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# Use of Waste Material for Sustainable Self-Compacting Concrete

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*Abstract-* **This paper explores one of the major environmental concerns which is disposal or recycling of the waste materials . Marble processing plants produce millions of tons of waste dust in the powder form every year . Having a considerable high degree of fineness in comparison to cement, marble powder may be utilized as filler for the production of Self-Compacting Concrete (SCC) . This research paper aimed at developing an eco-friendly and workable self-compacting concrete with the maximum amount of marble powder . For this, a control mix and four other mixes with varying amounts of marble powder as 5%, 10%, 15%, and 20% are prepared. These mixes are then tested for their new properties by slump flow, j-ring, and V-funnel at T 5minutes. Compressive strength is used to evaluate the hardened concrete. It was found that up to 15 % marble powder addition, the fresh and hardened properties of the concrete mix did not vary considerably. However, it was also found that with the addition of marble powder, the compressive strength decreased.**

*Index Terms*—**Waste Material, Sustainable, Marble Powder, Compressive Strength, Slump Flow, J Ring, V Funnel.**

## I. INTRODUCTION

Concrete composite human-made material is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well-graded fine and coarse aggregates, water, and admixtures. **[1]**

The most crucial benefit of concrete is its ability to conform to any shape that we want it. However, ordinary concrete requires compaction to fulfill this ability. The compaction is provided by either external or internal vibrators. The use of vibrator requires skill and time, which increases the cost and high chances of uncertainty in the uniform placement of concrete, resulting in a decrease in the strength of a particular member. When the construction industry in Japan experienced a decline in the availability of skilled labor in the 1980s. That is need was felt for concrete that could overcome the problems of defective artistry. This led to the development of self-compacting concrete, primarily through the work by Okamura **[2]**. The first usable version of self-compacting concrete was completed in 1988 . It was named “High-Performance Concrete”, and later proposed as “Self-Compacting High-Performance Concrete”.

Self-compacting concrete (SCC) is a unique, very liquid concrete type that can settle into the heavily reinforced, narrow and deep sections by its weight, and can consolidate itself without necessitating internal or external vibration, and while providing with these features can keep its cohesion (stability) without leading segregation and bleeding **[3]**. Especially, the developments in superplasticizer technology have contributed considerably to the formation and progression of the self-compacting concrete **[2]**.

From the definition given by Okamura, it is concluded that SCC must exhibit three characteristics:

- Passing Ability.
- Filling Ability.
- Segregation Resistance.

Passing ability is the ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking. Filling ability is the ability of SCC to flow into and fill all spaces within the formwork completely under its weight. Segregation resistance is the ability of SCC to remain homogeneous in composition during transport and placing.

These characteristics are obtained by careful proportioning of the mix. Some guidelines were set for the proportioning of the SCC including the reduction of water/powder ratio, increasing paste volume, controlling the total amount of coarse aggregates and its maximum particle size, and using a powerful superplasticizer along with the vast quantities of powders and viscosity modifying admixtures (VMA) to fine-tune the balance between deformability and stability **[4]**.

The reduced size and content of coarse aggregates decrease the frequency of collision between the aggregate particles, thus reducing the internal friction. In this way, it helps provide passing and flowing abilities. The higher amount of fines with lower exceptional ratios and use of admixtures create a cohesive mix that avoids segregation; thereby, segregation resistant concrete will be useful in passing and flowing abilities. The amounts of coarse and fine aggregates, fines, water, and admixture are to be adjusted to achieve the required properties. In case of insufficient segregation, resistance blockage can occur. If concrete is highly flowing able, it may be prone to isolation, and less flowability can cause a blockage. It is the balance of the above-discussed factors which are responsible for right SCC.

The fines can be either pozzolanic additions such as silica fume, fly ash, ground granulated blast furnace slag or inert fillers like crushed limestone and sandstone, etc. The composition of the blend of cement and fines is significant in SCC, as the high amount of pozzolans with lower water contents may cause autogenous shrinkage. Pozzolanic additions can significantly improve the long term performance of the concrete.

## II. LITERATURE REVIEW

Sustainable development is the organizing principle for meeting human development goals while at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. The desired result is a state of society where living conditions and resource use continue to meet human needs without undermining the integrity and stability of the natural system. Sustainable development can be classified as development that meets the needs of the present without compromising the ability of future generations **[5]**.

