[illegible]

[illegible] *

[illegible] **

[illegible]

[illegible] **Ressiner's** [illegible]

EFFECT OF CYCLIC HEATING ON REINFORCED CONCRETE THICK PLATES

Dr. AH AHMAD *
H.M.A. HASAN **

ABSTRACTR

The aim of this investigation is to study the effect of cyclic heating and cooling on the nonlinear analysis of the reinforced concrete plate at different load conditions before and after cracking up to failure, and it`s effect on cracking and crushing of concrete and yielding of steel.Also to calculate the stresses and strains due to the applied load under the effect of cyclic heating and cooling .

The study also present the mathematical mode for the behavior of the reinforced concrete plate under cyclic heating with different variables , such as temperatures , duration of heating, and number of cyclic heating ,The relation between load and deflection .is presented .

Ressiner`s theory has been used to represent the behavior of thick plate . The Finite Difference method and Dynamic Relaxation have been used in the solution of the differential equations ..

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** MSc. Graduate .

استلم في ٢٠٠٤/٩/١٩ قبل في ٢٠٠٥/٤/١٠

Introduction — 1

[illegible]

1.1 Nonlinear behavior of Plates

[illegible] **(Material nonlinearty)** [illegible] **(Geomatric nonlinearty)** [illegible]

[illegible] **(Hand)** [illegible] **[1]** [illegible] **(elastoplastic)** [illegible] **[2](Speare & Kemp)** [illegible]

1.2 Effect of Cyclic Heating on Concrete properites

[illegible] **[3]** [illegible]

1.3 Concrete Members Subjected to High Temperatures

[illegible] **[4] Khan & Royles** [illegible] **(20-800)°C** [illegible]

(Deformed [illegible] **(Plane Bars)** [illegible] **Bars)** [illegible] **.(Load-Deflection)** [illegible]

[illegible] **[5]** [illegible] **Huang** [illegible] **(Finite Element)** [illegible] **(Thick Plate Theory)** [illegible]

1.4 [illegible] :

Effect of High Temperature no the Reinforcing Bars During Heating and After Cooling

[illegible]

[illegible] **[6]** [illegible] **Homles** [illegible] **(20-700)°C** [illegible]

[illegible]

[illegible] **[7]** [illegible] **600°C** [illegible] **(750-900)°C** [illegible] **(24% & 28%)** [illegible]

[illegible] **[8]** [illegible] **476 MPa** [illegible] **345MPa** [illegible] **500°C** [illegible] **600°C** [illegible] **89%** [illegible] **70%** [illegible] **700°C** [illegible]

[illegible] **S420M** [illegible] **[9]** [illegible] **Mäkeläinen** [illegible] **(stress-strain)** [illegible] **(400-700)°C** [illegible]

Materials Constitutive Relationship- [illegible] -2

2.1 [illegible] :

Ultimate Strength of Concrete under Biaxial Compression

[illegible] [10] Liu [illegible] (1) [illegible] :

$$\alpha < 0.2 \qquad \frac{\sigma_P}{\sigma_{\circ T}} = 1 + \frac{\alpha}{1.2 - \alpha}$$

$$0.2 \le \alpha \le 1.0 \qquad \frac{\sigma_P}{\sigma_{\circ T}} = 1.2$$

$$1.0 \le \alpha \le 5.0 \qquad \frac{\sigma_P}{\sigma_{\circ T}} = \frac{1.2}{\alpha} \qquad (1)$$

$$\alpha > 5.0 \qquad \frac{\sigma_P}{\sigma_{\circ T}} = \frac{1}{\alpha}\left(1 + \frac{1}{1.2\alpha - 1}\right)$$

[illegible]

$\sigma_{\circ T}$: [illegible].

α : [illegible] (σ_1/σ_2).

σ_P : [illegible].

2.2 [illegible] :

Strain at Ultimate Biaxial Compression Stress

[illegible] **[10] Liu** [illegible] :

$$\varepsilon_P = -2500 \times 10^{-6} \qquad \textbf{(Major Direction)} \ \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

