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Compressive Behaviour of Mortar Cube of Riversand and Msand with PVA fiber

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Abstract:

In this paper, the combined effect of river sand and Manufactured sand(Msand) as fine aggregate on compressive strength is studied. Fine aggregate of Msand and river sand which is 0.8 by mass of EEC mix has been combined in varied percentage to study the compressive strength. The fibre interactions and the chemical elements responsible for the hydration process for achieving estimated compressive strength are studied by the Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) analysis. Poly Vinyl Alcohol(PVA) fiber at 2% by volume is used in this mix. SEM image results show mixing of ingredients is carried out in such a way that balling of fibres is avoided. Strength of the composite is enhanced by proper gradation of fines of Msand and riversand that acts as fillers to the mix. Compressive strength of ECC made with 100% Msand is found to be higher than any other percentage mix tested. Compressive strength of ECC made with 100% Msand is found to be higher than ECC made with 100% river sand by a percentage difference between them is found to be 12.34%

Keywords: Engineered Cementitious Composites, River sand, Msand, fibre interaction, compressive strength, PVA fibre

I.Introduction:

Engineered Cementitious Composite (ECC) is a special type of high performance fibre-reinforced cementitious composite of high ductility that can be attained with only 2% fibre content by volume[1,4-6,8,22]. ECC with sand to binder ratio (S/B) of 0.36 to maintain adequate stiffness and volume stability. ECC-M45 has water to binder (w/b) ratio of 0.26 to attain a good balance of fresh and hardened properties. The binder system is defined as the total amount of cementitious material, i.e. cement and fly ash (Type F) in ECC.[2-3,22]. Although ECC is similar to conventional fibre reinforced concrete in terms of ingredients, the characteristics of the materials such as aggregate size, fibre type etc. used in its production lead to superior tensile ductility properties. Besides, the compressive strength of ECC is high enough to be used in all engineering structures. Despite the superior properties that make ECC a preferable material in most respects, individual constituents make it too costly to use instead of concrete in whole structures. [3].

ECC materials contain considerably higher cement content, typically two to three times higher. The high cement content in ECCs is a consequence of rheology control for easy fibre dispersion and, more essentially, matrix toughness control for strain-hardening behaviour. ECC materials use cement paste or mortar with fine sand as a matrix, and typically have cement content at 830 to 1200 kg/m^3 (1400 to 2023 lb/yd^3). High cement usage results in undesired high hydration heat as well as high material cost [4]. M. Sahmaran et al. investigated ECC mixtures containing either crushed dolomitic limestone sand or gravel sand with high flyash content. The results showed that, larger the aggregate size, the higher the local water to cement in the interfacial transition zone and, consequently, weaker the concrete.The results obtained also indicate that increasing the maximum size of aggregate from 1.19 to 2.38 mm (0.047 to 0.094 in.) for the different sands does not lead to a significant change in the ECC compressive strength[5,9]. Like other cement-based composites, sand, as an economical filler, not only saves cost but also has a significant impact on dry shrinkage and strength. However, low-volume and expensive Ultrafine Silica Sand (USS) in conventional ECC induces negative influence on shrinkage and thus limits the wide application of ECC. Sahmaran et al. reported that the crush sand and gravel sand could substitute USS in ECC without significantly reducing tensile strain while obviously decreasing the compressive strength[5,6]. Li and Yang used recycled concrete fines (maximum size 2650 µm and 0.22 sand/binder) as fineaggregate for the production of ECC. The study indicated that the strain capacity was slightly more than 0.8%[6,10]. Zhang et al. reported that crumb rubber as fineaggregate, helped to increase flexural ductility, but it adversely impacted ECC's strength properties with about 35% reduction of compressive strength[6,8].Yu et al. increased sand/binder ratio to 0.54 and obtained the larger strain (more than 8%) by the use of polyethylene (PE) fibre. This strain is ultra-high in present ECC research. However, the aggregate in the mixture was still USS (maximum size 181 mm). Xinchun Guan et al. investigated ordinary river sand with a maximum size of 4750 µm and sand/binder ratio to 0.55. The size of the river sand is almost 20 times that of ultrafine silica sand (USS) in traditional ECC. The investigation showed that the replacement of USS by river sand does not significantly influence the strength in the same water to binder ratio. And the increase of sand/binder ratio for Coarse River Sand-ECC and Fine River Sand-ECC has little influence on compressive strength, [6]. Lakshmi Meghana Srikakulam et. al focused their study on the influence of Msand on the strength characteristics of ECC mixture with polypropylene fibres, waste rubber, Msand and riversand. The result showed that superior strength properties are due to rough surface texture and sharp edges of the fine particles in M sand that act as a filler and enhances strength thereby reducing the environmental impact[7]. Radhakrishna et al noted that Msand, Pond Ash and slag sand are some of the alternatives, whose behaviour when used in cement composites are not very much clear[11]. The development of a cost-effective ECC with locally available materials is essential for such composite material to be used more commonly in the construction industry in future. Commercially available microsilica sand is relatively expensive and difficult to obtain when compared with commonly available sands[5].

