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Assessment of Mechanical Properties of Normal Strength Concrete and Modified Reactive Powder Concrete under the Effect of Repeated Load and Elevated Temperatures

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ABSTRACT

This research presents an experimental investigation to study the effect of elevated temperatures and repeated load on mechanical properties of normal and modified reactive powder concrete. The mechanical properties which investigated in this study are compressive strength, tensile strength, modulus of rupture and modulus of elasticity. Twenty four tested specimens were casted for each property; twelve specimens were tested with static load with different exposed temperatures (28 ^{O}C, 60 ^{O}C, 100 ^{O}C and 150 ^{O}C), other twelve specimens were tested with repeated load exposed to same exposed temperature, the overall numbers of tested specimens were ninety six. The results indicate the effect of increasing the elevated temperatures have a vital role to decrease the compressive strength, tensile strength, modulus of rupture and modulus of elasticity of tested specimens. In addition, loading the specimens with repeated load causes a decrease of the compressive strength about 50%, tensile strength about 50%, modulus of rupture about 50% and modulus of elasticity 20%in comparison with statically loaded specimens.

Keywords - elevated temperatures, modified reactive powder concrete, cyclic load, compressive strength, tensile strength, modulus of rupture and modulus of elasticity

I. INTRODUCTION

The structural behavior of reinforced concrete structures is mainly depending on type of the applied load. Further move, there are a large number of structure collapsed due to lake of taking in to account the type of applied load[1].

Repeated load applied on structures in different amplitude and closed time such as the seismic load. It is considered one of the most dangerous types of loads on construction. So, the researchers are interested in recent years to study this type of loading during the great improvement made in the construction materials world and appearing of new types of concrete did not discovers its behavior under the influence of this type of loading [2].

The exposure of concrete structures to high temperatures is considered one of the most dangerous events for buildings and constructions. The concrete is one of the construction materials that significantly affected by fire. Therefore, the evaluation of concrete after exposure to fire is an importat aspect of structural engineering.

The exposure of buildings to fire may be for a long period, or for a short period with high intensity. The risk of fire increase in nuclear reactor pressure vessels, the becomes necessary to study the change in the mechanical properties of concrete after fire [3].

The resistance of concrete buildings to fire is well depends on the properties of steel and concrete after exposure to fire [4]. Several studies [5,6]have shown that the degree of damage is affected by type of concrete and aggregate used.

II. EXPERIMENTAL PROGRAM

The experimental work of this study is based on two tested groups: group one (G1) contains twenty-four cube specimens, forty-eight cylinder specimens and twenty-four prism specimens, with average cube compressive strength (36 MPa), group two (G2) contains twenty-four cube specimens, forty-eight cylinder specimens and twenty-four prism specimens, with average cube compressive strength (75 MPa). Details of these groups are shown in Table 1.

Two types of concrete are used; normal strength concrete and modified reactive powder concrete. These types of concrete is exposed to different elevated temperatures (60, 100 and 150) C^O then subjected to repeated load.

Table 1: Specimens Dimensions

Group No.	Cube Specimens (mm3)	Cylinder Specimens for Splitting Tensile Strength (mm)	Cylinder Specimens for Modulus of Elasticity (mm)	Prism Specimens (mm)
G1	150	100x200	150x300	100x100x500
G2	100	100x200	150x300	100x100x500

III. MATERIALS

Below the specifications of construction materials used in this study:

III.1 CEMENT

The chemical compounds and physical properties of cement are shown in Tables 2 and 3. They conform to the ASTM C-150 Specifications [7]. To avoid the damage of cement, it was kept in dry conditions.

Table 2: Chemical Composition of Cement

Chemical Composition	**Percentage By Weight**	**Limit of ASTM C-150 [7]**
SIO2	22.7	-
AL2O3	6.12	-
FE2O3	4.25	-
CAO	62.31	-
MGO	2.98	<5
SO3	1.92	<2.8
I.O.I	2.95	<4
I.R	0.95	<1.5
CA3	1.97	0.66-1.02

Table 3: Physical Properties of Cement

Physical Properties	**Test result**	**Limit of IOS 5:1984**
Fineness using Blaine air permeability apparatus (m^2/kg)	3100	> 2300
Soundness using autoclave method	0.19 %	< 0.8 %
Initial setting time (min) Finalsetting time (hrs:min)	198 4.5	> 45 min < 10 hr
Compressive strength (MPa)at 3 days 7 days 28 days	 19.4 29.75 48.33	 >15 > 23 -

III.II FINE AGGREGATE

Fine aggregate used in this study, has a maximum size less than (5 mm) and brought from natural source. The grading of the fine aggregate is shown in Table4; which conforms to the British Standards 882 (1992)[8].

