International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 12 (2018), pp. 2099-2124

http://www.irphouse.com

Strength of Concrete Having Different Ratios of MetaKaolin under Graduated Temperatures Rising

Assist Lec. Lubna Mohammed Abd [1]

[1]*(Environmental Engineering Department, College of Engineering / Al-Mustansiriyah University, Baghdad, IRAQ)*

Lec. Dr. Arshad Nadhom Mohammed Ali [2]

[2]*(Civil Engineering Department, College of Engineering / Al-Mustansiriyah University, Baghdad, IRAQ)*

Lecturer Muhannd Waleed Majeed [3]

[3]*(Water Resources Engineering Department, College of Engineering / Al-Mustansiriyah University, Baghdad, IRAQ)*

ABSTRACT

In this research work, the influence of low and high temperature on several features of concrete was studied. Partial replacement of sand in engineering projects reduces the cost of construction with ecological benefits. The percentages of replacement of Meta Meta Kaolin is (0, 15, 30 and 45) % used in the mixture. The flat plate slabs was subjected to graduated temperature rising of (0, 100, 200 and 300) °C. This research presents the best reinforced concrete flat slabs that resist burning of low cost and high efficiency. It is noticed that the value of Pu was the maximum at 15% replacement of all temperature especially with 100 °C which it is 33 kN. Also the maximum deflection was the lowest values at 15% with 100 °C.

Keywords: Meta Kaolin, Flat slab concrete, Graduated temperatures

I. INTRODUCTION

Reinforced concrete floor structures can provide a cost-effective solution to a wide variety of situations [1]. The variant in concrete features due to temperature rising will be determined by the use of nature coarse aggregate. A fire-resistive feature is one of the most benefits of concrete building materials; so concrete structures must be designed for fire impact. Structural work must still be capable for resisting live and dead loads without failure. Even though the temperature rising leads to a reduction in strength and elasticity modulus of concrete and reinforcement. Also, completely developed fires cause expansion of structural works and the resultant resisting stresses and strains. Structural design building code necessities for fire resistance is occasionally ignored then, lead to expensive errors. It is common to find that a concrete slab floor system may involve a smaller thickness to satisfy ACI 318 strength requirements than the thickness required by a building code for a 2-hour fire resistance. For safe and sound design, temperature requirements must be a portion of the initial design phase. Evaluating the temperature ranking for a member structure can differ in involvement from mining the related ranking using a simple table to a properly complex and ostentatious analysis [2].

Rising of temperature causes a reduction in the strength and elasticity modulus for both concrete and steel reinforcement. Though, the average at which strength and modulus reduction is governed by the temperature increasing of the fire and the isolating features of concrete. Note that concrete does not burn [3].

I.I META KAOLIN

"Meta Kaolin" is the resultant from the word (Kau-Ling), or high range the name particular to a hill near Jau-chau Fu, in China, where Meta Kaolin was first excavated. Meta Kaolin, usually denoted to as china clay, is a clay that comprises (10–95 %) of the mineral Meta Kaolinite and typically contains generally of Meta Kaolinite (85–95 %)[4]. Table **1** shows the physical properties of Meta Kaolin were brought from the state company of Geological survey and mining.

Table 1 Properties of Meta Kaolin

Property	**Value**	**Standard**
Plastic limit %	21	ASTM D4318
Liquid limit, %	34	ASTM D4318
Plasticity index, %	13	
Liquidity index, %	25.8	
Specific gravity	2.72	
Maximum dry unit weight kN/m^3	16.57	ASTM D1557
Optimum moisture content, %	17.65	ASTM D1557
Soil symbol according to (USCS)	CL	

I.II PUNCHING SHEAR

Punching shear is a category of collapse of reinforced concrete slabs exposed to high confined forces. In flat slab structures this happens at column support points.

The collapse owes by shear. This category of failure is cataclysmic since no observable marks are shown earlier to failure. Punching shear failure disasters have happened numerous times in this past period, as shown in Fig. **1 and 2** [5].

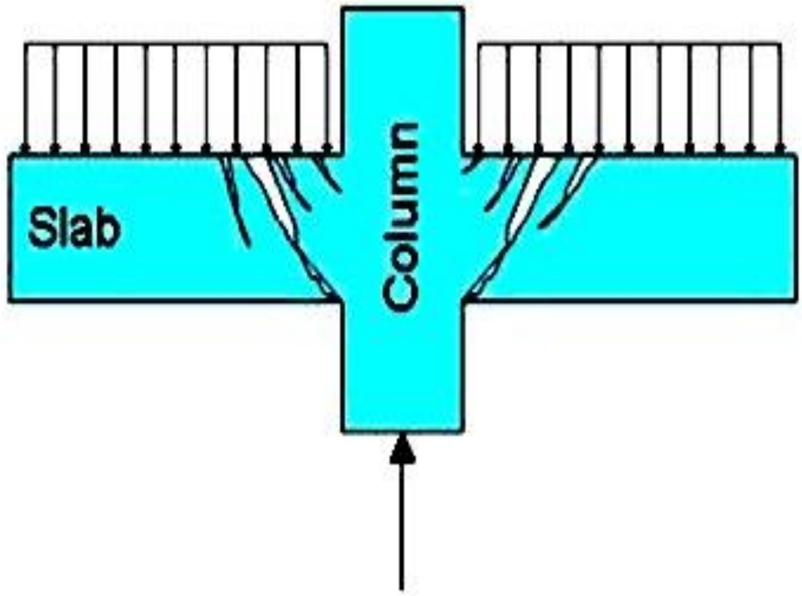


Fig 1 Punching shear failure

Fig 2 Punching shear failure

Punching shear also known as two-way action shear, is one of the main difficulties in such slabs at the joining between the slab and the column such type of failure is generally unexpected and leads to advanced collapse of flat slab structures. So, attention is needed in the design of such slabs and consideration should be given to avoid the unexpected collapse condition [6].

Punching shear collapse of reinforced concrete slabs happens when focused loads are started, causing a high value of shear. Firstly, stress combination presentation leads to radiated cracks, starting at the edge of the load application zone. Cumulative the load causes tangential cracks nearby the load application zone. The failure stage is reached when the inclined cracks form around the column with a usual cylindrical punching collapse cone as shown in Fig. **3**, the column splits from the slab. Without shear reinforcement, the punching shear collapse achieves in a brittle mode within the gap region of the highly stressed slab at the column [7].

