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Research Paper

Performance of sustainable lightweight foam concrete with synthetic micro and macro fibers as reinforcement

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ABSTRACT

In the current research, lightweight foam concrete blocks made from recycled concrete powder, reinforced with plastic macro fibers and polypropylene micro fibers have been proposed as sustainable concrete approach. By adding Recycled Concrete Powder (RCP) in the amount ranging from 15 to 30% by weight of cement, have only a mild impact on the strength properties of foam concrete. Addition of mono fibers and hybrid fibers improves the mechanical properties of foam concrete with RCP. The tensile strength, flexural strength and compressive strengths of concrete are enhanced by the addition of micro and macro fibres. As the percentage of macro fiber increases the strength of the light weight concrete also increases. when the proportion of micro fibers is more compared to macro fibers, the strength properties are slightly reducing as the micro fibers reduces the plasticity of foam mix. In hybrid fiber reinforcement 0.3% plastic and 0.2% polypropylene showed an improvement in mechanical properties compared to other specimens.

1 Introduction

Foam concrete, which has a high degree of porosity and a relatively low density of about 1600 kg/m³, is a useful lightweight construction material. It finds its application as acoustical and thermal insulation barriers and is also affordable and environmentally friendly. Since the porosity and density are inter connected, the low strength of concrete is inevitable due to high porosity. In general, foamed concrete due its reduced self-weight, is suitable for non-load-bearing structural components such external wall insulation boards, road and bridge construction, and subway tunnels. Numerous investigators have tried to create foam concrete with exceptional strength and low density. Basalt fibers and silica fume were added to the wet mix to improve the strength attributes of foam concrete and strengthen its structural integrity. It was found that adding silica fume can have a substantial impact on the pore network and improve the Fibre Paste matrix [1]. Foamed concrete

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prepared using ultra-fine slag as partial replacement for Portland cement enhances the compressive strength. Ultra fine slag provides great filling and particle grading effect, and it also accelerates the formation of C-A-S-H gel and densified the microstructure, thereby increasing the strength [2]. Yellow river silt when used a supplementary binder material reduces the the fluidity of fresh foam concrete, the dry density, mechanical properties, thermal conductivity and drying shrinkage [3]. The untreated coir fibre was added in foamed concrete in percentages of 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% by mix volume fraction [4]. Many researchers were interested in improved resource utilization rate; steel slag was utilized as fine aggregate to prepare slag-based foam concrete. High optimal mixture ratio was obtained for slag foam concrete which has high compressive strength, low thermal conductivity and improved water stability characteristics [5]. Meanwhile, the fibres also had an influence on the workability and rheological properties of fresh foam concrete slurry through changing the bubble numbers and distributions. The carbon fibre and polyacrylonitrile fibre are conducive in distributing the strain field in the foam concrete in a homogeneous fashion and delayed crack widening after the peak loads effectively [6]. The thermal conductivity of the low density foam concrete can be reduce by incorporating phase change material which can used in moder construction [7]. Local minerals with suitable foaming agent has an impact on the strength and microstructural properties of foam concrete [8]. Expanded polystyrene particles when added to foam concrete help to improve the pore characteristics and thermal conductive properties. the water absorption rate of polystyrene foam concrete were 38-50 % lower than the regular foam concrete [9]. Addition of excavated soil and foam has an influence on the strength of foam concrete. As The particle size and quantity of foam increases the strength of concrete drastically reduces [10]. Like all other concretes, foam concretes have lower tensile strength than the compressive strength, in addition they are subject to massive shrinkage caused by large amounts of entrained air. The use of different fibers and wastes like waste marble dust, silica fume and fly ash in concrete mixtures decreases shrinkage crack and increases durability and strength. Steel, synthetic and glass fibers are widely considered in concrete [11, 12]. Basalt and Hemp fibers of different length were added to foam concrete to improve the tensile property and reduce shrinkage characteristics. Despite the many advantages of foam concrete, its main disadvantages are lower strength & shrinkage. Shrinkage can be reduced by the effective use of natural fibers while in order to increase strength, synthetic fibers have a vital role. The addition of an optimum hybrid combination of synthetic and natural fibers in foam concrete can enhance its strength and make it more durable [13, 14]. Along with basalt fibers steel slags and waste marble powder were used as fine aggregates for foam concrete. Waste marble powder along with basalt fiber increases the physio chemical characteristics of foam concrete [15]. In order to solve the adverse effects of carbon fixation components on the mechanical properties and optimize carbon absorption properties, a specific amount of polyvinyl alcohol (PVA) was added in foam concrete and a serial of test was employed to study the production process of nano-modified foam, and some basic properties of the foam concrete [16]. the use of green building materials for construction has been noticeably popularized. The effects of basalt fibers and re-dispersible latex powder on the dry and wet densities, water adsorption rate, compressive strength, and microstructure of the foamed concrete, were studied [17]. structural fibered foamed concrete by the addition of polypropylene fiber, fly ash, and silica fume. Foamed concrete was obtained by replacing sand with fly ash. The properties of the foamed concrete were enhanced with polypropylene fiber and fine silica fume [18]. Considering the need for more efficient handling method by simultaneously handling both solid waste materials, this study reports an innovative solution to transform waste concrete and waste polyester fabric into environmentally friendly product, recycled foamed concrete [19]. Reusing recycled powder (RP) including recycled concrete powder (RCP) and recycled mortar powder (RMP) as an eco-friendly alternative binder benefits the reclamation of construction waste and reduces the cement demand. A research work studied the influence of recycled concrete powder type and replacement on the performance of newly-made Foam concrete [20]. Therefore, from the recent survey it can be stated that the addition of different supplementary materials and fibers help to improve the strength properties of foam concrete. Different solid and industrial waste materials are effectively used in foam concrete which leads to a ecofriendly and sustainable concrete solution.

