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Improvement of Engineering Properties of Fibre Reinforced Self Compacting Concrete with Addition of Granite Waste

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ABSTRACT

Construction industry is causing paramount pollution to the ecosystem, which is unbearable as safe and better environment are important and burning concerns of today. Our environmentalists are stressing on 3R's to save the environment, out of these R's reuse is the best and cheapest option. On the same lines, granite a construction material used in flooring or other purposes, ample of waste discarded during polishing and cutting of granite. This granite waste (GW) when mixed with water poses threat to the environment. So, in the present work GW is used as a partial substitute to cement used in fibre reinforced Self Compacting Concrete. This in-length research was carried out mainly to study the behaviour of FRSCC with varying granite waste content. This effect of modifier is studied by detailed experimental program on concrete mix comprising Bulk Density Test, Compressive Strength Test, Split Tesile strength Test and Abrasion Test. Out of these split tensile and compression test helped in reaching the optimum mix. The trend of density increases with GW content as 1.09, 0.97, 4.17 and 4.37 for 5, 10, 15 and 20% GW content respectively. So, addition of GW causes a significant increase in density. The trend of compressive strength is +1.46, +5.84, -8.15 and -14.84% with addition of 5, 10, 15 and 20% GW content resp, so the trend of strength first increases and then decreases with GW content. The trend of tensile strength decreases by 9.57% with addition of 5, 10, 15 and 20% GW content, so the trend of strength decreases with GW content. Whereas the strength increases with increase in fiber content. Loss of thickness as noted from abrasion test is reduced by addition of both GW and PP fibres, so more resistance is developed by addition of these modifiers against abrasion. It was inferred from above tests that at 10%GW content and 0.1%PP content, mix showed best results in all tests. The present work suggests a solution for the environmental problems related to GW disposal and novel way of cement/concrete production.

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1. INTRODUCTION

Coarse and fine aggregates when bound through the binder named cement as an amalgamated mix with sufficient strength, the process is termed as casting. Cement can be casted in different shapes and forms as desired. Concrete behaves different in different states i.e. fresh or hardened state. It is not impractical to say that no one can understand this variant/irregular behavior of concrete to the fullest. In construction industry, cement tops in order of consumption. Durability of many massive structures rests on the strength of concrete used in their construction, so it must be handled, placed and designed with proper care. Casting is always accompanied by the process of compaction. This compaction ensures strength, if done with proper care. In case of design-mix, compaction is carried out on-site with the help of vibrators. But, generally there arises lapse while carrying out this compaction, resulting into improper compaction. Due to inadequate compaction the subsequent mix, so formed, is fragile/weak. This low-quality concrete results into weak structure.

The concrete which can be compacted under its self-weight and requires a little or no external compaction through vibrators or other compactors is termed as self-compacting concrete or just SCC. This type of cement concrete is generally used in the construction of heavily reinforced structures, which requires excellence in structural performance. This concrete is modified or strengthened by the use of fibers in it, the modified concrete formed by embedding fibers in it is referred as Fibre Reinforced Self Compacting Concrete (or FRSCC). It is a composite material with higher tensile strength and improved characteristic compressive strength. This addition of fiber changes the brittle SCC to a ductile FRSCC. This concrete is also capable of self-compaction.

2. Literature Review's

Dr. D. L Venkatesh Babu et al (2014) concluded in their investigation that concrete faces many challenges when used as a construction material; it is subjected to many stresses like reverted cycles of load causing fatigue and impact loading, leading to cracks. There are critical issues coming out of plain concrete. They weaken the concrete performance in a long term fortunately polymer fibers and steel fibers have the solution for these issues. Plain concrete is very brittle and lacks ductility, while polymer and steel fibers do have. So, Polymer modified and steel fiber reinforced concrete is primarily used to arrest cracking in structural concrete applications, with proven superior results.

They carried out test on Birla Super Cement (53 Grade) concrete, with sp. Gravity value of 3.15. Values of Initial and Final setting times were 70- and 220-mins resp. The modifiers proposed by them were SBR latex and Steel fibers. The optimum content of modifiers as suggested by their investigation was SBR latex @ 5% and SF @ 0.5%.