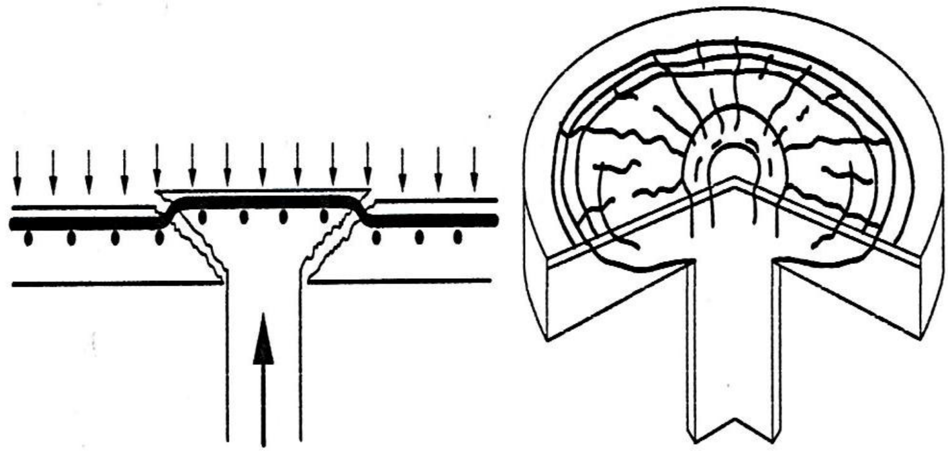


Fig 3 Cracking pattern and cylindrical cone of the punching shear failure

II. EXPERIMENTAL PROGRAM

Normal concrete flat slabs of (450*450*50) mm have been prepared using confident quantities of cement, fine aggregate (with partially replacement of Meta Kaolin in some specimens), coarse aggregate and water. In the testing program, the compressive strength of concrete was reserved constant which it is 30 MPa. The mix proportion was (1:2:3) by weight for cement, sand and gravel respectively with w/c ratio of (0.35). OPC type I with (350) kg/m^{3}content. AL-Ukhaider natural sand with fineness modulus (2.6) and specific gravity 2.63 was used. The gravel with maximum size (20) mm and specific gravity 2.65 was used. Meta Kaolin was partially percentages of (15, 30, 45) % replaced by sand. The reinforcement of the slabs was used with 6mm deformed bars of yield stress (400) MPa as shown in Fig. **4**. All specimens are casted in wooded mold as shown in Fig. **5** and totally vibrated on a vibrating table. The vibration time to reach full compaction is certain upon by the end of air bubbles passage from concrete fresh state. The specimens are then cast into three layers, in which 25-30 seconds are required for compaction per layer. They were named in to four groups and left for curing. After that the specimens were burned into (100, 200, and 300) °C and prepared for testing and comparing with reference specimens**.**

Fig 4 Deformed bars reinforcement

Fig 5 Wooded mold

III.TEST RESULT

As cited before, the key of this study is to explain the performance of 16 flat slabs with and without burning in relation of deflection and cracking. Load versus deflection was recorded. Crack patterns with first crack load are also studied. Ultimate load capacity with corresponding failure mode was recorded.

III.I CRACKING AND ULTIMATE LOADS

Cracking load is the load which is the first observable surface cracks on the surfaces of the member. While the ultimate load is the maximum load of the member which reaches to failure. Table **2** and Fig. **6 and 7** below show the first crack and ultimate loads for the specimens.

Table 2 Cracking and Ultimate loads of specimens

Name	Pu	Pcr	Pcr/ Pu %	Pu/ Pu R%
NC0% - 0C°	28	10	35.71	
NC15% - 0C°	30	11	36.67	107.14
NC30% - 0C°	26	7	26.92	92.86
NC45% - 0C°	22	5	22.73	78.6
NC0% - 100C°	30	11	36.67	
NC15% - 100C°	33	13	39.4	110
NC30% - 100C°	28	9	32.14	93.33
NC45% - 100C°	25	7	28	83.33
NC0% - 200C°	26	7	26.9	
NC15% - 200C°	29	10	34.5	111.5
NC30% - 200C°	27	9	33.33	103.85
NC45% - 200C°	24	6	25	92.3
NC0% - 300C°	22.5	5	22.22	
NC15% - 300C°	28	9	32.14	124.4
NC30% - 300C°	26	7	26.9	115.6
NC45% - 300C°	21	4	19	93.33

Where:

