STUDY ON DURABILITY PROPERTIES OF LIMESTONE POWDER CONCRETE INCORPORATED WITH STEEL FIBRES

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ABSTRACT

Concrete is the most widely used construction material in the world with annual consumption estimated at between 21 and 31 billion tones. Structures made of concrete can have a long service life. In the last few decades, considerable research effort has been spent on the utilization of natural resources (limestone powder) as partial replacement of Ordinary Portland cement (OPC). The use of limestone 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. Here in this paper, we are discussing about the durability properties of concrete where Steel Fibres are added. Limestone Powder are partially replaced with Ordinary Portland Cement for certain Percentages. Limestone powder (LMSP) was used as a compensating material with different ratio of cement include 0, 10, 15, 20, 25 and 30 %. Addition of Steel Fibers (SF) into the concrete improves the crack resistance(or ductility) capacity of the concrete. Traditional rebars are generally used to improve the tensile strength of the concrete in a particular direction, whereas steel fibres are useful for multidirectional reinforcement.

Keywords: Coarse Aggregates (CA), Fine Aggregates (FA), Limestone Powder (LMSP), Ordinary Portland cement (OPC), Steel Fibres (SF).

I. INTRODUCTION

The benefits of addition of supplementary materials to Ordinary Portland cement are well documented. Limestone powder was substituted for cement makes perfect sense in these lower w/c concretes, saving money and energy and reducing carbon dioxide emissions. 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 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).

The marked brittleness with low tensile strength and strain capacities of high-strength concrete(HSC) overcame by the addition of steel fibres. The properties such as compressive, splitting tensile strengths, modulus of rupture and toughness index were examined. The steel fibres were added at the volume fractions of 0.5%, 1.0%, 1.5% and 2.0%. The compressive strength of the fiber-reinforced concrete reached a maximum at 0.75% volume fraction, being a 15.3% improvement over HSC (Song.P.S, Hwang.S, 2004). When steel fibres are added at 0.75%, an improvement of fire resistance and crack resistance as characterized by the residual strengths were observed. Mechanical strengths results indicated that SFRC performed better than non- SFRC (Lau.A, Anson.M, 2006). SFRC is tough and demonstrated a high residual strengths after appearance of the first crack. The role of steel fibres having different configuration in combination with steel bar reinforcement resulted that it was focused on the influence of the steel fibre types and amounts of flexural tensile strength, fracture behavior and workability of the steel bar reinforced high-strength concrete beams. For all the selected fibre contents, a more ductile behavior and higher load levels in the post-cracking range were obtained (Holschemacher.K et al, 2010).

Proper selection of other materials like microsilica, fly ash and superplasticizers has also high importance because of the influence on fresh and hardened concrete properties and this leads to effective and low cost solutions that may be used in new structures as well as for retrofitting existing ones (Abid.A.Shah, Ribakov.Y, 2011).

II. EXPERIMENTAL DETAIL

2.1 Materials Used

2.1.1 Cement

Ordinary Portland cement of 53 grade available in local market under the trademark name “Chettinad” cement is used in the investigation. The cement used has been tested for various properties as per IS: 4031-1988 and IS: 4032-1999. And found to be confirming to various specifications of IS: 12269-1987.

2.1.2 Aggregates

For the experimental work, locally available natural sand with 4.75 mm maximum size was used as fine aggregate. Crushed granite angular aggregate having specific gravity of 2.71 and of size passing through 12 mm and retained on 10 mm size sieve taken from local source was used as coarse aggregate. The fine and coarse aggregates were tested as per the procedure given in IS: 383-1970.

2.1.3 Limestone Powder (LMSP)

Limestones are sedimentary rocks primarily of Calcium Carbonate. Limestones are generally obtained from the calcareous remains of marine or fresh water organisms embedded in calcareous mud. They change from the Soft Chalks to hard crystalline rocks. Limestone Powder of size 300 microns is bought from Sri Venkateshwara Minerals, Karur.

2.1.4 Steel fibres (SF)

Steel fibres has led to the improvement of the concrete’s mechanical properties such as material toughness in tension as well as durability properties.

The fibers are bonded to the material, and allow the fiber reinforced concrete to withstand considerable stresses during the post-cracking stage. The actual effort of the fibres is to increase the concrete toughness.

2.1.5 Water

Available Portable Water was used for the experimental work.

2.1.6 Super plasticizers

Conplast SP-430 was used in the experimental work and it complies with IS: 9103: 1999 and BS: 5075 Part 3. Conplast SP 430 conforms to ASTM-C-494 Type ‘F’ ans Type ‘A’ depending on the dosages used.

