EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH WASTE MARBLE POWDER IN CEMENT PASTES

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the degree of

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IN
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DECLARATION

I, **Kirti Vardhan**, hereby declare that this thesis report entitled " **Effect of partial replacement of cement with waste marble powder in cement pastes** " submitted in the partial fulfillment of the requirements for the award of degree of Master of Engineering in Structural Engineering, in the Civil Engineering Department, Thapar University, Patiala is wholly my own work. The matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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ABSTRACT

.The economical benefit of using waste material usually attributes to the reduction of the amount of expensive and or scarce ingredients with cheap materials. Environmentally, when industrial wastes are recycled, so that not only the CO_2 emissions are reduced but residual products from other industries are reused and therefore less material is dumped as landfill and more natural resources are saved. The waste materials which have potential to be used as an alternative to cement are waste marble powder, coal fly ash, diatomite etc.

Waste marble powder has been taken for detailed study as a lot of research work has already been done on other waste materials and there is a lot of scope for research on WMP as a replacement to cement, sand or both. Here in this case, cement has been partially replaced with in varying proportions from 0% to 50% and its effect was analysed on the standard consistency, soundness, setting times of cement and compressive strength of cement mortar mixes.

The study shows that the Standard consistency of cement paste made with cement partially replaced with WMD has slightly decreased due to lesser specific surface of WMD as compared to cement is less than the specific surface of cement. Soundness of cement is not affected by use of WMP. The initial and final setting times remain well within the permissible limits as per codal provisions.

Compressive strength of cement mortar decreases by 10% with 10% replacement of cement with WMP. Hence use of waste marble powder upto 10% as a cement replacement is recommended as per strength requirements so as to utilize waste marble powder, which is an humanitarian issue, requiring urgent attention to safeguard against environmental pollution.

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CHAPTER 1

CONCRETE MADE BY USING WASTE MATERIALS

1.1 INTRODUCTION

Cement, sand and aggregate are basic needs for any construction industry. Sand is a prime material used for preparation of mortar and concrete which plays a major role in mix design. Nowadays erosion of rivers and considering environmental issues, there is a scarcity of river sand. The shortage of river sand will affect the construction industry, hence there is a need to find the new alternative material to replace the river sand, such that excess river erosion and harm to environment is prevented. Many researchers are finding different materials to replace sand.

The demand of natural sand is very high in developing countries to satisfy the rapid infrastructure growth. The developing country like India faces shortage of good quality natural sand and particularly in India, natural sand deposits are being used up and causing serious threat to environment as well as the society. Rapid extraction of sand from river bed causing so many problems like losing water retaining soil strata, deepening of the river beds and causing bank slides. Loss of vegetation on the bank of rivers disturbs the aquatic life as well as disturbs agriculture due to lowering of the water table in the well etc. Physical as well as chemical properties of fine aggregate affect the durability, workability and also strength of concrete. Fine aggregate is a most important constituent of concrete and cement mortar. Generally river sand or pit sand is used as fine aggregate in mortar and concrete. Together fine and coarse aggregate make about 75- 80% of total volume of concrete and hence it is very important to find suitable type and good quality aggregate nearby site. Recently natural sand is becoming a very costly material because of its demand in the construction industry. Hence research began for cheap and easily available alternative material to natural sand. Fly-ash, quarry dust or limestone and siliceous stone powder, filtered sand, copper slag etc. are used in concrete and mortar mixtures as a partial or full replacement of natural sand.

Researchers and Engineers have come out with their own ideas to decrease or fully replace the use of river sand and use recent innovations such as M-Sand (manufactured sand), robot silica or sand, stone crusher dust, filtered sand, treated and sieved silt removed from reservoirs as well as dams besides sand from other water bodies. A sustainable infrastructural growth requires the alternative material that should satisfy technical requisites of fine aggregate as well as it should be available locally with large amount.

The economical benefit of using waste material usually attributes to the reduction of the amount of expensive and or scarce ingredients with cheap materials. Environmentally, when industrial wastes are recycled, so that not only the CO_2 emissions are reduced but residual products from other industries are reused and therefore less material is dumped as landfill and more natural resources are saved. The materials which have potential to be used as an alternative to fine aggregates are discussed in following sections.

1.2 DIFFERENT ALTERNATIVES MATERIALS TO RIVER SAND

A lot of alternate materials that are wastes generated by manufacturing industries are potential source of being an alternative to the river sand used as fine aggregate in the construction industry.

1.2.1Copper Slag

The slag is black glassy particles and granular materials in nature and has a similar particle size range like sand. The specific gravity of the slag is 3.91. The bulk density of granulated copper slag varies from 1.9 to 2.15 kg/m3 which is almost similar to bulk density of convectional fine aggregate. The hardness of the slag lies between 6 and 7 in Mohr scale. This is almost equal to the hardness of gypsum. The pH value of aqueous solution of aqueous extract as per IS 11127 varies from 6.6 to 7.2. The free moisture content present in slag was found to be less than 0.5%.The presence of silica in slag is about 26% which is desirable because it is one of the constituents of the natural fine aggregate used in normal concreting operations. The fineness of copper slag was calculated as 125 m^2 /kg.

At present about 33 million tonnes of copper slag is generating annually worldwide among that India contributing to 6 to 6.5 million tonnes. 50 % copper slag can be used as replacement of natural sand to obtain mortar and concrete with required performance, strength and durability. In India, a study has been carried out by the Central Road Research Institute (CRRI) shows that copper slag may be used as a partial replacement for river sand as fine aggregate in concrete up to 50 % in pavement concrete without any loss of compressive and flexural strength and such concretes shows about 20 % higher strength than that of conventional cement concrete of the same grade.

1.2.2 Granulated Blast Furnace Slag(GBFS)

According to the report of the Working Group on Cement Industry for the 12th five year plan, around 10 million tonnes of blast furnace slag is currently being generated in the country from iron and steel industry. The compressive strength of cement mortar increases as the replacement level of GBFS increases. GBFS sand can be used as an alternative to natural sand from the point of view of strength. The use of GBFS up to 75 per cent is Recommended (Nataraja et al. 2013)

Granulated Blast Furnace Slag is a by-product of the manufacturing of iron in a blast furnace where iron ore, limestone and coke are heated up to 1500^{o} C. When these materials melt in the blast furnace, two products are produced i.e. molten iron and molten slag. The molten slag is lighter and floats on the top of the molten iron. The molten slag comprises mostly of silicates and aluminates from the original iron ore, combined with some oxides from the limestone. The process of granulating the slag involves cooling the molten slag through high pressure water jets. This rapidly quenches the slag and forms granular particles generally no larger that 5 mm in diameter. The rapid cooling prevents the formation of larger crystals, and the resulting granular material comprises some 95% non-crystalline calcium-alumino silicates. The granulated slag is further processed by drying and then ground to a very fine powder, which is GGBS cement. Grinding of the granulated slag is carried out in a rotating ball mill.

Different forms of slag product are produced depending on the method used to cool the molten slag. These products include air-cooled blast furnace slag (ACBFS) or GBFS expanded or foamed slag, palletized slag, and granulated blast furnace slag. The GBFS is glassy particle and granular materials in nature and has a similar particle size range like sand. According to the report of the Working Group on Cement Industry for the 12th five year plan, around 10 million tonne blast furnace slag is currently being generated in the country from iron and steel industry. The compressive strength of cement mortar increases as the replacement level of GBFS increases. GBFS sand can be used as an alternative to natural sand from the point of view of strength. Use of GBFS up to 75 per cent can be Recommended . (Nataraja et al. 2013)

The specific gravity of the slag is 2.63. The bulk density of granulated slag varies from 1430 kg/m3 which were almost similar to bulk density of convectional fine aggregate. The water absorption of slag was found to be less than 2.56%.The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used in normal concreting operations. The fineness of slag is 2.37. It is observed by various researchers that GBFS could be utilized partially as alternative construction material for natural sand in mortar applications. Reduction in workability expressed as flow can be compensated by adding suitable percentage of super plasticizer (Vipul D. Prajapati, et al. 2013). Advantages of using GBFS as partial replacement to sand are-Increased strength & durability, reduced permeability, high resistance to chloride penetration & sulphate attack, very low heat of hydration, chemically more stable, enhanced architectural appearance, reduction in maintenance and repair costs, slashes lifetime construction costs, virtually zero CO_2 emissions, and no emissions of SO_2.

1.2.3 Coal Fly Ash

Coal Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is removed by the dust collection systems from the exhaust gases of fossil fuel power plants as very fine, predominantly spherical glassy particles from the combustion gases before they are discharged into atmosphere. The size of particles is largely dependent on the type of dust collection equipment. Diameter of fly ash particles ranges from less than 1 μm to150 μm. It is generally finer than Portland cement. The chemical composition of fly ash is determined by the types and relative amounts of incombustible material in the coal used. The major chemical constituents in fly ash are silica, alumina and oxides of calcium and iron. Because of its fineness and pozzolanic and sometimes self-cementitious nature, fly ash is widely used in cement and concrete. Depending upon the collection system, varying from mechanical to electrical precipitators or bag houses and fabric filters, about 85-99.9% of the ash from the flue gases in retrieved in the form of fly ash. Fly ash accounts for 75-85% of the total coal ash, and the remainder is collected as bottom ash or boiler slag. Fly ash because of its mineralogical composition, fine particle size and amorphous character is generally pozzolanic and in some cases also self cementitious whereas bottom ash and boiler slag are much coarser and are not pozzolanic in nature. Therefore, It is important to note that all the ash is not fly ash and the fly ashes produced by different power plants are not equally pozzolanic and, therefore, are not always suitable for use as mineral admixture in concrete. Fly ash generated in coal burning power plants is an inherently variable material because of several factors. Among these are the type and mineralogical composition of the coal, degree of coal pulverization, type of furnace and oxidation conditions including air-to-fuel ratio, and the manner in which fly ash is collected, handled and stored before use. Since no two utilities or plants may have all of these factors in common, fly ash from various power plants is likely to be different. The fly ash properties may also vary within the same plant because of load conditions over a twenty four hour period. Non-uniformity of fly ash is a serious disadvantage and sometimes is the main hurdle.

Currently India is producing over 100 million tonnes of coal ash. . Fly ash accounts for 75-85% of the total coal ash, and the remainder is collected as coal bottom ash (CBA) or boiler slag. Fly ash has found many users but bottom ash still continues to pollute the environment with unsafe disposal mechanism. The mechanical properties of special concrete made with 30 per cent replacement of natural sand with washed bottom ash by weight has an optimum usage in concrete in order to get a required strength and good strength development pattern over the increment ages. Coal bottom ash is a by-product obtained from thermal power plants and is formed in coal furnaces. It is made from agglomerated ash particles that are too large to be carried in the flue gases and fall through open grates to an ash hopper at the bottom of the furnace. Bottom ash is mainly comprised of fused coarser ash particles. These particles are quite porous and look like volcanic lava. Bottom ash forms up to 25% of the total ash while the fly ash forms the remaining 75%. **Currently India** is one of the most common user for bottom ash is as structural fill. Published literature on the use of CBA as an alternative to natural sand show that there is a strongly possibility of coal bottom ash being used as replacement of fine aggregate (sand). Its use in concrete becomes more significant and important in view of the fact that sources of natural sand as fine aggregates are getting depleted gradually, and it is of prime importance that substitute of sand be explored.The properties of fresh as well as hardened concrete are closely associated with the characteristics and relevant proportioning of its constituent materials. The research reports show that inclusion of bottom ash as sand replacement in concrete influences the workability, setting times, loss of water through bleeding, bleeding rate and plastic shrinkage of fresh concrete and density, strength, porosity, durability of hardened mass. The research literature shows that the strength development pattern of bottom ash concrete is similar to that of conventional concrete but there is decrease in strength at all the curing ages. The decrease in strength of concrete is mainly due to higher porosity and higher water demand on use of bottom ash in concrete. The compressive strength can be improved by reducing the water demand by using super plasticizers.

1.2.4 Quarry Dust

Quarry dust has been used for different activities in the construction industry such as road construction and manufacture of building materials such as light weight aggregates, bricks, and tiles. Due to its high fines of quarry dust it is proved to be very effective in assuring very good cohesiveness of concrete. Quarry dust through reaction with the concrete admixture improves pozzolanic reaction, micro aggregate filling and concrete durability. As the properties are good as sand, it is used as fine aggregate in replacement with sand in the cement concrete.

About 20 to 25 per cent of the total production in each crusher unit is left out as the waste material as quarry dust. The ideal percentage of the replacement of sand with the quarry dust is 55 per cent to 75 per cent in case of compressive strength. If combined with fly ash (another industrial waste), 100 per cent replacement of sand can be achieved. The use of fly ash in concrete is desirable because of benefits such as useful disposal of a byproduct, increased workability, reduction of cement consumption, increased sulphate resistance, increased resistance to alkali-silica reaction and decreased permeability. However, the use of fly ash leads to a reduction in early strength of concrete. Therefore, the concurrent use of quarry dust and fly ash in concrete will lead to the benefits of using such materials being added and some of The the undesirable effects being negated (Chandana Sukesh et al. 2013)

1.2.5 Foundary Sand

Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of ferrous and non-ferrous metal casting industries, where sand has been used for centuries as a molding material because of its thermal conductivity. Foundries successfully recycle and reuse the sand many times in a foundry. When the sand can no longer be reused in the foundry, it is removed from the foundry and is termed as foundry sand. The physical and chemical characteristics of foundry sand depend on the type of casting process and the industry sector from which it originates The automotive industries and its parts are the major generators of foundry sand. Foundries purchase high quality size specific silica sands for use in their molding and casting operations. India ranks fourth in terms of total foundry production. Foundry sand which is very high in silica is regularly discarded by the the metal industry. Currently, there is no mechanism for its disposal, but international studies say that up to 50 per cent foundry sand can be utilized for economical and sustainable development of concrete (Umoh,2012).

1.2.6 Construction and Demolition waste

Construction and demolition waste generated by the construction industry has no documented quantification of amount of construction and demolition waste being generated in India. Municipal Corporation of Delhi says it is collecting 4,000 tonnes of construction and demolition waste daily (Umoh, 2012) sand and aggregate from construction and demolition waste is said to have 10-15 per cent lesser strength then normal concrete and can be safely used in non-structural applications like flooring and filling. Delhi already has a recycling unit in place and plans to open more to handle its disposal problem, which posed an environmental challenge and can only be minimized by the reuse and recycling of the waste it generates.

1.2.7 Volcanic Ash

Volcanic ash (VA) is formed during volcanic eruptions. Ash is created when solid rock shatters and magma (molten rock) separates into minute particles during explosive volcanic activity. The usually violent nature of an eruption involving steam (phreatic eruption) results in the magma and solid rock surrounding the vent is torn into particles of clay to sand size. The plum that is generally seen above an erupting volcano is composed primarily of ash and steam. The very fine particles maybe carried away for miles together, settling out as a dust-like layer across the landscape. This is known as 'ash fall'. The commonly used term for any material explosively thrown out from a vent is tephra, also known as pyroclasstic debris. If liquid magma is ejected as spray, the particles will solidify in the air to small fragments of volcanic glass. Tephra particles of gravel are termed cinders. The ejection of large quantities of ash will produce an ash cone. A layer of volcanic ash tends to become cemented together to form a solid rock called 'tuff'.

