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COMPARATIVE STUDY ON DURABILITY PROPERTIES OF ENGINEERED CEMENTITIOUS COMPOSITES WITH POLYPROPYLENE FIBER AND GLASS FIBER

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The durability characteristics of Engineered Cementitious Composites (ECC) with various fibers such as polypropylene and glass were investigated in view of developing composites with high resistance to cracking. ECC offer large potential for durable civil infrastructure due to their high tensile strain capacity and controlled micro-crack width. In this study, fibre volume fractions (0.5%, 1%, 1.5%, and 2%) of both polypropylene and glass fibers varied and durability measures such as a rapid chloride penetration test, sorptivity, water absorption, acid attack, and sulphate attack were measured. Increasing the fiber content up to 1.5% improved the durability properties of ECC. The test results indicate that the glass fiber-reinforced Engineered Cementitious Composites have better durability characteristics than polypropylene fiber-reinforced ECC.

Keywords: Engineered Cementitious Composites, Polypropylene fiber, Glass fiber, Durability, Fly ash, Concrete.

1. INTRODUCTION

Concrete is brittle and rigid in nature. This brittleness of concrete increases with an increase in compressive strength. High strength concrete possesses high brittleness than low strength concrete.

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For the past few decades, due to the development of high-rise buildings, concrete with increasingly high compressive strength is used for structural applications [1], and this leads to the development of cracks when high stress concentration occurs within. In order to overcome this, concretes with high tensile strain capacity, known as Engineered Cementitious Composites (ECC) have been developed.

ECCs are a class of new generation high performance fiber-reinforced cementitious composites with high ductility and medium fiber content [2]. ECC exhibits a pseudo strain- hardening behaviour under a tensile load by developing micro cracks [3]. The tensile strain capacity of ECC is in the range of 3 – 5%, when compared to the 0.01% of normal concrete [4]. The strain-hardening behaviour of Engineered Cementitious Composites is attracting their potentiality in structural applications [5, 6]. The fiber volume fraction of ECC is limited to 2% of the total volume of the concrete to keep the permeability of the composites low [4]. The large strain capacity of ECC is due to the development of multiple cracks, instead of a continuous increase of a crack opening. The damage tolerance and controlled crack width of ECC improve the durability and serviceability performance of infrastructures. ECC has a variety of unique properties, including tensile properties superior to other fiber-reinforced composites. Engineered Cementitious Composites are suitable for structural applications [7] and are widely used in bridge deck overlays and coupling beams in high rise buildings.

Engineered Cementitious Composites have high durability due to their tight crack width and closely spaced microstructure [8]. ECCs maintain multiple cracking and strain–hardening behavior with ductility above 2% after 200 days of environmental exposure [5]. The long-term durability properties of Engineered Cementitious Composites are attractive when compared to ordinary concrete because of its low permeability. Past studies on durability properties of Engineered Cementitious Composites were based on the polyvinyl alcohol fiber-reinforced ECC or with polyethylene fiber-reinforced ECC [8, 9, 10, 11]. In order to develop a new class of ECC, polypropylene and glass fibers were reinforced with ECC in this study and durability testing including a sulphate attack, chloride attack, water absorption, sorptivity, and a rapid chloride penetration test was performed to assess the effect of polypropylene fiber and glass fiber on the durability properties of ECC.

2. Experimental procedure

The objective of this investigation is to identify a new class of ECC with high resistance to cracks, higher durability, better structural performance, and longer service life. In this view, polypropylene and glass fibers were monolithically added into the ECC and the ideal mix ratio suggested by Michael and Victor [7] (as shown in Table 1) was used as the guideline to determine the proportions of various constituents in the composites. Eight mixes of ECC were prepared by monolithically adding the polypropylene fiber and glass fiber into the base mix in different fractions (0.5%, 1%, 1.5%, and 2%) to the volume of ECC, and one conventional mix without fiber was prepared as well. The water/cement ratio and the amount of super plasticizer from the ideal mix were altered by conducting the marsh cone test on various trial mixes. To access the workability of 9 mixes, a mini slump cone test was conducted. In order to identify the mechanical and durability properties of each mix, specimens were cast per the given standards. To evaluate the tensile strain capacity of ECC, a direct tensile strength test was conducted on the dog bone shaped specimens of each ECC mix and on the conventional mortar specimens. The results indicated that the direct tensile strength of ECC was 4.2 % higher than that of conventional mortar. This confirmed the newly-developed composites as ECC, and tests such as a compression strength test, acid attack, sulphate attack, RCPT, sorptivity, and a water absorption test were conducted and the results were calculated. Based on the results, an optimum amount of fiber required to produce ECC with high resistance to cracks and low permeability was identified.

