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Comparative Study on the Strength and Durability Properties of M 50 Grade Self Compacting Concrete with Micro Concrete

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Abstract

Repair and rehabilitation of RC structures has become a common event in the field of civil engineering. This is mainly due to the quality of the materials used, poor quality of workmanship, insufficient funds and so on. The expected life of an RC structure is 100 years and now there is no such case and for repair of these RC structures, most importantly used material is concrete. In this paper, we have discussed about performance of concretes used in repair and rehabilitation scenarios namely Self-Compacting Concrete (SCC) and micro concrete. Two brands of micro concrete available in the market were chosen and its mechanical and durable properties were tested. For application in site, field study was carried out and the proportion of aggregates to be used in these micro concretes to achieve better results was derived. Specimens were casted, cured and tested, to study and compare the mechanical and durable properties of SCC (M-50), micro concrete (no aggregate) and micro concrete (with aggregate). This study will help in understanding whether self-compacting concrete can match the performance of micro concrete in the repair and rehabilitation of RC structures.

Keywords: *Micro-Concrete; Durability; SCC, Repair and Rehabilitation*

1. INTRODUCTION

Micro concrete which has high initial strength is generally used in the repair and rehabilitation works. It is mainly used to increase the load bearing capacity of RCC column and used for the repair of beams, wall and other RC elements. Due to its self flow able nature it also used in places where reinforcement is congested, where compaction is not possible and in places where human access in restricted. In spite of all its advantage, it has some drawback: the constituents of the ingredients in the micro concrete are not disclosed and hence properties cannot be altered to our convenience. It is only used for repair purposes and it is not affordable for all construction projects.

On the other hand SCC is also a flowing concrete, which is able to consolidate under its own weight. It is well suitable for sections with congested reinforcement and the highly fluid nature of SCC makes it easy to be poured in places where human access is difficult. Felekoglu et al (2009) investigated the Effects of fibre type and matrix structure on micro-concrete composites of self-compacting nature and studied its mechanical performance. Lorca et al (2014) studied the mechanical properties of micro concrete with partial replacement of ordinary Portland cement with fly ash and hydrated lime. In addition to that they have also studied the performance of the same with several levels of cement replacement, ranging from 15% to 75%.

Gracia et al (2014) studied the suitability of using mechanically recycled glass fiber reinforced plastics (rGFRP) from different sources as short fibers for precast micro concrete components. Carballosa et al (2015) used two types of expansive additives (K and G) and two different types of cement and developed a self-compacting concrete for structural elements and their performances were compared. Fernando et al (2016) discussed about the results of an experimental work carried out on SCC made with recycled coarse aggregates and residue of masonry used as mineral admixture. Mastali and Dalvand (2016) studied the effects of silica fume as partial replacement for cement and recycled steel fiber in the reinforced self-compacting concrete and reported its mechanical properties and impact resistance. Past studies showed that lot of research work has been carried out to study the performance of micro concrete separately and SCC separately. But comparison of SCC and Micro concrete has not been done and studies have not been carried out to check up to which extent SCC can be used as replacement for micro concrete. This study will help in understanding whether SCC can match the performance of micro concrete in the repair and rehabilitation of RC structures by comparing the mechanical and durability properties.

2. EXPERIMENTAL INVESTIGATIONS

2.1. Material properties

Two brands of micro concrete, viz., Rendroc RG manufactured by M/s Fosroc Chemicals and Chempatch manufactured by M/s DON Chemicals, were procured and their strength and durability properties were evaluated. The SCC of grade M50 was designed and the mechanical strength and durability characteristics were evaluated. Specific gravity, water absorption, sieve analysis and bulk density test on coarse aggregate (gravel) and fine aggregate (sand) was carried out and the results are tabulated in Table 1. The specific gravity test of Cement and fly is also included ash in table 1. Physical test on micro concrete namely flow test, unrestrained expansion, fresh wet density as prescribed by BS 4551-1980 were carried out and the results tabulated in Table 2.

