UTILIZATION OF INDUSTRIAL WASTES IN MANUFACTURE OF SELF COMPACTING CONCRETE AND EXAMINING ITS FLEXURAL BEHAVIOUR

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Abstract. Recent studies indicate that marble processing industries and limestone quarries produce tons of waste in the form of powder which is found as a major concern for disposal. Considering significant high degree of fineness of these filler materials in contrast to cement, they may be employed for manufacture of Self Compacting Concrete (SCC). For the study, Self-Compacting Concrete is achieved by partially replacing Cement (70%) with filler materials like Limestone Powder (LP) and Marble Powder (MP) at different percentages by mass of cement and M-sand is used as fine aggregate as a complete replacement for river sand. The study focuses on determination of macro properties of concrete mixes and flexural behaviour of Self Compacting Concrete beams using the above materials. A total of 4 mixes were taken for the study namely Conventional mix, 15% lime powder(LP), 15% marble powder(MP) and 30%LPMP (15% LP and 15% MP). As per EFNARC conditions, following tests like Slump flow, V-funnel, L-Box tests were conducted to qualify the achieved concrete mix as SCC. At the age of 7 and 28 days respectively, strength aspects such as compressive strength, split tensile strength, and flexural strength tests of different proportioned mixes were determined. Flexural behaviour of casted SCC beams with and without filler materials was also examined and studied. Results proved that mix incorporated with lime powder and marble powder (30LPMP) reported the higher strength values than other mixes and exhibited better flexural behaviour.

1. Introduction
Self-compacting concrete (SCC) is an innovative concrete that is highly workable and is compacted without any vibration under its own weight. In SCC mixes, the requirement for cement content will be greater for sufficient stability to reduce bleeding, segregation and settling [1]. This will lead to material cost as well as negative effects on the properties of concrete like shrinkage, hike in thermal stress etc. this increased powder content requirement is usually met by the use of pozzolanic filler materials. Super plasticizer is an inevitable admixture of Self Compacting Concrete for achieving a highly fluid concrete mix[2]. The properties of SCC differ considerably from conventional slump concrete.

The analysis principal objective is to research the impact of Limestone powder (LP) and Marble Powder (MP) as fillers on strength aspects of Self Compacting Concrete (SCC) of 30% replacement of cement content with various combinations as shown below.

- Control mix (cement + 0% filler materials)
- Cement+15%LP
- Cement+15%MP
- Cement +15%LP+15%MP

Early research results were obtained by conducting various tests in which river sand was used as a fine aggregate. In present investigation, M-sand obtained from nearby quarry is used as fine aggregate for all mix combinations as availability of river sand is scarce and strength properties of SCC along with flexural behavior of SCC beams were determined [4].
2. Materials and Methods of Testing SCC

2.1 Materials Used

Throughout the project, Ordinary Portland Cement confirming to 53 Grade (as per IS 12269:1993) was used. The cement used was found to have a consistency of 34% with 45 minutes and 600 minutes of initial setting and final setting time respectively. As tested by using sieving method (as per IS 4031 Part 1:1996) fineness of cement was 7%, while the specific gravity was 3.15. M-sand was used as fine aggregate with a specific gravity of 2.76. Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm and retained in 10mm sieve as per IS 383-1970 with specific gravity of 2.68 was used as coarse aggregate. New generation super plasticizer named Glenium B233 which is a modified polycarboxylic ether was used producing SCC. Super plasticizer used must comply with IS 9103-1999.

Lime powder and marble powder obtained from nearby locality as shown in Figure 1 were considered as industrial waste material in this investigation which are found to be utilized in SCC production with the chemical properties of each waste is given in table 1[1].