The average grain-size of rock fragments and volcanic ash erupted from an exploding volcanic vent varies largely amongst eruptions and also during a single explosive eruption, lasting from hours to days. Heavier, large-sized rock fragments typically fall back to the ground on or close to the volcano and progressively smaller and lighter fragments are blown farther from the volcano by wind. Volcanic ash, the smallest particles (2 mm in diameter or smaller, even less than 0.001mm), can travel hundreds to thousands of kilometers downwind from a volcano depending on wind speed, volume of ash erupted, and height of the eruption column.

The size of ash particles, which fall on the ground decreases exponentially with increasing distance from a volcano. Also, the range in grain size of volcanic ash typically diminishes downwind from a volcano. The distribution of ash particle sizes can vary widely. Volcanic ash is not the product of combustible materials, like the soft fluffy material generated by burning wood, leaves, or paper. Volcanic ash is hard and abrasive, and does not dissolve in water. Uses of volcanic ash are based on its physical properties of fine size, angularity of particles, friability, light color, and chemical or pyro-chemical properties. Because of its fineness, angularity, and moderate hardness (5.5-6.0 on Mohr scale), Volcanic ash could be used as an abrasive for use as a polishing, scouring, and cleansing agent. Processing of volcanic ash for abrasive uses generally includes only drying and the screening out of coarser particles and incidental contaminants.

The substitution of volcanic ash for equivalent amounts of other materials in ceramic glazes does not affect the final glaze, although the firing temperature may be slightly lower due to the surprisingly low fusion temperature of the ash. In ceramic bodies, however, the results are not so predictable. Number of test bodies with different types of clays and shale and with varying amounts of volcanic ash indicated that 7-15% volcanic ash additions to shale or red-firing clay body lowers the vitrification temperature, increasing the firing range for a matured body, and producing a greater rigidity in the ware at the maximum temperature. These qualities produced by the volcanic ash additions permit economy in use of fuel, and reduce losses in the kiln due to the less critical temperature range requirements and the ability of the ware to stand up under its own weight at the maximum temperatures attained in the kiln. Volcanic ash has the same function in glass and vitreous enamel as it has in case of ceramic glazes. Because of the lower content of the iron oxide, the use of volcanic ash in glass and vitreous enamels products is limited. Volcanic ash could be an important ingredient in fiber glass and foam glass where the slight darkening of color is not very important.

Volcanic ash could be used for making lightweight aggregates . The Oklahoma Geological Survey has investigated the possibility of producing light-weight aggregates, cellular blocks and concrete. Besides having cementing properties, volcanic ash can also serve the purpose of a fine aggregate that fills the voids between the fine sand aggregate and the cement.

CHAPTER 2

WASTE MARBLE POWDER (WMP)

2.1 INTRODUCTION

In previous chapter, we have discussed various materials that can be used as replacement of aggregates. Out of all these materials, waste marble powder (WMP) is taken for detailed study. The basic properties of waste marble powder are discussed in following sections :

2.2 MARBLE POWDER

Granite is an igneous rock which is widely used as construction material in different forms. Granite industries produce a lot of dust and waste materials. The wastes from the granite polishing units are being disposed off to the environment which causes health hazards. This granite powder waste can be utilized for the preparation of concrete as partial replacement of sand.

In general, the industry of dimensional stone marble has contributed to the development of major environmental problems due to waste generation at different stages of mining and processing operations. Waste generation continues from mining process to finished product and is about 50% of mineral mined; the dried slurry product is quiet fine. 90% of the particles are below 200 μm. Depending on the kind of process involved, the sludge generated is equal to between 20% and 30% of the weight of the stone worked. Among these waste materials, waste marble dust is a byproduct of marble processing factories. Some references estimate that 20-25% of the marble/granite produced results in powder in the form of slurry, as for each marble or granite slab of 20 mm produced; 5 mm is crushed into powder during the cutting process (Pareek 2007). This powder flows along with the water forming marble slurry. Waste marble dust can be used as an additive material in production of cement and cost of the cement production can be reduced by this application (Huseyin, 2010).

2.3 PROPERTIES OF WASTE MARBLE POWDER

2.3.1 Chemical Composition

Major component of chemical composition in waste marble powder is calcium oxide (CaO) as reported by various researchers. Chemical composition is given in Table 2.1

TABLE 2.1 CHEMICAL COMPOSITION

CHEMICAL	MARBLE POWDER (%)
SiO_2	1.0
CaO	52.6
MgO	2.1
Al_2O_3	0.2
Fe_2O_3	0.2
SO_3	0.07
K_2O	0.04
TiO_2	0.01
Na_2O	0.06
CL	-
MnO	-
LOI	43.63

2.3.2 Physical Properties

Some researchers say that blaine fineness for WMP is much more than for portland cement i.e. 5960 cm^2/g against 4375cm^2/g . Due to high degree of fineness of WMP, it has resulted to be very effective in providing very good cohesiveness of mortar and concrete. It also result in decreasing the porosity **.** However, the fineness reported by other researchers is comparable to sand and can be used as replacement of sand.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

Waste marble powder has been used by many researchers in mortar and concrete both as a partial replacement of cement and fine aggregates i.e. sand. The following sections discusses the results obtained by addition of waste marble powder in concrete.

3.2 USE OF WMD AS PARTIAL REPLACEMENT OF SAND

The fine aggregate i.e. sand has also been extensibly replaced partially with waste marble powder by various researchers . The same is discussed here under.

3.2.1 Arulraj et al. (2013) has made experimental investigation of mechanical properties for using granite powder waste as partial replacement of sand in concrete. Compressive and split tensile strength properties were studied; fine aggregates were replaced as 0%, 5%, 10%, 15%, 20% & 25% with granite powder waste.

Material

- Cement OPC 53 grade.
- Coarse aggregates: 10 mm size having specified gravity 2.68.
- Fine Aggregates : Locally available sand of zone 3, FM 2.33 & specified gravity 2.56.
- Water : Locally available drinking water.
- Admixture : 0.5% super plasticiser to produce slump of 100mm for improving the Workability of concrete.
- Granite Powder: This waste of igneous rock has density 2.65 to 2.75 g/cm^3. Specific Gravity 2.61, coeff of curvature 1.95, coeff of uniformity 7.82, alumina 14.42% and silics 72.04%.

Tests

Concrete mixes in grade M_{20}, M_{30} & M_{40} were designed as per IS 10262-2009. Cubes of size 150x150x150 mm were casted for compressive strength and cylinders of size 300x150mm were casted for split tensile strength. Total no. of specimen casted = 36+54 = 90 nos. The specimen were cured for 28 days in water storage tank.

Compressive Strength These dried cement concrete specimens were centred / placed on compression testing machine of 2000 KN capacity. Load @ 14 KN/mm^2/Minute was applied at a uniform rate by machine. The results of compressive strength testing for M_{20}, M_{30}, M_{40} grade are given in Table 3.1.

TABLE 3.1 COMPRESSIVE STRENGTH

S. No.	*G.P. Replacement*	*Compressive Strength MPa*		
		M_{20}	**M_{30}**	**M_{40}**
1	0%	25.81	31.08	40.00
2	5%	26.96	32.11	46.67
3	10%	29.70	33.03	50.07
4	15%	32.20 (+25%)	35.47 (+14%)	53.33 (+33%)
5	20%	31.30	33.51	44.00
6	25%	25.50	30.07	38.81

The results shows that there is a gradual increase in compressive strength with increase of replacement %age of granite powder . Maximum increase is at 15% replacement level . Then it decreases gradually. At 15% replacement, there is an increase of about 25% for M_{20}, 14% for M_{30} & 33% for M_{40} grade concrete. Hence max beneficial effect is for M_{40} gr concrete when it increase to 53.30 MPa with respect to reference concrete of CS of 40 MPa i.e. increase of about 33%.

Split Tensile Strength

The results of split tensile strength of M20, M30, M40 gr concrete with GP replacement are shown below in Table 3.2.

TABLE 3.2 SPLIT TENSILE STRENGTH

S. No.	*G.P. Replacement*	*Split Tensile Strength*		
		M_{20}	**M_{30}**	**M_{40}**
1	0%	2.05	2.62	3.39
2	5%	2.14	2.71	2.26 (-33%)
3	10%	2.44	2.99	2.83
4	15%	2.95 (+44%)	3.39 (+39%)	3.51 (+14%)
5	20%	1.40	1.98	3.32
6	25%	1.27 (-33%)	1.84	3.04

Test results shows that more increase in split tensile strength is at 15% replacement level. There is an increase of 44% for M_{20}, 30% for M_{30}, 14% for M_{40}. Hence replacement of fine aggregate with granite powder has beneficial effect on the mechanical properties of concrete. The optimum dose recommended is 15% both for compressive strength and split tensile strength. Its use is likely to be helpful in disposal problems of waste material as well as the same will safeguard against environmental pollution. Its use will also be for making concrete cost less due to rising cost of fine aggregates as well as limited availability & depleting resources of sand.

3.2.2 Hebhoub et al. (2011) has carried out the experimental investigation on use of waste marble aggregates in concrete on three series of concrete mixtures: sand substitution mixture, gravel substitution mixture and a mixture of both aggregates (sand and gravel). The concrete formulations were produced with a constant water/cement ratio. . The natural and recycled aggregates were characterized. Concrete mix designs with 25%, 50%, 75% and 100% of aggregates substitution were formulated. The performances of the ‘‘recycled aggregates” concrete were measured through tests of density, air content, workability and compressive and tensile strength.

Materials

Aggregates are crushed gravel (limestone) and rounded sand. The recycled aggregates are gravel and from wastes of the white marble quarry. The value of fineness modulus of natural sand is 1.95. It indicates that the sand is fine and may improve workability of concrete at the expense of the strength. The FM of recycled sand is 3.12. It is a coarse sand which would help to have good resistance values but probably not a good workable mix.

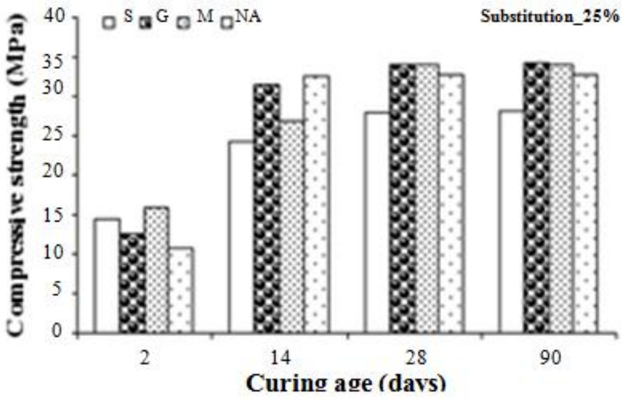

Fig.3.1. The compressive strength versus the curing age

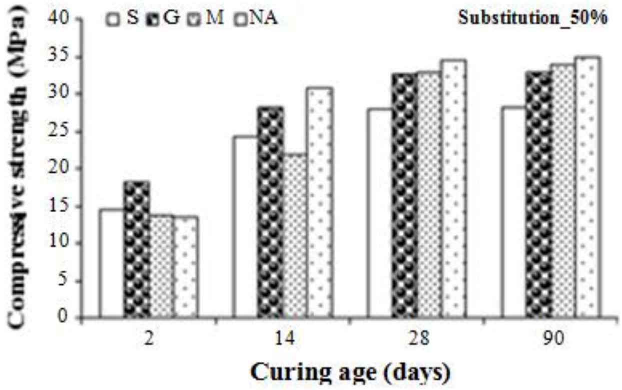

Fig. 3.2.. The compressive strength versus the curing age

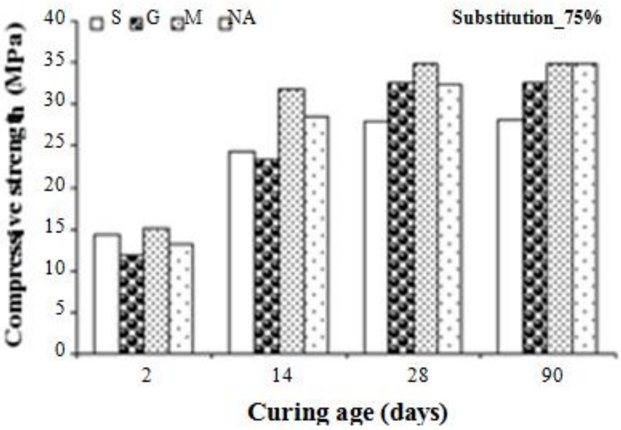

Fig. 3.3. The compressive strength versus the curing age.

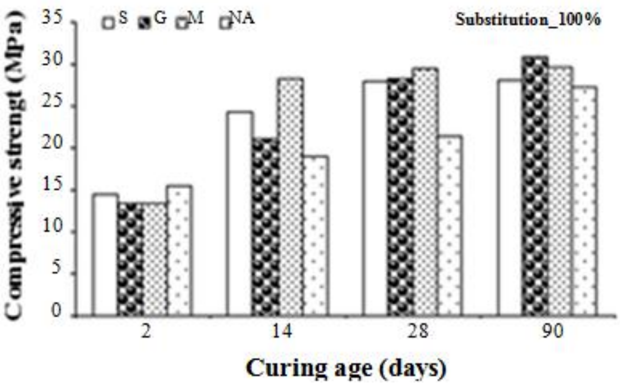

Fig. 3.4 The compressive strength versus the curing age.

Results & Discussion

The recycled aggregates affected the compressive and tensile strengths at a certain rate of substitution. The (S) formulation showed a significant strength gain, the compressive and tensile strength substitution rate of 25%, 50% and 75% are fairly greater than values obtained with natural aggregates i.e. comp strength gain of 17.2%, 23.65%, 16.1% respectively. The concrete with 100% substitution rate provided poor results in compressive strength. i.e. (-23.29%). Gain in comp strength for (G) formulations is 21.86%,17.56%,25.08% and 22.2%,16.84%,16.84%. The bars of 100% rate of substitution are relatively close to the ones of natural aggregates which points out that the concrete mixtures at 25%, 50% and 75% of substitution rate improve the concrete strength. We noticed a correlation between compressive and tensile strength behaviour for the three formulations. Furthermore, the tensile strength rises after 28 days of curing; this increase is not visible for the compressive strength bars .The simple tensile test does not measure the bond strength at the aggregate interface but it is possible to compare the effect of the aggregates substitution. The values of compressive strength of the substitution at 25% (Fig3.1) and 50% (Fig.3.2) of formulations (S), (G) and (M) are relatively close but it should be noted that there is a difference for the early age of concrete (2 and 14 days). The values of the compressive strength at 75% of substitution (Fig 3.3) of (S), (G) and (M) formulations are much greater when compared to those of the natural aggregates concrete. The formulations (G) and (M) with a substitution rate of 100% (Fig. (3.4) provided values close to those of the natural aggregates concrete. The formulation (S) of sand substitution provided low compressive strength. That being said, the substitution of natural aggregates with waste marble aggregates at a certain %age of any formulation appears beneficial for the resistance except for 100% which reduces the resistance.

