Diyala Journal of Engineering Sciences

ISSN 1999-8716

Printed in Iraq

Vol. 08, No. 02, pp. 116-133, June 2015

EFFECT OF HEATING ON SIMPLY SUPPORTED REINFORCED CONCRETE DEEP BEAMS

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(Received: 4/11/2013; Accepted: 18/8/2014)

ABSTRACT: - This laboratory research is concerned with the behavior of reinforced concrete deep beams, being exposed to high temperatures for one time or more. Two types of mixing water are used, namely, drinkable water (tap water) and non-drinkable water (raw water) brought from local wells in Baquba city, a situation which is currently under use in Iraq especially in large urban and nonurban engineering facilities. The specialized high temperature furnace is manufactured used in this study to heat twenty-four specimens. Later on after deep beams are casted, specimens are cooled down by two ways, gradually, by leaving them in the air for one day, and the fast way by gently putting them in water. This is to reflect the case of fire extinguish process with integrity of concrete. Testing of beams is carried out by loading each beam, using flexural machine, with two concentrated loads till failure.

Test results show that using raw water in casting concrete (no heat exposure) leads to significant decrease in shear strength and an increase in deflection in comparison with using tap water. It is also observed that heat and then rapidly cooling causes a touchable strength decrease and deflection increase especially when raw water is used for concrete casting.
Finally, it is worth to mention that the lowest percent reduction in loading strength recorded is that for specimens cast with non-drinkable water and exposed to cyclic temperatures, with rapid cooling at each time.

Keywords: deep beam, heating, cyclic heating, way of cooling, raw water.

1. INTRODUCTION:

Concrete has good strength properties concerning high temperature resistance compared with other materials and it covers and protects steel during fire exposure. Concrete suffers changes in its chemical composition and physical structure when exposed to fire. Such changes in the physical and mechanical properties of concrete are related to temperature increase.

(Lau and Anson, 2006) studied the chemical and physical changes within the concrete, such as the decomposition of calcium hydroxide $Ca(OH)_2$, the incompatibility at the aggregate–cement paste boundary and the crystal transformation of quartz SiO_2 (1).

(Hsu and Lin, 2006) studied the residual bearing capabilities of fire-exposed reinforced concrete beams. They concluded that the shear reinforcement provides the main shear strength in common states but decreases quickly when yielding strength has been influenced by high temperature. They also concluded that the covered concrete may delay the effect of high temperature on the strength of shear reinforcement. Increasing the thickness of covered concrete is helpful to protect the damage of fire on the shear strength (2). (Bratina et al., 2007) studied the effects of different strain contributions on the response of RC beams in fire. They established that the consideration of creep and transient strains in concrete has little effect on the fire resistance time of statically determinate beams under bending or unconstrained centrically loaded columns (3).(Chen et al., 2009)studied the effect of fire exposure time on the post-fire behavior of reinforced concrete columns. They showed that the residual load-bearing capacity decreases with increase in fire exposure time. In addition, the reduction in residual stiffness is higher than that in ultimate load (4).

After studying the effect of fire on the flexural strength of shallow reinforced concrete beams, (Chadha and Mundhada, 2012) concluded that the majority of fire damaged RCC structures is repairable. However, the effect of elevated temperature above 900°C on the reinforced concrete beams was observed to cause a significant reduction in flexural strength (5).

(Choi&Shin, 2011) studied the structural behavior and simplified thermal analysis of normal-strength and high-strength concrete beams under fire. They investigated the effects of concrete compressive strength and cover thickness on the structural behaviour of reinforced concrete beams under fire. Test results for normal-strength and high-strength concrete beams evaluated the heat distribution and displacement changes of simply supported beams subjected to sustained loads under fire (6).

(Mundhada & Pophale, 2013) studied the effect of elevated temperatures on performance of RCC beams. Results revealed robust performance up to 550°C. The drop in flexural strength & other parameters was noticeable but not alarming up to 750°C. Around 950°C, the RCC members lost their fidelity on all counts (7).

2- MATERIALS USED IN THE EXPERIMENTAL WORK:

2.1 Water:

Two types of water are used in experimental work. The first one is tap water (drinkable) and the second is raw water brought from a local well in Baquba. Well water is similar to that of tap water in terms of transparency and odour. It is tested in Water National Laboratory / Diyala. Chemical analysis results of well water are shown in Table 1.