![Limestone Powder and Marble Powder](image)

Figure 1 – Limestone Powder and Marble Powder

| S.No | Constituents | Marble powder | Limestone powder |
|------|--------------|---------------|-----------------|
| 1    | SiO₂         | 2.08          | 4.32            |
| 2    | Al₂O₃        | -             | 1.47            |
| 3    | Fe₂O₃        | 0.74          | 1.157           |
| 4    | MgO          | 0.86          | 0.8             |
| 5    | CaO          | 41.482        | 41.65           |
| 6    | Na₂O         | -             | -               |
| 7    | K₂O          | -             | -               |
| 8    | P₂O₅         | -             | -               |
| 9    | Cl           | -             | 0.29            |

A total of four concrete mixes were taken for the study with various proportions inclusive of conventional concrete mix (CCM) as shown in Table 2. Limestone powder(LP) and marble powder(MP) were added as a replacement by mass of cement. The proportion of Fine aggregate and Coarse aggregate for all the four mixes remains unchanged along with Water-Cement ratio remaining constant. W/C ratio was taken as 0.40 for all mixes by conducting marsh cone test and Glenium B233 was used as a super plasticizer to manufacture Self compacting concrete.

| Mix   | OPC | LP | MP | W/C |
|-------|-----|----|----|-----|
| CCM   | 100 | -  | -  | 0.40|
| 15LP  | 85  | 15 | -  | 0.40|
| 15MP  | 85  | -  | 15 | 0.40|
| 30LPMP| 70  | 15 | 15 | 0.40|
2.2 Fresh Property Tests

Slump flow, V-funnel and L-box experiments have tested the workability properties of manufactured Self Compacting Concrete according to EFNARC (2005) specifications. Slump flow as shown in Figure 2 is one of the most widely used SCC tests which can be practised easily on site. Concrete mixes with different proportions is tested for slump flow. It has to be observed that the higher the value of slump flow, the greater is its filling ability.

![Figure 2- Slump Flow Test](image)

The L-box as shown in figure 3 is conducted for all the mixes in which the level of concrete in the chimney is recorded as H1 and the level of concrete in the trough is recorded as H2. The L-box value is simply the ratio between H2/H1.

![Figure 3- L-Box Test of SCC](image)

V-funnel test as shown in figure 4 is used to determine the filling ability of the concrete with a maximum aggregate size of 12.5 mm. Concrete is filled in the funnel and the bottom trap door is opened to empty the concrete filled in funnel where the time taken to empty the funnel is recorded using a stopwatch.

![Figure 4 – V Funnel Test](image)
2.3 Hardened Property Tests
Based on the specifications given in IS 516-1959[13] and IS 5816-1999[14], strength properties such as compressive, split tensile and flexural were performed. For each mix, 150mm x 150 mm x 150mm cubes and a diameter 150mm and height 300mm cylinder were casted and tested for determining the strength aspects after a curing period of 7 days and 28 days respectively. Three prisms of size 100mm x 100mm x 500mm were casted and tested after 28 days of curing to evaluate the flexural strength. The experimental setup to determine strength properties is shown in figure 5.

![Figure 5 – Experimental setup for determining Compressive, Split tensile and Flexural strength](image)

2.4 Flexural Behaviour on SCC beams with and without filler materials
To analyse the flexural behaviour, reinforced concrete beams of size 1500mmx100mmx175mm were casted for control mix and mix containing all the filler materials in equal percentage. 10mm diameter Fe 500 grade steel bars were provided as longitudinal reinforcement and 6mm diameter stirrups were provided at 150mm spacing. Mould for the beam specimen were oiled properly and the mix were poured into the mould after verifying all the fresh properties. While pouring the concrete it has to be ensured that concrete flows through the entire area. Surface were finished and kept for 48 hrs. On demoulding the beam, it is cured for a period of 28 days. Load was applied through load cell and dial gauges were fixed at distance L/2 and L/3 where L is the span of the beam to record the deflection of the beam during loading. The beam was loaded up to failure. Figure 6 shows the experimental set up of beam subjected to loading.

![Figure 6 – Experimental setup of SCC beam](image)

3. Discussion of Results
3.1 Test results of Fresh Concrete
Table 3 displays the result for the fresh concrete. All the specimens met the fresh properties SCC acceptance requirements. Mixtures containing marble powder and lime stone powder had less flow capacity compared to the control mix, while the mixture contains all the filler materials in equal
percentage had good flow ability. It is also found that mix containing marble powder were less flowable when compared to those with limestone powder. The variation in the fresh properties was plotted in graphs and is shown in figure 7.

