Investigation of the compressive strength of various mix designs (M20, M30 and M40) of Galvanized Iron stone chips concrete

Rubieyat Bin Ali*, Md. Mofizul Islam
Department of Civil & Structural Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh
*E-mail address: rubieyat.bin.ali@gmail.com

ABSTRACT

Galvanized Iron wire is considered as a low-cost wire. In this study, this wire is mixed with black stone chips concrete and this concrete is recognized as fiber concrete. Fifty-four specimens are tested to detect the compressive behavior of fiber concrete and normal concrete. The mix ratio variations are also adopted for this study. The differences between the compressive behavior of fiber concrete and normal concrete are recorded. 7, 14 and 28 curing days are considered to investigate this study. Some recommendations are also attached at the end portion of this study.

Keywords: Galvanized Iron wire, fiber concrete and compressive behavior

1. INTRODUCTION

Concrete is considered as the backbone of any kind of civil Engineering construction. Any kind of sophisticated structures can not possible without concrete. The concrete may carry good compressive stress which is the strongest part of this. But very weak in tensile stress and ductility behavior is not up to the mark. The main components of concrete are cement, fine aggregates, coarse aggregates (½ inch or ¾ inch downgrade black stones or brick chips) and water. To improve the overall property of concrete, many supplementary materials
are added to them. Among these materials, steel fiber, glass fiber, wood fiber or nanofiber etc. are the major items. But these items are too expensive. So, a low-cost fiber may be the better solution for this. Galvanized Iron wire (G.I. wire) is one of the low-cost fiber which can be mixed with concrete without replacement of any kind of components of concrete. Galvanized Iron wire is manufactured from mild steel and thinly coated with zinc and also considered as a low-cost wire. The cost of G.I. wire is 1 dollar per kg. [World market rate]. It has been used just to bind reinforcement before column casting. But now a day, it can be used as a supplementary material in many mediums and low-income countries because of its cheap rate. But there are limited investigations have done on the effect of the properties of G.I. wire mixed concrete. Md. A. Bashar Emon (2007) et al. investigated on the effect of G.I. wire (2.5% by weight) in brick chips reinforced concrete without replacement of any type of components of concrete. They also found that the compressive strength is increased 4-15% at 28 curing days than normal concrete. And G.I. wire fiber reinforced concrete shows better energy adsorption capacity and load-deflection behavior than normal concrete [1]. More investigations should be needed for the binding property, creep and shrinkage of the G.I. wire fiber reinforced concrete which may be the potential research gap of such study. Large-scale research should be conducted on this type of study to provide specific code recommendation for Galvanized Iron wire (size and weight) which can be used in concrete (brick or stone chips). The main goal of this study is to experiment the compressive strength of various mix designs of Galvanized Iron stone chips concrete (GISC). 2% by weight and 1-inch length G.I. wire is considered in this study.

2. LITERATURE REVIEW OF SUPPLEMENTARY MATERIALS USED IN CONCRETE

W. Kubissa (2015) et al. studied the basic properties of concrete by using recycled concrete aggregate in lieu of natural aggregate. They investigated in two steps. In the first step, 25% NA is replaced by RCA and then 50% NA is replaced by RCA. The replacement proportion of RCA has increased the compressive strength and the water absorption capacity of concrete [2].

Z.Z. Ismail and E.A. AL-Hashmi (2008) investigated the effect of waste plastic in concrete in lieu of fine aggregate. They found that maximum 20% replacement of fine aggregate by plastic waste can give better compressive strength, flexural strength, dry density, fresh density and slump value of corresponding concrete. They also found that plastic waste can create micro crack which is adversely affected the binding property of concrete. Being a hydrophobic material, waste plastic can create harmful effects of the hydration process of cement. Though plastic waste having some demerits but (using good proportion) it can be a good solution to solid waste management by using a proper proportion in concrete [3].

N. Chusilp (2009) et al. studied the use of sugarcane bagasse ash as the partial replacement of cement in concrete. They found that the binding property of SCBA is good because of having a better proportion of Silicon in it. They also found that the percentage of SCBA of the replacement of type I Portland cement up to 30% can improve the compressive strength of concrete, but reduces the water permeability and the overall temperature in concrete [4].
K. Gunasekaran (2013) et al. investigated the flexure property of concrete by using the coconut shell as a coarse aggregate. They found that the flexural strength and strain capacity of a reinforced concrete beam is increased by using the coconut shell as a coarse aggregate. And the binding property of the coconut shell is very good so there is no microcrack is produced in this concrete corresponding reinforced beam by using the coconut shell as a coarse aggregate. They concluded that the coconut shell increased the ductile behavior of this corresponding reinforced concrete beam [5].

