Effects of Long- Term Cyclic Load [LTCL] on the Behaviors of Early (Young) Age and Old Age Reinforced Concrete. A Comparison Study[1]

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Abstract

This paper discusses an experimental process and result data of the effects of long term cyclic load [LTCL] on young and old age reinforced concrete sample. The paper further discusses the preloading effects on both young and old concrete in terms of strength and structural integrity. Two sets of samples with different age of concrete (21 days and 300 days) were cast and tested in the University of Detroit Mercy in USA . The test results showed that a redistribution of the internal forces occurred between the steel and the concrete [LTCL] due to the creep effects. Furthermore, cracks appeared in the samples at minimum loading level of [LTCL] and were more pronounced in the young age sample. The test results also showed that the young age pre-loaded concrete sample lost part of its strength due to [LTCL] compared with that of the non-pre-loaded. Experiment shows that (stress-strain) behavior has changed due to [LTCL] for both young and old age pre-loaded reinforced concrete samples.

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1. Introduction

Cast-in-place concrete is immediately affected by variable loads after removing its mold during the phase of increasing solidity. Examples of loading conditions affecting young concrete are:

a) Filling and emptying cylindrical concrete tanks expose the concrete to a long term cyclic loading (LTCL), causing stresses that vary between maximum and minimum levels at a frequency of about 3-5 times per month as mentioned in [1],[2].

b) Stresses in the concrete of lower levels columns continue to increase during high building construction.

The high stresses in the young age concrete (YAC) cause early plastic deformation in the mortar which covers the aggregates. This fact leads to a decrease in the strength of concrete [3].

Studies were carried out on creep of concrete under the cyclic loading by . Aliksandrovski S.V. [3] ,Hs studied the creep of concrete under periodic loading . Aliksandrovski S.V. [4] , studied the effect of changeable stress on creep of concrete.

Baryshnikov A.E. [1] studied the creep of concrete and reinforced concrete under cyclic loading . Nichola S.J.[5] studied creep in structures in the pre-stressed concrete beams . But none of them studied the cracks in the cylindrical structures under the [LTCL].

2. Experimental Program

An experimental study carried out on prismatic samples with the dimensions of 100 x 100 x 400 mm, with vertical reinforcement of 4 plain steel bars of 6mm diameter

(μ= 113 /10000= 0.0113), subjected to similar conditions of hardening (see Fig.1).

The resistance for prismatic concrete sample was measured after 28 days and it showed that R_{PT} = 12.37 MPa.

Fifteen reinforced concrete samples were cast with cross section of 100 x 100 mm, four bars of 6mm diameter, and 400mm height, attached with steel plates of 20 mm thickness at bottom and top.

Twenty one concrete samples were cast with cross section of 100 x 100 mm, and 400 mm in height, tested at the age of 3, 7, 14, 21, 28, 100 and 300 days for determination of strength and elasticity modulus of elasticity .

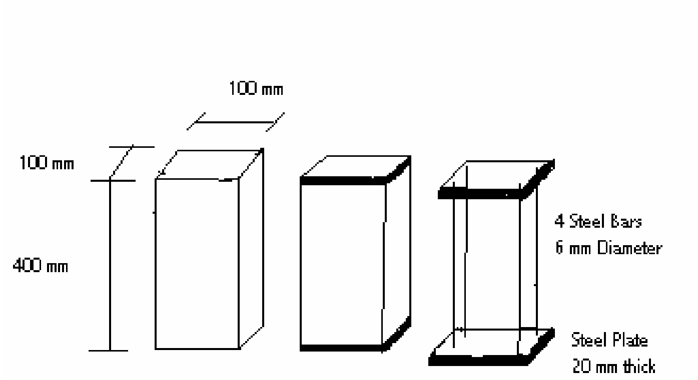

Fig.1 Concrete and reinforced concrete samples

The samples were set up as follows:
Three reinforced concrete samples loaded at age 21 days.
Three reinforced concrete samples loaded at age 300 days.
Three reinforced concrete samples set to determine shrinkage in the reinforced concrete
Three reinforced concrete samples tested to determine the stress-strain behavior at age (21 and 70) days.
Three reinforced concrete samples tested to determine the stress-strain behavior at age (300 and 70) days.

2-1 Loading conditions:

1) The load was applied axially on the samples
2) Total time of the cycle was 10 days: 5 days max load, and 5 days min load.
3) Total number of cycles was 7
4) Nmax = 93 kN, Maximum Stress: σ_{max} = 93 MPa
5) Nmin =10 kN, Minimum Stress: σ_{min} = 10 MPa (See table 1) .

Table 1 Sample Description and loading conditions

Sample Description	1st Set	2nd Set
Size	100·100·400mm	100·100·400mm
Number of Samples	3	3
Age of concrete at the start of loading	21 days	300 days
Ratio of reinforcement in the concrete section	μ= 0.0113	μ= 0.0113
Steel Section Area	A=4φ6mm =113 mm^2	A=4φ6 mm =113mm^2
Total Experimental Time	70 Days	70 Days
Number of cycles	7	7
System loading for every cycle	5 days max load 5 days min load	5 days max load 5 days min load
Maximum load	93 K.N	93 K.N
Minimum load	10 K.N	10 K.N

The maximum stress in concrete was about 0.56 R_{PT} , as recommended in [6],[7].

a) Determination of the strain for every cycle.

The strains were measured mechanically by strain gauges . The strain in every cycle was divided into four stages .

* The momental elastic strain with the max loading $\varepsilon_{el\,1}$.

* The plastic strain (creep) at max loading εc_2 .

* The momental elastic strain at minimum loading $\varepsilon_{el\,2}$

* The reflective plastic strain at minimum loading (relaxation) ε_{aft} .

b) Comparison of the strain value between the young (YAC) and old age concrete (OAC) samples.

c) Comparison of the re-distribution of forces between the concrete and the steel in reinforced young and old age concrete.
d) Effect of cyclic long term loading on the cracking.

2-2 Modules of Elasticity (Table 2 and Table 3)

Concrete modulus of elasticity $E_c(t)$ for several ages was defined by separate concrete samples, which were taken from the same concrete casting and the same circumstances of hardening.