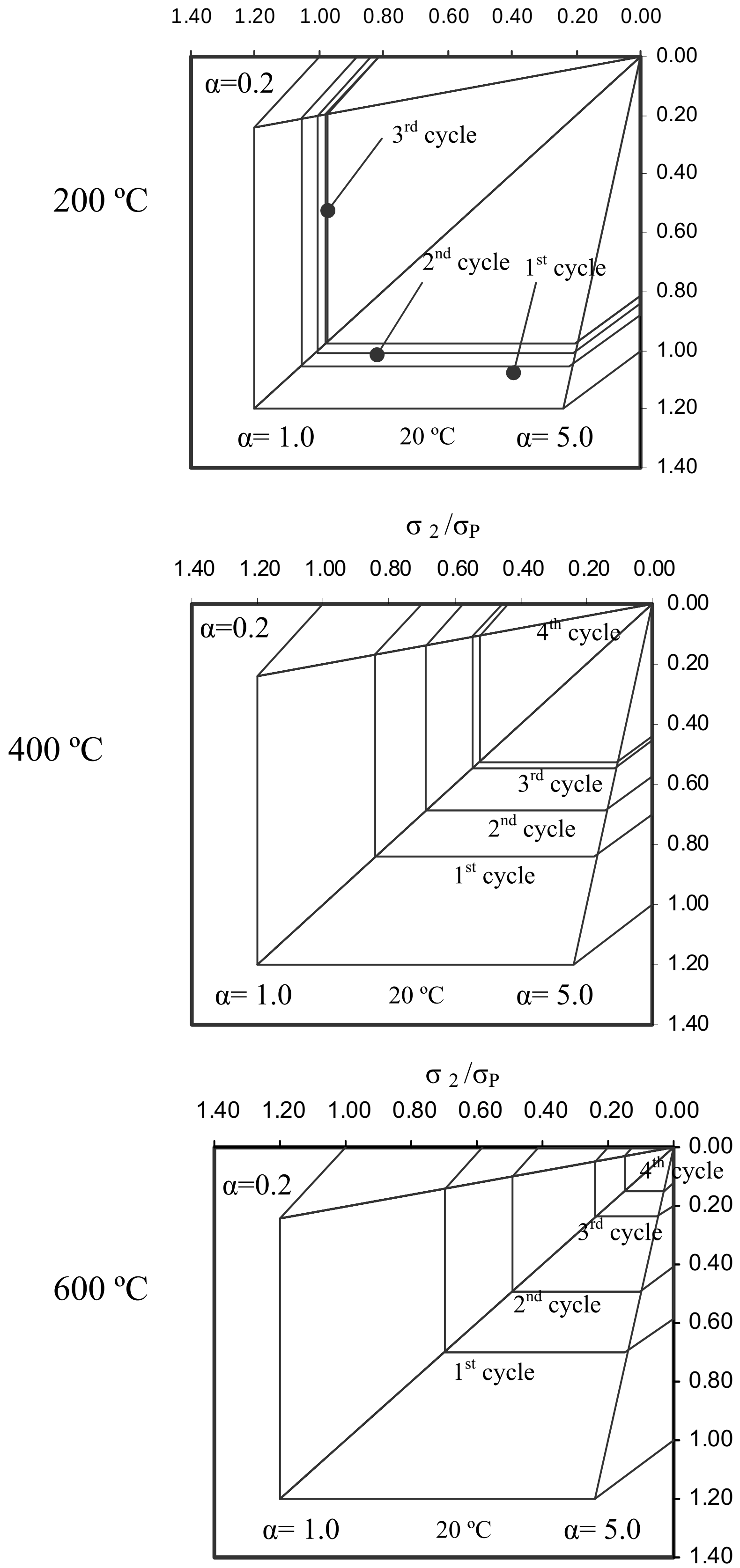
$$\varepsilon_P = (500 + 79.8\sigma_P) \times 10^{-6} \qquad \textbf{(Miner Direction)} \ \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

[illegible] :

$$\varepsilon_P = -0.0025 \times \xi \qquad \textbf{(Major Direction)} \ \ldots\ldots\ldots\ldots\ldots (4)$$

$$\varepsilon_P = (500 + \xi_1 \cdot \sigma_P) \times 10^{-6} \qquad \textbf{(Minor Direction)} \ \ldots\ldots\ldots\ldots\ldots (5)$$

$$\xi_1 = 0.0266\left(500 + \varepsilon_P(\text{major}) \times 10^6\right)$$


200 ºC
400 ºC
600 ºC
α=0.2
α= 1.0
α= 5.0
20 ºC
1st cycle
2nd cycle
3rd cycle
4th cycle
σ 2 /σP
σ 1 /σP
1.40 1.20 1.00 0.80 0.60 0.40 0.20 0.00

[illegible] (1) [illegible]

DžĚ ƘĭΘ

ξ (ǖDžFyDž ǖǬǤĭŖ ǖFyƧǮŰĚ ĂΤƽŰĚ ǔǤEĐDžĚ ǔǤĚǤΘĚFĆ) = ($\frac{\varepsilon_T}{\varepsilon_{20}}$) ǕPljNj ǤƘĐŦĭ ǤǬǨĆ hǚŦǤǨĆ ǔǤĚǤǿΘĚ ǔǤNǤ ǨǨǿYNj ǸĚǤNjǬ

ƾĚ ǮŦƽǨǤĭNj ǬĭǤGĦĚ **[3]** . .