Environment sustainability concerns the natural environment and how it endures and remains diverse and productive. Since natural resources are derived from the environment, the state of air, water, and the climate is of particular concern. Environmental sustainability requires society to design activities to meet human needs while preserving the life support system of the planet. For example, it entails using water sustainably, utilizing renewable energy, and sustainable material supplies **[6]**.

Sustainable construction is attracting more attention lately. Sustainable development means designing, renovating, or converting a building in compliance with the environmental rule and energy-saving method. In particular, it aims to promote environmentally friendly materials and the companies that use them. And therefore, it significantly contributes to the well-being and sustainability of buildings **[7].**

In Europe, the construction industry is responsible for 34.7 percent of the continent's total waste. Green buildings minimize waste with their lower environmental impact and use of renewable sources and materials. Products such as demolition debris, sand, and burnt coal can be used with excellent aesthetic and ecological results **[8]**. Recycled materials used during the construction process are contributing significantly to the protection of the environment and the reduction of waste. Traditional materials like cement, concrete, bricks, and tiles are broadly used significant construction material. Theses construction materials consume natural resources for their production, and this further causes environmental damage. Most of the building materials production processes such as lime decomposition, calcium carbonate, and binding material cement manufacturing emit a large amount of carbon monoxide and oxides of Nitrogen and Sulphur. The release of these toxic gases into the environment leads to severe air, soil, and water pollution and gravely affects human health **[9]**. Carbon dioxide emissions from such materials can be controlled by replacing cement or proportion of cement with waste material such as marble powder that potentially improves the specifications.

The environmental impact of marble wastes recycling towards sustainable construction materials has great practical significance. The mineral powder, such as marble powder. Galetakis and Soultana reviewed thirty-eight articles in which the usage of marble powders as waste material in the construction sector was investigated, and it was found that the marble powder has a positive effect on the mechanical and durability properties of the concrete

## III. RESEARCH METHODOLOGY

To investigate the properties of fresh and hardened SCC using waste marble powder, a control self-compacting concrete mix was prepared to keep in view the (EFNARC, 2002) **[10]** guidelines. The effect of waste marble powder (WMP) was studied by replacing the cement content by varying amounts of marble powder. Locally available materials have been used in the preparation of these concrete mixes. The properties that have been used in the development of concrete mixes are as follows:

### *a. Fine Aggregates*

Lawerancepur sand was used in the preparation of mixes. Some physical properties are as under:

Table 1: Properties of Lawerancpur Sand

| **Property** | **Value** |
|---|---|
| Bulk Density | 1617.41 kg/m$^3$ |
| Specific Gravity (SSD) | 2.68 |
| Water Absorption | 2.01 % |

Moisture content was also found out while taking into account water requirements.

### *b. Coarse Aggregates*

Sargodha crush was used as a coarse aggregate. It was selected due to local availability. The collected crush then passed through a 19 mm sieve, and the rest of the material is discarded. The fraction passing 19 mm sieve then separated into two fractions: one 19 mm down and one 13 mm down. 30% of total aggregates with particle range from 19 mm to 13 mm and 70% of total sums 13 mm down was used in the preparation of the mixes

Figure 1: Sieving of Coarse Aggregates

Table 2: Properties of Sargodha Crush

| Property | Value |
|---|---|
| Bulk Density | 1465.69 kg/m$^3$ |
| Specific Gravity (SSD) | 2.64 |
| Water Absorption | 1.16 % |

### *c. Cement*

Ordinary Portland cement type-1 was used. Cement under the brand name of "Maple leaf" was used in the preparation of the mixes.

### *d. Marble Powder*

Marble powder was collected from marble cutting and sawing workshops located near Icchra on Ferozepur road, Lahore. Per bag cost containing non-sieved marble powder of approximately 20 kg weight was 60 rupees. Sieved marble powder obtained from one such bag approximately 3 to 4 kg. Fraction passing sieve no. 100 was used to sieve the material. This fraction was used keeping in view the fineness requirements of powder content.