2 Research significance

Foam concretes are used for production of padding for bridges components, wall and floor insulation panel. Nowadays research is mainly focused on the usage of solid waste and industrial by products for sustainable development in various field. Using such sustainable materials results in the economic and social benefits, which also leads to the development of new sustainable construction material. The government and research organisation are also encouraging the recycling of industrial by products and waste materials. Industrial Waste materials such as marble powder, ground blast furnace slag, fly ash and silica fume are used as cement replacement for the development of cement-based composites. This research focuses on the usage of two different dosage of recycled powder concrete waste as replacement of cement to develop a sustainable waste concrete powder foam concrete. Fiber in concrete help to increase the tensile strength and flexural strength and reduces

the drying shrinkage in foam concrete. Various fibers such as basalt, kenaf, sisal, steel glass and carbon fibers are used in foam concrete and its properties were studied by different researchers. Shrinkage can be reduced by the effective use of natural fibers while in order to increase strength, synthetic fibers have a vital role. The addition of an optimum hybrid combination of synthetic micro and macro fibers in foam concrete can enhance its strength and make it more durable. This research focuses on the usage of micro and macro fibers to arrest crack in concrete at the early stage and prevent the development of major crack plane. Therefore, this research work focuses on the development of waste concrete powder, hybrid fiber reinforced foam concrete with better mechanical and durability properties.

Table 1 – Physical properties of foaming agent

Name	Foam expansion times	Dilution ratio	Bleeding rate for 1 h/%	Label Sedimentation for 1 h/mm	Paste sedimentation rate/%
GY-L-2	27 min	40	71.6	4	2.0

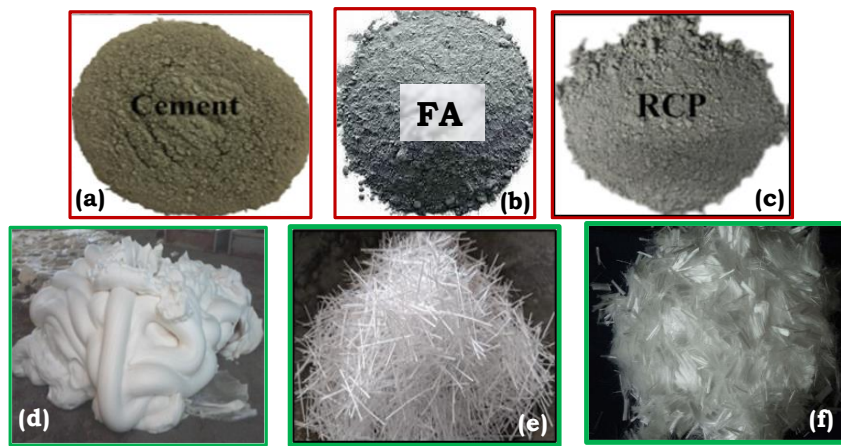


Fig. 1 – Ingredients used in foam concrete (a) cement (b) Fine Aggregate (c) Recycled Concrete Powder (d) Generated foam mix (e) plastic fiber (f) polypropylene fiber

Table 2 – Physical properties of micro and macro fibers

Physical property	Micro fiber	Macro Fiber
Raw material	Polypropylene	Polyvinyl chloride (Plastic)
Type	Monofilament	Structural fiber
Length	4-5 mm	50 mm
Diameter	30-40 μ m	0.5 mm
Melting point	105 $\pm$ 10 $^{\circ}$ C	180 $^{\circ}$ C
Softening point	95 $\pm$ 10 $^{\circ}$ C	110 $^{\circ}$ C
Acid & alkaline resistance	Strong	strong
Density	0.91 g/cm ³	1.48 g/cm ³
Colour	White	white
Water absorption	No	0.06
Specific gravity	0.9	0.91
Youngs modulus	3.45 GPa	10 GPa
Tensile strength	s551 MPa	3 MPa

4 Materials used and mix design

Ordinary Portland Cement (53 grade), Fine Aggregate (FA), Recycled Concrete Powder (RCP), foaming agent and potable water were the four main ingredients used for foam concrete preparation. The foaming agent consisted of hydrolysed proteins. Protein-based foam agent was used for production which consisted of antibacterial and enzyme-based proteins. Density of foaming agent was 1.03 kg/l. The properties of foaming agent are listed in Table 1. The foaming agent was diluted with water in a ratio of 1:40 (by volume), and then aerated to a density of 75 kg/m³. The recycled powder was prepared by crushed recycled aggregate (≤ 10 mm) and then dried completely. Afterwards, the grinding of recycled aggregate into coarse RP by a conventional ball mill. Subsequently, a secondary ball mill was used to grind these coarse RP into fine RP of size ≤ 75 μ m by grinding in a planetary mill for 30 minutes. The micro polypropylene fibers of length 6 mm were used for arresting micro cracks and reduce shrinkage. Macro plastic fibers of length 50 mm were added to foam concrete mix to increase the strength and reduces the shrinkage and porosity of foam concrete. The properties of micro and macro fibers are listed in Table 2. The pictures of the ingredients used to prepare foam concrete is shown in Figure 1.

