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Research paper



Carbon Fiber Strengthening of Geopolymer Concrete Wall Panels with Iron Fillings

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Abstract

Wall is a vertical plate member resisting vertical (in-plane) or lateral loads. Load-Bearing walls were referred to RC wall panels which were commonly used as load-bearing structural members, braced and laterally supported by the rest of the structure, local materials such as Metakaolin and alkaline solutions are used to cast (600x400) mm reinforced concrete wall panels with 40 mm thickness. To find the ultimate bearing capacity and lateral deflection of wall panels. Seven specimens are divided in two groups to study the variation effect of iron filling (0, 0.5, 0.75 and 1.0)% and carbon fiber (225, 125 and 90)mm spacing center to center of strips. The result shows that the maximum increasing are 17% and 14% for ultimate bearing capacity and cracking load of wall panels respectively, when iron filling is 1%. Also, the using of carbon fiber with 90 mm spacing center to center of strips leds to increasing in ultimate bearing capacity and cracking load by 31% and 7% respectively. Lateral deflection of wall panels was measured and compared with the reference wall to investigate the strengthening effect.

Keywords: *CFRP, Geopolemer Concrete, Iron Fillings, Wall Panels.*

1. Introduction

Production of 1.6 trillion tons of cement annually accounts for about 7% of total carbon dioxide to the atmosphere. Cement Currently used main hydraulic cement is not only one of energy intensive building materials but also causes a large amount of conservatory smoke. In order to produce 1 ton of Portland cement, Portland cement clinker absorbs about 1 tone of carbon dioxide energy in the air. Furthermore, when large amounts of raw materials such as limestone and clay and oil such as coal are collected, deforestation and soil degradation frequently occur. [1].

"Geopolymer concrete" is a kind of inorganic macromolecular compound which has emerged as a potential binding material established based on the use of new manufacturing materials in recent years and is a biologically friendly structural industry. Sustainable when exchanging / refilling conventional concrete [2]. The highly comfortable Metakaolin of silica and alumina reacts with an alkaline solution such as sodium hydroxide NaOH or potassium hydroxide KOH and sodium silicate Na2SiO3 or potassium silicate K2SiO3 to form a gel bound to fine and coarse aggregate Form. Specific Geopolymers do not require water to bind the matrix, but alkaline solutions react with silicon and aluminum present in Metakaolin or Fly ash. The polymerization process involves a substantially rapid chemical reaction under alkaline conditions on the Si - Al mineral [3].

Carbon fiber reinforced polymer composite (CFRP) materials are lightweight and strong materials used in the manufacture of numerous products used in our daily lives. CFRP is a term used to describe a fiber reinforced composite material that uses carbon fiber as the primary structural component. In general, CFRP compounds use thermosetting resins such as epoxy, polyester or vinyl ester [4].

In this paper, waste concrete were used with the Metakaolin with alkalin solution and improved resistance by using steel filings. The efficiency of these materials was verified and reinforced by carbon fiber sheet to study the effect of this fiber on the resistance and lateral deflection, as well as the improvement of ductility.

2. Research Significance

(Sabir et al, 2001) [5] carried out a study on the use of Metakaolin as a pozzolanic material for mortar and concrete. They reported that the use of Metakaolin as a pozzolan will help in the growth of initial strength and some improvement in long-term strength.

(Badogiannis et al, 2004) [6] Evaluated the conclusion of Metakaolin on concrete. He discovered that when Metakaolin replaced cement, its positive effect on the strength of concrete, the highly reactive pozzolanic materials that can cause the production of concrete with excellent performance.

3. Experimental Program

The purpose of the practical aspect was to find the effect of different percentages of iron filling and carbon fiber load on the structural behavior of GPC wall panels in two directions in plane action. Seven Specimens of wall panels with a size of 600mm, 400mm and 40mm thick were tested. Experimental parameters details are shown in Table1.

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Table1: Experimental Parameters Particulars

Wall sample	Aspect Ratio H/L	Steel Reinforcement	Carbon Fiber (mm)*	Iron Filling%
WG0	1.5	0.0267	---	0
WG1	1.5	0.0267	---	0.5
WG2	1.5	0.0267	---	0.75
WG3	1.5	0.0267	---	1
WG4	1.5	0.0267	225	---
WG5	1.5	0.0267	125	---
WG6	1.5	0.0267	90	---

*center to center of carbon fiber sheet

3.1 Materials

The origin of Metakaolin was Iraqi kaolin clay. Metakaolin prepared by grinding the clay by air jet and then it is burned in the oven until 700ºC ± 20ºC during 2 hour,Then, the Metakaolin was cooled to room temperature during 24 hours. This preparation procedure was recommended by Ibrahem and Wahab [7]. The chemical composition of Metakaolin is shown in Table 1. Specific surface area of the prepared Metakaolin was 13.3 m2/g.

