ISSN(Online): 2319 - 8753
ISSN (Print) :2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 1, January 2015

Study on the Properties of Concrete Incorporated With Various Mineral Admixtures – Limestone Powder and Marble Powder (Review Paper)

C.Dhanalaxmi[1], Dr.K.Nirmalkumar[2]

Student of Final Year M.E., Department of Structural Engineering, Kongu Engineering College, Perundurai, Erode, Tamil Nadu, India[1]

Professor, Department of Civil Engineering, Kongu Engineering College, Perundurai, Erode, Tamil Nadu, India[2]

ABSTRACT: In the last few decades, considerable research effort has been spent on the utilization of industrial by products (marble powder) and natural resources (limestone powder) as partial replacement of Ordinary Portland cement (OPC). The benefits of addition of supplementary materials to Ordinary Portland cement are well documented. Limestone powder substitution for cement makes perfect sense in these lower w/c concretes, saving money and energy and reducing carbon dioxide emissions. The use of marble powder as mineral addition for mortars and concretes, in the presence of a superplasticizing admixture provided maximum compressive strength at the same workability level, comparable to that of the reference mixture after 28 days of curing. This paper describes about the Properties of Concrete Incoparted with Mineral Admixtures – Limestone Powder and Marble Powder. Limestone Powder and Marble Powder are partially replaced with Ordinary Portland Cement for certain Percentages. Limestone powder (LMSP) and Marble Powder (MBP) was used as a compensating material with different ratio of cement include 0, 10, 15, 20, 25 and 30 %.

KEYWORDS: Limestone Powder (LMSP); Marble Powder (MBP); Ordinary Portland cement (OPC)

I. INTRODUCTION

Most cement plants consume much energy and produce a large amount of undesirable products, which affect the environment. In order to reduce energy consumption and CO_2 emission and increase production, cement manufacturers are blending mineral additions such as slag, natural pozzolan, sand and limestone (Ghrici et al, 2007), limestone has been used in concrete production for the last 25 years, not only for the main purposes of lowering the costs and environmental load of cement production, but also to increase the concrete durability, more recently limestone is also used as a filler material to improve the workability and stability of fresh concrete and for a high flowable concrete. The presence of limestone in hardened cement paste has a filler effect. Limestone is an inert or quasi-inert material being non-cementitious from hydraulic points of view.

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 C_3A. (Ali allahverdi et al,2010). Another partial replacement material used in this study is WMP which is of limestone origin waste material not being recycled nor used in any industries. Some factories have water recycling plants containing flocculation tank and filter press unit. The sample obtained from filter press is very fine (60 lm) and high purity (51.70% CaO) . In recent times, marble dusts have found some use in the construction industry and research has been conducted to examine their applications. Extensive studies were carried out and the hardened properties of bituminous concrete with

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marble dust as filler. Fillers are fine aggregate material that passes 0.063mm sieve. The behaviour of bituminous concrete with marble dust compared very well with bituminous concrete with lime and stone dust. (Satish et al). The abrasion resistance of concrete made by percentage substitution of sand by marble waste powder, the result compared well with concrete without marble powder. In the same study, increment in percentage of substitution of sand caused a significant increment in the Sodium Sulphate resistance of concrete whereas water penetration depth of concrete with marble dust at 15% substitution was found considerably less than that of concrete with 0% marble powder (Houari et al). More research is still needed to see its wider application in concrete, especially as partial replacement of cement. If this is successful there will be less demand on cement, thus providing possible solutions to environmental concerns of CO2 pollution and waste production. Therefore, utilization of Marble Powder in the production of new materials will help to protect environment. Recently the use of Marble Powder as replacement materials has been investigated. Agarwal and Gulati demonstrated that the presence of Marble Powder in the matrix enhances the early compressive strength of the mortar, and the strength of the mortar decreases with the increasing Marble Powder content.

II. PROPERTIES OF LMSP AND MBP

Limestone powder can also physically improve the denseness of hardened Portland cement paste due to its filling effect. The optimum use of limestone powder as a supplementary material to Portland cement has therefore technical benefits such as improved workability, bleeding control, lower sensibility to the lack of curing, and a little bit increased early strengths. On the other hand, loss of strength at later ages due to incorporation of limestone has also been reported. During the last decade, LMSP as calcite, or crystalline $CaCO_3$, has proven to be an effective partial replacement for OPC. LMSP has two functions: it acts as a relatively inert calcareous filler and a limited participant in the hydration process. During cement hydration, finely ground $CaCO_3$ reacts with C_3A and C_4AF to form high and low forms of carboaluminates. Calcium hemicarboaluminate forms as an early hydration product in calcite-containing OPC, and then converts nearly completely to calcium monocarboaluminate, a stable AFm phase, after about 28 days. The particle size of LMSP must be considered in the mix design because the early strength of the concrete depends on blended cement composition and LMSP fineness, since interaction between gypsum and limestone during early C_3A hydration interferes with setting time. An acceleration of C_3S hydration may occur at early ages when LMSP is interground with clinker. The catalytic effect results from the high specific surface area of LMSP, which produces nucleation sites for cement hydration products such as calcium carbosilicate hydrate, thus reducing the size of C–S–H agglomerations. In blended cements with up to 5% calcite, for example, almost all of the added calcite reacts with cement. The resulting concretes show compressive strength, flexural strength, and drying shrinkage similar to control concretes without LMSP. At 25% sand mass replacement with LMSP in mortar specimens, the fine $CaCO_3$ particles produce denser packing of the cement paste and better dispersion of cement grains. When LMSP replacement of OPC exceeds 15% by mass, however, the less reactive calcite has a dilution effect on the more reactive cement; the amount of cement paste is considerably reduced, resulting in lower compressive strengths and physical modifications. Durability decreases as water absorption and chloride diffusion coefficients increase. (Celik et al, 2014). It is observed that the incorporation of the Marble Powder in cement enhance the compressive strength of the mortar compared to the mortar. The increase in the strength of mortar can be attributed to the calcium carbonate content of Marble Powder. The additional surface area provided by the calcium carbonate in Marble Powder may provide sites for the nucleation and growth of hydration products that leads to further increase in strength .The flexural strength for the specimens with Marble Powder is explained.