Table1. Basic Mix Proportions of ECC

Mix	Cement	Fine Aggregate	Fly ash	W/C	Volume of Fiber (%)*
M45	1	0.8	1.2	0.56	2%

3. Materials

The ingredients used to make the ECC were cement, fine aggregate, water, super plasticizer, fly ash, and fiber. Coarse aggregates were not used in the ECC mix deliberately in order to reduce the brittleness number of the composites [1]. In this study, ordinary grade 43 Portland cement was used and its properties are shown in Table 2. Polypropylene fiber (PF) and glass fiber (GF) with fiber volume fractions of 0.5%, 1%, 1.5%, and 2% were monolithically added into ECC. The properties of polypropylene and glass fibers are shown in Table 3. Super plasticizer was used as an admixture to achieve higher workability without altering the water content in the mix. The properties of the super plasticizer are shown in Table 4. Locally available river sand was used as a fine aggregate which conformed to IS: 383-1970. The properties of the fine aggregate are shown in Table 5. Class F fly ash conforming to IS: 3812-1987 was used to reduce the content of the cement.

Table 2. Properties of Cement

S.No	Physical properties	Test values
1	Standard consistency	28.32 %
2	Initial Setting time	45 Minutes
3	Final setting time	250 Minutes
4	Specific gravity	3.15
5	3 days compressive strength in N/mm^2	28
6	7 days compressive strength in N/mm^2	37
7	28 days compressive strength in N/mm^2	45

Table 3. Properties of Polypropylene and Glass Fibre

Fiber	Fiber Length (mm)	Tensile strength (MPa)	Young's modulus (GPa)	Fiber Elongation (%)	Density (kg/m^3)
PF	12	600	5	25	0.91
GF	12	2200	80	0-4	2.78

Table 4. Properties of Super Plasticizer

S.No	Chemical and Physical Properties	Values
1	Specific gravity	1.2
2	Chloride content	Nil
3	Air Entrainment	Approximately 1% air is entrained

Table 5. Properties of Fine Aggregate

S.No.	Property	Value
1	Specific gravity	2.5
2	Fineness modulus	2.49 %

4. Mix Proportions

The mix design of ECC is based on the micromechanics principle. Micromechanics are applied at the material constituent level which captures the mechanical interactions among the fiber, mortar matrix, and fiber-matrix interface [13]. It relates the macroscopic properties to the microstructures of a composite and forms the backbone of materials-based design. Typically, polypropylene and glass fibers are millimeters in length and tens of microns in diameter, whereas sand particles, cement grains, and mineral admixture particles range from the nano-to-millimeter scale. However, the micromechanics-based mix design requires the pullout test to be carried out on the polypropylene and glass fibers, which is difficult to achieve in laboratory settings.

One mix of cement mortar and four mixes of ECC M45 with different proportions of glass and polypropylene fibers were prepared and examined to quantify the properties of the ECC. Table 6 presents various compositions of ECC mixtures. The proportions of fibers varied at 0%, 0.5%, 1%, 1.5%, and 2% from the total volume of the concrete. After the trial mixes, the water/cement ratio was selected as 0.54. A Marsh cone test was conducted and the optimum amount of super plasticizer dosage was found to be 1.3% to the weight of cement.