J. Blyszko (2017) inspected on the effect of creep on concrete by using reinforced steel fibers (FRC). The use of FRC in concrete increases the creep than natural concrete. They also found that first 24-hours of loading condition, the deformation rate is higher of FRC concrete than natural concrete. But when the load is increased than the creep is decreased [6].

G.M. Sadiqul Islam (2017) et al. used glass waste powder as a 0-25% replacement of ordinary Portland cement in concrete and found high compressive strength than normal concrete because of having Silicon in glass waste powder which created a C-S-H (calcium silicate hydrate) powder gel as a good pozzolanic material [7].

Claudiu Aciu (2017) et al. collected waste paper from the environment and recycled them to mix with cement and formed as a plastering mortar which is an important building material. They found that this type of plastering mortar is thermally protected because cement is a good hindrance to oxygen and waste paper. So, overall burn process is slow [8].

3. MATERIALS DESCRIPTION

The materials which are used for different mix designs are given below.

3.1. Galvanized Iron Wire

21 no. Galvanized Iron wire is used for this investigation. The price of this wire is 1 dollar per kg [world standard]. Required G.I. wire is cut 1-inch equal by wire cutting tools. 2% G.I. wire is used according to the total weight of mix design without replacement of any components of mix design of concrete. Figure 1 shows the pictorial view of G.I. wire.

Figure 1. The pictorial view of G.I. wire.
3. 2. Coarse Aggregate

There two types of coarse aggregates are used. 70% ¾ inch downgrade black stone and 30% ½ inch black stone chips are used according to the required coarse aggregate (by weight) of each mix design. Figure 2 and Figure 3 represent the ¾ inch downgrade black stone and ½ inch black stone chips.

Figure 2. The ¾ inch downgrade black stone.

Figure 3. The ½ inch black stone chips.
3. 3. Fine Aggregate

Sylhet sand is used for this purpose which is collected from the Sylhet division of Bangladesh. And the fineness modulus of this sand is around 2.5. Figure 4 indicates the fine aggregate.

![Figure 4. The fine aggregate (Sylhet sand).](image)

3. 4. Cement

Ordinary Portland cement is used for this purpose. Seven Rings Gold (OPC) cement is used for these investigations. Figure 5 shows Seven Rings Gold cement bag.

![Figure 5. Seven Rings Gold cement bag.](image)
3.5. Water

Distilled water which is purified from the BUET water treatment plant is used for this treatment. Figure 6 shows ingredients mix with G.I. wire.

![Figure 6. The ingredients mix with G.I. wire.](image)

Figure 7 shows the cylinder specimens for this investigation.

![Figure 7. The cylinder specimens for this investigation.](image)
4. EXPERIMENTAL INVESTIGATION

4.1. Mix Design For M20 Concrete

The mix design of M20 concrete is conducted according to the ACI guidelines [ACI-211] [9]. 8-inch height, 4-inch diameter cylinder is considered in this investigation. The area of this cylinder is computed as $1.6 \times 10^{-3} \text{ m}^2$. Table 1 shows the mix proportions of M20 concrete according to ACI guidelines.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Required amount according to ACI guidelines (Kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>355</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>1016</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>799</td>
</tr>
<tr>
<td>Water</td>
<td>185</td>
</tr>
</tbody>
</table>

The amounts of ingredients which are used to cast the cylinder are estimated. So, Table 2 shows the estimated amount of ingredients which are used to cast the cylinder.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>The Required amount of single cylinder according to ACI guidelines (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>0.56</td>
</tr>
<tr>
<td>Coarse aggregate (C.A.)</td>
<td></td>
</tr>
<tr>
<td>¾ inch downgrade black stone (70% of C.A.)</td>
<td>1.62</td>
</tr>
<tr>
<td>½ inch black stone chips (30% of C.A.)</td>
<td>1.13</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>0.48</td>
</tr>
<tr>
<td>Water</td>
<td>1.27</td>
</tr>
<tr>
<td>G.I. wire (2% of total weight of cylinder)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Six sets of the cylinder are cast where each set consists of three cylinders. First three sets are cast without G.I. wire which is considered as normal concrete. But second three sets are cast with G.I. wire which is considered as fiber concrete. So, compressive strength tests
are performed on the normal concrete on different days of these nine cylinders where first three samples at 7 days, second three samples at 14 days and last three samples at 28 days. And all day are counted according to curing condition. Table 3 shows the compressive strength test results of M20 normal concrete.

Table 3. The compressive strength test results of M20 normal concrete (N.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-1 (7,14,28)</td>
<td>18</td>
</tr>
<tr>
<td>C-2 (7,14,28)</td>
<td>19</td>
</tr>
<tr>
<td>C-3 (7,14,28)</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 4 shows the compressive strength test results of M20 fiber concrete.