It is clear from Table 1 the following indicators:

- Turbidity value is about six times more that permitted for drinking water.
- T.D.S. is six times more than permitted in drinking water.

2.2 Cement

Iraqi national ordinary Portland cement produced in Tasloja according to the Iraqi standard specification (IOS, No.5, 1984) is used throughout the research work (8).The chemical and mineralogical analysis of the used cement is conducted at the National Center of Construction and Research Laboratories / Diyala, see Table 2.

2.3 Fine aggregates

River aggregates obtained from Al-Ekheidher area having a fineness modulus of (1.79) and a gradation compatible to the Iraqi standard specification (IOS, No.45, 1984)[9]are used. Analysis is done in the National Center of Construction and Research Laboratories / Diyala. Other characteristics are shown in Table 3. The sieve analysis of sand used throughout this work lies within the range defined by (ASTM C33-03, 2002).

2.4 Coarse aggregates

River gravel available in the suburbs of Baquba area (Sudour) with a maximum aggregate size of (6mm) is used. The sieve analysis of sand used throughout this work lies within the range defined by (ASTM C33-03, 2002) (1). Analysis is done in the National Center of Construction and Research Laboratories / Diyala. Characteristics of coarse aggregate are shown in Table 3.

2.5 Reinforcing steel bars

Deformed steel bars of (4 and 6mm) diameter are used. Table 4 shows the properties of these reinforcing bars. The tests are made in the Engineering Consultancy Bureau at College of Engineering, Baghdad University.

2.6 Concrete Compressive Strength

The aim of this study is not to get a job-mix-formula but to study deep beam behavior casted with raw water and under fire heat. The followings are some details of concrete mixture conducted in Diyala University – College of Engineering laboratory according to (Teychenné D. C. et al., 1997) (11):

- Concrete compressive strength (for 100mm x 100mm x 100mm cube), $f'c$= 40 MPa.
- Water cement ratio, w/c= 0.55.
- Water content is 250 kg/m^3.
- Fine aggregate is 720kg/m^3.
- Coarse aggregate is 975 kg/m^3.

So, for (150mm x 300mm cylinder), $f'c \approx 40 \times 0.85 \times 0.85 \approx 28.9$ MPa

3- EXPERIMENTAL WORK

Twenty-four specimens divided into four groups of deep beams are castedin the construction materials laboratory of the Civil Engineering Department of Diyala University in order to cover all conditions and parameters that are intended to be studied in this work, as shown in Table 5. All beams having same dimensions which are 50mm×120mm×480mm cast in four steel forms fabricated especially for this work, see Figure 1. The reinforcing bars are cut to the desired lengths, and 90-degree hooks are formed at the ends of each 6mm diameter deformed tension bar. Stirrups made from 4mm diameter deformed bars are provided to prevent shear failure, with a 6mm concrete cover, see Figure 2 and Figure 3. Two beams from group A and two beams from group B are retained as reference beams for 28 days; twenty beams are exposed to fire heat with different temperature levels of exposure. The specimens including 100mm x 100mm x 100mm cubes cast from each batch of concrete pouring in order to measure the compressive strength of concrete $f'c$ before and after any heating.

Fabricated high temperature furnace is used in this study in providing heat for specimens. Furnace internal dimensions are 710mm×300mm×760mm made of 0.5 cm thick steel plates with brick cover face as shown in Figure 4, to heat two prisms and four cubes in each time. The temperature is monitored by using a digital thermometer inside the furnace with a digital temperature reader as shown in Figure 5. Heating time is kept one hour after reaching the required temperature. Later on after deep beams heating, specimens are cooled down by two ways, gradually, by leaving them in the air for one day, and the fast way by gently putting them in water, see Figure 6. This is to reflect the case of fire extinguish process on integrity of concrete.

One day before testing, each specimen is carefully cleaned, supporting and load application points are marked accurately, then finally painted to clarify the propagation of cracks.

Load is applied on each specimen through two concentrated points on top of the beam and all beams are tested till total failure. Beam own dead load is neglected here because based on previous studies dead load effects are negligible in comparison with the effects of concentrated failure loads (Niranjan and Patil, 2012)[12]. Testing of beams is carried out by loading each beam, using flexural machine as shown in Figure 7.

