The Effect of Fire Flame on Geopolymer Bubbled Slabs

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***ABSTRACT**: in this study, eight specimens of Reinforced concrete bubbled and Geopolymer bubbled slab exposed to fire flame and tested under punching shear failure with dimensions (450*450*70 mm), reinforcement area (Ø3@25), plastic ball diameter (40 mm) and concrete cover (15 mm) and the temperatures were (150-300- 450 ˚C) with a burning time of 30 minutes. From the results of laboratory tests, When RC bubbled slabs and Geopolymer concrete slabs exposed to fire flame 150 ℃ at 30-minute the ultimate strength was approximate same as reference slabs without exposed to fire flame. RC bubbled slabs exposed to fire flame (300 & 450) ℃, fire duration 30-minute and compressive strength (30 Mpa) the ultimate load decrease by (27.5, 19.3) %, Also spalling an occur. The ultimate load of Geopolymer concrete bubbled slabs, exposed to fire flame (300, 450) ℃ in 30-minute decrease by (34.2, 22.2) % respect to reference slab. In comparison with RC bubbled slabs with same compressive strength the ultimate load decrease by (54 %) and (59 %).*

***KEYWORDS** -Geopolymer, punching shear, glass fiber, bubbled, Fire flam.*

I. INTRODUCTION

Portland cement concrete is a major construction material worldwide use is said to be second only to water. Unfortunate, the production of Portland cement releases large amount of CO2 in to the atmosphere. This gas is a major contribution to the greenhouse effect and the global warming of the planet. To reduce greenhouse gas emissions, efforts are needed to develop environmentally friendly construction materials. Unlike with regular concrete the chemical reactions that form Geopolymer concrete alternative do not give off carbon dioxide or require high temperatures, which also lead to CO2 emissions. [1]

In 2019 Haitham H. [2] study the behavior of reinforced concrete bubble slabs exposed to fire flame. The experimental work concluded casting and burning nine specimens under static load. The test parameters were; The dimension of specimens was (700x450x80) mm, all specimens have same compressive strength 30 MPa (normal concrete), ball diameter was 40 mm, ratio of reinforcement at top and bottom of slabs 0.00417, fire flame temperature was (200, 300 and 400) ℃, fire flame duration (30 and 60) minutes and concrete cover (20 and 10) mm. the specimens were simply supported in two directions. The test results show that, RC bubble slab exposed to 200℃ at 30 and 60 minutes with 20 mm cover spalling not happened but in specimen with 10 mm concrete cover spalling occurred. All RC bubble slab exposed to 300℃and 400℃spalling occurred, damage of spalling for bubble slabs exposed to 300℃ in 30-minute fire duration more than 400℃ by (32 %) otherwise at 60-minute fire duration damage of spalling in 400℃ more than 300℃ by (49 %). Deflection during burning was observed due to static load and elevated of temperature, deflection increase with increase fire flame temperature and duration, increase of fire duration to 60 minute from 30-minute lead to increase in deflection with fire flame rate (200, 300 and 400) ℃ by (57, 79 and 68) % respectively in compassion with slabs exposed same fire rate at 30 minute.

In 2020 Wissam Kadhim et al. [3] fifteen 700x500 mm concrete flat slabs made of Geopolymer concrete were examined under concentrated to identify the maximum punching shear resistance under the influence of various factors such as steel fiber content, slab thickness, flexural reinforcement ratio, in addition to replacing 10% of metakaolin by silica fume under the influence of temperature increasing up to 300 °C in addition to testing ninety control specimens to investigate the mechanical properties. It was observed there was a beginning to change in the structural behavior when the temperature reached 100 °C due to an increasing in the pressure by the liquid vapor, then an important drop in the capacity and behavior when reaching the temperature 300 °C. The presence of iron fibers led to a decreasing in the distance between the edge of the column and the critical section, which reduced the punching shear values. Decreasing of the maximum and cracking of the punching shear were recorded at 37% and 42%, respectively, when the temperature increased to 300 °C.