(31.33 MPa) ŲFƩŢǿǚǚ hǿDžNjFƽDžĆ hǚŦǿ ƨǤǬ ĂǿŦY ǸĭǤǚĆ hƨ ĚǤǬ ĂŦY hǚĭǚĆDž hǿƽĆF ƨ ĚŰǬFǿyDžĚNj

hǚǬFyDžĚ ƝĚǤŦƽĚ !Ŧ hƧŦǬǬDž ŲFƩŢǚǚ hǚDžNjFƽDž !ĭƽĆNj hǚŦF ƨǤǬĚ DžDž njǤǬĆ ƱĚNjǚĚ ĂŦY ŰǬFyDžĚ ĽΡlj !ĭDžyŦ ƒ ǤƩĚNj

: hǚĭŎĚ

$$\varepsilon_p = \left(500 + \xi_1 \times \sigma_p \times \frac{-31.33}{\sigma_\circ}\right) \times 10^{-6} \qquad \text{...(6)}$$

DžĆ ƘĭΘ

. hǚŦF ƨǤǬŦĚ njNjΤƽĚ ŲFƩŢǚŰĚ hǚDžNjFƽDž hǚDžĭƽ : $\sigma_\circ$

ƾ : ŲFƩŢǚŰĚ - ǬŢĚNj ĬƏFǚƘĚ ǤNjΘDžĚ ǎΡ ǬŢĚ ǸŰFΘ ǬǚY hǚŦǿ ƨǤǬĚ 2.3

Concrete Under Biaxial Tension and Tension Compression Cases

DžĭŦǬFyDžĚ ǤNjFΘDžĚ hǚĭƏFǚƘ ǸĚǬFNJǚǚ ǤĭƘĐĦĆ hǚŦF ƨǤǬŦĚ hǚĆǘΤĚ hƺNjƧΤDžĆ hǚDžΙΘĐDžĚ hƽǘyĚ hǚĆǿŦĪ DžǿĪDžĭ

Nj **E1b** ǖǿyƧĚ ǤĭFyDžĚNj DžNjƨNjĆ hǚƨǚ hǚŰǬĆ ţ ƽĚ ǤĭFyDž hǚDžĭƽ DžY ǤĭĆyŦĚ DžĪDžĭ ƘĭΘ .hǚǚNjǬŖDžĚ hƩǿĭΤĚFĆ

: ĬĚFŦĚ NjΘǚĚ ĂŦYNj **E2b**

$$\begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix} = \begin{bmatrix}\lambda' E'_{1b}/E'_{2b} & \lambda' \nu_1 & 0\\ \lambda' \nu_1 & \lambda' & 0\\ 0 & 0 & E'_{1b}E'_{2b}/\left(E'_{1b}+E'_{2b}+2E'_{2b}\nu_2\right)\end{bmatrix} \begin{Bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{Bmatrix}$$

$$\begin{bmatrix}\tau_{13}\\ \tau_{23}\end{bmatrix} = \begin{bmatrix}E'_{1b}E_C/\left(E'_{1b}+E_C+2E_C\nu_1\right) & 0\\ 0 & E'_{2b}E_C/\left(E'_{2b}+E_C+2E_C\nu_2\right)\end{bmatrix} \begin{Bmatrix}\gamma_{13}\\ \gamma_{23}\end{Bmatrix} \qquad \text{....(7)}$$

DžNjĪŦ ĬƏFǚƘĚ ǤNjΘDžĚ ǎΡ ŲFƩŢǚŰĚ hǚFΘ Ĭƺ DžĆ ƘĭΘ

$$E'_{1b} = \frac{E\left[1-\left(\varepsilon_1/\varepsilon_P\right)^2\right]}{\left[1+\left(\frac{E}{E_S(1-\nu\alpha)}-2\right)\left(\frac{\varepsilon_1}{\varepsilon_P}\right)+\left(\frac{\varepsilon_1}{\varepsilon_P}\right)^2\right]^2} \qquad \text{.......................(8)}$$

$$E'_{2b} = \frac{E\left[1-\left(\varepsilon_2/\varepsilon_P\right)^2\right]}{\left[1+\left(\frac{E}{E_S(1-\nu\alpha)}-2\right)\left(\frac{\varepsilon_2}{\varepsilon_P}\right)+\left(\frac{\varepsilon_2}{\varepsilon_P}\right)^2\right]^2} \qquad \text{.......................(9)}$$

[illegible]
uniaxial modulus of elasticity

$$E'_{1b} = E'_{2b} = E \qquad \ldots\ldots(10)$$

$$\lambda' = E'_{1b} \big/ \left(E'_{1b} / E'_{2b} - \nu^2 \right)$$

2-4 [illegible]:

Stress-Strain Relations for Cracked Concrete

[illegible]