Table 3 – Specimen details

S.no	Specimen ID	Description	Water binder ratio	RCP (%)	Fiber dosage (%)
1	Control FC	Control foam concrete	0.4	-	-
2	FC-0.15RCP	Foam concrete with 15% RCP	0.43	15	-
3	FC-0.3RCP	Foam concrete with 30% RCP	0.43	30	-
4	FRFC-0.15RCP-0.3PI	Fiber reinforced foam concrete with 15% RCP and 0.3% plastic fiber	0.45	15	0.3
5	FRFC-0.15RCP-0.3PP	Fiber reinforced foam concrete with 15%RCP and 0.3% polypropylene fiber	0.45	15	0.3
6	HFC-0.15RCP-0.3PI+0.2PP	Hybrid fiber reinforced foam concrete with 15% RCP and 0.3% plastic fiber and 0.2 % polypropylene fiber	0.45	15	0.5
7	HFC-0.15RCP-0.2PI+0.3PP	Hybrid fiber reinforced foam concrete with 15% RCP and 0.2% plastic fiber and 0.3 % polypropylene fiber	0.45	15	0.5
8	FRFC-0.3RCP-0.3PI	Fiber reinforced foam concrete with 30% RCP and 0.3% plastic fiber	0.45	30	0.3
9	FRFC-0.3RCP-0.3PP	Fiber reinforced foam concrete with 30%RCP and 0.3% polypropylene fiber	0.45	30	0.3
10	HFC-0.3RCP-0.3PI+0.2PP	Hybrid fiber reinforced foam concrete with 30% RCP and 0.3% plastic fiber and 0.2 % polypropylene fiber	0.45	30	0.5
11	HFC-0.3RCP-0.2PI+0.3PP	Hybrid fiber reinforced foam concrete with 30% RCP and 0.2% plastic fiber and 0.3 % polypropylene fiber	0.45	30	0.5

4 Mix proportion and specimen details

In this research, totally 11 foam concrete specimens were prepared in which two percentage of RCP of 15% and 30% by weight of cement was used to prepare sustainable foam concrete mix. The percentage of RCP was decided based on the previous research work [20]. The maximum percentage was restricted to 30% since the addition of RCP beyond 30 % reduces the strength properties of foam concrete. In order to reduce shrinkage and porosity in foam concrete micro and macro fibers were added at the maximum dosage of 0.5% by volume of concrete. In the fiber reinforced foam concrete (FRFC) one set of specimens were prepared with only micro polypropylene fibers and in other type only macro plastic fibers were added at the maximum dosage of 0.3%. In the hybrid fiber reinforced foam concrete (HFC) different percentage of micro and macro fibers were added in combination and the maximum fiber dosage was restricted to 0.5%. The waster binder ratio of the control mix was kept at 0.4, assuming that, fly ash also has some binding properties. With the addition of RCP and fiber the water binder ration was slightly increased (0.45) to compensate for the water absorption by RCP and fiber dosage. The control specimen mix proportion of Cement: M-Sand: water: foam was 270:870:270:1.4 kg/m³. For specimen preparation the protein-based

foaming was used, which was diluted with water in the ratio of 1:40 and steady foam were prepared using foam generator. First the dry ingredients (fly ash, cement, RCP) were fed into the mixer and mixed for 1 min at 140 rpm. After getting a uniform dry mix, water was added at 2% by weight and mixed at 285rpm for 1 min to get a wet mortar mix. After wards, the steady foam which was already prepared were poured into the wet mix and mixed for 2 minutes until a homogenous foam concrete mix was obtained. The specimen details and mix proportion are listed in Table 3. The step-by-step process of preparation of foam concrete is shown in Figure 2.

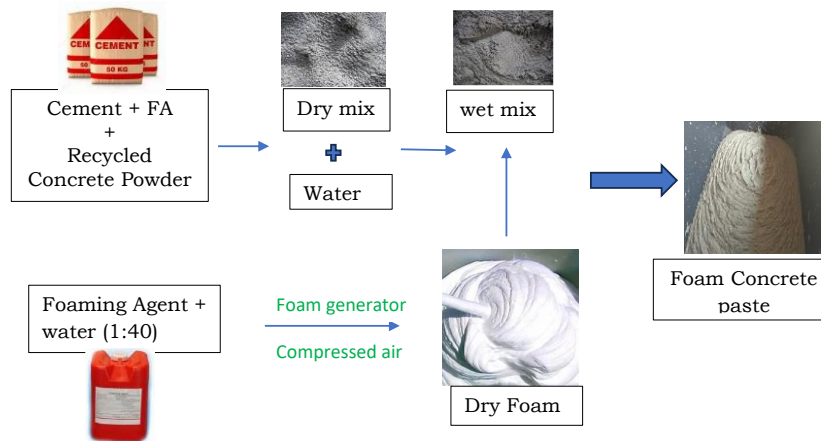


Fig. 2 – The process of preparation of foam concrete

5 Experimental study

The mechanical and durability properties were studied using cube, cylinder, and beam specimen as per codal provision. The compressive strength test, water absorption test, bulk density measurement in foam concrete were conducted on 50 x 50 x 50 mm cube specimens as per IS 2250:1981. The splitting tensile test was done on foam concrete cylinders of 38 mm diameter and 76 mm height, casted and water cured for 28 days. The flexural strength of foam concrete was tested using a prism specimen of size 160 x 40 x 40 mm. Three specimens were tested for each category of mix and the average values were noted. The casted specimen before testing is shown in Figure 3(a-c). The test setup for flowability, compression and flexure is shown in Figure 3(d-f).