Hence orientation of this research has shown that setting certain parameters has identified the best percentage for each type of aggregate. Analysis of these results substitution has revealed that the appropriate incorporation of marble waste aggregates in place of natural aggregates can lead to interesting characteristics in terms of strength. The use of marble aggregates resulted in a considerable increase in the compressive and tensile strength. The enhancement in resistance is very significant for 25%, 50% and 75% of substitution. Concrete workability can be improved by the correct quantity of water and proportioning and grading of the ‘‘recycled sand” and the recycled aggregates which can provide the practical formulations.

3.2.3 Omar et al. (2012) reports the experimental study undertaken to investigate the influence of partial replacement of sand with limestone waste (LSW), with marble powder (MP) as an additive on the concrete properties. The effects of LSW as fine aggregate on several fresh and hardened properties of the concretes were investigated. The investigation included testing of compressive strength, indirect tensile strength, flexural strength, modulus of elasticity, and permeability.

Materials

Test specimens were prepared from available local materials in Egypt. These include natural siliceous sand, crushed stone, OPC cement, tap drinking water, marble powder, chemical admixture(ADDICRETE BVF), limestone waste.

Concrete mixes & Tests

The research program consists of two phases. **Phase I with cement content 350 kg/m^3**. One mix was control mix, three mix incorporating LSW in 25%, 50% and 75**% replacement from sand**. Twelve mixes incorporating LSW in 25%, 50% and 75% **replacement from sand with marble powder as additive** by percent 5, 10, and 15% by cement weight. Phase II, the above experiment is repeated with the same components but with different content of cement. **Phase II cement content is 450 kg/m$^{3.}$** The investigation included testing of compressive strength, indirect tensile strength, flexural strength, modulus of elasticity, and permeability.The fixed water-cement ratio of 0.47 was kept. In phase I, and II, the concrete mixes were designed to have a near constant slump in the range of 90-110 mm.

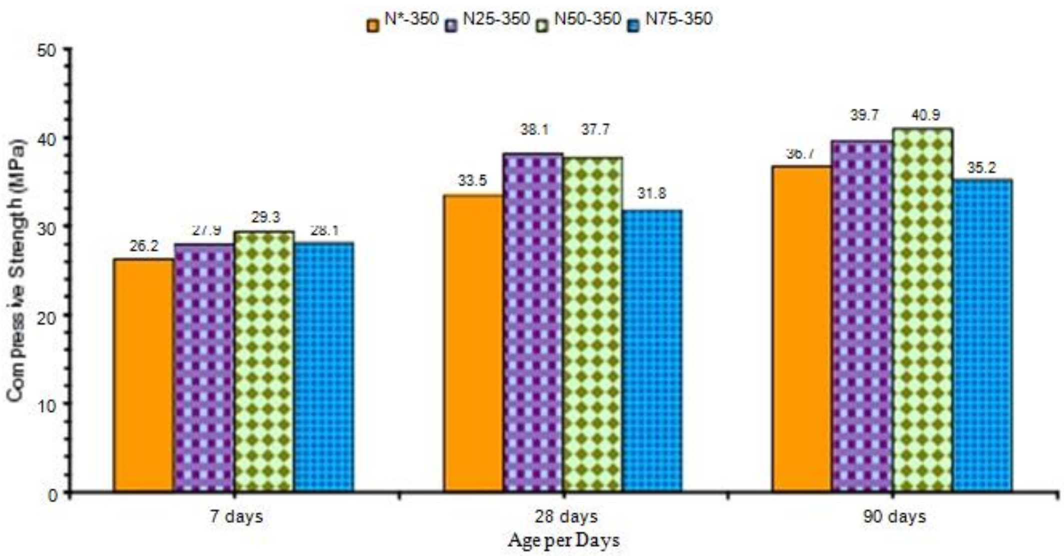

Fig. 3.5. Effect of 25%, 50% and 75% LSW as a replacement from sand, as compared to normal strength concrete, phase I (350 kg/m^3).

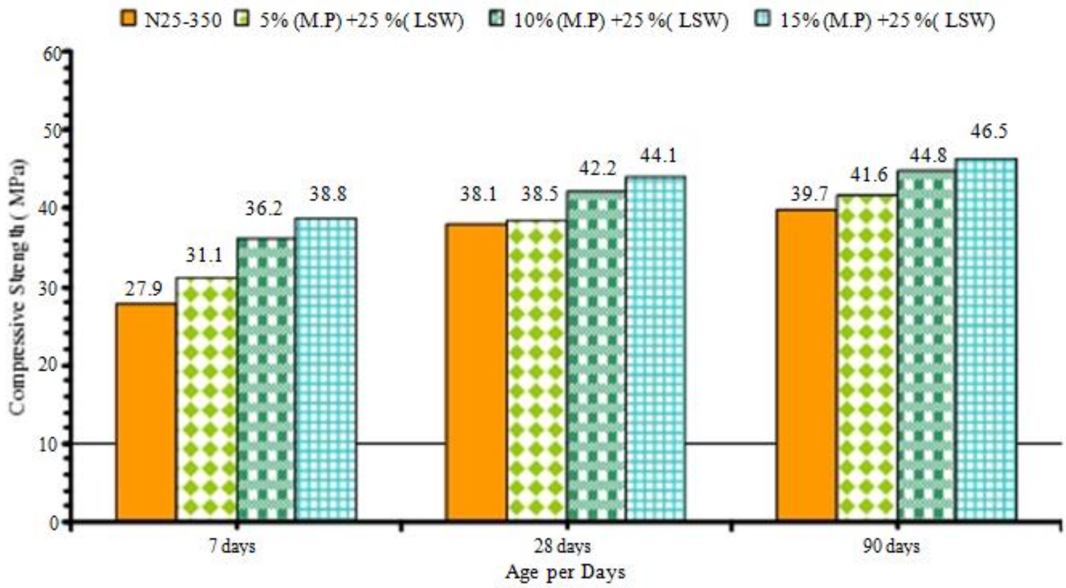

Fig.3.6 Effect of 25% LSW as a partial replacement of sand weight, with 5%, 10% and 15% MP by weight from cement, phase I (350 kg/m^3).

Compressive Strength

Compressive strength of mix containing cement content of 450 kg/m^3 is higher than the strength of mix prepared with 350 kg/m^3 by 24% at 28 days. Compressive strength test results of normal concrete with LSW with different replacement percentages with sand in phase 1 are presented in Fig. 3.5 for 0, 25, 50, and 75%, respectively. Using LSW with levels 25% and 50% increased 28 days compressive strength about 13%, and 12% respectively as compared with the normal concrete N 350. Using LSW with level 75% decreased it by 5%. The loss of the compressive strength at a replacement level 75% can be related to its physical and chemical effects for limestone powder. Similarly for phase 2, the increase is 0.5% at LSW 25% and decrease of 8% & 3% for LSW 50% & 75%.

Compressive strength of normal concrete with M.P with different %ages of 5, 10, and 15% as additive for phase 1 increased about 5%, 16% and 21%. Similarly for phase 2, the increase is 5, 16 & 20%. LSW is nil in this case.

Compressive strength of concrete in phase 1 with 25% (fig 3.6), 50%, and 75% LSW replacement at different percentages 5, 10, and 15% M.P respectively. It can be observed that, using LSW with 15% MP increased the compressive strength by 15%, 16% and 27% as compared with normal mix N_{25-350}, N_{50-350}, N_{75-350} at 28 days, respectively.

Similarily for phase 2, the increase is by 19%, 20% & 28%.

Tensile Strength

Splitting tensile strength of concrete with 50% LSW with 15% M.P increased by about 17% as compared with normal concrete mix N 350. On the other hand using 50% LSW with 15% M.P increased the splitting tensile strength about 8% as compared with normal concrete mix N 450.

Flextural Strength

The flexural strength markedly increased by about 7% using 50% LSW with 15% MP as compared with normal mix N350 . The increase is about 8% with respect to N 450.

Modulus of Elasticity

The results of modulus of elasticity of green concrete increased with increasing **LSW with Marble Powder** in cement content 350 kg/m^3. The limited gain of the modulus of elasticity were 1.2% and 5.3% as compared with normal concrete mix N 350.The gain is 1.5%, and 3.8% with respect to N450 mix. Hence cement content of 350 kg/m^3 has better performance and is more economical than 450 kg/m$^{3.}$ the workability of green concrete is not affected by the LWS percentage. The rate of the strength gain decreased as the percentage of LWS replacement increase more than 50%.

Hence using LSW up to 50% replacement increase, gain in comp strength is about 12%. The flextural and indirect tensile strength has max increase with 50% LSW and 15%MP.

3.3 USE OF WASTE MARBLE POWDER AS PARTIAL REPLACEMENT OF CEMENT

The WMP has been extensible used by various researchers for replacement of cement. The same is discussed here under.

3.3.1 Yılmaz Aruntas et al. (2010) has made experimental study for the usage of waste marble dust (WMD) as an additive material in blended cement. For this purpose, waste marble dust added cements (WMDCs) have been obtained by inter grinding WMD with Portland cement clinkers at different blend ratios i.e. 2.5%, 5.0%, 7.5% and 10%.

Materials

The materials used are Portland cement (PC) and pozzolan containing Portland composite cement (PCC) used in the experimental study were CEM I and CEM II type cements (control cements), respectively. Waste marble dust (WMD) supplied from Turkey was used as an additive material in cement production. The sand used was standard The CEN type conforming to EN 196-3. The water used in mortar production was regular tap water.

Waste marble powder was used as partial replacement of PC clinker grounded together with PC clinker and gypsum in order to produce composed cement with additive. Amount of gypsum was fixed as 5% by weight in the cement manufacturing in this study. Amount of WMD was substituted with the same amount of Portland cement clinker. Samples were tested for tensile strength and compressive strength.

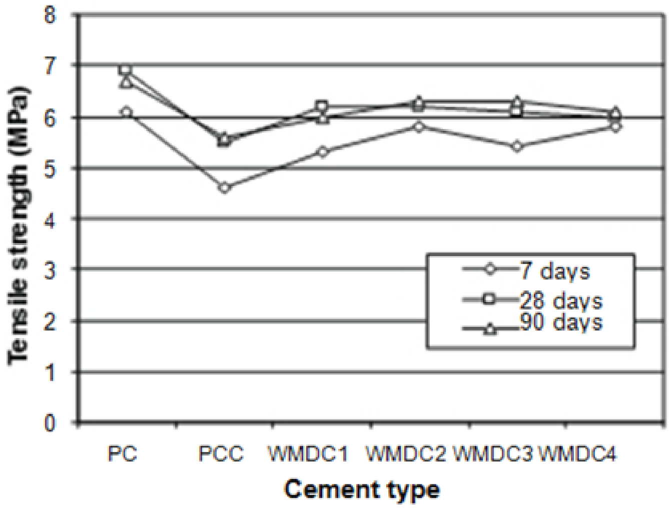

Fig. 3.7 . Comparisons of tensile strengths of cement type.

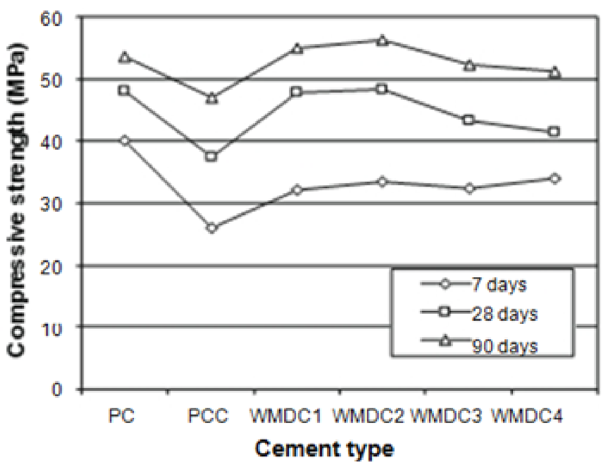

Fig. 3.8 Comparisons of compressive strengths of cement type.

Tensile strengths (Fig 3.7) of cement mortar that were cured for 90 days. Strengths of WMDC were lower than the strength of PC control cement and higher than the strength of

PCC control cement. The strengths of WMDC1,WMDC2, WMDC3 and WMDC4 were lower compared to strength of PC as 10%, 6%, 6% and 9%, respectively However, strengths of WMDCs were higher than the strength of PCC produced with the same manner as 7%, 13%, 13% and 9%, respectively. Similar were the strength results of cement mortars cured for 7 and 28 days. Compressive strength (fig 3.8)results of cement mortars cured for 90 days for WMDC1 and WMDC2 higher as 2% and 5%, the strengths of WMDC3 and WMDC4 lower as 3% and 4% than the strength of PC control cement, respectively. On the other hand, the strengths of WMDCs were determined higher than the strength of PCC produced with the same manner as 17%, 20%, 11% and 9%, respectively. The higher strengths of the WMDC mortars can be explained by their higher PC contents than that of the PCC. Addition of WMD in order to form composed cement increases the compressive strength slightly. Almost similar results were obtained for 7 & 28 days comp strength.
Hence 10% WMD can be used as an additive material in production of cement.

3.3.2 Belaidi et al. (2011) made an experimental investigation on the effect of using both natural pozzolana and marble powder on the fresh and hardened properties of self compacting conc (SCC). OPC was partial replaced by different percentages of pozzolana and marble powder (10-40%). The workability of fresh SCC was measured using slump test, V-funnel flow time test, J-Ring, L-Box and sieve stability tests.. The results indicate an improvement in the workability of SCC with the use of pozzolana and marble powder. Compressive strength of binary and ternary SCC decreased with the increase in natural pozzolana and marble dust content, but strength at 28 and 90 days indicate that even with 40% (natural pozzolana + marble powder), suitable strength could be achieved.

Materials

The cement used in the present study was a CEMI 42.5. The mineral additives used are natural pozzolana (PZ) and marble powder (MP). PZ presents angular shapes with rough surface texture. A polycarboxlic-ether type superplasticiser (SP) with a specific gravity of 1.07 and a solid content of 30% was used. Continuously graded coarse aggregates (3/8 and 8/15 mm) were used in this study with a specific gravity and water absorption of 2.7% and 2.52% respectively. The fine aggregates were river sand with a specific gravity and water absorption of 2.6% and 0.58%

Tests

A total of 12 concrete mixtures were prepared having a constant water/powder ratio of 0.4 and total powder of 475 kg/m^3. The control mixture included only OPC as the binder while the remaining mixtures incorporated binary (OPC + PZ) and ternary (OPC + PZ + MP) cementations blends in which the OPC was replaced with PZ and MP. The replacement ratios for PZ were 5%, 10%, 15%, 20% and 25% while those of both PZ and MP were 10%, 15%, 20%, 30% and 40% by mass of total cementations materials. The compression test was conducted at the age of 7, 28, 56 and 90 days.

For Binary mixtures up to 15% PZ, there was no effect on the slump flow as compared to control concrete However, at 20% and 25% PZ, slump flow of concrete has a reduction of 55% and 65%. PZ remarkably reduced the slump flow diameters of SCC, especially for replacement levels higher than 15%.For Ternary mixtures, use of MP in ternary systems improved the workability. The less flowability for SCC with PZ is related to the higher surface area of PZ and hence its higher water requirement.

