Enhancement the Mechanical Properties of Concrete by using Special Types of Meshes

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Abstract. Failure of concrete under flexural loading considered as one of the important problems which facing the engineers. This study is to investigate the properties of concrete by using three types of mesh (steel wire, galvanized iron wire and PVC coated wire). For this reason, test specimens of 150 mm cube was used to measure the compressive strength at age of 28 days, also tiles of 500x500x50mm (thickness) were cast to measure the flexure test at age of 28 day, all the specimens were cast with 3 layers of meshes in addition to the reference samples. The results showed that the type of meshes didn’t effect on the compressive strength while, the flexural strength of the specimen increases when using 2 layers of galvanized iron mesh with 1 intermediate layer of PVC coated layer also, the shape of fracture and the expanded of it affects by the type of the meshes.

1. Introduction

Sustainability is invention of new composite material which leads to reduce the large consumption of natural resources. During the last 20 years, a considerable development has been made to understand the behavior of mesh reinforced cementitious composite which is known Ferrocement if it is reinforced with steel or thin reinforced cementitious composites [1-3]: because of it is manufactured uses less natural sources [4,5]. A lot of researchers and building materials manufactures have found many methods to substitute concrete with cementitious composites since these materials have superior mechanical behavior of such composites [6].

Ferrocement manufactured uses simpler construction techniques method such as putting closely spaced layers of small size and continuous wire mesh as the main reinforcement between the section and matrix (mortar) which contain cement, sand and water [1, 2, 7, 8]. The steel wire mesh provide a lot of benefits especially for construction with complex curvatures and shapes since they have many properties such as light in weight to handle, and easy to cut and bend. The meshes used may be metallic or other suitable materials [8, 9].

The mortar constituents and mortar fineness should be appropriate with the tightness and opening of the reinforcing system [8]. In ferrocement coarse aggregates are not used since it has harmful affect on the ductile performance of composites also, to give the sustainable advantages of maximum sources system [10, 11].
There are numerous uses for thin cement composites especially in roof slabs, strengthening work, shell, petition, and etc. [1-3] in different fields such as agriculture, urban infrastructures, housing industry and water supply and sanitation. But the disadvantage of ferrocement is the number of mesh layer since the thickness of cementitious composite ranges between 10 and 25mm [3, 13]. Sakthivel and Jagannathan (2012a) [4] used two types of mesh (galvanized steel weld and PVC-coated mesh) in 250x250x15mm slabs with 1-3 layers of steel mesh. They concluded that the energy absorption for slabs with galvanized steel weld mesh was much better than that of PVC-coated mesh while, there was no effective impact strength for slabs containing 1 and 2 layers mesh compared to slabs with 3 layers mesh.

In other study for Sakthivel and Jagannathan (2012b) [5] used the same size of slabs but, increased the thickness to 25mm and same type of mesh but, increased the number of layers between 1 to 5. They found that the 3-5 layers of galvanized steel weld mesh was much performance as an effective reinforcement than PVC-coated steel weld mesh.

Lara and Bolander (2004) [14] investigated the performance of 305 x76 x12.7 mm slabs reinforced with welded-wire square mesh and using quartz sand. They found that the ultimate strength of slabs affected by the status of the reinforcement at the failure section. Also, Mahmood and Majeed (2009) [15] concluded that when using single layer of mesh there was no increasing in strength of the panel because this layer existing at mid depth, which means that close to the neutral axis of the panel. While, when using two layers of mesh the performance of the mesh has significantly increased in ductility, energy absorption and stiffness.

Ibrahim (2011) [3] experimented on using different types of cementitious slabs thickness 40, 45, 50 and 60mm. Results showed that, the stiffness of the slabs increased and the ductility decreased with the increase of thickness.

The goal of this study is to investigate the properties of concrete i.e. compressive, flexural strengths and the shape of failure by using three types of meshes (steel wire, galvanized iron wire and PVC coated wire).

2. Materials

2.1 Cement
Ordinary Portland cement (Type I), with C3A contain 7.4 % and 380 m²/kg specific surface area, from local factory was used through this investigation. It was stored in taut plastic containers to avoid air humidity.

2.2 Fine Aggregate
Al-Ekhaider natural sand of 2.36 finesse modulus, 2.61 specific gravity, 0.35 5 by weight sulfate content and absorption 0.61 %, was used as fine aggregate. The grading result of and physical properties of fine aggregate indicate that the sand it’s within the requirements of the Iraqi specification No.45/1984, fine aggregate grading explained by “Figure 1”.