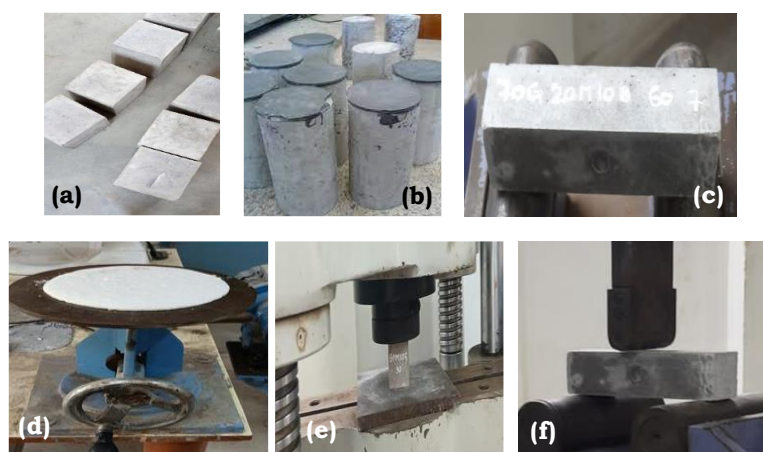


Fig. 3 – Casted foam concrete specimen before testing

6 Results and Discussion

6.1 Flow table test

The flow table test result for foam concrete with different RCP powder content and micro and macro plastic fiber reinforcement is shown in Figure 4. The overall flow diameter varied from 152 mm maximum to a minimum of 80 mm which

was recorded for control foam concrete mix and HFC-0.3RCP-0.2PI-0.3PP respectively. With 15% and 30% replacement of cement with RCP in foam concrete the flow diameter reduces by 9% and 20 % respectively. Thus, the increase in the recycled concrete powder content makes the mix stiff which reduces the flow diameter. This result is very similar to the one reported by [20]. For plastic fiber reinforced foam concrete mix, the flow diameter reduced to 120 and 118 mm for 0.15 and 0.3% RCP content respectively. The presence of fibers increases the stiffness of the mix further which interrupts the flow of foam concrete mix. Increase in the fiber content also reduces the flow diameter which was reported by [1, 6, 21] and many other researchers. Addition of poly propylene fibers reduces the workability of foam concrete mix due to the absorption of water by fibers and increase in friction between the particles in foam paste. Least flow diameter of 95 and 85 mm was recorded for foam concrete mix with micro poly propylene fibers only. For the hybrid fiber reinforced foam concrete the flow diameters reduced by 26% and 34% for high percentage of plastic fiber when compared to polypropylene fibers. In hybrid fiber reinforced foam concrete mix, as the percentage of micro fibers increases the flow diameters is drastically reduced by 40 - 47%. The least flow diameter (80mm) was reported for hybrid fiber reinforced foam concrete with 0.3% RCP and 0.2% plastic fibers. The flow test for control mix and hybrid fiber reinforced foam concrete is shown in Figure 5. From the figure it is clearly visible that addition of fibers reduces the flowability of concrete, which can be improved by increased foam content in the mix.

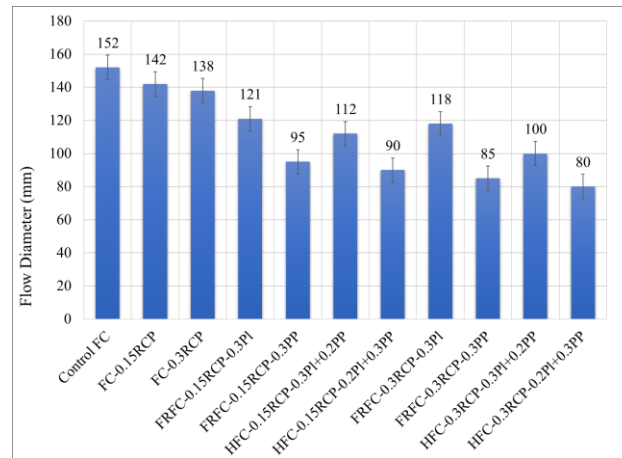


Fig. 4 – Flow diameter for foam concrete with micro and macro fiber

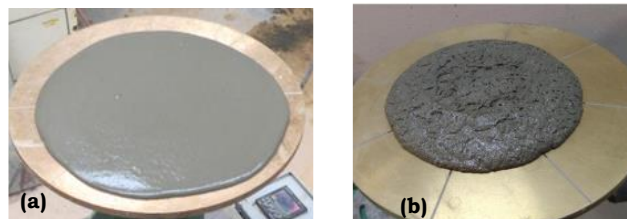


Fig. 5 – Flow table test for (a) control mix (b) Hybrid fiber reinforced FC

6.2 Compressive Strength

A concrete with compressive strength values of equal or above 17 MPa after 28 days of curing to be suitable for structural applications. The compressive strength variation of different foam concrete mixes is shown in Figure 6. From the figure it is clearly visible that all the specimen showed a compressive strength greater than 17 MPa. Therefore, all the mix reported in this research are suitable for structural application. Compared to control mix, foam concrete with 15% and 30 % replacement with concrete powder slightly reduces the compressive strength by 5% and 8% respectively. This may be due to the reason that the addition of concrete powder interferes with the new hydration product and makes the concrete porous as the RCP content increases [20]. Similar result was reported by the researcher. In foam concrete with 15% RCP, addition of macro and micro fibers increases the compressive strength by 11% and 5% respectively. In case of hybrid fiber reinforcement, the compressive strength increased by 8% for 0.3%PI and 0.2PP. the micro polypropylene fibers helps to arrest the crack at the early stage of load and prevents local concentration of stress. But as the micro fiber content is more when compared to macro

