INVESTIGATION OF INTERLOCKING CONCRETE BLOCK OF DIFFERENT CONFIGURATION TO ENHANCE STRENGTH AND SEISMIC EFFECT

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Abstract — Interlocking blocks play an influential role in strength development of any structure it provides effective assistance in seismic and compression ability. Majority of constructions is possible due to blocks. These blocks comprise the different configuration of interlocking embargo with each other to resist displacement with resistibility against earthquake and sudden impacts.

In present analysis experimental analysis was performed on interlocking blocks of two configurations named as sample – 1 and sample – 2 in which four holes and three holes were implemented on concrete block to success the interlocking effect the M30 grade is used with 12 mm aggregate size, casted in mould and curing is done for 7 and 28 days total 32 samples were prepared for testing the effect of flexural and compression effect with a load of 280, 330, 360, 400 KN, thermal effect was also analyzed for analyzing thermal resistibility of interlocking block. Further seismic analysis was done using ANSYS CIVIL 15.0 to predict natural frequency, from these analysis it was observed that Sample – 2 (three holes configuration interlocking block) found to be higher strength compared to sample – 1 (four holes configuration), thus sample – 2 could be considered for future investigation in interlocking blocks.

Keywords — Interlocking Block, Concrete, Compressive Strength, Flexural Strength, Thermal effect, Seismic effect.

I INTRODUCTION

Interlocking Concrete Block (ICB) has been appreciably used in some of international locations for pretty sometime as a specialised hassle-fixing approach for presenting pavement in areas where conventional kinds of creation are less long lasting because of many operational and environmental constraints. ICB technology has been introduced in India in construction, a decade in the past, for precise requirement viz. Footpaths, parking areas and so on. But now being followed considerably in different makes use of where the conventional construction of pavement using hot bituminous mix or cement concrete era isn’t possible or suitable. The paper dwells upon cloth, production and laying of concrete block pavement as a brand new technique in creation of pavement using Interlocking Concrete Blocks.

II Application of ICB Technology

Some of the proven areas where ICBP technology is being applied are listed below [9 & 10]:

1. Non-traffic Areas: Building Premises, Footpaths, Malls, Pedestrian Plaza, Landscapes, Monuments Premises, Premises, Public Gardens/Parks, Shopping Complexes, Bus Terminus Parking areas and Railway Platform, etc.

2. Light Traffic: Car Parks, Office Driveway, Housing Colony Roads, Office/Commercial Complexes, Rural Roads, Residential Colony Roads, Farm Houses, etc.

4. Heavy and Very Heavy Traffic: Container/Bus Terminals, Ports/Dock Yards, Mining Areas, Roads in Industrial Complexes, Heavy-Duty Roads on Expansive Soils, Bulk Cargo Handling Areas, Factory Floors and Pavers, Airport Pavement, etc.

III. Materials

The quality of materials, cement concrete strength, durability and dimensional tolerance of paving blocks, etc. is of great importance for the satisfactory performance of block pavements. These aspects and the block manufacturing process itself, which immensely affect the quality of paving blocks, have been outlined in the Indian Roads Congress Special Publications [9]. The Central Road Research Institute (CRRI) has prepared the specifications for ICBP [10].

IV. Paving Blocks

The quality of materials, strength of cement concrete and durability as well as dimensional tolerances etc. are of great importance for satisfactory performance of block pavement. The recommended thickness of block and grades of concrete for various applications and specification for paving in which materials used for preparation of blocks, physical requirements, physical test methods, sampling and acceptance criteria has already been formulated in BIS Code [10].

Problem Identification

As per literature survey the previous investigations on flexible pavement addition of waste plastic, a studied the durability, flexibility and temperature resistance is less to the conventional mix. Flow stability and strength of pavement during high temperature and loads, hence required to be improvement in stability, strength, maintain durability and temperature resistibility of pavement due to different traffic conditions including environmental effects.