Figure 2: Sieving of Marble Powder

### *e. Admixture*

Chemrite 303 SP manufactured by Imporient Chemicals (Pvt.) Ltd. was used as a superplasticizer. Its density is 1.06 ± 0.01 kg/liter at 25°C.

### *f. MIX PROPORTIONING*

A control mix was prepared following the (EFNARC, 2002) guidelines. A total of 4 different mixes were made. The mixes were designated as SCC-1, SCC-5, SCC-10, and SCC-15 and SCC-20. Cement was replaced in these mixes as 0%, 5%, 10%, 15%, and 20%, respectively, with 100µm sieved marble powder. The dosage of the admixture was kept constant for all replacement mixes concerning the weight of cement. Initially, the work was started to look into a point where the addition of marble powder ceases to give acceptable fresh properties. The mix design calculations and summary is presented in table 3.3 and 3.4, respectively

Table 3: Mix Design Calculations

| Quantity | SCC-1 | SCC-5 | SCC-10 | SCC-15 | SCC-20 |
|---|---|---|---|---|---|
| | (kg/m$^3$) | | | | |
| Cement | 525 | 500 | 475 | 450 | 425 |
| Marble Powder | 0 | 25 | 50 | 75 | 100 |
| Total Powder | 525 | 525 | 525 | 525 | 525 |
| Water | 185 | 187.5 | 189.75 | 191.55 | 195.4 |
| Fine Aggregates | 825 | 830 | 840 | 850 | 850 |
| Coarse Aggregates 13 mm retained | 225.225 | 225.225 | 225.225 | 225.225 | 225.225 |
| Coarse Aggregates 13 mm down | 525.525 | 525.525 | 525.525 | 525.525 | 525.525 |
| Super plasticizer | 7.875 | 7.875 | 7.875 | 7.875 | 7.875 |

| Quantity | SCC-1 | SCC-5 | SCC-10 | SCC-15 | SCC-20 |
|---|---|---|---|---|---|
| | ($m^3$/ $m^3$) | | | | |
| Volume of cement | 0.1672 | 0.1592 | 0.1512 | 0.1433 | 0.1353 |
| Volume of Marble Powder | 0 | 0.0096 | 0.0192 | 0.0288 | 0.0384 |
| Volume of Powder | 0.1672 | 0.1688 | 0.1705 | 0.1721 | 0.1738 |
| Volume of Water | 0.185 | 0.1875 | 0.1897 | 0.1915 | 0.1954 |
| Volume of Paste | 0.3522 | 0.3563 | 0.3602 | 0.3637 | 0.3692 |
| Volume of Coarse Aggregates | 0.2843 | 0.2843 | 0.2843 | 0.2843 | 0.2843 |
| Volume of Fine Aggregates | 0.3078 | 0.3097 | 0.3134 | 0.3171 | 0.3171 |
| Volume of Mortar | 0.6600 | 0.6660 | 0.6736 | 0.6808 | 0.6863 |
| W/C (weight) | 0.3523 | 0.375 | 0.3994 | 0.4256 | 0.4597 |
| W/P (weight) | 0.352 | 0.357 | 0.36143 | 0.36486 | 0.37219 |

Table 4: Mix Design Summary

| Quantity | SCC-1 | SCC-5 | SCC-10 | SCC-15 | SCC-20 |
|---|---|---|---|---|---|
| | ( Per Batch in kgs) | | | | |
| Cement | 13.90 | 13.24 | 12.58 | 11.92 | 11.25 |
| Marble Powder | 0 | 0.66 | 1.32 | 1.98 | 2.64 |
| Total Powder | 13.90 | 13.90 | 13.90 | 13.90 | 13.90 |
| Water | 3.76 | 3.96 | 4.01 | 4.06 | 4.16 |
| Fine Aggregates | 23.45 | 23.45 | 23.45 | 23.45 | 23.45 |
| Coarse Aggregates (total) | 19.92 | 19.92 | 19.92 | 19.92 | 19.92 |
| Super plasticizer | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |

Mixing was done in a high-speed mixer, with a speed of 300 rev/min. Mixing of ingredients was initiated with preparation if paste i.e., mixing of water, cement, and fillers in two-thirds of water. After the preparation of paste, the aggregates were added to the mixer and admixtures were also added to the mixer. Total Mixing was done in nearly less than 5 minutes.

