Optimized replacement of waste marble dust as partial replacement of sand in self compacting concrete

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Abstract: Waste marble dust (WMD), obtained from marble cutting and shaping process, has a potential to be used as a filler material in concrete. It has been observed that chemical and physical properties of WMD can map well with the properties of fine aggregates . development of concrete using waste materials is required to be followed so that load on land fill should be decreased. Also utilization of waste marble dust will tend to reduce the cost of construction material. This study is based on the utilization of waste marble dust (WMD) as a partial substitute of the sand in concrete production and its various affect on the workability and compressive strength of the concrete. The workability behaviour of concrete has been studied on conventional concrete and self compacting concrete as well. Effect on compressive strength behaviour has also been studied at 28 days with replacement of sand with WMD, at 5%, 10%, 15%, 20% 30%, 45%, 60%, 75%. In all mixes, Workability behaviour and 28-day compression results have been reported. Based on the results, it was recommended to use WMD up to 30% in the concrete mix as a replacement of sand in conventional as well as self compacting concrete.

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Keywords: Waste Marble Dust, workability, Compressive strength, Sand replacement

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1. Introduction

Marble is a metamorphic rock which results from the transformation of pure limestone. Chemically, calcite, dolomite, or serpentine materials are the major components of marble as crystalline rocks [1]. Marble waste can be recycled as a useful material. Most suitable inactivating method nowadays is recycling waste by producing new products or by addition as admixtures so that the environment is protected from waste deposits [2]. Results of several scientific works, studied the incorporation of marble waste into cement-based products such as normal concrete and high strength concrete [3], indicate an improvement in the compressive strength of concretes. It is helpful in decreasing the waste to be dumped at landfill sites and also utilization of waste will tend to reduce the cost of construction material. Based on the previous researches the influence of 60% replacement of sand with quarry dust and marble powder has been reported corresponding to the chemical composition of marble powder being used [4]. Marble powder obtained as a by-product of marble sawing and shaping. Waste marble dust "WMD" is an inert material which is obtained as an industrial by product during sawing, shaping, and polishing of marble and causes a serious environmental problem [5]. M.S. Hameed et al. [6] studied that the application of industrial waste in concrete may lead to various benefits, such as reduced construction material cost, reduced environmental pollution, development of sustainable construction material and availability of land for development of infrastructure as landfill land will be reduced appreciably. Green concrete is very cheap to produce, because, waste products are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption in production is lower, and durability is greater. Green concrete performs satisfactorily in strength and quality aspect. Industrial waste can be used as an mineral admixture corresponding to compatibility of particle size and chemical composition for satisfactory strength achievement. They concluded that the replacement of fine aggregate with 50% marble powder and 50% quarry rock dust green concrete gives an excellent result in workability and it satisfy the self compacting concrete performance without affecting the strength of concrete. Slump flow increases with the increase of marble sludge powder content. V funnel time decreases with the increase of marble sludge powder content. Also, they found that the compressive strength of concrete made of quarry rock dust are nearly 14% more than the conventional concrete. K. Shi-Cong, and P. Chi-Sun [7] the slump of crushed fine stone CFS concrete mixes was decreased with an increase in CFS content probably due to the angular shape of the CFS when compared to river sand. Also, H. Donza et al. [8] found that water demand in concrete will be modified corresponding to the replacement percentage in concrete, shape of particles and the texture of the marble dust particles. R. Ilangovana et al. [9] observed that hundred percent replacement of conventional sand with industrial waste of marble industry may give satisfactory result depending upon the chemical composition of industrial waste. Also, they concluded that the partial replacement of fine aggregate with 50% marble powder and 50% quarry rock dust gives an excellent result in tensile strength. Andrew et al. [10] concluded that the cohesiveness of mortar and concrete in the presence of industrial waste that is, marble powder proved to be very efficient in maintaining workability for self compacting concrete, in the presence of a superplasticizing admixture, provided that water to cement ratio was adequately low. It has been observed that waste mable powder has given satisfactory results in presence of ultrafine materials used as mineral admixtures and shows good cohesive properties. In terms of mechanical performance, 30% substitution of sand by the marble powder in the presence of a superplasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing. Moreover, an even more positive effect of marble powder is evident at early ages, due to its filler ability. H. Hebhoub et al. [11] studied the role of recycled coarse aggregates and their effect on strength properties. The significant strength gain, the tensile strength with the replacement of 25%, 50% and 75% are quite greater than values obtained with natural aggregates. The concrete with 100% replacement provided quite low results in strength. It has been an important observation by climate experts Pereira- de- Oliveira, of the globe that condition of climate is worsening at a higher rate than expected. As per reports of united nations summits by Pereira- de-Oliveira, it is required to control the total CO_2 emissions [12]. Cement production is contributing to 7-8% of world CO_2 emissions. India is leading cement production at second position [13]. Use of industrial waste as replacement of cement and aggregates can be used as a remedial measure to control the environmental issues rising through CO_2 emissions. Also the benefits of self compaction can be added to enhance the benefits of industrial waste[14]. In order to use it as a mineral addition for mortars and concretes, particularly for self-compacting concrete, a powder obtained as a by-product of marble sawing and shaping was characterized from a chemical and physical point of view. The Blaine fineness value for this marble powder was a very high 1500 m2/kg, with 90% of the particles being finer than 50 lm and 50% being under 7 lm. Results obtained indicate by T. Celik that a 10% substitution of marble powder for sand produced the highest compressive strength at a very similar workability [15]. Marble dust is a by-product of marble manufacturing plants that contributes significantly to environmental pollution. Therefore, by using it as a replacement for very fine aggregate in normal strength concretes, it may be able to prevent environmental pollution, particularly in areas with excessive marble production, and to use less natural resources overall . Supplementary materials in self compacting concrete tend to increase the strength and durability behavior. Use of special concrete based upon waste from industrial and agricultural waste can be a hopeful solution . Binici et al. [16] have studied some mechanical properties of concrete containing marble and limestone dusts; mixes were modified to 5%, 10% and 15% marble and limestone dusts instead of fine sand aggregates and their compressive strengths were compared. It is also investigated in another study the durability and the fresh properties of concrete made with granite and marble as recycled aggregates. 10% substitution of sand by the marble powder has provided maximum compressive strength at about the same workability; mixtures were evaluated based upon cement or sand substitution by the marble powder [17]. The marble wastes are not only substitutes or additives to concrete; they can also be used for other kinds of building materials. Experiments carried out by Saboya et al. [18] have shown that the use of 15–20% of powder marble content in red ceramic raw material could be considered the best proportion to enhance the properties of brick ceramic. Akbulut et.al [19] demonstrated that the physical properties of the marble waste aggregates are within specified limits and these materials can potentially used as aggregates in light to medium trafficked asphalt pavement binder layers. It is difficult to make comparisons between existing concrete results and behaviour of concrete developed using available with the locally available materials.