From the previous studies on Engineered Cementitious Composites since last decades, it is clear that complete study with cementitious material like flyash, GGBS with PVA, polypropylene and polyester fibres varying water to binder ratio, superplasticizer to binder ratio have done. In India, the construction industries, have started using Msand due to ban on river sand in many areas across the country. In general, the most common practical application of conventional ECC is for repair and rehabilitation purposes because of the lack of local materials in it. The present investigation focuses on the effective use of functional fineaggregate materials such as river sand and Msand in the study of compressive strength of ECC. The study investigates the possibility of replacement of Msand or riversand in different proportions to achieve the compressive strength of conventional M45 ECC.

2. Experimental Program:

2.1 Materials and Specifications:

For the present study, Ordinary Portland Cement (OPC) of 53 grade conforming to IS: 12269-2013 [13] is used with the specific gravity of 3.12 and consistency of 30%. Angular texture is noted in the Msand with the fineness modulus of 2.68, and specific gravity of 2.59. The water absorption of Msand is 1.94, whereas, for riversand, it is 0.72. Both Msand and River sand falls under zone II of IS 383:1970[14]. Water used is normal potable water. The pH value is 8.

Class F flyash confirming to IS 3812:1981(R1999) [17] obtained from Tuticorin, South India has a specific gravity of 2.67. MasterGlenium SKY 8630, Polycarboxylate Ether (PCE) based superplasticizer used as high range water reducer (HRWR) conforming to IS 9103:1999(R 2004) [18] provided by M/s. BASF, the chemical company. Polyvinyl Alcohol (PVA) fibre used is FiberBN 1500, purchased from M/s.Bangneg Fiber, China. The physical properties of FiberBN 1500 are listed in table 1.

Property	PVA Fibre
Modulus of Elasticity	35GPa
Specific Gravity	1.3
Tensile Strength	Above 1500MPa
Size	12 mm
Diameter	39µm

Table: 1 Physical properties of PVA Fibre

The surface of the PVA fibres is coated with a proprietary oiling agent 1.2% by mass to tailor the interfacial properties between fibre and matrix[1].

2.2 Mixing Procedure and Proportions:

This work investigates the usage of Manufactured Sand (Msand) and river sand in the ECC mixture. River sand and Msand are used as fine aggregate in mix proportion (0.8 by mass) varying from 0% to 100% to study the compressive strength. Mix proportions by weight for 100% replacement of Riversand (R) and Msand (M) are in table 2. The influences of riversand and Msand in ECC mixture is studied from these variable proportions.

Mix ID	Cement	Flyash	River sand	Msand	W/B	PVA (by volume)	HRWR
0%M	1	1.2	***0.8***	-	0.23	2%	0.023
90%R+10%M	1	1.2	***0.72***	***0.08***	0.23	2%	0.023
80%R+20%M	1	1.2	***0.64***	***0.16***	0.23	2%	0.023
70%R+30%M	1	1.2	***0.56***	***0.24***	0.23	2%	0.023
60%R+40%M	1	1.2	***0.48***	***0.32***	0.23	2%	0.023
50%R+50%M	1	1.2	***0.40***	***0.40***	0.23	2%	0.023
40%R+60%M	1	1.2	***0.32***	***0.48***	0.23	2%	0.023
30%R+70%M	1	1.2	***0.24***	***0.56***	0.23	2%	0.023
20%R+80%M	1	1.2	***0.16***	***0.64***	0.23	2%	0.023
10%R+90%M	1	1.2	***0.08***	***0.72***	0.23	2%	0.023
100%M	1	1.2	-	***0.8***	0.23	2%	0.023

Table 2: Mix Proportion by mass

10% of river sand and 90% of Msand are used in the same mix. Similarly, other mixes are replaced with 20% of river sand and 80% of Msand till 100% of riversand and 0% of Msand. The mix ID 100%R stands for 0% Msand and 100%M stands for 0% river sand.