The water was added in two rounds by pouring two-thirds part of water during paste preparation, and the left one third was used in the development of an aqueous solution of a blend of admixtures, which was added after right after the aggregates were poured in the mixer.

## IV. RESULTS

### 1. *TESTS FOR FRESH PROPERTIES*

As already mentioned, SCC has three workability parameters i.e. passing ability, filling ability and segregation resistance. The results obtained from these properties may then be used to evaluate the possible cause of the defect in the concrete mix and similarly by identifying the correct cause possible corrective actions can be applied. (EFNARC, 2002) Guidelines ANNEX C contains the troubleshooting guide which can be used to find the faults and their corrective measures to be done in the design mix.

#### a. *Slump Flow Test*

Table 5: Slump Flow Test Results

| Identity | Slump Flow | VSI | Range | |
|---|---|---|---|---|
| | | | Min. | Max. |
| | (mm) | | (mm) | (mm) |
| SCC-1 | 672 | 0 | 650 | 800 |
| SCC-5 | 670 | 0 | 650 | 800 |
| SCC-10 | 683 | 0 | 650 | 800 |
| SCC-15 | 690 | 0 | 650 | 800 |
| SCC-20 | 615 | 0 | 650 | 800 |

Figure 3:Slump Flow Test (EFNARC, 2002)

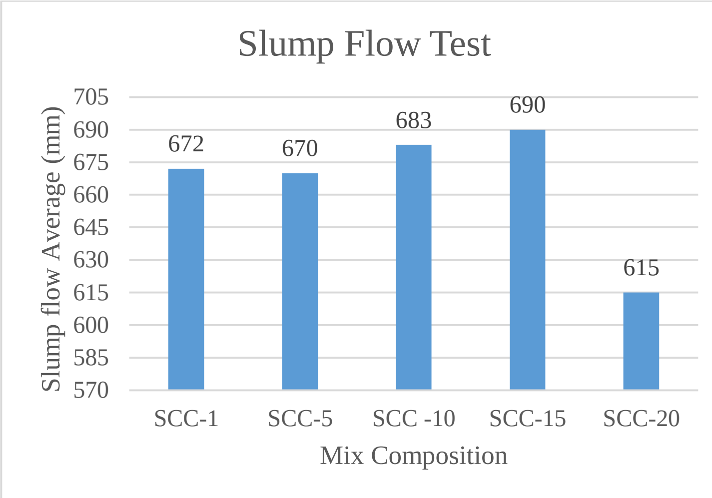


Figure 4: Slump Flow Results (Graphical)

### *b. J-Ring Test*

Table 6: J-Ring Test Results

| Identity | J-Ring Flow | Height difference | Range for height difference | |
|---|---|---|---|---|
| | | | Min. | Max. |
| | (mm) | (mm) | (mm) | (mm) |
| SCC-1 | 644 | 8 | 0 | 10 |
| SCC-5 | 641 | 9 | 0 | 10 |
| SCC-10 | 653 | 9 | 0 | 10 |
| SCC-15 | 659 | 11 | 0 | 10 |
| SCC-20 | 587 | 13 | 0 | 10 |

Figure 5: J-ring Test (EFNARC, 2002)