Table 3- Fresh Properties(Workability) Test results of SCC with different proportions

| MIX ID           | SLUMP FLOW (mm) | V- FUNNEL (Sec) | L BOX (H2/H1) |
|------------------|-----------------|-----------------|---------------|
| EFNARC LIMITS    | 600-800         | 6-12            | 0.8-1         |
| CCM              | 660             | 11.23           | 0.90          |
| 15LP             | 710             | 9.10            | 0.964         |
| 15MP             | 690             | 11.10           | 0.875         |
| 30LPMP           | 700             | 10.58           | 0.932         |

Figure 7 – Test Results for Slump flow test of different SCC mixes

3.2 Test results of Hardened Concrete

The compressive strength was determined at the age of 7 and 28 days and the results are shown in Table 4. It can be concluded that compressive strength at 7th and 28th day respectively for the reference concrete was 26.29 MPa and 32.76 MPa. Whereas concrete mix 15MP which had 15% MP showed compressive strength at 7 and 28 days up to 31.32 MPa and 32.99 MPa respectively, when compared to control concrete mix but in such a case of 30LPMP mix the strength at 7 days was 31.87 MPa and 35.24 MPa at 28 days. It can be noted that, when compared to reference concrete the strength was increased up to 7.57 % for 28 days.

Table 4 – Compressive Strength Test Results

| Mix ID | Weight (kg) | Density(Kg/m³) | Compressive strength(N/mm²) | Percentage increase in strength % |
|--------|-------------|----------------|-----------------------------|---------------------------------|
|        |             |                | 7 days                      | 28days                          |
| CCM    | 8.28        | 2437.93        | 26.29                       | 32.76                           | 0                              |

Figure 7 – Test Results for Slump flow test of different SCC mixes
From that test result as shown in table 5, it showed that split tensile strength of control mix recorded a value of 1.83 MPa at 28 days but in the case of 15LP mix, the strength was 2.68 MPa at 28 days. Comparing the tensile strength result of 30LPMP mix to reference concrete, due to presence of calcium carbonate content in marble powder increase in strength was achieved because of denser micro structure.

Table 5 – Experimental results of Split Tensile Strength

| Mix ID | Weight (kg) | Density(Kg/m³) | Split tensile strength(N/mm²) |
|--------|-------------|----------------|-------------------------------|
|        |             |                | 7 days | 28 days |
| CCM    | 12.96       | 2445.86        | 1.57   | 1.83   |
| 15LP   | 12.94       | 2442.09        | 2.21   | 2.68   |
| 15MP   | 12.90       | 2433.59        | 2.20   | 2.95   |
| 30LPMP | 12.93       | 2440.20        | 2.73   | 3.44   |
From experimental test result shown in Table 6, it is showed that the flexural strength of reference concrete was 4.51 MPa at 28 days. It can be vindicated that the strength of 30LPMP mix showed improved values when compared to all other mixes and showed an increase of 20.93% for 28 days. This significant increment in flexural strength may be due to incorporation of all filler materials reduced the voids in concrete mix which can be observed from the reduction in weight of prism.

Table 6 – Flexural Strength Test Results

| Mix ID   | Weight (kg) | 28th day Flexural strength (N/mm²) |
|----------|-------------|-----------------------------------|
| CCM      | 12.50       | 4.51                              |
| 15LP     | 12.456      | 6.73                              |
| 15MP     | 12.568      | 5.99                              |
| 30LPMP   | 12.326      | 6.69                              |

Figure 10 – Flexural Strength Test Result

3.3 Flexural Behaviour of SCC beams

For the study two beams were casted for control mix as well as for mix which incorporates both the industrial wastes. On examining the load deflection curve, it is found that in both the beams tested the curve is linear at first crack load and on further application of load deviation in curve was observed.
The below table 7 and 8 indicates the deflection obtained during loading at L/2 and L/3 distance respectively. Figure 11 and 12 represents the Load deflection curve at distance L/2 and L/3 respectively.

