVA fibres are replaced with Polypropylene fibres.” Lime stone calcinated clay cement is a combination of 55% ordinary port land cement,15% lime stone, 30% Metakaolin.” It produces the low amount of carbon emissions rather than normal ECC. It also helps in producing the self-healing ECC.[11,12]However, in this present article self-healing behaviour evaluation is not highlighted. Polypropylene fibres were taken from ranges 1 to 2 % at each 0.2% intervals. For this study it was of interest to investigate the exact flowable behaviour and compressive strength of LC3 cement based ECC.

2. Experimental Program

2.1 Materials and properties: In this study, OPC of grade 53 confirming to IS 12269:2013 specifications, Fly ash quality is governed by IS 3812-part II- 2013, metakaolin quality confirming to IS 16354:2015, potable water was utilized. Properties of OPC, metakaolin and fly ash were represented in the Table 1. In this experiment, 2% of polypropylene fibres were added based on the weight of cement content. Polypropylene fibres are white in colour as shown in the Figure 1. For the proper dispersion of fibre content, PCE (poly carboxylate ether) based super plasticizer with density and pH value is 1.1 Kg/litre and 6.5 respectively. Super plasticizer was procured from the brand name Sika Viscocrete-3430. Table 2 represents mix proportions of different mix ids.

![Figure 1. Polypropylene fibres](image)

Table 1. Physical properties of OPC, Fly ash and Metakaolin

| Chemical composition (%) | OPC        | Fly ash    | Metakaolin |
|--------------------------|------------|------------|------------|
| SiO₂                     | 21.1       | 57.01      | 43.8       |
| Al₂O₃                    | 5.54       | 20.96      | 37.8       |
| Fe₂O₃                    | 3.10       | 4.15       | 0.38       |
| MnO                      | 0          | 0.033      |            |
| CaO                      | 64.39      | 9.79       | 0.9        |
| MgO                      | 1.10       | 1.75       | 0.91       |
| Na₂O                     | 0.23       | 2.23       | 0.22       |
| K₂O                      | 0.57       | 1.53       | 0.72       |
| SO₃                      | 2.52       | 0          | 0.21       |
| TiO₂                     | 0          | 0.68       | 0          |
| LOI                      | 1.45       | 0          | 0.68       |
| Specific gravity         | 3.15       | 2.38       | 2.2        |
2.2 Composition of mixes and Mix proportion
Mix proportion of ECC has no standard mix design. Control mix proportion was based on the previous experiments. Firstly, total amount of fine aggregate was added to mixer and rotated up to 2 min. Parallely, the water is mixed with the HRWR and VMA. Next, 90-95% of the chemical admixture-based water is added to ball mixer. Time elapse of 2 minutes was maintained for rotation in between of adding the materials cement and fly ash. Rest of the water is added to make the walls of mixer free from materials. Total mixture is allowed to rotate for 5 minutes, then mixture gets uniformly mixed. Later, Fibres were added to mixer and were enabled to rotate at high speed for proper dispersion of pp fibres. 200mm bottom diameter and 100 mm top diameter cone with 300mm height was taken to check the workability of the fresh mixture. Later, 70.6 mm cubes specimens and prepared for testing compressive strength. Figure 2 shows the cube specimens. Both the tests were tested confirming with Indian standards IS 516 1959 and IS 1199 1959.

Table 2. Mix proportions of different mix ids.

| Mix id | OPC  | MK  | LS  | FA   | PP  | Water | SP   |
|--------|------|-----|-----|------|-----|-------|------|
| Mix 1  | 490  | 0   | 0   | 1078 | 2%  | 470   | 6.37 |
| Mix 2  | 270  | 147 | 73  | 1078 | 2%  | 470   | 10.78|
| Mix 3  | 270  | 147 | 73  | 1078 | 1.5%| 470   | 9.8  |
| Mix 4  | 270  | 147 | 73  | 1078 | 1.2%| 470   | 8.82 |
| Mix 5  | 270  | 147 | 73  | 1078 | 1%  | 470   | 7.84 |

Note All units are taken in Kg/m³, except pp content in percentage (%)

Figure 2. Compressive strength test cube specimens

3. Results and discussion

3.1. Fresh properties of LC3 based ECC
From the Figure 3, it has been noticed that the slump values of LC3 based ECC were ranged from 680 mm to 700mm at different admixture content. It has been found the high fibre content requires more SP content to disperse properly. Flowability of LC3 based ECC was good at lower fibre content. Very slight differences are been observed at different mixes. Even though, for self-compacting concrete slump values ranges from 680 to 700 mm diameter confirming to EFNARC guidelines.[13] Thus, the mixes considered in this study is completely good at flowable behaviour.[14] An assumption can also be made the voids can be densified based on this LC3 based ECC. Lime stone powder with fly ash has capability to fill the voids as it has good packing effect.[2]
3.2. Hardened properties of LC3 based ECC

According to IS 516.1959, compressive strength was executed. At the age of 7 and 28 days, compressive strength of LC3 based ECC specimen was ranged from 29.626 MPa to 26.87 MPa and 32.56 MPa to 28.89 MPa respectively. Increase in the fibre content has very slight effect on compressive strength.[15] Figure 4 represents the compressive strength values of LC3 based ECC mixes proposed in this article. It has been observed that early strength was achieved up to 90% at the age of 7 days, due to addition of lime stone powder that reacts easily with aluminates present in the cement matrix.[2] Both incorporation of metakaolin and pp fibre reduced the compressive strength than the PVA based ECC, it is due to the high specific surface area of metakaolin and difference in the mechanical properties of pp fibres.[16,17]
4. Conclusions

On this basis, we conclude that

- The flowability of LC3 based ECC was ranged from 680 to 700 mm almost similar to the EFNARC standards. It was also achieved due to the constant proportion of metakaolin, lime stone powder content with low pp fibre content in the mix.

- The compressive strength of LC3 based ECC attained early strength at age of 7 days it is due to the incorporation of lime stone powder. But the usage of metakaolin and pp fibre gave the slight negative effect on the compressive strength due to the high specific surface area and poor mechanical properties of Polypropylene (PP) fibres compared to the Poly vinyl alcohol (PVA) fibres.

- The self-compactable ECC can also be achieved by using the viscosity modifying agent. It can also reduce the cost of the ECC and the carbon emissions can also be reduced due to use of supplementary materials instead of cement up to 45%.

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