IMPACT OF POLYPROPELENE CRYSTALS IN SELF COMPACTING CONCRETE

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ABSTRACT:

Sustainability is one of the main factor of any kind of infrastructure which is measured by its economic and environmental impacts throughout its life process. Concrete industries are much concerned to increase the sustainability of civil engineering structures. The application of plastic materials in concrete is getting more popular in concrete structures as it can reduce the cost of construction and environmental impacts. The study analyses the performance of Self compacting concrete while incorporating Polypropylene crystals as a replacement of natural fine aggregates. SCC designed for speedy construction, low labour cost and enhanced durability. Hence polypropylene crystals in SCC is having more significance in modern construction. The variables in this study are the percentage of replacement level of Polypropylene crystals (0%, 10%, 20%, 30%, 40%). Experimental studies were carried on different concrete specimens like cubes, cylinders, beam, disc and slab. Investigations are presented in terms of workability, compressive strength, split tensile strength, modulus of elasticity, ultra sonic pulse velocity, permeability, impact strength and punching shear stress. Results indicated that mechanical properties like compressive strength, split tensile strength, modulus of elasticity, impact strength and punching shear stress values are decreased with increasing replacement levels of Polypropylene crystals. UPV values shows good results at 10% replacement level and then decreased with increasing percentages of Polypropylene

crystals from 10% to 40%. Similarly, Permeability analysis indicates that at 10% polypropylene crystals water penetration depth is low compared to conventional 0% level. But values are then gradually decreased up to 40% replacement level. This investigation will open new opportunities for sustainable constructions by using optimized proportions of non-biodegradable plastic waste materials.

INTRODUCTION:

The construction industry increasingly depends on Self-Compacting Concrete (SCC) because of its excellent workability and flowability, resulting in reduced man power and cost. Polypropylene crystals are commonly used in concrete in order to reduce cracking, to enhance the durability and to reduce environmental impact. Polypropylene crystals are produced from plastic waste materials and it can replace aggregates and can improve total quality of SCC. This study aims to analyse the impact of modified Polypropylene crystals in self-compacting concrete and to understand its vital role on various properties on SSC.

Desirable percentage of Polypropylene crystals to be added to the concrete is very important such that there will not be much reduction in flow characteristics of the Self compacted concrete. Workability characteristics like Slump flow, V funnel test, L box ratio test etc should be calculated for different percentages of Polypropylene crystals to understand fresh properties of concrete. Evaluation of hardened properties are very crucial because these properties will affect the structural performance of the mix. Addition of Polypropylene crystals will influence main hardened properties like Compressive strength, Split tensile strength, Modulus of elasticity, Impact strength, and Punching shear strength. Hence evaluation of these properties is very important. These mechanical qualities decrease noticeably with increase in Polypropylene crystals content. Reduction in these mechanical properties results in reduction in ability to with stand compression, tension, bending

resistance, and stiffness. But optimum addition of Polypropylene crystals without much reduction of strength and stiffness is to be figure out.

Crack formation in concrete is very severe issue which influences the structural performance. Cracks can compromise structural integrity and finally may leads to failure of the structure. Through cracks there is \a chance of movements of water and other chemicals and may leads to deterioration of concrete and corrosion of the reinforcement. Incorporation of Polypropylene crystals can influence crack formation. Water permeability study also determines structures integrity characteristics. It determines durability and longevity of the structure. Optimization of concrete mix is required for the reduction crack and permeability. Hence optimal concentration of Polypropylene crystals to be find out in order to reduce crack and permeability. These characteristics are critical for buildings in aggressive environment. . This study will provide a new horizon for producing green concrete by using non-bio degradable waste plastic material. Besides this saves energy and keep the environment clean.

OBJECTIVES:

- To analyze fresh properties of M 30 SCC with Polypropylene crystals
- To study the hardened properties and structural performance of SCC with Polypropylene crystals
- To study durability properties of SCC with Polypropylene crystals

EXPERIMENTAL PROGRAMME:

The experiment is conducted to find out various fresh and hardened properties of Self compacting concrete containing Polypropylene Crystals. M 30 mix is selected for Self-compacting concrete and poly propylene crystals are added in various percentages by

replacing fine aggregates by 0% (ID M30/0), 10% (ID M30/10), 20% (ID M30/20), 30% (ID M30/30) and 40% (ID M30/40).