fibers, the strength reduces by 5%, which may be because the high volume of micro fibers reduces the plasticity of the mix and makes the mix stiff and more porous. For fiber reinforced foam concrete with 30% RCP, concrete with macro plastic fibers increases the compressive strength by 4%, for the remaining mix the strength reduces as the fiber content and RCP content increases. Maximum reduction in the compressive strength was reported for HFRFC-0.3RCP-0.2PI-0.3PP. therefore the hybrid fiber reinforcement produces a positive result for a limited amount of macro fibers. The failure pattern of control FC, and hybrid fiber reinforced foam concrete is shown in Figure 7. The failure pattern of control mix showed a single crack plane, while the fiber reinforced and hybrid fiber reinforced FC showed large number of micro cracks which prevent the sudden failure, when used a structural element.

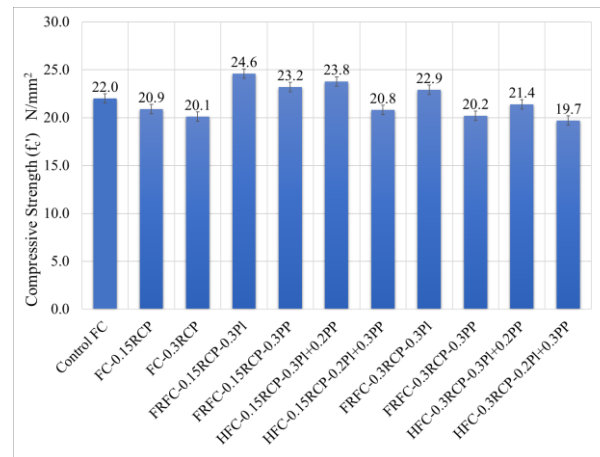


Fig. 6 – Compressive strength of hybrid fiber reinforced foam concrete

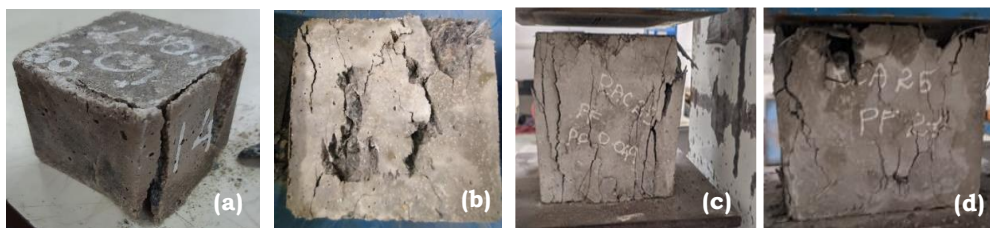


Fig. 7 – Failure pattern for (a)Control (b)plastic fiber(c)polypropylene (d) Hybrid fiber FC

6.3 Splitting tensile strength

Generally, the splitting tensile strength of foam concrete is less compared to normal concrete due to the absence of aggregate. In this study the addition of micro and macro fibers increases the splitting tensile strength of concrete. The splitting tensile strength of foam concrete with different fiber content is shown in Figure 8. The maximum splitting tensile strength of 3.15 MPa was achieved for FRFC-0.15RCP-0.3PI mix. Addition of 0.3% of plastic fiber increases the tensile strength by 12% compared to control mix. Replacement of cement with RCP tends to reduce the tensile strength by 14% and 17% compared to regular foam concrete without RCP. Replacement of cement with RCP intercepts with the hydration process of foam concrete and reduces the strength property. Addition of micro polypropylene fibers does not contribute toward the splitting tensile as only 1 % increase in strength was observed. The reason may be due to the accumulation of micro fibers or uneven distribution of micro polypropylene fibers in the foam concrete mix. In hybrid fiber reinforced foam concrete the splitting tensile strength increases by 10% for 0.3 PI and 0.2PP content, and 5% for 0.3PP and 0.2PI fiber content. It can be observed from the above hybrid mix, that the increased proportion of plastic fiber contributes more towards the splitting tensile strength, when compared to increased proportion of micro polypropylene fibers. Similar type of result was observed for 30% RCP foam concrete mix. Tensile strength of 3.01MPa and 2.68MPa was observed for plastic fiber and PP fiber reinforced foam concrete mix respectively. Increase in the RCP content slightly reduces the strength compared to 15% RCP replacement. Similar type of result was observed by [20] with the addition of concrete and mortar powder. In the case of hybrid fiber reinforcement also the strength properties reduce compared to the control foam concrete mix. The failure pattern of foam concrete cylinder without fibers, with mono fiber, and hybrid fibers is shown in Figure 9. Control form concrete mix

failed with the formation of a single wide crack as shown in Figure 9(a). With the addition of fibers, the crack formation was split in different direction and the failure of the specimen was delayed (Figure 9(b)). The magnified image of hybrid fiber reinforced concrete is shown in Figure 9(c). the fibers bridge the cracks and distributes the stress in different direction and also increases the tensile strength of foam concrete.