II. EXPERIMENTAL PROGRAM:

THIS RESEARCH INCLUDES STUDYING THE MECHANICAL PROPERTIES, THE COMPRESSIVE STRENGTH , FRACTURE MODULUS, INDIRECT TENSILE AND ELASTIC MODULUS AS WELL AS FINDING WORKABILITY AND DENSITY OF CONCRETE, OF GEOPOLYMER CONCRETE BASED ON METAKAOLIN AND USING ALKALI SOLUTION AND ORDINARY AGGREGATE AS A FINE AND COARSE AGGREGATE AFTER ITS EXPOSED TO FIRE FLAM OF 150, 300 AND 450 DEGREES CELSIUS, THEN STUDYING THE BEHAVIOR OF GEOPOLYMERIC CONCRETE SLAB UNDER THE INFLUENCE OF TEMPERATURE, WHERE LOAD DEFLECTION CURVE, CRACK LOAD, MAXIMUM LOAD, FAILURE ANGLE, CRITICAL AREA, CRACK PATTERN AND TYPE OF FAILURE. THE MOST PARAMETERS WILL BE ADOPTED, WHICH ARE THE TEMPERATURE DEGREE OF BURIN (150, 300 AND 450) ˚C AND THE PERCENTAGE OF THE GLASS FIBER. TABLE (1) SHOW THE DETAILS OF TESTED SLABS.

Table (1) Tested Slabs.

Number of specimens	**Labeling**	**Fire Flame Rate ˚C**
1	NC-ROOM	Without fire
2	NC -150	150
3	NC -300	300
4	NC -450	450
5	GP-ROOM	Without fire
6	GP-150	150
7	GP-300	300
8	GP-450	450

III. Material and Methods:

3.1 cement Portland cement of type (1), which is widely utilized in Iraq has been applied in the presented study. The cement bags were kept in a secured container to avoid getting in touch with humidity. The results of the test indicated that the properties of cement agree with IOS No.5/1984[4].

3.2 Metakaolin: The nature of the metakaolin is clay mineral kaolinite and can produce by chemical compositions from Al2Si2O5 (OH)4. The methodology and processes to converting kaolinite to metakaolin relay on the applied temperature in which (100-200 Co) the most quantity of water will be lost and (500-700 Co) loss all water.

Al2Si2O5 (OH) 4 →Al2Si2O7 + 2H2O

Chemical, physical and the requirements based on the ASTM C618 [5].

3.3 Sodium Silicate: The brand of sodium silicate (Na2SiO3) adapted in the present study manufactured in United Arab Emirate shown properties by weight listed in Table (2).

Table (2): Sodium Silicate's Properties (supplier brochure)

Description	Value
SiO_2/ a_2O	2.4± .05
%H2O	55.10
%Na2O	13.10-13.70
%SiO2	32-33
Density	51± 0.5
Specific Gravity	1.534-1.551
viscosity	600-200

3.4 Sodium Hydroxide:

The sodium hydroxide (NaOH) is the most important component to prepare the Geopolymer concrete. The sodium hydroxide prepared by dissolving caustic soda flakes in water. The chemical reaction between sodium hydroxide and water was an exothermic component
after that the compositions cool in air for two hours. the test results and compare with the requirements based on ASTM E 291-09 [6].
The methodology that adapted to prepared alkaline solution by prepared from the (NaOH) and (Na2SiO3) by flaky high purity sodium hydroxide more or equal to (98%) in distilled water. One litter solution was prepared by mixing (560 g) of (NaOH) [For example, a 14 molar NaOH solution consists of 14 × 40 = 560 g of NaOH solids per liter of solution, 40 is the molecular weight of NaOH, Na = 23, O = 16, H = 1] with (826 ml) water so that the concentration by weight is (0.404) needed to prepare 1 liter of 14 Molar NaOH solution, is as follows.
Concentration by weight (w/w) = 560/ (560+826) =0.404
The Molarity (mole/l) for adopted mix was (14) and the weight of (NaOH) flakes is (404 g).

