Strength Properties of Concrete with Partial Replacement of Mineral Admixtures and Marble Waste

[1] Jayaraman Jeevitha, [2] K.Madhavi Latha
[1] M.Tech, G. Pulla Reddy Engineering College, Kurnool
[2]Assistent professor, G. Pulla Reddy Engineering College, Kurnool

Abstract : Concrete is one of the main material in the construction industry. The global cement industry contributes around 6% of all CO2 emission into the atmosphere. Global warming is caused by the emission of excessive greenhouse gases into the atmosphere hence reduce the environmental problems the cement is partially replaced by diatomite and waste marble powder. Diatomite is a pozzolanic material containing amorphous silica, cristabolite and minor amounts of residual minerals. Waste marble powder and marble stones is an inert material which is obtained as an industrial by-product during sawing, shaping, and polishing of marble. This waste is dumped on to open land which creates a lot of environmental problems and severe scarcity of natural aggregates for the production of concrete primary aggregates are partially replaced with marble aggregates. This paper describes the procedures and results of a laboratory investigation of mechanical properties carried out on the concrete specimens containing diatomite and WMP as partial replacement of cement and marble stones as partial replacement of coarse aggregate in concrete. Test results indicated that the best compressive and flexural strength of the concrete specimens containing 10% diatomite, 5% WMP and combination of 10% diatomite + 5% WMP replacement by weight of the cement and marble aggregate replacement to the coarse aggregate is 25% of the total volume of the aggregates together 10% diatomite + 5% WMP replacement by weight of the cement using a super plasticizing admixture to improve the mechanical properties of the conventional concrete mixtures. The main objective of this study is improving the mechanical properties of the concrete with low cost, economy and reducing environmental problems and global warming.

***IndexTerms* - Diatomite, Marble waste, super plasticizer, Compressive strength, Flexural strength**

INTRODUCTION

The most important mechanical properties of concrete are compressive and flexural strength. The mechanical properties of concrete can be improved with alternative materials used for partial replacement of Portland cement and coarse aggregate in concrete. One of these materials is diatomaceous rocks. Several large diatomaceous deposits have been discovered in Afyonkarahisar – Turkey. Diatomite is a sedimentary rock of biogenic origin with high natural amorphous silica content. This type of SiO2 can react with Ca(OH)2 and produce calcium silicate hydrates (CSH), which are responsible for the development of strength. Diatom skeletons are highly porous, light in weight and chemically stable and inert. Diatomite has been used in variety of applications, mainly as filtration agent and functional fillers for paints and plastics. Diatomite has high surface area because of its eased grindability. Another partial replacement material used in this study is waste marble stones and marble powder. The effect and usage of WMP as a limestone additive source in cement, the presence of limestone in hardened cement paste has a filler effect. Limestone is an inert or quasi-inert material.

The effects of limestone on cement properties are not only physical (corresponding to reduction in paste porosity) but also chemical. The chemical interactions take place between calcite and Portland cement paste leading to calcium carboaluminates formed by a reaction between hydrated calcium aluminate and carbonate ions. Calcareous filler has an important binding property that is developed by hydration of calcite and C3A. Waste marble aggregates for production of concrete were investigated and determined that could be used to improve the mechanical properties of the conventional concrete mixtures.

EXPERIMENTAL STUDY

Materials and Chemicals

In this study ordinary Portland cement 43 grade conforming to Indian standards 12269-1987 was used. The specific gravity of cement was 3.15. The targeted 28-days-compressive concrete strength was set at 38.25 MPa.

Different types of aggregates were used when casting the test specimens, namely: crushed stone III (12-22 mm), crushed stone II (6-12 mm) and river sand (0–4 mm).