Table 1 Physical Properties of FA, CA and LMP

Properties	FA	CA	LMP
Type	Uncrushed	Crushed	Powdery substance
Specific Gravity	2.56	2.80	2.71
Fineness Modulus	2.507	7.78	0.15 micron meter
Water absorption	1.05 %	0.5 %	0.43%
Moisture content	0.16 %	NIL	0.10%

Table 2 Physical Properties of Steel Fibres

Properties	Values
Density	7800 kg/m^3
Tensile Strength	400 to 1500 N/mm^2
Young’s Modulus	200000 N/mm^2

2.2 Concrete Mix Proportions

The Conventional mix LMSP-0 (0% LMSP) was designed as per IS: 10262-2009 for M40 grade concrete. Five concrete mixes (LMSP-5, LMSP-10, LMSP-15, LMSP-20, LMSP-25) was made by replacement of cement by LMSP in 5%, 10%, 15%, 20% and 25% respectively. The steel fibers of three different percentages 0.5%, 0.75% and 1.0% by volume of concrete was added to the optimum LMSP replacement. The water-cement ratio used in the experimental work was 0.4.

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.

2.3 Concrete Properties

The effect of incorporating limestone powder (5%, 10%, 15%, 20% and 25%) and steel fibre (0.5%, 0.75% and 1.0%) in concrete on durability properties were evaluated.

2.3.1 Fresh Concrete Properties

The effects of LMSP on Slump for M40 Grade concrete mixes LMSP-0%, LMSP-5%, LMSP-10%, LMSP-15%, LMSP-20% and LMSP-25% was determined. Slump cone of base diameter 20cm, top diameter 10cm and height 30cm cone was used and tested as per the procedure given in IS 1199-1959. Maximum slump of 65mm was observed for 15% replacement of Limestone Powder. Figure.1 shows the slump values for different replacements of LMSP.

2.3.2 Durability Properties on Concrete

The ability of concrete to resist weathering action, chemical attack and abrasion and also to withstand the conditions for which it is designed without deterioration for a long period of years is known as Durability. Acid attack, Alkali attack, Rapid Chloride Penetration Test (RCPT) are the various durability test performed on concrete specimen.The Cube specimen of size 150mm x 150mm x 150mm, Cylinder specimen of 100mm x 50mm for RCPT test was casted. The curing is done for 28 days. After 28 days curing, the specimen was immersed in the respective acids and alkalis for about 90 days. The Compressive strength and loss of weight of the specimen after the acid, alkaline attack were evaluated.

Various tests performed were Acid Test, Alkaline Test for a period of 90 days and Rapid Chloride Penetration test at the age of 28 days.

III. RESULTS AND DISCUSSIONS

3.1 Fresh Concrete Test Results

3.1.1 Slump Test

The slump test results for Limestone Powder at different proportions were shown in Figure 1. Maximum slump was observed for 15% replacement of Limestone Powder.

It is observed that the slump decreases as the percentage of Limestone Powder keeps increasing. Hence, optimal use of Limestone Powder gives better results on slump.

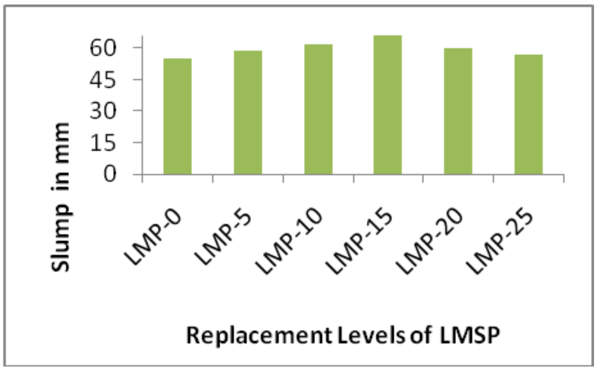

Fig.1 Slump Test Results

3.2 Durability Test Results

3.2.1 Acid Test

The acid attack was carried out on the concrete cubes of size 150mm x 150mm x 150mm. The acid attack was carried out on the concrete cubes of size 150mm x 150mm x 150mm. The concrete cubes casted were dried in normal room temperature of 27°C ± 2°C and after 28 days of curing, the specimens were taken out and allowed to dry for one day. The weight (W_1) of cubes was noted. The sulphuric acid solution was prepared by adding 3.0% sulphuric acid of 1N (by volume of water) to 20litres of distilled water. The concrete cubes were then immersed in 2.0% sulphuric acid solution for a period of 90days. The observations were then made after 90days from the date of immersion in sulphuric acid solution. Fig.2 shows the concrete specimen immersed in Acid Solution. After taking out from immersion and drying, the surfaces of the cubes were cleaned and they were kept in room temperature for a period of 24hours, the weight (W_2) of concrete cubes was noted. The compressive strength and loss of weight were calculated by using the following formulas below (Al Dulaaijan et al 2003, Gengying Li and Xiaohua Zhao 2003, Saricimen et al 2003, Bassuoni and Nehdi 2007)