PROPERTIES OF MATERIALS:

The materials used in this study are:

1. Cement
2. Fine aggregates
3. Coarse aggregates
4. Superplasticizers
5. Fly ash
6. Polypropylene crystals

For this experiment 53 grade ordinary Portland cement confirming to IS:12269-1987 is used. The specific gravity of this cement is 3.15, the initial setting time is 35 minutes, and the final setting time is 600 minutes. Aggregate with a maximum size of 4.75 mm, specific gravity of 2.65 and water absorption of 2.96% is used as fine aggregate. The sand belonging to zone II of IS:383(2016) is used for this experiment. Crushed gravel having a maximum size of 12.5 mm, and specific gravity of 2.74 is used as coarse aggregate. The water absorption of coarse aggregate is 0.67%.

Superplasticizer used in this study is Auramix 450 and it is based on polycarboxylic ether polymer. Auramix 450 plays an important role in concrete mixes.. This admixture is in yellow colour with specific gravity 1.09. Superplasticizers are crucial in SCC enabling it to flow and fill in complex structures without vibration. .Fly ash conforming to Class F is selected for the mix. The specific gravity of fly ash is 2.19. The fineness of fly ash is 325 m^2/kg. Polypropylene crystals are the recycled plastic waste materials and can be used

in concrete as a replacement of fine aggregate for improving different properties of concrete. Specific gravity of polypropylene crystals is 0.93. The use of polypropylene crystals in concrete as aggregate reduces dependence on natural aggregates.

CONCRETE MIX DESIGN

Concrete mix design is a process to find out various proportions of materials required to form concrete. Various proportions of materials are finalized based on IS:10262 (2009). The mix proportions are selected based on trials batches conducted in the lab. In this study the selected mix is M30 Self compacting concrete. Proportions of various materials are fixed based on Slump flow test, V funnel test and L box test.

. Mix design for M30 concrete

Mix ID	Materials in kg per cubic meter of Self compacting concrete corresponding to Mix ID (kg/m^3)							
	Cement	Fly ash	Admixture	Water	Coarse Aggregate	Fine Aggregate	Powder content	water powder ratio
M30/0	325	108	5	195	718	974.3	490	1.091

WORKABILITY PROPERTIES OF SCC

Slump flow test by Abram's cone – This is the one of the common test used for SCC for measuring workability. In this fresh concrete is filled in Abram's cone. After lifting the cone, the diameter of the spread concrete can be measured. This shows filling ability of the concrete. A higher Slump flow indicates its higher ability to fill formwork by its own weight. T 50 test is determined using slump flow test. This is the time required for the concrete to

flow to a diameter of 50 cm. T50 tome is also an indication of flow. A higher time indicates lower flow ability.

L- box test – It shows passing ability of concrete. It is very important in structures having complicated form work design and having dense reinforcement structures. Blocking ratio can be calculated from this by dividing height of concrete at the middle and at the end of the box. If the concrete flows as freely without any obstruction blocking ratio value will be one. Hence the nearer this test value the blocking ratio is to unity, the better the flow of concrete.

V Funnel test – It indicates filling ability of the concrete. V funnel time can be calculated by measuring time required for the concrete to drain out from the V shaped funnel. Better results means it can easily fill within the formwork without segregation. This test measures the ease of flow of concrete. Shorter flow time shows greater flow ability.

Mix ID	workability properties			
	Slump flow (mm)	T-50 (sec)	Blocking ratio	V funnel (sec)
M30/0	695	3.2	0.87	6.15
M30/10	690	4	0.85	6.92
M30/20	675	5.81	0.83	7.9
M30/30	660	6.2	0.74	11.15
M30/40	650	7.8	0.69	14.85

Poly propylene crystals are added in various percentages of replacement of fine aggregate, such as 0% (ID 30/0), 10% (ID 30/10), 20% (ID 30/20), 30% (ID 30/30) and 40% (ID 30/40). Mix proportions for various percentage of polypropylene are given below

Weight of constituent materials in kg per cubic meter of concrete corresponding to Mix ID (kg/m^3)								
Mix ID	Cement	Fly ash	Admixture	Water	Coarse Aggregate	Fine Aggregate	Poly propylene granules	w/c
M30/0	325	108	5	195	718	974.3	0	0.45
M30/10	325	108	5	195	718	876.87	33.397	0.45
M30/20	325	108	5	195	718	779.44	66.885	0.45
M30/30	325	108	5	195	718	682.01	100.282	0.45
M30/40	325	108	5	195	718	590.58	133.77	0.45

CASTING FOR DIFFERENT TESTS.