Figure 1: Experimental materials

Table 1

Chemical Composition of Cement

components	Composition (%)
SiO_2	19.30
Al_2O_3	5.57
Cao	63.56
Na_2O	0.13
MgO	0.86
K_2O	0.73
SO_3	2.91
Free Cao %	0.70
L.O.I %	2.78

Figure 2: Cement

Figure 3: Superplasticizer

A water-reducing admixture was added to the mixtures at the ratio of 1% of binder materials by weight. It was constituted of polycarboxylates based polymer and high range water-reducing superplasticizer. Master Glenium sky 920 superplasticizer was used in this work collected from “BASF INDIA LIMITED”, NAIDU PETA, NELLORE. Diatomite is a sedimentary rock. Diatomite ore characterized as natural pozzolana material. The diatomite samples were crushed and homogenized. Diatomite rocks commonly contain carbonate and clay minerals, quartz, feldspars and volcanic glass. Diatomite is a sedimentary rock. It is a pozzolanic material containing amorphous silica, cristabolite and minor amounts of residual minerals. In this present study Diatomite powder was collected from “ASTRRA CHEMICALS”, CHENNAI.

Table 2

Chemical Composition of diatomite

components	Composition (%)
SiO_2	88 to 92
Al_2O_3	4 to 7
Fe_2O_3	3.54
Cao	10.71
MgO	0.68
K_2O	0.71
SO_3	0.28

Figure 4: Diatomite

Marble is a metamorphic rock that forms when lime stone is subjected to the heat and pressure of metamorphism. It is composed primarily of the mineral calcite (CaCO3) and other minerals, micas, quartz, pyrite, iron oxides and graphite. Marble is an inert material, these aggregates have the lowest water absorption when compare to the basalt and granite. Marble dust was collected from "A.N.MARBLES", DHONE, KURNOOL DISTRICT. The area is rich in marble mineral content.

Table 3

Chemical Composition of marble powder

components	Composition (%)
SiO_2	0.18
Al_2O_3	0.67
Fe_2O_3	0.44
Cao	51.70
MgO	0.40
K_2O	0.21
SO_3	0.08

Figure 5: Marble powder

Figure 6: Marble aggregates

III. SAMPLE PREPARATIONS AND TEST METHODS

In order to assess the effects of diatomite and waste marble powder (WMP) as partial replacement of cement on the behavior of concrete, a constant water/binder ratio of 0.4 was used for all the test specimens. Four series of concrete specimens were cast. The variables in this research were diatomite, WMP and WMC content. 5%, 10% and 15% diatomite replacement for Series-I, 5%, 10% and 15% WMP replacement for Series-II, 5% and 10% diatomite and WMP together replacement for Series-III and 25%, and

50% WMC as partial replacement of coarse aggregate in addition to the combination of diatomite and WMP for series-IV were used.

The concrete specimens were termed as Control, D5, D10, D15, WMP5, WMP10, WMP15, D5 + WMP5, D10 + WMP5, D5 + WMP10, D10 + WMP10, D10 + WMP5 + WMC25, D10 + WMP5 + WMC50.

For each investigated mixture, six 150X150X150 mm cubes and six 500×100×100mm beams were tested from each of the four series (i.e., Series- I, II, III and IV). The cubes and beams specimens were tested to study the variation of the compressive strength and flexural strength, respectively for each of the test series.

Figure 7: Casting test specimens

Compressive strength test was performed in accordance with IS 516: 1959. The test was performed on 150X150X150 mm cubic samples at 7 and 28 days. Compressive strength of each mix was taken as average value of three specimens. The flexural strength of the concrete was carried out as per IS 516: 1959. Beams of size 500X100X100mm size were cast then subjected to the flexural strength test using universal testing machine (UTM) at the age of 7 and 28 days.

