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Study and Experimental Investigation of Marble Waste as a Concrete Ingredient

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Abstract: The rapid growth of the construction industry has led to an increasing demand for raw materials such as cement, fine aggregate, and coarse aggregate. Simultaneously, the disposal of marble waste from quarrying and processing poses environmental challenges. This study explores the use of marble waste as a partial replacement for fine and coarse aggregates in concrete production**,** promoting sustainability and waste management**.** Various percentages of marble waste were incorporated into the concrete mix to evaluate its impact on strength, durability, and workability**.** Experimental investigations indicate that marble waste can enhance certain properties of concrete while reducing dependency on natural aggregates.

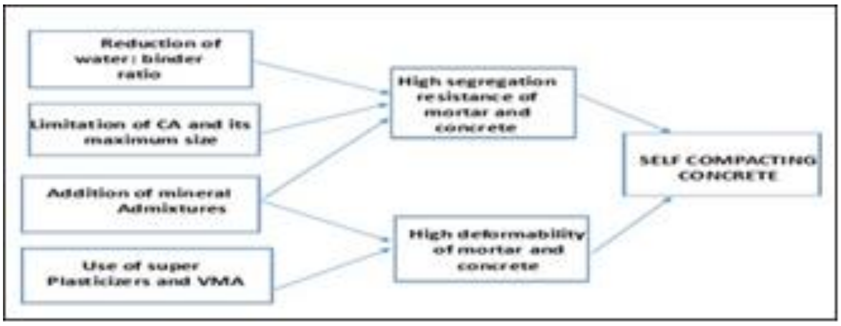
Keywords: Marble waste, concrete, sustainability, waste management, fine aggregate, coarse aggregate, strength, durability, construction materials.

Introduction

Self-Compacting Concrete (SCC), which flows under its own weight and does not require any external vibration for compaction, has revolutionized concrete placement. SCC was first introduced in the late 1980‘s by Japanese researchers, is a highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding. For SCC, it is generally necessary to use super plasticizers in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. SCC was introduced in India in the Nineties (Shetty, 2004). European Federation of natural trade associations representing producers and applicators of specialists and guidelines for SCC to provide a framework for design and use of high-quality SCC. It is highly workable concrete which flows in densely reinforced and complex structural elements which flow under its own weight and adequately fill all voids without segregation and excessive bleeding in absence of need forvibration.

Originate of SCC

The SCC is a self-consolidating concrete used in congested reinforced structures and the history of origin as follows, In 1980s, Japan constructed durable concrete structures using SCC. It was advocated by Professor Hajime Okamura (the University of Tokyo, now Kochi Institute of Technology). Later in 1990, this technology reached Europe and they added powders (cement, supplementary cementations' materials, and inert materials) to increase plastic viscosity in SCC Okamura et al., (1999). After that, it comes to India, which was the first construction started in Delhi with this concrete.



Limitations of SCC

Even though many advantages in SCC, some disadvantages also therelike

- Increases formwork costs due to possibly higher form workpressures
- Required technical expertise to develop and control mixes
- Chances for variability in workability
- Possibilities of risk and uncertainty associated with the use of a newproduct.

Marble waste

Marble waste is produced from the marble processing plants during the cutting, shaping and polishing in stone quarries. During this process, about 20- 25% of the processed marble is turned into powder form and 10-15% is in the form of chips. India is the topmost exporter of marble, every year around 7 million tons of marble waste is generated from the stone quarries. The maximum resources of marble waste are from Rajasthan. The disposal of this waste marble on soils causes a reduction in permeability and also contaminates the groundwater when it is deposited along the catchment area simultaneously it affects the plants grow too. Thus, utilizing these marble wastes in the construction industry would help to protect the environment from dumpsites of marble and also limit the excessive mining of natural resources.

Literature Review Several studies have explored the comparative analysis of materials:

- **Aijaz Ahmad Zende et al., (2014)** have carried out a review on Self- Compacting Concrete (SCC) and compare it with Normal Concrete (NC). Particularly in India, the use of Self-compacting concrete for routine construction is not much because of the lack of awareness in countries like Canada apart from Japan, due to not clear of existing design codes and also no standard codes are available for the mix design of SCC. Apart from few methods developed by the researcher sand many institutions, RMC, companies are using their own methods with one or other limitations for the practical use of self-compacting concrete. For flowability and segregation control, the viscosity modifying agents along with high-range water reducing like super plasticizers agent are very essential.
- **Rajdip Paul et al., (2015)** have proposed the mechanical properties of SCC in comparison to

conventional concrete. This holds particularly true for in-situ concrete‘s, with medium and low strengths and considerable for future is fiber reinforced self-compacting concretes. The concrete have service life design (SLD) as an important design for safety and serviceability, increased attention to the role of microstructure of the various types of available SCC‘s and its role on durability too.