The mixing process aims to improve the fibre dispersion in the ECC mix. The mixing is done using, the planetary mixer of 10liter capacity in three steps as follows. First, the binder materials – cement and fly ash are dry mixed. Second, the fine aggregates - Msand and riversand are added, and mixed for four minutes to get homogenous mixture. Thirdly, PVA fibre and HRWR are added and mixed for two minutes at low speed, and one minute at high speed until achieving apparent full-fibre distribution [19]. The fresh mixture is placed in the mould after the flow table test. The moulds are demoulded after 24 h, and placed in curing tank for the process of hydration.

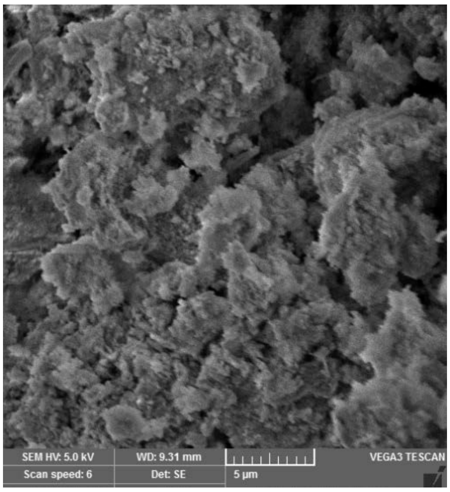
3. Experimental Investigations:

The flow table test is conducted to study the easy to flow nature of the mixes with fibre as IS 2386(Part VI)-1963 [11,15]. Total number of 66 cubes of size 70.7 x 70.7 x 70.7 mm were casted . The compressive strength test on cubes were conducted on the specimens for 3^{rd},7^{th} and 28^{th} days as per IS 2386(Part VI)-1963[11,15]. The compression testing was conducted using Universal Testing Machine at the loading rate of 0.14MPa/s.

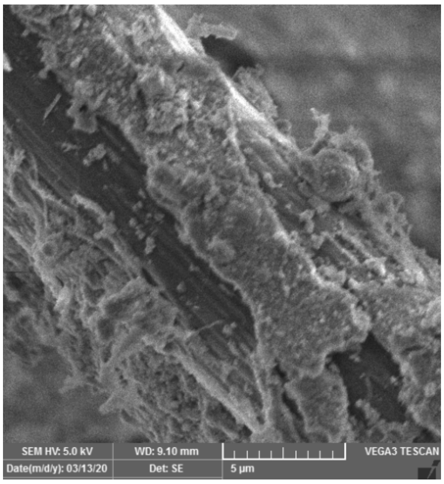
4. Results and Discussion:

4.1 SEM image:

The uniform fibre dispersion is carried out with mixing technique followed by Jian Zhou et al.[19]. The specimen from compressive strength test after 28 days curing are taken for the study in 100% R and 100% M mixes. In figure 2, the Scanning Electron Microscope (SEM) image of 28^{th} day of 100%R and 100%M are showed. The river sand and Msand does not show balling of fibres with the mixing technique. The completely hydrated pastes are seen around the fibres.



(a)100% River Sand mix – 28th day



(b) 100% Msand mix – 28th day

Fig. 2 SEM images

4.2 *Microstructual analysis of hydration using EDX:*

The Energy Dispersive X-ray (EDX) microanalysis is a technique of elemental analysis associated to electron microscopy based on the generation of characteristic Xrays that reveals the presence of elements present in the specimens[30].

The specimen from compressive strength test after 28 days curing are taken for the study in 100% R and 100% M mixes. The figure 3 shows the spectrum of element present for the 100% M mix. Other elements found to be are, Calcium, Aluminium and Silicon.These are very much responsible for hydration process.

Early stages of hydration forms ettringates in the matrix. The formation of C-S-H (Calcium – Silicate- Hydrate) gel takes place during hydration. The strength of the cement matrix is mainly due to the strong CSH 'chains'[21].

Heavy metals are not found in the 100%M mix. Since, the weight percentage of oxygen is more formations of oxides with other elements leads to retardation of setting time in the mix. Weight percentage of elements in spectrum of 100% Msand at 28th day are given in table 3.

