STUDY ON PARTIAL REPLCEMENT OF CEMENT WITH MARBLE POWDER IN CONCRETE

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ABSTRACT

Concrete is an important construction material and there is problem in acquiring its main constituents namely cement, sand, fine and coarse aggregates, and water. After all the issues, the greatest environmental concerns in construction industry are the production of cement which emits large amount of Carbon dioxide to the atmosphere. Therefore, the past two decades of research was diverted primarily in making concrete without cement or at least partially in low or high volumes, replacing cement by suitable alternatives from industrial wastes. Marble by its variety of products has been widely used in structures since ancient times and with the increase in production of marbles it increases the waste during quarrying by means of cutting, sawing, shaping and finishing processes. These waste contains heavy metals which makes the water unfit for use and also creates environmental problems having great impact on human health as well as on nature. Waste management of the marble powder is planned and tried to investigate the effect of utilizing it for partial replacement of cement in concrete. Aiming for a preliminary study, M30 grade concrete is designed and partial replacement up to 25% is considered, the three directional properties like workability, strength and durability characteristics are investigated. It is observed that the optimum level of replacement of cement with marble powder is observed to be 15% for strength and 10% for durability requirements.

Key words: Cement replacement, replacement materials, marble waste, workability, strength, durability.

Introduction

Marble is one of the most important decorative materials used in buildings and monuments since ancient times. Starting from the quarry and marble industries to the utilisation places, by processing, it generates considerable amount of wastes (20-25%) and in fine powder form creates environmental problems polluting the soil, water and healthy atmosphere. As very fine in particle fraction and possessing pozzolanic characteristics by chemical composition like other waste materials such as flyash, rice husk ash, silica fume and slag, the marble powder has been recognized as a cement replacing material among the concrete researchers. In line with the reduction of the emission of carbon dioxide by avoiding the excess production and use of cement in concrete and aiming for green atmosphere, the utilisation of marble powder can promote waste management system if properly understood and managed through proper research activities.

Literary Survey

Marble waste (MW) has been referred differently as marble sludge waste (MSW), marble sludge dust (MSD), waste marble powder (WMP), marble powder (MP) and waste marble granule (WMG). By its variations in the particle fraction, this has been used as a replacement material mostly for cement and also for fine and coarse aggregates. The incorporation of marble powder as a replacement material for the concrete constituents is reviewed and briefly presented.

Arshad et al., 2014: tried over 0-100% replacement of cement with marble sludge waste (MSW) in concrete and concluded that addition of MSW by 10% increased the compressive and splitting tensile strength of concrete and cement can be replaced by up to 7% safely. Shirule et al.,2011: studied MPW based M20 grade concrete and observed that up to 10% replacement level with marble powder, the compressive and tensile strength have comparatively increased enhancing the fresh properties of concrete. Sountharazajan and Sivakumar, 2013: tried to replace cement upto 15% with marble powder and observed that up to 10% replacement, the strength, found to increase but reduction in the workability. Veena Pathan and Gulfam Pathan,2014: also revealed that the compressive strength and split tensile strength of concrete can be increased by 10% replacement of cement with marble powder and also observed that the marble powder has an impact on the properties like consistency, settling time and soundness. Jashandeep and Bansal, 2015: reported the test results of M25 concrete having cement partially replaced upto 20% with waste marble powder, concluding that the optimum replacement level is 12% for maximum compressive and tensile strength.

Tanpreet Singh and Anil Kumar, 2012: studied the possibilities of using up to 20% of marble powder waste, for the production of Mortar (1:3) and concrete mix (M35). It is revealed that replacement of cement with marble powder decreases the mortar compressive strength and on the other hand the compressive strength of concrete for up to 10% replacement increases the compressive strength and increases the flexural strength up to 15% replacement. It is also observed that the workability of concrete by slump also increases as the increase in the cement replacement with marble powder. Desmukh et al., 2015: studied the influence of marble powder upto 20% replacement of cement on the strength of M25 concrete and reported that 15% is optimum for improving the strength properties of concrete. Hassan Mohamadien, 2012: tried upto 50% replacement with marble powder and concluded that the optimum replacement level is 15% by which the strength in 7 days and 28 days has increased by 22.7% and 27.8% respectively. Chockalingam, 2014: reported to have better compressive and flexural strength and workability characteristics of SCC having effective replacement of cement with 15% of marble powder and silica fume up to 30% and compared with conventional concrete. Deborah and Akinpelu, 2014: reported that the 20% cement replacement with marble powder decreased the compressive strength but increased the durability related properties of light weight concrete.