Dina Sadek et al. (2016) explained the mechanical properties of steel fiber concrete together of acrylic polymers. during this study fiber percentage are varied 0.5% by weight of cement upto 1.5% also as acrylic polymer content are varied as 3%,7% and 10% by weight of cement. Significant curing of specimens carried as total water immersed curing by Folic method. Result observed showed an improvement altogether properties of control concrete when steel fibers were added. While addition of acrylic polymers along with steel fiber showed a greater influence than steel fiber ferro-concrete. There was (14.2%-29.2%) increment in compressive strength of steel fiber ferro-concrete, while it had been found (44.8- 86.64%) increment in PMSFRC. Splitting lasting-ness the rise upto (50-91%) was observed for steel fibres concrete which matches on increasing upto (102.4-124.7%) just in case of PMSFRC. Similar increment was observed in flexural strength as (24.2-48.3%) for SFRC and (62-78%) for PMSFRC.7% of P/C was found to be optimal with 1% variation within the volume fraction.

Roziere et al. (2007) presented an experimental study on specimen with varying paste volume. The key properties which were work out in their investigation were fracture and shrinkage. The experiments through which specimens were undergone were

- Fracture analysis through three point bending test
- Test for modulus of rupture
- Acoustic emission analysis

From the results of above experiments it was concluded that with increase in volume of paste SCC become more and more brittle.

H. Okamura and M. Ouchi (2003) suggested methods of preparing SCC and discussed mechanisms behind it. The major characteristic of SCC which was highlighted in their work was deformability. The key points suggested by their research to form SCC were as follows:

- Aggregate content should be limited so that seggregation can be avoided
- Water cement ratio should be kept as low as possible
- Plasticisers can be used to impart self compactibility by making viscous cement mix. Also an in-depth discussion was done on factors affecting SCC. The content suggested by their paper for coarse and fine aggregate were 50% and 40% of mortar volume.

3. MATERIAL USED

The following materials are implemented to reach the desired objectives.

- Fine aggregates
- Coarse aggregates
- Cement
- Fly ash
- Granite waste
- PP Fibres
- Water

Mix Proportion: The mix proportion used in present investigation are tabulated below:

Table Mix proportions

	Cement	Fly ash	Fine aggregate	Coarse aggregate	Water
Quantity of materials/$m^3$of concrete	431 kg/m^3	97 kg/m^3	913 kg/m^3	755 kg/m^3	194 lit /m^3

The following mix combinations are used for various proportions of GW, flyash and Polypropylene fibres.

Control- Control concrete with cement 75% and flyash 25%

$G_0P_{0.05}$ - Concrete without GSW + 0.05% Polypropylene fibres
$G_0P_{0.1}$ - Concrete without GSW + 0.1% Polypropylene fibres
$G_0P_{0.15}$ - Concrete without GSW + 0.15% Polypropylene fibres
$G_5 P_0$ - Concrete with 5% cement replaced with GSW + 0% Polypropylene fibres
$G_5 P_{0.05}$ - Concrete with 5% cement replaced with GSW+ 0.05% Polypropylene fibres
$G_{10} P_0$ -Concrete with 10% cement replaced with GSW+ 0% Polypropylene fibres
$G_{10} P_{0.05}$-Concrete with 10% cement replaced with GSW + 0.05% Polypropylene fibres
$G_{10}P_{0.1}$ - Concrete with 10% cement replaced with GSW + 0.1% Polypropylene fibres
$G_{10}P_{0.15}$ - Concrete with 10% cement replaced with GSW+ 0.15% Polypropylene fibres
$G_{15} P_0$ - Concrete with 15% cement replaced with GSW + 0% Polypropylene fibres
$G_{15} P_{0.05}$- Concrete with 15% cement replaced with GSW + 0.05% Polypropylene fibres
$G_{15}P_{0.1}$ - Concrete with 15% cement replaced with GSW + 0.1% Polypropylene fibres
$G_{15}P_{0.15}$ - Concrete with 15% cement replaced with SW + 0.15% Polypropylene fibres
$G_{20} P_0$ - Concrete with 20% cement replaced with GSW + 0% Polypropylene fibres
$G_{20} P_{0.05}$- Concrete with 20% cement replaced with GSW+ 0.05% Polypropylene fibres
$G_{20}P_{0.1}$ - Concrete with 20% cement replaced with GSW+ 0.1% Polypropylene fibres
$G_{20}P_{0.15}$ - Concrete with 20% cement replaced with GSW+ 0.15% Polypropylene fibres