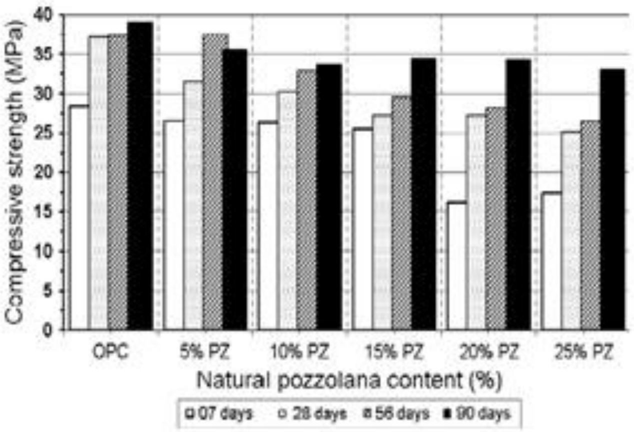

Fig. 3.9. Compressive strength of binary SCC

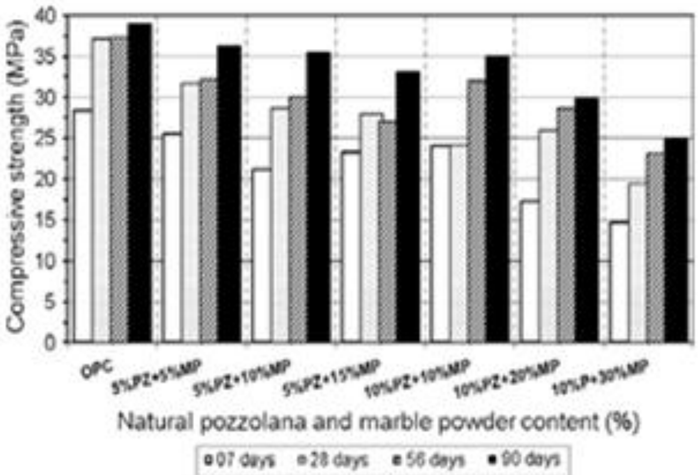

Fig. 3.10. Compressive strength of ternary SCC

Compressive strength results of concrete made with PZ are shown in Fig. 3.9 and that of concrete made with both PZ and MP shown in Fig. 3.10. It can be seen from Fig. 3.9 that strength decreases with the increase in PZ content at all ages. Similarly, for concrete made with (PZ + MP) content, strength decreased at all ages. Apparently, the slower evolution of strength is caused by the presence of PZ in the concrete mixture. Its chemical composition and in particular its high content of SiO_2 made good pre requisites for activity not as filler only but partially as binder due to pozzolanic activity. The same effect on compressive strength has also been observed with slag for SCC. Therefore, the performance of SCC containing both PZ and MP can be considered satisfactory taking into account that the decrease in compressive strength is relatively less important at late ages (56 and 90 days).

Hence at a constant water/powder ratio and SP content, the use of both PZ and Marble powder by substitution to cement has no negative effects on the workability of SCC. In binary systems, an improvement of workability was observed up to 15% of PZ content. In ternary systems, the use of MP content (5-30%) enhances the rheological properties of both mortar and concrete. However, a reduction of compressive strength was observed with PZ and MP addition compared to control concrete. The results indicate that PZ in binary systems increases the strength at long term i.e. 90 days. The max strength obtained at 28 days was with 5% of PZ in binary systems and with (5% PZ and 5% MP) in ternary systems.

3.3.3 Ergün Diatomite (2010) has studied the effects of the use of diatomite and WMP as partial replacement of cement on the mechanical properties of concrete. Diatomite is a pozzolanic material containing amorphous silica, cristabolite and minor amounts of residual minerals.

Materials

Ordinary Portland cement type CEM I 42.5R, as per European Standards EN-197/1, was used when preparing the concrete specimens. The cement used had a fineness of 4375 cm^2/g. The targeted 28-days compressive concrete strength was set at 48.5 MPa. Four different types of limestone aggregates were used when casting each of the test specimens, namely: crushed stone III (12-22 mm), crushed stone II (6-12 mm), crushed sand stone (0-6 mm) and river sand (0-4 mm).A water reducing admixture was added to the mixtures @1% of binder materials by weight. It was constituted of polycarboxylates based polymer and high range water-reducing superplasticizer that has a third generation superplasticizer for concrete and mortar. Diatomite ore was from a deposit in Turkey. It is characterized as natural pozzolan material. Its origion is from sedimentary rocks with high natural amorphous silica content which produces CSH gel after hydration. WMP used as a source of limestone additive. XRD patterns showed that calcite is the main crystalline mineral of the WMP. The presence of limestone in hardened cement paste has a filler effect. Lime stone is an inert or quasi-inert material being non-cementitious from hydraulic points of view.

Tests

In order to assess the effects of diatomite and WMP as partial replacement of cement on the behavior of concrete, a constant water/binder (cement + fine addition) ratio of 0.50 was used for all the test specimens. Three series of concrete specimens were cast. The variables in this research were diatomite and WMP content. 5%, 7.5% and 10% diatomite replacement for Series-I, 5%, 7.5% and 10% WMP replacement for Series-II and 5% and 10% diatomite and waste marble powder together replacement for Series-III were used. The designations, proportions, and some properties of the concrete mixtures for this three series (i.e., Series-I, II and III) are given in Table 3.3.

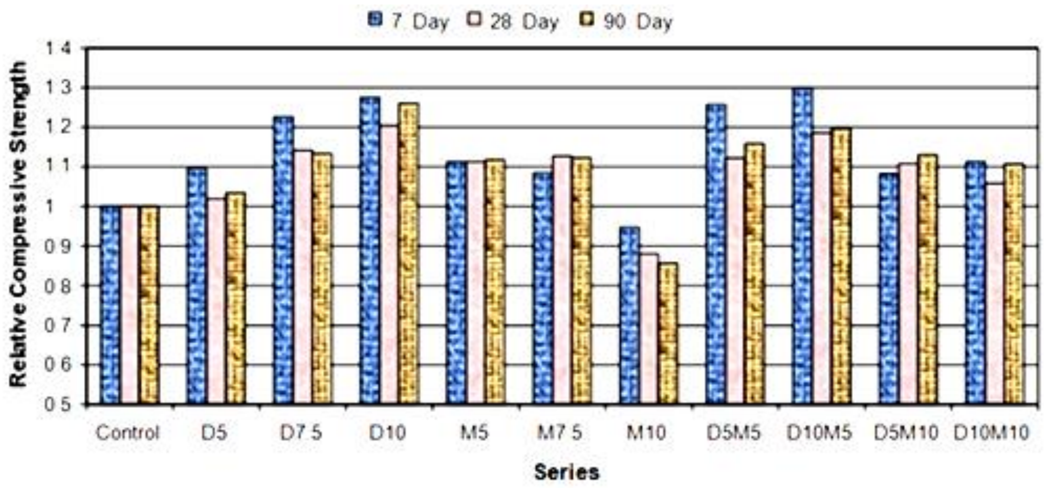

Fig. 3.11 Comparisons of the compressive strength of concrete with diatomite and WMP at any age against control specimens

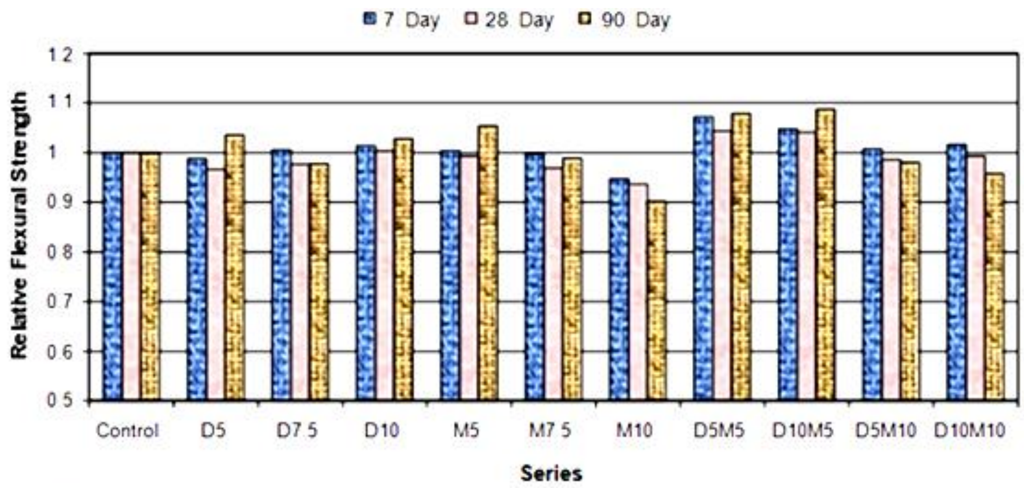

Fig. 3.12 Comparisons of the flexural strength of concrete with diatomite and WMP at any age against control specimens

Table 3.3 Concrete Mix Proportions(kg/m^3)

Materials (kg/m^3)	Control	Series-I			Series-II			Series-III			
		D5	D7.5	D10	M5	M7.5	M10	D5M5	D10M5	D5M10	D10M10
PC	300	285	277.5	270	285	277.5	270	270	255	255	240
Diatomite	0	15	22.5	30	0	0	0	15	30	15	30
WMP	0	0	0	0	15	22.5	30	15	15	30	30
Water	150	150	150	150	150	150	150	150	150	150	150
Super-plasticizer	3	3	3	3	3	3	3	3	3	3	3
River sand	312.3	312.3	312.3	312.3	312.3	312.3	312.3	312.3	312.3	312.3	312.3
Crushed sand stone (0–4 mm)	507.7	507.7	507.7	507.7	507.7	507.7	507.7	507.7	507.7	507.7	507.7
Crushed stone II (6–12 mm)	648.7	648.7	648.7	648.7	648.7	648.7	648.7	648.7	648.7	648.7	648.7
Crushed stone II (12–22 mm)	565	565	565	565	565	565	565	565	565	565	565

Table 3.4
Variations of mechanical properties of test specimens.

	Compressive strength (MPa)			Flexural strength (MPa)		
	7 days	28 days	90 days	7 days	28 days	90 days
Control	27.2	35.4	36.6	5.1	5.3	5.7
D5	29.8	36.1	37.9	5.0	5.1	5.9
D7.5	33.4	40.4	41.5	5.1	5.2	5.5
D10	34.7	42.6	46.1	5.1	5.3	5.8
M5	30.3	39.4	40.9	5.1	5.3	6.0
M7.5	29.5	39.9	41.1	5.1	5.1	5.6
M10	25.8	31.1	31.3	4.8	5.0	5.1
D5M5	34.2	39.7	42.4	5.4	5.5	6.1
D10M5	35.3	42.0	43.8	5.3	5.5	6.1
D5M10	29.5	39.2	41.3	5.1	5.2	5.5
D10M10	30.3	37.5	40.5	5.1	5.3	5.4

Diatomite & WMP replacement of PC by 5% to 10% together or separately by keeping aggregates, admixture & water constant resulted in increase of Comp & flextural strength as shown in table 3.4 & in fig 3.11and 3.12. Microfossils in diatomite, source of reactive silica, play an important role in the strength development of the concrete specimens. Combination of reactive silica, high surface area (Blaine) as diatomite* replacement and low water demand as per superplasticizing admixture in concrete improved mechanical properties.

.Due to filler properties of WMP as in limestone powder and low water demand caused by adding superplasticizing admixture, there was increase in comp strength & hence improvement in mechanical properties.

The concrete containing 5% WMP as partial replacement by weight for cement with a superplasticizing admixture had higher compressive strength than that of the control concrete specimens *D10M5 i.e. 10% diatomite +5% WMP mutual replacement of PC had highest compressive and flexural strength (Table 3.4). The relative compressive strengths of this series with respect to control concrete specimens were 1.30 at the age of 7 days while the relative flexural strength was 1.09 at the age of 90 days. The combination of pozzolanic effect of diatomite, the filler material effect of waste marble powder and low water demand effect of superplasticizing admixture increased the compressive and flexural strength of D10M5.

*COV values of concretes with diatomite replacement and control specimens are approximately similar at all curing times.

The results of this study showed that the replacement of cement with diatomite and WMP separately or together (5% to 10%) using a superplasticizing admixture could be used to improve the mechanical properties of the conventional concrete mixtures. Of the mechanical strengths, compressive strength of concrete is the main feature which allows assessment of concrete.

3.4 USE OF WMP AS PARTIAL REPLACEMENT OF SAND AND PARTIAL CEMENT REPLACEMENT OF CEMENT

The WMP has also been limitedly used as partial replacement of sand & partial replacement of cement by various researchers . The same is discussed here under.

3.4.1Aliabdo et al. (2013) studied re-use of waste marble dust in the production of cement and concrete. The properties of concrete contained marble dust analysed as a cement replacement and as a sand replacement . The replacement ratios which have been studied were 0.0%,5.0%, 7.5%, 10.0% and 15% by weight. Water to powder ratio (w/p) or water to cement ratio(w/c) were 0.50 and 0.40 in case of cement replacement and in case of sand replacement respectively. Physical, mechanical and chemical properties of cement and concrete modified with marble dust were investigated.

Materials

Ordinary Portland cement was used which complies with the ASTM C150. Natural siliceous sand with FM of 2.35 and crushed pink lime stone with nominal maximum size of 19.0

mm was used. Marble dust obtained in wet form as slurry was dried and manually sieved through sieve no. 200. High range WRA which comply with ASTM C494 Type F was used indifferent ratios by weight of cement to get required a slump within range of 100 ± 200 mm. Potable water was used for mixing and curing process. Proportions of concrete mixtures are shown in Table 3.5.

Micro Structural Aaalysis

During scanning (SEM) process, it was observed that marble dust blended cement specimens are denser and less porous than control specimens. At this age, the microstructure of pastes is composed of amorphous particles of calcium silicate hydrate (C-S-H) and calcium hydroxide (CH) crystals that appear in massive layers.

Compressive strength

As cement replacement :- At all levels of marble dust as a cement replacement, the compressive strength slightly decreases. Most likely this is due to the reduction in C_3S and C_2S which is mainly responsible for concrete strength. For concrete with **0.50 w/p ratio**; the reduction in compressive strength after 28 days is 7%, 4%, 5% and 14% for specimens with 5.0%, 7.5%, 10.0% and 15.0% marble dust as cement replacement compared to control mix. For concrete with 0.40 w/p ratio; the substitution with marble dust **up to 10%** by weight of cement **slightly increases the comp strength**. On the contrary, there is a reduction in concrete compressive strength at 15.0% marble dust as cement replacement. The increase in compressive strength at 28 days is 6%, 8% and 9% for concrete with 5.0%, 7.5% and 10% marble dust, while at 15.0% marble dust; the reduction in compressive is 7%, 0% and 5% at 7,28 and 56 days.

As sand replacement, compressive strength increases up to 15.0% replacement. This trend is the same for concrete with 0.50 and 0.40 w/c ratio. Also, the use of marble dust as sand replacement is more effective with lower w/c ratio of 0.4 As an example; for concrete with 0.40 w/c ratios; after 28 days; the increase in concrete compressive strength is 17%, 21%, 25% and 22% for specimens with 5.0%,7.5%, 10.0% and 15.0% marble dust as sand replacement.