Figure 8: Flexural strength test (UTM)

Table 4

MIX DESIGN IS CARRIED OUT FOR M30 GRADE CONCRETE DONE BY IS 10262:2009

Unit of batch	CEMENT (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)
Content	336	749	1352	134.11
Ratio of ingredients	1	2.22	4.02	0.4

IV. EFFECT OF DIATOMITE REPLACEMENT

Chemical properties of diatomite present in Table 2. Chemical analysis indicated that the PC and diatomite have different compositions and are principally composed of calcia and silica respectively. Since diatomite powder has high surface

area, cements containing diatomite powder have also high surface area. As expected the compressive strength increased with age. The compressive strength development of concrete with diatomite is related to the cement replacement level and curing age. It was observed that the replacement of PC with 10% diatomite significantly increased the compressive strength. When these values compared

with the control concretes, it could be seen that the specimens containing diatomite had higher compressive strength than that of the control concrete. The rate of strength is dependent on the combination of clinker hydration and the pozzolanic activity of diatomite. The main factors that affect the contribution of diatomite in strength are: (a) the filler effect, (b) the dilution effect, (c) the pozzolanic reaction of diatomite with CH, and (d) using a water-reducing admixture.

V. EFFECT OF WMP REPLACEMENT

Chemical properties of WMP presents in Table1. Chemical analysis indicated that the main component of WMP is calcia. WMP had higher surface area than PC because of the fineness of WMP used. The 5% replacement of WMP with cement leads to an increase in the compressive strength. The increase in compressive strength could be explained with pore-filling effect of fine-ground limestone powder, providing suitable nucleus for hydration and catalyzing the hydration as a result. The usage of WMP in concrete showed as a filler effect. The reason could be said as that the filler was an inert addition and it could be assumed as ultrafine aggregates filling voids in concrete. The usage of WMP reduced the porosity in concrete matrix physically, and had an important binding property which was developed by hydration of calcite and C3A chemically.

VI. EFFECT OF DIATOMITE AND WMP REPLACEMENT TOGETHER

Test results showed that up to a certain value of replacing cement with either diatomite or WMP using a superplasticizing admixture in concrete matrix had high compressive strength. It was thought that concrete added both diatomite and WMP using a superplasticizing admixture had higher compressive strength. The concrete specimens including the replacement of cement with the combination of 10% diatomite and 5% WMP showed the highest increase in compressive and flexural strength at all ages. The rate of strength depended on the clinker hydration and pozzolanic activity of diatomite, filler effect of WMP and water-reducing effect of a superplasticizing admixture and 5% WMP showed the highest increase in compressive and flexural strength at all ages. The rate of strength depended on the clinker hydration and pozzolanic activity of diatomite, filler effect of WMP and water-reducing effect of a superplasticizing admixture.

VII. RESULTS AND DISCUSSION

The replacement content of the PC by diatomite and WMP separately and together was changed from 5% to 15% by weight while aggregate, water and superplasticizing admixture quantities were kept constant. The replacement content of the coarse aggregate by marble aggregates was changed from 25% to 50% by weight while maintaining optimum percentages (%) of the diatomite and WMP. The compressive and flexural strength of the concrete were determined at 7 and 28 days.

Figure 9: Compressive strength test

Table 4

VARIATIONS OF MECHANICAL PROPERTIES OF TEST SPECIMENS

Series	Mix designation	Compressive strength (mpa) 7 days	Compressive strength (mpa) 28 days	Flexural strength (mpa) 7 days	Flexural strength (mpa) 28 days
M1	CC	27.2	38.44	5.1	5.3
M2	D 5 %	30.2	38.22	5.1	5.3
M3	D10%	35.11	44.44	6.87	6.95
M4	D 15%	27.55	36	5.0	5.1
M5	WMP 5%	30.6	39.4	5.1	5.3
M6	WMP 10%	25.8	31.1	4.8	5.0
M7	WMP 15%	21.6	28.3	4.6	4.75
M8	D 5%+WMP 5%	34.2	39.7	5.4	5.5
M9	D 10% + WMP 5%	35.3	42.0	5.3	5.5
M10	D 5% + WMP 10%	29.5	39.2	5.1	5.2
M11	D10% +WMP 10%	30.3	37.5	5.1	5.3