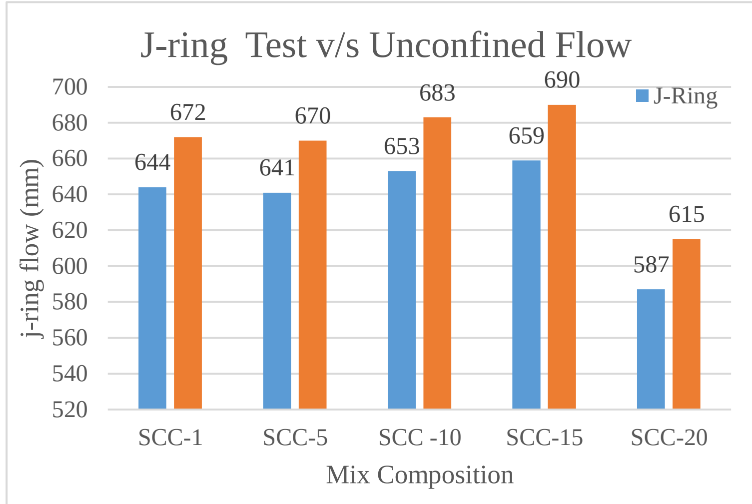


Figure 6: Comparison of J-Ring & Unconfined flow

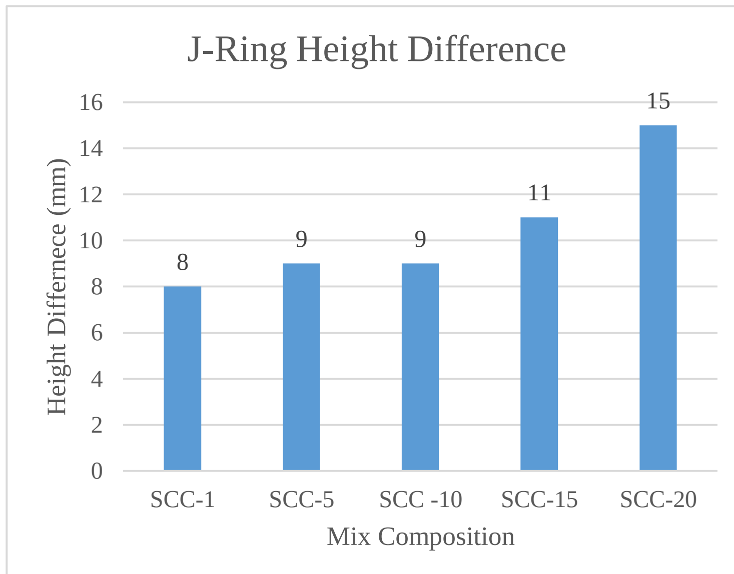


Figure 7: J-Ring Test Results (Graphical)

### *c. V-funnel at T 5 minutes*

Table 7: V-funnel Test Results

| Identity | V-funnel | V-funnel at T 5 minutes | V-funnel | | V-funnel at $T_{5min}$ | |
|---|---|---|---|---|---|---|
| | | | Min. | Max. | Min. | Max. |
| | (sec) | (sec) | (sec) | (sec) | (sec) | (sec) |
| SCC-1 | 8.4 | 8.7 | 6 | 12 | 0 | +3 |
| SCC-5 | 10 | 11.3 | 6 | 12 | 0 | +3 |
| SCC-10 | 9.2 | 10.1 | 6 | 12 | 0 | +3 |
| SCC-15 | 9 | 9.8 | 6 | 12 | 0 | +3 |
| SCC-20 | 9.2 | 10.7 | 6 | 12 | 0 | +3 |

Figure 8: V-Funnel Test (EFNARC, 2002)

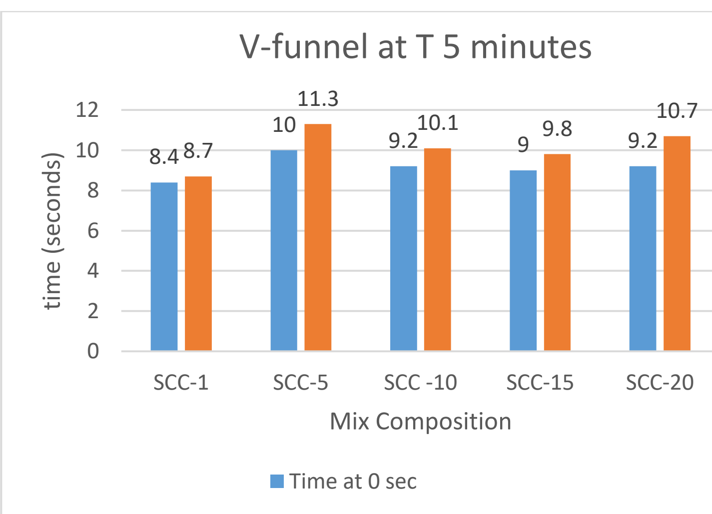


Figure 9: V-funnel at 0 sec & 5 min Results

## 1. *TESTS ON HARDENED CONCRETE*

Cylinders having a diameter of 150 mm and 300 mm height were cast to evaluate the compressive strength of the concrete mix at the age of 7 and 28 days, respectively.