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Table 2 Development of Modulus of Elasticity Ec(t) in Concrete

Age(day)	21	28	100	200	300
Ec(t) * 10^{+4}MPa	1.87	1.92	1.95	2	2

2-3 Reinforced Concrete Shrinkage (See Table 3)

The shrinkage of reinforced concrete was taken by separate samples before applying the load for determination the stress in both steel and concrete [8],[9] .

Table 3 Development of Shrinkage (εsh) in Reinforced Concrete

Age(day)	21	30	60	90	120	300
εsh* 10^{-5}	22	30	34	37	40	48

2-4 Stages of Deformation

For determination of the strain of every cycle, the loading cycle is divided into 4 stages (See fig2).

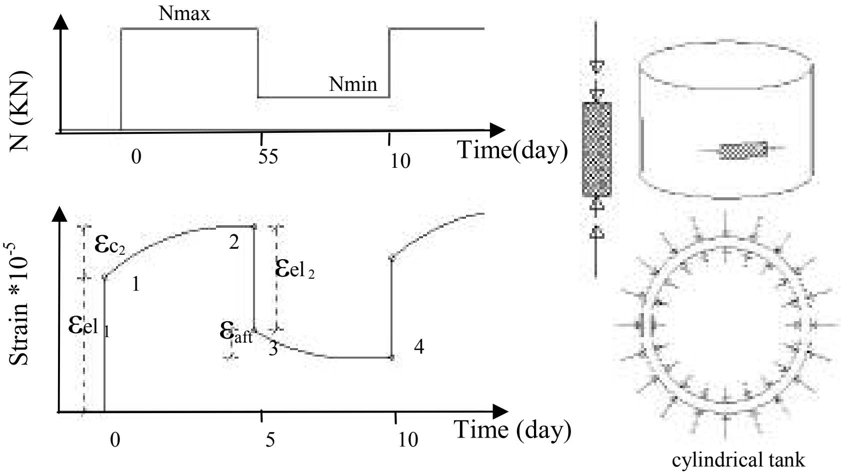


Fig.2 –stages of loading and strain per cycle

Point1: Represents the end of flexural elastic strain ε_{el_1} by applying the load.

Point 2: Represents the end of plastic strain (creep) ε_{c2} by applying constant maximum load.

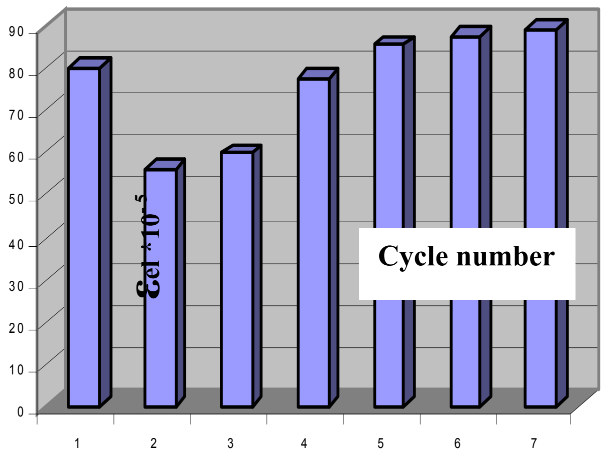
Point3: Represents flexural elastic strain ε_{el2} at removing the load incompletely.
Point 4: Represents the end stage of reflective plastic strain (relaxation) ε_{aft}, by removing the load incompletely.

3. Experimental Results:

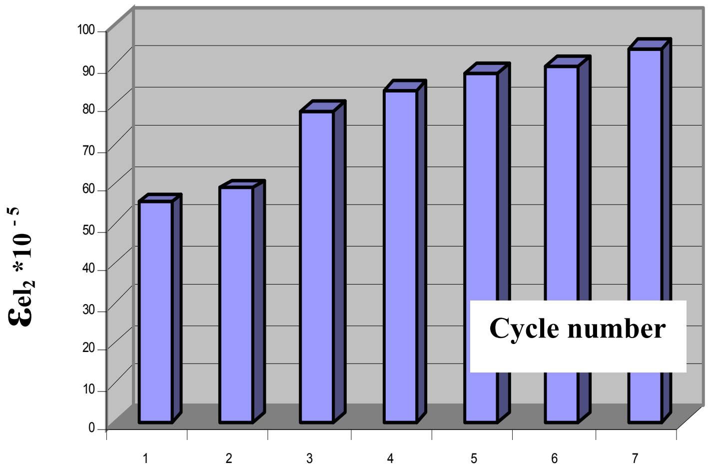
Table (4 and 5) , and Fig.(3 and 4) show the values of strain in the cycles for (YAC) and (OAC) .Tables (6 and 7) and Fig. 5 and 6, show the creep and relaxation in every cycle.

Table 4 Strain stages in loading cycles for young concrete

Duration of load (DAY)	Cycle No.	$\varepsilon el1*10^{-5}$	$\varepsilon\ c2*10^{-5}$	$\varepsilon\ el_2*10^{-5}$	$\varepsilon\ aft*10^{-5}$
0 - 10	1	80.2	45.5	55.2	10.9
10 -20	2	56	25.6	58.7	8.2
20 - 30	3	59.9	11.6	78.2	5.4
30 - 40	4	77.4	13.7	83.4	5
40 - 50	5	85.5	11.5	88	4.7
50 - 60	6	87.7	10.4	89.4	5
60 - 70	7	89	11.5	93.9	5

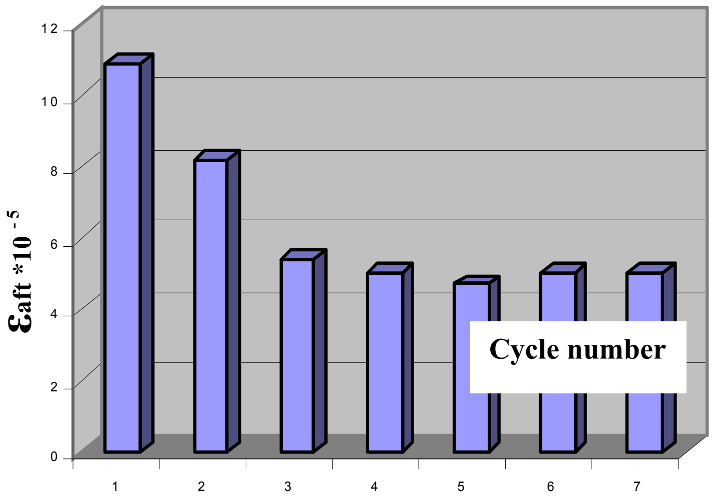


(a) The end of momental elastic strain εel_1 by applying the load.