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \\ \tau_{13} \\ \tau_{23} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & C_1E & 0 & 0 & 0 \\ 0 & 0 & G'_{12} & 0 & 0 \\ 0 & 0 & 0 & G'_{13} & 0 \\ 0 & 0 & 0 & 0 & G'_{23} \end{bmatrix} \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{Bmatrix} \qquad \ldots\ldots(11)$$

[illegible] **(1)** [illegible]

[illegible] **(C=1.0)** [illegible] **(C)** [illegible]

$:G_{ij}$ [illegible]

[illegible] **[1,13,14]** [illegible] **[1] (0.4)** [illegible]:

$G'_{12} = 0.4G$	$G'_{13} = 0.4G$	$G'_{23} = G$	**(1)** [illegible]
$G'_{12} = 0.4G$	$G'_{13} = G$	$G'_{23} = 0.4G$	**(2)** [illegible]
$G'_{12} = 0.4G$	$G'_{13} = 0.4G$	$G'_{23} = 0.4G$	[illegible]

2.5 Tension Stiffening

[illegible] **(Vecchio and Collins)** **[11]** [illegible] (α_1 , α_2) [illegible]

$$\sigma = \frac{\alpha_2 \alpha_2 f'_t}{1 + \sqrt{500\varepsilon_i}} \qquad \varepsilon_i > \varepsilon_{cr} \qquad \mathbf{(12)}$$

ε_{cr} : [illegible].

α_1 **=1.0** [illegible] **(Deformed Bar)**.

α_1 **=0.7** [illegible].

α_2 **=1.0** [illegible].

α_2 **=0.7** [illegible].

ۑ βεβΘ‖ε lƒШβᵍĠ ĬƴĠǓ βĭȜ ŊϳΘǆ ĂǂƳ hǔǆƑƨβᵍ‖ε βķĐǂ‖ ($\alpha_2 = 0.7$)hǔĎĭƼ f βȥ !ǂ hƨεβᵍ‖ε ǕPǀj ĬȥŊ
. ƑŊǆĭᵍǀƨǂ ƀƑǆķĉ lŰƑƴƻǆε ᵍ‖ŊǂŊ
!ƒøƼ pø‖P üøШŰŊ Û hǔǆƑƨβᵍ‖ε Ĭȥ ǈķŊᵍΘ Ďǀ ĎĎ‖ε βƑǓᶅǆŰε βƑĠǂƳŰε ĎĭƴĠ ƤᵍĐǂ !‖ hƨĠƑƨ‖ε h‖ᵍƑƴĎ‖ε
ƘŊᵍøΘ hĭǆƑ‖Ďǆ ĎĭƳ βĠƴĭ ăP‖ε (α_3) βᵍ ǖĎƑƳ hȥƑȚǆĠ **[12] (Abrishami & Mitchell)** ĎƑķΘƑĠ‖ε
(c/d) hĠƨøǆ ĂøǂƳ pø‖P Ĭȥ §ᵍĎǂƴĎ hƨƨᶅǂĎ‖ε βĭȜ hǔǆƑƨβᵍ‖ε Ĭȥ ηĭǂƨǂ‖ε ᵍĭᵍΘ üŊǓ ĂǂƳ hĭβƑǓᶅǆε lƑƨƨᶅǂ
: hĭǂŎε hȤĭȚ‖ƑĠ **(12)** h‖ᵍƑƴĎ‖ε ηĠȚǂ‖

$$\sigma_t = \frac{\alpha_1 \alpha_2 \alpha_3 f_t'}{1 + \sqrt{500\varepsilon_i}} \qquad \textbf{(13)}$$