4- TESTING OF SPECIMENS

4.1 Group A, cast by using drinkable (tap) water

Eight specimens of group A which are beams cast with tap (drinkable) water are loaded till failure. It is observed that loading level in beams exposed to heat is less with higher deflection in comparison with the reference beams that are not exposed to temperature, see Table 6. Figure 8 shows load-deflection curves and Figure 9 shows beams of group A after testing. Strength in beams rapidly cooled is less with higher deflection in comparison with their counterparts which are cooled gradually.

4.2 Group B, cast by using drinkable (tap) water, heat cycled

Four specimens (specimens of group B) which are beams cast by using tap (drinkable) water are loaded till failure as shown in Table 7. Figure 10 shows load-deflection curves and Figure 11 shows beams of group B after testing.

Heat cycling, refers to the process of heating – cooling – heating – cooling and the like. This type of cycles may have an actual ground in real life and the probability of fire is a great event, and happening once (or twice or even more) again in the same place in another time. The cooling takes place either by rapid direct water jets or by leaving the fire to get down by itself.

Here, the four beams of group B are heated to 350^{o}C, and after that, cooled then heated again to 650 ^{o}C and finally cooled, while two of them are heated additionally to 850^{o}C then also cooled.

It was observed that loading level in beams exposed to cyclic heat is less with higher deflection in comparison with the reference beams that are not exposed to temperature. Strength in beams rapidly cooled is less with higher deflection in comparison with their counterparts which are cooled gradually.

4.3 Group C, cast by using raw (well) water

Eight specimens of group C, which are beams, cast by using raw (well) water are loaded till failure as shown in Table 8. Figure 12 shows load-deflection curves and Figure 13 shows beams of group C after testing. It was seen that replacing tap water by well one leads to strength decrease and deflection increase for beams CDB1&CDB2 in comparison with ADB1&ADB2.

It was also seen that exposing specimens to heat in addition to using well water leads to extra strength decrease and deflection increase while strength in beams rapidly cooled is less with higher deflection in comparison with their counterparts which are cooled gradually.

4.4 Group D, cast by using raw (well) water, heat cycled

Two concentrated forces are applied to four specimens (specimens of group D) which are beams cast by using well water as shown in Table 9. Figure 14 shows load-deflection curves and 15 shows beams of group D after testing.

Here, the four beams of group D are heated to 350^{o}C, and after that, cooled then heated again to 650^{o}C and finally cooled, while two of them are heated additionally to 850^{o}C then also cooled.

It was observed that loading level in beams exposed to cyclic heat in addition to using of well water is much less with extra higher deflection in comparison with the reference beams that are not exposed to temperature (CDB1&CDB2). Strength in beams rapidly cooled is less with higher deflection in comparison with their counterparts which are cooled gradually.

5. EFFECT OF HEATING

According to (Piasta J. et al., 1984) concrete is a brittle composite material that consists of binder (cement) paste in addition to sand and gravel [14]. It is well-known that paste of cement, sand and gravel have different thermal expansion coefficients. At a lower elevated temperature, the expansion due to heat of the paste of cement is a little greater than that of the sand and gravel. So, in the concrete matrix, the paste of cement is under hydrostatic compression, while the sand and gravel are under biaxial compression and tension. As the temperature further increases, the thermal strain of the paste of cement changes to negative (shrinking) due to chemical changes, while the aggregate continues to expand. The concrete corresponding stresses are that, the sand and gravel are under hydrostatic compression and the cement paste is under biaxial compression and tension. Also, the development of micro-cracks increases beyond (300°C) and firstly occurs around calcium hydroxide $Ca(OH)_2$ crystals, and partial volatilization of calcium silicate hydrate gel commenced at about (500°C). The pore size and porosity of the hydrate matrix will increase, and the mechanical properties (compressive strength and modulus of rupture) of the hydrates will be weakened.

In all heating cases of the four groups above, it is observed that high temperature has inversely proportional effect on the strength of concrete ($f'c$), see Figure 16, and on the shear strength of the beam (2P), see Figure 17. In contrast to ($f'c$) and (2P), deflection increases while temperature increases, see Figure 18.

6. CRACKS PROPAGATION

During the tests made using the compression testing machine, the cracks are visually traced, marked, and photographed. Continuous recording of mid-span deflection and incremental loads are conducted throughout the loading history. It is seen that when the load is increased, vertical cracks take place in the zone between support and load. With more load increment, the cracks in the support zone transform to diagonal cracks, spreading in the direction of load point application. With further load increment, the diagonal cracks spread to the load point application and at last lead to specimen failure.