- **Amit Kumar Tomar et al., (2016)** have found about 45% of the marble block will be wasted during its cutting in the form of powder. A the waste marble powder decreases the fertility of the soil and also pollute the environment. Therefore, as a solution for these problems is replacing the fine aggregates with waste marble powder (WMP). By the use of this waste marble powder in the concrete, we can increase or change various properties of the concrete mix and also used as self-compacting concrete. From the previous studies, it concludes that use of waste marble powder as the replacement of fine aggregate as well as cement had a good prospective.
- **Shahidan et al., (2016)** have made to summaries the previous research work related to utilization of waste minimization in SCC from 2009 to 2015 and utilizing of waste materials in developing sustainable SCC should be supported, explored and expended through focus researches to be verified through performance on fresh state and hardened state to understand the behaviour of each material either in short term or long term effect for sustainable use in concrete industry.
- **Isham Ismail et al., (2016)** proposed many researches done using common materials like Limestone Powder (LP), Fly Ash (FA), Silica Fume and Granulated Blast Furnace Slag (GBFS) and where there are many alternative or recycled material can be used in producing SCC but this review only focus on waste material from Marble Powder (MP), Dolomite Powder (DP), Crump Rubber (CR), Recycled Aggregate (RA) and Rise Husk Ash (RHA). Utilizing of MP, DP, CR and RA significantly show an improvement of workability but cannot ensure to have a good result in compressive strength and similarity effect in fresh and hardened state of SCC.
- **Viramgama et al., (2016)** concluded that ceramic industry about 5- 10% production goes as waste in various processes while manufacturing. This creates environment pollution and cost of deposition of ceramic waste in landfills so it is substituted as a powder of 0%, 10%, 15%, 20%, 25%, 30% and Fly ash 25% by the binder contain of self-compacting concrete. The result decides 30% ceramic waste powder is best result of fresh and hardens property, thus saving landfill; reduce CO_2 emission by the use of less cement and cost of concrete is reduced up to 13.27% in ―M25‖ grade.
- **Manwani et al., (2017)** proposed a fine aggregate replacement of waste marble chips from 10% to 25% gives optimum compressive strength of concrete when compared from traditional concrete. Several researchers found that the marble chips can be replaced in the place of fine aggregates during concrete production, and then the results of split tensile strength and the flexural strength follow the same pattern quasi results of compressive strength of concrete and also found increase in abrasion resistance.
- **Robert Busi et al., (2018)** have investigated that huge number of discarded waste tires can be incorporated in self-compacting concrete by partially replacing the natural fine and coarse aggregate, reducing consumption of sand and gravel and preserving these natural materials.

Methodology

Materials:-

The constitute of SCC are (OPC) cement, river sand, coarse aggregate less than 12.5 mm, chemical admixture like super plasticizer, mineral admixture like fly ash, viscosity modifying agent. SCC needs no vibration and it flows like a liquid. In this research, marble powder and marble aggregate is used to replace the cement and river sand respectively. The properties of materials are tested in the laboratory confirming to respective codes. The properties of the concrete in fresh and hardened state are tested and mix is designed to find the strength of the hardened concrete.

Preliminary testing on materials:-

The basic tests are conducted to find the physical and chemical properties of materials which are to be used in self-compacting concrete along with marble waste.

Cement:-

It is a binding material used in bonding sand and the aggregate, where OPC 53 grade available in local market is used. Tests are conducted to find the quality and the properties of cement. As per **IS 12269 (2013)**, the cement should be dark with a light greenish shade, free from lumps. The cement should enhance sound flow and setting properties which should be compatible to the chemical and mineral admixtures, viscosity modifying agents are also added to marble powder. The physical and chemical properties of cement were tested and shown in **Tables 1** and **2** as per Indian Standard Specifications.

Table 1 Physical characteristics of cement

Characteristics	Values Obtained	Standards	Standard Values
Specific gravity of Cement	3.15	IS: 4031(Part XI)-1988	Around 3.15
Consistency	35 %	IS 4031(Part IV) 1988	30-35
Initial setting time of cement	45 min	IS 4031(Part V) 1988	>30 minutes
Final setting time of cement	360 min		<600 minutes
Fineness	4.20	IS 4031(Part I) 1988	<10

Table 2 Chemical characteristics of cement

Chemical requirements	Ultra Tech OPC 53	IS 12269 (2013)
Loss on ignition (%)	2.6	1.3 <4
Insoluble residue (%)	1.1	1.0 <3
Magnesium oxide (%)	1.73	1.4 <6
Lime saturation factor	0.89	0.8-1.02
Alumina iron ratio	1.2	>0.66
Sulphuric Anhydride (%)	2.88	<3.00
Alkalis (%)	0.2	-
Chlorides (%)	0.01	<0.1
Tricalcium aluminate	-	6.0
Silica di oxide (SiO_2)	23.6	-
CaO	64.6	-