Most of the studies reported to have better performance in strength characteristics quoting the optimum level of replacement except Deborah and Akinpelu, 2014. Further, the workability characteristics found to reduce with the increase of level of replacement demanding for workability agents. There are variations in the composition of marble powder particularly in the CaO content used by several authors and hence there are variations in the pozzolanic and the reactive capacity of marble powder. The variations and comparison with cement composition are presented in Table 1.

Experimentation

The main constituents of concrete are procured from local resources and their physical properties and applicable chemical composition are determined. The physical properties are given in Table 2. The properties of basic constituents are presented in Table 3. Based on the design data, a mix design for M30 concrete is made.

Table 1 Comparison of composition of marble waste used by authors

No	Authors	Chemical composition %				
		SiO_2	Al_2O_3	Fe_2O_3	CaO/ $CaCO_3$	MgO/$MgCO_3$
1	Aalok et al (2014)	28.35	0.42	9.70	40.45	16.25
2	Ahmed et al (2011)	1.58	0.99	0.22	54.17	3.87
3	Animesh Mishra et al (2013)	0.8	0.10	0.20	58.10	0.10
4	Arshad et al (2014)	0.33	-	0.41	97.80	1.22
5	Bahar Demirel (2010)	28.35	0.42	09.7	40.45	16.25
6	Candra Aditya et al (2014)	1.62	0.37		52.69/41.92	0.84/1.76
7	Deborah and Akinpelu (2014)	64.86	4.45	11.99	01.58	08.74
8	Desmukh et al (2015)	20-25	2- 4	1-2	38-42	1.5-2.5
9	Osman Sivrikaya et al (2014) Calcitic/ Dolomitic based	0.29 0.09	0.05 0.03	0.04 0.24	55.86 30.56	0.36 21.24
10	Sounthararajan and Sivakumar	-	0.70	0.33	51.49	0.36
11	Noha M. Soliman (2013)	13.8	2.50	1.90	43.20	2.70
12	Sivakumar (2015)	11.38	0.23	0.09	45.18/88.50	0.2/0.42

Table 2 Physical properties of marble powder

No	Properties	Results
1	Physical state	Fine powder
2	Appearance	Pure white clear particles
3	Pack density	1.100 g/ml
4	pH (5% Solution)	6. 0
5	Specific gravity	2. 6 % Max.
6	Moisture	Below 0.5 %
7	Particle size	325 Mesh

Table 3 Properties of concrete constituents

Properties	Properties of constituents		
	Cement	Fine	Coarse
Fineness (90µ)	8.16%	-	-
Specific gravity	3.15	2.61	2.63
Consistency	33%	-	-
Initial setting time	33 min	-	-
Final setting time	130 min	-	-
Fineness modulus	-	2.66	5.28
Maximum size	-	-	20mm
Impact value	-	-	19.12%
Crushing value	-	-	5.26%

Replacement of cement with marble powder by 0, 5, 10, 15, 20 and 25% is considered and concrete prepared. The materials of required quantities are batched by weighing and hand mixed. For each replacement level, workability measurements are made by slump test and compaction factor. The variation in the workability characteristics are shown in figure 1.

Steel moulds are used for casting and with concrete vibrated over placing in the vibrating table. Concrete cubes of 150mm size, cylindrical specimens of 150×300mm and prisms of size 100×100×500mm are cast in a standard manner. The cast specimens are demoulded after 24 hours and kept for pond curing until testing. Strength in compression, indirect tension and flexure and concrete modulus are determined using respective specimens in respective machines as per the relevant Indian standards. The rate of gain of compressive strength, the 28 day strength in tension and flexure are presented in figures 2 and 3. The concrete modulus is presented in figure 4.