2.4 Problem Formulation

To resolve the above described identified problem the several sets of sample of interlocking block was prepared including different interlocking phenomenon in block mix with M30 grade, the several tests is to be performed on each sample for following outcome results i.e. temperature resistibility, compression strength, flexural strength, seismic resistibility.

Objectives

- To create samples of interlocking blocks including combination of different configuration of sample.
- To perform tests for determination of different effects this will be obtained after optimizing the interlocking block.
- To compare the results and to determine optimum strength and properties of interlocking block.
- Particular test would be performed in interlocking block sample whose optimum results are improved than other samples.

3.3 ORDINARY PORTLAND CEMENT

1. The ultra tech cement of 53grade manufactured by the ULTRATECH Cement Company was considered in this study, which is Indian standard code – IS 12269:1987 having strength for 28 days being a minimum of 58MPa or 530 kg/sqcm.

Design of Concrete Mix of Grade M - 30

CONCRETE MIX DESIGN GRADE M - 30

(FOR INTERLOCKING BLOCK)

1. STIPULATIONS FOR PROPORTIONING

(a) Grade designation : M - 30
(b) Type of cement : OPC- 53 grade confirming to IS:12269
(c) Maximum nominal size of aggregate : 12 mm (angular)
(d) Minimum cement content : 380 Kg/m³
(f) Maximum water - cement ratio : 0.38 IRC-SP-63-2004

(g) Type of aggregate : Crushed angular aggregate


(i) Exposure condition : Normal

(j) Method of concrete placing : Machine

(k) Degree of supervision : Good

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### TEST DATA FOR MATERIALS

<table>
<thead>
<tr>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
</tr>
</thead>
</table>
| Cement used | Specific Gravity of Cement | Specific Gravity of :
| : ULTRATECH OPC - 53 Grade | : 3.15 | :
| | | 1) Coarse aggregate : 12 mm : 2.893
| | | 2) Fine aggregate, Classified sand : 2.808
| | | Water absorption :
| | | 1) Coarse aggregate : 12 mm : 0.862
| | | 2) Fine aggregate, Classified sand : 1.528
| | | AIV ( % ) : 12.160
| | | Free (Surface) moisture :
| | | 1) Coarse aggregate : NIL
| | | 2) Fine aggregate : NIL

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### TARGET STRENGTH FOR MIX PROPORTIONING

\[ f'_{ck} = f_{ck} + 1.65 \sigma \]

\[ f'_{ck} = \text{target average compressive strength at 28 days} \]

\[ f_{ck} = \text{characteristic compressive strength at 28 days} \]

\[ \sigma = \text{standard deviation} \]

From MORT&H Table:1700-5  Current margin for M-30 grade concrete is 12 N/mm²

Therefore, target strength = 30+12 = 42 N/mm²

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### SELECTION OF WATER - CEMENT RATIO

From IRC-SP-63-2004, maximum W/C ratio = 0.38 (Adopted)

(Water Cement Ratio= 0.34 To 0.38)
CALCULATION OF CEMENT CONTENT

Water cement ratio = 152/0.38 = 400

From IRC-SP-63-2004 minimum cement content. = 380 Kg/m³

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From IRC-SP-63-2004, volume of coarse aggregate corresponding to 12.0 mm size aggregate and fine aggregate (Zone -II) = 0.40

Volume of fine aggregate = 1 - 0.40 = 0.60

Sample: 12 mm Aggregate

AVERAGE % PASSING

<table>
<thead>
<tr>
<th>IS Sieve (mm)</th>
<th>% PASSING</th>
<th>AVERAGE % Passing</th>
<th>Specific Limit as per Morth table - 1000-1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample 1</td>
<td>Sample 2</td>
<td>Sample 3</td>
</tr>
<tr>
<td>20</td>
<td>100.00</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
<td>100.00</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>82.05</td>
<td>80.13</td>
<td>82.45</td>
</tr>
<tr>
<td>4.75</td>
<td>8.28</td>
<td>7.87</td>
<td>6.31</td>
</tr>
</tbody>
</table>