M12	D 10% +WMP 5%+ WMC 25%	30.77	40.22	5.2	5.3
M13	D 10% +WMP 5%+ WMC 50%	25.44	35.26	4.8	5.0

VIII. COMPRESSIVE AND FLEXURAL STRENGTH GRAPH FOR DIFFERENT MATERIALS

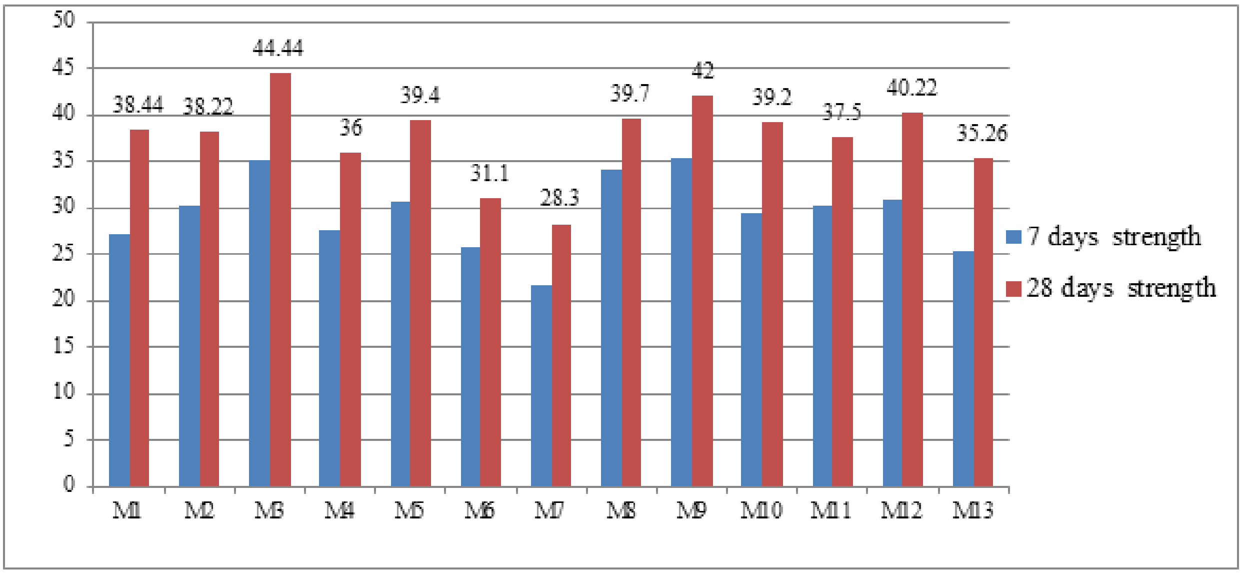

Figure 10: Compressive strength graph for different materials

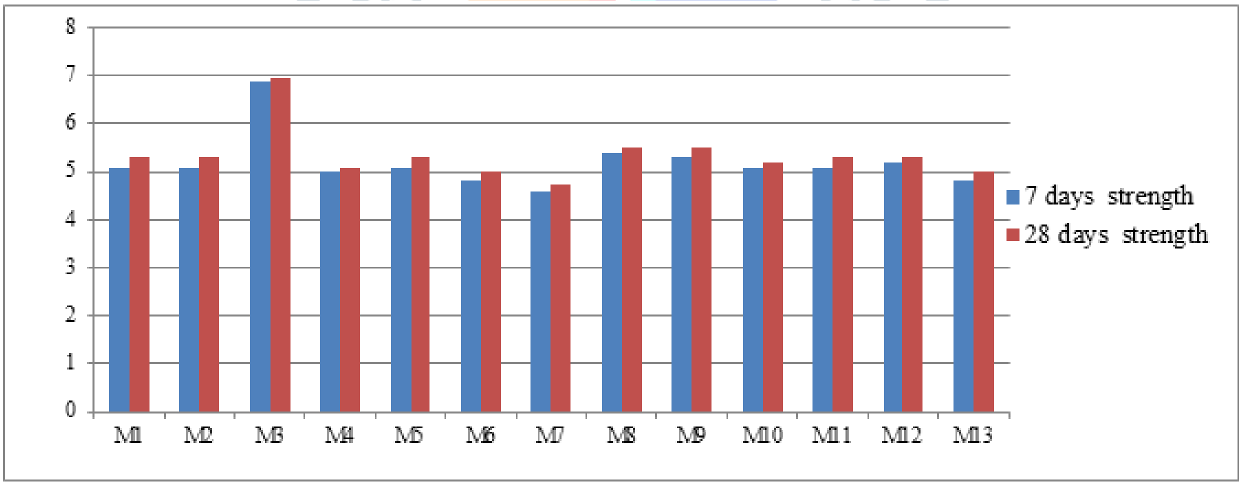

Figure 11: Flexural strength graph for different materials

SUMMARY AND CONCLUSIONS

The following conclusions are proposed based on the experimental study

- The compressive strength of concrete containing cement replacement by the diatomite 10% increased. It is known that the microfossils in diatomite which are source of reactive silica play an important role in the strength development of the concrete specimens.
- 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.

- The concrete specimens containing 10% diatomite +5% WMP mutual replacement of PC (D10M5) had highest compressive and flexural strength than the control concrete.
- The marble aggregate replacement to the coarse aggregate is 25% of the total volume of the aggregates together 10% diatomite + 5% WMP replacement by weight of the cement using a super plasticizing admixture had higher compressive strength than that of the control concrete specimens.
- Due to the severe scarcity of natural aggregates for the production of concrete primary aggregates are partially replaced with marble aggregates.
- Compressive strength of concrete is the main feature which allows assessment of concrete durability. Since diatomite and marble waste are available in vast amounts, by using these materials reduce the environmental problems, controlling emission of excessive greenhouse gases into the atmosphere and most economical for the production of concrete.