$\alpha_3 = 1.0$ **for** $c/d_b > 2.5$

$\alpha_3 = 0.8(c/d_b) - 1$ **for** $1.25 \le c/d_b \le 2.5$

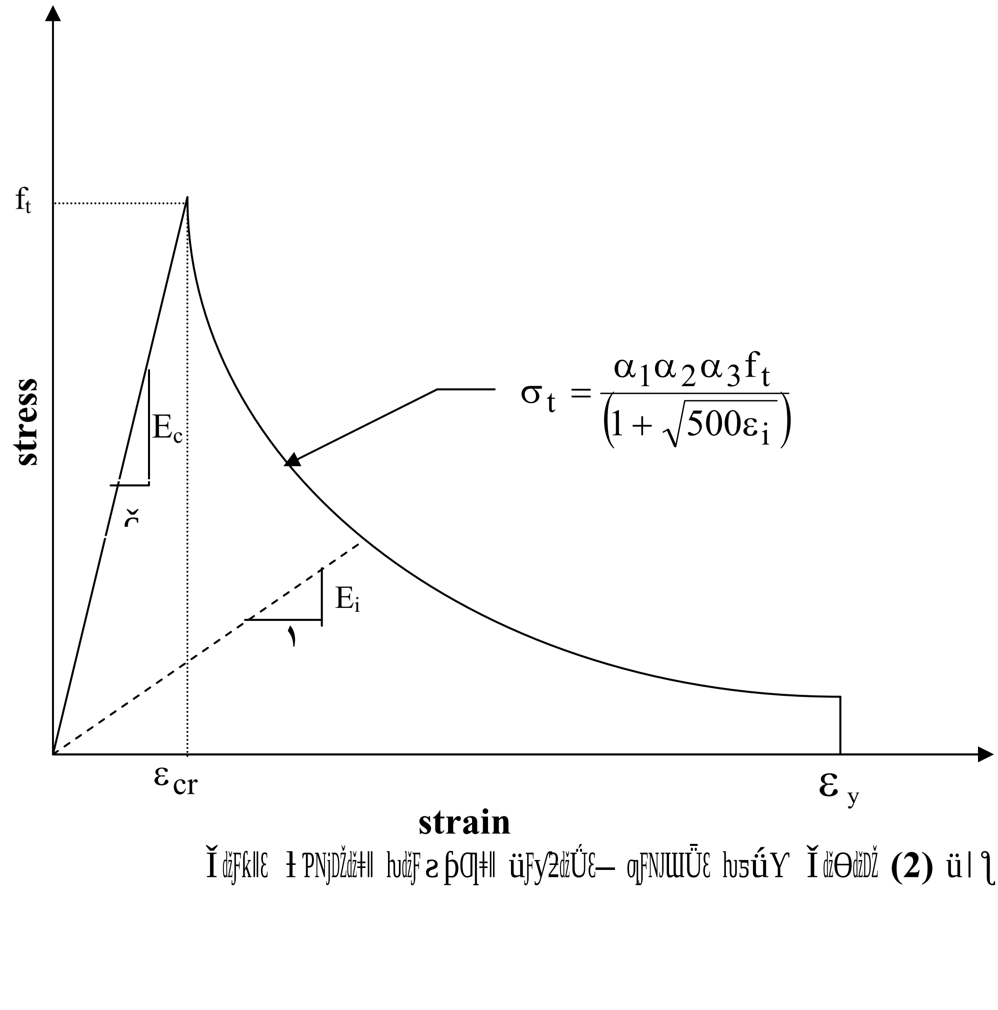
$\alpha_3 = 0.0$ **for** $c/d_b < 1.25$

Ďǆ ƘĭΘ

Ĭǆƒƨβᵍ‖ε ƀƑǓȣ‖ε pĎƨ üķĎǂ : **c**

!ᵍᵍǂƨĎ‖ε ηĭǂƨǂ‖ε ᵍĭᵍΘ βǓƼ : **db**

βĭƑƴĎ‖ hĭŊƑƨĎ hǆŊβĎ‖ε üĎƑƴĎ hĎĭƼ Ƥᵍĉ !ǂ ƘĭΘ Û!ᵍᵍǂƨĎ‖ε üƑƴƻǆŰĉ - ᵍƑŊШŰĉ ĬǆΘǆĎε üķĎĭ **(2)** ü‖ᶅ‖εŊ
ᵍǆƳ üƑƴƻǆŰε hĎĭƼ ĂǂƳ ᵍĎǂƴĭ ᵍᵍΘĎ üƑƴƻǆε Ă‖ε ƑŊ‖‖ŊȚŊ ᵍǆƳ ᵍᶅ‖ε hĎŊƑƨĎ üƑĎǀjŊ lƑƨƨᶅǂ‖ε ƘŊᵍΘ ᵍƴĠ ǕǓƑƨ‖ε
.Ƽƨᶅǂ‖ε hǂΘβĎ



ĬǆƑķ‖ε ǂƤŊĎǆǂ‖ hǔǆƑƨβᵍǂ‖ üƑƴƻǆŰε– ᵍƑŊШŰε hƼűƳ ĬǆΘǆĎ **(2)** ü‖ᶅ‖ε

Behavior of Steel Reinforced **-2.6** [illegible]

[illegible] **(3)** [illegible] **[6] (Homles)** [illegible] **.(4)** [illegible]

Method of Analysis 3- طريقة التحليل

[illegible]

[illegible]

$$-\frac{\partial^2 \overline{M}_x}{\partial \bar{x}^2} - 2\frac{\partial^2 \overline{M}_{xy}}{\partial \bar{x}\partial \bar{y}} - \frac{\partial^2 \overline{M}_y}{\partial \bar{y}^2} + \overline{D}_f \frac{\partial \bar{\omega}}{\partial \bar{t}} + \bar{m}\frac{\partial^2 \bar{\omega}}{\partial \bar{t}} = \bar{q} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(14)$$