NC0% - 0C° : Slab without burning, without Meta Kaolin replacement

NC15% - 0C°: Slab without burning, with 15% Meta Kaolin replacement

NC30% - 0C° : Slab without burning, with 30% Meta Kaolin replacement

NC45% - 0C° : Slab without burning, with 45% Meta Kaolin replacement

NC0% - 100C° : Slab with100 C° burning, without Meta Kaolin replacement

NC15% - 100C° : Slab with100 C° burning, with 15% Meta Kaolin replacement

NC30% - 100C° : Slab with100 C° burning, with 30% Meta Kaolin replacement

NC45% - 100C° : Slab with100 C° burning, with 45% Meta Kaolin replacement

NC0% - 200C° : Slab with 200 C° burning, without Meta Kaolin replacement

NC15% - 200C° : Slab with 200 C° burning, with 15% Meta Kaolin replacement

NC30% - 200C° : Slab with200 C° burning, with 30% Meta Kaolin replacement

NC45% - 200C° : Slab with200 C° burning, with 45% Meta Kaolin replacement

NC0% - 300C° : Slab with 300 C° burning, without Meta Kaolin replacement

NC15% - 300C° : Slab with 300 C° burning, with 15% Meta Kaolin replacement

NC30% - 300C° : Slab with 300 C° burning, with 30% Meta Kaolin replacement

NC45% - 300C° : Slab with 300 C° burning, with 45% Meta Kaolin replacement

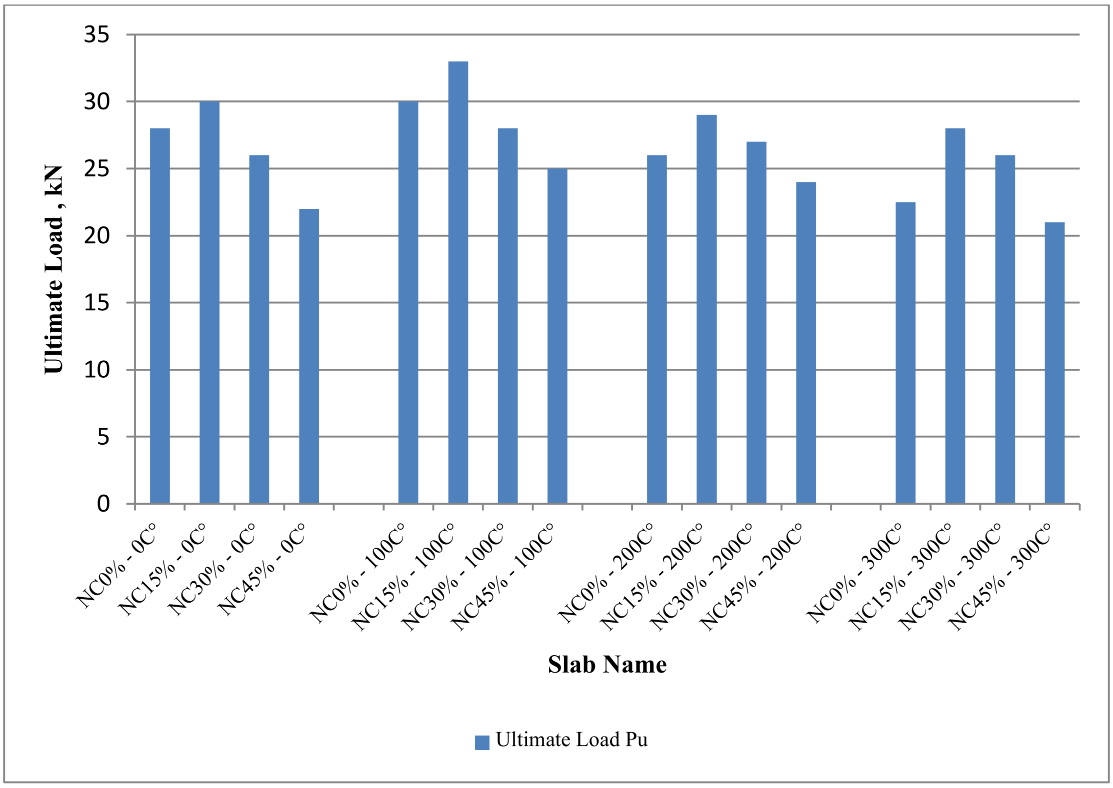


Fig 6 Ultimate loads of specimens

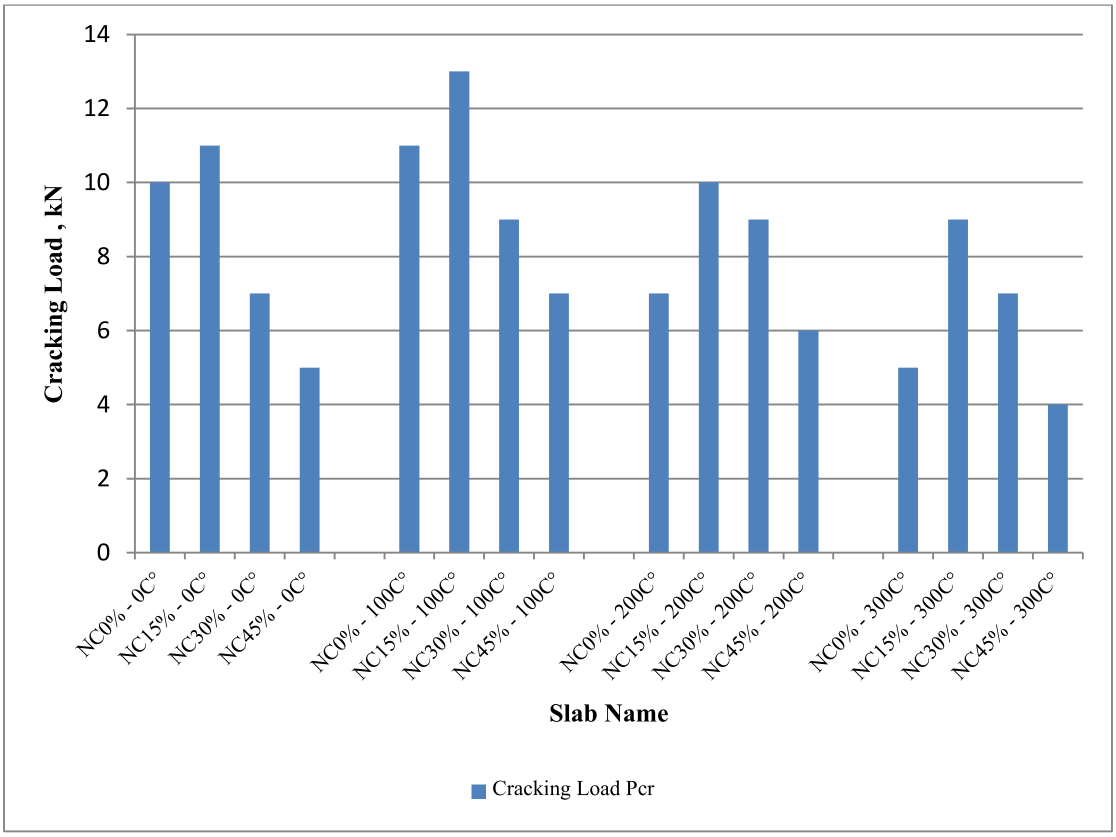


Fig 7 Cracking loads of specimens

From the table and Figures above, in all specimens, it is shown that the percentage 15% of Meta Kaolin replacement gives the larger values of ultimate load (Pu) and cracking load (Pcr) than the other percentages of Meta Kaolin , this result of the excellent role of excellent addition for bonding the materials to resist burning and loads until failure.

The increment of temperature over than 100° C burning make the slab more brittle that leads to ultimate and cracking loads smaller than the other groups of such decreasing temperature slabs.

The percentages of Pcr/Pu % was the maximum values at 100 °C than the other temperatures this mean, that was not affected at small temperature burning and the presence of Meta Kaolin strengthen the slab to resist loads as shown in Fig. **8**.

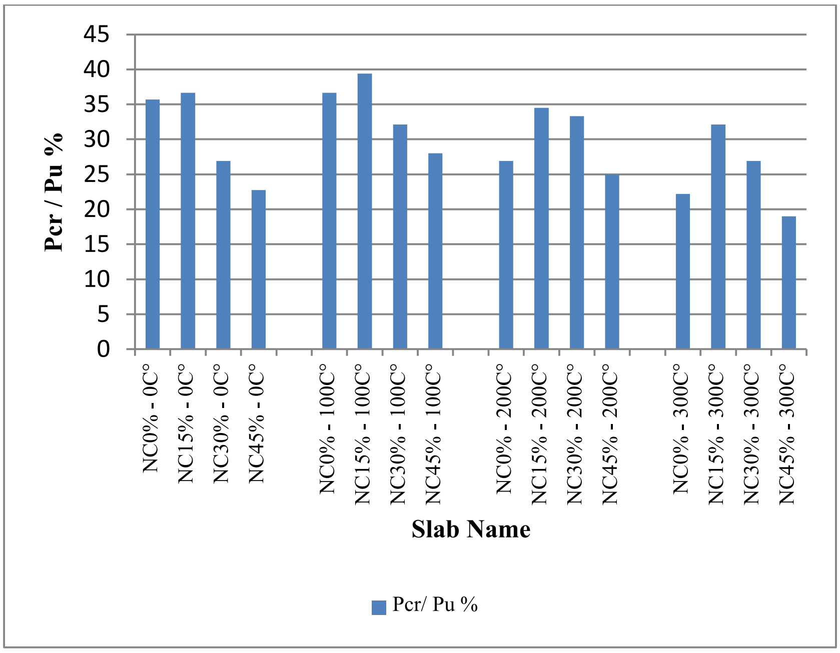


Fig **8** The percentages of Pcr/Pu % of specimens

The percentage Pu/Pur % gives more results in the group of 300° C burning especially with 15% replacement Meta Kaolin because the bigger values of Pu which it is (124.4%) as shown in Fig. **9**.

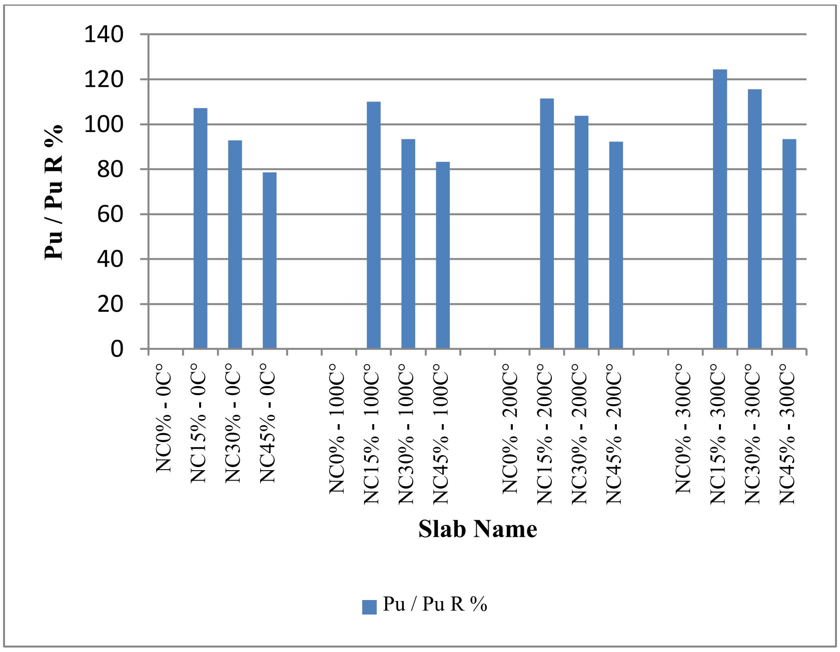


Fig 9 The percentage Pu/Pur % of specimens

Also, the Fig. from **10 to 13** show the ultimate load for different temperatures but with the same percentage of Meta Kaolin replacement.

