LIGHT WEIGHT CONCRETE BY USING STEEL SLAG & ZINC STEARATE

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Abstract: As the growth of population is the main problem faced by world, demand for construction of houses is increased day by day and demand for concrete also increased. In concrete coarse aggregate is used, which adds weight to the concrete. To reduce that weight steel slag is used in the place of coarse aggregate cement is used as a binding material which is responsible for environmental pollution. To reduce that pollution zinc stearate is used in the place of cement varying of strength with different propositions of zinc stearate is studies. By using 100% steel slag replaced with coarse aggregate decreased weight of 19% and zinc stearate is replaced with cement 1%, 2%, 3%, 4%, 5% decreased with of 19.3%, 19.2%, 19.1%, 19%, 18.9%.

Index Terms – light weight concrete, steel slag, zinc stearate.

CHAPTER- 1 INTRODUCTION

1.1 PORTLANDCEMENT:
Portland cement is a fine gray powder. Among the various kinds of cement it is the most commonly used as binding material. It is made of a mixture of chalk or limestone together with clay.

The limestone or chalk and the clay, in appropriate proportions, are fed into a wet grinding mill and reduced to a creamy substance known as slurry. The slurry is pumped to a large cylindrical "kiln" which is about 90 m long and 3 m in diameter. The slurry enters the kiln at its upper end while pulverized (crushed) coal, gas or other fuel is blown in at the other end.

1.2 AGGREGATES:
Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement). Aggregates can be divided into several categories according to different criteria.

A) IN ACCORDANCE WITH SIZE:
Coarse aggregate: Aggregates predominately retained on the No. 4 (4.75 mm) sieve. Form mass concrete, the maximum size can be as large as 150 mm.
Fine aggregate (sand): Aggregates passing No. 4 (4.75 mm) sieve and predominantly retained on the No. 200 (75 μm) sieve.

B) IN ACCORDANCE WITH SOURCE:
Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone, and gravel.
Manufactured (synthetic) aggregates: This is a kind of man-made materials produced as a main product or an industrial by-product. Some examples are blast furnaceslag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel).

C) IN ACCORDANCE WITH UNIT WEIGHT:
Light weight aggregate: The unit weight of aggregate is less than 1120 kg/m³. The corresponding concrete has a bulk density less than 1800 kg/m³. (Cinder, blast-furnaceslag, volcanic scoria).

1.3 STEELSLAG:
The current utilization rate of steel slag is only 22% in China, far behind the developed countries. At present, the amount of slag deposited in storage yard adds up to 30 Mt, leading to the occupation of farm land and serious pollution to the environment.
1.4 WATER

Water plays a vital role in achieving the strength of concrete. For completion hydration it requires about 3/10th of its weight of water. It is practically proved that minimum water cement ratio 0.35 is required for conventional concrete.

CHAPTER 2 LITERATUREREVIEW

2.1 ORDINARY PORTLAND CEMENT

Sashwata Mukherjee, Saroj Mandal, Adhikari, U.B

An experimental investigation has been carried out to study the physical and mechanical property of high volume fly ash cement paste. Ordinary portland cement was replaced by 0, 20, 30, 40, 50, 60 and 70 % class F fly ash (by weight). Water- binder ratio in all mixture was kept constant at 0.3. Cube specimens were compacted in table vibrator. As expected bulk density decreases with fly ash increment in the mixture. Apparent porosity and water absorption value increases with replacement of cement by fly ash. Results confirm the decrease in compressive strength at 3, 7 and 28 day with fly ash addition and it is more prominent in case of more than 30% fly ash content mixes. Ultrasonic pulse velocity test results indicate that the quality of the paste deteriorates with increase of fly ash content in the mixture.

M. Alexander, B. Elsener, E. Gartner, J.L. Provis, R.

The aim of Cement and Concrete Research is to publish the best research on cement, cement composites, concrete and other allied materials that incorporate cement. In doing so, the journal will present: the results of research on the properties and performance of cement and concrete; novel experimental techniques; the latest analytical and modelling methods; the examination and the diagnosis of real cement and concrete structures; and the potential for improved materials. The fields which the journal aims to cover are:

CHAPTER 3 MATERIAL PROPERTIES

3.1 CEMENT

3.1.1 NORMAL CONSISTENCY OF CEMENT

Aim: To determine the normal consistency of given cement sample.