Durability related properties like water absorption, alkaline resistance, sulphate resistance and acid resistance are also determined. The water absorption for 60minutes is observed by immersion of 100mm cubes in water after oven drying for 24 hours at 105°C temperature.

Different samples are immersed in 5% dilute HCl acid (pH value 2), 5% Sodium hydroxide and % sodium sulphate solutions separately. After 60 days immersion, drying for three days, the weight loss if any and the residual compressive strength are obtained for specimens. The results of the durability tests are given in figures 5, 6 and 7.

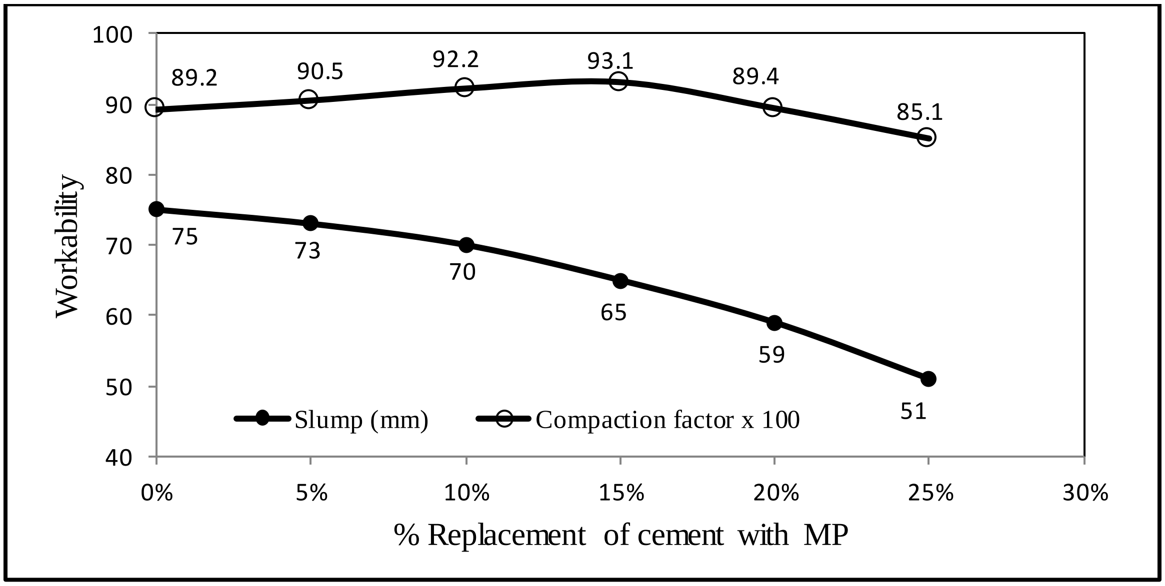

Fig.1 Comparison of workability characteristics

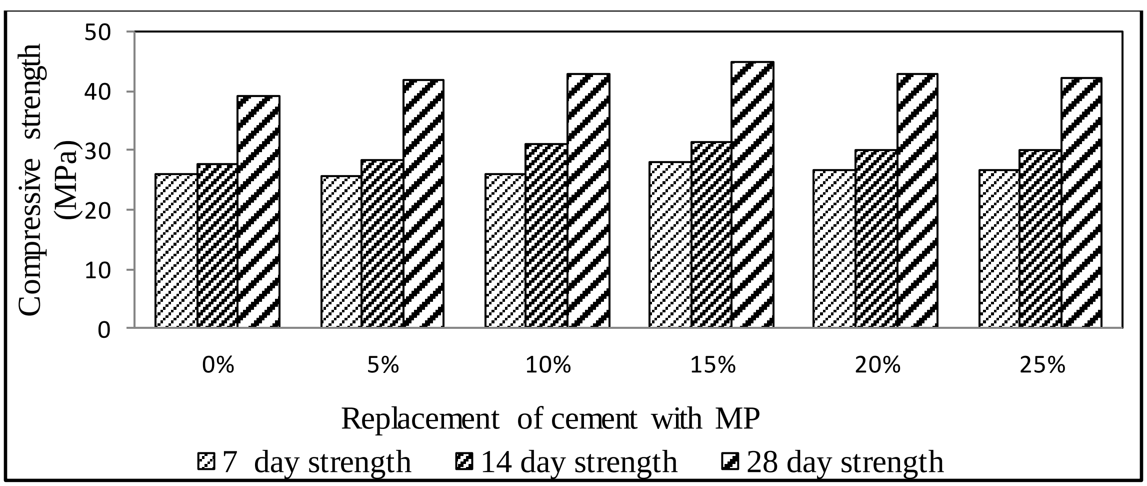

Fig. 2 Comparison of rate of gain of compressive strength

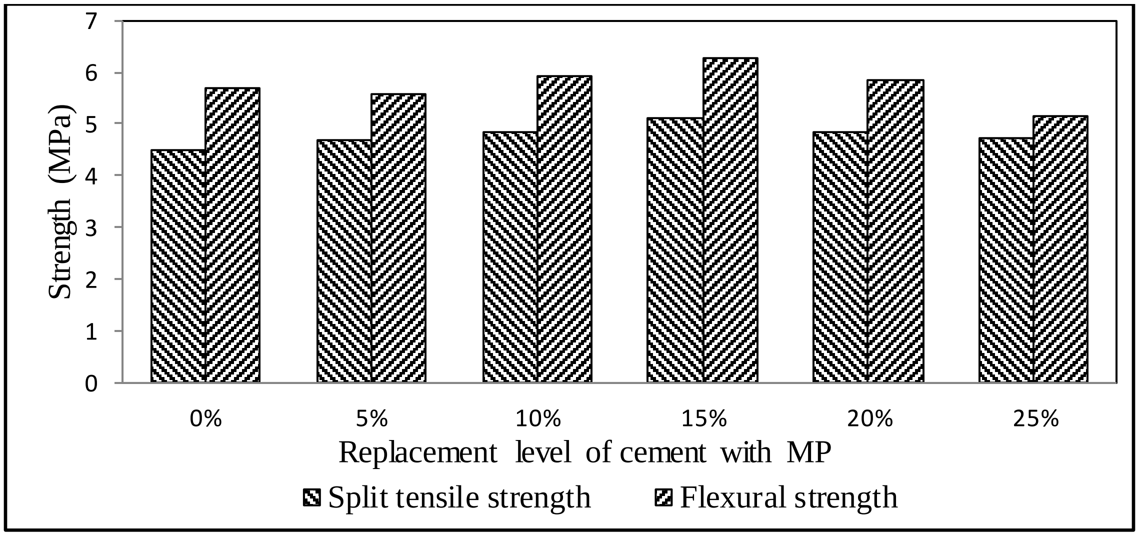

Fig.3 Comparison of 28 day tensile/flexural strength

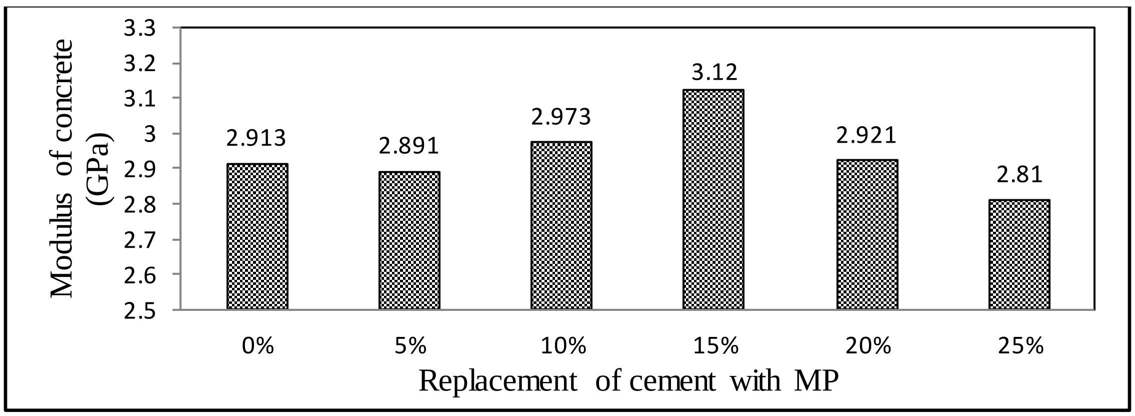

Fig.4 Comparison of Concrete modulus

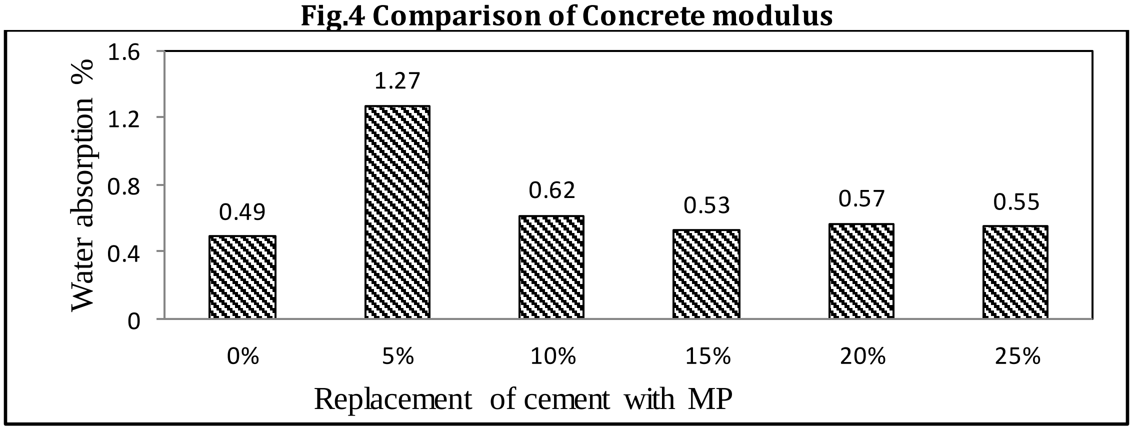

Fig.5 Comparison of Water absorption