An attempt along the same path has been made to identify the replacement of locally available marble dust from marble cutting and shaping sites in place of use of river sand as fine aggregate in conventional concrete. In addition to this, an attempt has been tried on self compacting concrete so that benefits of self compaction can be clubbed with the potential replacement of natural aggregates in concrete . In this paper, experimental study on the marble waste available at Jalandhar marble cutting site has been performed for replacement of fine aggregates in self compacting concrete. Concrete mix designs with 5%, 10%, 15%, 30%, 45%, 60% and 75% of fine aggregates substitution were formulated.

2. Experimental study

As per the experimental work involved locally available materials were used and the relevant testing of materials conducted based on IS codes of various materials. The mix code has been designed with numerals corresponding to replacement of sand with waste marble dust in both conventional concrete and self compacting concrete. Table 1 presents the physical characteristics of ordinary Portland cement used from local supplier. Table 2 gives the sieve analysis observations for fine aggregate indicating its conformation to grading zone II as per relevant IS code. Chemical composition of Waste marble dust is shown in Table 3. The main characteristics of the coarse aggregates are listed in Table 4. Fresh properties of self compacting concrete are tested as per EFNARC code [15]and are listed in Table 5

2.1 Material Properties

Physical and chemical properties of components of concrete have been studied.

Table 1: Physical properties of cement

S.No.	Characteristics	Values
1	Fineness (m^2/kg)	225
2	Setting time (initial)	30 minutes
3	Setting time (final)	360 minutes
4	Consistency (%)	30
6	Specific gravity	3.15

Table 2: Sieve analysis for fine aggregate

Sieve Designation	Wt. retained (Kg)	Cum. Wt. retained (Kg)	% Cum. Wt. retained (Kg)	% Passing
10 mm	0	0	0	100
4.75 mm	0.026	0.026	1.3	98.7
2.36 mm	0.214	0.240	12	88

1.18 mm	0.262	0.502	25.1	74.9
600 µ	0.5	1.002	50.1	49.9
300 µ	0.405	1.407	70.35	29.65
150 µ	0.459	1.866	93.3	6.7
Pan	0.134	2		