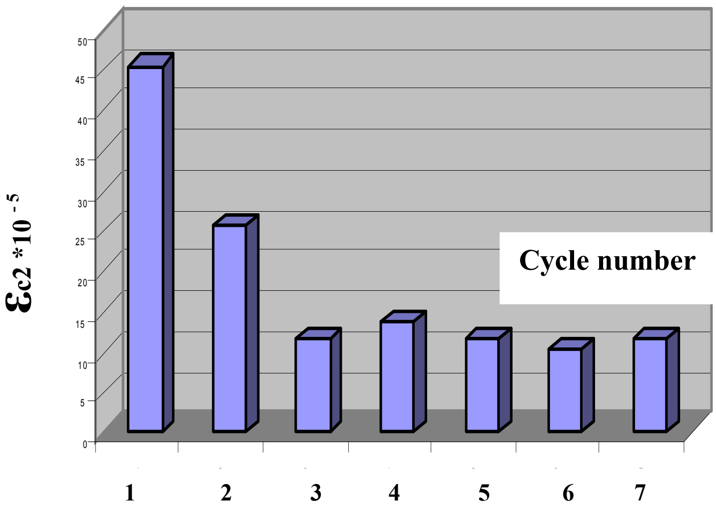


(b) The momental elastic strain εel2 at removing the load incompletely.

Fig .3 Strain stages for young age concrete



(c) The end stage of reflective plastic strain

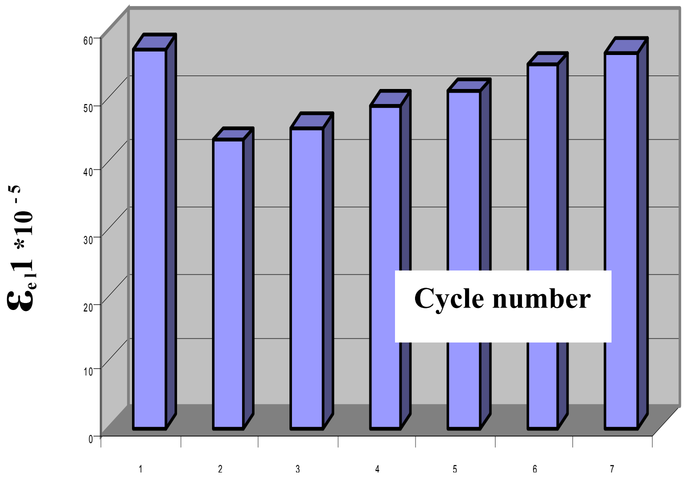


(d) The end of plastic strain by applying constant maximum load.

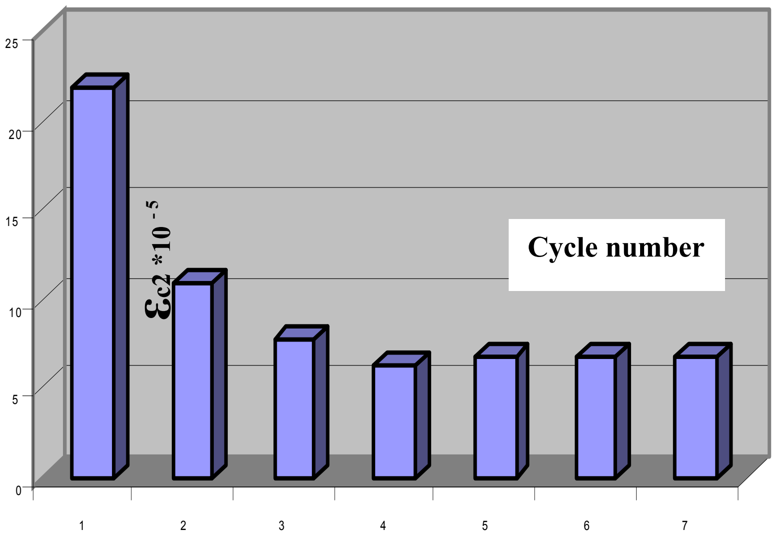
Fig .3 Strain stages for young concrete

Table 5 Strain stages in loading cycles for old concrete

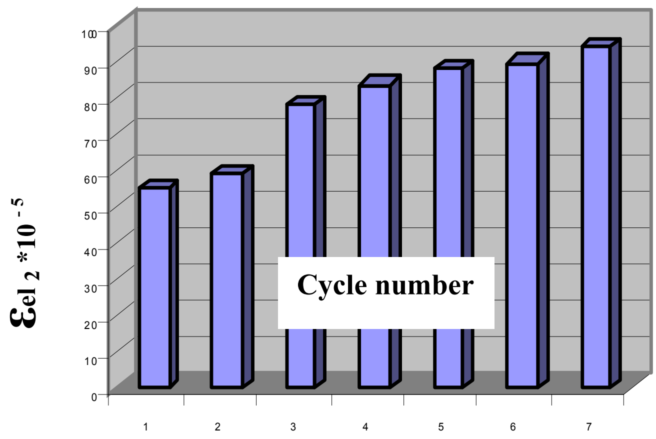
Duration of load (DAY)	No. of Cycle	ε_{el1} * 10^{-5}	εc_2* 10^{-5}	ε_{el2} *10^{-5}	ε_{aft} *10^{-5}
0 - 10	1	57.2	22	41.7	5.4
10 -20	2	43.2	10.9	45.3	5.1
20 - 30	3	45.3	7.8	47.6	5.1
30 - 40	4	48.7	6.3	49.6	5
40 - 50	5	50.8	6.8	54	5
50 - 60	6	54.8	6.8	56.1	5
60 - 70	7	56.6	6.8	63	5



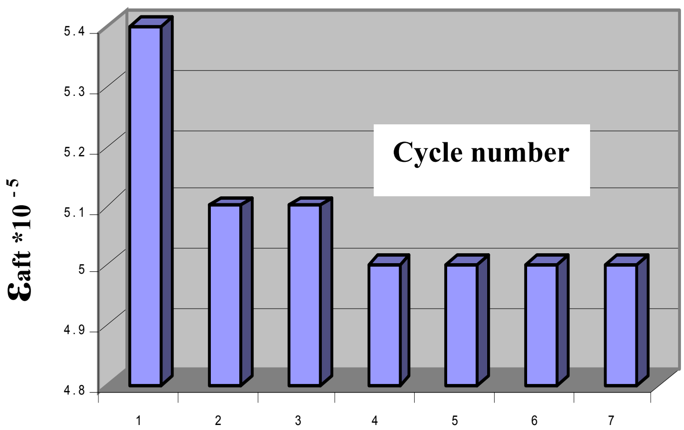
(a)The end of flexural elastic strain εel1 by applying the load.