The alkaline solution consists of sodium hydroxideNaOH and sodium silicateNa2SiO3. Sodium hydroxide is available in local markets in the form of pellets with a purity of more than 98 percent. The 10 molar solution was prepared for this study. The sodium silicate solution has a SiO2/ Na2O ratio of 2.4, including 32.5% of SiO2, 13.4% of Na2O, and 54.1 % of water. A high-range water reducer (Glenium 51) is used for the production of plastic concrete. It is depended on a naphthalene sulfonate polymer.

Recycled concrete was used as aggregates in the concrete mixes, to reduce the environment of rubble and produce cheap local concrete. A locally available crushed concrete extent of 12.5mm is used as coarse aggregate, and 4.75 mm is used as fine aggregate. The recycled aggregates obtained from the demolished construction, in this investigation beams, cubes, cylinders and prisms are used to produce the aggregate Classification and sulfate the content was Adaptive to the requests of Iraqis Standard, IQS No.45/1984-Zone2[8]. Iron filing, which is produced locally in large quantities in workshops and steel mills. The reinforcing mesh contains of deformed bars of 6mm in diameter plasced in single layer at the midle depth of the wall panels. The spacing of the bars of 80mm c/c spaced in both directions, which is represented a maximum spacing according to ACI 318-2008 [9] with a transparent side cover of 10 mm. In addition, a steel reinforcement (8 mm) is placed around the wall to strengthen or protect the edges of the wall. Sikadur-330 (Epoxy Used) In order to avoid any gab between tested specimen and the steel frame, an epoxy (Sikadur-330) resin is filled inside this gab around the specimen for (7) days curing of epoxy to brace (control) the fixity of the wall at supports.

3.2 Mix Proportions

Mix Proportion for GPC based on (Basil et al, 2015)[10] mix with some improvement involved.

Table 2: Geopolymer Concrete Mix

Parameter	Percentage
Metakaolin kg/m^3	400
Sand kg/m^3	720
Gravel kg/m^3	1100
Alkalin solution kg/m^3	180
Water % of Metakaolin	10
Superplasticizer % of Metakaolin	3

Table 3: Chemical Composition For Metakaolin

Oxide composition	Content percent %
SiO_2	54.2
Al_2O_3	39.00
Fe_2O_3	0.92
CaO	1.37
MgO	0.15
SO_3	0.45
Na_2O	0.22
K_2O	0.27
LOI	0.71
TIO2	0.8

3.3 Casting of Wall Panels

The aggregates are prepared on a saturated surface in the dry state, SSD. The recycled concrete aggregate (fine and coarse aggregate) are first diverse composed in dry custom in a bucket blender for three minutes and then Metakaolin was add and mixed for two minutes. the alkaline liquid was added to the Geopolymer concrete mix and the 65% superplasticizer was mixed with additional water for not less than two minutes and gradually added to the dry materials in the mixer tray during five minutes. After that the iron filling and 35% of superplasticizer are added and mixed for two minutes. Then the concrete was compacted with a vibrating table. Fact, The compaction requires a lot of skill because the concrete of Geopolymer based on Metakaolin has a low drop.

3.4 Curing of Samples

Placing the specimen under direct sunlight outside the laboratory after demolding. Models were poured during temperatures 27° to 30°, placed models are under the ambient temperature based on previous research[10].

3.5 Testing of Wall Panels

Before the 28 days of the test, it was cleaned and painted white to ensure that the crack pattern can be easily observed on the wall surfaces and to obtain a clear visibility of the cracks during the test. After the test equipment has been repaired, the panel is fixed to the top and bottom brackets, the wall panels are labeled and placed precisely along the edges of the brackets. Leveling the panel to ensure perpendicularity of the panel. The axial load is applied to the eccentricity= t/6 from the center of the samples and the quadrant meters are placed in the middle center of the wall panels. During the test, the applied loads and the corresponding deflections of the middle section are recorded using a precision dial of 0.01 mm and a capacity of 25 mm located on the face of the wall panels.

At the beginning of each test, approximately (1 kN) is applied to seat the supports and the loading system, then the load is released after applying the seat load. The compression axial load is applied progressively in increments of 10kN. This amount of gradual loading allowed a sufficient number of loads and the resultant deflections during the test, which gives a realistic idea of the structural behavior of the wall panels. The cracking loads, the maximum axial load with its corresponding deflections in the center of the wall and the reading of the maximum crack width are observed.



Fig. 1: Set-up for lateral deformation

4. Expermintel Results

4.1 Initial crack load and Maximum load

Table 4 shows the first values of cracks load and ultimate load for the samples in two courses of load in the plane. The first crack load was taken as the load conforming to the point at which the load deflection curve develops non-linear.