GRADATION OF FINE AGGREGATE

Sample: 1 (C. Sand)

<table>
<thead>
<tr>
<th>IS (mm)</th>
<th>Sieve</th>
<th>Wt. Retained (gm)</th>
<th>% Retained</th>
<th>Cum. % Ret.</th>
<th>% Passing (Zone -I)</th>
<th>Specific Limit as per IS 383</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00</td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>100.00</td>
<td>100</td>
</tr>
<tr>
<td>4.75</td>
<td></td>
<td>9.00</td>
<td>0.75</td>
<td>0.75</td>
<td>99.25</td>
<td>90 - 100</td>
</tr>
<tr>
<td>2.36</td>
<td></td>
<td>135.00</td>
<td>11.25</td>
<td>12.00</td>
<td>88.00</td>
<td>60 - 100</td>
</tr>
<tr>
<td>1.18</td>
<td></td>
<td>375.00</td>
<td>31.25</td>
<td>43.25</td>
<td>56.75</td>
<td>30 - 70</td>
</tr>
<tr>
<td>0.60</td>
<td></td>
<td>295.00</td>
<td>24.58</td>
<td>67.83</td>
<td>32.17</td>
<td>15 - 34</td>
</tr>
<tr>
<td>0.30</td>
<td></td>
<td>203.00</td>
<td>16.92</td>
<td>84.75</td>
<td>15.25</td>
<td>5 - 20</td>
</tr>
<tr>
<td>0.15</td>
<td></td>
<td>85.00</td>
<td>7.08</td>
<td>91.83</td>
<td>8.17</td>
<td>0 - 10</td>
</tr>
<tr>
<td>PAN</td>
<td>98.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1200.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.10 MIX CALCULATIONS

For,

<table>
<thead>
<tr>
<th>Cement Content ( Kg )</th>
<th>= 400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water - Cement ratio</td>
<td>= 0.38</td>
</tr>
<tr>
<td>Water Content (Ltr )</td>
<td>= 152</td>
</tr>
</tbody>
</table>

The mix calculations per unit volume of concrete is as follows:

(a) Volume of concrete mix = 1 M³

(b) Volume of Cement = (Mass of Cement / Sp. Gravity of Cement) x (1/1000)
= 400 / 3.15 x 1/1000
= 0.127

(c) Volume of Water = (Mass of Water / Sp. Gravity of Water) x (1/1000)
= 152 / 1 x 1/1000
= 0.152

(d) Volume of Admixture = Dry & Low Slump Mix

(e) Volume of all in aggregate = [1 - (b+c)]
= 0.721

(f) Mass of Coarse aggregate = e x Volume of Coarse aggregate x Sp. Gravity of Coarse aggregate x 1000
= 0.721 x 0.40 x 2.893 x 1000
= 834.3412 Kg
12 mm aggregate (40 %) = 834.34 Say 834.34 Kg

(g) Mass of Fine aggregate = e x Volume of Fine aggregate x Sp. Gravity of Fine aggregate x 1000
= 0.721 x 0.60 x 2.808 x 1000
= 1214.7408 Say 1214.74 Kg
c. Sand (60 %) = 1214.74 Say 1214.74 Kg

MIX PROPORTIONS FOR TRIAL NO. 3

Condition of aggregate : SSD

Cement = 400.00 Kg
Coarse aggregate (12 mm) = 834.34 Kg
Fine aggregate (Sand) = 1214.74 Kg
Water = 152.00 Ltr

2601.08 Kg

NOTE: Aggregate to be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregate are dry, the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made in mass of aggregates. the surface water and percent water absorption of aggregates shall be determined according to IS:2386 (Part-3)