(b) The end of plastic strain by applying constant maximum load.
Fig .4 Strain stages for old concrete



(c) The flexural elastic strain ε_{el2} at removing the load incompletely.



(d) The end stage of reflective plastic strain

Fig .4 Strain stages for old concrete

Table 6 Development of the creep and relaxation in every cycle for young concrete

Age (day)	0	0.5	1	2	3	4	5
Cycle No.	Creep $*10^{-5}$						
1	0	27	34	40	43	45	45.5
2	0	12	18.5	21	24.2	25.5	25.6
3	0	6.8	9.1	11.1	11.4	11.5	11.6
4	0	6.2	8.7	10.8	11	11.4	13.7
5	0	5.4	8.1	10.1	10.3	11.2	11.5
6	0	5.2	7.8	9.9	10.4	10.3	10.4
7	0	5.1	7.1	9.5	10.8	10.8	11.5
Cycle No.	Relaxation $*10^{-5}$						
1	0	-7.8	-10.5	-10.2	-10.4	-10.6	-10.8
2	0	-6.6	-7.7	-7.8	-8.0	-8.1	-8.2
3	0	-4.3	-5.1	-5.1	-5.2	-5.3	-5.4
4	0	-4.2	-4.8	-4.7	-4.9	-5.0	-5.0
5	0	-3.5	-4.1	-3.6	-3.6	-3.7	-3.7
6	0	-4.3	-4.4	-4.5	-4.8	-4.9	-5.0
7	0	-4.4	-4.6	-4.7	-4.9	-5.0	-5.0

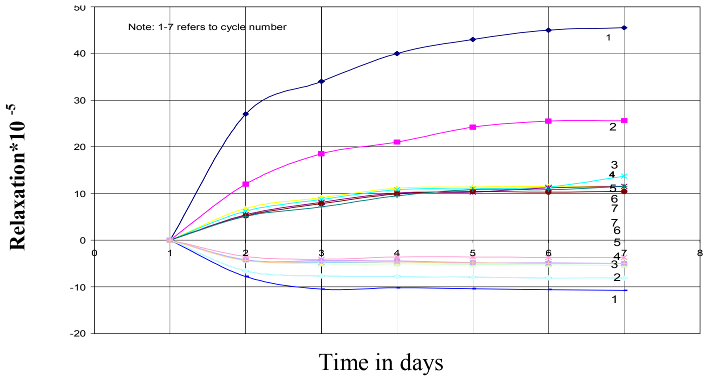


Fig.5 Development of creep and relaxation of reinforced concrete in every cycle for young concrete

Table 7 Development of creep and relaxation in every cycle for old concrete

Age (day)	0	0.5	1	2	3	4	5
Cycle No.	Creep $*10^{-5}$						
1	0	10.3	15.1	18.6	20.2	21	22
2	0	5.4	8.1	10.2	10.5	10.7	10.9
3	0	5.2	6.8	7.3	7.5	7.6	7.8
4	0	5.1	6.5	6.7	6.8	6.4	6.3
5	0	5.2	6.2	6.4	6.6	6.7	6.8
6	0	5.1	5.8	6.4	6.5	6.6	6.8
7	0	4.8	5.6	6.3	6.4	6.8	6.8
Cycle No.	Relaxation $*10^{-5}$						
1	0	-4.4	-4.7	-5	-5.2	-5.2	-5.4
2	0	-4.1	-4.5	-4.7	-5	-5.1	-5.1
3	0	-3.9	-4.5	-4.6	-4.8	-5	-5.1
4	0	-4	-4.3	-4.8	-4.9	-5.2	-5.4
5	0	-3.8	-4.2	-4.5	-4.7	-4.8	-5
6	0	-3.6	-4	-4.4	-4.8	-4.9	-5
7	0	-3.4	-4.1	-4.3	-4.7	-4.8	-5

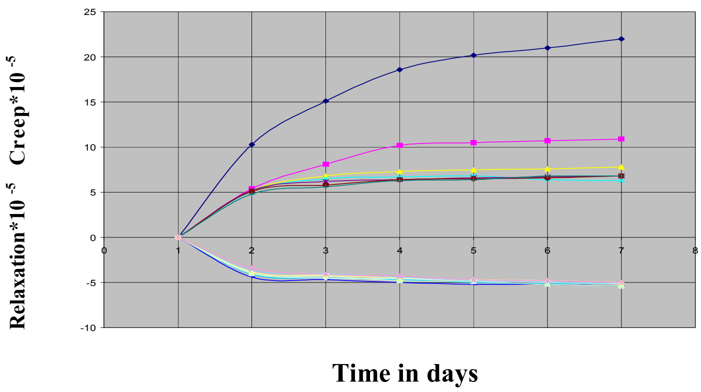


Fig.6 Development of the creep and relaxation of reinforced concrete in every cycle for old age concrete

4. Determination of the stress in both steel and concrete

The following symbols were used in the calculation of the stresses in steel and concrete:

$\varepsilon_{sh}(t)$: Vertical shrinkage strain of reinforced concrete samples.

μ: Ratio of steel in the reinforced concrete section: $\mu = As/Ac$

As: Area of steel in the reinforced concrete section

Ac: Area of concrete in the reinforced concrete section

$\sigma_{s\ sh}(t)$: Stress in the steel as a result of concrete shrinkage.

$\sigma_{c\ sh}(t)$: Stress in the concrete as a result of concrete shrinkage.

N_{max}: Maximum load applied on the sample

N_{min}: Minimum load applied on the sample.

$\sigma_c\ (t,\tau)$: Stress in the concrete as a result of loading .