Table 4: First Crack Load And Ultimate Load For Walls With Iron Filling

Sample	(Pcr) in kN	(Pu) in kN	Deflection at Cracking Load (Δcr) mm
WG0	38	250	9.92
WG1	40	260	9.75
WG2	42.5	285	8.52
WG3	43.5	292.5	8.42

The maximum strength of the wall panel growths with the increasing in the percentage of iron filling. Table 4 show that increasing of iron filling from 0 to 0.5% , 0.75%,and 1.0%, resulted increasing percentage of ultimate bearing capacity of load with 4%, 14%, and 17 %, also the same increasing in iron filling caused an increasing in cracking bearing load by 5%, 12%, and 14 %, and lateral deflection decreasing by 2%, 14%, and 15%.

Table 5: First Crack Load And Ultimate Load For Walls With Carbon Fiber

Sample	(Pcr) in kN	(Pu) in kN	Deflection at Cracking Load (Δcr) mm
WG4	51.5	370	7.38
WG5	53	405	6.88
WG6	55	485	6.74

The maximum strength of wall panel growths with the decreasing of spacing between carbon fiber sheets. Table5 show that decreasing of spacing between carbon fiber sheet from 225mm to 125mm and 90mm spacing c/c, resulted increasing percentage of ultimate bearing capacity of load with 10%, and 31 %, and increasing in cracking bearing load by 3%, and 7 %, and lateral deflection decreasing by 7% and 9%.

4.2 Load - Deflection Behaviour

Based on the observations, the load-deflection graphs was plotted for the specimens and are shown in Figs.2 to 4.

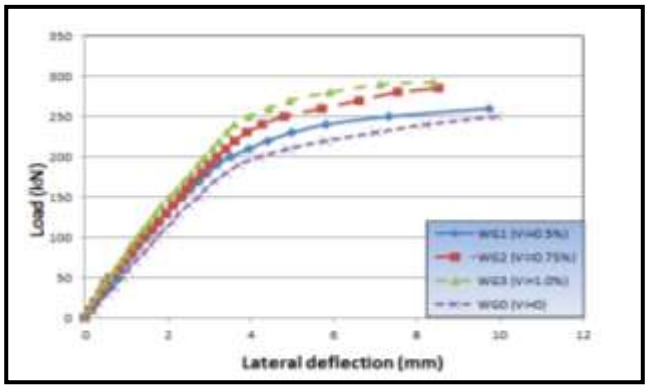


Fig. 2: Load the deflection curves of the test walls with iron filling.

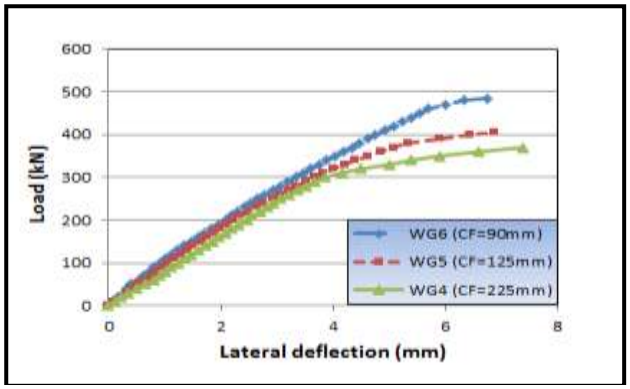


Fig. 3: The Load the deflection curves of the test walls with carbon fiber.

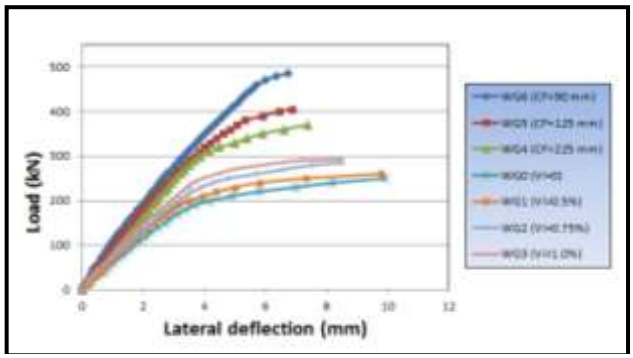


Fig. 4: Load-deflection curves of testing walls for seven samples.

The lateral deflection decreases with the increasing of the iron filling ratio in two ways in the flat load. Maximum deflection of 9.92 mm is gained for the final load of 250 kN in the case of panel WG0. Maximum deflection for panel WG1, WG2 and WG3 was 9.75, 8.52 and 8.42 mm respectively.