Table 6. Mix Proportions of Polypropylene ECC and Glass ECC

S. No	Quantities in kg/m^3				
	Cement	Fine Aggregate	Fly ash	% of fiber	Water
1	570	456	684	-	307.8
2	570	456	684	6.27	307.8
3	570	456	684	12.54	307.8
4	570	456	684	18.81	307.8
5	570	456	684	25	307.8

5 Durability tests of ECC

5.1 Sulphate attack test

A sulphate attack test was conducted on 70.6mm x 70.6mm x 70.6mm cube specimens after 28 days of water curing. The specimens were weighed and immersed in water diluted with 5% sodium sulphate powder, as shown in Fig. 1. The cubes were tested after 30, 60, and 90 days for weight loss and compressive strength. Compression strength tests were conducted on three cube specimens of each mix, and the average values were considered. The influence of varying percentages of fiber in the ECC on the immersed sodium sulphate is shown in Table 7. The percentage fiber versus the compressive strength of the ECC specimen after 90 days of sulphate curing is shown in Fig. 2. Fig. 3 shows the compressive strength of the ECC specimen after 28 days of water curing versus the percentage of fiber present. There was an increase observed in the percentage of weight loss along with an increase in the curing periods of 30, 60, and 90 days. The percentage of weight loss and compression strength loss of both the polypropylene fiber and glass fiber was less when compared to the conventional mortar specimens. This shows that cement mortar is less dense than the ECC mix, and the presence of fiber in ECC makes the mix denser and increases its durability. Similarly, the fiber volume fraction of 1.5 % in ECC had less weight loss when compared to the other mixes. The compressive strength of the ECC increased up to the 1.5% mix, and then decreased for both the polypropylene fiber and glass fiber ECC.

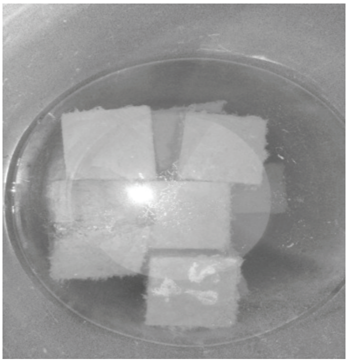

Fig 1. Specimen immersed in water diluted with 5% sodium sulphate powder

Table 7. Results of Sulphate Attack Test

Mix	Initial Weight (g)	% weight loss @ 30 days	% weight loss @ 60days	% weight loss @ 90 days	Compressive strength after 28 days water curing	Compressive strength @ 90 days after sulphate attack
CC	698	1.12	2.1	2.9	31.6	24.7
PECC 0.5	708	0.98	1.68	2.12	33.2	26.2
PECC 1.0	708	0.93	1.65	2.05	37.5	29.5
PECC 1.5	706	0.87	1.58	1.98	40.7	32.4
PECC 2.0	711	0.91	1.64	2.17	38.3	30.1
GECC 0.5	706	0.9	1.53	1.85	34.3	30.9
GECC 1.0	704	0.89	1.55	1.82	38.7	33.8
GECC 1.5	710	0.87	1.5	1.78	42.9	37.4
GECC 2.0	713	0.92	1.54	1.83	40.2	35.1