$\sigma_s\ (t,\tau)$: Stress in the steel as a result of loading

Ec: Elasticity modules of concrete at the age (t, τ)

εel_1: Momental elastic strain at time of applying maximum load (N_{max}).

ε_{c2}: Plastic strain of concrete (creep) after applying maximum load.

ε_{el2}: Momental elastic strain at time of partial removal of the load ($\Delta N = N_{max} - N_{mim}$)

ε_{aft}: Reflection plastic strain (relaxation of concrete) after partial removal of the load

t: Age of concrete at the beginning of load cycle.

R_{C1}: Yong age concrete (YAC)

R_{C2}: Old age concrete (OAC)

The stresses in concrete and steel may be calculated from these equations :

$\sigma_c(t) = \varepsilon_{sh} \cdot E_s \cdot \mu$

$\sigma_s(t) = \varepsilon_{sh} \cdot E_s$

$\sigma_{c1}(t,\tau) = N_{max}/ [A_c + (E_s/E_c(t,t)) \cdot A_s] - \sigma_c(t)$

$\sigma_{s1}(t,\tau) = [(E_s/E_c(t, \tau)) \cdot N_1] / A_c + (E_s/E_c(t,\tau)) A_s] + \sigma_s(t)$

$\sigma_{s2}(t,\tau) = \sigma_{s1}(t, \tau) + (\varepsilon_{c2} - \varepsilon_{c1}) E_s$

$N_s(t,\tau) = N_{max} - N_{s2}(t,\tau)$

$\sigma_{s2}(t,\tau) = N_{c2}(t\ \tau,) / A_c$

$N_3(t,\tau) = N_{max} - N_{min}$

$\sigma_{s3}(t,\tau) = \sigma_{s2}(t,\tau) - [(E_s/E_c(t, \tau) \cdot N_3(t,\tau)]/ [A_c + (E_sA_s/ E_c(t,\tau)]$

$\sigma_{s3}(t,\tau) = \sigma_{s2}(t,\tau) – [N_3(t,\tau)]/ [A_c + (E_s/A_s/ E_c(t,\tau)]$

$\sigma_{s4}(t,\tau) = \sigma_{s3}(t,\tau) + (\varepsilon_{aft} - \varepsilon_{c12}) E_s$

$N_{s4}(t,\tau) = \sigma_{s4}(t,\tau) \cdot A_s$

$N_{c4}(t,\tau) = N_{min} - N_{s4}(t,\tau)$

$\sigma_{s4}(t,\tau) = N_{c4}(t,\tau) / A_c$

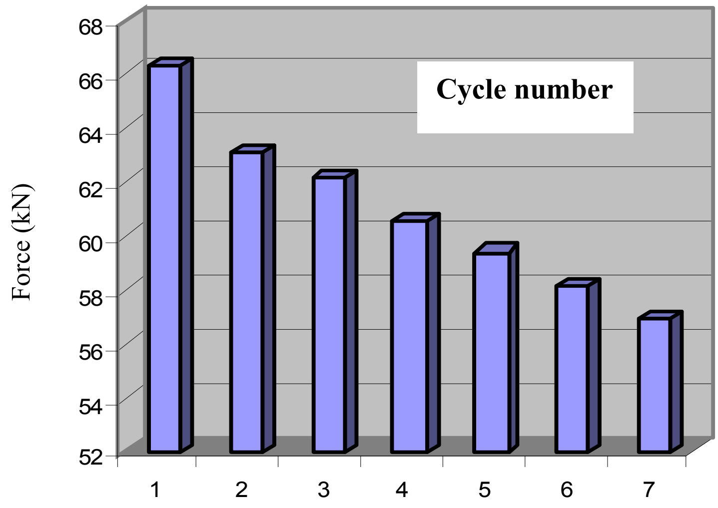
This system of calculation is repeated for every cycle to define (Ns) and (Nc) for every point of the graph. The forces in steel and concrete are shown in Table 7 and Table 8 and displayed in Fig.7 , Fig.8 , Fig.9 and Fig.10 .

Table 8 Development of Forces in Steel and Concrete at Maximum Loading

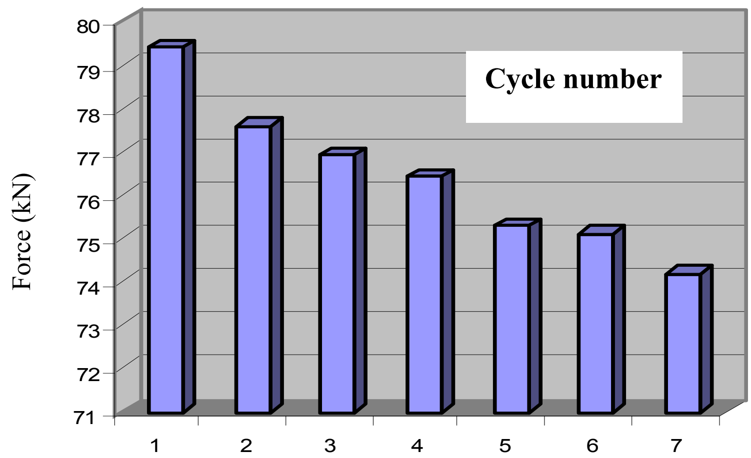
Sample	Force (KN)	Point	Number of Cycles 1	2	3	4	5	6	7
RC1 (YAC)	Nc1	begin	76.2	68.4	64.3	63.4	61.8	60.2	59.3
		end	66.3	63.1	62.1	60.5	59.4	58.1	56.9
	Ns1	begin	16.8	24.6	28.7	29.6	31.1	32.8	33.7
		end	26.7	29.9	30.9	32.5	33.5	34.9	36.1
RC2 (OAC)	Nc2	begin	82.29	79.7	78	77.3	77.1	76.6	75.6
		end	79.4	77.6	76.9	76.4	75.3	75.1	74.2
	Ns2	begin	10.71	13.3	15	15.7	16.8	16.4	17.4
		end	13.6	15.4	16.6	16.6	17.6	17.9	18.8