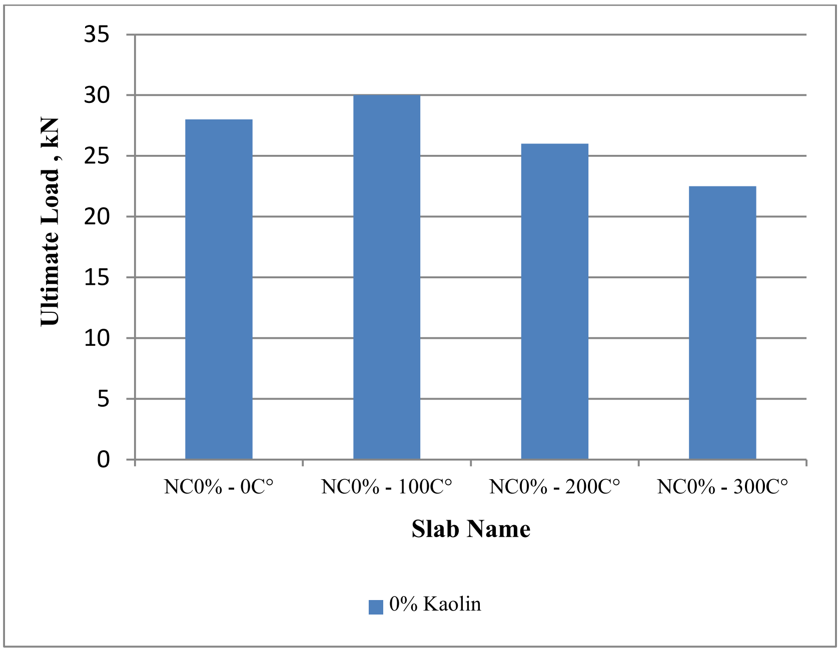


Fig 10 Ultimate loads for 0% Meta Kaolin replacement with different temperatures

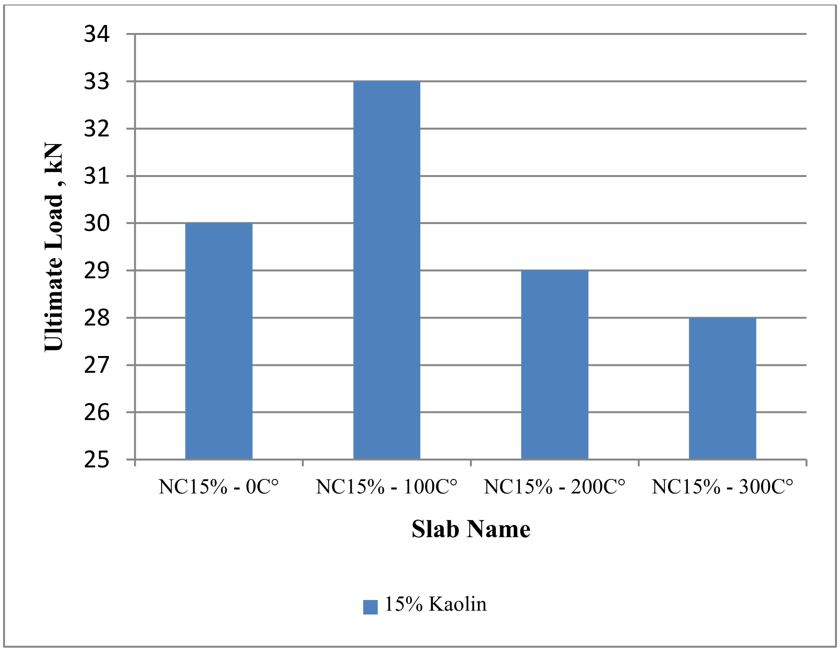


Fig 11 Ultimate loads for 15% Meta Kaolin replacement with different temperatures

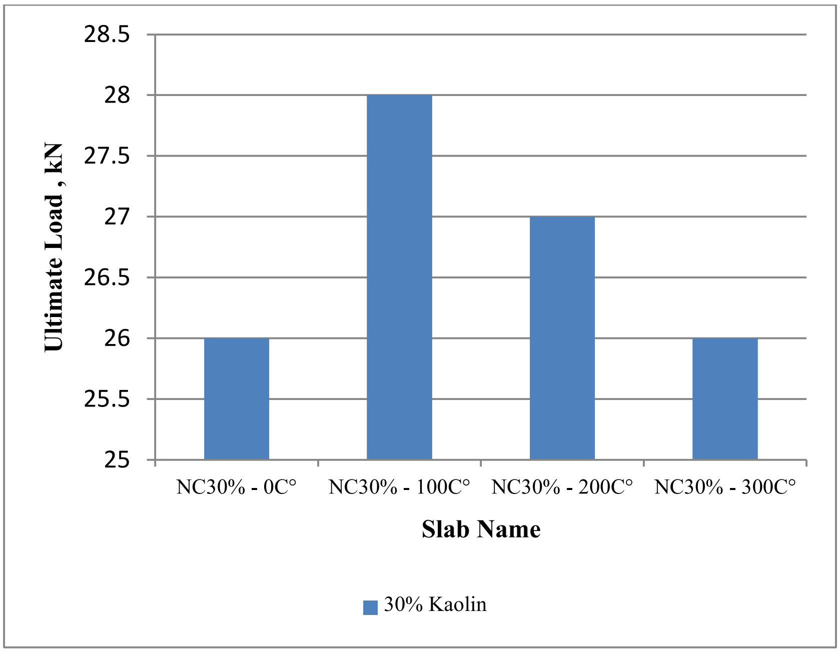


Fig 12 Ultimate loads for 30% Meta Kaolin replacement with different temperatures

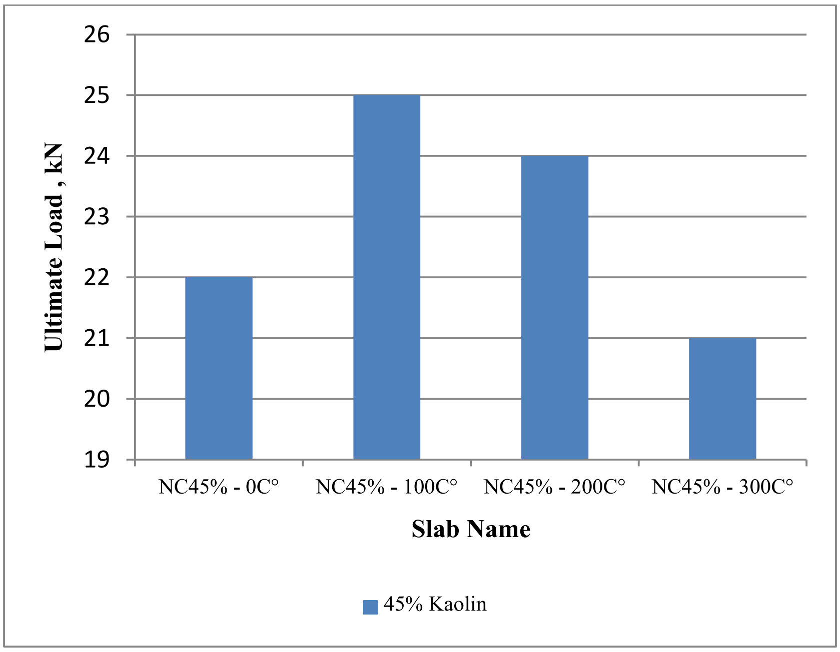


Fig 13 Ultimate loads for 45% Meta Kaolin replacement with different temperatures

For the Fig. from 10 to 13, the percentage15% replacement of Meta Kaolin gives the maximum values of Pu, this mean that it is excellent percentage that increase the concrete resisting under loads.

The Fig. **14** below shows the percentages of the burning ultimate loads to the ultimate loads of the reference specimens without burning for the same percentage of Meta Kaolin replacement.