Table 1 Material Properties- SCC

Test	Cement	Flyash	Coarse aggregate	Fine aggregate
Specific Gravity	3.15	2.45	2.74	2.62
Sieve analysis	-	-	12 mm	Zone-1
Bulk Density	-	-	0.5 kg/m^3	0.727 kg/m^3

Table 2 Micro concrete - Material Properties

Test	Rendroc (RG)	DON CHEMPATCH
Flow test (Workability)	23.95	23.62
Unrestrained Expansion	1.61 %	1.61 %
Fresh wet Density	2228.57 kg/m^3	2285.71 kg/m^3

2.2 Mix Design

The Mix Design for SCC has been carried out as per Indian Standard Method of IS: 10262-2009. For the micro concrete, a field study was carried out to ascertain the percentage of aggregates that are being added to the concrete so as to bring down the cost as well as to increase the mechanical strength. The micro concrete mixes were designed based on the field survey, and a practical dosage of 12 mm aggregates were added in the field. The details are tabulated in Table 3. The mix proportion for SCC (M-50) is 1:1.69:1.86:0.33:0.45. And details of chemical admixture is given in Table 4

2.3 Preparation of specimens

The mix for micro concrete mortar cubes was done using Hobbat mixer. Micro concrete sample of 2 kg was taken and filled in to the Hobbat mixer. A dry mix was done for about a minute. Water was slowly added to the Hobbat mixer and mixed for 2 minutes and specimens were casted. A total of 24 cubes (70.6 mm), 6 cylinders (75 mm diameter and 150 mm height) and 6 beams (350 × 25 × 25 mm) were casted. Micro concrete cube, beam and cylinder specimen is shown in Figure 1

For preparation of micro concrete with Aggregates, 80% of the total water was first poured in to the drum and micro concrete was added slowly while the mix was mixed using a hand mixture for a time of about one minute. The weighed Aggregates were then added to the drum along with the remaining 20% water and the contents were further mixed well for three more minutes. After proper mixing concrete was then poured in to their respective moulds, harden for 24 hours and soaked in to the curing take later on. For this mix, a total of 24 cubes (100 mm), 6 cylinders (100mm diameter and 200mm height) and 6 beams (500×100×100mm) were casted. Preparation of micro concrete with aggregate and placing of concrete in mould is shown in Figure 2

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For SCC concrete of M50 grade total of 12 cubes (100 mm), 3 cylinders (100 mm diameter and 200mm height) and 3 beams (500×100×100mm) were casted. The details of the all specimen and its identification are listed in Table 5. Micro concrete without aggregate is designated as MC and micro concrete with aggregate is designated as MCA.

Table 3 Mix Design- Micro Concrete

Test	Rendroc (RG)	DON CHEMPATCH (Don)
Concrete to Aggregate Ratio	1: 0.5	1:0.5
Water/ Paste Ratio	0.16	0.16
Micro concrete	25 Kg	25 Kg
Aggregate	12.5 Kg	12.5 Kg

Table 4 Mix Design- SCC

Cement	Fine Aggregate	Coarse Aggregate	Fly ash	Water	Ad mixture
1	1.69	1.86	0.33	0.453	$8 \times 10^{-0.3}$

Chemical Admixture - BASF Master Glenium SKY 8233

Figure 1 plain micro concrete cube, beam and cylinder specimens

Figure 2 Preparation of micro concrete with aggregate and placing in cube and beam mould

Figure 3 Preparation of SCC (M50) and placing of Concrete in mould

2.4 Testing of Specimens

Experimental investigations namely Compressive test on cube, Flexural test on beams and Split Tensile test on cylinders were carried out on the test specimens at the age of 1, 3, 7 and 28 days. Rapid Chloride Penetration test was done on the prepared specimen at the age of 56 days from the Date of Casting. Finally the Mechanical and durability properties of three types of

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Table 5 Specimen details and its identification