COMPRESSION TEST - Compressive strength is a very important property which indicates load bearing capacity of concrete elements. Three numbers of Cube of size 150x150x150 mm casted for each of 5 mix proportions. Compressive strength is calculated with the help of compression testing machine. For this cube is casted and kept for curing 28 days and then applying gradually increasing load until cube fails. Test is repeated for each of three specimens for each mix. Compressive strength is obtained by dividing maximum load with cross sectional area of the specimen.

SPLIT TENSILE STRENGTH – This test is used for evaluating tensile characteristics of concrete by applying compressive load diametrically across a cylindrical specimen. Three numbers of cylinder 150mm diameter and 300 mm height casted for each 5 mix proportions.

Split tensile strength = $2P/ \pi LD$

Where P is the maximum load, L is the length and D is the diameter of the specimen. Split tensile strength is an important characteristic of concrete which helps to understand materials resistance to tensile stress.

IMPACT STRENGTH – Impact test refers to ability of structure to withstand sudden loads. This test gives toughness characteristics of specimen. It is calculated by measuring number of blows required for the first crack of specimen. Three numbers of disc specimens of size 170mm in diameter and 60 mm in height casted for each of 5 mix proportions. The weight of the hammer is 13.5kg and it is dropped from a height of 0.5m. The test was conducted based on specification ACI544-2R/2017. The energy absorbed by the specimens is calculated using the equation below.

Energy = E = NB x M x h x g

where, NB represents the number of blows, a drop height is represented by h, a gravitational acceleration constant is depicted by g, and a solid ball mass is denoted by M, respectively.

PUNCH SHEAR TEST - It is a direct shear test. This test is done by using circular punch head to build shear failure surface. Compressive force is applied through a punch head at a clamped surface causes shearing along edges of the punch. It is based on ACI318/2019 specifications. The specimen is used for this test is a Slab with a dimension of 300mmx300mmx60mm. A notch of 110mm and 30mm depth is made at the centre of the specimen. Specimen is casted for each of 5 mix proportions. Punching shear stress can be calculated using the following formula.

Tv = Vu / (b0xt).

Where Tv is the punching shear stress, Vu is the applied shear force, b0 is the perimeter of the critical section, t is the effective depth of the slab. The critical section for punching shear is a perimeter around the column.

UPV TEST - Ultra sonic pulse velocity test is one of the non-destructive test used to find quality of the material, defects in the material, crack in the material and structural changes. In this test a transmitter sends an ultra-sonic pulse to the material and receiver calculates its time of travel through the material. Velocity is obtained by dividing distance by the travel time.

Higher velocity shows better material quality. Specimen used for this test is cube of size 150mmx150mmx150mm and it is casted for each 5 mix proportions. Thus it helps to evaluate quality, integrity and homogeneity of the structure.

PERMEABILITY TEST - This test is used to find out the easiness in movement of fluids through the specimen. It helps to assess the durability, water pressure bearing capacity and chemical attack. It can be find out by applying hydrostatic pressure into the materials and by calculating the amount of water that moves through the material over a period of time. Specimen used is cube of size 150mmx150mmx150mm and it is casted for each 5 mix proportions. In this test samples after 28 days curing subjected to hydrostatic pressure 500 Kpa in testing apparatus. After 3 days, the depth of water penetration is measured by cracking the sample vertically.

MODULUS OF ELASTICITY TEST – It is a property which defines elasticity of material. This shows materials resistance to deformation. It is also known as Youngs modulus obtained by the ratio of stress and strain.