Element	Symbol	Unit weight, wt%	Normal weight, wt%
Carbon	C	26.21	43.22
Oxygen	O	11.08	18.28
Calcium	Ca	11.72	19.32
Silicon	Si	5.58	9.21
Aluminium	Al	1.20	1.99
Gold	Au	3.71	6.12
Palladium	Pd	1.13	1.86

Table 3: Weight percentage of elements in spectrum of 100% Msand at 28th day

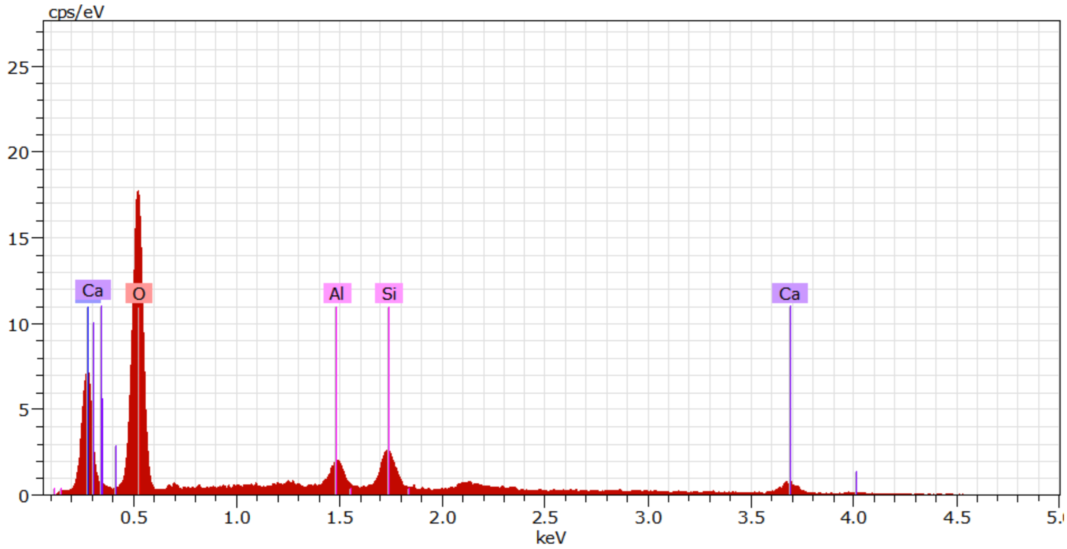


Fig.3 Spectrum of elements present in 100% Msand at 28th day

The figure 4 shows the specturum of elements in the 100%R mix. Heavy metals such as palladium (Pd), and gold (Au) are in this mix, apart from calcium, silica, aluminium and oxygen. Palladium is a silvery white metal from the family of silver. Gold and palladium are highly non reactive metal and it does not affect the strengthening process of the ECC mix.

