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Suitability of using Marble Dust Powder and Rice Husk Ash in Production of Self-Compacting Concrete: A Review.

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ABSTRACT: Self-compacting concrete (SCC) is a type of concrete that does not require mechanical vibration during compaction. Recently, SCC has been gaining popularity due to its ease of construction and improved strength. The use of marble dust powder and rice husk ash in the production of SCC has been proposed as a means of improving strength and reducing costs. The review focused on the use of marble dust powder and rice husk ash in the production of SCC. The review explored the potential benefits, both from an economic and environmental perspective, as well as the potential drawbacks that may be encountered when using these materials in concrete production. In addition, the review also considered the various methods and techniques that have been proposed for incorporating these materials into concrete mixes, as well as the various research studies that have assessed the efficacy of using marble dust powder and rice husk ash in concrete production. Overall, this review suggests that the use of marble dust powder and rice husk ash has advantages in terms of cost and environmental impact. However, further research is needed to assess the efficacy of these materials in concrete production, and the various methods/techniques for incorporating these materials into concrete mixes should be assessed to ensure optimal performance.

KEYWORDS: Pozzolanic Materials, Portland Cement, Marble Dust Powder, Rice Husk Ash, Mechanical Properties, Compressive Strength, Flexural Strength and Durability.

I. INTRODUCTION

Most concrete structures in the world are constructed using Ordinary Portland Cement. The rapid increase in the price of OPC has made building construction very expensive. Besides the exorbitant cost of cement, its production requires a very high temperature of about 1500^{0}C which requires an enormous amount of energy which is expensive to attain and maintain. Cement manufacturing factories emit one of the highest carbon footprints into the atmosphere. The activities of these cement-producing companies have depleted the natural environment and released a huge amount of poisonous gasses such as CO_2 and NO_2 into the atmosphere causing environmental pollution. It makes traditional concrete unsustainable in the future. Agricultural and industrial waste materials can be used as partial replacements for cementing materials (Ojedokun et al., 2014). People living in developing countries are faced with inadequate provision of physical infrastructures such as shelter and other related amenities which are typical factors of under-development that need to be addressed through the provision of cheap and alternative materials. In these areas, development requires the use of alternative binders and aggregates for the production of concrete.

Canadian Standard Association, (2000) defines pozzolanic material as a siliceous or alumino-siliceous material that in finely divided form and the presence of moisture, chemically reacts at ordinary room temperature with calcium hydroxide, released by the hydration of Portland cement, to form compounds possessing cementitious properties. Fapohunda et al., (2021) reported that most researchers in the construction industry are doing their best to minimize the cost of construction materials by the use of locally available materials. Research efforts have been geared towards the use of local alternative construction materials such as agricultural wastes and industrial residues as construction materials.

Marble is a commonly used material all over the world. 30-70% of marble is wasted during the processing of marble from raw to polished form. Marble dust powder is produced in large quantities as waste material all over the

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world (Ulubeyli and Artir, 2015). It is alkaline and produces environmental hazards. This large amount of wasted marble needs to be converted to a construction material to protect the environment from pollution. Marble powder contains CaO (from $CaCO_3$) which is a very good binding material. Ashish et al (2016) used marble waste powder as a partial replacement for cement in concrete, they found a very good result and stated that Marble Powder prevents environmental hazards. Rice Husk Ash is widely used as a partial replacement for cement. Fapohunda et al., (2017) stated that Rice Husk Ash produced under controlled incineration is suitable for construction purposes and shows better results. RHA in concrete results in impervious concrete hence chloride ingress and sulphate attacks are controlled. RHA-containing concrete shows better dimensional stability.

II. LITERATURE REVIEW

Self-compacting concrete (SCC) is a new kind of concrete with excellent deformability and segregation resistance. It was first developed in Japan in 1986. It is a special concrete that can flow on its weight and fill the gaps of reinforcement in concrete placing without any need for vibration and compaction.

2.1 Self-Compacting Concrete (SCC).

SCC has been the most revolutionary development in concrete construction for several decades. Insufficient compaction after placing concrete results in the creation of voids which reduces the strength and durability of concrete structures. Self-compacting concrete (SCC) provides a permanent solution to these problems. Self-compacting concrete (SCC) was first developed in 1988 in Japan. It can be achieved without segregation and high deformability in three ways. They are limiting aggregate content, low water powder ratio and the use of superplasticizers (Hajime and Masahiro, 2003). The main characteristics which allow SCC to show greater efficiency in heavily reinforced concrete are flow ability and durability (EFNARC, 2002). In the plastic state, SCC flows under its weight through confined sections without segregation and bleeding. It maintains uniformity while filling any formwork and flowing around congested reinforcement and in a hardened state, its strength and durability are either the same or more than those of normal concrete.