$E = \sigma/\in$

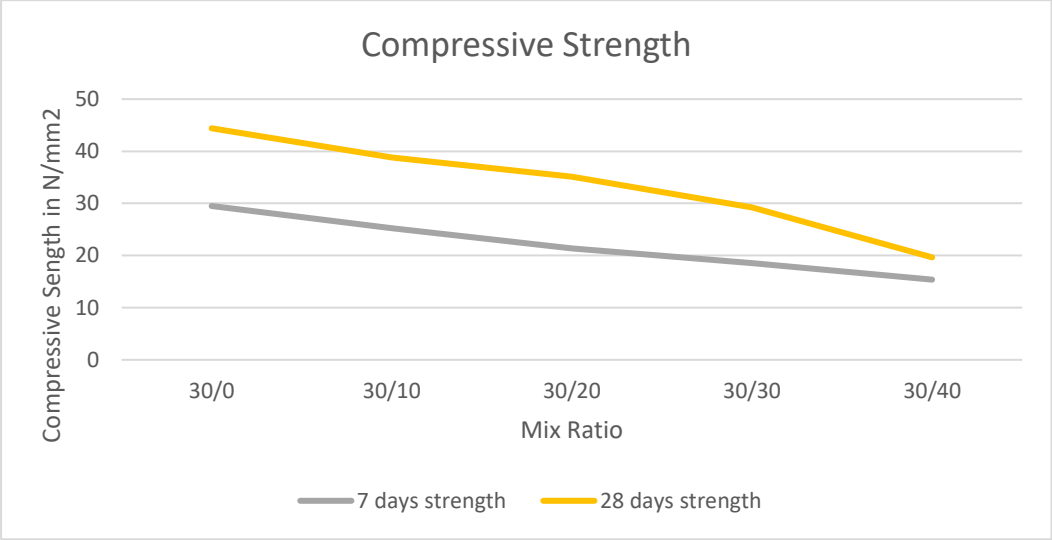
Where E is the modulus of elasticity, σ is the applied stress and $\in$ is the resulting strain. High modulus of elasticity means material is more stiffer having less deformation. Cylinder having 150 mm diameter and 300 mm height is casted for the test and casting has done for 5 different proportions. This property describes its resistance to deformation under stress.

RESULTS AND DISCUSSIONS

COMPRESSIVE STRENGTH

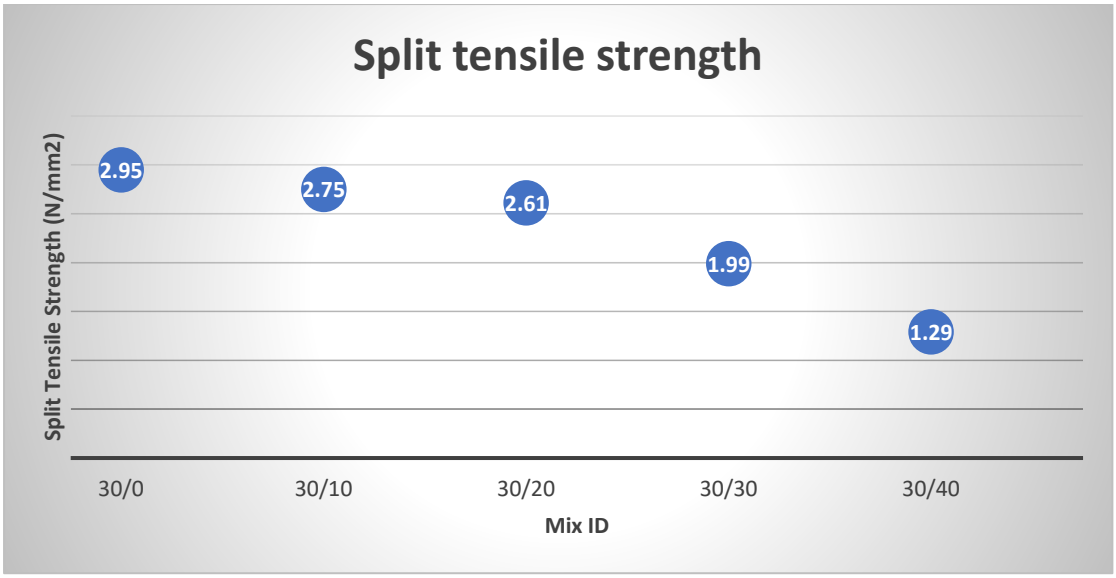
Compressive strength of specimen is tested for 7 days and 28 days using compression testing machine. The test has done for specimens of self-compacting concrete without polypropylene