3.12 AGGREGATE IMPACT VALUE TEST

Laboratory No. MIX DESIGN M-30 Date of Sampling 10/02/2021
Type of Material COARSE AGGREGATE 10 MM Sampled by Jointly
Location of sample 103+200 Date of testing 17/02/2021
<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Observation</th>
<th>Unit</th>
<th>Sample No.1</th>
<th>Sample No.2</th>
<th>Sample No.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wt. of oven dried aggregate before crushing W1</td>
<td>gm</td>
<td>355.5</td>
<td>360.5</td>
<td>358.0</td>
</tr>
<tr>
<td>2</td>
<td>Wt. of aggregate retained on 2.36 mm sieve after crushing W2</td>
<td>gm</td>
<td>326.5</td>
<td>327.0</td>
<td>325.0</td>
</tr>
<tr>
<td>3</td>
<td>Wt. of aggregate passed 2.36 mm sieve after crushing W3</td>
<td>gm</td>
<td>29.0</td>
<td>33.5</td>
<td>33.0</td>
</tr>
<tr>
<td>4</td>
<td>A.I.V (W3 / W1) X 100</td>
<td>%</td>
<td>8.2</td>
<td>9.3</td>
<td>9.2</td>
</tr>
<tr>
<td>5</td>
<td>Average A.I.V</td>
<td>%</td>
<td>8.89</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mixing of materials**

After the process of batching, the materials were selected in a ratio and they were mixed together, the process is called the Mixing. Mix was prepared using volumetric proportions for M30. The following figure shows the process of manual mixing of material.

**Placing of concrete**

After mixing of materials, they were placed in the cube mould and the process of placing

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**Figure – Mould sample for interlocking block.**

The process included the 5 basic steps and these steps are as follows:

- Weighing & Batching
- Mixing
- Placing
- Compacting
- Curing

**Aggregate Sample**

**Figure: Sample of aggregate.**

**Figure: Placing of concrete in mould for interlocking block.**
Curing of test samples

The total 24 samples were prepared using different proportions as given in Table 3-3. These test samples were cured for 7 days and 28 days respectively & the process of curing is shown in figure.

![Curing of samples](image1)

Figure: curing of samples

![Compressive strength test of interlocking block](image2)

Figure: Compressive strength test of interlocking block.

COMPRESSIVE STRENGTH TEST RESULT

Below shown table represents the comparison between compressive stresses obtained with respect to different loads applied on interlocking block in 7 days and 28 days.

<table>
<thead>
<tr>
<th>Load (KN)</th>
<th>Sample - 1 (7 days)</th>
<th>Sample - 1 (28 days)</th>
<th>Sample - 2 (7 days)</th>
<th>Sample - 2 (28 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>17.69</td>
<td>26.58</td>
<td>18.06</td>
<td>25.85</td>
</tr>
<tr>
<td>330</td>
<td>16.66</td>
<td>24.25</td>
<td>18.96</td>
<td>24.23</td>
</tr>
<tr>
<td>360</td>
<td>15.06</td>
<td>23.33</td>
<td>16.55</td>
<td>24.85</td>
</tr>
<tr>
<td>400</td>
<td>14.96</td>
<td>20.96</td>
<td>15.56</td>
<td>22.06</td>
</tr>
</tbody>
</table>

Table: Results of compressive strength test for sample - 1.

![Graph shows results of compressive strength test](image3)

Figure: Graph shows results of compressive strength test.

Above shown graph represents a comparative analysis for compression testing in sample – 1 of interlocking block from above comparison the conclusion would be withdrawn for compressive strength of different configurations, the failure load of sample – 1 from which cracks are initiated at 360 KN load.

Table 4.2 Results of compressive strength test for sample - 2.

<table>
<thead>
<tr>
<th>Load (KN)</th>
<th>Sample - 2 (7 days)</th>
<th>Sample - 2 (28 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>18.06</td>
<td>25.85</td>
</tr>
<tr>
<td>330</td>
<td>18.96</td>
<td>24.23</td>
</tr>
<tr>
<td>360</td>
<td>16.55</td>
<td>24.85</td>
</tr>
<tr>
<td>400</td>
<td>15.56</td>
<td>22.06</td>
</tr>
</tbody>
</table>

![Graph shows results of compressive strength test](image4)

Figure: Graph shows results of compressive strength test.