2.1.1 Advantages of Self-Compacted Concrete

EFNARC (2002) gave the advantages of using SCC as follows;

(1) Fast construction and easy placement in Reinforced concrete
(2) It reduces site manpower and saves the overall cost of construction.
(3) Potential for better surface finishes
(4) Ability to enhance the durability of concrete.
(5) SCC helps in the production of thinner concrete sections
(5) Absence of vibration reduces noise on site.

2.1.2 Properties of Self-Compacting Concrete

The three essential properties of Self-Compacting Concrete are filling ability, passing ability and resistance to segregation. These three properties must be carefully maintained to achieve the self-compacting capacity of concrete (EFNARC, 2002).

(i) **Filling Ability**: SCC must have the ability to flow and fill up all voids under its weight.

(ii) **Passing Ability**: - SCC containing the required aggregate size must be able to flow through and around restricted spaces between steel reinforcing bars and other embedded objects under its weight and without blocking.

(iii) **Segregation Resistance**: - The concrete must remain homogeneous during transport, placing and after placing.

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Table 1: Acceptance criteria for Self-Compacting Concrete.

	Method	Unit	Typical range of values	
			Minimum	Maximum
1	Slump flow by Abrams cone	mm	650	800
2	T50cm slump flow	sec	2	5
3	J-ring	mm	0	10
4	V-funnel	sec	6	12
5	Time increase, V-funnel at	sec	0	+3
6	T5minutes	(h2/h1)	0.8	1.0
7	L-box	(h2-h1) mm	0	30
8	U-box	%	90	100
9	Fill-box	%	0	15
10	GTM Screen stability test	Sec	0	5

Source: EFNARC, 2002

2.2 Marble Dust Powder (MDP)

Several million tons of Marble Dust Powder are produced during quarrying worldwide (Ashish et al., 2016). Hence, its re-utilization has become an important alternative material that helps to improve the hardening properties of concrete. Marble is a metamorphic rock which results from the transformation of a pure limestone. The purity of the marble is responsible for its colour and appearance. It is white if the limestone is composed solely of calcite (100% $CaCO_3$). MDP is settled by sedimentation and then dumped away which results in environmental pollution. There are possibilities of using replacement materials such as waste MDP in concrete production. Ofuyantan et al., (2019) said that the use of MDP offers cost decreases, energy reserves, and better durability with the reduction of hazards to the environment. Ashish et al., (2016) used marble powder as partial cement replacement material of up to 15% in a research study and found good results and concluded that the re-utilization of marble dust powder in concrete is a proper solution to the environmental hazards that it constitutes.

2.2.1 Benefits of using Marble Dust Powder in Concrete.

(i) Marble dust retard the setting time of cement

(ii) Marble dust can be used as an aggregate as well as a binder in concrete.

(iii) Marble dust increases both flexural and compressive strengths as compared to normal concrete.

(iv) A Homogeneous mix of the concrete is created and reduces the segregation and bleeding

2.2.2 Properties of Marble Dust Powder

Table 2: Showing Physical Properties of MDP (Vaidevi, 2013).

Properties	Requirements
Colour	White
Form	Powder
Odour	Odourless
Moisture Content (%)	1.59

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Table 3: Chemical Properties of Marble Dust Powder.

Properties	Oxides (%) (Vaidevi, 2013)	Oxides (%) (Omar et at., 2012)
SiO_2	28.35	13.8
Al_2O_3	0.42	2.50
Fe_20_3	9.70	1.90
CaO	40.45	43.20
MgO	16.25	2.70

2.2.3 Partial Replacement of Cement with Marble Dust Powder.

Mohammed and Rai (2020) investigated the use of MDP in concrete production. Four concrete specimens containing 0%, 5%, 10%, and 15% marble dust powder were produced. The study showed that Marble Dust Powder can be used as an alternative material in concrete and can replace cement by up to 10%. MDP gives an extremely good result in energy as compared to normal concrete.

Maria and Shimza (2019) focused on the mechanical behaviour of concrete with the waste rice husk ash (RHA) and marble powder (MP) as partial cement and sand replacement materials respectively. The waste rice husk ash is sieved and burnt at 750° C for 6 hours. The separate and combined effects of RHA (10 &15%) and MP (10 & 20%) are investigated. Compressive, split cylinder tensile and flexural strengths of these concrete at 7, 28 and 56 days showed comparable results to those of ordinary concrete. The sieved (but not ground) RHA caused a slight reduction in the concrete strength while MP enhanced the strengths. The combined MP and RHA either increased the strengths or showed similar results in an acceptable range. The utilization of RHA and MP in concrete effectively transforms these waste materials into useful products thus resolving the disposal and natural resource exhaustion issues, providing environmentally friendly, economical and sustainable concretes.