granules (M30/0) and having 10% (M30/10), 20% (M30/20), 30%(M30/30), 40%(M30/40). From results it is understood that compressive strength decreases with increase in polypropylene percentage. 7 days compressive strength decrease from 29.5 N/mm^2 to 15.38 N/mm^2 as the percentage of polypropylene increases from 0 to 40%. 28 days compressive strength decreases from 44.4 N/mm^2 to 19.65 N/mm^2 as the percentage of polypropylene increases from 0 to 40%



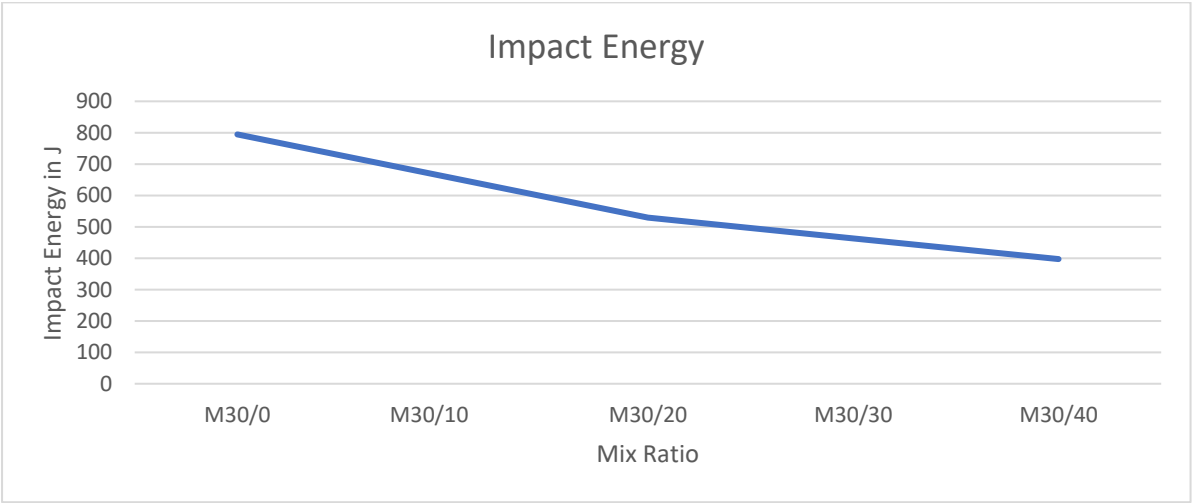
SPLIT TENSILE STRENGTH

The Split tensile strength test has done for specimens of self-compacting concrete without polypropylene granules (M30/0) and having 10% (M30/10), 20% (M30/20), 30%(M30/30), 40%(M30/40). Results shows that split tensile strength decreases with increase in polypropylene content. For M30/0 specimen tensile strength result obtained is 2.95 N/mm2 and for M30/40 specimen result obtained is 0.92 N/mm2. Although usage of polypropylene crystals encourages usage recycled plastic materials and has positive effects in environment, they also control the structural parameters of the structure.