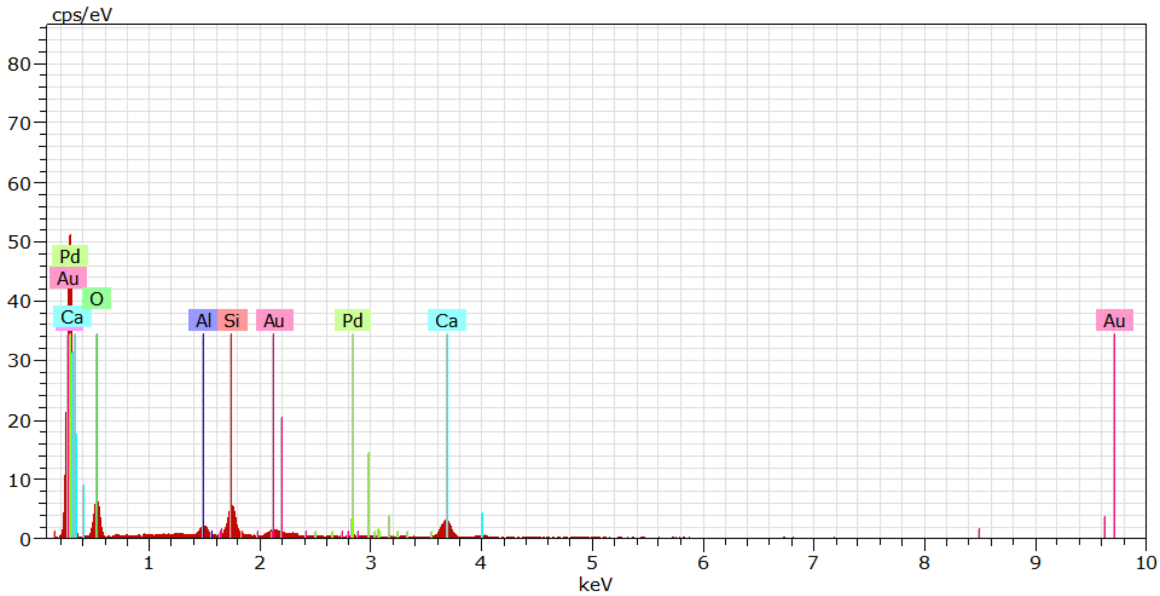


Fig.4 Spectrum of elements present in 100% river sand at 28th day

Element	Symbol	Unit weight, wt%	Normal weight, wt%
Carbon	C	7.70	12.44
Oxygen	O	28.59	46.21
Calcium	Ca	17.94	28.99
Silicon	Si	6.02	9.73
Aluminium	Al	1.62	2.63

Table 4: Weight percentage of elements in spectrum of 100% Rsand at 28th day

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4.3 Influence of flow table test on Compressive Strength

When the water to binder ratio is less than 0.4, not all the cement is hydrated, and the cores of the cement clinker do not react. Hence, the porosity of the final product decreases significantly[21]. The flow table test conducted with the water to binder ratio of 0.23 and sand to binder ratio of 0.37. The results obtained are plotted against compressive strength, as shown in figure 5. The observations are when the percentage of Msand increases the flow percentages declines. Initially, with 0% of Msand or with 100% of river sand the flow percentage is 80.45, whereas it declines to 60% with 100% of Msand. This can be attributed to the enhancement in paste volume due to the increase in fines, which offsets the reduction in flowability due to the rough surface texture of M-sand particles[11]. The surface of PVA fibres absorbed a great deal of free water due to good hydrophilia of PVA fibres. As a result, the smaller particle size of sand reduced the workability of the composites[24].

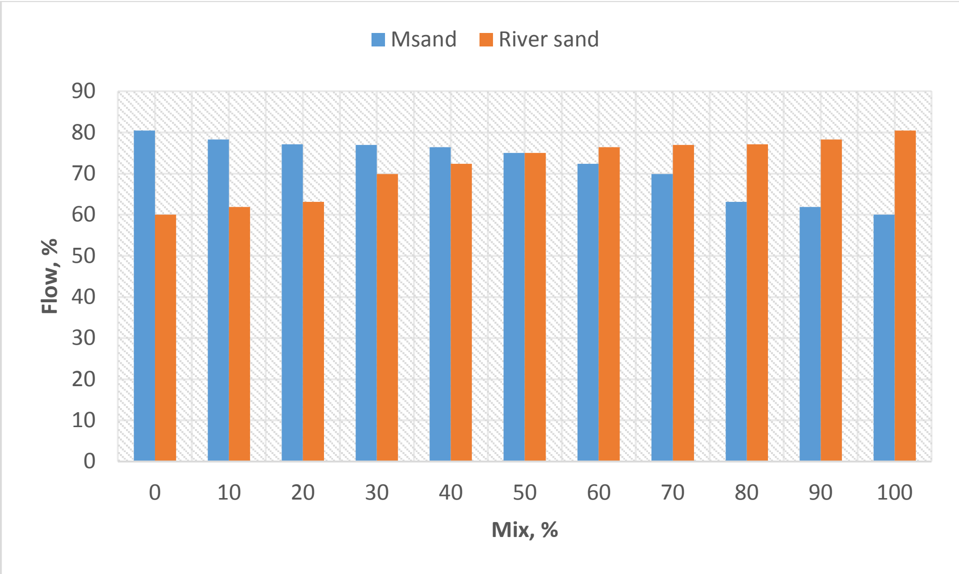

Fig. 5 Correlation between flow and compressive strength

The influence of the properties of the fine aggregate is mainly dependent on the paste volume of the mortar. Thus, by increasing the paste volume, adverse effects of poorly graded and shaped aggregates can be eliminated or significantly reduced[23]. Msand at 100% observed to yield 60% flowability gives the compressive strength of 59.72MPa at 28th day.

4.4 Influence of percentage replacement of fine aggregates on Compressive Strength

The marginal increase in the compressive strength from 10% to 50% Msand and 10% to 50% of river sand found. The comparison graph, given in figure 6 for compressive strength is a plot against mix percentages of fine aggregates.