Shanu et al., (2017) revealed that MDP contains high calcium oxide content of more than 50% in its chemical composition. The content of cement is reduced in concrete and replaced by MDP at 0%, 3.5%, 7%, 10.5%, 14%, 17.5% and 21% by weight for M25 grade concrete. Maximum compressive strength was observed when MDP replacement with cement was about 14%. which reduces cost and its addition also increases the strength and durability of concrete.

Anjaneyulu and Srinivasa (2017) investigated the mechanical properties of concrete such as compressive strength, splitting tensile strength and flexural strength of conventional concrete which were compared with results of M30 grade obtained by partial replacement of marble powder and granite powder with cement. On replacement of cement with marble powder and granite powder at 5%, 10%,15%,20%,25% and 30% by weight of cement. Accelerated curing is adopted which generally gives early strength when compared to normal curing. All strength tests after 3 days, 14 days and 28 days of curing were obtained. After 10% replacement all mechanical strengths decreased gradually.

2.2.4 Partial Replacement of Fine Aggregates with Marble Dust Powder.

Tahir and Anuj (2022) replaced fine aggregates with marble dust powder. Cylinders and cubes were cast. After casting, compressive and tensile strength tests were conducted at 7 days and 28 days. In conclusion, 5% of marble dust in partial replacement of fine aggregate and at 28 days after curing, gave the highest compressive strength at 40.68N/mm^2.

Kabeer and Vyas (2018) replaced marble powder with fine aggregate in mortars. Four different mortar mixtures were prepared to observe the influence of marble powder on the fresh and hardened properties of the mixture. They concluded that due to the thixotropic property of marble powder, its replacement with river sand resulted in a reduction in the water amount of the mortar mixture. Reduced water content and marble powders' seed effect accelerated the hydration of C3S, and its formation of calcium carbon-aluminates with C3A has led to the formation of a denser microstructure. They concluded that 20% replacement of marble powder as sand replacement could enable considerable savings of river sand in construction projects. It would also help with waste disposal problems due to the process of marble dimension stone manufacturing.

Khyaliya (2017) evaluated the usage of marble waste as a fine aggregate replacement in mortar mixtures. They reported that using marble waste from 25% to 50% could give a benefit in terms of water requirement and better

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mechanical properties compared to control cement mortar mixtures. Marble waste containing mortar showed good performance in both aggressive and non-aggressive environments. Drying shrinkage of marble waste containing mortar mixtures was found to be in the order of cement mortar mixture shrinkage.

2.3 Rice Husk Ash (RHA).

According to FINELIB (2019), Nigeria is the largest producer of rice in West Africa. Rice husk is largely generated as a waste material. Rice husk ash is produced by burning rice husk in a controlled environment. Rice husk ash (RHA) can be produced either through open field burning (usually below 500^0C) or under incineration conditions in which temperature (more than 700^0C) and duration are controlled. Above 700^0C, ash with high pozzolanicity is formed. It has been found that the RHA produced from open burning adversely affect concrete performance with low reactivity (Hwang and Chandra, 2016).

RHA is a highly pozzolanic material which is suitable for use in concrete production. The pozzolanic reactivity is a result of its non-crystalline silica and high specific surface area. RHA is classified as a pozzolan in cement and concrete because it satisfies the requirements for the chemical requirement of pozzolans (ASTM C618). The combined proportion of silicon dioxide (SiO_2), aluminium oxide ($A1_2O_3$) and iron oxide (Fe_2O_3) in the ash is more than 70% according to ASTM requirements.

2.3.1 Chemical Properties of Rice Husk Ash.

Table 4: Chemical Properties of Rice Husk Ash (Ayyappan, 2019)

Composition	Weight % RHA
Silicon dioxide (SiO_2)	91.2
Aluminium oxide ($A1_2O_3$)	0.94
Ferric oxide (Fe_2O)	0.37
Calcium Oxide (CaO)	2.15
Magnesium oxide MgO	0.88

2.4 Self-Compacting Concrete Produced with MDP and RHA

Ayyappan et al., (2019) presented the results of a study on the influence of rice husk ash in self-compacting concrete. The replacement percentages of cement by RHA are 0%, 10%, 15% and 20%. The water/cementitious ratios of 0.35 ordinary concrete and water /powder ratio of 1 were used to make concrete specimens. Compressive, split tensile, flexural strength and elasticity modulus were analysed. The acceptable fresh properties of SCC were obtained with the replacement of cement with rice husk ash from 0 percent to 10 percent. The best-hardened results are in self-compacting as a 10 % replacement of rice husk ash in concrete. The elasticity modulus varies with the age of the concrete. SCC give the maximum elasticity modulus at 28 days.

