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Optimum replacement of waste marble dust as partial replacement of sand in sustainable construction material

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Abstract: It may be possible to use waste marble dust (WMD), which is produced during the shaping and cutting of marble, as a filler in concrete. The physical and chemical characteristics of WMD have been found to correlate strongly with the characteristics of fine aggregates. It is necessary to follow the process of developing sustainable construction material utilising waste materials in order to reduce the load on of land fill and reducing soil pollution as well. Additionally, using leftover marble dust will probably lower the cost of building supplies. This study examines the effects of using waste marble dust (WMD) partially in place of sand during the construction of concrete, specifically in relation to the workability and compressive strength of the self compacting concrete. The impact of substituting WMD for sand at percentages of 5%, 10%, 15%, 20%, 30%, 45%, 60%, and 75% on the behaviour of compressive strength has also been investigated after 28 days. Workability behaviour and 28-day compression outcomes have been recorded for all combinations. It was advised, in light of the findings, to substitute sand in conventional and self-compacting concrete with up to 30% more WMD in the mix.

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

Introduction

Pure limestone undergoes a change to become marble, a metamorphic rock. Marble is mostly composed of crystalline rocks that contain calcite, dolomite, or serpentine elements [1]. Waste marble can be recycled and used again. Nowadays, recycling garbage to create new products or using it as admixtures is the most effective inactivating approach for protecting the environment from waste deposits [2]. The compressive strengths of concretes have grown, according to the findings of several scientific research that looked at adding leftover marble to cement-based products like standard and high strength concrete [3]. Utilising garbage can also help to lower the cost of building materials by reducing the amount of waste that is disposed at landfills. According to earlier studies, the impact of replacing 60% of the sand with marble powder and quarry dust has been documented [4], which is consistent with the chemical makeup of the powder being utilised. As a byproduct of cutting and sculpting marble, marble powder is produced. Waste Marble Dust ("WMD") is an inert substance that is produced as an industrial byproduct when marble is sawed, shaped, and polished. It creates an environmental problem [5]. In accordance to studies done by M.S. Hameed et al. [6], the use of industrial waste in concrete may have a number of benefits including a decreased price for building materials, less pollution for the environment, the development of sustainable building materials, and an increase in the amount of land available for infrastructure development because landfill space will be significantly reduced. Because waste items are partially substituted for cement, waste disposal fees are avoided, production energy consumption is reduced, and durability is increased, green concrete can be produced at a very low cost. Green concrete works admirably in terms of strength and quality. Industrial waste can be utilised as a mineral additive to provide the necessary strength by matching the chemical composition and particle size.

They found that adding 50% marble powder and 50% quarry rock dust to green concrete instead of fine aggregate produced great workability and satisfied the needs of self-compacting concrete without compromising the concrete's strength. As the powdered marble sludge content rises, so does the slump flow. The amount of marble sludge powder reduces as the V funnel time increases. Researchers additionally found that concrete with crushed rock had a nearly 14% more compressive strength than regular concrete. The angular shape of CFS, as compared to river sand, is likely the reason why K. Shi-Cong and P. Chi-Sun [7] found that the slump of crushed fine stone CFS concrete mixes decreased as the CFS level increased.