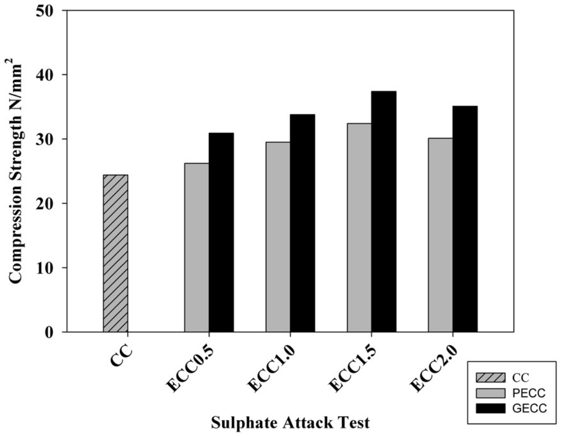

Fig 2. Results showing compressive strength after 90 days of sulphate attack

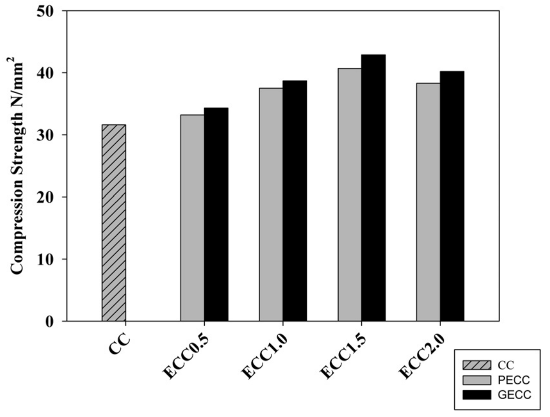

Fig 3. Results showing compressive strength after 28 days of water curing

5.2 ACID ATTACK TEST

An acid attack test was conducted on 70.6mm x 70.6mm x 70.6mm cube specimens after 28 days of water curing. The specimens were weighed and immersed in water diluted with 1% of sulphuric acid, as shown in Fig. 4. The acid attack was evaluated by measuring the percentage of weight loss and compressive strength of the 3 cube specimens of each mix at 30, 60, and 90 days, and the average values were considered. The percentage of weight loss and compressive strength for various mixes of polypropylene and glass fiber ECC is shown in Table 8 and Fig. 4. It was proven that the percentage of weight loss increases with an increase in the curing period. The fiber volume fraction 1.5% of polypropylene fiber and glass fiber ECC had less weight loss and higher compressive strength when compared to other ECC and mortar mixes. It is therefore evident that ECC with 1.5% of fiber added is denser and contains less pores when compared to the other mixes.

Table 8. Acid Attack Test Results

Mix	Initial Weight (g)	%weight loss @ 30 days	% weight loss @ 60days	% weight loss @ 90 days	Compressive strength after 28 days water curing	Compressive strength @ 90 days after acid attack
CC	696	1.42	2.33	3.58	31.6	23.0
PECC 0.5	702	1.18	2.01	3.26	33.2	24.5
PECC 1.0	705	1.15	1.96	3.25	37.5	27.8
PECC 1.5	708	1.07	1.92	3.2	40.7	30.2
PECC 2.0	707	1.12	1.96	3.24	38.3	28.4
GECC 0.5	711	1.26	2.06	3.31	34.3	28.3
GECC 1.0	710	1.2	2.02	3.27	38.7	30.2
GECC 1.5	707	1.18	1.98	3.21	42.9	33.1
GECC 2.0	712	1.21	2.05	3.25	40.2	31.5

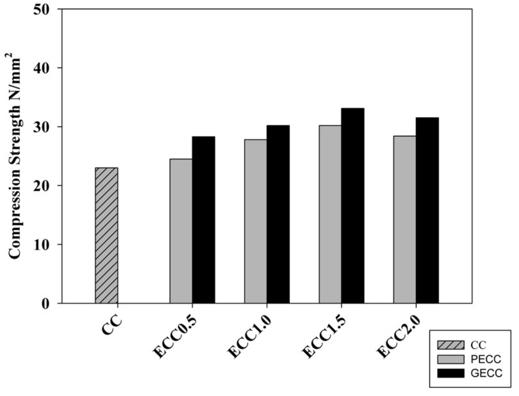

Fig 4. Results showing compressive strength after 90 days of acid curing

5.3 Saturated water absorption test

Water absorption tests were carried out on a 70.6mm x 70.6mm x 70.6mm cube specimen after 28 days of curing, per ASTM C 642 [14, 15]. A water absorption test was conducted on 3 cube specimens for each mix, and the average values were taken into account. The water-saturated specimens were weighed and allowed to dry in a hot air oven at a temperature of 105° C (Fig. 5), and were then cooled and weighed. The weight differences between the measured water saturated mass and the oven dried mass gives the water absorption value. The influence of the varying percentages of fiber on the immersed water absorption is shown in Table 9. The percentage of fiber versus the percentage of water absorption is shown in Fig. 6. The absence of fiber in cement mortar leads to higher permeability, which results in higher water absorption than that of the ECC. The percentage of water absorption decreased until reaching the 1.5% amount of fiber in ECC, and increased steadily thereafter.

Fig 5. Specimen placed in oven

Table 9. Water Absorption Test Results

Mix	Initial Weight (g)	24 Hours in oven (g)	Immersed in water (g)	% water absorption
CC	701	670	725	7.52
PECC 0.5	712	688	736	7.12
PECC 1.0	714	662	708	6.94
PECC 1.5	712	680	720	5.88
PECC 2.0	710	691	742	7.38
GECC 0.5	703	669	715	6.87
GECC 1.0	706	680	717	5.44
GECC 1.5	707	676	704	4.14
GECC 2.0	706	684	730	6.72