Apparatus:

- Vicat apparatus (confirming to IS: 5513–1968) with plunger (10 mm diameter).
- Vicat mould.
- Gauging trowel.
- Measuring jar.
- Balance
- Tray
Theory

The standard consistency or normal consistency of a cement paste is defined as the amount of water (in percentage by weight of dry cement) that permits the Vicat plunger to penetrate to a depth of 5 to 7 mm from the bottom of the Vicat mould.

Procedure

- Take 400 g of cement and prepare a paste with about 28% (by weight of cement) water by taking care that the gauging time is from 3 to 5 minutes. The gauging time is counted from the instant of adding of water to dry cement until the mould is disfilled.

Observations

<table>
<thead>
<tr>
<th>Amount of water (%)</th>
<th>Initial reading</th>
<th>Final reading</th>
<th>Depth of penetration from bottom (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>38</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>32</td>
<td>38</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>35</td>
<td>38</td>
<td>32</td>
<td>6</td>
</tr>
</tbody>
</table>

Result

- Normal consistency of the given cement sample is 35%.
- This can be done by using a Vicat apparatus having 10 mm dia. of plunger.
- Where the depth of penetration of plunger is limited to 5 to 7 from bottom that % of water can be treated as consistency of cement.

3.1.2 INITIAL SETTING TIME OF CEMENT

Aim: To determine the initial setting time of the given cement sample.

Theory

In order to place the concrete in position, it is necessary that the initial setting time of the cement is not too low. Once it has been laid, the hardening should be rapid so that the structure can be subjected to the incidental loads as early as possible.

Procedure

- Prepare a cement paste by gauging 400 gms of cement with 0.85P water, where P is the normal consistency of the given sample of the cement.
- The gauging time is between 3 and 5 minutes; the gauging time is counted from the instant of adding water to dry cement.
- Fill the Vicat mould with the prepared paste and level it to the top of the mould. The cement block thus prepared is known as the test block.
- Place the test block on a non-porous plate and set it below the Vicat needle. Lower the needle to make contact with the surface of the test block.
- Quickly release the needle and allow it to sink. Note the reading.
- Repeat the experiment until the needle fails piercing the block at a level 5 to 7 mm from the bottom.

Observations

- Weight of cement taken: 400 gms.
- Amount of water added: 119 ml.

Results

Initial setting time of the given cement sample is: 36 min.

3.1.3 FINAL SETTING TIME OF CEMENT

Aim: To determine the final setting time of the given cement sample.

3.2 SPECIFIC GRAVITY OF CEMENT

**Aim:** To determine the specific gravity of given cement sample.

**Apparatus:**
- Specific gravity bottle of 50 ml capacity
- Balance of accuracy up to 0.1 g
- Kerosene

**Precautions**
- Only kerosene which is free of water is to be used.
- All air bubbles shall be eliminated in filling the apparatus and inserting the stopper.
- The whole procedure shall be done at temperature of 271°C.
- Weighings shall be done quickly after filling the apparatus and shall be accurate to 0.1 milligram.
- Precautions shall be taken to prevent expansion and overflow of the contents resulting from the heat of the hand wiping the surface of the apparatus.

**Observations**

The observations are as given below.
Weight of empty specific gravity bottle, \( W_1 = 44.1 \text{g} \)
Weight of sp. gr. bottle + wt. of cement, \( W_2 = 70 \text{ g} \)

\[
\text{Weight of sp. gr. bottle} + \text{cement} + \text{kerosene}, \ W_3 = 106.2 \text{g}
\]

\[
\text{Weight of sp. gr. bottle} + \text{kerosene}, \ W_4 = 83.8 \text{g}
\]

Specific gravity of cement = 
\[
(W_2 - W_1) \times \frac{(W_4 - W_1) - (W_3 - W_2)}{(W_3 - W_2)}
\]

Result
Specific gravity of cement is found to be \( \approx 3.15 \)

3.3 SIEVE ANALYSIS ZONE

The Sieve Analysis of sand is carried out to know the zone of the sand. The results of sieve analysis are given in Table No. 3

<table>
<thead>
<tr>
<th>Sievesize</th>
<th>Weight Retained gm</th>
<th>% passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75mm</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2.36mm</td>
<td>14</td>
<td>98.6</td>
</tr>
<tr>
<td>1.18mm</td>
<td>149</td>
<td>83.7</td>
</tr>
<tr>
<td>600 micron</td>
<td>564</td>
<td>27.3</td>
</tr>
<tr>
<td>300 micron</td>
<td>208</td>
<td>6.5</td>
</tr>
<tr>
<td>150 micron</td>
<td>56</td>
<td>0.9</td>
</tr>
<tr>
<td>75 micron</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1000 gm</td>
<td></td>
</tr>
</tbody>
</table>

Fig 3.3 IS Sieveset

From the sieve analysis result, sand falls under Zone II.