Type of concrete		Micro concrete without aggregate		Micro concrete with aggregate		SCC
		MC -RG	**MC-Don**	**MCA -RG**	**MCA-Don**	
Cube	Dimension	70.6×70.6 ×70.6 mm	70.6×70.6 ×70.6 mm	100×100 ×100 mm	100×100 ×100 mm	100×100 ×100 mm
	No. of Specimen	12	12	12	12	12
Cylinder	Dimension	75×150 mm	75×150 mm	100×200 mm	100×200 mm	100×200 mm
	No. of Specimen	3	3	3	3	3
Beam	Dimension	350 × 25 × 25 mm	350 × 25 × 25 mm	500×100 ×100 mm	500×100 ×100 mm	500×100 ×100 mm
	No. of Specimen	3	3	3	3	3

Concrete specimen namely plain micro concrete, micro concrete with aggregate, and SCC were evaluated.

3.RESULT AND DISCUSSION

The results of the mechanical and durability test namely Compressive Strength, Flexural Strength, split tensile Strength and RCPT are discussed below

3.1 Compressive strength

According to Indian Standards 516:1959, compression test was carried out using compression testing machine of 1000 KN Capacity on all cube specimens. Three cubes were tested for each mix combination at the ages of 1, 3, 7 and 28 days. The results are tabulated in Table 6. The graphical representation of compressive strength of plain micro concrete (MC-RG, MC-Don) is shown in Figure 4 and the compressive strength of micro concrete with aggregate and SCC is shown in Figure 5.

Table 6 Compressive strength of Micro concrete and SCC specimens

Cube	Compressive Strength (Mpa)			
	1 day	3 days	7 days	28 days
MC-RG	28.64	37.42	48.95	74.01
MC-Don	27.88	35.63	45.30	62.21
MCA-RG	19.17	29.3	52.18	65.47
MCA-Don	17.43	26.21	41.06	58.41
SCC	21.88	31.43	52.74	66.77

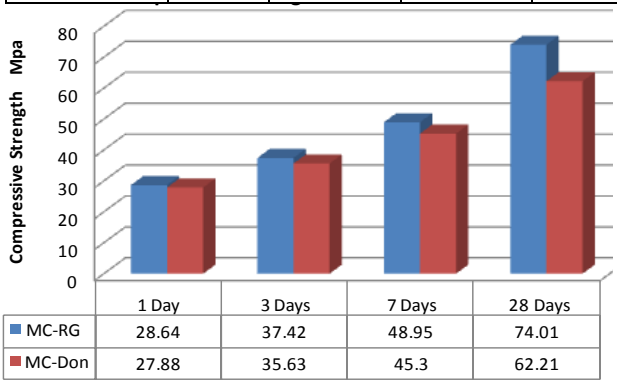

Figure 4 Compressive strength of plain Micro concrete cubes

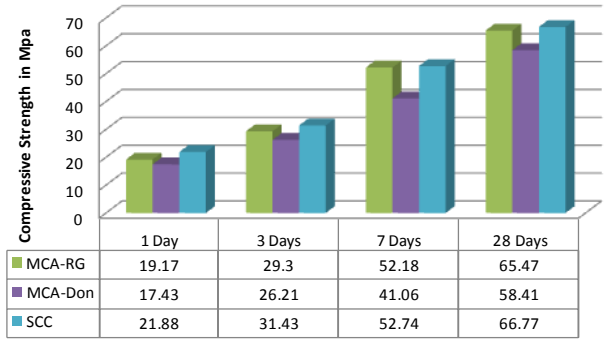

Figure 5 Compressive strength of micro concrete with aggregate and SCC

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From Fig. 4 It is inferred that the compressive strength of mortar cubes of MC-RG is 74MPa against MC-DON which is 62MPa. Fig. 5 shows that the SCC mix has crossed the target strength of 58MPa and its average compressive strength is 66.77 Mpa at the age of 28 days. The average compressive strength of Rendroc micro concrete with aggregates (MCA-RG) is 65MPa at the age of 28 days, while in the case of the DON micro concrete mix with aggregates (MCA-DON), the compressive strength is 58MPa at the age of 28 days.