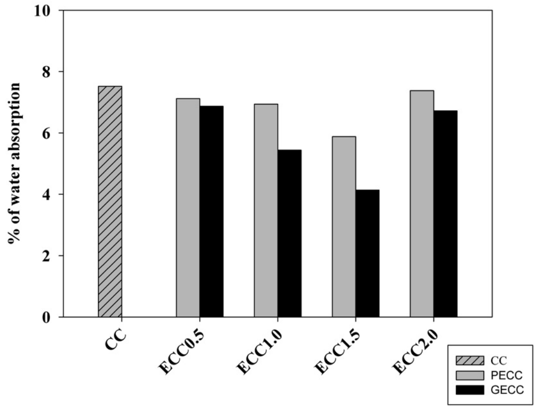

Fig 6. Results showing % of water absorption after 28 days of water curing

5.5 Sorptivity test

The sorptivity test was based on ASTM C 1585. Sorptivity can be determined by measuring water absorption by capillary rise action on reasonably homogenous material [16]. After 28 days of curing, 70.6mm x70.6mm x 70.6mm cube specimens were dried in an oven at a temperature of 100+10^o C [17]. The specimens were then placed in a tray with a water level no more than 5mm above the base of the specimen, as shown in Fig. 7. The flow from the peripheral surface was prevented by sealing it with non-absorbent coating. The quantity of water absorbed was measured over a time period of 30 minutes by removing the specimen from the tray and weighing it after wiping off excess water from its surface. The cumulative water absorption increased as the square root of elapsed time (t).

I = S* t 0.5

Therefore Sorptivity S = I/ t 0.5

Where t = elapsed time in minute.

I = Δ w / Ad

Δ w = Change in weight = W2 –W1 W1 = Oven dry weight of specimen in grams

W2 = Weight of specimen after 30 minutes capillary suction of water in grams

A = Surface area of the specimen through which water penetrated

d = density of water

The sorptivity coefficient decreases up to the 1.5% mix, and then it tends to increase for both the polypropylene and the glass fiber ECC, as shown in Table 10. The percentage of fiber volume fraction versus the sorptivity value is shown in Fig 8. The sorptivity test results clearly indicate that cement mortar has higher number of pores when compared to the ECC mixes. Sorptivity values of glass fiber-reinforced Engineered Cementitious Composites were lower than those of polypropylene fiber-reinforced Engineered Cementitious Composites and cement mortar.

Fig 7. Sorptivity test specimen

Table 10. Sorptivity Test Results

Mix	Dry Weight (W_1) g	Wet weight (W_2) g	Average S=I/t½ (mm/m$^{0.5}$)
CC	658	671	0.049
PECC 0.5	667	685	0.043
PECC 1.0	652	667	0.037
PECC 1.5	654	666	0.029
PECC 2.0	664	678	0.034
GECC 0.5	665	680	0.037
GECC 1.0	675	688	0.031
GECC 1.5	673	682	0.021
GECC 2.0	669	683	0.032

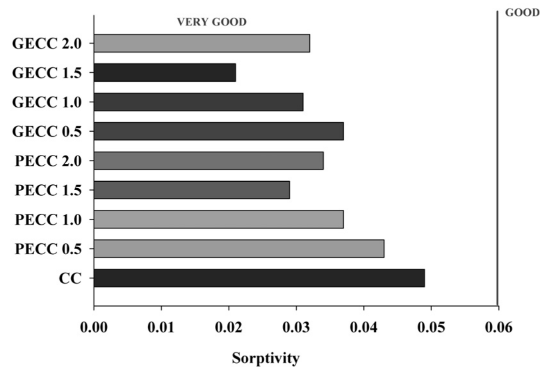

Fig 8. Variation of sorptivity with respect to percentage of fiber

5.6 Rapid Chloride permeability testing (RCPT)

The mixtures' resistance to chloride ion penetration was measured by the rapid chloride permeability test (RCPT) in accordance with ASTM C1202 [18]. It was performed by measuring the amount of electrical current passing through a sample which is 50mm thick and 100mm in diameter for 6 hours [19, 20]. For each mix, 3 disc specimens were tested and the average of the three specimen was considered as the RCPT value. A 60V DC was maintained across the ends of the samples throughout the test. One end was immersed in a 3% Sodium Chloride solution and the other in a 0.3M Sodium Hydroxide solution (Fig. 9). Based on the charge that passed through the sample, a qualitative rating was made of the concrete's permeability. Table 11 shows the variation in charge passing with respect to the various mixes of ECC. The charge passed versus the percentage of fiber is shown in Fig. 10.

