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Effects of Polypropylene Fibers on the Mechanical Performance of a 3D Printable Mix

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Abstract: ***Application of automation in construction work has now become need of the hour. Automation in construction work can be done by implementing a technique known as additive manufacturing technique. Use of additive manufacturing in construction sector has the potential to bring fourth industrial revolution by using 3D concrete printers. This paper is based ona parametric experimental study to evaluate the effect of Polypropylene (PP) fibers on mechanical properties of a 3D printable concrete. PP fibers were used invaryingpercentage ratio of 0.02, 0.04, 0.08, 0.12 and 0.16 of binder at constant W/B ratio.***

Keywords: Additive Manufacturing,3d Concrete Printing, Free-Form Construction, Polypropylene Fibers, Compressive Strength, Split Tensile Strength And Flexural Strength.

I. INTRODUCTION

The construction industry now a days facing many issues related to time consumption for construction activities, environmental impacts, availability of labors in remote areas and etc. These problems can be resolved by implementing automation in construction sector. One of the better option for implementation of automation in construction industry is use of additive manufacturing in the field of construction which is also known as 3D concrete printing (3DCP) [1]. 3DCP is the technology is which a 3D concrete structure is created by depositing the layer of one concrete mix over another layer of concrete without using the formworks by the use of designed 3D model [2].

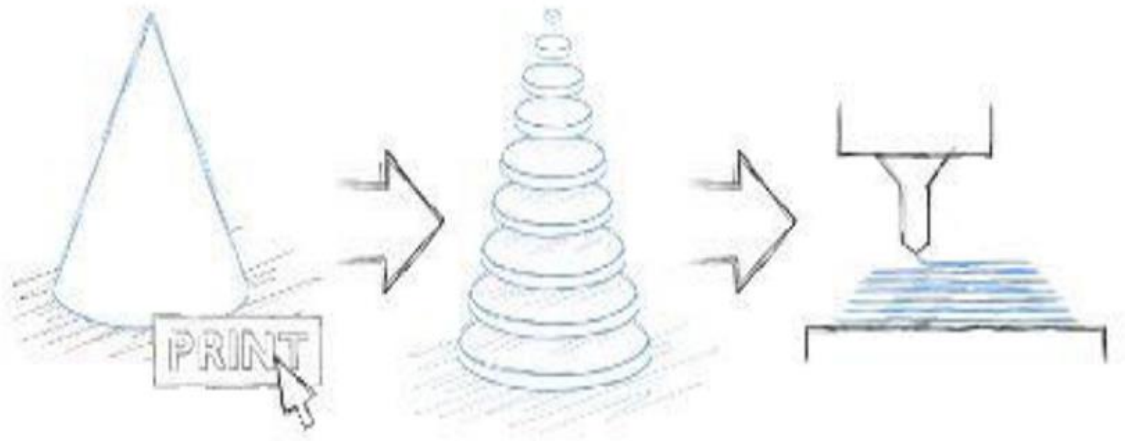

Figure 1 Stages of 3D concrete printing

3DCP technology is creating a lot of buzz around the world because its advantages over traditional construction method in terms carbon di-oxide emission, low labor intensive work, higher geometric freedom, lesser time consumption and reduction in cost of construction.

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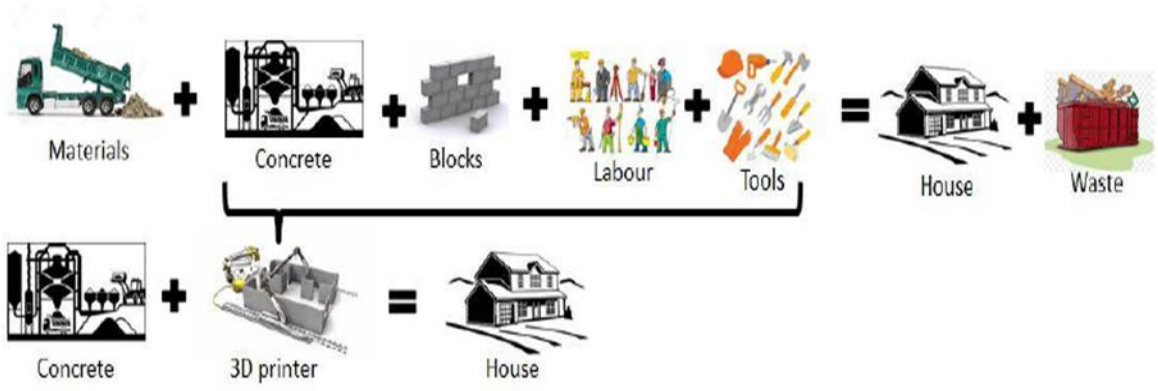