TABLE 3.5 PROPORTIONS OF CONCRETE MIXTURES

Mix No.	Notes	Cement (kg/m^3)	Marble dust (%)	Marble dust (kg/m^3)	Water (kg/m^3)	W/P or W/C	Sand (kg/m^3)	Coarse aggregate (kg/m^3)	Admixture (L/m^3)
1	Control mix	400	0.0	0	200	0.5	686	1028	0.9
2	Cement replacement w/p = 0.50	380	5.0	20	200	0.5	684	1026	1.1
3		370	7.5	30	200	0.5	683	1025	1.2
4		360	10.0	40	200	0.5	682	1023	1.3
5		340	15.0	60	200	0.5	681	1021	1.3
6	Sand replacement w/c = 0.50	400	5.0	34	200	0.5	651	1027	0.9
7		400	7.5	51	200	0.5	633	1027	1.3
8		400	10.0	68	200	0.5	616	1026	1.8
9		400	15.0	103	200	0.5	581	1025	2.0
10	Control mix	400	0.0	0	160	0.4	726	1089	4.5
11	Cement replacement w/p = 0.40	380	5.0	20	160	0.4	725	1087	5.1
12		370	7.5	30	160	0.4	724	1086	5.4
13		360	10.0	40	160	0.4	723	1084	5.7
14		340	15.0	60	160	0.4	721	1082	5.9
15	Sand replacement w/c = 0.40	400	5.0	36	160	0.4	689	1088	5.4
16		400	7.5	54	160	0.4	671	1088	6.1
17		400	10.0	72	160	0.4	652	1087	5.7
18		400	15.0	109	160	0.4	616	1086	6.8

Splitting tensile strength (f_t)

for concrete mix with 0.50 w/p ratio; tensile strength increases with the increase of marble dust content up to 10.%. The maximum tensile strength achieved is at 7.5% marble dust for all curing ages, while the minimum concrete tensile strength is observed at 15.0% marble dust. On the other hand, it is observed that in case of 0.40 w/p ratio; substitution with marble dust up to 15% by weight increases the tensile strength for all curing ages. For concrete with 0.40 w/p ratio; the increase in concrete tensile strength after 28 days is 8%, 13%, 15% and 8% for concrete with 0%, 7.5, 10.0% and 15.0% marble

dust as cement replacement respectively. The use of marble dust as sand replacement enhances the tensile strength of concrete whereas the tensile strength increases with increase of marble dust content up to 15%. For concrete with 0.40 w/c ratio; the increase in concrete tensile strength after 28 days is 20%, 23%, 28% and 20% for concrete with 5.0%, 7.5%, 10.0% and 15.0% marble dust as sand replacement respectively.

Hence the use of marble dust as sand replacement has more significant effect on the mechanical properties of concrete compared with using it as cement replacement. Marble dust has no noticeable role during the hydration process. The concrete compressive strength increases with the increase of marble dust ratio as sand replacement up to 15.0% of sand by weight. Also, the use of marble dust as sand replacement is more effective with lower w/c ratio. Significant improvement in concrete tensile strength is recorded due to the use of marble dust as cement replacement as well as sand replacement.The use of marble dust up to 15.0% as cement replacement or as sand replacement positively affects the steel-concrete bond strength. Porosity of concrete decreases in both cement or sand replacement.

3.4.2 Valeria Corinaldesi et al. (2009) has characterized marble powder from a chemical and physical point of view in order to use it as mineral addition for mortars and concretes, especially for SCC i.e. self compacting concrete. The amount of marble powder addition (10% and 20% by weight of cement), the basis for adding marble powder (as either cement or sand replacement), and by eventually adding a superplasticizing admixture (at a dosage of 0.5% by weight of very fine materials, i.e., cement plus marble powder). The proportions of these paste mixtures are shown in Table 3.6.

TABLE 3.6 PASTE MIXTURE PROPORTIONS

Cement paste	W/C	Cement (g)	Water (g)	Marble powder (MP) (g)	Admixture (ADM) (g)
CEM (0.5)	0.5	100	50	–	–
CEM + MP10 (0.5)	0.5	90	50	10	–
CEM + MP20 (0.5)	0.5	80	50	20	–
CEM + ADM (0.5)	0.5	100	50	–	0.5
CEM + ADM (0.4)	0.4	100	40	–	0.5
CEM + ADM + MP20 (0.5)	0.5	80	50	20	0.5
CEM + ADM + MP20 (0.4)	0.4	80	40	20	0.5
CEM + ADM + MP10 (0.4)	0.4	90	40	10	0.5

Materials

OPC cement type CEM II/A-L42.5 was used having Blaine fineness as 410 m^2/kg and its relative density (sp. Gr.) was 3.05. Natural sand 5 mm maximum size, with 0.9% passing 200 ASTM sieve was used. Its relative density was 2.62, and its water absorption of 3.0%.In some cases, a water-reducing admixture was added to the mixtures. It was constituted of a carboxylic acrylic ester polymer in the form of 30% aqueous solution. Marble Powder has a very high Blaine fineness value of about 1500 m^2/kg, with 90% of particles finer than 50μm and 50% under 7μm. Potable water used for mixing and curing process.

Concrete Mixes

Prismatic specimens, 40X40X160 mm in size, were manufactured for mechanical tests (126 at all, three for each curing time and mortar mixture). These specimens were cast in stainless steel moulds and wet cured at 20°C until the time of test.

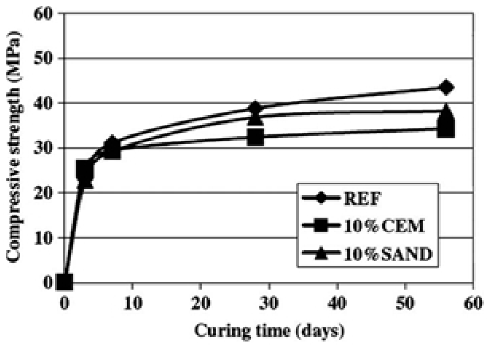

Fig3.13 Compressive strengths vs. curing time for cement mortars Without superplasticizer.

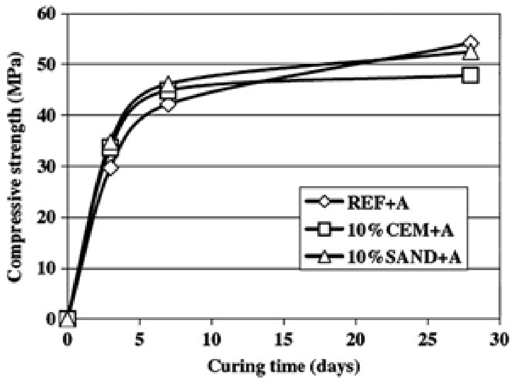

Fig.3.14. Compressive strengths vs. curing time for cement with superplasticizer.

* Marble Powder have 90% of particles finer than 50 and 50% under 7 as per gr μm grain size distribution using laser diffraction. The marble powder is produced as slurry. The weight loss was registered with the aim to reach a constant weight. The sample loses water quickly and reaches the constant weight after about 24 hours.

* The pastes prepared with marble powder, superplasticizing admixture, and water/cement of 0.4 showed the highest values of the yield stress, more than 40 MPa. Quite high values also were obtained for the cement pastes prepared with marble powder and water/cement ratio of 0.5.

* The addition of marble powder is very effective in improving segregation resistance of concrete in the presence of a superplasticizing admixture (e.g., for preparing self-compacting concrete), provided that water/cement is lower than 0.5. Otherwise, a viscosity-modifying agent should be added to the mixture for adjusting its rheological behaviour .

*,An excellent ability to flow through narrow sections can be predicted for SCCs containing marble powder. The reason for this excellent rheological behaviour conferred to concrete mixtures by marble powder (high cohesiveness when already placed and low energy loss when put into movement) can be ascribed to the particular grain size distribution of the powder (and to the corresponding fineness). In fact, the fineness of the marble powder is higher than cement and other mineral additions uch as fly ash, limestone powder etc.

*Compressive Strength decreased about 10-20% with 10% replacement of either cement or sand with marble powder. However, marble powder used as the replacement of sand performed better (10% decrease) than the case for the marble powder used as the replacement of cement (20% decrease) (Fig.3.13). As a matter of fact, marble powder showed a filler effect (particularly important at early ages) and did not play any noticeable role in the hydration process

With addition of superplasticizing admixture, compressive strength 10% replacement of either cement or sand with marble powder caused a small loss (about 10%) of strength (Fig.3.14). In fact, use of WMP in combination with superplasticizing admixture allowed for compensating the high water demand of marble powder itself. Consequently, the water to cement ratio could be maintained in order not to compromise the concrete mechanical strength. Again, WMP used as the replacement of sand performed equal to or better than the case of the marble powder used as the replacement of cement.

Hence Marble powder proved to be very effective in assuring good cohesiveness of mortar and concrete due to its quiet high cohesiveness, even in the presence of a superplasticizing admixture with adequately low water to cement ratio. On the basis of the low thixotropy values obtained, it seems that the use of marble powder would not be accompanied by an evident tendency to energy loss during concrete placing, as it is usual for other ultrafine mineral additions (such as silica fume) that are able to confer high cohesiveness to the concrete mixture. In terms of mechanical performance, 10% substitution of sand by the marble powder in the presence of a super plasticizing admixture provided maximum compressive strength at the same workability.

3.5 OBSERVATIONS DURING LITERATURE REVIEW

The following observations can be made from the detailed literature review on use of waste marble powder in cement concrete.

1. Waste marble powder can be used as partial replacement of sand

Replacement of sand with granite powder has beneficial effect on the mechanical properties of concrete. The optimum dose recommended is 15% both for compressive strength and split tensile strength. Compressive strength increases by about 25% & split tensile strength by about 33%. Its use will safeguard against environmental pollution & will make concrete cost less due to the rising cost of fine aggregates as well as limited availability & depleting resources of sand.

2. Waste marble powder can used as partial replacement of cement

Up to10 % marble dust as cement replacement, the compressive strength of concrete has been found to be either comparable or less than control mix and tensile strength decreases by about 12% . Cost of concrete cost is decreased by replacing 10% cement with marble dust.

3. Waste marble powder can be used as partial replacement of cement and as partial replacement of sand

By partial using WMP in both cases it has been found that concrete is less porous, initial & final setting times are not affected, there is no noticeable role of WMP during hydration process and there is significant improvement in tensile strength.. The compressive strength of concrete made with 15% marble dust as cement replacement has been found to be either comparable or less than control mix. There is max increase of increase 9% in compressive strength by replacement of cement with 10% WMP and max increase of22% in compressive strength by replacement of sand with 15% WMP at W/C ratio of 0.4.

Hence most of the research work has concluded that use of waste marble powder as replacement of sand is more effective and there is more significant effect on the mechanical properties of concrete compared with using it as cement replacement.

3.6 NEED FOR PRESENT RESEARCH WORK

Almost all the research work so far has been carried out on concrete, which is an hetrogenous mix and is affected by the properties of all its constituents. It is intended to see the effect of partial replacement of cement with waste marble powder on the basic properties of cement only. It includes its fresh properties (Initial setting time, Final setting time, Consistency etc) and the hardened properties (compressive strength). Therefore the present work is carried out on cement pastes.

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CHAPTER 4

MATERIAL TESTING AND EXPERIMENTAL PROGRAMME

4.1 GENERAL

This chapter deals with the material properties and the results obtained from different tests conducted for finding out the suitability of waste marble dust in cement mortars and concretes and in what proportions this waste material can be used such as to reduce the environmental pollution caused by this waste material. Various tests to determine the physical and mechanical properties of cement and mortar were carried out. In order to achieve the objective of this present study, an experimental programme was devised for investigating the effect of waste marble powder, in partial replacement to cement, on the consistency, soundness, initial and final setting times of cement and the compressive strength of cement paste.

The percentages of granite waste powder added to replace cement by weight were 0%, 10%, 20%, 30%, 40% and 50%.

4.2 MATERIALS USED

The properties of materials used for making cement mortar mixes were determined in the laboratory as per relevant Indian Standard codes and under controlled conditions. The material characterization was carried out for all the major ingradients of cement mortar. The purpose of the characterization is to check their acceptability as per the relevant Indian Standards so as to enable an Engineer to design a concrete mix for a particular required strength. The properties of various materials which are required in this study are Ordinary Portland Cement (grade 43), waste marble powder, standard sand of grade 1,2 and 3 and water. These are presented and discussed herewith in further sub sections :

4.2.1 Portland Cement (OPC)

The selection and proper use of cement is important for obtaining most economical balance of properties desired for any particular concrete mixture. Cement is the most active component of concrete and usually have the greatest unit cost. It fills the voids present in the fine aggregates and makes the concrete impermeable. It enables the concrete to get strength by binding the aggregates into the solid mass due to its setting and hardening properties when mixed with water. Although it accounts for about 20% of the total volume of concrete mix but its contribution to the compressive strength is maximum. A good quality cement should satisfy all the requirements as per Indian Standard codes and their specifications. The amount of cement required for a given mix should be in the range of minimum and maximum for the given grade as per codal provisions of IS. Portland cement, also referred to as ordinary Portland cement (OPC), is the most important type of cement and is a fine powder produced by grinding Portland clinkers. OPC has been categorized in three grades such as Grade 33, Grade 43, Grade 53 depending upon the required 28 days strength. The specifications of the cement of any grade is given by various IS codes. IS 8112:2013 provides the specifications of the OPC 43 grade cement.

Ordinary Portland Cement ,Grade 43 (Shree Ultra) from a single lot was used throughout the course of the investigation. It was fresh one and free from any lumps. The physical properties of the cement were tested in laboratory as per the IS Standard specification and results are presented in Table 4.1. Chemical composition of the cement was supplied by the manufacturer and is presented in the Table 4.2. Compressive strength of OPC at 3 days, 7 days and 28 days of curing are represented in Table 4.3

TABLE 4.1 PHYSICAL PROPERTIES OF OPC

S.NO.	CHARACTERISTICS	RESULT	REQUIREMENTS AS PER IS:8112-1989
1	Normal consistency	28%	-
2	Initial setting time	114 min	Min 30
3	Final setting time	229 min	Max 600
4	Specific gravity	3.15	-
5	Blain's fineness	287 m^2/Kg	-
6	Soundness	1	Max 10

TABLE 4.2 CHEMICAL PROPERTIES OF OPC

S.NO	OXIDE COMPOSITION	VALUES
1.	CaO	60-65%
2	SiO_2	22%
3	Al_2O_3	5.93%
4	Fe_2O_3	0.5 to 6%
5	SO_3	1.3 to 3%
6	MgO	0.1 to 4%
7	K_2O	0.4 to 1.3
8	Na_2O	-

TABLE 4.3 COMPRESSIVE STRENGTH OF OPC (GRADE 43)

S.NO.	DAYS OF CURING	COMPRESSIVE STRENGTH (MPa)
1	3 days	26.5
2	7 Days	38.2
3	28 days	53.6

4.2.2. Waste Marble Powder

The marble dust in powder form was collected from locally available source in Tripuri town locality in Patiala. It was white in colour, air dried and was packed in bags in powder form as shown in fig 4.1.

CHEMICAL ANALYSIS

Since the waste marble powder was to be used as partial replacement of cement, its chemical composition is the most important aspect to see wheather it can actually replace cement. Chemical analysis of various parameters of waste marble powder is presented in Table 4.4.