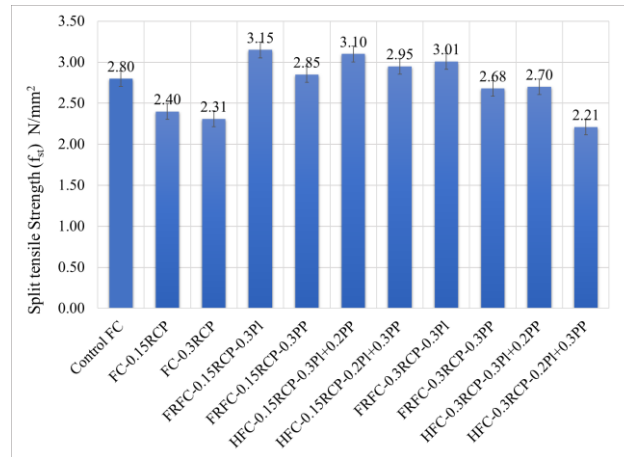


Fig. 8 – Splitting tensile strength of hybrid fiber reinforced foam concrete

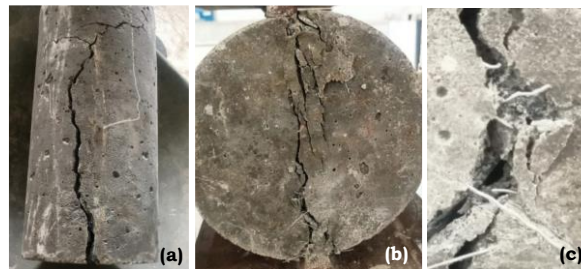


Fig. 9 – Splitting tensile strength of foam concrete cylinders

6.4 Flexural Strength

The flexural strength of foam concrete without fibers, with mono fibers, and hybrid fibers with different percentage of concrete powder is shown in Figure 10. The flexural strength of control foam concrete mix was 5.8 MPa, which reduces to 5.4 MPa and 5.31 MPa with the replacement of 15% and 30% of cement with recycled concrete powder. replacement of up to 15% RCP have only a slight impact on the strength properties of foam concrete.

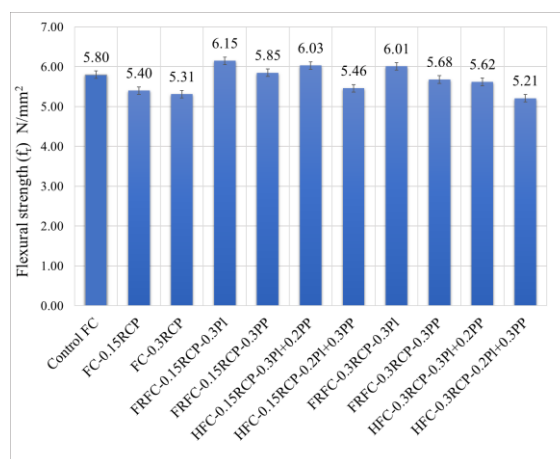


Fig. 10 – Flexural strength of fiber reinforced foam concrete

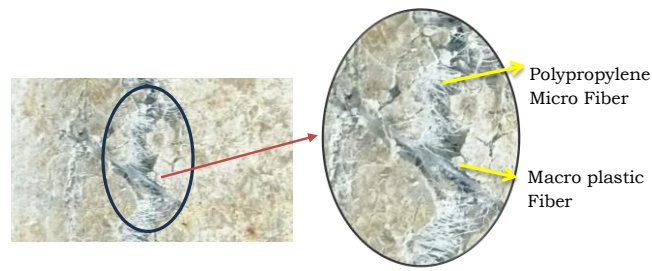


Fig. 11 – Flexure test of foam concrete beam (a) Failure of hybrid fiber reinforced beam (b) bridging of cracks by micro and macro fibers

The flexural strength of foam concrete was enhanced by the addition of macro fibers. The stress in the cement matrix was distributed by the macro fibers and prevents the formation of major crack plane [22]. The flexural strength increased by 7% and 4% with the addition of 0.3% plastic fibers for 15% RCP and 30% RCP foam mix respectively. Addition of micro fibers also increase the flexural strength, but to a very minimum level. Even with the addition of micro polypropylene fibers, as the amount of RCP increases the flexural strength gets reduced (FRFC-0.3RCP-0.3PP). In hybrid fiber reinforcement the flexural strength was better for the mix with high proportion of macro fibers compared to micro fibers. The bridging of cracks by the micro and macro fibers to reduce the stress concentration is shown in Figure 10. The flexural strength was 6.03 MPa and 5.62 MPa for 0.3PI and 0.2 PP mix. As the proportion of micro fibers increases when compared to macro fibers, the strength is greatly reduced. The flexural strength of HFC-0.15RCP-0.2PI-0.3PP is 5.46MPa, while the strength for hybrid mixes with 30% RCP and 0.2PI and 0.3PP is 5.21 MPa. The failure of specimen in flexure and the bridging of cracks by the micro and macro fibers to reduce the stress concentration is shown in Figure 11(a &b).

7 Strength of masonry blocks with hybrid fiber reinforcement

After studying the fresh and mechanical properties of foam concrete with hybrid reinforcement, masonry block was casted to study the performance of the light weight foam concrete block and its performance as masonry wall unit. Four light weight hybrid fiber reinforced foam concrete block of size 600x200x150 mm were placed one above the other with GFRP sheet in between each masonry blocks with 10 mm thick mortar bed. The process of formation of foam concrete masonry unit is shown in Figure 12. The failure of masonry unit when subjected to compression load is shown in Figure 13.