For carbon fiber, the lateral deflection decreases with the decrease in the separation between the carbon fiber sheets in two ways in the flat load. Maximum deflection of 6.74 mm is gained for the final load of 485 kN in the case of panel WG6. The maximum deflection for WG5 and WG4 panels are 6.88mm and 7.38mm respectively. This shows that the use of carbon fiber increases resistance and resistance to deflection.

4.3 Crack Pattern

The patterns of crack for seven panels are shown in Fig.5 to Fig.11.

1. For panels WG0, WG1, WG2 Crush at top and bottom of the wall with horizontal and diagonal cracks in panels WG1, WG3 at top and bottom of the wall, for WG2 and WG3 have diagonal cracks at middle of the wall

2. For panels WG4, WG5, WG6 Crush at top and bottom of the wall, with horizontal cracks between carbon fiber sheet and diagonal cracks in the middle of WG6.



Fig. 5: Crack pattern for the specimen WG0



Fig. 6: Crack pattern for the specimen WG1



Fig. 7: Crack pattern for men the specimen WG2



Fig. 8: Crack pattern for the speci- WG3



Fig. 9: Crack pattern for the specimen WG4



Fig. 10: Crack pattern for the specimen WG5

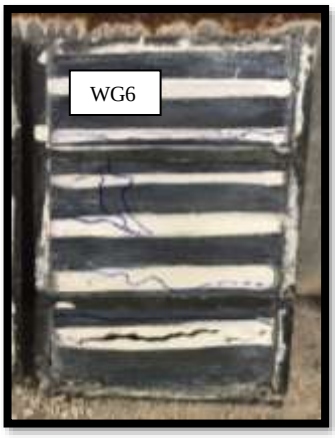


Fig. 11: Crack pattern for the specimen WG6

5. Conclusions

From the education carried out, it can be observed that:

1. The maximum strength of the wall panel increases with the increase in the percentage of iron filling in two directions in flat action. The increase in final load is about 17% for an increase in iron filling from 0 to 1%.
2. The lateral deflection decreases with the increase in the percentage of iron filling, which indicates improvements in the concrete, filling the gaps and improving the internal structure of the Geopolymer paste.
3. The gain in ultimate load was about 31% for andecrease the distance between carbon fiber sheet from 225mm to 90mm.
4. The lateral deflection decreases with the decrease in the distance between carbon fiber sheets from 225mm to 90mm.
5. Iron filling,improves the value of the concrete. It fills the voids and improves the internal structure of Geopolymer paste. The phenomenon of baking does not occur, which leads to the spread of the iron filling in the combination and positively affect on the resistance.
6. Carbon fibers that include high rigidity,high tensile strength,low weight,high chemical resistance,tolerance to high temperatures and low thermal development. These fibers increase resistance and reduce lateral deflection.

References

[1] P. Kumar Mehta "Reducing The Environmental Of Concrete", Concrete International, Bill.Semioli @aci-int.org , 2001.

[2] Peter Duxson, "Understanding the relationship between geopolymer composition, microstructure and mechanical properties".Journal of Colloids and Surfaces A: Physicochemical and Engineering Aspects, 269, 47-58,(2007) .

[3] M. I. Abdul Aleem and P. D. Arumairaj, "Optimum Mix for the Geopolymer Concrete" Indian Journal of Science and Technology, Vol. 5, No. 3, (2012), pp. 2299 –2301.

[4] https://www.thoughtco.com/understanding-CFRP-composites-820393.

[5] Sabir B.B, Wild S, Bai J, "Metakaolin and calcined clay as pozzolans for concrete :a review" Cement and concrete composite 23 ,(2001),pp.441-454.

[6] Badogiannis E, Papadakis V.G., Chaniotakis E, Tsivilis S, "Exploitation of poor Greek kaolins: Strength development of Metakaolin concrete and evaluation by means of k-value" Cement and Concrete Research 34 (2004),pp.1035–1041.

[7] A.M. Ibrahem and A.A. Wahab, "Effect of Temperature on the Pozzolanic Properties of Metakaolin Produced from Iraqi Kaolin Clay". AL- Fatih Journal, Diyala University, Iraq, Vol. 4, Issue 32, (2008), pp. 268-285.

[8] IOS No.45/1984, Iraqi Specification, "Aggregate from Natural Sources for Concrete and Construction", Central Agency for Standardization and Quality Control, Baghdad, 1984.

[9] ACI Committee 318, "Building Code Requirements for Structural Concrete and Commentary", American Concrete Institute, Detroit, 2008.

[10] Basil S. Al-Shathr, Tareq S. Al-Attar, and Zaid A. Hasan," Optimization of Geopolymer Concrete Based on Local Iraqi Metakaolin" The 2nd International Conference of Buildings, Construction and Environmental Engineering,(2015) pp 97-100.