TABLE 4.4 CHEMICAL ANALYSIS OF WMP

S. No.	PARAMETER	TEST METHOD	UNIT	RESULTS
1.	Silica as SiO_2	IS 1727-1967, Reaffirmed in 2004	%	06.01
2.	Calcium as CaO	Digestion followed by AAS	%	30.73
3.	Magnesium as MgO	Digestion followed by AAS	%	15.21
4.	Loss on Ignition (LOI)	IS 1727-1967, Reaffirmed in 2004	%	37.87

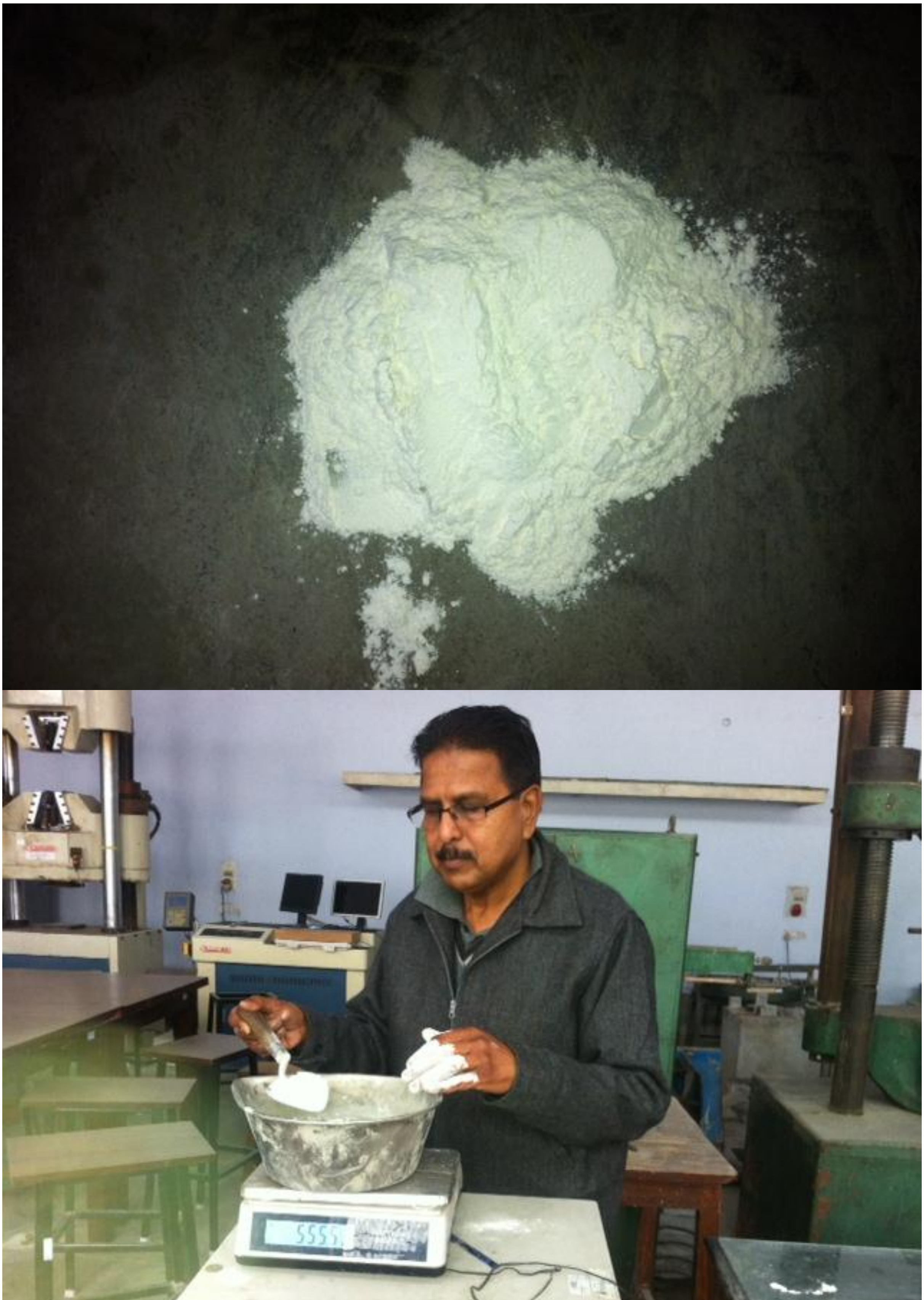

Fig. 4.1 Waste Marble Powder

4.2.3 Water

Fresh and clean tap water from concrete lab at Thapar University was used for casting the specimens in the present study. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per Indian standard. Quality of water plays a vital role as impurities in water may interfere with the setting of the cement and may cause straining of its surface which may lead to corrosion of the reinforcement.

4.2.4. Fine Aggregates

The aggregates most of which pass through the 4.75 mm IS sieve are termed as fine aggregates. The fine aggregates may be of following type: Natural sand, i.e. the fine aggregates resulting from natural disintegration of rocks, crushed stone sand, i.e. the fine aggregates produced by crushing hard stone, crushed gravel sand i.e. the fine aggregate produced by crushing natural gravel. Depending upon the particle size distribution IS 383 has divided the fine aggregates into four grading zones i.e.(Grade 1 to 1V). The grading zones become finer from grading zone 1 to 1V. Here in this study, we have used Standard Sand as fine aggregate.

All the cement industries in India are procuring the **standard sand** as approved by Bureau of Indian Standards (IS: 650-1991) to test the quality of the cement produced in each batch in their factories by preparing the standard sand cubes using standard sand of TAMIN and testing them for compressive strength. Tamil Nadu Mineral Limited popularly known as TAMIN, is a wholly owned blue chip company of Government of Tamil Nadu. TAMIN is engaged in exploitation, processing and marketing of Granite and other minerals such as Stone, Quartz, Indian Standard sand and Graphite etc.

As regards Silica sand, TAMIN process the raw silica sand into three different size fractions and clean them from any extraneous material for ready use to prepare cement cubes to determine the quality of cement after subjecting the cubes to compressive strength analysis. The standard sand is divided into three categories depending upon its size and is used in equal proportions, as shown in Table 4.5.

TABLE 4.5 SIZE,SPECIFICATION AND GRADE OF STANDARD SAND

S. NO.	SIZE	GRADE	QUANTITY RECOMMENDED
1.	2.0 mm to 1.0mm	Grade 1	33.3%
2.	1.0 mm to 0.5 mm	Grade 2	33.3%
3.	0.5 mm to 0.09 mm	Grade 3	33.3%

4.3 TESTS PERFORMED

The tests that were performed in order to study the efficiency of waste marble powder as partial replacement of cement included fresh state and harden state tests. These results are summarized in the following sections.

4.3.1 Standard Consistency

This test is performed to know the amount of water to be added to the cement so as to get a paste of normal consistency i.e. the paste of a certain standard solidity. It is also used to fix the quantity of water to be added in cement before performing tests for initial and final setting times, soundness and compressive strength. The consistency and the setting time of fresh pastes were tested according to IS 9597:1989. The consistency is measured by the Vicat apparatus using a 10 mm dia plunger fitted into the needle holder. A controlled trial paste of cement and water is mixed in the prescribed manner and is placed in the mould. The plunger is then brought down into the top surface of the paste and released. Under the action of its own weight, the plunger will penetrate the paste. The depth of penetration depend on the consistency of paste. This is considered to be standard when the plunger penetrates the paste to a point of 6 ± 1 mm from the bottom of mould. The water content of the standard paste is expressed as a percentage by mass of the dry cement, the usual values of should be in the range of 26% to 33%. Further paste mixes are made in the similar manner by partially replacing cement with waste marble dust. The different replacement ratios are 10%, 20%, 30%,40% and 50%.

The consistency of fresh pastes, with or without partial replacement of cement were tested according to IS 9597:1989. The material used for performing the tests for different mixes is presented in Table 4.6.

TABLE 4.6 QUANTITY OF MATERIALS USED FOR STANDARD CONSISTENCY

S.NO.	CEMENT (gm)	WMP (gm)	WATER (gm)
1	400	0% (0)	112
2	360	10% (40)	110
3	320	20% (80)	110
4	280	30% (120)	108
5	240	40% (160)	108
6	200	50% (200)	106

4.3.2 Initial and Final setting time

The initial set is a stage in the process of hardening after which any crack that may appear will not re-unite. The concrete is said to be finally set when it had obtained sufficient strength and hardness. In order that concrete may be placed in position conveniently, it is necessary that the initial setting time of cement is not too quick and after it has been laid, hardening should be rapid so that structure can be made use of as early as possible. Vicat mould is filled and smoothened off. For initial setting time needle was gently lowered and process is repeated until needle fails to pierce the block for about 5 to 7 mm. This period from start of adding water and time at which needle fails to penetrate by 5 to 7 mm is called initial setting time. For final setting time needle is replaced with annular attachment. The cement is considered finally set when upon applying the needle gently to surface of test block, the needle makes an impression but attachment fails to do so.

Setting of paste is caused by a selective hardness of cement compounds. Out of four compounds of cement, C_3S & C_3S are the first ones to react and set. Therefore these two compounds control the IST of the cement. The gypsum in cement delays the formation of calcium aluminate hydrate as it reduces the flash setting properties of C_3A. It is, therefore, C_3S that sets first. Pure C_3S mixed with water also exhibits an initial set but C_2S stiffens in a more gradual manner and is responsible for final set. The cement pastes made with WMP must also follow the guidelines laid for pastes made with OPC.

Certain limits have been specified for initial and final setting time as per codal provisions for Ordinary Portland Cement. Initial setting time should not be less than 30 minutes and final setting time should not be more than 600 minutes.

Neat cement paste is prepared by gauging the cement with 0.85P where P is the standard consistency as found earlier. The gauging time is kept between 3 and 5 minutes.

Mass of cement and waste marble powder (as per replacement %) taken= 400 gm

Mass of water taken= 0.85P x 400 gm.

The amount of materials taken for measuring the setting times for all the mixes are presented in Table 4.7.

TABLE 4.7 SETTING TIME RESULTS

S.N0.	WMP (%)	CONSISTENCY (%)	SAMPLE MASS		WATER (gm)
			CEMENT (gm)	WMP (gm)	
1	0	28.0	400	0	95.0
2	10	27.5	360	40	93.5
3	20	27.5	320	80	93.5
4	30	27.0	280	120	92.0
5	40	27.0	240	160	92.0
6	50	26.5	200	200	90.0

4.3.3 Soundness

It is very essential that the cement paste, once it has been set, does not undergo a large change in volume. In particular there must not be any appreciable expansion which, under the conditions of restraint, could not result in a disruption of the hardened cement paste. Such expansion may take place due to delayed or slow hydration or other reaction of some compounds present in the hardened cement, namely free lime, magnesia and calcium sulphate.

The test is conducted by accelerating the slaking process by the application of heat and to measure the extent of expansion and to see that this expansion is less than the specified limits. LE-CHATELIER apparatus is used for conducting this test. 100gm of sample i.e. cement and marble powder (as per replacement percentage) was mixed with 0.78 times the water required to make a paste of standard consistency

The apparatus was placed on a glass plate and after filling paste, the same is covered at top by another glass sheet. Then immediately, it is submerged in water for a period of 24 hours at temperature of 27±2 degree. After 24 hours, distance D_1 between the indicator points was measured by extracting moulds from water and moulds were again submerged in water at the same temperature. Water is brought to boiling point and kept the same for 3 hours. After removing moulds from boiling water, these were allowed to cool and distance between indicator points was measured as D_2. The difference (D_2 - D_1) between the two measurements gives the expansion of cement.

Soundness of all the mixes with or without waste marble powder were measured as per IS 269-1976. The quantity of materials required for performing the soundness tests are listed in Table 4.8.

TABLE 4.8 QUANTITY OF MATERIALS REQUIRED FOR SOUNDNESS TEST

S No	%age WMP	STANDARD CONSISTENCY (%)	WATER 0.78P (gm)	MASS OF SAMPLE	
				MASS OF CEMENT (gm)	MASS OF WMP (gm)
1.	0	28.0	21.84	100	0
2.	10	27.5	21.45	90	10
3.	20	27.5	21.45	80	20
4.	30	27.0	21.06	70	30
5.	40	27.0	21.06	60	40
6.	50	26.5	20.67	50	50

Total mass of sample taken = 100 gm

4.3.4 Compressive Strength of Concrete Mixes

According to IS:269-1976, cement sand mortar of the ratio of 1:3, containing (P/4+3.0) percent of water should be used for making cubes to determine the compressive strength of cement. Accordingly the material required for each mix was calculated for one cube. Quantities of cement and standard sand is as follows.

Total of 54 cubes were casted for 3,7 and 28 days compressive strength i.e. 9 each for 0%,10%,20%,30%,40% and 50% replacement level of cement with Waste Marble Powder.

Water required for 9 cubes with 0% replacement= (P/4+3)% x total weight of sample

= (28/4+3)% x7200= 720 gm

Similarly water calculated for 10%,20%,30%,40% &50% replacement comes out as 711gm, 711gm, 702gm, 702gm and 693gm respectively.

For casting of cement paste samples, the quantities of cement, each size of aggregate and water for each batch were determined by weight. The ingradients were mixed in the DIGI mortar mixer. Standard sand grade 1 being coarser was added first, then grade 2 and lastly grade 3 sand is added. Cement was then added along with WMP. The period of mixing should be not less than two minutes after all the materials are in the drum and had to continue till the resulting mix is uniform in appearance. Then water was slowly introduced and mixing was continued till uniform mix was obtained. The entire procedure as laid down above was diligently followed for preparation of all the concrete mixes.

The mould for test specimen confirming to IS: 10086-1982 were used for casting of cubes as per laid down specifications to be used in the tests of cement mortar. Compression test specimens were cubical sized with dimensions of 70.5x70.5x70.5 mm.

The test sample were made as soon as practicable after mixing and in such a way so as to produce full compaction of mortar/concrete with neither segregation nor laitance. Table vibrator was used for compaction of the mix in the mould. The test specimens were stored in a place, free from vibration, in the moist air of at least 90% relative humidity and at a temperature of $27 \pm 2^{o}C$ for 24 hours. After this period, the specimen were marked and removed from the mould and then stored in clean water until the time of the test. The test samples were cured in the curing tank which is available in the laboratory. At the time of test, the samples were tested immediately on removal from the water, when they were still in the wet condition. The samples were tested after curing period of 3,7 and 28 days for compressive strength

The materials used for each mix is summarized in Table 4.9.