3.4 SPECIFIC GRAVITY AND WATER ABSORPTION

Aim: To determine the specific gravity and water absorption of coarse aggregate.

Apparatus:
- Balance: capacity not less than 3 kgs
- Oven
- Wirebasket
- Tray: Ashallow tray of area not less than 325 sq. cm, air tight container
- Cloths: Two pieces of soft absorbent clothes not less than 750 mm * 450 mm
Observations

Weight of aggregates (A) = 504 gms

Weight of pycnometer = 632 gms

Weight of pycnometer + Water (C) = 1508 gms

Weight of pycnometer + Water + aggregates (B) = 1815 gms

Weight of oven-dried sample (D) = 497 gms

Specific gravity = \( \frac{D(A - B)}{C(B - C)} \)

3.4.1 Calculation of Specific Gravity of Fine Aggregate

1) Weight of empty pycnometer (W1) = 632 gms.

2) Water equivalent volume of water (W4-W1)-(W3-W2) = 197 gms

Specific gravity = \( \frac{W2-W1}{W4-W1-(W3-W2)} \)

Water absorption = \( \frac{(A-D)}{100} \)

Result

- Specific Gravity of fine aggregate = 2.55
- Water Absorption of given aggregate = 0.6%

Result

- Specific Gravity of course aggregate = 2.97
- Water Absorption of given aggregate = 0.34%

Chapter 4: Objectives of Investigation

4.1 Steel Slag

Two common methods are used in steel production as basic oxygen furnace and electric arc furnace. Electric arc furnace is used more than 40% of global steel production in the world because scrap recycling is more economical and sustainable production.
ZINC STEARATE

Zinc stearate is a chemical material which is a perfect replacement with the cement.

So, in this investigation, Zinc Stearate has been used as replacement for Cement in different percentages and various tests have been conducted.

CHAPTER 5 MIX DESIGN

5.1 General:

In the present work, IS 10262-2009 has been used to get proportions for M20 grade Concrete, and Mix Design as follows.

5.2 Mix Design for M20

Grade of concrete $f_{ck} = 20$ Mpa

Max size of aggregate = 20

Degree of workability = 0.7 (Compacting factor)

Specific gravity of cement = 3.15

Specific gravity of sand = 2.6

Specific gravity of aggregate = 2.68

Sand belongs to zone II

1) Target mean strength for design

$F_{ck} = F_{ck} + T_s = 20 + 1.65 \times 4 = 26.6$ N/mm$^2$

2) Selection of water–cement ratio

As per IS:456–2000, Table no: 5, Water: Cement ratio adopted as 0.5

5. Determination of coarse aggregate and fine aggregate contents

Mix proportion then becomes

Water: Cement : Sand : Coarse aggregate

180 : 360 : 584.5 : 1169.4

0.5 : 1 : 1.62 : 3.39

For 1 bag of cement

Water $= 50 \times 0.4 = 20$ Lit

Cement $= 50$ kg

Sand $= 50 \times 1.62 = 81$ kg

Coarse aggregate $= 50 \times 3.39 = 165$ kg

In the present work, IS 10262-2009 has been used to get proportions for M40 grade Concrete, and Mix Design as follows.

- Required water content = 180 lit/m$^3$
CHAPTER 6 EXPERIMENTAL INVESTIGATIONS

6.1 DETAILS OF FINAL MIX PROPORTIONS IN M20 & M40

In this project, we are using steel slag as the replacement of coarse aggregate. We are replacing the coarse aggregate with 100% steel slag.

Zinc stearate is a chemical material which is perfectly replacement with the cement.

So, in this investigation, Zinc Stearate has been used as replacement for Cement in different percentages and various tests have been carried out.