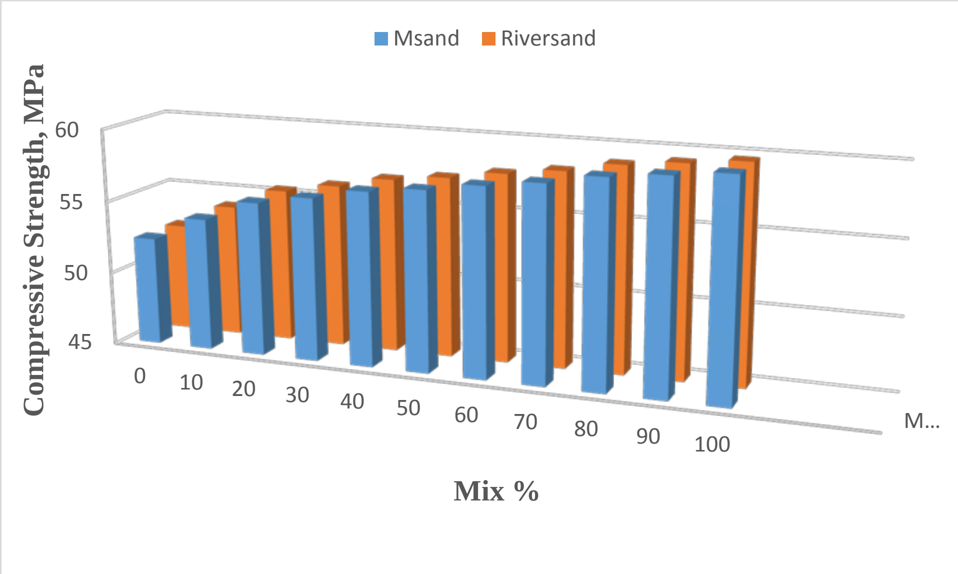

Fig. 6 Compressive strength for the mixes

The percentage difference between 20%, 30%, 40% of Msand and river sand is 6.29%, 3.87% and 1.7% respectively. The average percentage difference from 10% to 50% of the replacement of fine aggregates is 4.34%. The increase in compressive strength of 100%M and 100% R mix with respect to days are in figure 7. The result shows that river sand of size 0.6mm and Msand can also use as the replacement of micro silica sand in ECC as compressive strength concerned.

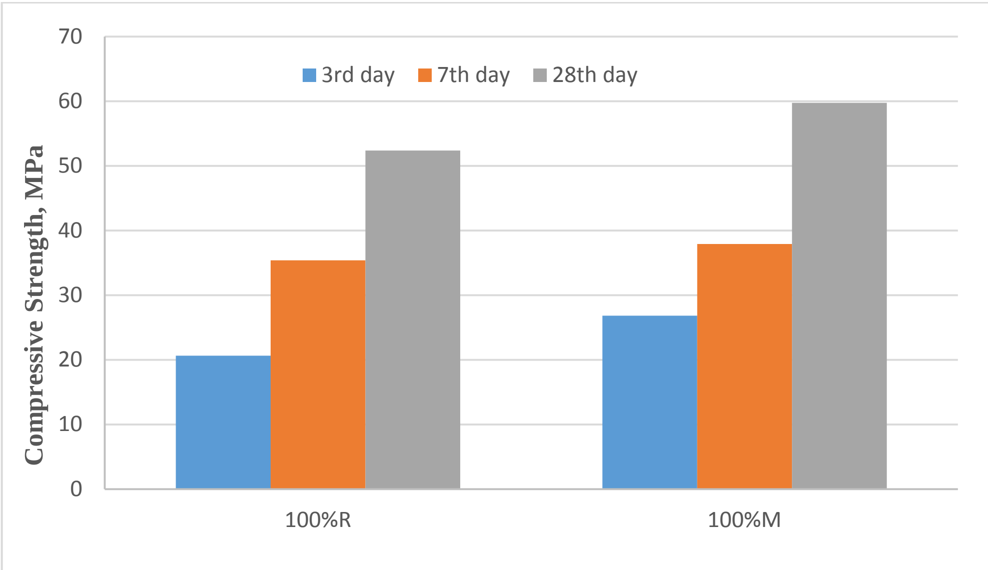

Fig. 7 Compressive strength for 100% R and 100%M with respect to days

5.Conclusion:

This study has the following concluding remarks based on the experimental results obtained.

1. The SEM and EDX analysis are done for 100% M and 100% R mixes. The SEM images show the fibre interaction and spacing of fibre avoid clumping of fibres. The combined effect of river sand and Msand in the single mix does not find any negative impact on fibre spacings and interactions.