TABLE 4.9 QTY OF MATERIALS REQUIRED FOR COMPRESSIVE STRENGTH

S. N.	MIX	WMP (%)	CONSIS-TENCY (%)	CEMENT (gm)	WMP (gm)	STANDARD SAND (gm)			WATER (gm)
						GRADE 1	GRADE 2	GRADE 3	
1.	M1	0	28.0	200	0	200	200	200	80
2.	M2	10	27.5	180	20	200	200	200	79
3.	M3	20	27.5	160	40	200	200	200	79
4.	M4	30	27.0	140	60	200	200	200	78
5.	M5	40	27.0	120	80	200	200	200	78
6.	M6	50	26.5	100	100	200	200	200	77

CHAPTER 5

RESULTS AND DISCUSSION

5.1 GENERAL

This chapter deals with the observations of the results from the various tests conducted on physical, chemical and mechanical tests in connection with finding the usability of waste marble dust in cement mortar/ concrete. The results are compared with the control mixes for various percentage replacement levels of cement with waste marble powder dust. Tests were conducted for finding the effect on consistency, soundness and initial and final setting times of cement by changing the replacement levels of cement with waste marble dust. The strength characteristics of mortar containing marble dust are also discussed in this chapter. The tests were performed on the hard cement mortar under standard laboratory conditions and compressive strength of cement mortar cubes was observed at curing ages of 3, 7 and 28 days respectively.

5.2 STANDARD CONSISTENCY TEST

The consistency and the setting time of fresh pastes were tested according to IS 9597:1989. The consistency is measured by the Vicat apparatus using a 10 mm dia plunger fitted into the needle holder. A controlled trial paste of cement and water is mixed in the prescribed manner and is placed in the mould. The plunger is then brought down into the top surface of the paste and released. Under the action of its own weight, the plunger will penetrate the paste. The depth of penetration depend on the consistency of paste. This is considered to be standard when the plunger penetrates the paste to a point of 6 ± 1 mm from the bottom of mould. The water content of the standard paste is expressed as a percentage by mass of the dry cement, the usual values of should be in the range of 26% to 33%. Further paste mixes are made in the similar manner by partially replacing cement with waste marble dust. The different replacement ratios are 10%, 20%, 30%,40% and 50%. The results of all these standard consistencies are represented in Table 5.1 and Figure 5.1.

TABLE 5.1 STANDARD CONSISTENCY TEST RESULTS

WMP (%)	CEMENT (gm)	WMP (gm)	WATER (gm)	STANDARD CONSISTENCY (%)
0	400	0	112	28.0
10	360	40	110	27.5
20	320	80	110	27.5
30	280	120	108	27.0
40	240	160	108	27.0
50	200	200	106	26.5

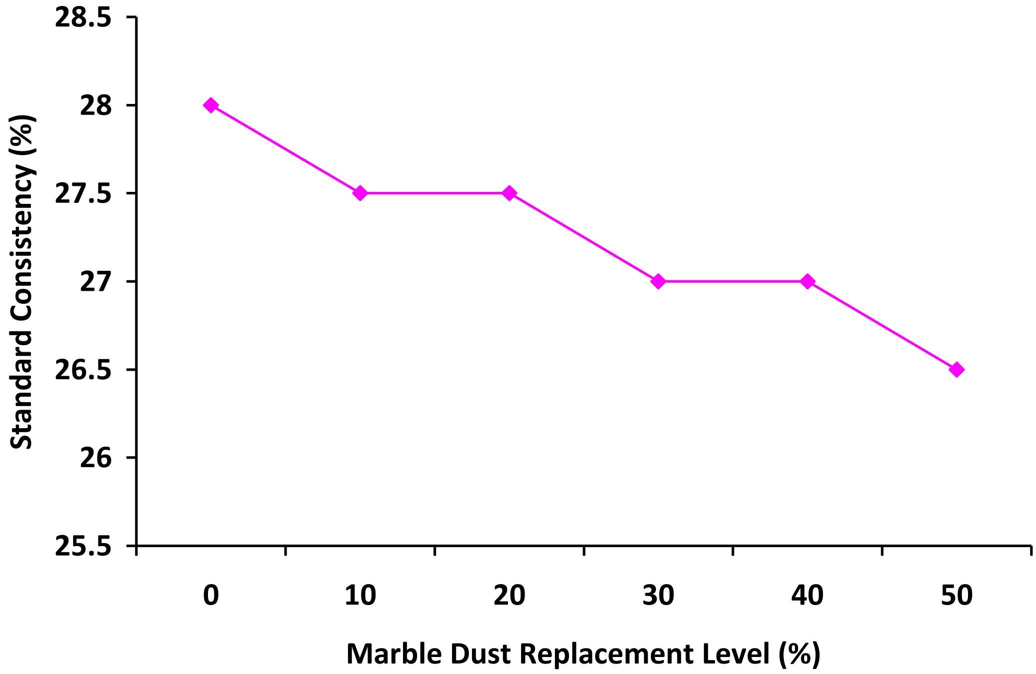

Fig. 5.1. Variation of results of standard consistency of cement & WMP with different % replacement levels of marble dust

From above results, it is seen that standard consistency decreases with increase in replacement percentage of cement with waste marble powder. It illustrates that need of water for WMP is less. The reason for this is that specific surface of WMD is less than the specific surface of cement. As a result of this, the water requirement value decreases related to the control cement by increasing the WMD ratio in cement.

5.3 INITIAL AND FINAL SETTING TIMES

Vicat mould is filled and smoothened off. For initial setting time needle was gently lowered and process is repeated until needle fails to pierce the block for about 5 to 7 mm. This period from start of adding water and time at which needle fails to penetrate by 5 to 7 mm is called initial setting time. For final setting time needle is replaced with annular attachment. The cement is considered finally set when upon applying the needle gently to surface of test block, the needle makes an impression but attachment fails to do so. The values of Initial and Final setting time for various mixes are shown in Table 5.2.

TABLE 5.2 SETTING TIME RESULTS

S.N0.	WMP (%)	CONSISTENCY (%)	SETTING TIME		Δt (minute)
			INITIAL (minute)	FINAL (minute)	
1	0	28.0	114	229	115
2	10	27.5	150	250	100
3	20	27.5	201	286	85
4	30	27.0	225	315	90
5	40	27.0	235	345	110
6	50	26.5	250	370	120

It can be observed from the table that both IST and FST increase with increase in percentage of WMP. However, the values still remain in the permissible limit as presented by IS 4031- (Part 5)-1988, i.e the IST of all the mixes is greater than 30 min; FST is less than 600 min. The increase in settle time can be attributed to change in chemical composition of cement. Although the fineness of WMP is almost similar to cement, the chemical composition indicates lesser amount of CaO & SiO_2. Hence, the percentage of cement hydration compounds formed will decrease, which are responsible for setting of cement.

Similar results were found by Aliabdo et al. (2013) while studying the effect of replacement upto 15% of cement by waste marble powder.

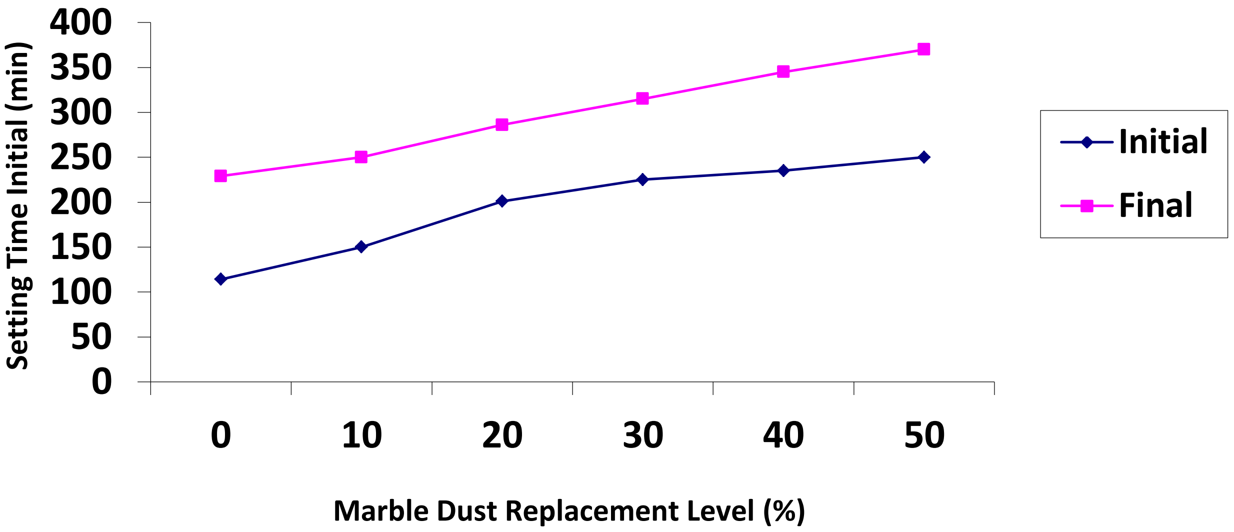

Fig. 5.2. Variation of Initial and Final Setting time with different % replacement levels of cement with marble powder

5.4 SOUNDNESS

This test is carried out to get the extent of free lime and magnesia present in cement as these slake very slowly and cause appreciable change in volume after setting. This results in cracks, distortion and disintegration. This has injurious effects on concrete and reinforcement. This defect is called unsoundness.

The test is conducted by accelerating the slaking process by the application of heat and to measure the extent of expansion and to see that this expansion is less than the specified limits. LE-CHATELIER apparatus is used for conducting this test. 100gm of sample i.e. cement and marble powder (as per replacement percentage) was mixed with 0.78 times the water required to make a paste of standard consistency

The apparatus was placed on a glass plate and after filling paste, the same is covered at top by another glass sheet. Then immediately, it is submerged in water for a period of 24 hours at temperature of 27$\pm$2 degree. After 24 hours, distance D_1 between the indicator points was measured by extracting moulds from water and moulds were again submerged in water at the same temperature. Water is brought to boiling point and kept the same for 3 hours. After removing moulds from boiling water, these were allowed to cool and distance between indicator points was measured as D_2.The difference (D_2 - D_1) between the two measurements gives the expansion of cement and as per codal provisions in IS: 269-1976, this difference should not be more than 10 mm. Details of soundness values for all the mixes are presented in Table 5.3.

TABLE 5.3 SOUNDNESS TEST RESULTS

S No	%age WMP	SAMPLE CEMENT+WMP (gm)	WATER 0.78P (gm)	DISTANCE BETWEEN INDICATOR POINTS		CEMENT EXPANSION (D_2 - D_1) (mm)
				INITIAL D_1 (mm)	FINAL D_2 (mm)	
1.	0	100+0	21.84	26.0	27.0	1.0
2.	10	90+10	21.45	27.0	27.5	0.5
3.	20	80+20	21.45	37.5	39.0	1.5
4.	30	70+30	21.06	40.0	41.0	1.0
5.	40	60+40	21.06	21.0	22.0	1.0
6.	50	50+50	20.67	22.0	23.0	1.0

From above results, it is observed that expansion values are not influenced due to replacement of cement with marble powder. Expansion values comply with the IS codal provisions where it is recommended that expansion is not to increase more than 10 mm. Similar results were found by Aliabdo et al. (2013) while making a maximum replacement of 15% by WMP.

Soundness depends on presence of free line and magnesia. Although the percentage of free lime in WMP (30%) is lower than cement (60-65%), which could have reduced the value of soundness. Its effect was compensated by higher amount of magnesia in WMP (15%) as compared to corresponding value in cement (1-4%). This indicate that changed chemical composition of cement due to a replacement by WMP has no detrimental effect on soundness of cement.

5.5 COMPRESSIVE STRENGTH TEST RESULTS

5.5.1 General

Compressive Strength of cement paste is the most important of all the properties for structural use. The strength of the concrete depends on cohesion of cement paste and its adhesion to the aggregates and to a certain extent on the strength of aggregates. In order to eliminate the effect of aggregates on the properties of concrete, the quality of cement can be tested by eliminating aggregates from the system. Compressive strength of cement is tested by using standard aggregates. However, strength tests cannot be made on cement alone because of difficulties of moulding and testing will give large variability . Cement and mortar mixes were developed & cubes of size 70.5 mm were cast under strictly controlled conditions.

5.5.2 Test procedure and results for the compressive strength

Test specimens of size 70.5x70.5x70.5 mm were prepared for testing the compressive strength of both controlled as well as marble dust mix. The modified mixture with varying percentages of marble dust as a partial replacement of cement were prepared and were casted. Compressive strength results at curing ages of 3, 7 and 28 days for control mix as well as modified mixes are shown in Table 5.4, Table 5.5 and Table 5.6 respectively. The load was axially applied without the shock till the specimen was crushed. Fig 5.3 Shows the test set up for the compressive strength.

Three specimen for each specimen were tested and the corresponding values were observed and average values were taken for discussion. Fig. 5.4 to fig 5.9 shows the variation of compressive strength with varying percentages replacement of cement with waste marble powder at 3, 7 and 28 days of curing.

From the figures, it is clear that as the percentage of replacement of cement by WMP is increased, the compressive strength of cement sand mortar decreases. There is no decrease in compressive strength of mixes till 10% of replacement, after which the strength started decreasing. The 28 days compressive strength till 20% replacement level is still within the limits prescribed for 43 Grade cement. It can be concluded that waste marble powder can be used upto 20% as partial replacement of cement to make an overall economical mix. The decrease in strength with addition of WMP indicate that marble powder acts only as filler and does not play noticeable role in hydration process. The similar observations were made by Corinaldesi et al (2010).

Results of compressive strength of mortar mix without superplasticizers were compared with research work carried out on cement pastes made with waste marble powder by Corinaldesi et al (2009) for characterization of marble powder for its use in mortar and concrete where they have found that 10% replacement of either cement with marble powder caused about 20% compressive strength decrease in late age. When they used plasticizers, the decrease is 10%.

In the research work carried by undersigned, there is a small 10% decrease in compressive strength when cement is replaced with 10% waste marble powder. Hence the results obtained by this author are comparable.