The preparation of alkaline liquid by mixed one litter from (NaOH) with (3.5 litter) from (Na_2SiO_3). The adopted time mix was (1 day) before use the final mixture.

3.5 Sand and Crushed Gravel:

Local sand graded within zone 3 was used as fine aggregate with a fineness modulus of 2.67, a sulfate content of 0.41%, a clay content of 3.7%, and a specific gravity of 2.65. Whereas crushed gravel was used as coarse aggregate whose grades are in the range of 5-12 mm with a sulfate content of 0.088%, a clay content of 2.1% and a specific gravity of 2.61. All the physical and chemical properties of aggregates conform to the specifications of Iraqi Standard 45/1984[7].

3.6 Superplasticizer:

The super plasticizer that was used in the preparation of geopolymeric concrete is Glenium 51 manufactured in the United Arab Emirates with a value of PH 6.8, a light brown color, free of chlorine, and used at a dose of 3 liters per cubic meter.

3.7 Water:

Specimens have been casted and cured via the use of tap water.

3.8 Reinforcement Mesh:

Square welded meshes used to reinforcing slabs, the specifications of welded mesh were evaluated according to ASTM 185A/A185M-07[8] according to manufacturer.

3.9 Glass Fiber:

Cem-Fil Anti-Crack, HD-12mm, Alkali Resistant glass fibers were used throughout the experimental work. From the micro to the macro fiber range, these fibers control the cracking processes that can take place during the life-span of concrete [9].

3.10 Plastic Balls:

In the presented study, the plastic balls have been made from recycled plastic that has a diameter of (40mm).

3.11 Mixing concrete:

Firstly, a dry sand is loaded into the mixer and then added a 0.5L from water to moistening the sand. After that, gravel is mixed for 0.5 minutes with sand. After that, the cement has been added to mixer and all dry material are mixed for 1minute to ensure the homogeneity of the mixture. Water was added after that in three stages and subjected to a process of mixing for three minutes. Then, mixer has been stopped, moved by hand and then resume the mixing process for another (3) minutes. This step is for homogeneity of the mix [10].

The aggregates are prepared on a saturated surface in the dry state SSD; The aggregate (fine and coarse aggregate) are first mixed together in dry form in a bucket mixer for three minutes and then Metakaolin (cement) was added and mixed for two minutes. The alkaline liquid was added to the Geopolymer concrete mix (the 65% of the water was added) and the 65% super plasticizer was mixed with additional water for not less than two minutes and gradually added to the dry materials in the mixer tray (the 65% super plasticizer was mixed with 35% of water and added to it) during five minutes. After that, the Glass fiber was added and 35% of super plasticizer was added and mixed for two minutes; then the concrete was compacted with a vibrating table, fact the compaction requires a lot of skill. [11-12]. Table (3) shown the optimum mix proportions for Geopolymer concrete [13].

Table (3) the optimum mix proportions for Geopolymer concrete [13]

Number of specimens	1-4	5-8
Metakaolin (kg/m^3)	400	400
Sand (kg/m^3)	720	720
Gravel (kg/m^3)	1100	1100
Alkaline Solution (lit/m^3)	180	180
Water (lit/m^3)	40	40
Sp* %	3	3
Glass fiber %	0.5	1

superplasticizer*

3.12 Curing:

means placing the specimen under direct sunlight outside the laboratory after demolding for 28 days. Models were poured during temperatures 27° to 30°, placed models are under the ambient temperature based on previous researches.

IV. Burning Test:

slab specimens were subjected to fire flame by burners The fire flame of Two-headed fire subjected to tension face of slab and placed on ground, the high of slab from the fire flame is 400 mm. steel frame was used for presented the real condition of burning, the frame was closed from all sides with some openings. Thermocouple type K with the capacity of (-50 to 1300) ˚C which was used to measure the temperature in depth of slab (at mid depth) and the infrared thermometer with ability (-32 to 550) ˚C which was used to measure the fire rate on bottom face of slab.