2. The EDX microanalysis presents the element in the mixes responsible for hydration of the cementitious matrix. The amount of lead present in the 100%R mix, the reason for the reduction in strength rate compared to 100%M mix.
3. Msand and riversand show fineness and excellent gradation needed to avoid agglomeration in the mix, thereby ease to flow in placing and casting.
4. Water to binder ratio of 0.23 and sand to binder ratio of 0.37 gives maximum flow percentage of 80% and a minimum of 60% in the flow table test.
5. 100%M shows the maximum compressive strength of 59.72MPa whereas 100% R shows 52.35MPa on 28^{th} day for the same water to binder ratio and the same dosage of superplasticizer with PVA fiber.
6. River sand and Msand that passes sieve number 600µ can use as the replacement of micro silica sand in ECC as compressive strength concerned.

Declaration of Competing Interest

The authors declare that they have no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References:

[1] Mohamed A. A. Sherir, Khandaker M. A. Hossain, Mohamed Lachemi, Behaviour of Engineered Cementitious Composites Under Fatigue Loading, 3rd Specialty Conference on Material Engineering & Applied Mechanics, Ryerson University, Toronto, Ontario, Canada, May 29 to June 1, 2013.

[2] Victor C. Li, Engineered Cementitious Composites (ECC) – Material, Structural, and Durability Performance, University of Michigan, Ann Arbor, MI 48109 August 30, 2007

[3] Suleyman Bahadir Keskin, Mustafa Sahmaran, Ismail Ozgur Yaman, Mohamed Lachemi, Correlation between the viscoelastic properties and cracking potential of engineered cementitious composites, Construction and Building Materials 71 (2014) 375–383. http://dx.doi.org/10.1016/j.conbuildmat.2014.08.089

[4] Shuxin Wang and Victor C. Li, Engineered Cementitious Composites with High-Volume Fly Ash, ACI Materials Journal, May-June 2007. DOI: 10.1201/b15883-8

[5] M. Sahmaran, M. Lachemi, K. M. A. Hossain, Ravi Ranade, Influence of aggregate type and size on ductility and mechanical properties of engineered cementitious composites, ACI Materials Journal 106(3):308-316 · May 2009

[6] Xinchun Guan, Yazhao Li, Tianan Liu, Chenchen Zhang, Hui Li, Jinping Ou, An economical ultra-high ductile engineered cementitious composite with large amount of coarse river sand, Construction and Building Materials, Volume 201, March 20 2019, Pages 461-472. https://doi.org/10.1016/j.conbuildmat.2018.12.207

[7] Lakshmi Meghana Srikakulam, Veerendrakumar C. khed, Experimental investigation on the strength parameters of rubberized engineered cementitious composite with M sand, Materials Today: Proceedings https://doi.org/10.1016/j.matpr.2020.02.146

[8] Zhigang Zhang, Hui Ma, Shunzhi Qian, Investigation on properties of ECC Incoprparting crumb rubber of different sizes, Journal of Advanced Concrete Technology, vol 13, 241-251, May 2015. https://doi.org/10.3151/jact.13.241

[9] Mustafa Sahmaran, Hasan E. Yücel, Serhat Demirhan, Mehmet T. Arık, and Victor C. Li, Combined Effect of Aggregate and Mineral Admixtures on Tensile Ductility of Engineered Cementitious Composites, ACI Materials Journal, V. 109, No. 6, November-December 2012.

[10] Kequan Yu, Yichao Wang, Jiangtao Yu,Shilang Xu, A strain-hardening cementitious composites with the tensile capacity up to 8%, Construction and Building Materials, 137(2017) 410-419. http://dx.doi.org/10.1016/j.conbuildmat.2017.01.060

[11] Radhakrishna, Praveen Kumar K, Characteristics of Cement Mortar with M-sand as Replacement of Fine Aggregates, Materials Today: Proceedings 5 (2018) 25412–25419. https://doi.org/10.1016/j.matpr.2018.10.346

[12] J.P.Gonçalves, L.M.Tavares, R.D.Toledo Filho, E.M.R.Fairbairn, E.R.Cunha, Comparison of natural and manufactured fine aggregates in cement mortars, Cement and Concrete Research, Volume 37, Issue 6, June 2007, Pages 924-932.https://doi:10.1016/j.cemconres.2007.03.009

[13] IS 12269-2013, Specification for 53 grade ordinary Portland cement, Bureau of Indian Standards, New Delhi, India.

[14] IS 383-1970 (Reaffirmed 2002), Specification for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi, India.