[illegible]

$$\bar{\omega}^{\circ}_{(i)j} = \frac{1}{1+0.5\overline{D}_v}\left[(1-0.5\overline{D}_v)\bar{\omega}^{\circ}_{(i)j-1} + \frac{\Delta\bar{t}}{\bar{m}}\left(\left(\frac{\partial^2 \overline{M}_x}{\partial \bar{x}^2}\right)_i + 2\left(\frac{\partial^2 \overline{M}_{xy}}{\partial \bar{x}\partial \bar{y}}\right)_i + \left(\frac{\partial^2 \overline{M}_y}{\partial \bar{y}^2}\right) + \bar{q}_i\right)\right] \qquad (15)$$

: [illegible]

$$\sum_{k=1}^{k=j+0.5}\bar{\omega}_{(i)k} = \sum_{k=1}^{k=j-0.5}\bar{\omega}_{(i)k} + \bar{\omega}^{\circ}_{(i)j}\Delta\bar{t} \qquad (16)$$

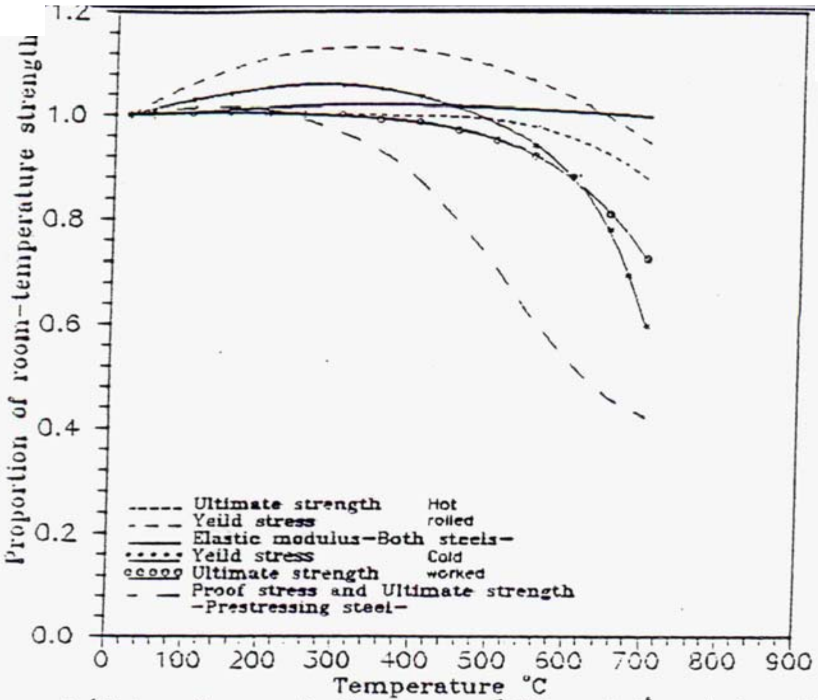
:[illegible]

$$D_v = \frac{\overline{D}_f \Delta\bar{t}}{\bar{m}}$$ [illegible]

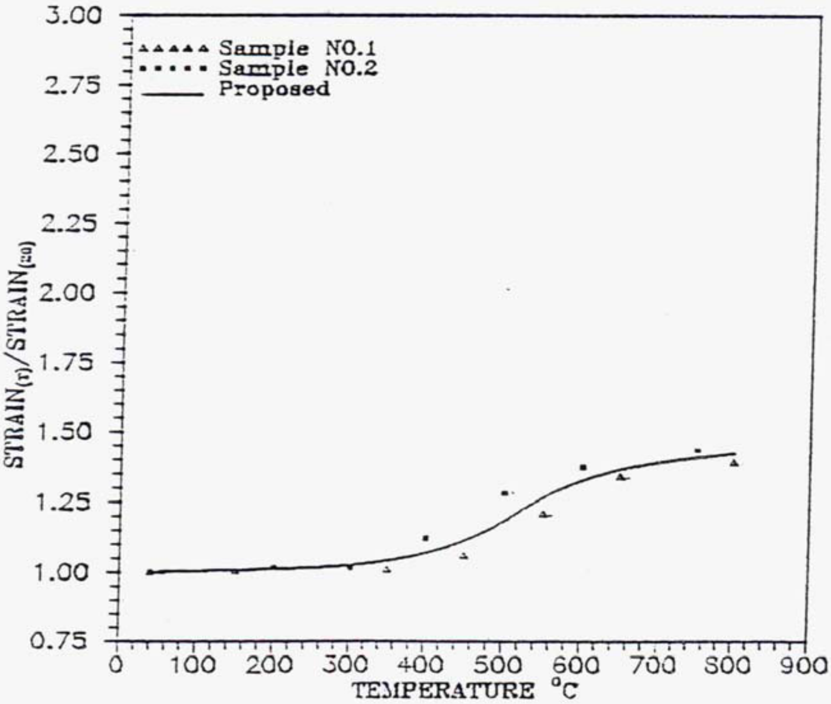
i : [illegible] .

j : [illegible] .