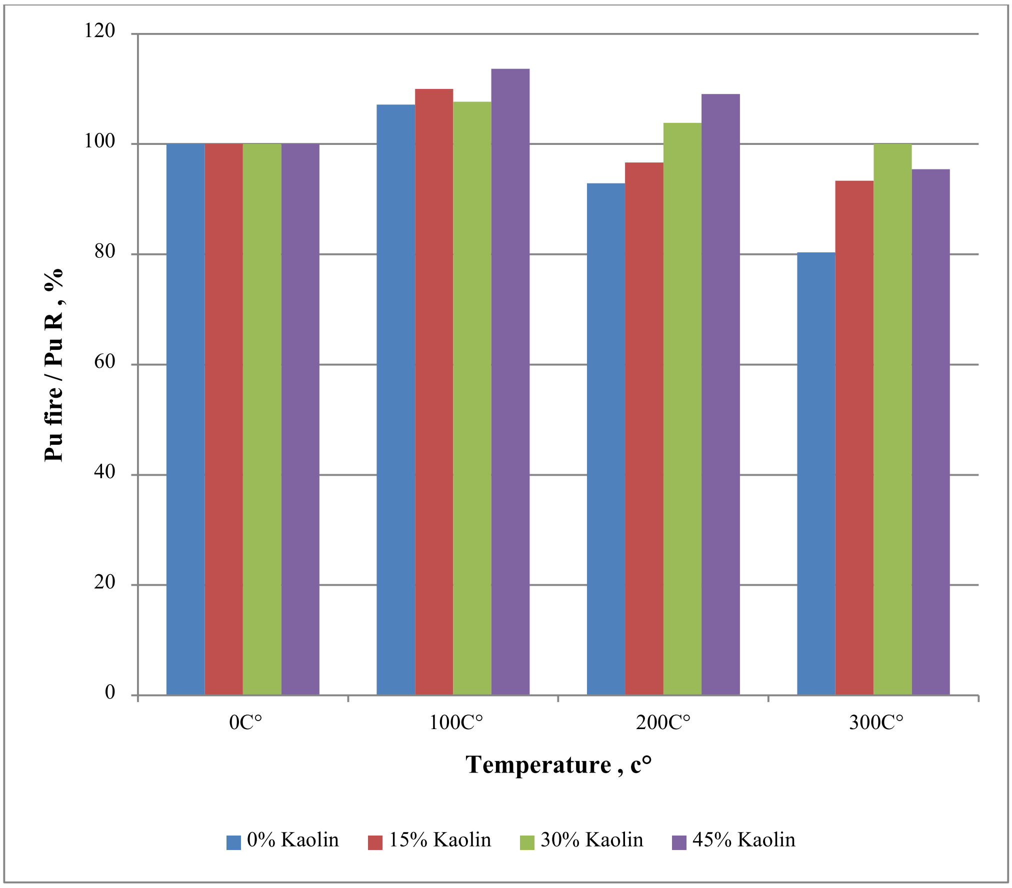


Fig 14 Pu fire / Pu% for all specimens

The Figure above, shows that the 100 °C gives the maximum values of Pu fire/Pu R % this mean that the concrete resist the high temperature values between (100 -200) ° C with little decrease of ultimate loads due to temperature effect while the Meta Kaolin bond the mixture very well and fill the gaps between gravel and other particle in the concrete mixture and this result very well ranges of Pu with burning.

III.II LOAD -DEFLECTION CURVES

The structural performance is usually clarified using load against deflection curves. The load-deflection curves in this study are occupied at center of all the tested slabs. Table **3** shows the maximum deflection in center of slabs with maximum load, and Fig. from **15 to 18** show the load-deflection curves of specimens.

Table 3 The maximum deflection of specimens

Name	Pu (kN)	Maximum deflection (mm)
NC0% - 0C°	28	5.5
NC15% - 0C°	30	5
NC30% - 0C°	26	6.18
NC45% - 0C°	22	6.96
NC0% - 100C°	30	4.95
NC15% - 100C°	33	4.51
NC30% - 100C°	28	5.63
NC45% - 100C°	25	6.22
NC0% - 200C°	26	6.11
NC15% - 200C°	29	5.27
NC30% - 200C°	27	5.87
NC45% - 200C°	24	6.95
NC0% - 300C°	22.5	6.57
NC15% - 300C°	28	5.42
NC30% - 300C°	26	6.22
NC45% - 300C°	21	7.35