According to H. Donza et al. [8], the water requirement of concrete varies depending on the form, texture, and replacement percentage of the particles in the concrete. According to R. Ilangovana et al. [9], depending on the industrial waste's chemical makeup, replacing of 100% of conventional sand with waste from the marble industry may yield satisfactory results. Additionally, they came to the conclusion that a great result in tensile strength can be obtained by partially replacing fine aggregate with a mixture of 50% marble powder and 50% quarry rock dust. According to Andrew et al. [10], cohesiveness of concrete and mortar in the presence of industrial waste—marble powder—proved to be highly effective in preserving workability for self-compacting concrete in the presence of a superplasticizing admixture, provided that water to cement ratio was adequately low. It has been noted that waste marble powder shows good cohesiveness and has produced satisfactory results when utilised as mineral admixtures with ultrafine materials. Mechanical performance was similar to the reference mixture after 28 days of curing when 30% of the sand was replaced with marble powder in the presence of a superplasticizer. This resulted in maximum compressive strength at the same workability level. Due to marble powder's filler properties, an even more substantial advantage is visible from a young age. Recycled coarse aggregates' function and impact on strength characteristics were investigated by H. Hebhoub et al. [11]. With replacements of 25%, 50%, and 75%, the tensile strength appreciably increases and surpasses the measured values. The concrete with 100% replacement provided quite low results in strength. The concrete that was 100% replacement yielded very poor strength values. The fact that the global climate is deteriorating faster than anticipated has been noted as a significant finding by climate specialists Pereira-de-Oliveira. Pereira-de-Oliveira's reports from UN summits state that overall CO2 emissions must be under control [12]. 7-8% of global CO2 emissions are caused by the manufacture of cement. In second place, India is largetst producer of cement. One remedial technique to control environmental issues arising by increased CO2 emissions is to substitute cement and aggregates with industrial waste. To increase the advantage of application of industrial waste, self-compaction feature can also be included. [14]. A powder that was a by-product of shaping and sawing marble was characterised chemically and physically so that it could be used as a mineral addition for mortars and concretes, especially self-compacting concrete. This marble powder had an extremely high Blaine fineness value of 1500 m2/kg, meaning that 90% of the particles were finer than 50 lm and 50% were less than 7 lm. Results show that T. Celik found that the best compressive strength was achieved at a fairly similar workability when 10% marble powder was substituted for sand [15]. One byproduct of marble manufacturing facilities that greatly pollutes the environment is marble dust.

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

Chemical	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	$CaCO_3$	$MgCO_3$	Al_2O_3	S	LOI*
WMD	3	0.14	52.28	0.39	0.50	93.3	1.04	0.14	0.03	0.05

Table 4: Physical characteristics of aggregates

Aggregate	Fine aggregate	Coarse aggregate
Specific gravity	2.63	2.67
Fineness modulus	2.69	06.14
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 marble 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

Workability behaviour of tested mix has been given in Table 5 and graphical representation of workability behaviour has been shown through Figure 1 to 5 and

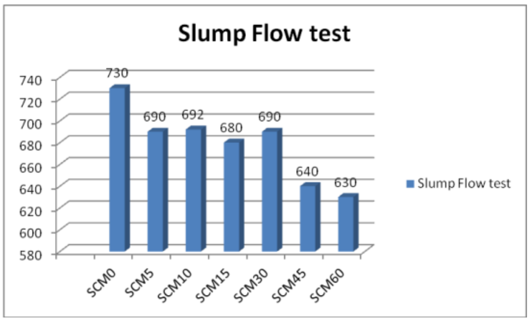

Figure 1: Slump flow test result for SCC with marble dust replacement of sand

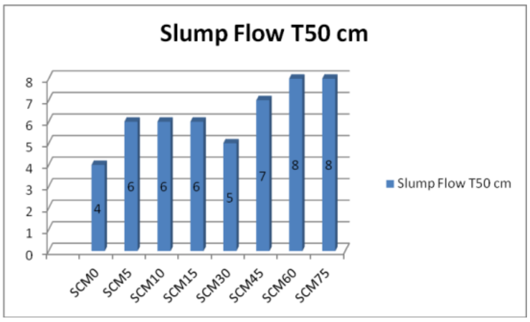

Figure 2: T50cm Slump flow test result for SCC with marble dust replacement of sand