ω° : [illegible]



شكل (13.5) تغيير خواص أنواع مختلفة من حديد التسليح بعد الدورة الأولى من التسخين



الشكل (14.5) تغيير إنفعال الخضوع في الحديد بعد الدورة الأولى من التسخين .

أما محددات ألإسناد لصفيحة بسيطة ألإسناد فهي كما يلي :

$$\left.\begin{array}{l}\omega = 0\\ M_x = 0\\ \phi_y = 0\end{array}\right\}$$ x is constant ……………………………….(17)

$$\left.\begin{array}{l}\omega = 0\\ M_y = 0\\ \phi_x = 0\end{array}\right\}$$ y is constant ………………………………..(18)

ŀōĂƙʅùďž!ƒ ƘƒƥǴǌŋǕƒ ŀ!Ǵơ ŀơǒƧŦ ýǂ Ŏ5 ƯƧƙƽǒ Ü ƠƒƒƧŦ ƖƥƵ Ĭ!ƒ ŀōǉǴʅƧƤ!ƒ ŀơǒ5Ʈ!ƒ ǁďʅ ĎǒʅƖƙ Ďƙ
ǇǂďǒƠƒƒƧŦ!ƒ ƜŖĂďǉ ĎƒƥƤƙʅǴhĂ Ü ŀơǒƧŦ!ƒ ƱʅĂ Ŏ5 ƥǴǌŋǕƒ ýƥƶď ŖƤďƙ ƘƒƥǴǌŋǕƒŀďǒƥ ǇǊĂ Ü (Plan Stress)
ǁďùʅ ýǖùƤ ƖƧƒƧùơ!ƒ ýōƨĂƙ ƧōǍƙ ýōǍďƙ ĬǁƵ ƥƵǴʅō ƒŖǋĂ . ŀơǒ5Ʈ!ƒ ǁďʅ ýǖƤ ŀ5ǁƙƤď!ƒ ƖƥǴď!ƒ ƒ ƒĂƤ ŖƤ
ƯƧù5 Ďùƙ ƥpĂ Ü ŀơǒƧŦ!ƒ ǁǁƙ Ŏ5 ƖƧƒƧơ!ƒ ŀŋƧƥ ŀďǒƥ ĬǁƵ ƭƥǴďƙƵƒ ŀơǒƧŦ ýǂ ƒ ƒĂƤ ŖƤ ǁ!ŖǂĂ . ŀơǒ5Ʈ!ƒ
. ƠƒƒƧŦ!ƒ ǇǊh ĎǴƙ ƒ p ƱhƧ ƥĂŋĂ

4- ĬƯƠǁƐ ƥĭƷ üĭǂƟŀǁƐ 5ƏƐƥƯ Nonlinear Analysis Methods

ƥùǉƵ ŀōʅǴùďǉď!ƒ ŀhǖƮ!ƒ ŀ5Ă5Ʈď ƧōùƺƙتمǊاستخدام الطريقة المعدلة للزيادات المحددة التي تعتمد على
ŀùùōƒƥh ƥǉƵ (D1)ŀōʅǴďǉď!ƒ ŀhǖƮ!ƒ ŀ5Ăù5Ʈď ŀďǒƥ ǇǊď ýùùpƒ ǇĂǂƙ Ŏùùƙ!ƒĂ (D2) ýďơ!ƒ ƱōǁʅƙŀōǴǌǉ
. ومن ثم تحسب قيمة معدل الجسائة المماسية كما يلي : ýďơ!ƒ Ʊōùǁʅƙ