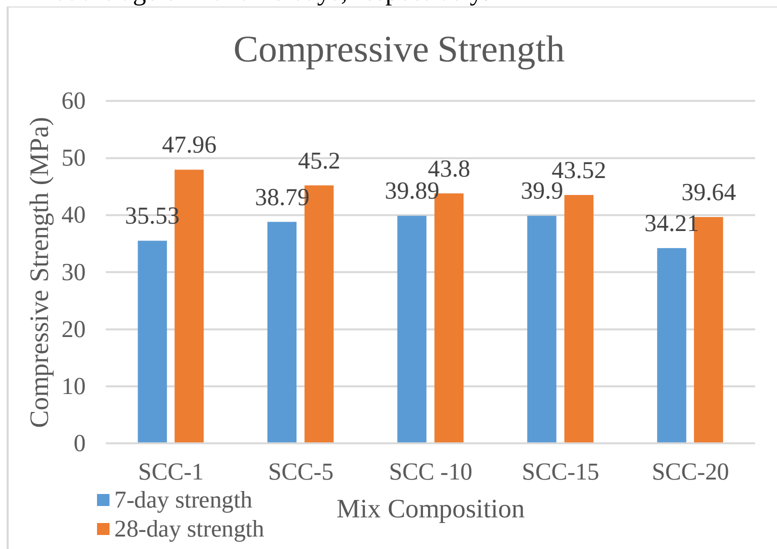


Figure 10: Compressive

Strength Test Results

Figure 11: Performance of Compression Test

## V. CONCLUSIONS

1. WMP can be effective filler for SCC concrete.
2. When the fresh properties such as flowability, passing ability, and segregation resistance are considered, 15 % of marble powder replacement has given good results.
3. Marble powder can be used up to 15 % without much affecting the strength. Up to 15% by weight of cement can be said as the most favorable amount of WMP with particle size below 100 µm as filler in producing good quality SCC.
4. It has been observed that marble powder increases the early age strength of the concrete.

## VI. RECOMMENDATIONS

1. The effect of WMP on autogenous and drying shrinkage needs to be examined.
2. The effects on durability properties such as corrosion resistance, alkali-aggregate reaction, sulfate attack, and freezing and thawing, etc. need to be studied.
3. Present researches can incorporate 50 % of marble powder in the preparation of SCC while fulfilling its all requirements.
4. The SCC may be studied with different powders e.g. fly ash, ground blast furnace slag, and crushed sandstone, etc.

## REFERENCES

[1] Duggal, S., 2008. *building materials.* New Delhi: NEW AGE INTERNATIONAL (P) LIMITED, PUBLISHERS.

[2] K. Maekawa, K. Ozawa & H. Okamura, 1989. *Development of High Performance Concrete.* s.l., s.n., pp. 699-704.

[3] M. Ouchi, K. Ozawa & H. Okamura, 1996. Development of a simple self- compactibility test method for acceptance at job site. Cario, s.n.

[4] Al-Mishhadani, S.A., Al-Rubaie & M.F., 2009. A Database for Self- Compacting Concrete in Iraq. *Eng. Technol. J.,* pp. 1203-1218.

[5] Shaker, R. R., 2015. The spatial distribution of development in Europe and its underlying sustainability cor-relations . In: *Applied Geography.* s.l.:s.n., p. 35.

[6] Barbier, E. B., 2006. *Natural resources and economic development.* s.l.:Cambridge University Press.

[7] Chausee, C. d., n.d. *Ecobuild Brussels.* [Online]
Available at:
https://www.ecobuild.brussels/en/professional/what-meant-sustainable-construction
[Accessed 14 January 2019].

[8] Pinch, L. & Masterson, J., n.d. *Construction Executive.* [Online]
Available at: http://www.constructionexec.com/article/ten-benefits-of-sustainable-construction
[Accessed 14 January 2019].

[9] Saxena, M., Mehrotra, P. & Asokan, P., 2011. Innovative building materials from natura fibre and industrial waste. In: *Land Contam Reclamant.* s.l.:s.n., pp. 355-363.

[10] EFNARC, 2002. *Specifications and Guidelines for Self-Compacting Concrete*, s.l.: s.n.