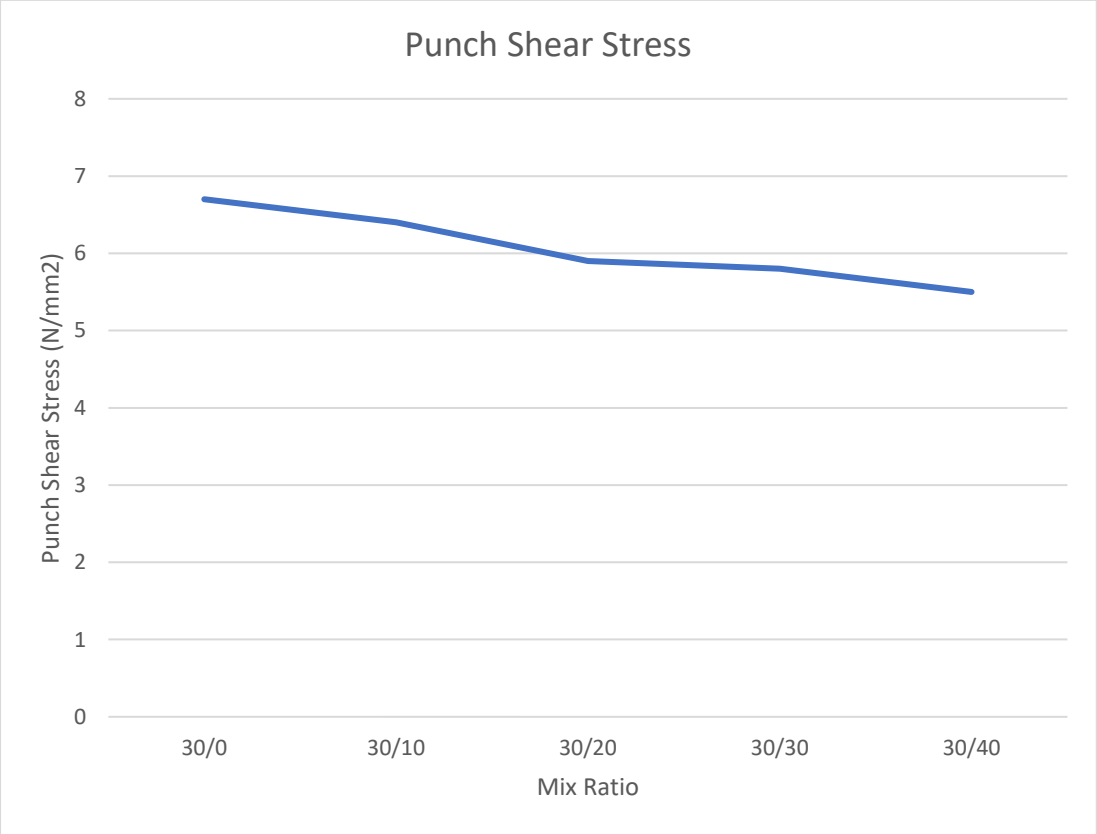
IMPACT STRENGTH

Impact test is done for self-compacting concrete specimens without polypropylene granules (M30/0) and having 10% (M30/10), 20% (M30/20), 30%(M30/30), 40%(M30/40). Results shows that number of blows required for the crack on the specimen is decreased from 12 to 6 as the percentage varied from 0 to 40%. Consequently, impact energy decreases from 794.61 J to 397.3 J. As the polypropylene content increases the impact energy decreases. polypropylene crystals supports green environment condition but reduces toughness characteristics of the structure.