On comparing the compressive strength of micro concrete without aggregate MC-RG mix is marginally higher than that of MC-Don at the ages of 1, 3, 7 and 28 days (Fig. 4). From Fig. 5, which shows the strength of SCC and Micro concrete with aggregate it is clear that the compressive strength of SCC mix is in the same range as that of the RG micro concrete mix with 50% aggregates (MCA-RG). The compressive strength of Don Chempatch with aggregate (MCA-Don) is marginally lower than that of the SCC and RG mixes.

3.2 Flexural strength

According to Indian Standard 516:1959**,** the flexural test was carried out at the age of 28 days on a beam specimen mentioned in Table 5. The test was carried out in a UTM of 1000kN capacity. Three points loading was given to the specimens for each mix, three beams were tested for each mix after the 28 days of curing and the mean value was reported.

The flexural strength of all the five types of mix are given in Table 7 and the graphical representation of flexural strength of plain micro concrete and micro concrete with aggregate and SCC is shown in Fig. 6.

Table 7 Flexural strength of Beam

Beam	Flexural strength (MPa)	Required Value ($0.7\sqrt{f_{ck}}$)
MC-RG	8.64	4.95
MC-Don	8.32	
MCA-RG	7.93	
MCA-Don	7.29	
SCC	7.14	

F_{ck} – characteristic strength of Concrete (50 MPa)

It is seen from Table 7 that the flexural strength of all five types of beam specimen satisfies the required minimum strength [$0.7\sqrt{(f_{ck})}$] at the age of 28 days.

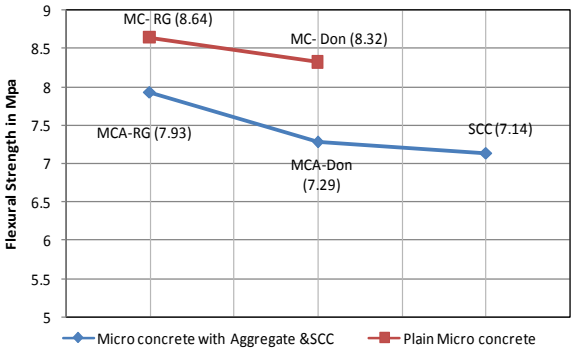

Figure 6 Flexural Strength of SCC and Micro concrete with and without aggregate.

The flexural strength of MC-RG is 8.64 Mpa which is marginally higher than MC-Don beams whose flexural strength is 8.32 Mpa (Fig. 8). The average flexural strengths of MCA-RG, MCA-Don and SCC mixes are 7.93 MPa, 7.29 MPa and 7.14 MPa respectively and the performance of the three mixes are very similar.

3.3 Split tensile strength

According to IS 516:1959, tensile test was carried out on cylinder specimens with dimension 75mm x 100mm and 100mm x 200mm. For each mix, three cylinders were tested and the mean value after 28 days of curing is reported in Table 8. The graphical variation of split tensile strength of SCC, plain micro concrete , micro concrete with aggregate in Fig. 7.

Table 8 Tensile strength of Cylinders

Beam	Tensile strength (MPa)
MC-RG	13.74
MC-Don	8.59
MCA-RG	5.38
MCA-Don	5.27
SCC	5.03

From Fig. 7 it is inferred that MC- RG has higher split tensile strength of 13.74 Mpa, at the age of 28 days, which is much higher than that of MC-Don and also it can be inferred that Micro concrete with aggregate and SCC show marginal variation in their tensile strength and their average spilt tensile strength values are 5.38MPa, 5.27MPa and 5.03MPa respectively. Graphical variation in Fig. 7 shows that micro concrete without aggregate has high tensile strength, than SCC and Micro concrete with aggregate.

From Table 9 it is clear that the charges passed during the RCPT tests are very high for both micro concrete mixes with aggregates. The RCPT values for the Rendroc RG with aggregates and DON Chempatch with aggregates are 2148 coulombs and 2830 coulombs. The RCPT values for both micro

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concrete mixes can be categorized as Moderate The RCPT value for the SCC mix is 936 coulombs and is very much on the lower side when compared to micro concrete with aggregates. The lower value of RCPT may be due to the addition of fly ash in the SCC mix.