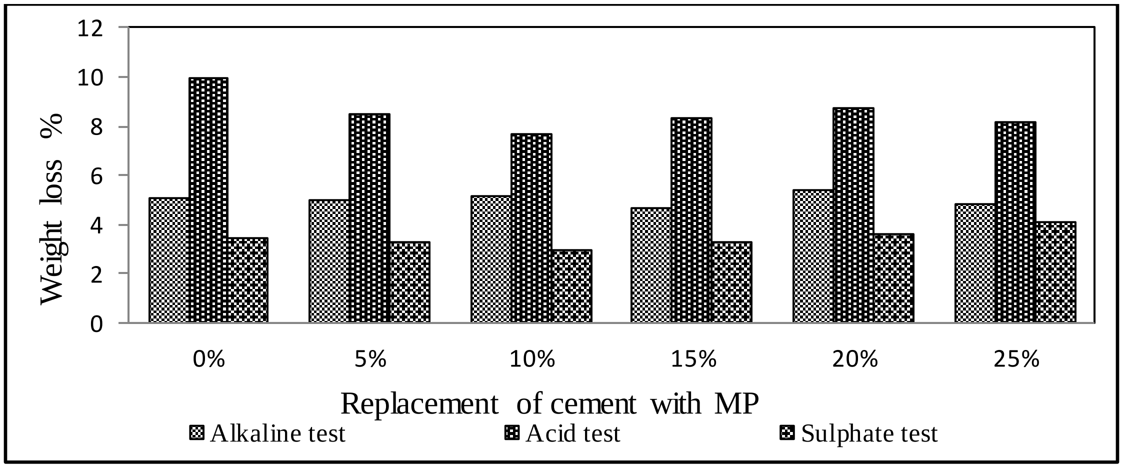

Fig.6 Comparison of Weight loss

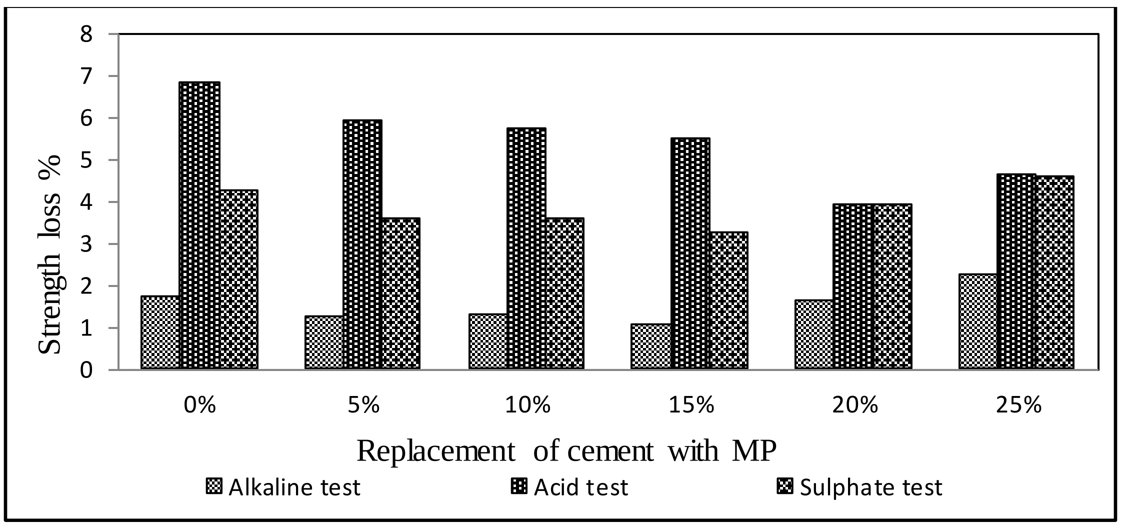

Fig. 7 Comparison of Strength loss

Discussion of Test Results

Workability

The compactor factor increased with the increase in the level of replacement up to 15% and thereafter decreased for further higher level of replacement but, the slump value decreased with the increase in the level of replacement

Strength

Generally, the compressive and tensile strength at 7, 14 and 28 days increased with the increase in the replacement level of cement up to 15% replacement at which the compressive strength is higher by 14.53% and the tensile strength by 14.25% compared to conventional concrete. The flexural strength of Marble powder concrete is considerably greater than that of standard concrete. The proportion which gives the maximum strength for the concrete in compression and split tension is same in the case of flexural strength also. The highest value is got for 15% replacement level and is 10.6% greater than the conventional concrete.

Modulus of elasticity