It is observed during testing, additional loading can still be carried even when the inclined cracks take place.

Finally, it is worth to mention here that the first flexural crack is observed about 40% of beam capacity, while the first shear crack extends to about 50%.

7. FAILURE OF BEAMS

It can be seen from Figures 8, 10, 12 and 14 the all load-deflection curves, in general, have the same trend of behavior. Each curve is characterized by low slope initially, i.e., large strain versus small load. Author attributes this stage behavior to the seating of beam under increased load. Distinct popping sounds can be heard at the initial stage of loading. Visual examination of beam afterwards supports this idea.

After this stage the load-deflection curve showsmuch higher hardening and the slope of the curve shows higher slope and continues as such till the total collapse of deep beams. This type of behavior is also observed by many former researchers such as (Ahmad S. et al., 2012) [(15)], (Gerardo Aguilar et al., 2002) [(16)], (M. R. Salamy et al., 2005) [(17)] and (Soo - Yeon Seo et al., 2004) [(18)].

In all cases, the failure takes place because of the compression of the strut and none of the longitudinal bars. In addition to that, the longitudinal skin reinforcing bars has also helped the flexural strength and, as a result, the concrete struts have failed in compression before yielding of the main longitudinal reinforcing bars.

This mode of failure is also observed by many researchers such as (Ahmad S. et al., 2012) [(15)], (M. R. Salamy et al., 2005) [(17)], (Niranjan B. R et al., 2012) [(12)] and (Pandurang & Amol, 2011) [(19)].

In other words, because a/d is about 1, the thrust line is steep and arch formation is detected in those specimens and finally they fail due to either sudden tensile crack formation parallel to the strut axes or compressive crush. This situation happens because of the more reserved load retained after crushing.

Figure 19 shows a proportional effect of concrete strength ($f'c$) on shear strength of the beam (2P) after heating.

8. CONCLUSIONS

The results of these preliminary experiments have given promising results that show that it might be possible to identify to what temperature reinforced concrete deep beam has been heated too during a fire and the way of fire extinguishing. This could aid in the decision making process when decided which parts of the building are safe to enter and also which parts of the building may need to be replaced due to not being structurally sound.

8.1 Specimens cast using drinkable (tap water)

1. One hour of 300ºC heat causes strength decrease about (15.2% & 17.7%) and deflection increase about (10.88% & 14.96%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (2.93%) and deflection increase about (3.55%).
2. One hour of 500ºC heat causes strength decrease about (20.6% & 26.29%) and deflection increase about (18.36% & 23.13%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (7.1%) and deflection increase about (3.86%).
3. One hour of 700ºC heat causes strength decrease about (28% & 38.5%) and deflection increase about (30.6% & 40.8%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (14.6%) and deflection increase about (7.24%).
4. Heat cycling for one hour at each time to 350ºC and then to 650ºC causes strength decreased about (49.35% & 56.95%) and deflection increased about (55.78% & 68.7%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (15%) and deflection increase about (8.3%).
5. Heat cycling for one hour at each time to 350ºC, then to 650ºC and finally to 850ºC causes strength decreased about (59.98% & 67.97%) and deflection increased about (77.55% & 95.92%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (20.17%) and deflection increase about (10.34%).

8.2 Specimens cast using raw (well water)

1. Just replacing drinkable mix water with raw one (and no use of heat) leads to strength decrease by (13%) and deflection increase by (11.56%).

2. One hour of 300°C heat causes strength decrease about (16.58% & 21.77%) and deflection increase about (10.97% & 15.24%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (6%) and deflection increase about (3.84%).
3. One hour of 500°C heat causes strength decrease about (23.02% & 29.54%) and deflection increase about (15.85% & 23.17%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (8.7%) and deflection increase about (6.3%).
4. One hour of 700°C heat causes strength decrease about (31% & 43.42%) and deflection increase about (31.09% & 45.7%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (18%) and deflection increase about (11.16%).
5. Heat cycling for one hour at each time to 350°C and then to 650°C causes strength decreased about (56.16% & 63.82%) and deflection increased about (60.36% & 74.39%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (17.48%) and deflection increase about (8.36%).
6. Heat cycling for one hour at each time to 350°C, then to 650°C and finally to 850°C causes strength decreased about (67.09% & 73.75%) and deflection increased about (82.31% & 106.09%) for rapid and gradual cooling respectively, i.e. rapid cooling leads to strength decrease about (20.22%) and deflection increase about (13.04%).