- Compressive strength = (P/A) MPa

where, P = ultimate load (load of failure) in Newton

A = Area of cube in mm^2

- Loss of weight = $\frac{(W_1 - W_2)}{W_1} X\ 100$ %

Where, W_1 = Initial weight of concrete specimen

W_2 = Final weight of concrete specimen

Fig.2 Concrete Cubes in Acid Solution

The graphical representation of the compressive strength of M_{40} grade of concrete specimens subjected to acid resistance tests are shown in the Figure 3.

After immersion in acid solution, the compressive strength of M_{40} grade of concrete is reduced. The acid attack on the concrete occurs at values of pH below 6.5, a pH of less than 4.5 leading to severe acid attack. The rate of the acid attack also depends on the ability of hydrogen ions to be diffused through the cement gel (C-S-H) after calcium hydroxide $Ca(OH)_2$ has been dissolved and leached out of the concrete. The strength of the specimen prepared by using the conventional concrete, 15% LMSP + 0.5% SF, 15% LMSP + 0.75% SF, 15% LMSP + 1% SF after immersion are 48.32MPa, 47.88MPa, 47.21MPa and 46.72MPa respectively as shown in the Figure 3. There is a difference of 0.44MPa between Conventional concrete and 15% LMSP + 1% SF concrete is 1.6MPa. It can be concluded that by replacement of 15% LMSP, the required mean target compressive strength of the concrete is 47.55 is achieved.

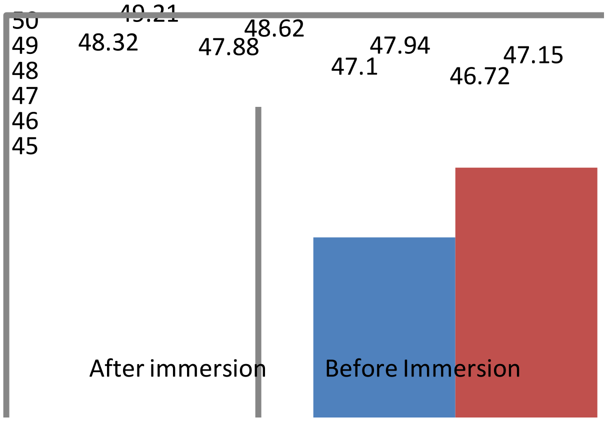

Fig.3: Compressive Strength of M_{40} grade of Concrete Specimens Before and after Immersion in Acid Solution

The graphical representation of the loss of weight of M_{40} grade of concrete specimens subjected to acid resistance tests are shown in the Figure 4.

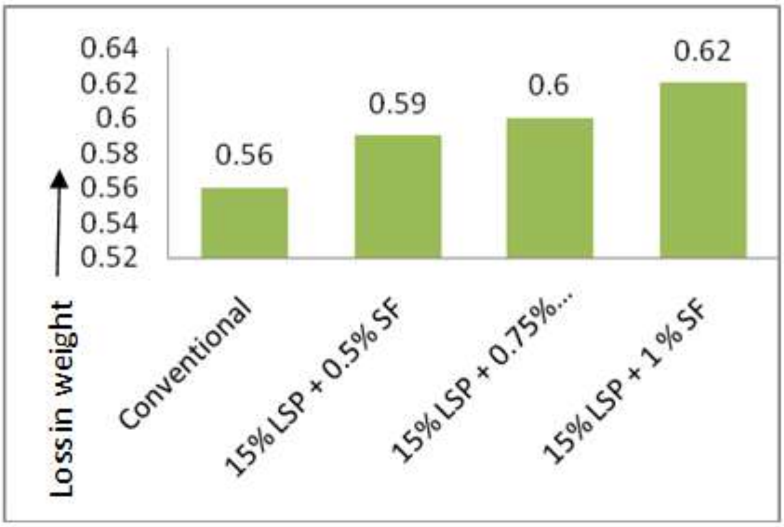

Fig.4: Loss of Weight of Concrete Specimens after Acid Resistance Test

The loss of weight of M_{40} grade of concrete, subjected to acid test, prepared by using the Conventional concrete, % LMSP + 0.5% SF, 15% LMSP + 0.75% SF, 15% LMSP + 1% SF are 0.56%, 0.59%, 0.60% and 0.62% respectively as shown in the Figure 4. The difference between the loss of weight of the conventional concrete and 15% LMSP + 1% SF is 0.06%. It can be inferred from the results that there is no significant effect on the concrete subjected to acid test.