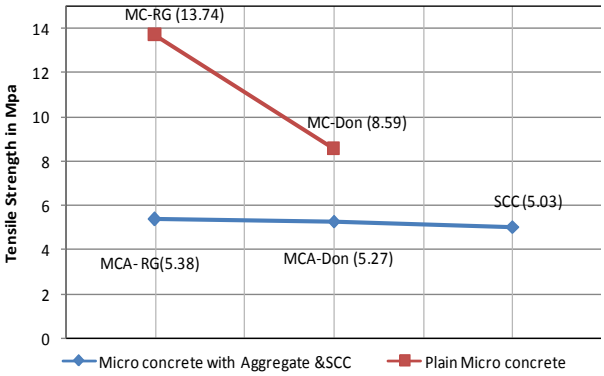

Fig. 7 Tensile strength of SCC and Micro concrete Cylinder specimen

3.4 Rapid Chloride penetration test

The test method involves obtaining a 100 mm (4 in.) diameter core from cylindrical samples. The side of the cylindrical specimen was coated with epoxy, and after the epoxy was dried, it is put in a vacuum chamber for 3 hours. The specimen was vacuum saturated for 3 hours and allowed to soak in water for 18 hours. It was then placed in the test device. Readings were taken for every 30 minutes. At the end of 6 hours, the sample was removed from the cell and the amount of coulombs passed through the specimen was calculated and the chloride ion permeability was determined. The RCPT result for micro concrete with aggregate and SCC is tabulated in Table 9.

Table 9 RCPT result for Micro concrete with aggregate and SCC

Mix type	Average charge passed (coulombs)	Chloride ion permeability
MCA- RG	2148.3	Moderate
MCA-Don	2830.5	Moderate
SCC	936	Very Low

4. CONCLUSION

Based experimental investigations carried on the mechanical and durability characteristics of two commercially available brands of micro concrete with and without aggregates and SCC mix, following are the conclusion derived:

The compressive strength of MC-RG is 10 % higher than MC-Don. The two brands of micro concrete mixes, viz Fosroc Rendroc RG and DON Chempatch with 50% replacement of aggregates showed marginally lower compressive strengths than that of SCC mix (28 days). The variation in the compressive strength between MC-RG and MC-Don the two brands of micro concrete mixes was very negligible.

The beam flexural strength of the two brands of commercial micro concrete mortar mixes satisfy the criteria of $0.7\sqrt{(f_{ck})}$ at the age of 28 days as specified in IS 456:2000. However, there was not much of a variation in the flexural strength of micro concrete without aggregate (MC-RG and MC-Don). At the age of 28 days the flexural strength of the micro concrete mixes with aggregates and SCC also satisfied the criteria of $0.7\sqrt{(f_{ck})}$ as specified in IS 456:2000. The flexural strength of the Rendroc Micro concrete mix with aggregates (i.e MCA-RG) was slightly higher compared to SCC and MCA-Don.

The MC-RG micro concrete mix exhibited a 30% greater tensile strength compared to that of MC-DON micro concrete mix. The split tensile strength of the micro concrete mixes with aggregates and SCC showed similar strengths.

The RCPT values for the Fosroc Rendroc RG with aggregates and DONChempatch with aggregates are on the higher side. The RCPT values for both micro concrete mixes can be categorized as Moderate, as per the guidelines given in ASTM C1202-12. The RCPT value for the SCC mix is very much on the lower side compared to the micro concrete with aggregates. The lower RCPT values may be due to the addition of fly ash in the SCC mix. The RCPT value for the SCC mix falls under the category of Very low as per the guidelines given in ASTM C1202-12.

It may be inferred that usage of fly ash as mineral admixture in concrete mixes results in improved durability characteristics compared to the micro concrete. Micro concrete being a pre-packed material, addition of mineral admixtures may cause variations in their properties and is generally not recommended and followed in the rehabilitation of RC structures. SCC has comparable mechanical strength when compared to micro concrete with aggregate and very high durability performance.

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