Table 4. The compressive strength test results of M20 fiber concrete (F.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa) (With 2% G.I. Wire)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-4 (7,14,28)</td>
<td>23</td>
</tr>
<tr>
<td>C-5 (7,14,28)</td>
<td>24</td>
</tr>
<tr>
<td>C-6 (7,14,28)</td>
<td>25</td>
</tr>
</tbody>
</table>

From the analysis of Figure 8, it is clearly understood that the compressive strength of fiber concrete is more than normal concrete. This is considered as a good use of the symbol of the G.I. wire in concrete. Figure 8 also narrates that the use of fiber in concrete can easily possible to get approximate M30 concrete mix strength in the M20 concrete mix which may be taken as a great achievement in concrete history.

Figure 8 shows the graphical representation of overall results.
From the analysis of Figure 8, it is clearly understood that the compressive strength of fiber concrete is more than normal concrete. This is considered as a good use of the symbol of the G.I. wire in concrete. Figure 8 also narrates that the use of fiber in concrete can easily possible to get approximate M30 concrete mix strength in the M20 concrete mix which may be taken as a great achievement in concrete history.

4.2. Mix Design For M30 Concrete

Table 5. The mix proportions of M30 concrete according to ACI guidelines

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Required amount according to ACI guidelines (Kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>385</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>1026.92</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>732.5</td>
</tr>
<tr>
<td>Water</td>
<td>181</td>
</tr>
</tbody>
</table>
The mix design of M30 concrete is conducted according to the ACI guidelines [10]. A 8-inch height, 4-inch diameter cylinder is considered in this investigation. The area of this cylinder is computed as $1.6 \times 10^{-3} \text{ m}^2$. Table 5 shows the mix proportions of M30 concrete according to ACI guidelines. The amount of ingredients which are used to cast the cylinder are estimated. So, Table 6 shows the estimated amount of ingredients which are used to cast the cylinder.

**Table 6.** The estimated amount of ingredients which are used to cast the cylinder

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>The Required amount of single cylinder according to ACI guidelines (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>0.61</td>
</tr>
<tr>
<td>Coarse aggregate (C.A.)</td>
<td></td>
</tr>
<tr>
<td>¾ inch downgrade black stone (70% of C.A.)</td>
<td>1.64</td>
</tr>
<tr>
<td>½ inch black stone chips (30% of C.A.)</td>
<td>1.14</td>
</tr>
<tr>
<td>½ inch black stone chips</td>
<td>0.5</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>1.17</td>
</tr>
<tr>
<td>Water</td>
<td>0.28</td>
</tr>
<tr>
<td>G.I. wire (2% of total weight of cylinder)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Six sets of the cylinder are cast where each set consists of three cylinders. First three sets are cast without G.I. wire which is considered as normal concrete. But second three sets are cast with G.I. wire which is considered as fiber concrete. So, compressive strength tests are performed on the normal concrete on different days of these nine cylinders where first three samples at 7 days, second three samples at 14 days and last three samples at 28 days. And all day are counted according to curing condition. Table 7 shows the compressive strength test results of M30 normal concrete.

**Table 7.** The compressive strength test results of M30 normal concrete (N.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-7 (7,14,28)</td>
<td>23</td>
</tr>
<tr>
<td>C-8 (7,14,28)</td>
<td>21</td>
</tr>
<tr>
<td>C-9 (7,14,28)</td>
<td>22</td>
</tr>
</tbody>
</table>
Table 8 shows the compressive strength test results of M30 fiber concrete.

**Table 8.** The compressive strength test results of M30 fiber concrete (F.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa) (With 2% G.I. wire)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-10 (7,14,28)</td>
<td>30</td>
</tr>
<tr>
<td>C-11 (7,14,28)</td>
<td>29</td>
</tr>
<tr>
<td>C-12 (7,14,28)</td>
<td>28</td>
</tr>
</tbody>
</table>

Figure 9 shows the graphical representation of overall results.

**Figure 9.** The graphical representation of overall compressive strength results.

From the analysis of Figure 9, it is clearly understood that the compressive strength of fiber concrete is more than normal concrete. This is considered as a good use of the symbol of the G.I. wire in concrete. Figure 9 also narrates that the use of fiber in concrete can easily
possible to get approximate M40 concrete mix strength in the M30 concrete mix which may be taken as a great achievement in concrete history.