Remarks: Sand confirms to zone II

Table 3: Chemical composition of waste marble dust

Binder	WMD
SiO_2	3
Al_2O_3	0.14
CaO	52.28
Fe_2O_3	0.39
MgO	0.5
$CaCO_3$	93.3
$MgCO_3$	1.04
Al_2O_3	0.14
S	0.03
LOI*	0.05

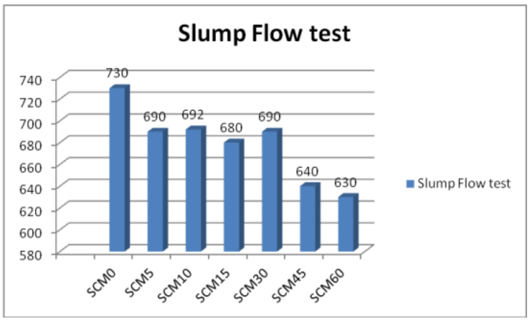
Table 4: Physical characteristics of aggregates

Aggregate	Fine aggregate	Coarse aggregate
Specific gravity	2.63	2.67
Fineness modulus	2.69	6.14
Absorption %	0.8	0.61
Bulk density Kg/m^3	1668	1568
zone	II	-

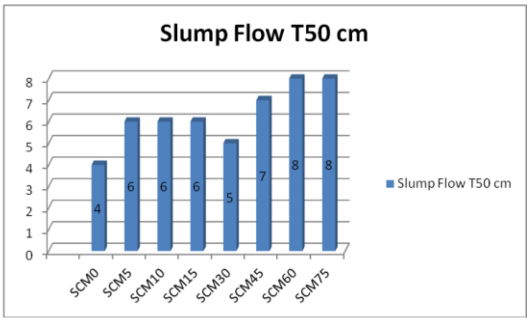
2.2 Fresh properties of self compacting concrete

Table 5: Workability results for self compacting concrete with varying replacement of sand with mable dust

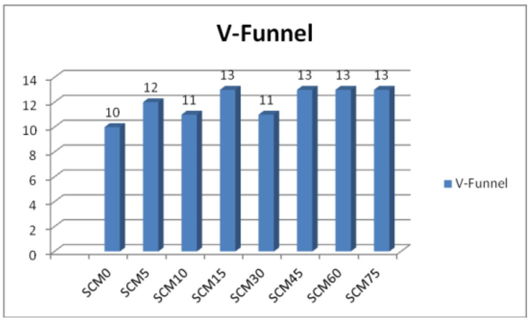
Mix Code for SCC	Slump Flow test	Slump Flow $T_{50\ cm}$	V-Funnel T_0	L-Box (H2/H1)	J-Ring
SCM0	730	4	10	0.9	10
SCM5	690	6	12	1.3	12
SCM10	692	6	11	1.2	11
SCM15	680	6	13	1.5	12
SCM30	690	5	11	0.9	9
SCM45	640	7	13	1.3	11
SCM60	630	8	13	1.44	11
SCM75	620	4	13	1.2	13



Graph 1: Slump flow test result for SCC with marble dust replacement of sand

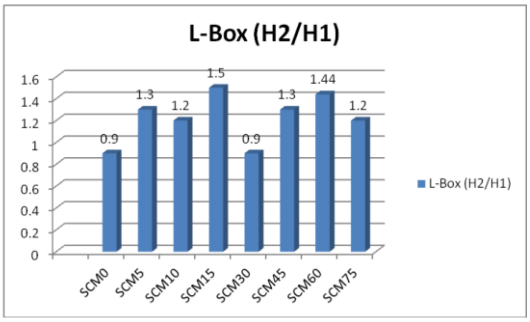


Graph 2: T50cm Slump flow test result for SCC with marble dust replacement of sand