Table 9 Development of Forces in Steel and Concrete at Minimum Loading

Sample	Force (KN)	Graph Point	Number of Cycles 1	2	3	4	5	6	7
RC1 (YAC)	Nc1	begin	-6.1	-5.8	-5.5	-6	-6.1	-7.2	-7.4
		end	-3.8	-4.1	-4.3	-4.3	-4.6	-6	-6.2
	Ns1	begin	16.1	15.6	15.5	16	15.9	17.2	17.4
		end	13.8	14.2	14.3	14.3	14.5	16	16.2
RC2 (OAC)	Nc2	begin	3.2	1.9	1.3	1.1	-0.9	-0.05	-1.9
		end	4.1	2.9	2.2	2.2	1.9	1	0.3
	Ns2	begin	6.8	8.1	8.7	8.9	8.9	10.05	11.9
		end	5.9	7.1	7.8	7.8	7.7	9	9.7

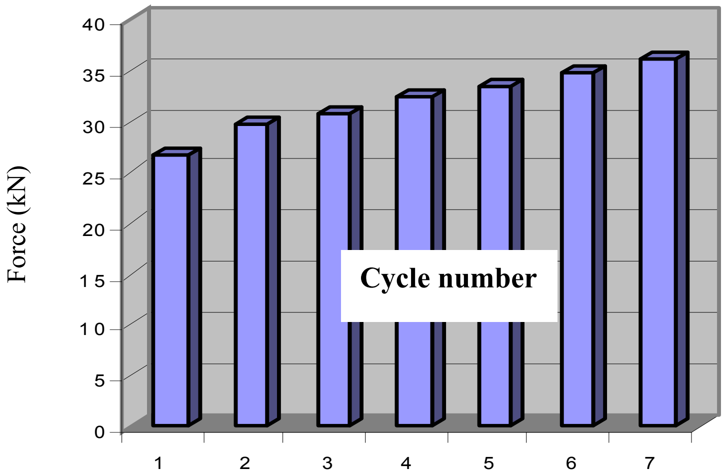


(a) Development Concrete Forces in YAC at MAX Loading

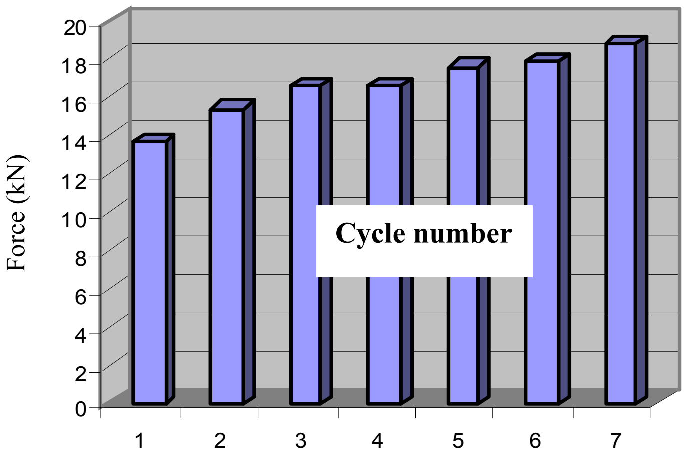


(b) Development Concrete Forces in OAC at MAX. Loading

Fig.7

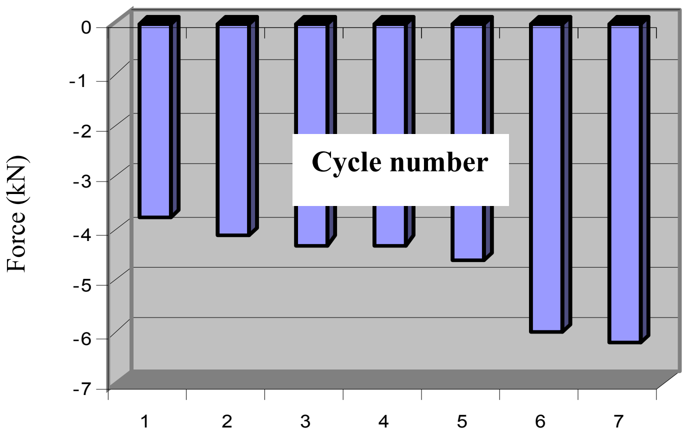


(a) Development of Steel Forces in YAC

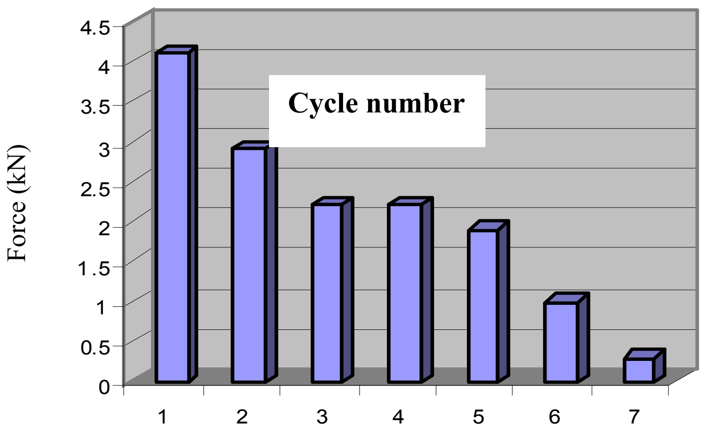


(b) Development of Steel Forces in OAC

Fig.8

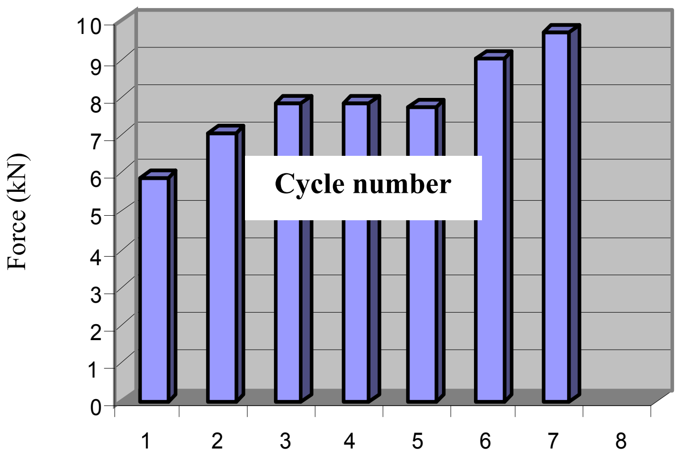


(a) Development of Concrete Forces in YAC at MIN loading

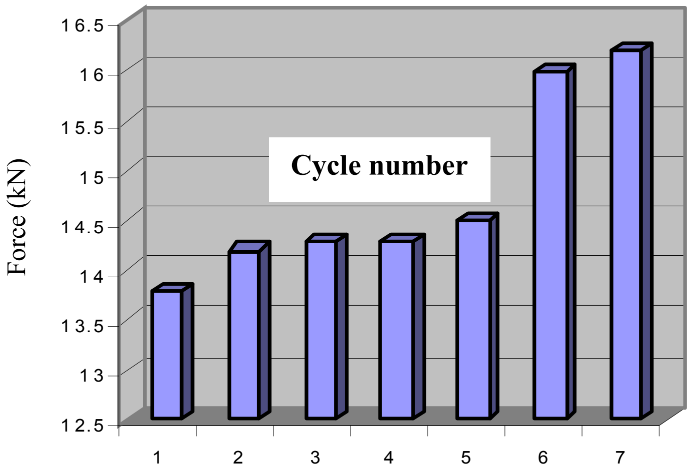


(b) Development of Concrete Forces in OAC at MIN loading

Fig.9



(a) Development Steel Forces in YAC at MIN loading



(b) Development Steel Forces in OAC at MIN loading

Fig.10

5. Discussion of Results:

Because of creep and relaxation in the concrete, forces in both concrete and steel were redistributed.

5.1 Redistribution of forces at maximum loading:

Creep in the young age concrete is higher than creep in the old age concrete, that is about two times :

$\varepsilon_c\ Rc_1 = 45.5 * 10^{-5}$, $\varepsilon_c\ Rc_2 = 22 * 10^{-5}$

Creep in the (YAC) and the (OAC) at the [LTCL] was considerably dropped to second cycle , then the rate of creep is decreased up to last cycle (see Table 6 and Table 7) .

The stress in concrete is decreased in every single cycle, and from cycle to cycle.

The stress in steel is increased in every cycle, and from cycle to cycle.

This development of forces appeared clearly in the young age concrete

For example, the forces in the steel of the (YAC) Rc1 samples have increased by 100%, and the forces in the concrete of the (YAC) Rc1 have decreased by 22%. Forces in the (OAC) has decreased 24.3%(see Table 10).

Table 10 Redistribution of forces between concrete and steel in the loading cycles

Force In kN	No .of cycles						
	1	2	3	4	5	6	7
Nc1 (YAC)	76.2 100%	68.4 95%	64.3 84%	63.4 83%	61.8 81%	60.2 80%	59.3 78%
Ns1 (YAC)	16.8 100%	24.5 145%	28.4 170%	29.5 175%	31.1 185%	32.7 194%	33.6 200%