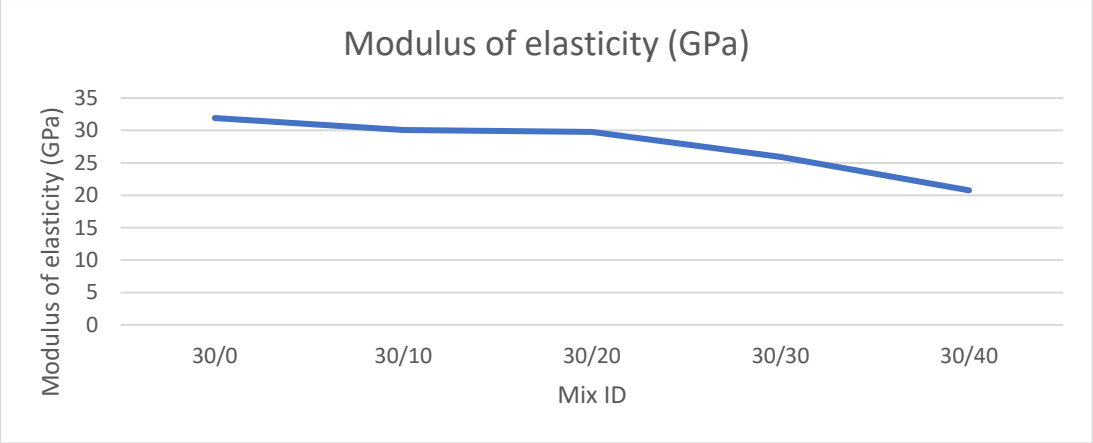
PUNCHING SHEAR STRENGTH

Punching shear test is done for self-compacting concrete specimens without polypropylene granules (M30/0) and having 10% (M30/10), 20% (M30/20), 30%(M30/30), 40%(M30/40). Punch shear stress for the M30/0 specimen is 6.7 N/mm2. Punch shear stress value decreases as the polypropylene content increases. Value obtained for M30/40 specimen is 5.5 N/mm2.



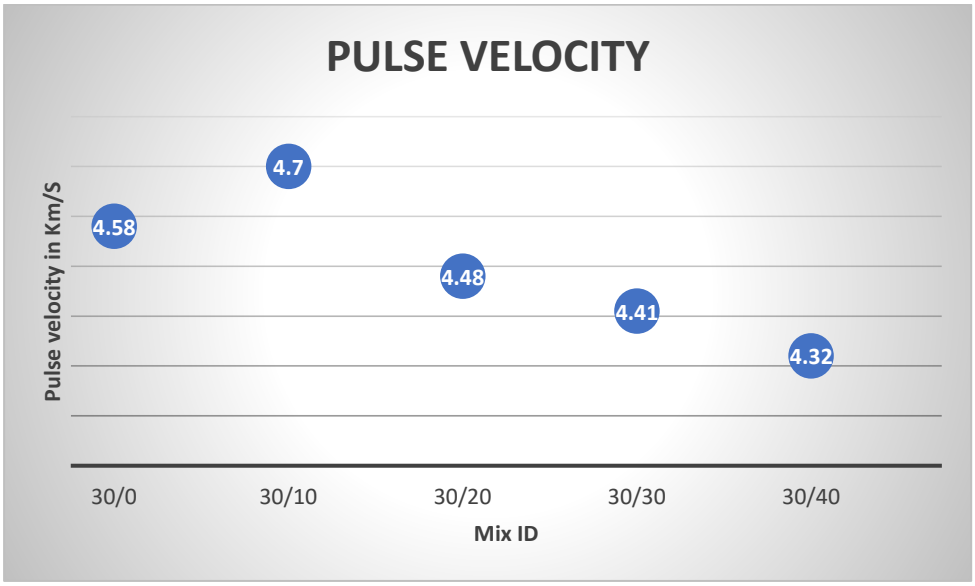
MODULUS OF ELASTICITY

Modulus of elasticity test is done for different 5 set of self-compacting concrete specimens. Modulus of elasticity value obtained for the sample M30/0 is 31.91 G Pa. Value of modulus elasticity gradually reduces for the increased percentages of polypropylene crystals. Optimum dosage of polypropylene is required for balanced strength requirement.



UPV TEST

UPV test is done for various self-compacting concrete specimens without polypropylene granules (M30/0) and having 10% (M30/10), 20% (M30/20), 30%(M30/30), 40%(M30/40). Pulse velocity obtained for the sample M30/0 is 4.58 km/s. There is a slight improvement of pulse velocity for the sample M30/10 and the obtained value is 4.7km/s. Then there is a gradual decrease of pulse of velocity with the increased percentages of polypropylene crystals. It shows good results are shown for specimen with 10 % polypropylene. However, for a higher percentages of polypropylene crystals particles are well distributed and there are aerated more cavities between aggregates



PERMEABILITY TEST

Permeability test is done for 5 different self-compacting concrete specimens (M30/0), (M30/10), (M30/20), (M30/30) and (M30/40). Permeability value obtained for the mix M30/0 is 94 mm and for the mix M30/10 is 92 mm. Results shows that sample with 10% polypropylene shows good permeability results than the conventional concrete mix. But Permeability increases with increase in percentages of polypropylene. Thus, moderate inclusion of polypropylene crystals enhances durability characteristics by reducing permeability rates.