3.2 Alkaline Attack Test

The alkaline attack test was carried out on the concrete cubes of size 150mm x 150mm x 150mm. The concrete cubes were prepared and allowed to cure for a period of 28days. The specimens were taken out from the curing tank and initial weight of the specimen was observed and noted. Then 3.0% of sodium hydroxide was aaded with water and the solution was prepared. The concrete cubes were then immersed in the solution for a period of 90days. Then the specimens were taken out from the alkaline water (sodium hydroxide solution) after 90days. The surface of the concrete cubes were cleaned, the specimens were weighed and then tested in the compression testing machine after the specimen had been centered in the testing machine. The compressive strength of the concrete cubes and the change in weight of the cubes was calculated by using the formula:

- Compressive strength = (P/A) MPa

where, P = ultimate load (load of failure) in Newton

A = Area of cube in mm^2

- Loss of weight = $\frac{(W_1 - W_2)}{W_1} X\ 100$ %

Where, W_1 = Initial weight of concrete specimen

W_2 = Final weight of concrete specimen

The graphical representation of the compressive strength of M_{40} grade of concrete specimens subjected to alkaline attack tests are shown in the Figure 5.

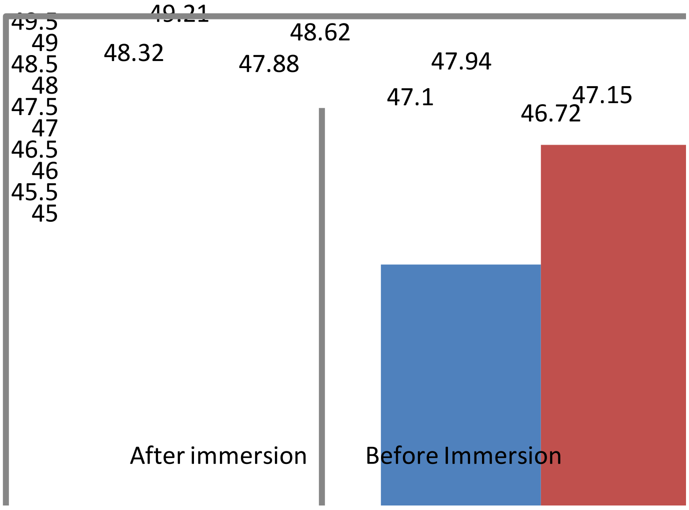

Fig.5: Compressive strength of M_{40} grade of concrete specimens before and after immersion in alkaline solution.

After immersion in alkaline solution, the compressive strength of M_{40} grade of concrete is reduced. The strength of the specimen prepared by using the conventional concrete, 15% LSP + 0.5% SF, 15% LSP + 0.75% SF, 15% LSP + 1% SF after immersion are 48.73MPa, 48.14MPa, 47.38MPa and 46.76MPa respectively as shown in the Figure 5. There is a difference of 0.44MPa between Conventional concrete and 15% LSP + 1% SF concrete is 1.97MPa. It can be concluded that by replacement of 15% LSP, the required mean target compressive strength of the concrete is 47.55 is achieved. The graphical representation of the loss of weight of M_{40} grade of concrete specimens subjected to alkaline attack tests are shown in the Figure 6.