III. MATERIALS FOR LMSP

Portland cement of type II ASTM standard, Limestone was used in this work. Limestone was firstly ground in a laboratory ball mill to attain a suitable fine powder. The specific surface area of limestone powder was measured in accordance with ASTM standard C240. The chemical composition and physical properties of the materials are given. Proportions of the studied mixes containing different amounts of limestone powder are given. (Ali Allahverdi et all,2010)

IV. MATERIALS FOR MBP

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The Marble samples were crushed, homogenized and mineralogical analyzed with the diffractometer. XRD patterns showed that calcite is the main crystalline mineral of the Marble Powder. In addition, dolomite is also identified in very low concentration at 31.5_ 2h. Chemical analysis of Marble Powder was performed on ground bulk samples with the XRF spectrometer. (Ali Ergun, 2011)

V. MIX PROPORTION FOR LMSP

The initial parameters considered for the cement mix design were the proportional aggregate fractions, powder content, and workability.The w/cm was held at 0.35 for all mixes;water reducer (SP) was added until the slump flow diameter was between 635 mm and 690 mm; and the flow time was 3–5 s until a diameter of 50 mm, T50, was attained. In order to reduce cement content, the ratio of total aggregates to cementing materials was fixed at 4 to 1, and the total cement replacement ratio ranged from 30 mass% to 65 mass%. The mix designs are designated 55 OPC–15 LMSP–30 Basaltic Ash, for example, for the 55 mass% OPC, 15 mass% LMSP, and 30 mass% Basaltic mix. The ratio of CA to FA was kept at a constant 1:1 mass% ratio. The control mixes contain either 100 OPC–0 LMSP–0 Basaltic Ash or 85 OPC–15 LMSP–0 Basaltic Ash as the powder materials. (Celik et al, 2014).

VI. MIX PROPORTION FOR MBP

The percentage of sand to cementitious materials (OPC+ MP) ratio was kept constant at 3:1 by weight in all mixes. The MP was used either as a replacement or as an addition of 0%, 5%, 10%, 15%, 20%, 30% and 50 % of cement content by weight. The water to cementitious materials [W/ (OPC +MP)] ratio was kept constant at 0.4 and the super-plasticizer dose was determined to obtain a constant slump flow diameter of 125 to 145mm. (Hassan A. Mohamadien, 2012)

VII. EXPERIMENTAL METHODS – MIXING OF LMSP

For each mix, concrete was prepared with the following procedure: the CA and a small amount of water were mixed for 30 s; the OPC, NP, and more water were added and mixed for 1 min; the limestone powder and the rest of the water were added and mixed for 1 min; the water reducer was added and mixed for 1 min. Finally, the FA was then added and mixed for 3 min. During that time, the mixer was stopped and the bottom scraped to remove any fine particles that might have collected at the bottom. The slump flow test was then performed. If the concrete was satisfactory, it was returned to the mixer and mixed for an additional minute before casting. If the slump flow was too low or flow time too high, the concrete was returned to the mixer, mixed for an additional minute and additional water reducer added until workability appeared sufficient. The slump flow test was again performed. If the concrete was satisfactory, it was then remixed for an additional minute before casting. Otherwise, it was discarded and the mix attempted again with more or less water reducer. The material was cast into eighteen 75X150 mm cylinders and three 100X200 mm cylinders in two lifts without mechanical vibration. Light shaking was allowed as the only method of consolidation.The cylinders were immediately covered with plastic wrap and left undisturbed for 24 h at 25 degree C in the ambient laboratory environment. The cylinders were then demolded. Each mix was then evaluated using slump flow, compressive strength, chloride penetration coefficient, water absorption, and gas permeability testing as basic indicators of workability,mechanical strength, and durability properties (Celik et all, 2014).