Vyshak et al., (2018) studied the effect of using marble powder as a partial replacement to Fine aggregate in self-compacting concrete. Hardened properties of SCC such as Compressive and flexural strength were assessed. Two types of curing (ponding and polythene curing) were used for the study. The mix design of M30 was used for specimen production. The optimum replacement of marble powder was found to be 20%. Optimum compressive strength with water curing at 28 days is 38 N/mm^2 and for polythene curing is 29 N/mm^2. The final results revealed the possibility of replacing fine aggregate with 20% marble powder and also recommended polythene curing in water-scarce areas.

Sumrerng and Chindaprasirt (2014) conducted and presented the results from the use of rice husk ash as a partial replacement of cement in self-compacting concrete (SCC). Cement was partially replaced with ground rice husk-bark ash (GRHBA) at different levels of 0%–40% by weight of binder. Compressive strength, chloride penetration, porosity and corrosion of SCC were determined. The test results reveal that the resistance to chloride penetration of concrete improves substantially with partial replacement of cement with a blend of rice husk ash and the improvement increases with an increase in the replacement level. The corrosion resistances of SCC were better than the conventional concrete. The results showed that the reduction in porosity was associated with the increase in compressive strength. The research work suggested that the RHA is effective for producing SCC with a 30% replacement level.

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Shriram and Mohitkar (2014) researched the effect of rice husk ash on fresh and hardened properties of SCC. Compressive strength, flexural strength test and split test were carried out at 7 days, 28 days and 90 days respectively. The final results showed that the required compressive strength, flexural strength split tensile strength, flowability and adequate self-compatibility were obtained at 20% replacement. RHA being pozzolanic materials showed much better performance after 90 days of curing as compared with the same at 28days. It was observed that the water absorption result was within acceptable limits. Hence the concrete will be impermeable.

Shazim et al., (2011) conducted a study to substantiate the feasibility of developing low-cost SCC using RHA. The test has been carried out on fresh and hardened properties of SCC using RHA as compared to control concrete. The compressive strengths developed by the SCC mixes with RHA were comparable to the control concrete. Cost analysis showed that the cost of ingredients of specific SCC mix is 42.47% less than that of control concrete.

Vilas and Shrishail (2009) emphasized the mixture proportion which is one of the important parameters in the self-compacting concrete. They used a modified Nan-su method and obtained a mix design in normal grades with different mineral admixtures & the compressive strength and flow properties of SCC were also studied.

Ahmadi et al., (2007) studied the Mechanical properties of up to 180 days of self-compacting and ordinary concretes with rice-husk ash (RHA) from a rice paddy milling industry in Rasht (Iran). Two different replacement percentages of cement by RHA, 10% and 20% were used in the study with two different water/cementitious material ratios (0.40 and 0.35). Specimens were cast for both self-compacting and normal concrete. The results of compressive, flexural strength and modulus of elasticity were revealed. It was concluded that RHA provides a positive effect on the Mechanical properties at age after 60 days. Based on the result self-compacting concrete specimens have a higher value than normal concrete specimens in all tests conducted except modulus of elasticity. Also, specimens with 20% replacement of cement by RHA showed the best performance.

III. CONCLUSION

The following conclusions were drawn from the findings of the study:

(1) The use of locally available material helps in cutting down spending on cement. The cost of construction is likely to reduce if rice husk and marble dust which are abundant in Nigeria can be extensively used as a binding material to replace cement in concrete production.

(2) Marble Dust Powder (MDP) can be used as an aggregate as well as a binder in concrete.

(3) MDP and RHA increase both flexural and compressive strengths as compared to normal concrete.

(4) Marble powder can be effectively utilized in preparing SCC replacing fine aggregate with marble powder.

(5) It is observed that the inclusion of marble powder increases the flow properties of SCC.

(6) RHA being pozzolanic materials showed much better performance after 90 days of curing as compared with the same at 28 days.

(7) Rice husk ash has a high water demand compared to cement therefore, the use as a supplementary cementitious material in SCC entails the application of a high dosage of superplasticizers.

(8) Rice husk ash was found to be very effective in increasing self-compacting concrete strength due to its high content of reactive amorphous silica and higher specific surface area.

(9) The SCC mixes with the replacement of 20% cement by RHA gave optimum results.

(10 Optimum percentage of Marble dust powder used for binder or fine aggregates is found to be 20%. From the above study, it is concluded that the waste marble powder can be used as a partial replacement material for cement; and 20% replacement of marble dust gives an excellent result in strength aspect and quality aspect and it is better than the conventional concrete.

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