Fig 9. RCPT experimental setup

Table 11. RCPT Test Results

Mix	Charge passed (Coulombs)	Chloride permeability
CC	812.5	Very low
PECC 0.5	771.1	Very low
PECC 1.0	762.4	Very low
PECC 1.5	751.6	Very low
PECC 2.0	767.3	Very low
GECC 0.5	746.4	Very low
GECC 1.0	734.8	Very low
GECC 1.5	725.2	Very low
GECC 2.0	747.5	Very low

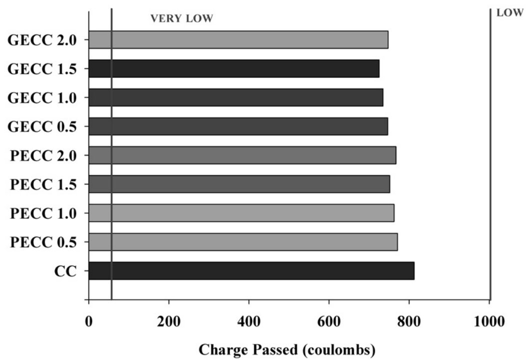

Fig 10. RCPT values of various mixes of ECC

6 CONCLUSIONS

This paper attempts to investigate the durability properties of ECCs with different volumes of fiber additives, ranging from 0.5% to 2.0%. It also compares the durability properties of ECC with those of cement mortar. Durability properties such as a sulphate attack, an acid attack, a saturated water absorption test, sorptivity testing, and a rapid chloride penetration test were adopted to verify the optimum amount of fiber required for the production of the ECC. The following conclusions were drawn from this study.

- ECC with a 1.5% fiber volume performs satisfactorily at all aspects of durability property testing. Fiber content above 1.5% makes the mix fibrous and difficult to handle. Therefore, the workability of the mix is lower, and the bond between the fiber and cement matrix will be a lesser one as well; this makes ECC with 2% fiber content less dense and more permeable, resulting in lower compression strength and lower durability properties.
- The compressive strength loss for the specimen exposed to 5% sodium sulphate powder diluted with water ranged from 21.0% to 21.4 % for the PECC specimen, 9.91% to 12.6% for the GECC specimen, and 22% for cement mortar after they were cured for 90 days in a sulphate mix.
- In the sulphate attack test, the 90 day compressive strength of the GECC 1.5 specimen was 8.2% higher than that of the PECC 1.5 specimen, and 34% higher than that of the CC specimen.
- The compressive strength loss for the specimen exposed to 1% sulphuric acid diluted with water was 25.8% to 26.2% for the PECC specimen, 17.49% to 22.8% for the GECC specimen, and 27% for the cement mortar specimen. The compressive strength loss of the GECC 1.5 specimen was 8.7% higher than that of the PECC 1.5 specimen and 43% higher than that of the CC specimen.
- The GECC 1.5 specimen absorbed less water when compared to the other mix proportions. This low water absorption level was a good indicator of reduced open porosity which can restrain the high absorption of water by the mortar.
- Sorptivity test results showed that the PECC 1.5 specimen and the GECC 1.5 specimen had lower number of pores when compared to other mixes, and the GECC 1.5 specimen showed lower sorptivity values than both the PECC 1.5 and CC specimens.
- Resistance to chloride permeability was highest for the mix with 1.5% fiber volume when compared to the other mixes.

- The GECC 1.5 specimen had higher resistance to chloride permeability than both the PECC 1.5 and CC specimens.
- The recommended mix proportion for the production of ECC for structural applications, as per this study, is 1.5% of glass fiber Engineered Cementitious Composites mix.