Nc2 (OAC)	87.59 100%	76.84 87.7%	73.46 83.8%	71.4 81.6%	70.18 80%	68.32 78%	66.82 75.7%
Ns2 (OAC)	33.4 100%	44.14 132%	47.54 142%	49.58 148%	50.81 152%	52.68 157%	54.66 163%

5.2 Redistribution of forces at minimum loading:

The relax creep in the young age concrete is higher than the relax in the old age concrete , that is about two times:

$\varepsilon_{c\ aft\ Rc_1} = -10.8 * 10^{-5}$, $\varepsilon_{c\ aft\ Rc2} = -5.4 * 10^{-5}$.

Relax creep increases in the young age concrete up to the second cycle, and then stopped. Relax creep increased weakly in the old age concrete up to the second cycle then stops.

At the period of every cycle of minimum loading, forces in concrete increase, and forces in steel decrease. But if the variation of forces has been examined from one cycle to cycle, we find that forces in concrete decrease, and forces in the steel increase ,(see Table 9) .

In sample R_{c1} (YAC), when the load in its minimum value, (N=10 kN) the force in concrete in the first cycle was (Nc_{Rc1}= -6. 1 kN) , then decreased to (Nc_{Rc1} = - 7. 4 kN) as a tension force in the seventh cycle.

$\Delta\ Nc_{Rc1} = -7.4 - -6.1 = -1.3$ KN

In the samples Rc2 (OAC), when the load in its minimum value (N =10 KN), the force in concrete (compression) in the first cycle was (NcRc2 == + 3. 2 kN), then dropped in the seventh cycle to (NcRc2 = - 1. 9 kN) (tension).

$\Delta\ Nc_{Rc2} = +3.2 - 1.9 = 5.1$ kN

i.e.: the forces in the old age concrete (OAC) developed about four times more than the forces in the old age concrete (OAC), (see Table 7 and Table 8).

After the seventh cycle, when the minimum load was removed completely, the horizontal cracks appeared wider in the (YAC) samples than in the (OAC) samples (see Figure 11).

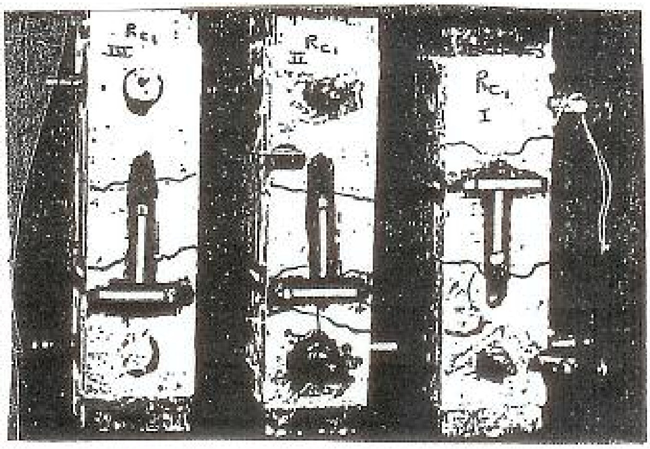


Fig.11 Horizontal Cracks in Samples after LTCL

6. Character of Reinforced Concrete after the [LTCL]:

An experimental study was carried out on the young and old age samples, after loading and then completely removing the load, to study the stress – strain behavior, and to make a comparison with the stress – strain curve of unloaded reinforced concrete by [LTCL].The results are shown in Table 11 and Table 12 .

The experiment took into account:

- Pre – loaded samples from (YAC) and (OAC).
- Unloaded samples with pre-loaded samples from the same age.
- All the reinforced concrete samples were tested until they collapsed.