2.3 Coarse Aggregate
Crashed gravel from Al-Ekhaider region with MAS (5-14) mm, 2.63 specific gravity, 0.035 by weight sulfate content and absorption 0.07%, was used as coarse aggregate. Results indicate that the coarse aggregate grading it's within the requirements of the Iraqi specification No.45/1984.

2.4 Superplasticizer
Turbid liquid with 6.6 pH value and 1.1 kg/1L density Sika 5930 L, was used in this work as a high performance superplasticizer concrete and mortar. It meets the requirement for superplasticizer according to ASTM-C- 494 Types G and F.

2.5 Mixing Water
Tap water was used to cast mix with superplasticizer which dissolved in water and added to the mix.

2.6 Reinforcement details
Three types of meshes were used in this work (table 1) shows their properties which was prepared by the factory, with 12.7mm square openings (steel mesh, Galvanized iron mesh and PVC coated mesh) in 3 layers, 12mm of concrete was the distance between each layer and covered by 12mm concrete as shown in “Figure 2”.

The 1st mix which was thereference mix (without any mesh), the 2nd mix contain 3 layers of steel mesh. 3rd mix was used 3 layers galvanized iron mesh while, the 4th mix was consist of 3 layers of PVC coated mesh later, 5th mix used of 2 layers of galvanized iron mesh and one middle layer of PVC coated mesh and finally, 6th mix consist of 2 layers of PVC coated mesh and one intermediate layer of galvanized iron mesh as shown in (table 2).

| Table 1. Details of meshes |
|---------------------------|
|                          |
| **Steel mesh**             | **Galvanized mesh** | **PVC coated mesh** |
| T.S Mpa                   | 400                 | 470                 | 225               |
| Y.S Mpa                   | 175                 | 225                 | 95                 |
| Elongation%               | 11.6                | 12.9                | 9.8                |
3. Details of casting, curing and curing of specimens

Twelve cubes of 150x150x150 mm were used to measure the compressive strength at age of 28 days for each mix. Also, 48 tiles size 500 x 500 x 50 mm were cast using three different types of wire mesh to measure flexural strength at age of 28 days. After mixes, the concrete was put in mould by using vibrating table for 24 h then the specimens were wrapped with nylon sheet at room temperature of 23 ± 2 ºC. After 24 h specimens were demoulded and cured in water till the time of testing. Compressive strength was tested according to ASTM C109 [16] with load rate of 0.9 kN/s. The average of three specimens at the age of 28 days for each mix were taken while, the flexural strength using two-point load was investigated according to ASTM C 78 / C78M – 18[17] and the average of 2 tiles at age of 28 days were taken as shown in “Figure 4”.

![Figure 2. Arrangement of concrete and mesh layers](image)

![Figure 3. Samples of tiles](image)
Table 2. Details of mix proportion

| Mix code | Layers of meshes details                  | w/c | Mix proportion (Cement: Sand: Gravel) |
|----------|------------------------------------------|-----|--------------------------------------|
| A1R      | Without                                  | 0.4 |                                      |
| A2S      | 3 layers of Steel mesh                   |     |                                      |
| A3G      | 3 layers of Galvanized mesh              |     |                                      |
| A4P      | 3 layers of PVC coated mesh              |     | 1:1.5:3                              |
| A5GP     | 2 layers of Galvanized mesh+ 1 layer of PVC coated mesh | 0.4 |                                      |
| A6PG     | 2 layers of PVC coated mesh+1 layer of Galvanized mesh |     | 1:1.5:3                              |
| B1R      | Without                                  |     |                                      |
| B2S      | 3 layers of Steel mesh                   | 0.4 |                                      |
| B3G      | 3 layers of Galvanized mesh              |     |                                      |
| B4P      | 3 layers of PVC coated mesh              |     | 1:2:4                                |
| B5GP     | 2 layers of Galvanized mesh+ 1 layer of PVC coated mesh |     |                                      |
| B6PG     | 2 layers of PVC coated mesh+1 layer of Galvanized mesh |     |                                      |
| C1R      | Without                                  | 0.5 |                                      |
| C2S      | 3 layers of Steel mesh                   |     | 1:1.5:3                              |
| C3G      | 3 layers of Galvanized mesh              |     |                                      |
| C4P      | 3 layers of PVC coated mesh              |     |                                      |
| C5GP     | 2 layers of Galvanized mesh+ 1 layer of PVC coated mesh |     | 1:2:4                                |
| C6PG     | 2 layers of PVC coated mesh+1 layer of Galvanized mesh |     |                                      |
| D1R      | Without                                  |     | 1:2:4                                |
| Code  | Description                                      |
|-------|--------------------------------------------------|
| D2S   | 3 layers of Steel mesh                           |
| D3G   | 3 layers of Galvanized mesh                      |
| D4P   | 3 layers of PVC coated mesh                      |
| D5GP  | 2 layers of Galvanized mesh + 1 layer of PVC     |
|       | coated mesh                                      |
| D6PG  | 2 layers of PVC coated mesh + 1 layer of Galvanized mesh |
4. Results and Discussion