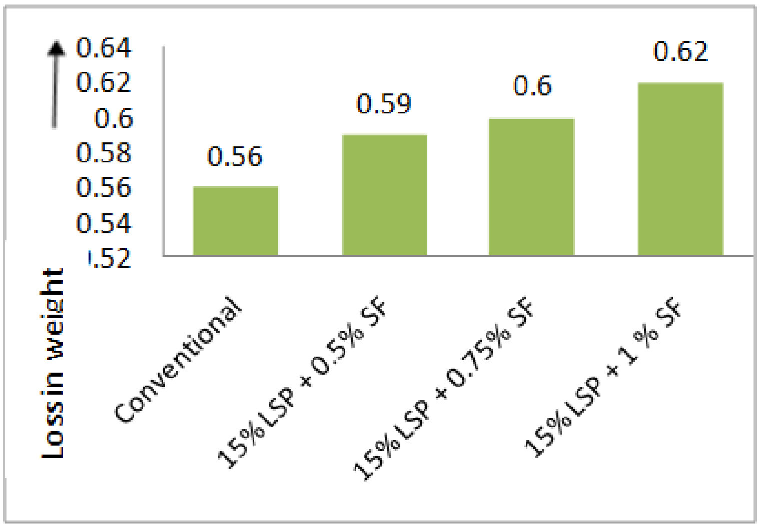

Fig.6 : Loss of Weight of Concrete Specimens After Alkaline Resistance Test

The loss of weight of M_{40} grade of concrete, subjected to alkaline attack test, prepared by using the Conventional concrete, % LSP + 0.5% SF, 15% LSP + 0.75% SF, 15% LSP + 1% SF are 0.55%, 0.58%, 0.62% and 0.65% respectively as shown in the Figure 6. The difference between the loss of weight of the conventional concrete and 15% LSP + 1% SF is 0.1%. It can be inferred from the results that there is no significant effect on the concrete subjected to alkaline test.

3.3 Rapid Chloride Penetration Test

The rapid chloride penetration test was performed as per ASTM C 1202 to determine the electrical conductance of the conventional concrete and concrete with 15% of limestone powder replacing cement and 1% Steel Fibres addition at the age of 28 days curing and to provide a rapid indication of its resistance to the penetration of chloride ions. The test method consisted of monitoring the amount of electrical current passed through 51mm thick slides of 102mm nominal diameter of cylindrical specimens for duration of six hours. The Rapid chloride penetration test apparatus consisted of two reservoirs. The specimen was fixed between two reservoirs using an epoxy bonding agent to make the test setup leak proof. One reservoir (connected to the positive terminal of the direct current source) with 3% sodium chloride solution. A DC of 60V was applied and maintained across the specimen by using two stainless steel electrodes(meshes) and the current across the specimen was recorded at 30minutes interval for duration of six hours. The total charge passed during this period was calculated in terms of coulombs using the trapezoidal rule as given in the ASTM C 1202,

- $Q = 900 (I_0 + 2I_{30} + 2I_{60} + \ldots + 2I_{330} + I_{360})$

Where Q = charge passed (coulombs)

I_0 = current (amperes) immediately after voltage is applied

I_t = current (amperes) at 't' minutes after voltage is applied

If the specimen diameter is other than 95mm, the value for total charge passed must be adjusted. The adjustment is made by multiplying the value established as above by the ratio of the cross sectional areas of the standard and the actual specimens.

- ie., $Q_S = Q_X / (3.75x)^2$

Where, Q_S = charge passed (coulombs) through a 95mm diameter specimen

Q_X = charge passed (coulombs) through x inch diameter specimen

x = diameter (inch) of the non-standard specimen

The standard chloride ion penetrability in the specimens based on current passed is given in the following table 3 as per ASTM C 1202.

Table 3: RCPT test results

S.No	Time (hrs)	Current I (A)
1	0	0
2	0.5	0.01017
3	1	0.02067
4	2	0.02303
5	3	0.02844
6	4	0.03315
7	5	0.04424
8	6	0.05123

The test results are compared to the values in the chart below. This chart was originally referenced in FHWA/RD-81/119 and is also used in AASHTO T277-83 and ASTM C1202 specifications.

$Q = 900 \times (I_0 + 2\times I_{30} + 2\times I_{60} + 2\times I_{120} \ldots\ldots + I_{360})$

$Q = 900 \text{ x } 1.329 = 1196.32$ C

Table 4: Chloride permeability based on charge passed

Charge passed (Columbs)	Chloride ion permeability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

For us, It is of "LOW" penetration.

IV. CONCLUSIONS

1. Limestone powder has a greater surface area and the smooth texture and spherical shape of enhance interparticle friction and ensuring greater packing density.
2. The slump of concrete relatively increase with higher values of the percentage of compensating of cement with Limestone Powder. The increase in the amounts Limestone Powder increased the viscosity of concrete.
3. 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 Limestone Powder.
4. The calcium carbonate in Limestone powder 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).
5. From the durability tests conducted on concrete, it was evident that there was no significant effect on concrete, when it was subjected to Acid test as well as Alkali Test.
6. The Rapid Chloride Penetration Tests conducted on concrete describes that the Chloride Permeability based on the charge passed was of "Low" penetration.

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