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Table (1): Analysis of the used raw water.

Parameter Mg/l	Water Type		Max. Permissible
	Raw	Clean	
Turbidity (NTU)	30		5
PH	6.9		6.5-8.5
E.C. (Ms/cm)	11457		/
T.D.S	6274		1000
Recommendation	Not for drink		

Table (2): Chemical and mineralogical analysis of cement.

Chemical Composition	(IQS: 5/1984)(%)	ASTM C150 (%)
CaO	63.06	
SiO_2	22.	
Al_2O_3	6.25	
MgO	2.95 (5.00 maximum)	6.00 maximum
Fe_2O_3	3.33	
SO_3	3.03 (2.80 maximum)	3.00 maximum
Mineralogical Composition	(IQS: 5/1984) (%)	ASTM C150 (%)
C_3S	47.04	
C_2S	28.11	
C_2A	10.98 (5.00 minimum)	
C_4AF	6.98	

Table (3): Properties of fine and coarse aggregate.

Aggregate Type	Specific Gravity		% Absorption
	SSD	Oven Dry	
Fine	2.54	2.55	1.44
Coarse	2.77	2.6	0.9

Table (4):.Properties of reinforcing steel bars.

Nominal Diameter (mm)	Measured Diameter(mm)	Cross-section Area (mm^2)	fy (MPa)	fu (MPa)
4	4	12.566	557	835
6	5.840	26.786	672	765

Table (5): Specimens' details

Group	f′c (MPa)	No. of Specimens	Water Type	Heating (ºC)	Specimen Index	Description
A	30.92	4	Potable (tap)	-	ADB1&ADB2	Tested without heating (reference)
				300	A300R	heating at 300ºC, rapid cooling
				300	A300G	heating at 300ºC, gradual cooling
	31.02	4		500	A500R	heating at 500ºC, rapid cooling
				500	A500G	heating at 500ºC, gradual cooling
				700	A700R	heating at 700ºC, rapid cooling
				700	A700G	heating at 700ºC, gradual cooling
B	29.88	4		350+ 650	BCG-II	heating at 350ºC&650ºC, gradual cooling
				350+ 650	BCR-II	heating at 350ºC&650ºC, rapid cooling
				350+ 650 +850	BCG-III	heating at 350ºC, 650ºC&850ºC, gradual cooling
				350+ 650 +850	BCR-III	heating at 350ºC, 650ºC&850ºC, rapid cooling
C	27.6	4	Raw (well)	-	CDB1&CDB2	Tested without heating (reference)
				300	C300R	heating at 300ºC, rapid cooling
				300	C300G	heating at 300ºC, gradual cooling
	26.95	4		500	C500R	heating at 500ºC, rapid cooling
				500	C500G	heating at 500ºC, gradual cooling
				700	C700R	heating at 700ºC, rapid cooling
				700	C700G	heating at 700ºC, gradual cooling
D	26.88	4		350+ 650	DCG-II	heating at 350ºC&650ºC, gradual cooling
				350+ 650	DCR-II	heating at 350ºC&650ºC, rapid cooling
				350+ 650 +850	DCG-III	heating at 350ºC, 650ºC&850ºC, gradual cooling
				350+ 650 +850	DCR-III	heating at 350ºC, 650ºC&850ºC, rapid cooling

Table (6):.Specimens' results of group A

Beam	$f'c$ before heating (MPa)	$f'c$ after heating (MPa)	P (kN)		Max Deflection (mm)	Strut Angle (Deg.)	
			Design load*	Actual Failure		STM* based	Actual
ADB1&2	30.92		41.83	44.23	1.47	42.62	44.8
A300G	30.92	29.16		37.5	1.63		43.2
A300R		27.48		36.4	1.69		44.4
A500G	31.02	25.51		35.1	1.74		44.8
A500R		23.71		32.6	1.81		45
A700G		21.25		31.85	1.92		43.8
A700R		19.27		27.2	2.07		45

* [Hwang, S.J. et al., 2010]