Table 4: Particle analysis of sand

No.	**Sieve size(mm)**	**Present work fine aggregate(% passing)**	**BS 882:1992 limits Zone"M" (% Passing) [8]**
1	5.0	90.52	89-100
2	2.36	80.10	65-100
3	1.180	67.72	45-100
4	0.60	44.64	25-80
5	0.30	7.09	5-48
6	0.15	3.43	0-15

III.III COARSE AGGREGATE

The ideal coarse aggregate should be clean. 100% crushed aggregate with a minimum of flat and elongated particles is used. Coarse aggregate is brought from natural source. Table5 shows the grading of the coarse aggregate, which conforms to the British Standards 882 (1992) [8].

Table 5 Particle analysis of gravel

No.	**Sieve Size (mm)**	**Present Work of Coarse Aggregate (% Passing)**	**B.S. 882:1992 Limit (% Passing)**
1	20	100	100
2	14	100	90-100
3	10	74.5	50-85
4	5.0	1.23	0-10
5	2.36	0	-

III.IV ADMIXTURES

Glenium51 was used to achieve high compressive strength of concrete. Table 6 shows the typical properties of Glenium51.

Table 6: Typical properties of Glenium 51*

No.	Main action	Concrete super plasticizer
1	Color	Light brown
2	pH. Value	6.6
3	Form	Viscous liquid
4	Chlorides	Free of chlorides
5	Relative density	1.08 – 1.15 gm/cm3 @ 25°C
6	Viscosity	128 ± 30 cps @ 20°C
7	Transport	Not classified as dangerous
8	Labeling	No hazard label required

***** Supplied by the manufacturer.

III.IV STEEL FIBERS

Through this experimental work, Hooked ends steel fibers were used with different volume fractions of (Vf= 1.0% and 2.0%) of concrete volume. The physical properties of steel fibers are shown in Table 7.

Table 7: Properties of the steel fibers*

Property	Specifications
Relative Density	7860 kg /m3
Yield strength	1130 MPa
Modulus of Elasticity	200x103MPa
Strain at Portion limit	5650 x10-6
Poisson's ratio	0.28
Average length	50 mm
Nominal diameter	0.5 mm
Aspect ratio	100

***** Supplied by the manufacturer.

III.VI MIX DESIGN

Details of trial mixes are given in Table 8.The group No.1 and No.2 is used as mix in all specimens with normal strength and modified reactive powder concrete.

Table8: Trial mixes

Group	w/c ratio	Mix Proportions (kg/m3)						
		Water	Cement	Sand	Gravel	Silica Fume	Superpl-astisizer	Steel Fiber
1	0.44	183	415	535	1250	---	---	---
2	0.3	252	843	1029	109	211	12.7	187

III. DISCUSSIONS AND RESULTS

III.I INFLUENCE OF REPEATED LOAD ON COMPRESSIVE STRENGTH

50% of compressive strength is the amount of reduction for normal strength and modified reactive powder concrete when loading with repeated load instead of static load, see Table 9 below. The test setup is shown in Fig.1.

Table9: Effect of repeated load on compressive strength of normal strength concrete and reactive powder concrete

Temperature (^{O}C)	Compressive strength (MPa)					Difference (%)
	Normal Concrete		Difference (%)	Modified Reactive Powder Concrete		
	Static Load	Repeated Load		Static Load	Repeated Load	
28	36.6	18.3	50%	74.5	37.25	50%
60	41.1	20.55	50%	61.87	30.935	50%
100	28.9	14.45	50%	56.56	28.28	50%
150	24.7	12.35	50%	27.22	13.61	50%

Fig.1 Compressive strength test setup

III.II INFLUENCE OF REPEATED LOAD ON MODULUS OF RUPTURE

Through observation of Table 10, the modulus of rupture of normal strength concrete specimens decreased when loading the specimens with repeated load. The amount of reduction in modulus of rupture is about (50%) for specimens exposed to (28^{O}C), (60 ^{O}C), (100 ^{O}C) and (150 ^{O}C) respectively.

In modified reactive powder concrete specimens, the amount of reduction in modulus of rupture reached to (50%) for specimens exposed to (28 ^{O}C), (60 ^{O}C), (100 ^{O}C) and (150 ^{O}C) respectively. The test setup is shown in Fig. 2.