Mix designations and composition

Mix Designation	Cement (kg/m^3)	GW (kg/m^3)	Flyash (kg/m^3)	Polypropylene Fibres (%)
Control concrete	431	0	97	0
$G_0P_{0.05}$	431	0	97	0.05
$G_0P_{0.1}$	431	0	97	0.1
$G_0P_{0.15}$	431	0	97	0.15
$G_5 P_0$	409.5	21.5	97	0
$G_5 P_{0.05}$	409.5	21.5	97	0.05
$G_5P_{0.1}$	409.5	21.5	97	0.1
$G_5P_{0.15}$	409.5	21.5	97	0.15
$G_{10} P_0$	388	43	97	0
$G_{10} P_{0.05}$	388	43	97	0.05
$G_{10}P_{0.1}$	388	43	97	0.1
$G_{10}P_{0.15}$	388	43	97	0.15
$G_{15} P_0$	366.5	64.5	97	0
$G_{15} P_{0.05}$	366.5	64.5	97	0.05
$G_{15}P_{0.1}$	366.5	64.5	97	0.1
$G_{15}P_{0.15}$	366.5	64.5	97	0.15
$G_{20} P_0$	345	86	97	0
$G_{20} P_{0.05}$	345	86	97	0.05
$G_{20}P_{0.1}$	345	86	97	0.1
$G_{20}P_{0.15}$	345	86	97	0.15

4. RESULTS & DISCUSSIONS

Test for compressive strength: This test is an important test and is carried out to ascertain the compressive strength of different concrete mix. This test is carried out with 150mm cubical specimen for all the 20 mix proportions. Results from reference sample and modified/altered samples are tabulated in table 4.2 below.

Table Compressive strength

Mix designation	Compressive Strength (N/mm^2)		Percentage increase or decrease at 28days
	7days	28 days	
Control Concrete	24.48	32.88	-
$G_0\ P_{0.05}$	25.52	32.43	-1.36
$G_0\ P_{0.1}$	26.7	33.8	+2.79
$G_0P_{0.15}$	25.4	33.5	+1.88
$G_5\ P_0$	25	33.36	+1.46
$G_5\ P_{0.05}$	27.2	36.7	+11.62
$G_5P_{0.1}$	29.16	39.4	+19.83
$G_5P_{0.15}$	25.54	34.5	+4.93
$G_{10}\ P_0$	26.13	34.8	+5.84
$G_{10}\ P_{0.05}$	27.16	37.2	+13.14
$G_{10}P_{0.1}$	30.15	40.2	+22.26
$G_{10}P_{0.15}$	27.2	35.6	+8.27
$G_{15}\ P_0$	22.22	30.2	-8.15
$G_{15}\ P_{0.05}$	23.8	31.7	-3.59
$G_{15}P_{0.1}$	24.78	32.6	-0.85
$G_{15}P_{0.15}$	22.87	30.5	-7.24
$G_{20}\ P_0$	19.2	28	-14.84
$G_{20}\ P_{0.05}$	22.8	30.4	-7.54
$G_{20}P_{0.1}$	23.85	31.8	-3.28
$G_{20}P_{0.15}$	22.72	30.7	-6.63

Inference: It is clear, from the results tabulated above, that the trend of compressive strength is +1.46, +5.84, -8.15 and -14.84% with addition of 5, 10, 15 and 20% GW content resp, so the trend of strength first increases and then decreases with GW content. Beyond the 10% GW content limit the strength declines and results become unfavourable. This is due to presence of some active silica in GW, which gears pozzolanic reaction thus increasing strength. But with higher content reaction become ineffective due to decreased workability. Whereas the strength increases with increase in fiber content. The strength at no GW content and 0.05, 0.1 and 0.15% fibre is -1.36, +2.79 and +1.88% respectively. This is very insignificant increase in strength but when both GW and PP fibres are used in combination they affects the strength significantly and can raise the strength to about +22.26% at 10%GW content and 0.1%PP content

Test for Split tensile Strength: In this test tensile strength of concrete is obtained by applying a compressive force along the length of the concrete cylinder. The specimen used for this method is of cylindrical size of dimensions 150mm in dia and 300mm in length. The instrument used for this method is universal testing machine. The specimen is prepared in standard manufacturing procedure and placed in layers by tamping 25 blows per layer in the mould. After a day the mould is removed and the specimen is placed in the curing tank at a temperature of 27+-2degree Celsius. Test specimen are properly cured and checked for strength after 28 days. The results are recorded in corresponding table.