Table (7):.Specimens' results of group B

Beam	$f'c$ before heating (MPa)	$f'c$ after heating (MPa)	P (kN)		Max Deflection (mm)	Strut Angle (Deg.)	
			Design load	Actual Failure		STM based	Actual
BCG-II	29.88	18.25	41.83	22.4	2.29	42.62	44.8
BCR-II		16.05		19.04	2.48		44.2
BCG-III		14.13		17.7	2.61		44.9
BCR-III		12.14		14.13	2.88		45.3

Table (8).Specimens' results of group C

Beam	$f'c$ before heating (MPa)	$f'c$ after heating (MPa)	P (kN)		Max Deflection (mm)	Strut Angle (Deg.)	
			Design load	Actual Failure		STM based	Actual
CDB1&2	27.6	27.6	41.83	38.48	1.64	42.62	44.8
C300G		25.9		32.1	1.82		45
C300R		24.3		30.17	1.89		45.2
C500G	26.95	22.3		29.62	1.9		44.4
C500R		20.56		27.11	2.02		43.9
C700G		18.76		26.55	2.15		43
C700R		16.9		21.77	2.39		43

Table (9):.Specimens' results of group D

Beam	$f'c$ before heating (MPa)	$f'c$ after heating (MPa)	P (kN)		Max Deflection (mm)	Strut Angle (Deg.)	
			Design load	Actual Failure		STM based	Actual
DCG-II	26.88	15	41.83	16.87	2.63	42.62	44.8
DCR-II		13.16		13.92	2.86		45
DCG-III		11.17		12.66	2.99		43.1
DCR-III		10.03		10.1	3.38		43