### Table 7 - Deflection at L/2 distance for corresponding load

| Load | CM (Deflection at L/2) | Stiffness | All Filler (Deflection at L/2) | Stiffness |
|------|------------------------|-----------|-------------------------------|-----------|
| 0    | 0                      | 0.00      | 0                             | 0.00      |
| 5    | 0.39                   | 12.82     | 5                             | 0.22      |
| 10   | 0.56                   | 17.86     | 10                            | 0.38      |
| 15   | 0.62                   | 24.19     | 15                            | 0.53      |
| 20   | 0.71                   | 28.17     | 20                            | 0.66      |
| 25   | 0.75                   | 33.33     | 25                            | 0.76      |
| 30   | 1.21                   | 24.79     | 30                            | 1.04      |
| 35   | 1.68                   | 20.83     | 35                            | 1.42      |
| 40   | 2.07                   | 19.32     | 40                            | 2.06      |
| 45   | 2.39                   | 18.83     | 45                            | 2.42      |
| 50   | 2.86                   | 17.48     | 50                            | 2.97      |
| 55   | 3.22                   | 17.08     | 55                            | 3.48      |
| 60   | 3.58                   | 16.76     | 60                            | 4.68      |
| 65   | 4.06                   | 16.01     | 65                            | 5.42      |
| 70   | 4.39                   | 15.95     | 70                            | 5.99      |
| 75   | 5.02                   | 14.94     | 90.00                         | 3.78      |
| 80   | 5.12                   | 15.63     |                               | 22        |
| 86.00| 3.92                   |           |                               |           |

### Table 8 - Deflection at L/3 distance for corresponding load

| Load | CM (Deflection at L/3) | Stiffness | All Filler (Deflection at L/3) | Stiffness |
|------|------------------------|-----------|-------------------------------|-----------|
| 0    | 0                      | 0.00      | 0                             | 0.00      |
| 5    | 0.33                   | 15.15     | 5                             | 0.22      |
| 10   | 0.54                   | 18.52     | 10                            | 0.37      |
| 15   | 0.64                   | 23.44     | 15                            | 0.48      |
| 20   | 0.85                   | 23.53     | 20                            | 0.63      |
| 25   | 1.05                   | 23.81     | 25                            | 0.73      |
| 30   | 1.44                   | 20.83     | 30                            | 1.01      |
| 35   | 1.75                   | 20.00     | 35                            | 1.27      |
| 40   | 2.05                   | 19.51     | 40                            | 1.87      |
| 45   | 2.4                    | 18.75     | 45                            | 2.22      |
| 50   | 2.6                    | 19.23     | 50                            | 2.68      |
| 55   | 2.98                   | 18.46     | 55                            | 3.18      |
| L  | Load KN | Deflection mm | L  | Load KN | Deflection mm |
|----|---------|---------------|----|---------|---------------|
| 60 | 3.32    | 18.07         | 60 | 3.47    | 17.29         |
| 65 | 3.44    | 18.90         | 65 | 4.02    | 16.17         |
| 70 | 3.7     | 18.92         | 70 | 4.57    | 15.32         |
| 75 | 4.21    | 17.81         | 90 | 3.60    | 25            |
| 80 | 5.11    | 15.66         |    |         |               |
| 86.00 | 3.91    | 22            |

Figure 11 - Comparison of Load Deflection curve at L/2 distance for both beams

Figure 12 - Comparison of Load Deflection curve at L/3 distance for both beams
4. Conclusion

From the experimental results discussed it can be concluded that using industrial wastes such as lime powder and marble powder for the manufacture of SCC has proven to be authenticated. All the four mixes taken for the study satisfied the EFNARC Specifications in fresh state. Due to the presence of calcium carbonate content in marble powder which densifies the concrete, compressive, split tensile and flexural strength for 30LPMP mix is found to be higher compared with other mixes. From the load deflection curve, it can be concluded that first crack load where it has been incorporated with LP and MP showed better performance than the control mix. The results obtained clearly show that mix 30LPMP has superior performance in the civil engineering sector with possible application. Further, the waste management issues from these industries can be minimised as they can be utilized in construction practice.

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