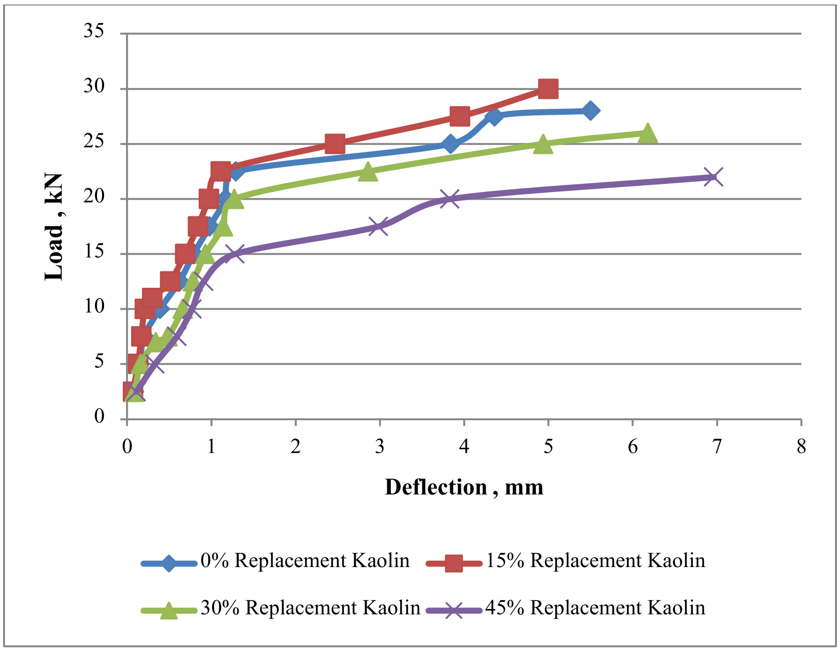


Fig 15 load deflection curves for 0°C

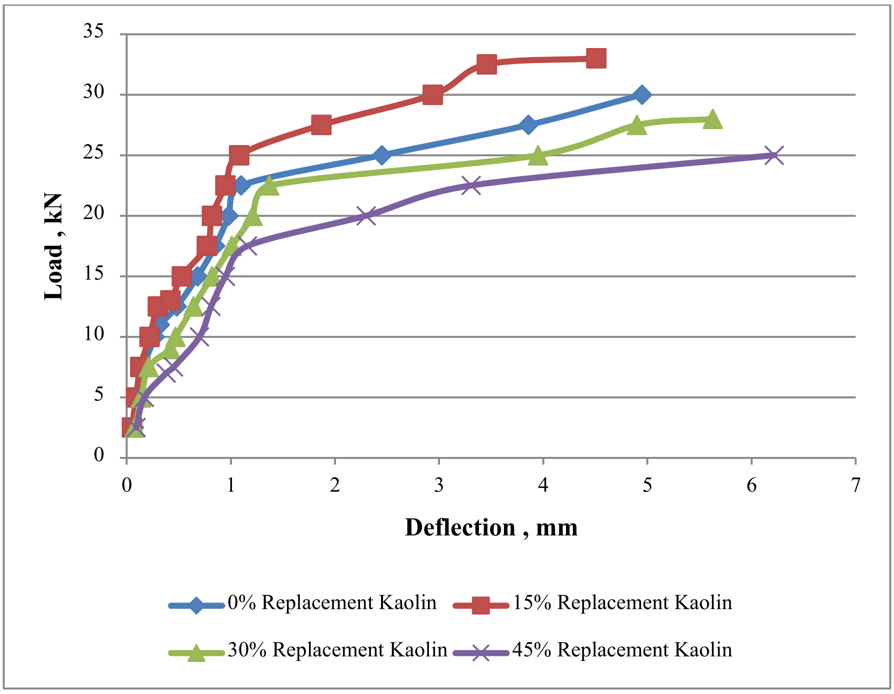


Fig 16 load deflection curves for 100°C

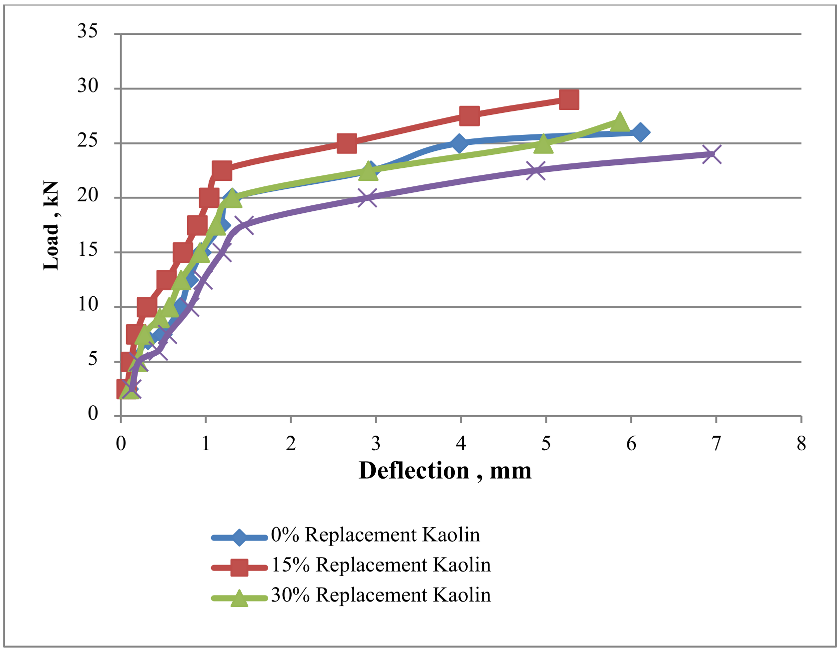


Fig 17 load deflection curves for 200°C

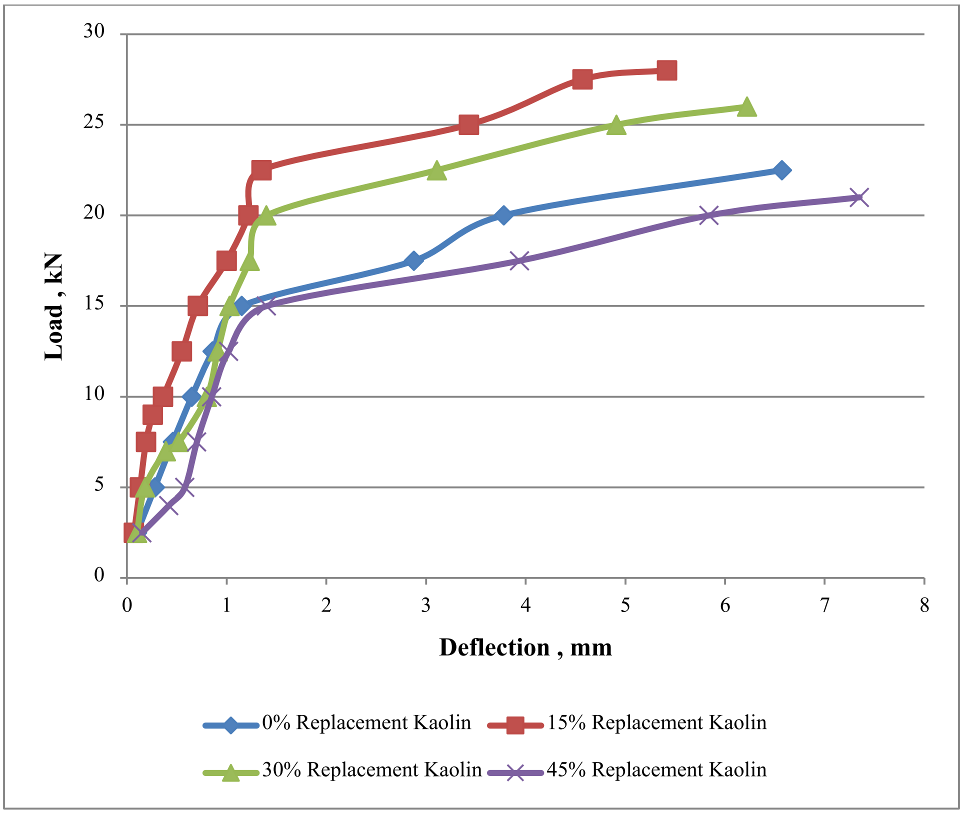


Fig 18 load deflection curves for 300°C

In load-deflection curves in Figures above, for all temperature variation, the mix of 45% Meta Kaolin replacement gives the larger deflection values than the other percentages of replacement while the 15% replacement gives the smallest values of deflection.

III.III CRACK PATTERNS AND MODES OF FAILURE

In this study, the slabs are designed with deformed bars of Φ6@50 mm spacing in two directions. These slabs fail by punching. The two directions steel reinforcement tied well together and makes a grid in order to certify that no bond failure between steel bars and adjacent concrete can happen**.** Crack width is measured by a simple gauge (knives) having a minimum thickness of 0.05 mm as shown in Figure **19** which is used to give an approximate crack size during visual surveys, this simple gauge has been designed to provide inspectors with a low cost alternative for determining the width of cracks in a concrete. Table **4** and Fig. **20** show the maximum crack width and modes of failure for the tested slabs.

Fig 19 Crack measurer

Table 4 Crack width and modes of failure

Slab Name	Pu kN	Crack width, mm	Mode of failure
NC0% - 0C°	28	2.50	Punching
NC15% - 0C°	30	2.45	Punching
NC30% - 0C°	26	2.45	Punching
NC45% - 0C°	22	2.40	Punching
NC0% - 100C°	30	2.65	Punching
NC15% - 100C°	33	2.50	Punching
NC30% - 100C°	28	2.55	Punching
NC45% - 100C°	25	2.45	Punching
NC0% - 200C°	26	2.75	Punching
NC15% - 200C°	29	2.45	Punching
NC30% - 200C°	27	2.50	Punching
NC45% - 200C°	24	2.45	Punching
NC0% - 300C°	22.5	2.80	Punching
NC15% - 300C°	28	2.60	Punching
NC30% - 300C°	26	2.55	Punching
NC45% - 300C°	21	2.55	Punching

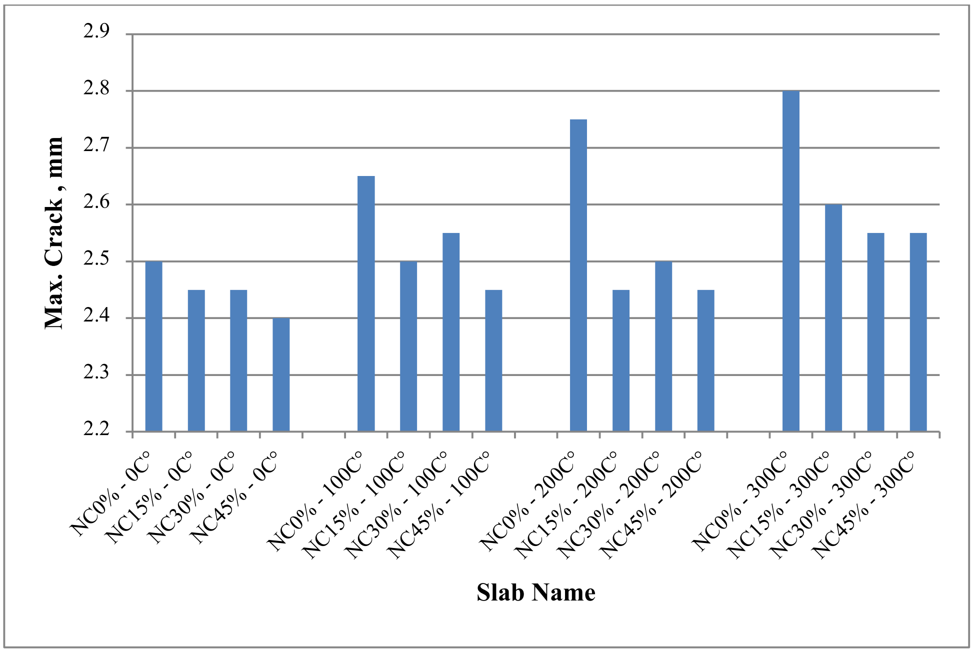


Fig 20 Maximum crack width of specimens

At all temperature variations, the maximum crack width is at the slab of 0% Meta Kaolin replacement, while when using Meta Kaolin replacement the maximum crack width decrease to (88)%. The Fig. from **21 to 24** show crack patterns of all specimens.