Fig.2 Modulus of rupture test setup

Table 10: Effect of repeated load on modulus of rupture of normal strength concrete and reactive powder concrete

Temperature (^{O}C)	Modulus of Rupture (MPa)					Difference (%)
	Normal Concrete		Difference (%)	Modified Reactive Powder Concrete		
	Static Load	Repeated Load		Static Load	Repeated Load	
28	5.77	2.887	50%	9.83	4.915	50%
60	4.98	2.49	50%	8.65	4.325	50%
100	5.01	2.505	50%	7.32	3.66	50%
150	5.085	2.542	50%	6.87	3.435	50%

III.III INFLUENCE OF REPEATED LOAD ON MODULUS OF ELASTISITY

It has been found that the modulus of elasticity decreased when loading the specimens repeatedly, see Table 11below.For normal strength concrete, the amount of reduction is about (19.95%) for all the specimens under different elevated temperatures.

The modified reactive powder concrete exhibit the same trend when the specimens exposed to elevated temperatures. The decreasing in modulus of elasticity is about (20%) for all cases. The test setup is shown in Fig. 3.

Table 11: Effect of repeated load on modulus of elasticity of normal strength concrete and reactive powder concrete

Temperature (^{O}C)	Modulus of Elasticity (MPa)					Difference (%)
	Normal Concrete		Difference (%)	Modified Reactive Powder Concrete		
	Static Load	Repeated Load		Static Load	Repeated Load	
28	35043	28050	19.95%	167058	133662	20%
60	31922	25553	19.95%	172982	138401	20%
100	29259	23422	19.95%	47678	38158	20%
150	25256	20220	19.95%	38826	31076	20%

Fig.3 Modulus of elasticity test setup

III.IV INFLUENCE OF REPEATED LOAD ON TENSILE STRENGTH

As shown in Table 12, the reduction in tensile strength of normal strength concrete specimens in case of repeated load is about (49.84%), (50%), (50%) and (50.16%) for specimens at temperatures (28^{O}C), (60 ^{O}C), (100 ^{O}C) and (150 ^{O}C) respectively.

In modified reactive powder concrete specimens, the amount of reduction is about (50%), (50%), (49.94%) and (50%) for specimens exposed to (28 ^{O}C), (60 ^{O}C), (100 ^{O}C) and (150 ^{O}C) respectively. The reduction in the tensile strength of concrete specimens is attributed to create new cracks in each cycle in addition to propagate old cracks in previous cycles. The test setup is shown in Fig. 4.

Table12: Effect of repeated load on tensile strength of normal strength concrete and reactive powder concrete

Temperature (^{O}C)	**Tensile Strength (MPa)**					**Difference (%)**
	Normal Concrete		**Difference (%)**	**Modified Reactive Powder Concrete**		
	Static Load	**Repeated Load**		**Static Load**	**Repeated Load**	
28	3.27	1.64	49.84%	7.32	3.66	50%
60	3.52	1.76	50%	7.96	3.98	50%
100	3.6	1.8	50%	9.23	4.62	49.94%
150	3.09	1.54	50.16%	6.37	3.18	50%

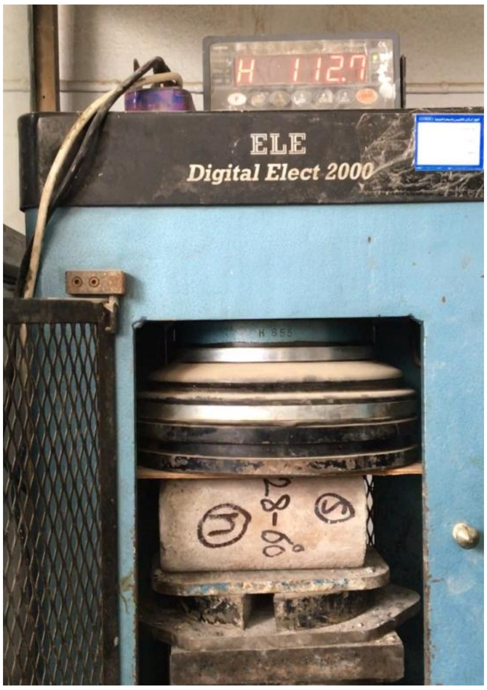

Fig. 4 Tensile strength test setup

IV CONCLUSIONS

The following conclusions can be adopted from this study:

1. A decrease in compressive strength of modified reactive concrete and normal strength concrete when loading the specimens with repeated load.
2. A reduction in tensile strength of modified reactive concrete and normal strength concrete when loading the specimens with repeated load.
3. There is a decrease in modulus of rupture of modified reactive powder concrete and normal strength concrete when loading the specimens with repeated load.
4. There is a decrease in modulus of elasticity of modified reactive powder concrete and normal strength concrete when loading the specimens with repeated load.

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