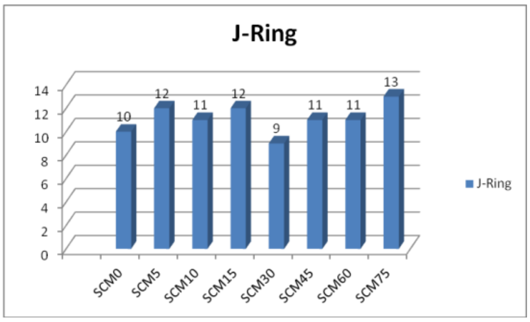


Graph 3: V-funnel test result for SCC with marble

dust replacement of sand



Graph 4: L-Box test result   for SCC with marble dust replacement of sand



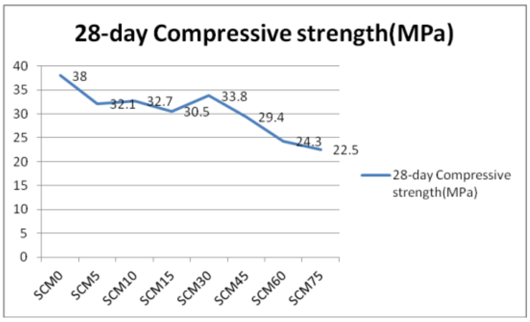
Graph 5: J-ring T0 test result   for SCC with marble dust as replacement of sand

As per the results of fresh properties of concrete, it has been obtained that the concrete mix with code SCM30 is giving all the results within permissible limits as per Indian standard code for self-compacting concrete.

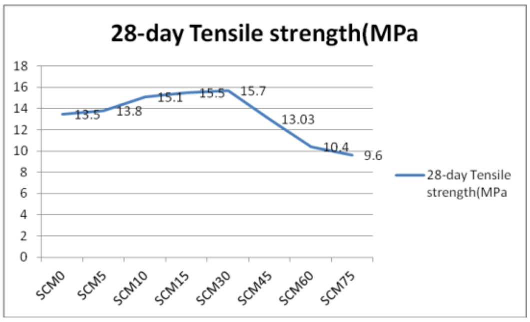
Table 6: 28-day strength results for self-compacting concrete with replacement of sand with marble dust

Mix Code	28-day Compressive strength (MPa)	28-day Tensile strength (MPa	28-day Flexural strength (MPa
SCM0	30.3	13.5	2.4
SCM5	32.1	13.8	2.5
SCM10	32.7	15.1	3.3
SCM15	33	15.5	3.43
SCM30	33.8	15.7	3.6
SCM45	29.4	13.03	2.2
SCM60	24.3	10.4	2.1
SCM75	22.5	9.6	1.8

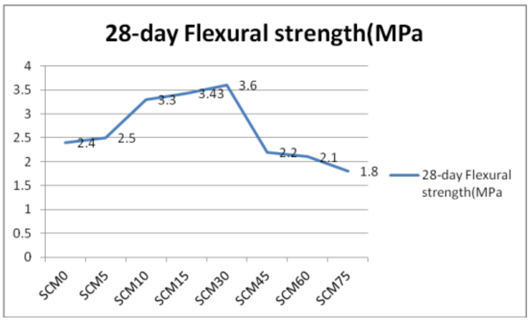
2.3 Hardened properties of self compacting concrete



Graph6: 28-day compressive strength of self compacting concrete with marble dust replacement of sand



Graph7: 28-day tensile strength of self-compacting concrete with marble dust replacement of sand



Graph8: 28-day flexural strength of self compacting

concrete with marble dust replacement of sand

3. Results and discussion

The obtained experimental results reveal the influence of the studied parameters on the behaviour of fresh and hardened properties of self compacting concrete . The use of WMD as a filler in the SCC composition increases intruded pore volume, reduces percentage of fine pores, and then increases compressive strength of the SCC. Results obtained confirm the trend of compressive strength values for SCM0, SCM5, SCM10, SCM15, SCM30, SCM45, SCM60, SCM75 (Table 6) because this strength is fundamentally a function of the distribution of the void space and porosity of concrete. According to the results of Table 6, the concrete SCM30, with marble powder content 30%, has a higher compressive strength than rest of concrete mix and nealy 11.5% than control mix (SCM0). SCM45 despite containing more marble powder than the second is due to the obtained segregation of this concrete which significantly decreases the compressive strength. In addition, the rheological and the self-compaction properties of SCC will be improved with amount of WMD upto 30%. It is confirmed by the obtained experimental data of slump test, slump flow time, V-funnel , L-Box and J-ring (Table 5).

4. Conclusion

This research is an experimental approach to substitute natural aggregates by the waste marble dust; the concern is towards the sustainable environment. Recycling the waste marble dust from marble cutting process can help in reducing the load on landfill as well the cost of construction material. The results obtained demonstrated the performance of various concrete mixtures which may help to understand the behaviour of WMD on fresh and hardened properties of self compacting concrete. It has been observed experimentally that marble dust can be used as a replacement of sand self compacting concrete upto 30% satisfactorily as per the strength behaviour. This research needs to be explored for durability studies such as freeze–thaw resistance, water permeability behaviour, sulphate attack and carbonation resistance.

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