The results of the stress –strain experiment show :

* The stress –strain curve of [LTCL] loaded reinforced concrete samples is significantly different from the stress – strain curve of unloaded reinforced concrete samples. The difference is due to the fact that the concrete lost most of its plastic deformation, then horizontal cracks appeared on the section.

* The curve can be divided into three stages:

1st Stage: Cracks closing stage .Steel in the samples was exposed to the loads as follows:

YAC: from 0.00 kN to 20.00 kN
OAC: from 0.00 kN to 10.00 kN

The stress – strain curve is linear in nature.

The calculated forces in the (YAC) samples had twice the values of those in (OAC) due to wider cracks in the (YAC).

2nd Stage: Steel and concrete in the samples were exposed to the loads as follows:

YAC: from 20.00 kN to 100.00 kN
OAC: from 10.00 kN to 100.00 kN

The (stress – strain) curve is non-linear in nature, hyperbolic shape (untypical of concrete curve shape), due to loss of most plasticity in the concrete exposed to [LTCL].

3rd Stage: A stage of concrete plastic deformation. Steel and concrete in the samples were exposed to the loads as follows:

YAC: from 100.00 kN to the collapse of the samples
OAC: from 100.00 kN to the collapse of the samples

* The strength of the (YAC) samples after [LTCL] was less by about 50 KN than the strength of unloaded samples for the same age as shown in Fig12.

* The strength of concrete for both pre-loaded and unloaded samples of (OAC) was almost the same.

* Strain of unloaded concrete was less than the one of the pre - loaded concrete for the same stress of (OAC) and (YAC). (see Fig 12 and 13).

Table -11 Relationship between the force and strain of the young age concrete

Force	0	10	20	40	60	80	100	120	140	160	180	200	220	250
Strain* 10^{-5} (1)	0	42	84	110	122	132	139	145	152	165	185	220		
Strain* 10^{-5} (2)	0	7	13	25	38	50	65	80	97	114	130	150	175	240

Table -12 Relationship between the Force and strain of the Old Age Concrete

Force(KN	0	10	20	40	60	80	100	120	140	160	180	200	220	240	250
Strain.10^{-5} 1)	0	41	70	90	100	110	115	122	130	138	150	162	180	200	225
Strain.10^{-5} 2)	0	5	10	20	31	43	56	70	86	104	125	145	165	197	225

1) Pre-Loaded reinforced concrete **2) Unloaded reinforced concrete**

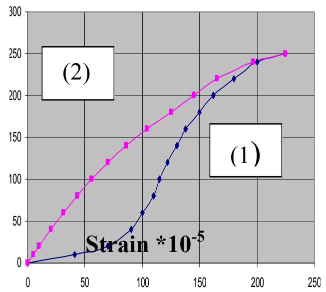


Fig.12 Relationship between the Force and Strain of the Young Age Concrete for
(1) Pre-Loaded reinforced
(2) Unloaded reinforced concrete

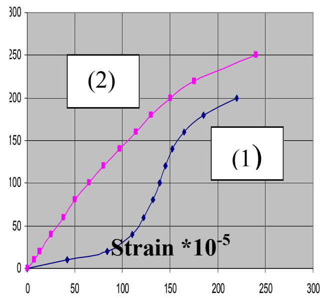


Fig.13 Relationship between the Force and Strain of the Old Age Concrete for
(1) Pre-Loaded reinforced concret concrete
(2) Unloaded reinforced concrete

7. Conclusion

7.1 Result of applying the [LTCL] on reinforced concrete samples

1) The forces between the steel and the concrete were redistributed as following:

a) For the maximum level loading stages:

During each cycle, the forces in the steel increased, and the forces in concrete decreased.

From cycle to cycle, the forces in the steel increased, and the forces in concrete decreased.

b) For the minimum level loading stages:

During each cycle, the forces in the steel decreased, and the forces in the concrete increased.

From cycle to cycle, the forces in the steel increased, and the forces in the concrete decreased.

2) It was noticed at the end of [LTCL], and due to the early cracks in the (YAC), that the forces in the (OAC) concrete decreased in a rate equal to 4 times the decrease of the forces in the (YAC) concrete, despite the fact that the value of relaxation in the (OAC) is half the one in the (YAC).

3) Tension forces, that caused horizontal cracks in the concrete, were developed in the minimum level loading stages as follows:

For the (YAC): tension forces developed in the first cycle continued to increase as tension forces to the last cycle.

For the (OAC): compression forces developed in the first cycle, decreased to the 4th cycle, then tension forces developed in fifth cycle and increased to the last cycle.

4) Most plasticity of concrete was lost due to applying the [LTCL] on the reinforced concrete samples.

5) The application of the [LTCL] system has caused the (YAC) samples with loose about 20% of its strength compared to the unloaded (YAC) samples.

7.2 Results of the stress –strain experiment:

a) Stress –strain curve of [LTCL] loaded reinforced concrete samples is significantly different from stress – strain curve of unloaded reinforced concrete samples. The difference can be explained by the fact that the concrete lost most of its plastic deformation, and horizontal cracks appeared on the section.

b) The curve can be divided into three stages:

1st Stage: Cracks closing stage .Stress – strain curve is linear in nature.

2nd Stage Stress – strain curve is non-linear in nature, due to loss of most plasticity in the concrete exposed to [LTCL]

3rd Stage: A stage of concrete plastic deformation.

The strength of concrete for both pre-loaded and unloaded samples of (OAC) was almost the same.

It is recommended that close attention should be given to the factors that have effects on Creep and Relaxation in the reinforced concrete, such as:

- Strength of the concrete
- Age of concrete at the beginning of loading
- Max to Min loading ratio
- Steel to concrete ratio in the reinforced concrete section
- Water to cement ratio
- Specifications of aggregates

Based on the previous results, to avoid cracks and weakness in structures, especially in structures where cracks are not permitted as for cylindrical tanks, it is recommended that:

1) The steel in reinforced concrete be maintained within the elastic range under the maximum loading levels of [LTCL].

2) The minimum loading levels of the [LTCL] be applied at values more than that cause tension stress in the concrete.

3) Concrete loading levels are proportional to its strength which is in turn proportional to the age of that concrete, especially at young stages.

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