References

1. Dhawale A.W., Mrs. Joshi, V.P. “Engineered Cementitious Composites for Structural Application,” International journal of application for innovation in Engineering and Management, 2, pp.198-202, 2013.
2. Shuxin Wang., Victor C Li, " High Early strength Engineered Cementitious Composites," ACI Materials journal,103(2),2005.
3. Zhigang Zhang, Shunzhi Qian, Hui Ma, "Investigating mechanical properties and self-healing behaviour of micro-cracked ECC with different volume of fly ash," Construction and Building Materials 52,pp.17–23,2014.
4. Shuxin Wang.,Victor C Li, "Engineered cementititous composites with High volume fly ash," ACI Materials journal,104(3),pp. 233-241, 2007.
5. Victor C. Li., Tetsushi Kanda," Engineered Cementitious Composites for structural applications," ASCEJ.Materials in Civil Engineering, 10(2), pp. 66-69, 1998..
6. Liu, Hezhi, Qian Zhang, Victor Li, Huaizhi Su, Chongshi Gu, "Durability study on engineered cementitious composites (ECC) under sulfate and chloride environment." Construction and Building
7. Lepech, M. D., Victor C Li, "Large-scale processing of Engineered Cementitious Composites." ACI Materials Journal, 105(4), pp.358-366, 2008.
8. Michael.D.Lepech., Victor C Li, "Water Permeability of Engineered Cementitious Composites." Cement & Concrete Composites, 31, pp. 744- 753, 2009.
9. Shaikh Faiz Uddin Ahmed., Hirozo Mihashi, " A review on durability properties of strain hardening fibre reinforced cementitious composites (SHFRCC) " Cement & Concrete Composites, 29, pp. 365- 376, 2007.
10. Scott Muzenski., Ismael Flores-Vivian., Konstantin Sobolev,"Durability of superhydrophobic engineered cementitious composites." Construction and Building Materials, 81, pp. 291-297, 2015.
11. Mustafa Sahmaran., Victor C. Li, ,"Durability of superhydrophobic Engineered Cementitious Composites." Cement and Concrete Research, 39,pp. 1033-1043,2009.
12. Gurkhan yildirim, Mustafa Sahmarasan,Muzeyyen Balcikanli, Erdogan Ozbay, Mohamed Lachemi, "influence of cracking and healing on the gas permeability of cementitious composites," Construction and building materials,85,pp.217-256,2015.
13. Victor C. Li "On Engineered Cementitious Composites (ECC) A review of the material and its application," Journal of Advanced concrete technology, 1(3),pp.215-230,2003.
14. ASTM C642. "Standard test Method for density, absorption, and voids in hardened concrete," American Society for Testing and Materials, USA, 1997.
15. Sahmaran Mustafa, Victor C. Li, "Influence of microcracking on water absorption and sorptivity of ECC," Materials and Structures, 42(5), pp.593–603,2009.
16. ASTM C1585. "Standard test method for measurement of rate of absorption of water by hydraulic-cement concretes," American Society for Testing and Materials, USA, 2004.
17. Ye, Guang. "Percolation of Capillary Pores in Hardening Cement Pastes." Cement and concrete, research, 35(1)pp.167-176,2005.
18. ASTM C1202. "Standard test method for electrical indication of concrete’s ability to resist cementitious composites (ECC) under sulfate and chloride environment." Construction and Building Materials, Vol.133, pp.171-181,2017.
19. Shi, C. "Effect of mixing proportions of concrete on its electrical conductivity and the rapid chloride permeability test (ASTM C1202 or ASSHTO T277) results." Cement and Concrete Research, 34(3), pp.537-545, 2004.
20. Yang, CC and CT Chiang. "On the Relationship between Pore Structure and Charge Passed from Rcpt in - Free Cement-Based Materials." Materials chemistry and physics, 93(1) pp. 202-07.

LIST OF FIGURES AND TABLES:

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BADANIE PORÓWNAWCZE WŁASCIWOŚCI WYTRZYMAŁOŚCIOWYCH INŻYNIERYJNYCH KOMPOZYTÓW CEMENTOWYCH Z WŁÓKNEM PROPYLENOWYM I WŁÓKNEM SZKLANYM

Słowa kluczowe: inżynieryjne kompozyty cementowe, włókno polipropylenowe ECC, włókno szklane ECC, wytrzymałość, popiół lotny, beton, beton wzmacniany włóknami, zaprawa cementowa.