Figure 2 Conventional construction vs 3D concrete printing

"3D concrete printing process reduces overall cost, CO2 emission, and energy consumption by 25.4%, 85.9% and 87.1% for the formation of bathroom unit of dimensions L=1620mm, W=1500mm, H=2800mm [3].This process is carried out into 3 steps- first one is the Data preparation, the second process involves preparation of mix and in the third step printing of structure is done [4,5]. From the civil engineering perspective second and third step is very crucial. A special kind of mix is required for this process that is having sufficient yield, flexural strength and split tensile strength because in 3DCP process one layer is deposited over the other layer so the lower layer must have sufficient yield strength, flexural strength and split tensile strength to hold the upper layer over it because whole construction process has been done without using the form-works. Therefore to enhance these mechanical properties fibers [6,7] can be used in the mix. This paper will focus on use of polypropylene fibers to analyze the effects of them over the mechanical properties of and the experimental results reveals that PP fibers can be used for increasing the flexural and split tensile strength of the mix, however the compressive strength of the mix decreases due to the use of PP fibers. The findings of the research work create the scope for the use of PP fibers in the field of 3DCP.

II. MATERIALS AND EXPERIMENTAL METHODS

Raw materials

Ordinary Portland cement of grade 43, Class F fly-ash obtained from Sarni thermal power plant, micro grey silica fumes and polypropylene fibers procured fromjogani reinforcement is used.

Mix proportions

Total six mixes with different percent of polypropylene fibers were prepared.The influence of polypropylene fibers over the mechanical properties is given below:

S.No	CEMENT (gm)	SAND (gm)	SILICA FUMES (gm)	FLY-ASH (gm)	PP FIBERS (gm)	W/B RATIO	SP (gm)
1.	2000	3000	286	571	0.00	0.27	20
2.	2000	3000	286	571	0.60	0.27	20
3.	2000	3000	286	571	1.15	0.27	20
4.	2000	3000	286	571	2.30	0.27	20
5.	2000	3000	286	571	3.45	0.27	20
6.	2000	3000	286	571	4.60	0.27	20

Tests performed

The most basic parameter through which a concrete structure is examined in terms of strength is its compressive strength. In case of 3D concrete printing also compressive strength is very crucial parameter because 3D printed structures have high degree of porosity which will seriously affect the compressive strength of the structure. In this research work effect of insertion of polypropylene fibers on compressive strength is analyzed with respect to a mix having zero percentage of polypropylene fibers. The Compressive strength test was carried out according to IS 4031-1988 andwas calculated for 3, 7 and 28 days for of each mix by averaging the values obtained from the samples of a particular mix.

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For each mix 3 samples were prepared for determining the compressive strength.

Since the 3D concrete printing work is a free form construction work and due to no involvement of formwork the side surfaces of the structures are subjected to direct tensile stresses therefore it is very necessary to analyze the tensile strength of the mix and the effect of polypropylene fibers on the direct tensile strength of the mix therefore split tensile strength test is performed over the mix.The split tensile strength which is also known as Brazilian test was performed on compressive strength testing machine on a cylindrical sample having diameter of 15 cm and length of 30 cm as per IS 5816-1999.

For the same above reason the tensile strength of the mix in bending is also determined and the effect of polypropylene fibers on the flexure strength is also analyzed. Flexural strength test was performed according to IS 516-1959 over a beam specimen of 10cm2 cross section area and 50cm of length because the nominal size of aggregate is less than 20 mm.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Compressive strength

The ultimate compressive strength of the mix was found to be decrease when the PP fiber content in the mix has increased beyond 0.08 % in comparison to the mix having 0% PP content. However there is no significant change in 3 days compressive strength.

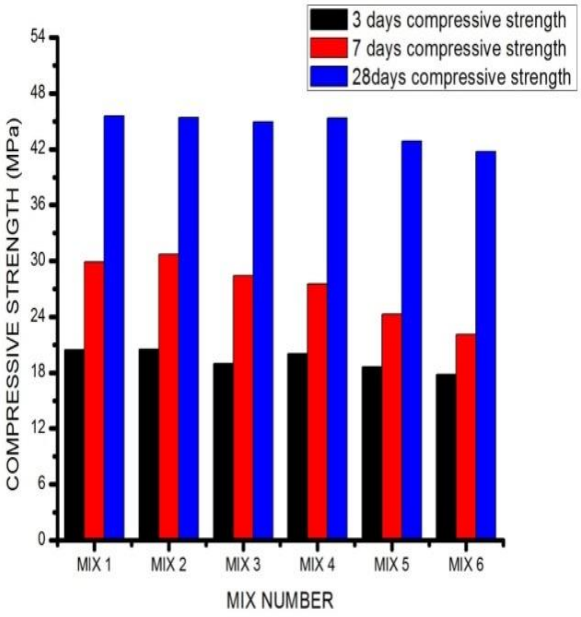

Figure 3: Comparison of 3, 7 and 28 days average strength

Split tensile strength

The split tensile strength of the mix increases when the content of PP fibers increases from 0.02% to 0.08 %. After further increment of PP fibers a gradual decrease in the split tensile strength of the mix has found.