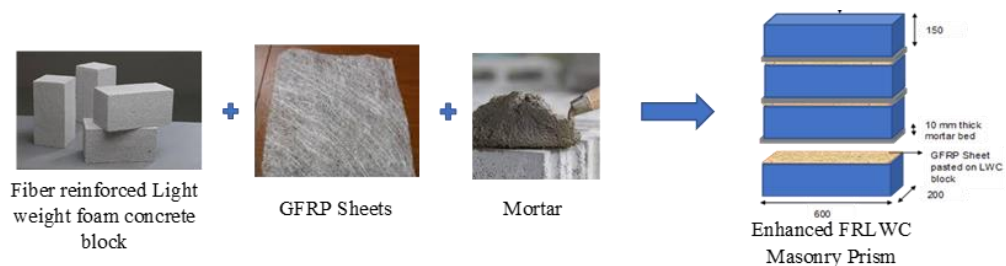


Fig. 12 – Process of making of foam concrete masonry units

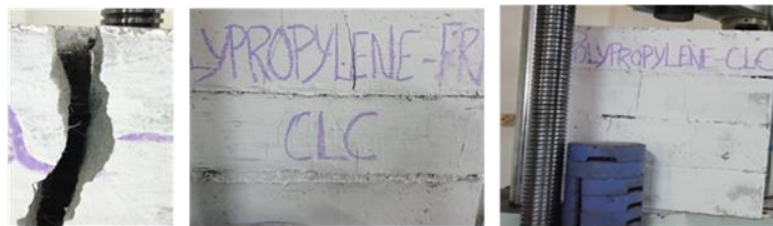


Fig. 13 – Testing of hybrid fiber reinforced foam concrete masonry unit

The masonry unit showed increased load carrying capacity and the hybrid fiber reinforcement in the foam concrete blocks reduced the stress concentration in masonry unit and distributed the crack in different direction. The GFRP sheet

reinforcement in between the masonry blocks improved the performance of masonry units and prevents the sudden failure of the masonry blocks. The stress strain pattern of fiber reinforced foam concrete masonry unit is discussed in authors previous publication [23]. The author suggests a detailed investigation can done to study the seismic performance of the masonry block and its suitability in the seismic zone.

8 Conclusion

From the experimental study carried out on sustainable foam concrete with partial replacement with recycled concrete powder and hybrid fiber reinforcement the following conclusions can be derived.

- Partial replacement of cement with recycled concrete powder in foam concrete results in the development of sustainable concrete solution. The flow characteristic of the foam concrete is slightly reduced by the addition of RCP. up to 15% replacement of cement with RCP have only a minor impact on the flow characteristics.
- Hybrid fiber reinforced foam concrete with 15%RCP showed a 11% increase in compressive strength. But in the same Hybrid fiber reinforced mix, when the micro fiber content is more than the macro fibers, the strength properties is affected due to the reduction in the plasticity of the foam mix.
- Addition of RCP beyond 30% has a negative impact on the compression, splitting, and flexural strength properties of foam concrete. but addition of macro plastic fibers improves the strength.
- The splitting tensile strength and flexural strength of hybrid fibers reinforced foam concrete is more compared to mono fiber reinforcement. Single fiber content beyond 0.3% of the volume of concrete has a negative effect on the strength properties as the workability of concrete is affected by fibers.
- Hybrid fiber reinforced masonry wall unit showed improved lateral load resistance and increased compression load carrying capacity. This hybrid fiber reinforced masonry wall units will be more suitable in the masonry construction subjected to lateral loads.
- The sustainable foam concrete solution prepared from the waste concrete powder and reinforced with plastic and PP fibers can be used in the construction of masonry wall in mild seismic environment thereby preventing major damaged to the structure. A detailed investigation on the performance of the hybrid fiber reinforced foam concrete masonry unit subjected to seismic lateral load need to performed.

REFERENCES

- [1]- O. Gencil, M. Nodehi, O. Yavuz Bayraktar, G. Kaplan, A. Benli, A. Gholampour, T. Ozbakkaloglu, Basalt fiber-reinforced foam concrete containing silica fume: An experimental study. *Construction and Building Materials*, 326 (2022) 126861. doi:10.1016/j.conbuildmat.2022.126861.
- [2]- M. Li, H. Tan, X. He, S. Jian, G. Li, J. Zhang, X. Deng, X. Lin, Enhancement in compressive strength of foamed concrete by ultra-fine slag. *Cement and Concrete Composites*, 138 (2023) 104954. doi:10.1016/j.cemconcomp.2023.104954.
- [3]- S. Jiang, J. Xu, Y. Song, Y. Xu, Alkali-activated fly ash foam concrete with Yellow River silt: Physico-mechanical and structural properties. *Construction and Building Materials*, 373 (2023) 130879. doi:10.1016/j.conbuildmat.2023.130879.
- [4]- M.A. Othuman Mydin, N.M. Zamzani, A.N.A. Ghani, Experimental data on compressive and flexural strengths of coir fibre reinforced foamed concrete at elevated temperatures. *Data in Brief*, 25 (2019) 104320. doi:10.1016/j.dib.2019.104320.
- [5]- G. Xiang, D. Song, H. Li, F.E. Jalal, H. Wang, Y. Zhou, Investigation on preparation and compressive strength model of steel slag foam concrete. *Journal of Building Engineering*, 72 (2023) 106548. doi:10.1016/j.job.2023.106548.
- [6]- X. Cong, T. Qiu, J. Xu, X. Liu, L. Wang, Y. Wang, C. Chen, L. Zhao, C. Xing, Y. Tan, Study on the effectiveness of fibre reinforcement on the engineering performance of foamed concrete. *Case Studies in Construction Materials*,