4.1 Compressive Strength

As expected the results showed that the compressive strength of all mixes increased with decreasing mix proportion at the same w/c for example the compressive strength of mix A (36.2 MPa) (mix proportion 1:1.5:3) with w/c ratio 0.4 comparison to 27.9 MPa for mix C (1:1.5:3) with w/c ratio 0.5 and for mix B 24.5 MPa while in mix D it 20.6 MPa. However, it decreasing with increasing w/c for the same mix proportion i.e. the compressive strength in A increased by 11.7 MPa about B while, it increased by 7.3 MPa between C and D as shown in “Figure 5 and table 3” that means that there is no relationship between type of mesh and compressive strength of concrete.
Table 3. Flexural and Compressive strength of the mixes at 28 days

| Mix code | Av. Flexural strength (MPa) at 28 day | Av. Compressive strength (MPa) at 28 day |
|----------|--------------------------------------|----------------------------------------|
| A1R      | 4.3                                  | 36.2                                   |
| A2S      | 5.1                                  |                                        |
| A3G      | 6.2                                  |                                        |
| A4P      | 4.6                                  |                                        |
| A5GP     | 6.7                                  |                                        |
| A6PG     | 5.0                                  |                                        |
| B1R      | 4.0                                  |                                        |
| B2S      | 4.9                                  |                                        |
| B3G      | 5.8                                  | 33.9                                   |
| B4P      | 4.3                                  |                                        |
| B5GP     | 6.0                                  |                                        |
| B6PG     | 4.6                                  |                                        |
| C1R      | 3.8                                  |                                        |
| C2S      | 4.8                                  |                                        |
| C3G      | 5.4                                  | 27.9                                   |
| C4P      | 3.7                                  |                                        |
| C5GP     | 5.6                                  |                                        |
| C6PG     | 4.5                                  |                                        |
| D1R      | 3.6                                  |                                        |
| D2S      | 4.3                                  |                                        |
| D3G      | 4.9                                  | 20.6                                   |
| D4P      | 3.2                                  |                                        |
| D5GP     | 5.4                                  |                                        |
| D6PG     | 4.0                                  |                                        |

4.2 Flexural strength

From “Figures 6, 7 and 8”; it can be seen that the flexural strength increased by 35.8 to 40.7% when using 2 layers of galvanized steel iron mesh with 1 intermediate layer of PVC coated mesh compared to the reference mix while, it increased by 30.6 to 35% when using 3 layers of galvanized iron mesh of course all these comparisons for the same mix proportions and w/c ratio. In general the mesh improve the flexural strength but at varying degrees and this improvement starts when using mix 5GP then 3G, 2S, 6PG, 4PVC respectively for different proportions and w/c ratio.

Also from notes the crack starts at the lower face of the tiles and expands to the sides and upper face till the tiles separate into two parts this behavior can be noticed in reference mix “Figure 9” but when using S, PVC and PG mesh the tiles did not separate as shown in “Figure 9” while, when using GP and G mesh the crack stopped at the sides of the tiles and did not expand to the upper face of the tiles although the tiles fail in flexural test as shown in “Figure 10”.
Figure 6. Comparison between Flexural strength of the mixes A&B at 28 days

Figure 7. Comparison between Flexural strength of the mixes A&C at 28 days

Figure 8. Comparison between Flexural strength of the mixes A&D at 28 days
5. Conclusions
It can be found from this research:
1- The type of mesh did not effect on the compressive strength of concrete.
2- The flexural strength increases when using 2 layers of galvanized iron mesh with 1 intermediate layer of PVC coated layer (GP mix) for different mix proportions and w/c ratios.
3- It had less improvement in flexion resistance when using PVC coated mesh only.
4- When using S, PVC and PG the crack starts at the lower face of the tiles and expands to the sides and upper face without separate.
5- Tiles contain GP and G mesh the crack starts at the lower face of the tiles and expands to the sides then it stopped till the tiles failed.

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