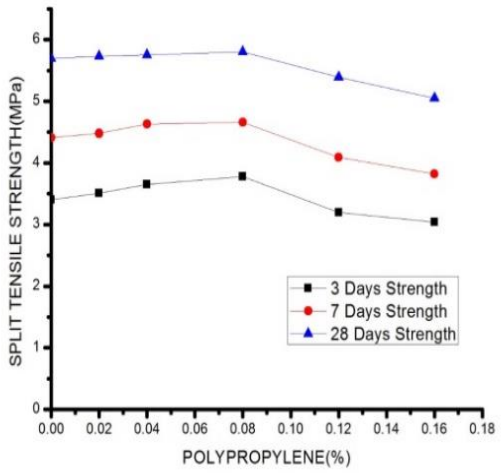

Figure 4: variation of split tensile strength with polypropylene fibres

Flexural strength

Flexural strength of the mix was found to be increase when the PP content was increased to 0.12%. The flexural strength of the mix also found to be decrease when PP fibers are used beyond 0.12%.

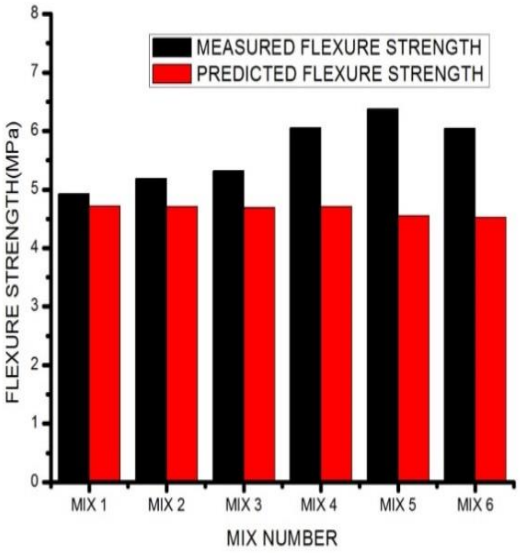

Figure 5: flexural strength of 6 mix

IV. CONCLUSIONS

- With the addition of polypropylene fibers in the mix causes significant changes in Split tensile strength and flexural strength of the mix.
- Using PP fibers up to 0.08% in the mix will help to increase the early split tensile strength of the mix up to 11% however the later split tensile strength of the mix was not much affected by the use of PP fibers.

- The influence of PP fibers on the flexural strength of the mix was found to be positive when PP fibers are used up to 0.12% of binder content. An increase in flexural strength by 30% is observed when PP fibers are used at 0.12% of binder content.
- When PP fibers are used beyond 0.12% than reduction in the split and flexural strength of the mix was observed probably due to improper dispersion of fibers into the concrete.
- Compressive strength of the mix containing PP fibers was found to be lesser with respect to the mix not containing PP fibers.
- PP fibers can be recommended to use in 3DCP to increase the flexural and split tensile strength which in turn decreases the rigidity of the structure and thereby helps to increase the ductility of the structure.

REFERENCES

1. Bogue, Robert. "3D printing: the dawn of a new era in manufacturing." Assembly Automation (2013).
2. Wu, P., Wang, J., & Wang, X. (2016). A critical review of the use of 3-D printing in the construction industry. Automation in Construction, 68, 21-31.
3. Weng, Y., Li, M., Ruan, S., Wong, T. N., Tan, M. J., Yeong, K. L. O., &Qian, S. (2020). Comparative economic, environmental and productivity assessment of a concrete bathroom unit fabricated through 3D printing and a precast approach. Journal of Cleaner Production, 121245.
4. Malaeb, Z., Hachem, H., Tourbah, A., Maalouf, T., El Zarwi, N., &Hamzeh, F. (2015). 3D concrete printing: machine and mix design. International Journal of Civil Engineering, 6(6), 14-22.
5. Le, T. T., Austin, S. A., Lim, S., Buswell, R. A., Gibb, A. G., & Thorpe, T. (2012). Mix design and fresh properties for high-performance printing concrete. Materials and structures, 45(8), 1221-1232.
6. Zhang, P., Li, Q., & Zhang, H. (2011). Combined effect of polypropylene fiber and silica fume on mechanical properties of concrete composite containing fly ash. Journal of Reinforced Plastics and Composites, 30(16), 1349-1358.
7. Hsie, M., Tu, C., & Song, P. S. (2008). Mechanical properties of polypropylene hybrid fiber-reinforced concrete. Materials Science and Engineering: A, 494(1-2), 153-157.

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