REFERENCES

[1] Baron J, Douvre C. Technical and economical aspects of the use of limestone filler additions in cement. World Cem 1987;18(3):100–4.

[2] Yıldız A. The geology of Seydiler diatomite deposit and investigation of usage as insulation brick, Master thesis, Afyon Kocatepe University; 1997 [inTurkish].

[3] Kastis D, Kakali G, Tsivilis S, Stamatakis MG. Properties and hydration of blended cements with calcareous diatomite. Cem Concr Res 2006;36:1821–6.

[4] Aydin AC, Gul R. Influence of volcanic originated natural materials as additive on the setting time and some mechanical properties of concrete. Construct Build Mater 2007;21:1277–81.

[5] Degirmenci N, Yılmaz A. Use of diatomite as partial replacement for Portland cement in cement mortars. Construct Build Mater 2009;23:284–8.

[6] Akbulut, H., Gürer, C., 2007. Use of aggregates produced from marble quarry waste in asphalt pavements. Build. Environ. 42 (5), 1921e1930.

[7] Amorim, P., de Brito, J., Evangelista, L., 2012. Concrete made with coarse concrete aggregate: influence of curing on durability. ACI Mater. J. 109 (2), 195e204.

[8] Aruntas¸ , H.Y., Gürü, M., Dayi, M., Tekin, I., 2010. Utilization of waste marble dust as an additive in cement production. Mater. Des. 31 (8), 4039e4042.

[9] Binici, H., Kaplan, H., Yilmaz, S., 2007. Influence of marble and limestone dusts as additives on some mechanical properties of concrete. Sci. Res. Essay 2 (9), 372e 379.

[10] Binici, H., Shah, T., Aksogan, O., Kaplan, H., 2008. Durability of concrete made with granite and marble as recycle aggregates. J. Mater. Process. Technol. 208 (1e3),299e308.