[15] IS 2386(Part VI)-1963(Reaffirmed 2011), Methods of test for aggregates for concrete Part VI- Measuring mortar making properties of fine aggregate, Bureau of Indian Standards, New Delhi, India.

[16] IS 2250-1981(Reaffirmed 2000), Code of practice for manufacturing and use of masonry mortars, Bureau of Indian Standards, New Delhi, India.

[17] IS 3812:1981(R1999) Specification For Fly Ash For Use As Pozzolana And Admixture, Bureau of Indian Standards, New Delhi, India.

[18] IS 9103:1999(R 2004), Concrete Admixtures- Specifications, Bureau of Indian Standards, New Delhi, India.

[19] Jian Zhou, Shunzhi Qian, Guang Ye, Oguzhan Copuroglu, Klaas van Breugel, Victor C. Li, Improved fibre distribution and mechanical properties of engineered cementitious composites by adjusting the mixing sequence, Cement & Concrete Composites 34 (2012) 342–348. https://doi.org/10.1016/j.cemconcomp.2011.11.019

[20] Fariborz Nateghi, Mohammad Hossein Ahmadi, Ayoub Dehghani, Experimental Study on Improved Engineered Cementitious Composite Using Local Material, Materials Sciences and Applications, 2018, 9, 315-329. https://doi.org/10.4236/msa.2018.93021

[21] J.Weerheijm, K.Van Breugel, Introduction to concrete: a resilient material system, Woodhead Publishing Series in Civil and Structural Engineering 2013, 1-15. https://doi.org/10.1533/9780857097538.1

[22] Mohamed A.A. Sherir, Khandaker M.A. Hossain and Mohamed Lachemi, Structural Performance of Polymer Fiber Reinforced Engineered Cementitious Composites Subjected to Static and Fatigue Flexural Loading, Polymers 2015, 7, 1299-1330. https://doi.org/10.3390/polym7071299

[23] Mikael Westerholm, Bjo¨rn Lagerblad, Johan Silfwerbrand, Eric Forssberg, Influence of fine aggregate characteristics on the rheological properties of mortars, Cement & Concrete Composites 30 (2008) 274–282. https://doi.org/10.1016/j.cemconcomp.2007.08.008

[24] Yi-Feng Ling, Peng Zhang, Juan Wang, Yan Shi, Effect of Sand Size on Mechanical Performance of Cement-Based Composite Containing PVA Fibers and Nano-SiO_2, Materials 2020, 13, 325. https://doi.org/10.3390/ma13020325

[25] Dong-Soo Kim, Kwang-Myong Lee, Nam-Ryong Kim and Seok-Woo Jin, Assessment of Local Damage Level in Engineered Cementitious Composites (ECC) using Stress Wave Propagation, Key Engineering Materials Vols. 321-323 (2006,) pp. 371-376. https://doi.org/10.4028/www.scientific.net/KEM.321-323.371

[26] Dan Meng, Ting Huang, Y.X. Zhang, C.K. Lee, Mechanical behaviour of a polyvinyl alcohol fibre reinforced engineered cementitious composite (PVA-ECC) using local ingredients, Construction and Building Materials 141 (2017) 259–270. https://doi.org/10.1016/j.conbuildmat.2017.02.158

[27] Victor C. Li, Micheal Lepech, General Design Assumptions for Engineered Cementitious Composites, International RILEM workshop on High Performance Fiber Reinforced Cementitious Composites (HPFRCC) in Structural Applications, Honolulu, Hawai 23-26, May 2005. https://doi.org/10.1617/2912143942.029

[28] Yun Yong Kim, Hyun-Joon Kong, and Victor C. Li, Design of Engineered Cementitious Composite Suitable for Wet-Mixture Shotcreting, ACI Materials Journal/November-December (2003) 511-518.

[29] Don de Koker and GPAG van Zij, Extrusion Of Engineered Cement-Based Composite Material, 6th RILEM Symposium on Fiber-Reinforced Concretes (FRC) - BEFIB 2004, 20 - 22 September 2004, Varenna, Italy, pp1301-1310.

[30] Manuel Scimeca, Simone Bischetti, Harpreet Kaur Lamsira, Rita Bonfiglio, and Elena Bonanno, Energy Dispersive X-ray (EDX) microanalysis: A powerful tool in biomedical research and diagnosis, European Journal of Histochemistry, (2018) Jan; 62(1): 2841. https://doi.org/10.4081/ejh.2018.2841