V. Results and Discussion:

5.1 Ultimate Load:

Ultimate load is an important value to investigate the structural behavior. Experimental results showed that the ultimate load of reinforced normal concrete and Geopolymer bubbled slab (NC-ROOM) (GP-ROOM) was (29and 17.5) kN respectively. When reinforced normal concrete and Geopolymer bubbled slab exposed to fire flame rate 150 ˚C at 30 min ultimate load increased by (6.8 and 2.7) % (NC-150) (GP-150) from references slabs without exposed to fire flame. At increasing fire flame rate to 300 ˚C at same fire deration 30 min ultimate load decreases by (27.5 % to 34.2 %) (NC-300) (GP-300) from references slabs without Exposure to fire flame. When slabs exposed to 450 ˚C the results show ultimate load Decreases by (19.3 % to 22.2 %) (NC-450) (GP-450). Table (4) shows the ultimate load of tested slabs. These results of ultimate load show that in 150 ˚C ultimate load was improving because it strengthens the concrete expelling excess water. The strength of slabs decrease in 300 ℃ is more than 450 ℃, it is because the temperature flow rate in 450 ˚C faster than 300 ˚C.

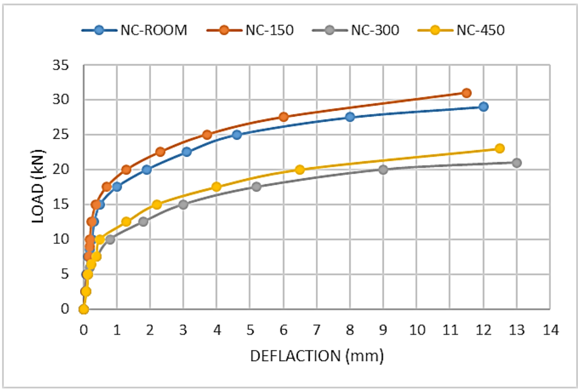
Table (4): the ultimate load tested slabs

Number of Specimens	Labeling	Ultimate Load (kN)	U. L / (U. L)R
1	NC - ROOM	29	--
2	NC -150	31	6.8
3	NC -300	21	-27.5
4	NC-450	23	-19.3
5	GP- ROOM	17.5	---
6	GP-150	18	2.7
7	GP-300	11.5	-34.2
8	GP450	13.6	-22.2

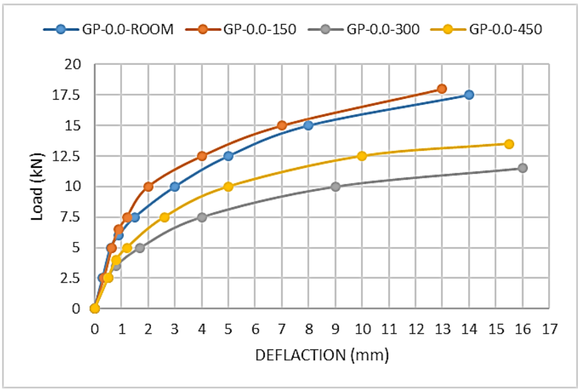
5.2 Loads Deflection:

Deflection was measured at center of slabs by (0.01mm) dial gage under load increment 2.5 KN and reading for this gages were recorded for each load increment. When a reinforced concrete slab is subjected to a gradual load increase, the deflection increases linearly with the load in an elastic manner. After the cracks start developing, deflection of the slab increases at a faster rate. After cracks have developed in the slab, the load-deflection curve is approximately nonlinear up to the yielding of flexural reinforcement after which the deflection continues to increase without an appreciable increment in load.

Figure (1) and figure (2) show that the response of slabs exposed to 150 degrees (NC-150) (GP-150) approximately similar to the reference slab, at rising the temperature to (300 and 450) ˚C the decrease in strength occurs. the result show that increased of deflection at 0.6 Ultimate load of 300 ˚C in comparison with 450 ˚C because the rate of fire in 300 ˚C more than 450 ˚C lead to best heat transport.