STRESZCZENIE:

Beton jest jednym z najważniejszych materiałów stosowanych w budownictwie. Zaletą stosowania betonu jest to, że można go formować w dowolnym kształcie i rozmiarze. Ze względu na kruchość betonu, posiada on szerokie właściwości ściskające i słabe napięcie. Kruchość betonu rośnie wraz ze wzrostem zawartości gruboziarnistego kruszywa. Wysoka kruchość betonu może prowadzić do powstawania pęknięć, jeśli beton posiada duże naprężenie. Aby przezwyciężyć ten problem i nadać betonowi wytrzymałość na rozciąganie, podjęto próbę wytworzenia betonu o dużej wytrzymałości na rozciąganie – opracowano mieszankę o nazwie ECC.

ECC jest kompozytem wzmocnionym włóknami o wysokiej wytrzymałości na rozciąganie, wysokiej wydajności i średniej zawartości włókien. W porównaniu do 0,1% standardowego betonu, ECC posiada wytrzymałość na rozciąganie w zakresie 3-5%. Powszechnie wiadomo, że dodanie włókien do kompozytów prowadzi do poprawy właściwości mechanicznych. Celem niniejszego badania jest dokonanie oceny właściwości wytrzymałościowych ECC i opracowanie nowej klasy ECC, które posiadają wysoką odporność na pękanie. Początkowo, mieszanka ECC M45 opisana w istniejących zbiorach literackich była traktowana jako podstawa do celów badawczych. Opracowano osiem mieszanek ECC, wytworzonych w procesie monolitycznego dodawania włókna polipropylenowego i włókna szklanego do podstawowej mieszanki w różnych proporcjach frakcji, takich jak 0,5%, 1%, 1,5% i 2% w stosunku do objętości ECC; ponadto przygotowano jedną konwencjonalną mieszankę bez żadnych dodatków włóknistych. Po opracowaniu próbnych mieszanek, stosunek wody do cementu został określony jako wartość 0,54. Dawka superplastyfikatora w

ilości 1,3% wagi cementu określonego w teście Marshala została dodana do mieszanki. Wyniki bezpośredniego badania wytrzymałości na ściskanie, przeprowadzonego na próbkach mieszanek ECC, były o 4,2% wyższe niż w przypadku konwencjonalnej mieszanki zapraw. Badanie wytrzymałości na ściskanie zostało przeprowadzone na próbce ECC o wymiarach 70,6 mm oraz na zaprawie cementowej, według IS: 4031-1988 (część 6). Badania wytrzymałościowe, obejmujące działanie siarczanu, działanie kwasu, badanie szybkiego przenikania chlorków, badanie sorpcyjne oraz badania wchłaniania wody zostały przeprowadzone na obu próbkach ECC i konwencjonalnej zaprawy.

Wytrzymałość na ściskanie ECC wzrasta aż do 1,5% zawartości włókien w próbce ECC, a następnie maleje. Wytrzymałość na ściskanie ECC wzmocnionego włóknami szklanymi z 1,5% zawartością włókien jest wyższa niż w przypadku wszystkich innych mieszanek. W badaniu działania siarczanu, 90-dniowa wytrzymałość na ściskanie 1,5% próbki ECC wzmocnionej włóknami szklanymi była o 8,2% większa w porównaniu do 1,5% próbki ECC wzmocnionej włóknami polipropylenowymi i o 34% większa w porównaniu do próbki zaprawy. Utrata masy i wytrzymałości na ściskanie w przypadku 1,5% ECC wzmocnionej włóknami szklanymi była mniejsza niż w innych mieszankach poddanych 90-dniowemu działaniu siarczanów i kwasów. 1,5% próbka ECC wzmocniona włóknami szklanymi wchłonęła mniejszą ilość wody w porównaniu z innymi proporcjami mieszanki. Wyniki badania sorpcyjnego jasno pokazują, że 1,5% próbka ECC wzmocniona włóknami polipropylenowymi i 1,5% próbka ECC wzmocniona włóknami szklanymi miały mniej porów w porównaniu do innych mieszanek. Odporność na przepuszczalność chlorków była wyższa w przypadku mieszanki z 1,5% zawartością włókien, w porównaniu do innych mieszanek. Jednakże, ECC zawierająca 1,5% włókien szklanych wykazuje lepsze właściwości wytrzymałościowe niż wszystkie inne mieszanki. W niniejszym badaniu opracowano nową klasę ECC poprzez dodanie 1,5% zawartości włókien szklanych do ECC, która posiada większą odporność na pęknięcia oraz większą wytrzymałość.