TABLE 5.4 RESULTS OF 3 DAYS COMPRESSIVE STRENGTH

S.NO.	WMP (%)	COMPRESSIVE STRENGTH (N/mm^2)	% RATE INCREASE/DECREASE
1.	0	27.84	-
2.	10	28.02	(+) 0.65
3.	20	25.28	(-) 9.20
4.	30	22.46	(-) 19.3
5.	40	19.96	(-) 28.3
6.	50	15.80	(-) 43.2

Fig. 5.3 Cement Mortar Cubes being tested by Compression Testing

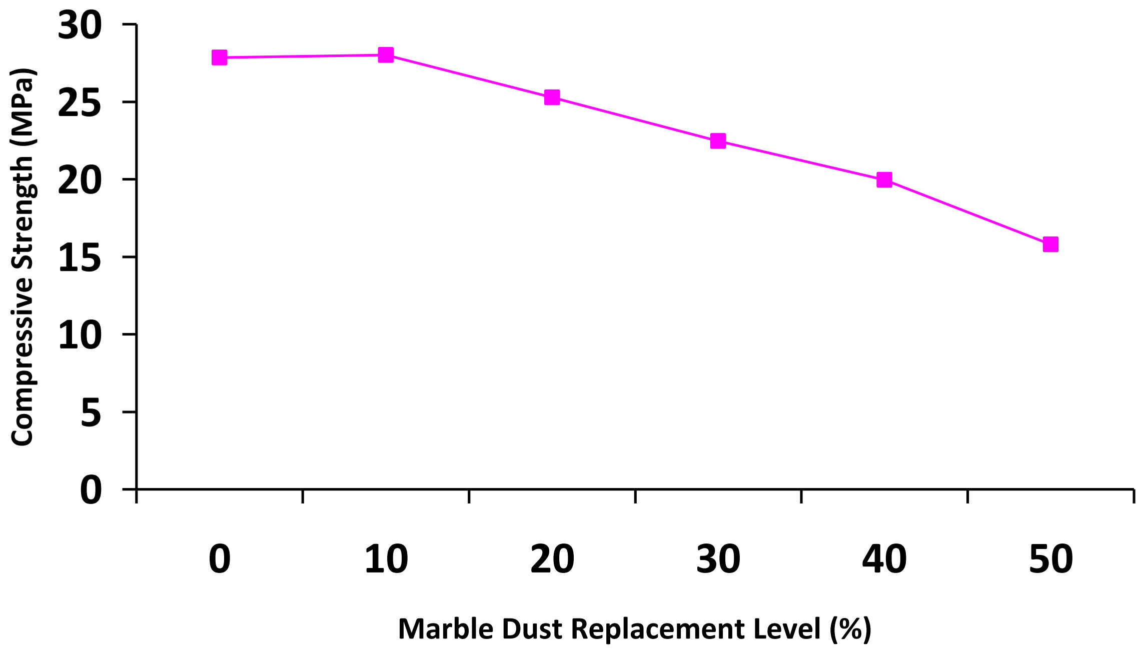

Fig. 5.4 Variation of Compressive Strength of cement mortar cubes with different % replacement levels of marble dust at 3 days curing ages

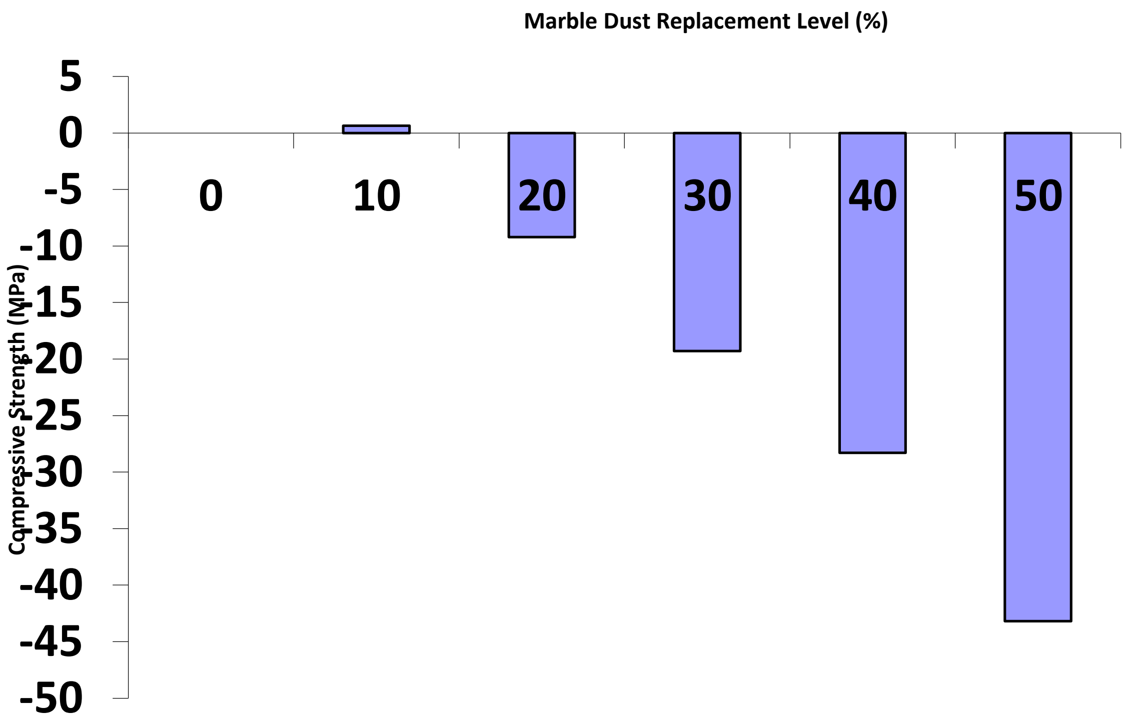

Fig. 5.5 Percentage Variation in compressive strength of various mixes as compared to the normal mix at 3 days curing period

TABLE 5.5 RESULTS OF 7 DAYS COMPRESSIVE STRENGTH

S.NO.	WMP (%)	COMPRESSIVE STRENGTH	% RATE INCREASE/DECREASE
1.	0	30.97	-
2.	10	31.09	(+) 0.39
3.	20	27.64	(-) 10.9
4.	30	24.40	(-) 21.30
5.	40	22.58	(-) 27.20
6.	50	17.84	(-) 42.50

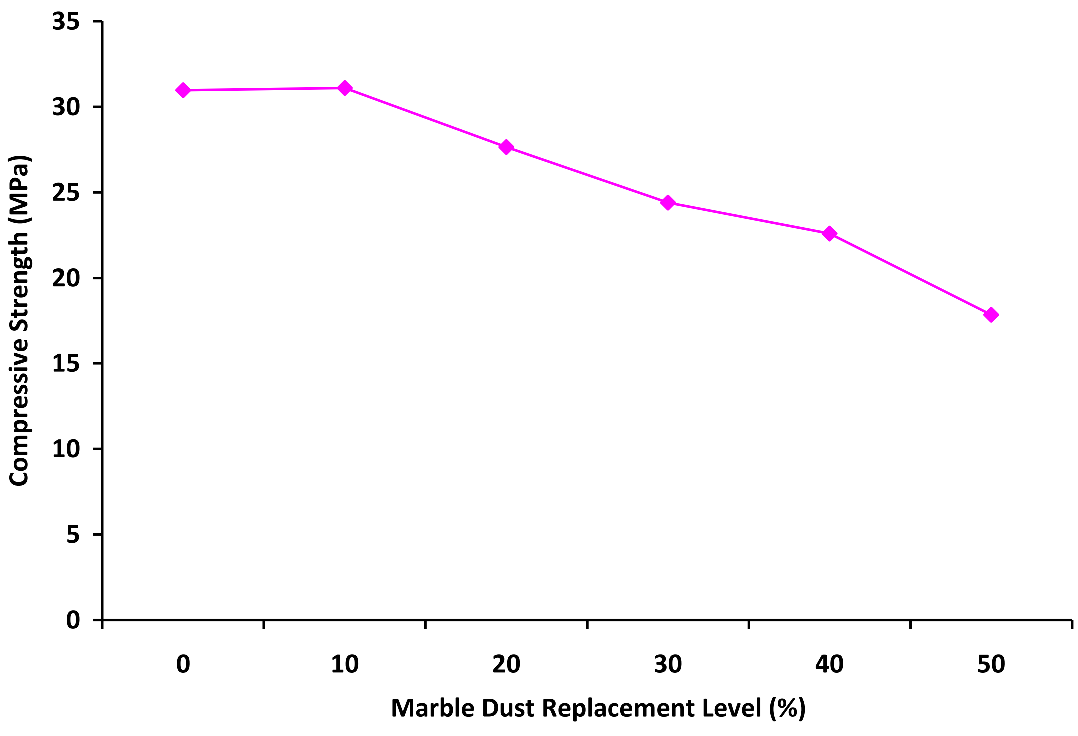

Fig. 5.6 Variation of Compressive Strength of cement mortar cubes with different % replacement levels of marble dust at 7 days curing ages

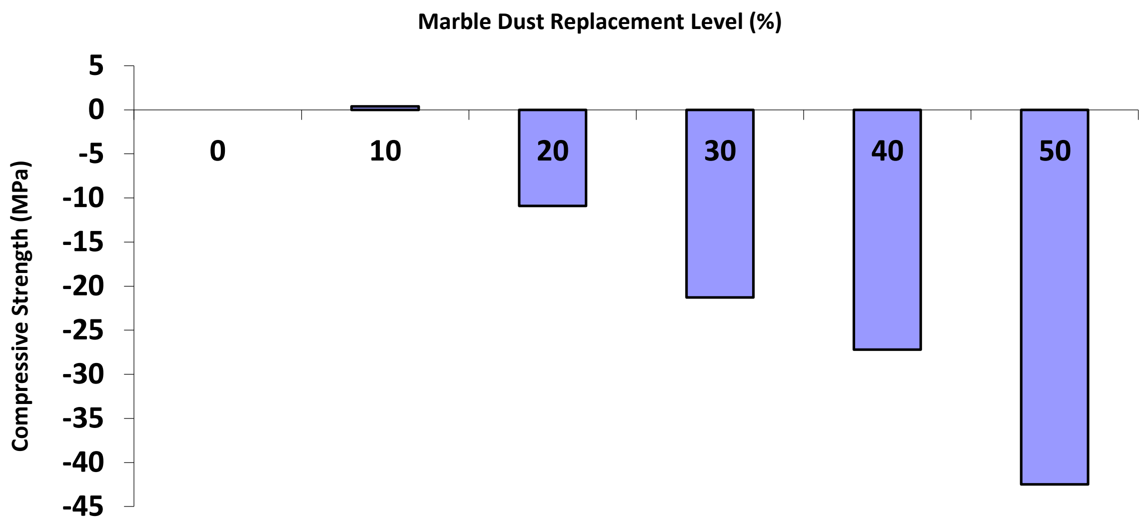

Fig. 5.7 Percentage Variation in compressive strength of various mixes as compared to the normal mix at 7 days curing period

TABLE 5.6 RESULTS OF 28 DAYS COMPRESSIVE STRENGTH

S.NO.	WMP (%)	COMPRESSIVE STRENGTH	% RATE INCREASE/DECREASE
1.	0	46.32	-
2.	10	46.41	(+) 0.39
3.	20	41.66	(-) 10.10
4.	30	31.47	(-) 32.10
5.	40	27.94	(-) 39.70
6.	50	25.66	(-) 44.60

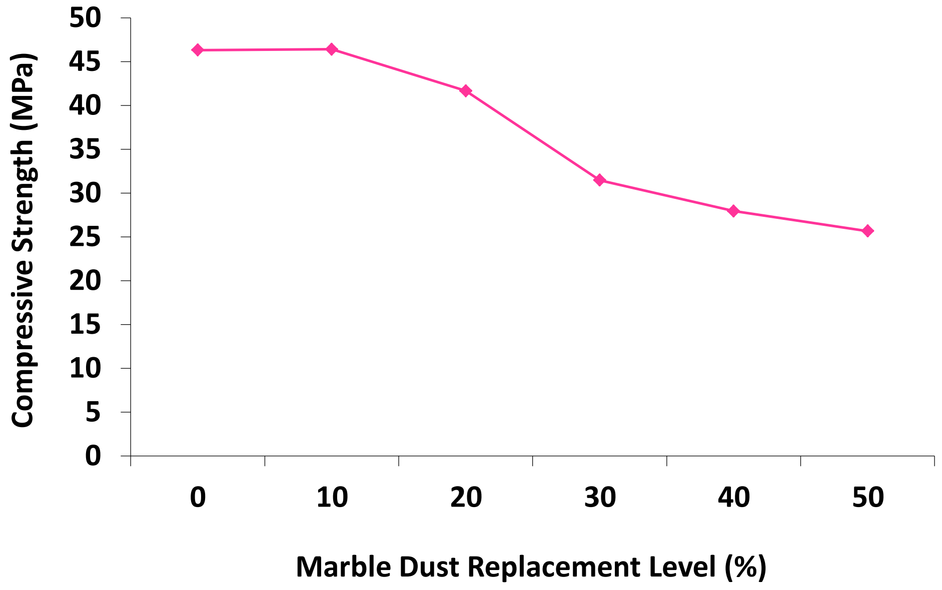

Fig. 5.8 Variation of Compressive Strength of cement mortar cubes with different % replacement levels of marble dust at 28 days curing ages

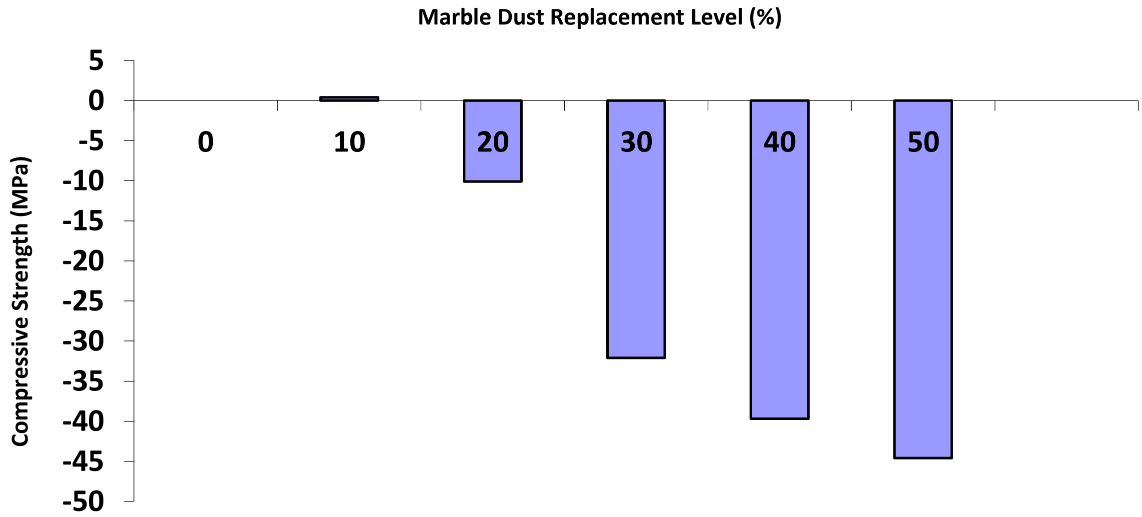

Fig. 5.9 Percentage Variation in compressive strength of various mixes as compared to the normal mix at 28 days curing period

CHAPTER 6

CONCLUSIONS

6.1 GERERAL

An experimental program was devised to study the effect of replacement of cement with waste marble powder on various properties of cement and cement mortar mix. Laboratory tests were performed under controlled conditions. Effect of waste marble powder was observed on standard consistency, soundness, initial and final setting time of cement and on compressive strength of mortar mix. Cement was replaced with waste marble powder with different percentages such as 0%, 10%, 20%, 30%, 40% and 50%. The compressive strength of cubes of size 70.5 mm were tested after 3, 7 and 28 days of curing period. A discussion of the results was carried out and the major observations from the study are elaborated here under.

6.2 OUTCOMES OF RESEACH WORK

The following findings have been made from this study :

(1) Standard consistency of cement paste made with cement partially replaced with WMD has slightly decreased. It decreases gradually from 28% for controlled mix to 26.5% for 50% replacement of cement. The reason for this is that specific surface of waste marble powder is less than the specific surface of cement. As a result of this, the water requirement value decreases by increasing the amount of waste marble powder in mix.

(2) The initial setting time and final setting time of cement pastes although increases to some extent by the use of waste marble powder but remain well within the permissible limits as per codal provisions.

(3) Soundness of cement was checked and is well with permissible limits in all the cases where cement has been partially replaced with waste marble powder. It shows that the continued effect of changed chemical composition of cement due to addition of waste marble powder has no detrimental effect on soundness of the resultant mix.

(4) Compressive strength of cement mortar decreases. However, from the general requirements of strength for 43 Grade ordinary Portland cement, waste marble powder can successfully be used upto 20% of replacement of cement.

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