The modulus of concrete increased up to 20% replacement level and the maximum is recorded for 15% replacement level which is found 7.1% more than the conventional concrete.

Durability

Water absorption is higher when compared with conventional concrete. It increases abruptly for 5% replacement and decreases up to 15% and increases further up to 25% replacement. The increase in water absorption for conventional to the 15% replacement of 28 days of cured specimen is 8.2%. The result of water absorption is not encouraging.

The weight loss is less when compared to conventional concrete in case of acid resistance test. It is decreased upto 10% replacement level and increased then upto 25%. However, the weight loss is always less when compared to conventional concrete. The weight loss is least for 10% replacement level. The strength loss is reduced for all levels of replacement (up to 25%) and the strength loss is least for 20% replacement level.

The weight loss is not significant when compared to conventional concrete in case of alkaline resistance test. It is increased for 10% and 20% replacements and decreased for others. The weight loss is least for 15% replacement level and is 8.4% less when compared to conventional concrete. The strength loss is reduced for all levels of replacement (up to 25%) and the least loss is for 15% replacement level and is about 40% less compared to conventional concrete.

The weight loss is reduced up to 10% replacement and increased afterwards in case of sulphate resistance test. The weight loss is least for 10% replacement level and is 15% less when compared to conventional concrete. The strength loss is reduced upto 15% replacement level and thereafter increased. The least weight loss is observed for 15% replacement level as 23.5% less compared to conventional concrete.

Conclusion

The optimum level of replacement of cement with marble powder is 15% based on the strength requirements and is 10% based on the durability requirements. However further study is required for higher grades of concrete and compatibility with reinforcing material.

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