It has been used in percentages of 1%, 2%, 3%, 4%, 5% replacements for Cement and several cubes have been casted in these percentages for investigation.

Table 6.1 Details of Weights (M20)

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Cement (Kg)</th>
<th>ZINC STREATE (Kg/m3)</th>
<th>FA (Kg/m3)</th>
<th>CA Replacement with steel slag (Kg/m3)</th>
<th>Water (Kg/m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>100% NA</td>
<td>360</td>
<td>N.A</td>
<td>0</td>
<td>584.5</td>
</tr>
<tr>
<td>2.</td>
<td>100%</td>
<td>360</td>
<td>0%</td>
<td>0</td>
<td>584.5</td>
</tr>
<tr>
<td>3.</td>
<td>99%</td>
<td>356.4</td>
<td>1%</td>
<td>3.6</td>
<td>584.5</td>
</tr>
<tr>
<td>4.</td>
<td>98%</td>
<td>352.8</td>
<td>2%</td>
<td>7.2</td>
<td>584.5</td>
</tr>
<tr>
<td>5.</td>
<td>97%</td>
<td>349.2</td>
<td>3%</td>
<td>10.8</td>
<td>584.5</td>
</tr>
<tr>
<td>6.</td>
<td>96%</td>
<td>345.6</td>
<td>4%</td>
<td>14.4</td>
<td>584.5</td>
</tr>
<tr>
<td>7.</td>
<td>95%</td>
<td>343</td>
<td>5%</td>
<td>18</td>
<td>584.5</td>
</tr>
</tbody>
</table>

NA = Natural aggregate concrete

6.2 COMPRESSIVE STRENGTH TEST

For each set, two standard cubes were casted to determine 7 and 28 days compressive strength after curing. Also, two of the cubes were casted to know the compressive strength of concrete. The size of cube is as per the IS 10086–1982.

6.3 CONCRETE MIXING

Thorough mixing is essential for the production of uniform, high-quality concrete. For this reason, equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work.

6.4 WORKABILITY

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete’s quality.

6.5 CURING

In all but the least critical applications, care needs to be taken to properly cure the concrete, to achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully.
6.6 PRECAUTIONS

Following precautions should be followed carefully while mixing and placing the concrete.
1. The plastic straws and sheetstakings should be cut up to our requirements without errors.
2. The water for curing should be tested every 14 days and the temperature of the water must be at 27±2°C.
3. The concrete moulds should be carefully removed from moulds, placed in water and taking to the tests without causing any failure.

6.7 Tests on Hardened Concrete

6.7.1 Compressive Strength of Concrete

Compressive strength was found out as per IS 516-1959. The compressive strength test was conducted after 28 days of curing. Standard cast iron moulds of dimensions 150 x 150 x 150 mm were used to cast the specimen. The capacity of the compressive strength testing machine used was 2000 KN. The Compressive Testing Machine used was 2000 KN.

![Compressive Strength with CTM](image)

Assuming concrete specimen behaves as an elastic body a uniform lateral tensile stress of Partelasticity (Ft) action along the vertical plane causes the failure of the specimen, which can be calculated from the formula.

\[ Ft = \frac{2P}{\pi DL} \]

Where \( P \) = load at failure, \( D \) = Diameter and \( L \) = length of the cube.
Aim: To determine the rupture of the concrete beam

Materials and equipment: Universal Testing Machine, A Concrete Beam Specimen, Bending stress

7.1 General

In this chapter, the result of workability, compressive strength, split tensile strength, and Flexural Tests for different Concrete Mix proportions of M40 with varying percentage of Zinc Stearate with cement are shown and discussed.

7.2 Normal Consistency of Cement

Table 7.2: Normal consistency of cement

<table>
<thead>
<tr>
<th>TRAIL NO.</th>
<th>WEIGHT OF CEMENT (gm)</th>
<th>% OF WATER ADDED</th>
<th>DEPTH OF PENETRATION N (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>35</td>
<td>6</td>
</tr>
</tbody>
</table>

Hence, the Consistency of cement is 35%.

7.3 Initial setting time of cement

Weight of cement sample taken = 400 gms

Consistency of cement = 35% as obtained above

Volume of water to be added = 0.85% * 35/100 * 400
Initial setting time obtained = 36 minutes.