4. 3. Mix Design For M40 Concrete

The mix design of M40 concrete is conducted according to the ACI guidelines [11]. 8-inch height, 4-inch diameter cylinder is considered in this investigation. The area of this cylinder is computed as $1.6 \times 10^{-3}$ m$^2$. Table 9 shows the mix proportions of M40 concrete according to ACI guidelines.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Required amount according to ACI guidelines (Kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>435</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>998.34</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>712</td>
</tr>
<tr>
<td>Water</td>
<td>183</td>
</tr>
</tbody>
</table>

Table 9. The mix proportions of M30 concrete according to ACI guidelines

The amount of ingredients which are used to cast the cylinder are estimated. So, Table 10 shows the estimated amount of ingredients which are used to cast the cylinder.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>The Required amount of single cylinder according to ACI guidelines (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>0.69</td>
</tr>
<tr>
<td>Coarse aggregate (C.A.)</td>
<td></td>
</tr>
<tr>
<td>$\frac{3}{4}$ inch downgrade black stone</td>
<td>1.59</td>
</tr>
<tr>
<td>(70% of C.A.)</td>
<td>1.11</td>
</tr>
<tr>
<td>$\frac{1}{2}$ inch black stone chips (30%</td>
<td>0.48</td>
</tr>
<tr>
<td>of C.A.)</td>
<td></td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>1.13</td>
</tr>
<tr>
<td>Water</td>
<td>0.29</td>
</tr>
<tr>
<td>G.I. wire (2% of total weight of cylinder)</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 10. The estimated amount of ingredients which are used to cast the cylinder

Six sets of the cylinder are cast where each set consists of three cylinders. First three sets are cast without G.I. wire which is considered as normal concrete. But second three sets
are cast with G.I. wire which is considered as fiber concrete. So, compressive strength tests are performed on the normal concrete on different days of these nine cylinders where first three samples at 7 days, second three samples at 14 days and last three samples at 28 days. And all day are counted according to curing condition. Table 11 shows the compressive strength test results of M40 normal concrete.

**Table 11.** The compressive strength test results of M40 normal concrete (N.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-13 (7,14,28)</td>
<td>31</td>
</tr>
<tr>
<td>C-14 (7,14,28)</td>
<td>33</td>
</tr>
<tr>
<td>C-15 (7,14,28)</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 12 shows the compressive strength test results of M40 fiber concrete.

**Table 12.** The compressive strength test results of M40 fiber concrete (F.C.).

<table>
<thead>
<tr>
<th>Type of cylinder specimen</th>
<th>Compressive strength (MPa) (With 2% G.I. wire)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>7 days</td>
</tr>
<tr>
<td>C-16 (7,14,28)</td>
<td>40</td>
</tr>
<tr>
<td>C-17 (7,14,28)</td>
<td>37</td>
</tr>
<tr>
<td>C-18 (7,14,28)</td>
<td>38</td>
</tr>
</tbody>
</table>

Figure 10 shows the graphical representation of overall results. From the analysis of Figure 10, it is clearly understood that the compressive strength of fiber concrete is more than normal concrete. This is considered as a good use of the symbol of the G.I. wire in concrete. Figure 10 also narrates that the use of fiber in concrete can easily possible to get approximate M50 concrete mix strength in the M40 concrete mix which may be taken as a great achievement in concrete history
Figure 10. The graphical representation of overall compressive strength results.

5. RESULT BASED DISCUSSION

Figure 11. The visible cracks of the specimen.
It is clearly observed that the fiber concrete has gained impressive compressive strength than normal concrete. But some cracks have arisen at the end portion of the concrete at 28 days. It may be observed because of the heterogeneous mixture of wire and other components of concrete. In case of the use of vibrating compactor, the wire may go to the lower part of the mixture because of its own weight. This is the main reason of heterogeneous mixture. So, more investigations should be needed to find out the actual cause of these cracks and try to solve this. Figure 11 shows the visible cracks of the specimen.

6. FUTURE RECOMMENDATION

1) Large-scale tests should be needed to apply this G.I. wire in the rigid pavement.
2) Easy G.I. wire cutting machine should be discovered.
3) The way of a homogeneous mixture of this wire and concrete should be invented.
4) The reason for cracks should be detected on the end portion of fiber concrete.
5) The use of G.I. wire in foundations or piers should be investigated.

7. CONCLUDING REMARKS

The use of G.I. wire on concrete may increase the compressive strength of this concrete. So, the overall investigations are satisfied with the study goal. But some problems are detected. So, more investigations are needed to solve this problem. So, it is high time to apply this any kind of sophisticated structures which are related to concrete. So, large-scale investigations should be needed to apply this practically.

Acknowledgment

A tremendous support is done by Concrete Laboratory of BUET to conduct such investigation and heartiest grateful to all the members of this lab.

References