VIII. EXPERIMENTAL METHODS – MIXING OF MBP

A total of 12 concrete mixtures were prepared having a constant water/powder ratio of 0.4 and total powder of 475 kg/m3. The control mixture included only OPC as the binder while the remaining mixtures incorporated (OPC + MP) cementitious blends in which the OPC was replaced with MP. The replacement ratios for MP were 10%, 15%, 20%, 30% and 40% by mass of total cementitious materials. The mixing procedure and time are very important, thus the mixing process was kept constant for all concrete mixtures. The batching sequence consisted of homogenising the powder and aggregates for 30 s in a rotary planetary mixer, then adding 70% of water and mixed for 1 min. Thereafter remaining water (30%) with SP was introduced, and the concrete was mixed for 5 min, then the mixing was stopped for

2 min and again the concrete was further mixed for 30 s before it was discharged from the mixer (A.S.E. Belaidi et al, 2012).

IX. RESULTS AND DISCUSSIONS

1. Limestone powder has a greater surface area than RHA, and the smooth texture and spherical shape of the LS particles are also important in determining the workability characteristics.
2. The use of Limestone Powder is intended to enhance the particle distribution of the powder skeleton, reducing interparticle friction and ensuring greater packing density.
3. Mixtures containing more limestone powder had lower water–binder ratios and unit weights. The water–binder ratio controls the amount of free space in the system in terms of void volume and the amount of fine material required to fill the voids. Void filling in packed systems may improve the particle arrangement, ensuring better water distribution and adequate fluidity.
4. However, substantial increases in viscosity and unit weight occur at the concentration at which close packing is reached.
5. With suitable proportions of limestone powder, the compressive strength was increased can increases the strength, mostly due to the micro-filling ability and pozzolanic activity of RHA. The calcium carbonate in LS reacts very little with cement hydrates, and improvement in strength are essentially due to void filling and acting as nucleation sites for cement hydrate crystals, mechanically improving the microstructure of the bulk paste matrix and transition zone and leading to increased compressive strength (Gritsada Sua-iam et al, 2013)
6. The use of MP increased remarkably the slump flow diameters of mortars.
7. Control OPC mortar gave a slump flow value of 287 mm whereas mortars made with cement gave slump values ranging from 293 to 308 mm and hence in the limit(250–300 mm).
8. Flow time of mortar with cement decreases with the increase of Marble Powder, indicating that viscosity decreases. The V-funnel value for control OPC was 5.37 s whereas mortars made with Marble Powder gave values ranging from 2.82 to 3.74 s
9. It is observed that the incorporation of the Marble Powder in cement enhance the compressive strength of the mortar compared to the mortar containing Marble Powder. The increase in the strength of mortar can be attributed to the calcium carbonate content of Marble Powder. The additional surface area provided by the calcium carbonate in Marble Powder may provide sites for the nucleation and growth of hydration products that leads to further increase in strength.
10. The flexural strength of the Marble Powder mortar was lower than that of the mortar containing Marble Powder. Hence, the improvement of flexural strength may be attributed to the nucleation around the fine and additions that replace the large and oriented crystals of calcium hydroxide with numerous, small and less oriented crystal (A.S.E. Belaidi et al, 2012)

X. CONCLUSIONS

1. Limestone Powder offers a number of advantage for its use as cement compensating by enhance flow properties and increase compressive strength.
2. The slump of concrete relatively increase with higher values of the percentage of compensating of cement with Limestone Powder.
3. Based on the results, it was observed that the compressive strength of concrete increase with the increase in Limestone Powder compensating, concrete made with 15% Limestone Powder compensating showed higher compressive strength.
4. In general, the compressive strength of Limestone Powder concrete, like that of normal concrete, decrease with increasing temperature. At 400°C a higher value in the compressive strength is observed to that at 200 °C is observed.
5. Using Limestone Powder resulted in an increase in the dosage of the superplasticizer in order to keep the target slump flow.
6. All of the concrete mixtures had slump flow times within the range of 2–5 s. Increasing the amount of Limestone Powder, irrespective of the type, generally increased the duration to reach 500 mm (T500 mm) in the slump flow test.

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7. The increase in the amounts Limestone Powder increased the viscosity of concrete.
8. Addition of Limestone Powder provided greater compressive strength for the both series of the mixtures. Accordingly, it can be inferred that Limestone Powder affects the hydration kinetics of the cement paste as well as filling ability.
9. Splitting tensile strengths of concretes showed relatively the same trend with compressive strength. The maximum splitting tensile strength values were achieved in concretes having 10% replacement level of Limestone Powder.
10. All of the sorptivity coefficient values of concretes incorporated Limestone Powder, were considerably less than that of the control mix.
11. The addition of Limestone Powder generally improved the chloride penetration resistance of the concretes.
12. The general effect of Marble Powder is to retard the setting time of the cement.
13. The replacement of OPC by Marble Powder influences the strength of the mortar.
14. The Incorporation of Marble Powder in an enhanced flexural strength compared to the Conventional Concrete.
15. The concrete containing Marble Powder demands higher water content than Control Specimen.
16. At a constant water/powder ratio and SP content, the use of Marble Powder by substitution to cement has no negative effects on the workability of Concrete.

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