No	Mix ID	DEPTH OF WATER PENETRATION (mm)
1	M30/0	34
2	M30/20	32
3	M30/20	42
4	M30/30	56
5	M30/40	67

CONCLUSIONS

This study comprehensively explores impact of poly propylene crystals in self-compacted concrete. As per the mix design and workability conditions of M30 SCC, specimens are

prepared with various percentage of polypropylene crystals and evaluated various fresh and hardened properties. The key findings from the study are abridged as follows.

- Increasing polypropylene percentage in concrete leads to a decrease in blocking ratio and slump flow and increase in V-funnel time and T50 time. Workability of concrete declined with increase in polypropylene percentage. Hence there should be an optimal balance that maximise the benefit of polypropylene without significantly affecting workability.
- By evaluating results of compressive strength, it is understood that by increasing percentage of polypropylene crystals, compressive strength of concrete decreases. Tensile strength, Modulus of elasticity, Impact strength and punching shear strength also decreases with the increase in polypropylene crystals.
- UPV test results shows that there is an increase in pulse velocity at 10% polypropylene sample compared to 0%. This shows better crack resistance ability at this sample. Similarly for permeability also there is good results at 10% polypropylene sample. Water penetration depth is low at this sample. Hence concrete containing 10% polypropylene content might be the optimum limit for both crack resistance and durable structure.

Inclusion of polypropylene as a replacement of fine aggregate for producing sustainable green concrete is an innovative concept in the construction field. Based on the experimental results it is suggested to use 10% polypropylene crystals for achieving green concrete without much reduction in structural properties. selection of optimum value of polypropylene crystals is very important to produce sustainable green concrete by protecting natural resources Aswell as prevents the environment from pollution.

REFERENCES

[1] Bala Rama Krishna Chunchu, & P Jagadeesh (2018). Fresh and hardened properties of self-compacting concrete replacing fine aggregate with high impact polystyrene plastic granules. *International Journal of Civil Engineering and Technology*, 9(12), 831-838. http://www.iaeme.com/IJCIET/index.asp

[2] Mustafa Maher Al-Tayeb et.al (2020). Ultimate Failure Resistance of Concrete with Partial Replacements of Sand by Polycarbonate Plastic Waste Under Impact Load. *Civil and Environmental Research*, Volume (12) 2224-5790. www.iiste.org

[3] Xuan Liu et al. (2024). Mix Design and Performance Study of High-Strength Self-Compacting Concrete with Manufactured Sand. *Construction and Building Materials*, *18*(1), 55; **https://doi.org/10.3390/ma18010055**

[4] Md. Shahjalal et.al (2021). Effect of polypropylene plastic on concrete properties as a partial replacement of stone and brick aggregate. *Case Studies in Construction Materials*., Volume 15. https://doi.org/10.1016/j.cscm.2021.09.075

[5] Hisham, et al. (2018). Fresh properties of green SCC made with recycled steel slag coarse aggregate under normal and hot weather. *Journal of Cleaner Production*, 349, 980-991. https://doi.org/10.1016/j.jclepro.2018.09.075

[6] Gunasekaran, et al. (2022). Influence of height and weight of drop hammer on impact strength and fracture toughness of two-stage fibrous concrete comprising nano carbon tubes. *Construction and building material*. https://doi.org/10.1016/j.conbuildmat.2022.128782

[7] Marcos, et al (2015 Numerical simulation of the punching shear behaviour of self-compacting fibre reinforced flat slabs. *Construction and building material*. 74, 25-36, https://doi.org/10.1016/j.conbuildmat.2014.10.003

[8] Hama et.al (2017). Fresh properties of self-compacting concrete with plastic waste as partial replacement of sand. *International Journal of Sustainable Environment*, 6(2), 299-308. https://doi.org/10.1016/j.ijsbe.2017.01.001

[9] Mallek et.al (2024). Durability of self-compacting rubberized concrete exposed to external sulphate attack. *Case Studies in Construction Materials*, 20, e02730. https://doi.org/10.1016/j.cscm.2023.e02730

[10] Adhikary et.al (2022). Lightweight self-compacting concrete: A 44 review. Resources, *Conservation & Recycling Advances*, 15,2001, https://doi.org/10.1016/j.rcradv.2022.200107

[11]] IS 10262-2019, "Concrete mix proportioning- guidelines" - Bureau of Indian Standards, New Delhi.