(1)



(2)

Figure (1) and Figure (2): show that the strength of slabs

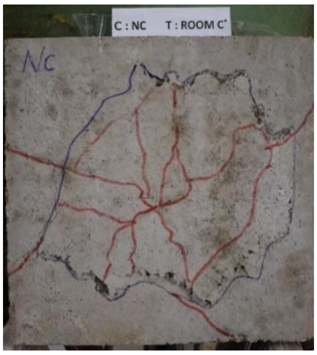
5.3 Size Zone Area of Failure Punching Tested:

The areas of the punching failure zones are measured by method by Auto Cad, the values of area these methods are illustrated in Table (5). the result show that area of punching load reinforced concrete bubbled slab without exposed to fire flam (NC-ROOM) was (35%) from total area of specimen, when slabs exposed to fire flam (150, 300 and 450)

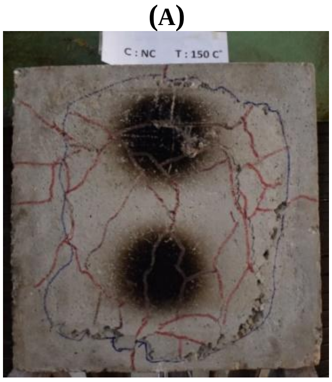
°C the punching area increase by (58%, 72% and 68%) respectively. In Geopolymer concrete bubbled slabs the punching area of reference slab was (37%) from total area of specimen, when slabs exposed to fire flam (150, 300 and 450) °C the punching area increase by (75%, 70% and 74%) respectively. Punching shear area decreasing with increase Glass fiber ratio. Shown in plate (1) which content 8 picture for punching zone of 8 specimens.

Table (5) Area of the Failure Zone of the Tested Slabs

Number of specimens	Labeling	Percentage of punching From total area (%)
1	NC -ROOM	61
2	NC -150	58
3	NC -300	72
4	NC-450	68
5	GP-ROOM	37
6	GP-150	75
7	GP-300	70
8	GP450	74



(A)



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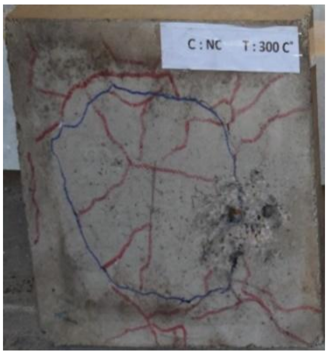
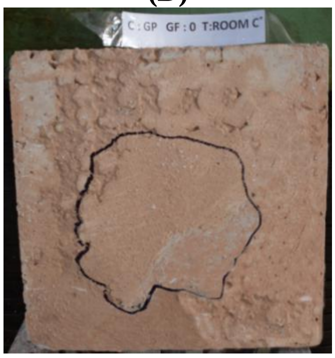


(C)

(D)



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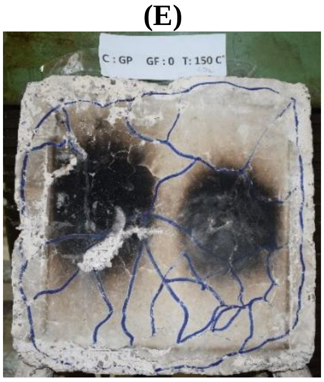

(G)

(H)

(I)

Plate (1) area of punching zone

6. Conclusions:

- The losses in ultimate load on the specimens when exposed to fire flame in Geopolymer more than in concrete
- No spalling occurs in Geopolymer at variance concrete clearly
- when Geopolymer concrete bubbled slab exposed to 150 ˚C increase an improvement in ultimate load.
- In 300 and 450 ˚C ultimate strength decrease due to exposed to elevated temperature.
- The strength of slabs decrease in 300 ℃ is more than 450 ℃.

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