Table Results of Splitting tensile strength test

Mix designation	Splitting tensile strength at 28 days (N/mm^2)	Percentage increase or decrease at 28 days
Control Concrete	2.82	-
$G_0P_{0.05}$	3.43	+21.63
$G_0P_{0.1}$	3.62	+28.36
$G_0P_{0.15}$	3.65	+29.43
G_5P_0	2.55	-9.57
$G_5P_{0.05}$	3.56	+26.24
$G_5P_{0.1}$	3.64	+29.08

$G_5P_{0.15}$	3.69	+30.85
G_{10} P_0	2.55	-9.57
G_{10} $P_{0.05}$	3.53	+25.18
$G_{10}P_{0.1}$	3.89	+37.94
$G_{10}P_{0.15}$	3.88	+37.58
G_{15} P_0	2.55	-9.57
G_{15} $P_{0.05}$	3.38	+19.86
$G_{15}P_{0.1}$	3.54	+25.53
$G_{15}P_{0.15}$	3.55	+25.88
G_{20} P_0	2.55	-9.57
G_{20} $P_{0.05}$	3.31	+17.38
$G_{20}P_{0.1}$	3.69	+30.85
$G_{20}P_{0.15}$	3.58	+26.95

Inference: It is clear, from the results tabulated above, that the trend of tensile strength decreases by 9.57% with addition of 5, 10, 15 and 20% GW content, so the trend of strength decreases with GW content. Whereas the strength increases with increase in fiber content. The strength at no GW content and 0.05, 0.1 and 0.15% fibre is +21.63, +28.36 and +29.43% respectively. There is also significant increase in strength when both GW and PP fibres are used in combinations, they affect the strength significantly and can raise the strength to the maximum of about +37.94% at 10%GW content and 0.1%PP content. This content marks the highest strength

5. CONCLUSION

1. The trend of density increases with GW content as 1.09, 0.97, 4.17 and 4.37 for 5, 10, 15 and 20% GW content respectively. So, addition of GW causes a significant increase in density. This is due to the fact that GW has higher specific gravity and increases the density of the mix in which it is introduced. But reverse in the case of addition of fibers. The density trend declines with the addition of fibre. At 15% GW content the decrease in density is 2.1, 1.3 and 0.45% with 0.05, 0.1 and 0.15% fibres respectively. At 20% GW content the decrease in density is 3.97, 2.31 and 1.34% with 0.05, 0.1 and 0.15% fibres respectively. So, it is not wrong to say that maximum density is attained at minimum fibre content, this is due to the fact that PP fibres are light weight and have low sp. Gravity thus they reduce the density of mix in which they are introduced.
2. The trend of compressive strength is +1.46, +5.84, -8.15 and -14.84% with addition of 5, 10, 15 and 20% GW content resp, so the trend of strength first increases and then decreases with GW content. Beyond the 10% GW content limit the strength declines and results become unfavourable. This is due to presence of some active silica in GW, which gears pozzolanic reaction thus increasing strength. But with higher content reaction become ineffective due to decreased workability. Whereas the strength increases with increase in fiber content. The strength at no GW content and 0.05, 0.1 and 0.15% fibre is -1.36, +2.79 and +1.88% respectively. This is very insignificant increase in strength but when both GW and PP fibres are used in combination they affects the strength significantly and can raise the strength to about +22.26% at 10%GW content and 0.1%PP content.
3. The trend of tensile strength decreases by 9.57% with addition of 5, 10, 15 and 20% GW content, so the trend of strength decreases with GW content. Whereas the strength increases with increase in fiber content. The strength at no GW content and 0.05, 0.1 and 0.15% fibre is +21.63, +28.36 and +29.43% respectively. There is also significant increase in strength when both GW and PP fibres are used in combinations, they affect the strength significantly and can raise the strength to the maximum of about +37.94% at 10%GW content and 0.1%PP content. This content marks the highest strength.
4. Loss of thickness as noted from abrasion test is reduced by addition of both GW and PP fibres, so more resistance is developed by addition of these modifiers against abrasion.Thus on a concluding note it is not wrong to say that at 10%GW content and 0.1%PP content FRSCC mix showed best results in almost all tests.

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