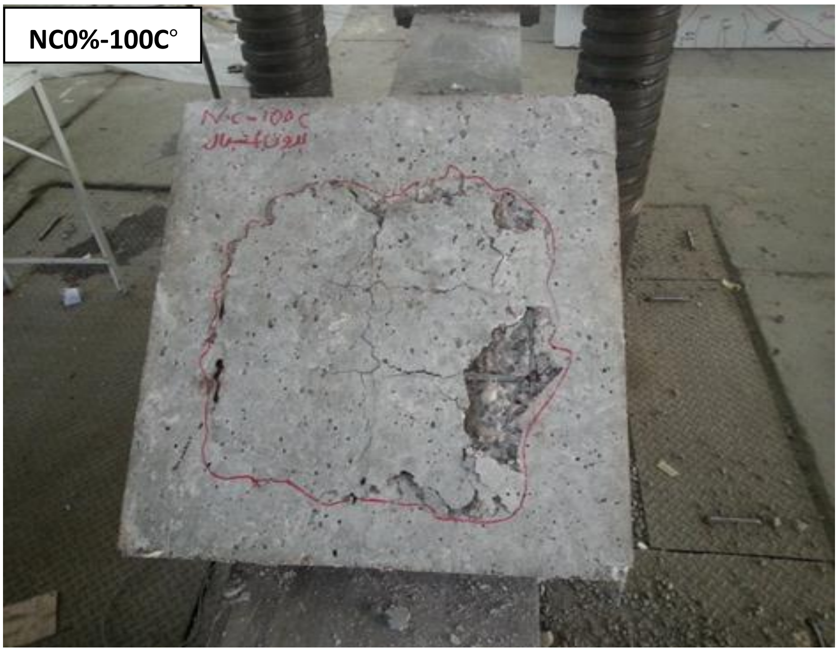
a) 0% Meta Kaolin replacement

b) 15% Meta Kaolin replacement

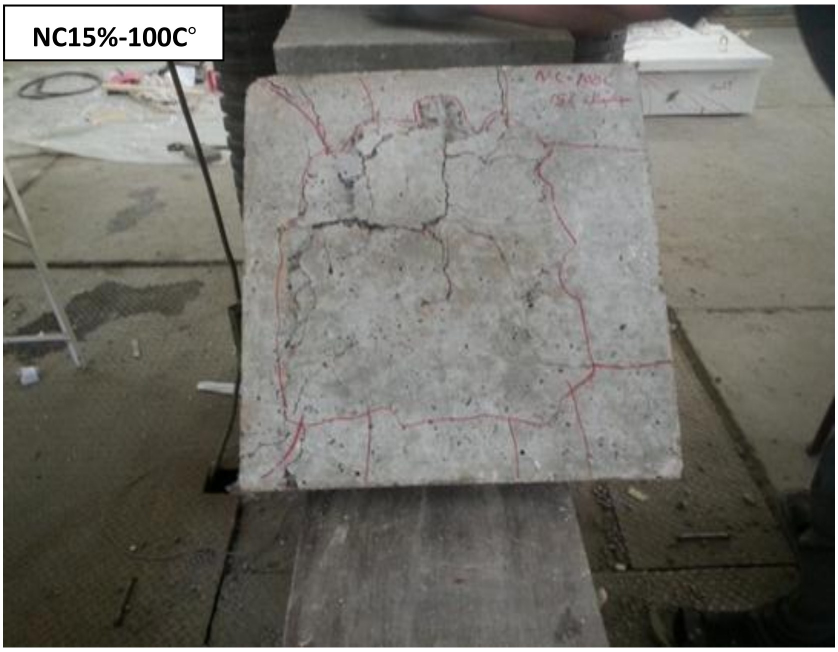
c) 30% Meta Kaolin replacement

d) 45% Meta Kaolin replacement

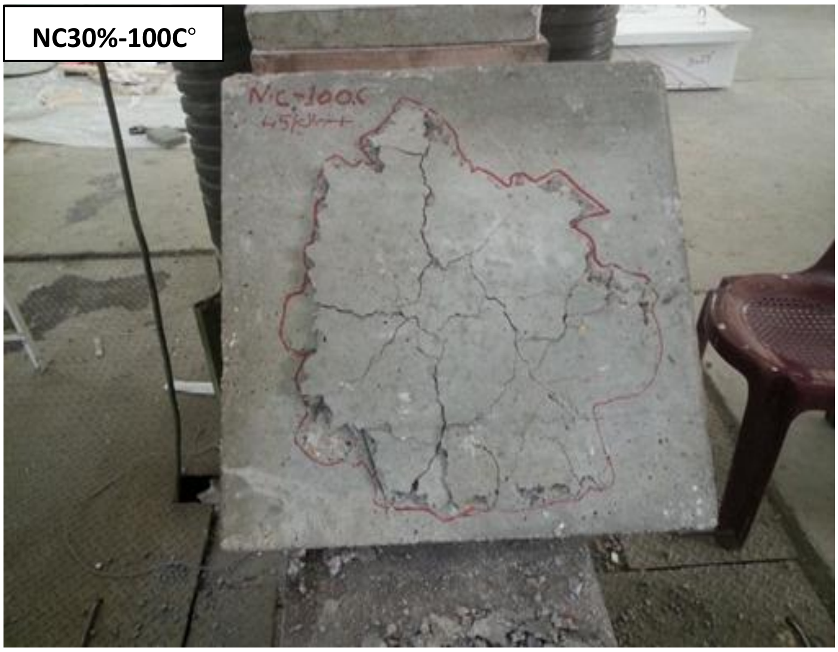
Fig 21(a,b,c and d) Crack patterns of specimens of 0°C