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Fine aggregate:-

The fine aggregate locally available river sand and size less than 4.75 mm is used. The grading should be uniform throughout the work. The moisture content or absorption characteristics are closely monitored as quality of SCC. To replace with the marble fine aggregate the properties are tested. The various physical properties are performed as per **IS 383 (1970)**

Table 3 Tests on fine aggregate

Characteristics	Values Obtained
Specific gravity of FA	2.58
Water absorption	1.3%
Fineness Modulus	2.14
Bulk density	1623.55kg/m^3

Results and Discussion

The tests were conducted on both fresh and hardened concrete states are detailed in chapters 4 and 5. The tests on fresh concrete is the workability test such as Slump test, L-box, V funnel, U-box test and Visual Stability Index results were described below. The strength and durability tests were conducted on hardened concrete and results were briefed as follows,

Workability test on SCC:-

The workability value for both the marble waste ratios gives the limiting value within the EFNARC (2005) code. According to the code, the standard tests like slump flow and V- funnel value shows the high viscosity flow able concrete in walls, slabs, columns, and deep foundations. The L- box test value also gives the flow with high pass ability in congested reinforcement with a perfect surface finish. The non-standard test like U-box and VSI index also give highly stable and stable flow able concrete.

Table 4 workability test on SCC with marble powder

Test	SCC	SCC + 10 % MP	SCC + 20 % MP	SCC + 30% MP	EFNARC Code Limit
SLUMP flow T50cm (Filling ability)	710mm, 4 sec	690mm, 4 sec	695mm, 3 sec	670mm, 3.6 sec	**650-800mm 2-5sec**
L-box(Passing ability)	0.93	0.90	0.86	0.83	**0.8-1.0**
V-funnel(Filling ability)	12 sec	12 sec	11.7 sec	11.4 sec	**6-12 sec**
V- funnelat T5min(Segregation resistance)	15 sec	14 sec	13 sec	13 sec	**0 - +3 sec**
U-box(Passingability)	30 mm	29 mm	28 mm	26 mm	**0 - 30 mm**
VSI	0	0	0	1	**< 3**

The class of flow viscosity VS2/VF2 (high viscos flow) was noted with respect to and passing ability class also for above mix L-test is PA2 (low pass ability)

Table 5 Workability test on SCC with marble fine aggregate

Test	SCC	SCC + 25 % MFA	SCC + 50 % MFA	SCC + 100 % MFA	EFNARC Code Limit
SLUMP flow T50cm (Filling ability)	710mm, 4 sec	650mm, 3 sec	640mm, 2.8 sec	630mm, 2.5 sec	650-800 mm 2-5sec
L-box (Passing ability)	0.93	0.81	0.80	0.78	0.8-1.0
V-funnel (Filling ability)	12 sec	11 sec	11.5 sec	12 sec	6-12 sec
V- funnel at T5 min(Segregation resistance)	15 sec	15 sec	16 sec	16.7 sec	0 - +3 sec
U-box (Passing ability)	30 mm	27 mm	26 mm	24 mm	0 - 30 mm
VSI	0	0	0	1	<3

The workability tests were conducted for the replacement of fine aggregate as a marble aggregate in SCC concrete. The V-funnel test at T5 for SCCMFA shows the higher segregation in the mixer. This is corrected by altering the super plasticizer content. The usage of less superplasticizer gives the value within the limits. Fine aggregate with different zones like zone I and zone III gives good packing density in fresh SCC.

Conclusion The research shows that 10% marble powder replacement with cement gives satisfactory results when compared with other percentages. The 25% marble fine aggregate gives optimum results when compared with other various proportion and curing days.

As per literature review done, many authors used SCC with alternative materials with partially replacement of cement and aggregate gives good effect in concrete. The workability properties were satisfied with the limits for both the replacements. The maximum strength was obtained in higher curing days; it means increasing curing days increases the strength of SCC in both the cases. Simultaneously the durability also increased. The chemical attack test concerned, no much effect on both acid and sulphate curing for least percentage marble waste addition. The structural beam test also gives safer for the maximum load. Totally, less percentage waste addition gives maximum and optimum strength results rather than increasing the waste percentage in SCC mix.

Apart from that, it can be a boon considering the improvement in concrete quality, concrete construction processes shortened construction time and much improvement in working conditions as it reduces noise pollution.

At last, SCC marble waste replacement, reduces the material cost and labour cost too, therefore it gives lower construction cost.

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