Figure 1.*Typical steel mold*

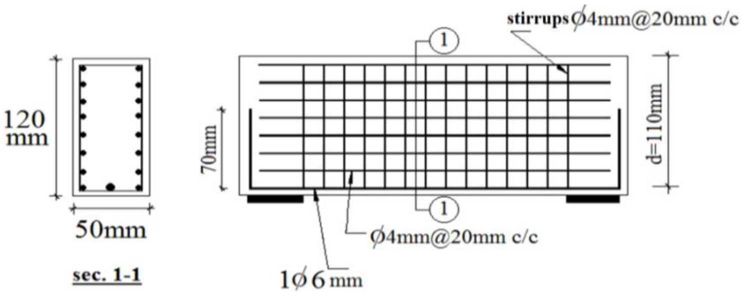

Figure2.*Reinforcement details*

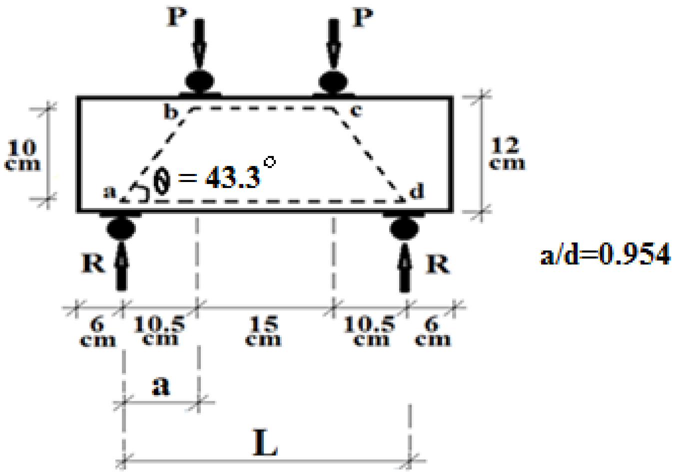

Figure 3.*Dimensions details*

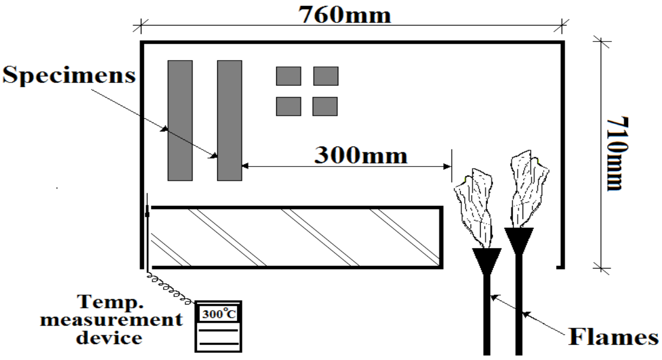

Figure 4.*The used steel furnace with heating resources and specimens*

Figure 5.*Digital thermometer used*

Figure 6.*Rapid cooling process*

Figure 7.*A specimen in compression machine*

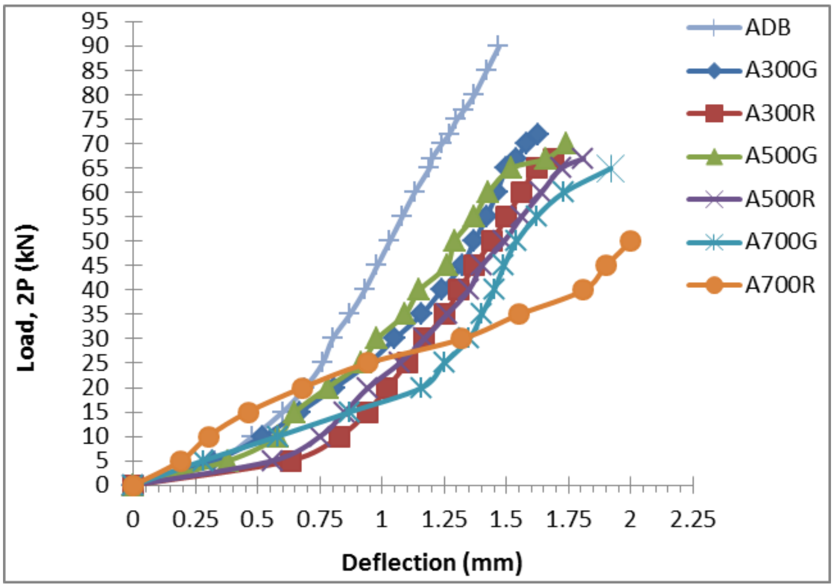

Figure (8): *Load-Deflection for the beams of group A, measured at mid-span*

Figure 9a.*ADB1*
(Group A, potable water, not heated)

Figure 9b.*ADB2*
(Group A, potable water, not heated)

Figure 9c.*A300G*
(Group A, potable water, heating at 300°C, gradual cooling)

Figure 9d. *A300R*
(Group A, potable water, heating at 300°C, rapid cooling)

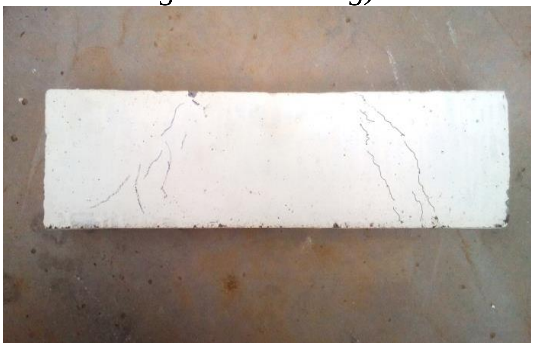

Figure 9e.*A500G*
(Group A, potable water, heating at 500°C, gradual cooling)

Figure 9f.*A500R*
(Group A, potable water, heating at 500°C, rapid cooling)

Figure 9g. *A700G*
(Group A, potable water, heating at 700°C, gradual cooling)

Figure 9h. *A700R*
(Group A, potable water, heating at 500°C, rapid cooling)