Above shown graph represents a comparative analysis on interlocking block for compression testing from above comparison the conclusion would be withdrawn for different loads in 7 days and 28 days cured samples the failure load of sample – 2 from which cracks are initiated at 400 KN load.
FLEXURAL STRENGTH TEST RESULT

Table 4.3 Results of flexural strength test in different loads.

<table>
<thead>
<tr>
<th>Load (KN)</th>
<th>7 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>16.22</td>
<td>22.66</td>
</tr>
<tr>
<td>330</td>
<td>16.96</td>
<td>21.45</td>
</tr>
<tr>
<td>360</td>
<td>15.55</td>
<td>19.65</td>
</tr>
<tr>
<td>400</td>
<td>14.02</td>
<td>18.52</td>
</tr>
</tbody>
</table>

Figure 4.3 Graph shows results of flexural strength test.

Above shown graph represents a comparative analysis of 7 days and 28 days cured samples of interlocking block for flexural testing from above comparison the conclusion would be withdrawn for flexural strength for sample – 1, the observed failure load during testing is found at 360 KN.

Table 4.5 - Represents the modes and frequency of interlocking block wall of sample – 1 and sample - 2.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Natural Frequency (KHz) (Sample - 1)</th>
<th>Natural Frequency (KHz) (Sample - 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.26</td>
<td>18.26</td>
</tr>
<tr>
<td>2</td>
<td>26.88</td>
<td>27.52</td>
</tr>
<tr>
<td>3</td>
<td>35.03</td>
<td>36.85</td>
</tr>
<tr>
<td>4</td>
<td>38.06</td>
<td>40.55</td>
</tr>
<tr>
<td>5</td>
<td>46.51</td>
<td>47.96</td>
</tr>
<tr>
<td>6</td>
<td>47.32</td>
<td>50.63</td>
</tr>
<tr>
<td>7</td>
<td>48.06</td>
<td>51.98</td>
</tr>
<tr>
<td>8</td>
<td>53.76</td>
<td>54.32</td>
</tr>
<tr>
<td>9</td>
<td>63.52</td>
<td>64.55</td>
</tr>
<tr>
<td>10</td>
<td>64.07</td>
<td>66.62</td>
</tr>
</tbody>
</table>

Table: Results of flexural strength test at different loads.

<table>
<thead>
<tr>
<th>Load (KN)</th>
<th>7 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>280</td>
<td>17.55</td>
<td>25.85</td>
</tr>
<tr>
<td>330</td>
<td>16.52</td>
<td>24.23</td>
</tr>
<tr>
<td>360</td>
<td>15.36</td>
<td>24.85</td>
</tr>
<tr>
<td>400</td>
<td>14.58</td>
<td>22.06</td>
</tr>
</tbody>
</table>

Figure 4.4 Graph shows results of compressive strength test.

Figure – Comparison of modes and frequency of interlocking block wall of sample – 1 and sample - 2.

The natural frequencies obtained were demonstrated for sample – 1 and sample - 2 identifies the frequency obtained in 10 modes, the maximum frequency that can be considered till 6 modes only beyond this mode resonance condition will be achieved.

VII CONCLUSION

- The test results of this study concludes that there is great potential for the utilization of interlocking block of different configuration Based on present study, the following conclusions can be made.
- Interlocking block with two holes exhibits higher strength i.e. with increase in stability and ability to resist high loads with bending loads.
- The compressive strength of the interlocking block increases in different compressive loads due to interlocking between holes during combining together with cement.
- Weight of concrete interlocking block is also found 10% less compared to normal concrete block this exhibits higher strength due to interlocking effect with increased strength.
- Natural frequency of both the samples are found to be maximum this concludes that proposed configurations of concrete interlocking block design have ability to resist maximum seismic effect.

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