a) 0% Meta Kaolin replacement



b) 15% Meta Kaolin replacement



c) 30% Meta Kaolin replacement

d) 45% Meta Kaolin replacement

Fig 22 (a,b,c and d) Crack patterns of specimens with 100° C

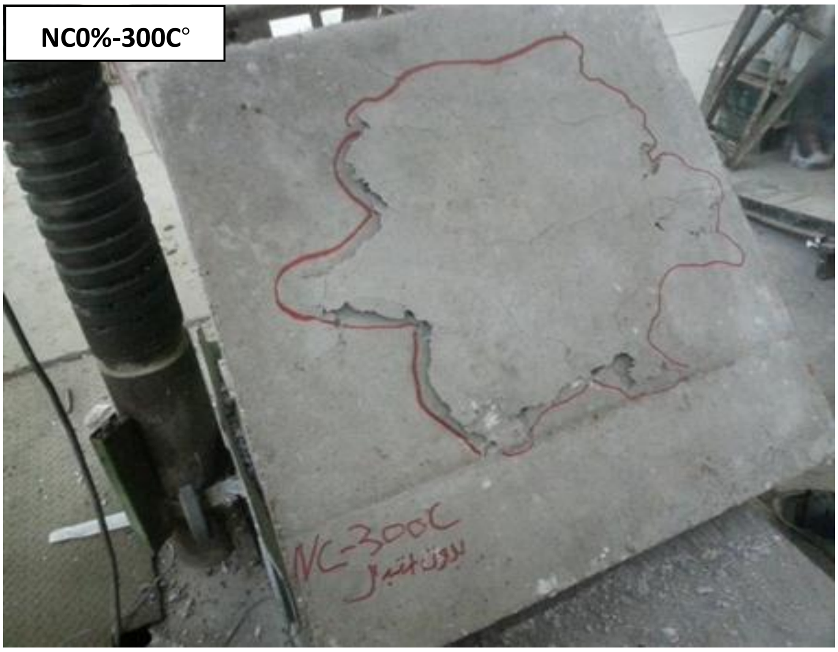
a) 0% Meta Kaolin replacement

b) 15% Meta Kaolin replacement

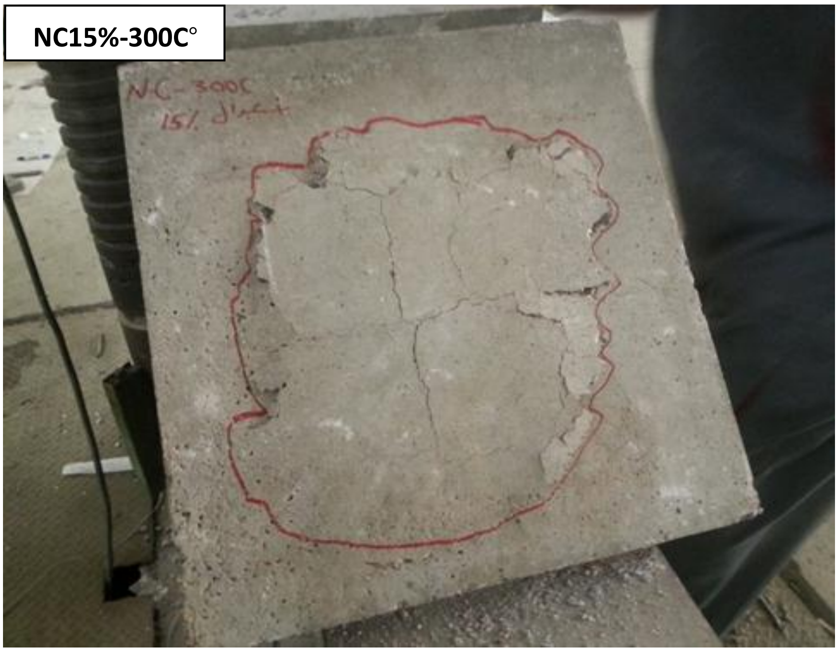
c) 30% Meta Kaolin replacement

d) 45% Meta Kaolin replacement

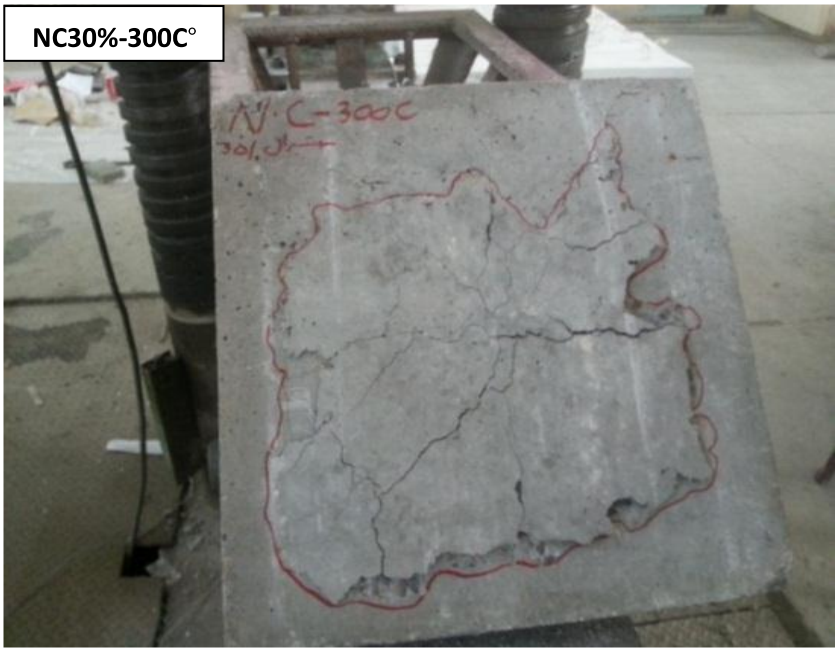
Fig 23(a,b,c and d) Crack patterns of specimens with 200 °C



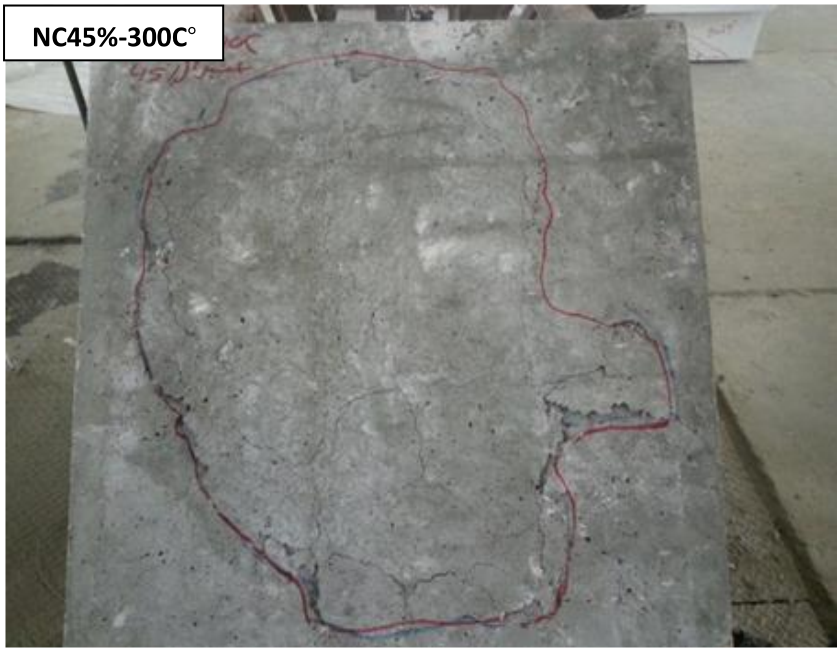
a) 0% Meta Kaolin replacement



b) 15% Meta Kaolin replacement



c) 30% Meta Kaolin replacement



d) 45% Meta Kaolin replacement

Fig 24 (a,b,c and d) Crack patterns of specimens with 300 °C

IV. CONCLUSIONS

Concrete is an inelastic material and fails unpredictably. Adding of Meta Kaolin to concrete vary its brittle mode of failure into a more ductile one then, develops the concrete ductility. The strength of concrete growths with Meta Kaolin content. It is real between (15 - 30) % as compared with the reference specimens especially of 15% replacement gives percentage of increase in ultimate load (113) %. But if the replacement more than 30%, the strength of concrete starts falling. So, it is desirable to use Meta Kaolin with (15-30) % replacement of cement and it gives the enhanced result. The fact is that the Meta Kaolin has calcium and aluminum content which enhances the pozzolana reactions when the water is added to the concrete mix. Also, the higher value of ultimate load is at 100°C with 110% increase. The failure mode is punching in all specimens of slabs.

REFERENCES

[1] David A. Fanella, Ph.D., S.E., P.E., and Iyad M. Alsamsam, Ph.D., S.E., P.E,"Design of Reinforced Concrete Floor Systems"Professional Development Series, September 2007.

[2] Lotfi, Hamid and Munshi, Javeed, “Preliminary Analytical Investigation of High Strength Concrete Column Structural Performance Under Fire Loading” unpublished report, Construction Technologies Laboratories, Inc. June 2001.

[3] David N. Bilow, P.E., S.E. and Mahmoud E. Kamara, " Fire and Concrete Structures", Structures 2008: Crossing Borders.

[4] Muhannd Waleed Majeed AL-Obydi, " Effect of using petroleum products on the characteristics of swelling soil", June 2012.

[5] https://civildigital.com/punching-shear-punching-shear-flat-slabs.

[6] Long, A.E. "Punching Failure of Slabs, Transfer of Moment and Shear" Journal of the Structural Division, St.4, April, 1973, pp. 665-685.

[7] Karsten Winkler and Friedhelm Stangenberg "Numerical Analysis of Punching Shear Failure of Reinforced Concrete Slabs", Ruhr-University Bochum, Universitätsstr. 150, 44780 Bochum, Germany Institute for Reinforced and Prestressed Concrete Structures.