7.4 Final setting time of cement

Weight of cement sample taken = 400 gms
Consistency of cement = 35% as obtained above
Volume of water to be added = 0.85% * 35/100 * 400 ml

Graph 7.7.1 Workability Comparison
Final Test Results

7.4.1 Workability

Table 7.7.1: Workability (Slump in mm) Results

<table>
<thead>
<tr>
<th>Mix property</th>
<th>Workability (Slump in mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Of Concrete</td>
<td>M20</td>
</tr>
<tr>
<td>Conventional concrete</td>
<td>85</td>
</tr>
<tr>
<td>Steelslag concrete (100%)</td>
<td>80</td>
</tr>
<tr>
<td>Zinc stearate concrete (1%)</td>
<td>90</td>
</tr>
<tr>
<td>Zinc stearate concrete (2%)</td>
<td>96</td>
</tr>
<tr>
<td>Zinc stearate concrete (3%)</td>
<td>104</td>
</tr>
<tr>
<td>Zinc stearate concrete (4%)</td>
<td>110</td>
</tr>
<tr>
<td>Zinc stearate concrete (5%)</td>
<td>117</td>
</tr>
</tbody>
</table>

7.7.3 Flexural test

Beams specimen of 50 cm length * 10 cm width * 10 cm height

Table 7.7.4: Flexural strength results at 28 days

<table>
<thead>
<tr>
<th>Mix property</th>
<th>Average flexural strength (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Of Concrete</td>
<td>M20</td>
</tr>
<tr>
<td>Conventional concrete</td>
<td>2.91</td>
</tr>
<tr>
<td>Steelslag concrete (100%)</td>
<td>2.35</td>
</tr>
<tr>
<td>Zinc stearate concrete (1%)</td>
<td>2.28</td>
</tr>
<tr>
<td>Zinc stearate concrete (2%)</td>
<td>2.21</td>
</tr>
<tr>
<td>Zinc stearate concrete (3%)</td>
<td>2.17</td>
</tr>
<tr>
<td>Zinc stearate concrete (4%)</td>
<td>2.06</td>
</tr>
</tbody>
</table>

Graph 7.7.2: Flexural strength results at 28 days
7.5 DISCUSSION OF TEST RESULTS

7.8.1 Workability

By replacement of Steel slag in place of Coarse aggregate, the Workability of Concrete is decreased by 6.85% up to 100% replacement. It is also further varied with replacement of zinc stearate 1%, 2%, 3%, 4% & 5% Workability is decreased by 2.36%, 5.11%, 6.22%, 7.4%, 7.9%, 8.2% for CC, M1, M2, M3, M4, M5 mixes with zinc stearate of 1%, 2%, 3%, 4% & 5% replacement.

7.8.4 Flexural Strength

For 7 days

By replacement of Steel slag in place of Coarse aggregate, the flexural strength of Concrete is decreased by 13.6% up to 100% replacement. It is also further varied with replacement of zinc stearate 1%, 2%, 3%, 4%, 5% flexural strength is decreased by 6.4%, 7.74%, 8.32%, 10.5% & 12.3% for CC, M1, M2, M3, M4, M5 mixes with zinc stearate of 1%, 2%, 3%, 4%, 5% replacement.

For 28 days

By replacement of Steel slag in place of Coarse aggregate, the flexural strength of Concrete is decreased by 13.25% up to 100% replacement. It is also further varied with replacement of zinc stearate 1%, 2%, 3%, 4%, 5% flexural strength is decreased by 4.81%, 6.74%, 8.32%, 10.5% & 12.3% for CC, M1, M2, M3, M4, M5 mixes with zinc stearate of 1%, 2%, 3%, 4%, 5% replacement.

8.0 CONCLUSION

- From the results, content of zinc stearate 1% to 5% can be used in construction works.
- If the percentage zinc stearate increases in cement, then decreases the strength of concrete but reduces self-weight.
- By effective utilization of the waste material like steel slag, the strength aspects can be increased, and can reduce their pollution by converting this pollution causing particulate matter into useful building materials.
9.0 REFERENCES


2. Cement and Concrete: Environmental Consideration from EBN (Environmental Building Volume 2, No. 2 - March/April 1993).

3. Indian Concrete Journal

4. Indian Unconstrained Journal