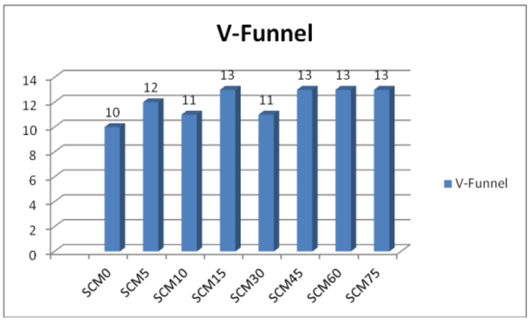

Figure 3: V-funnel test result for SCC with marble dust replacement of sand

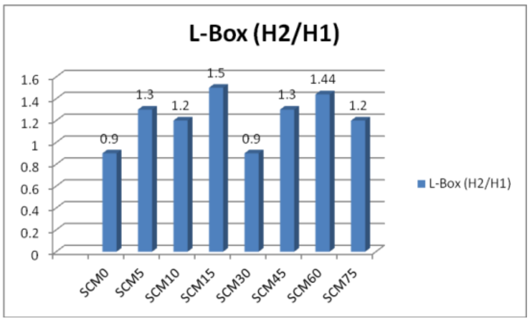

Figure 4: L-Box test result for SCC with marble dust replacement of sand

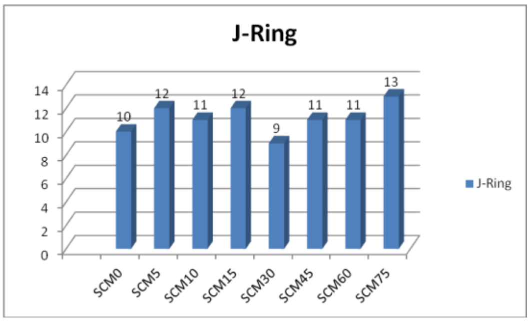

Figure 5: J-ring test result for SCC with marble dust as replacement of sand

As per the results of fresh properties of concrete, it has been obtained that the concrete mix with code SCM0, SCM10. SCM20, SCM30 is giving all the workability test results within permissible limits as per EFNARC 2005 referred for self-compacting concrete. Hence, replacement of fine aggregate upto 30% with waste marble dust is acceptable as per workability behaviour. After 30% replacement of fine aggregate with marble dust is not giving satisfactory behaviour and hence can not be recommended for SCC.

2.3 Hardened properties of self compacting concrete

Strength behaviour of self-compacting concrete has been shown in Table 6 and graphical representation has been shown in Figure 6 to 8.

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 Flexura 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

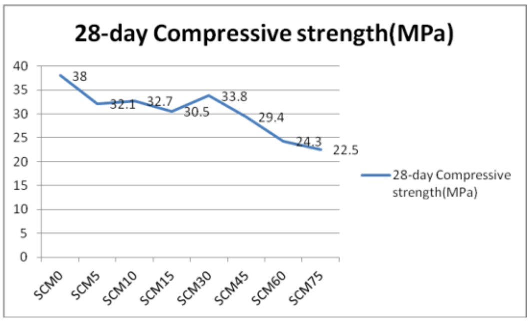

Figure 6: 28-day compressive strength of self compacting concrete with marble dust replacement of sand

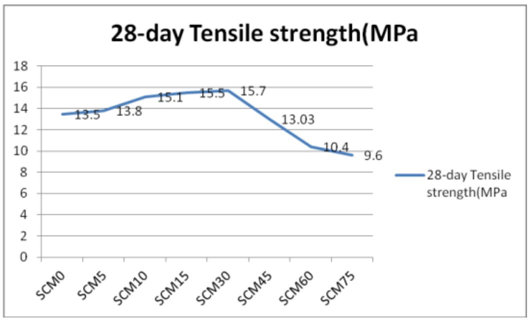

Figure 7: 28-day tensile strength of self-compacting concrete with marble dust replacement of sand

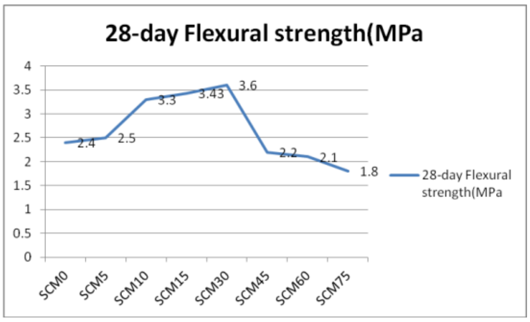

Figure 8: 28-day flexural strength of self compacting concrete with marble dust replacement of sand

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 nearly 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 study to identify optimal substitution of natural fine 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. As per observations it can be concluded that waste 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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