- 16 (2022) e01015. doi:10.1016/j.cscm.2022.e01015.
- [7]- S. Dora, R.B. Barta, K.M. Mini, Study on foam concrete incorporated with expanded vermiculite/capric acid PCM – A novel thermal storage high-performance building material. *Construction and Building Materials*, 392 (2023) 131903. doi:10.1016/j.conbuildmat.2023.131903.
- [8]- A. Compaoré, M. Sawadogo, Y. Sawadogo, M. Ouedraogo, B. Sorgho, M. Seynou, P. Blanchart, L. Zerbo, Preparation and characterization of foamed concrete using a foaming agent and local mineral resources from Burkina Faso. *Results in Materials*, 17 (2023) 100365. doi:10.1016/j.rinma.2023.100365.
- [9]- Y. Xu, S. Tong, X. Xu, J. Mao, X. Kang, J. Luo, L. Jiang, M.-Z. Guo, Effect of foam stabilization on the properties of foamed concrete modified by expanded polystyrene. *Journal of Building Engineering*, 73 (2023) 106822. doi:10.1016/j.jobbe.2023.106822.
- [10]- L.-l. Guan, Y.-g. Chen, W.-m. Ye, D.-b. Wu, Y.-f. Deng, Foamed concrete utilizing excavated soil and fly ash for urban underground space backfilling: Physical properties, mechanical properties, and microstructure. *Tunnelling and Underground Space Technology*, 134 (2023) 104995. doi:10.1016/j.tust.2023.104995.
- [11]- O. Gencel, O. Yavuz Bayraktar, G. Kaplan, A. Benli, G. Martínez-Barrera, W. Brostow, M. Tek, B. Bodur, Characteristics of hemp fibre reinforced foam concretes with fly ash and Taguchi optimization. *Construction and Building Materials*, 294 (2021) 123607. doi:10.1016/j.conbuildmat.2021.123607.
- [12]- J. Huang, S. Qiu, D. Rodrigue, Parameters estimation and fatigue life prediction of sisal fibre reinforced foam concrete. *Journal of Materials Research and Technology*, 20 (2022) 381-396. doi:10.1016/j.jmrt.2022.07.096.
- [13]- B. Raj, D. Sathyan, M.K. Madhavan, A. Raj, Mechanical and durability properties of hybrid fiber reinforced foam concrete. *Construction and Building Materials*, 245 (2020) 118373. doi:10.1016/j.conbuildmat.2020.118373.
- [14]- M.S. Mahzabin, L.J. Hock, M.S. Hossain, L.S. Kang, The influence of addition of treated kenaf fibre in the production and properties of fibre reinforced foamed composite. *Construction and Building Materials*, 178 (2018) 518-528. doi:10.1016/j.conbuildmat.2018.05.169.
- [15]- O. Yavuz Bayraktar, G. Kaplan, O. Gencel, A. Benli, M. Sutcu, Physico-mechanical, durability and thermal properties of basalt fiber reinforced foamed concrete containing waste marble powder and slag. *Construction and Building Materials*, 288 (2021) 123128. doi:10.1016/j.conbuildmat.2021.123128.
- [16]- D. Cao, Y. Gu, L. Jiang, W. Jin, K. Lyu, M. Guo, Effect of polyvinyl alcohol on the performance of carbon fixation foam concrete. *Construction and Building Materials*, 390 (2023) 131775. doi:10.1016/j.conbuildmat.2023.131775.
- [17]- X. Shi, B. Ning, J. Liu, Z. Wei, Effects of re-dispersible latex powder-basalt fibers on the properties and pore structure of lightweight foamed concrete. *Journal of Building Engineering*, 75 (2023) 106984. doi:10.1016/j.jobbe.2023.106984.
- [18]- Y.H. Mugahed Amran, R. Alyousef, H. Alabduljabbar, M.H.R. Khudhair, F. Hejazi, A. Alaskar, F. Alrshoudi, A. Siddika, Performance properties of structural fibred-foamed concrete. *Results in Engineering*, 5 (2020) 100092. doi:10.1016/j.rineng.2019.100092.
- [19]- R. Tang, Q. Wei, K. Zhang, S. Jiang, Z. Shen, Y. Zhang, C.W.K. Chow, Preparation and performance analysis of recycled PET fiber reinforced recycled foamed concrete. *Journal of Building Engineering*, 57 (2022) 104948. doi:10.1016/j.jobbe.2022.104948.
- [20]- D. Yang, M. Liu, Z. Zhang, P. Yao, Z. Ma, Properties and modification of sustainable foam concrete including eco-friendly recycled powder from concrete waste. *Case Studies in Construction Materials*, 16 (2022) e00826. doi:10.1016/j.cscm.2021.e00826.
- [21]- M. Harihanandh, V. Rajeshkumar, K.S. Elango, Study on mechanical properties of fiber reinforced self compacting concrete. *Materials Today: Proceedings*, 45 (2021) 3124-3131. doi:10.1016/j.matpr.2020.12.214.
- [22]- R. Sathia, R. Vijayalakshmi, Fresh and mechanical property of caryota-urens fiber reinforced flowable concrete. *Journal of Materials Research and Technology*, 15 (2021) 3647-3662. doi:10.1016/j.jmrt.2021.09.126.
- [23]- V. Ramalingam, Study on the performance of GFRP strengthened, fiber reinforced lightweight foam concrete. *Građevinski materijali i konstrukcije*, 65(4) (2022) 137-148. doi:10.5937/grmk2204137r.