Figure 9.*Specimens of Group A after test*

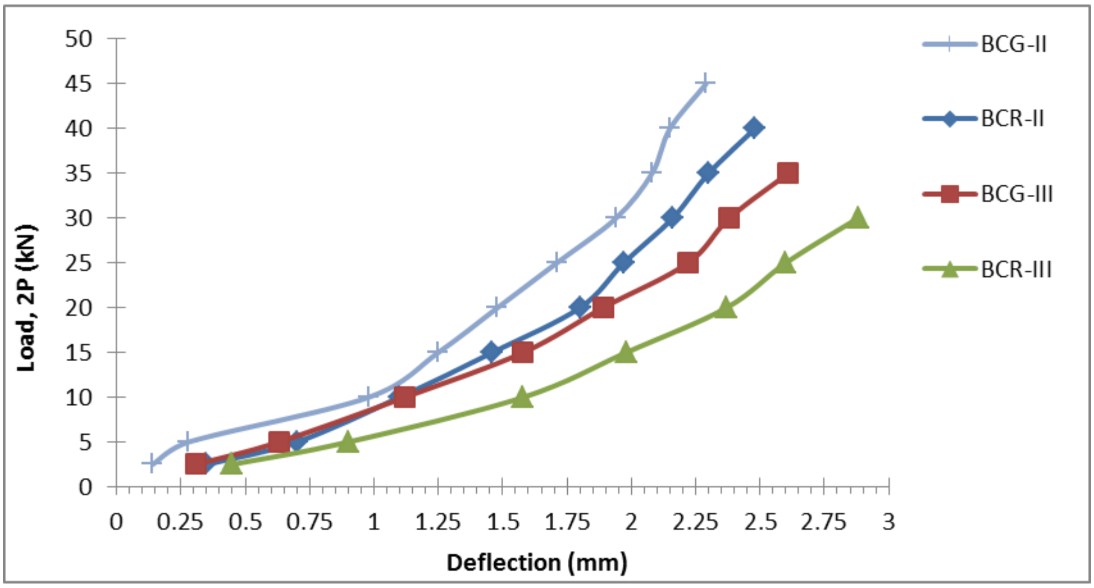

Figure 10. *Load-Deflection for the beams of Group B, measured at mid-span*

Figure 11a.*BCG-II*
(Group B, potable water, cycling heating 350°C and 650°C, gradual cooling)

Figure 11b.*BCR-II*
(Group B, potable water, cycling heating 350°C and 650°C, rapid cooling)

Figure 11c.*BCG-III*
(Group B, potable water, cycling heating 350°C, 650°C and 850°C, gradual cooling)

Figure 11d. *BCR-III*
(Group B, potable water, cycling heating 350°C, 650°C and 850°C, gradual cooling)

Figure 11.*Specimens of Group B after test*

تأثير التسخين على العتبات الخرسانية المسلحة العميقة ذات الاسناد البسيط

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الخلاصة

ان هذا العمل المختبري تناول تصرف العتبات الخرسانية المسلحة العميقة، ذات الابعاد المتساوية، عند تعرضها لدرجات حرارة عالية. نوعان من مياه الصب تم استخدامها، ماء الشرب (ماء الحنفية) و ماء البئر (غير صالح للشرب) المأخوذ من ابار عميقة في مدينة بعقوبة. و اللتي يتم اللجوء اليها حاليا بسبب شحة ماء الشرب عند صب المنشات الكبيرة او البعيدة. تم استخدام فرن حراري خاص لهذه الدراسة لتوفير الحرارة المطلوبة لتسخين العينات. بعد التسخين تم تعريض العينات الى نوعين من طرق التبريد، تدريجي و ذلك بتركهم يبردون بالتعرض للهواء لمدة يوم كامل، و تبريد سريع و ذلك بتعريضهم للماء. و ذلك للوقوف على تأثير طريقة اطفاء الحرائق على الخرسانة. تم فحص قابلية تحمل العينات بجهاز فحص الانضغاط بتسليط قوتين منفردتين وسط العتبة حتى الانهيار. نتائج كل فحص تم تحليلها لدراسة تأثير كل من درجات الحرارة المختلفة، نوعية ماء الصب، طريقة التبريد، تأثير عدد المرات المتتالية للتعرض للحرارة على مقاومة العتبات و مقدار الاود الحاصل اضافة الى تحري التشققات الناتجة.

لقد تم ملاحظة ان استخدام ماء البئر (و بدون التعرض للحرارة) يؤدي الى انخفاض ملحوظ بمقاومة القص و ارتفاع بالاود بالمقارنة مع حالة استخدام ماء الشرب بالصب. كما تم ملاحظة ان تأثير الحرارة و من ثم التبريد المفاجئ يسبب انخفاض ملحوظ بمقاومة القص و ارتفاع بالاود خصوصا عند استخدام ماء البئر بالصب.

من الجدير بالذكر، ان اكبر نسب انخفاض بالمقاومة و ارتفاع بالاود حصل بين العينات التي صبت بماء البئر و تعرضت للحرارة عدة مرات مع التبريد الفجائي في كل مرة بالمقارنة مع العينة التي صبت بماء الشرب و لم تتعرض للحرارة اصلا.

و اخيرا و ليس اخرا، منحنيات الحمل-الاود، قوة القص- حرارة التسخين،مقاومة الخرسانة-حرارة التسخين، الاود-حرارة التسخين، و قوة القص-مقاومة الخرسانة تم رسمها لكل حالة تحميل اضافة الى تقديم تحريات عن التشققات، و ذلك لتحليل تأثير العناصر سالفة الذكر على تكون التشققات بسبب الاود و القص.