$$D_{av} = \frac{D_1 + D_2}{2}$$

5- Ƣʅ5ƑďǕǁƐǋ ƛƏƑŀďǁƐ Results and Discussion

1-5 ăƥƐƥƟǁƐ ƥƑʅŀďǕƈ Thermal diffusing

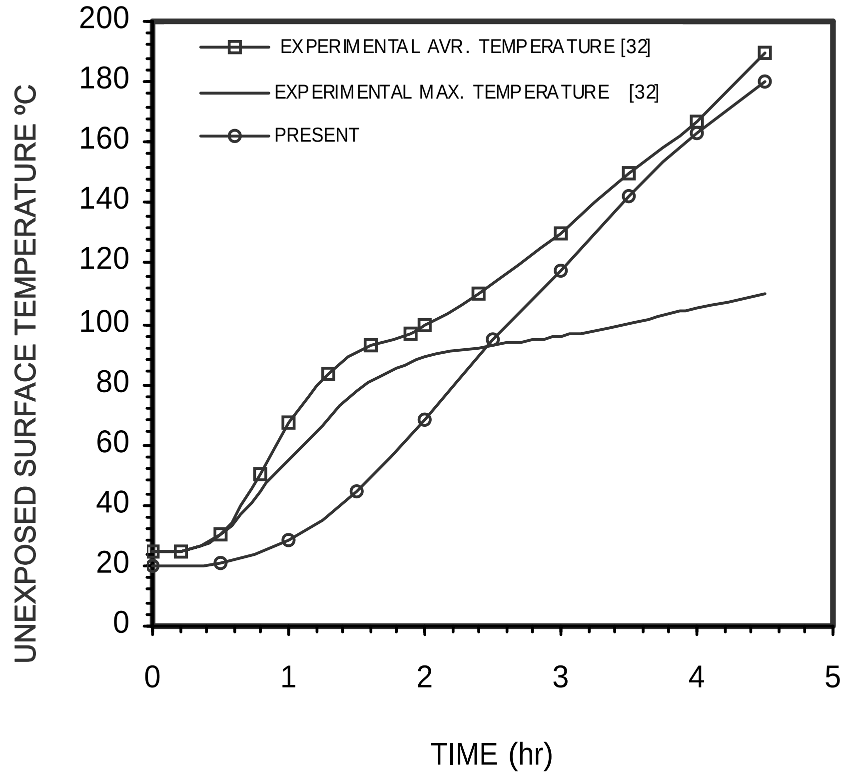
ŖùƤďhĂ ƧƧùǂƙď!ƒ ǇǒƤʅùƙ!ƒ ƧōǍùƙh ƯƧƷ!ƒ ƒŖǋ! ƥƶď!ƒ ǊďǴǉƧh!ƒ ĎƒƥƤƙʅǴh ƖƥƵ ƠƑǴ5Ʈ! ýōǁơƙ!ƒ ǅƒƧŋƺ Ďƙ
ŀưƧƶď (2375 kg/m³) ŀ5ǴǋǂhĂ (177.8mm) ǁďʅh ŀōǉǴùʅƧƤ ŀùơǒ5Ʈ ƧǴōùƙƤƒ Ďƙ ƥǁ5 Ü ƖƥƵ ƘƒƧōƺƙď
-: ǴǌǉĴ ŀōƒƧơ!ƒ ƒ ƒĂƤ!ƒĂ (ISO 834) Ŏʅǵǁ!ƒ ƽōƧơ ƒ ơ5 Ĭ!ƒ

- 1.3 W/m.C^{o} ǐƧƒƧơ!ƒ ýōƮĂƙ!ƒ ýďǴƶď.
- 850 J/kg.C^{o} ŀōƵĂǉ!ƒ ƖƧƒƧơ!ƒ.

Ü ƽùōƧơǁ! ƯƧùƶď!ƒ ƧōƷ ǋŋĂ!ƒ ƖƧƒƧơ ŀŋƧƥ ýď ƽōƧơǁ! ƯƧƶƙ!ƒ ƖƧƙ5 ǇǊōh ŀƥǖƶ!ƒ ƠưĂō (5) ýǂŦ!ƒĂ
. [14] ŀōǁďƵ ǋƑǴƙǉ ýď ǴǌōǁƵ ýĂƮơ!ƒ Ďƙ ǐŖ!ƒ ǋƑǴƙǉ!ƒ ǇǊōh ŀǉƧǴǁďĂ

ǋƑǴùƙǉ Ĭù!ƒ ǐƥƌō ƖƧƒƧơ!ƒ ƘǴŋƧƥ ƳǴ5ƙƧƒ ýď ŀǉǴʅƧƤǁ! ŀōƒƧơ!ƒ ƒ ƒĂƤǁ! ƘhǴǋ ƧƒƥǁďƯƧ5 ǇǊ Ʊơǖō
ýùōǁơƙ!ƒ ǅƒƧŋƺ ƯƧƷ! ǐƧƒƧơ!ƒ ýōǁơƙ!ƒ ĎƒƥƤƙʅǴh ƠďʅōǴďƶď ýƥƒĂǁ! ŀhƧǴǁď ǴǌǉǊƧō ŀōǁďƶ!ƒ ǋƑǴƙǉǁ! ŀǁhǴƱď ƧōƷ
. ƳʅǴǉď ǐƧƒƧơ ƜƧƥƙ ĬǁƵ ýĂƮơ!ƒĂ ŀō!Ǵƶ!ƒ ƖƧƒƧơ!ƒ ƘǴŋƧƥ ƧōǍƙh ŀōǉǴʅƧƤ!ƒ ƠƑǴ5Ʈǁ! ŎƑǴƮǉǕƒ

ƘƒƧĂƥù! ƯƧùƶƙ!ƒ ýǖùƤ ƘhǴǋ ƧƒƥǁďƯƧ5 ŀǉǴʅƧƤǁ! ŀōƒƧơ!ƒ ƒ ƒĂƤ!ƒ ǇǊ ĬǁƵ ŀʅƒƧƥ!ƒ ǉŖǋ Ŏ5 ƥǴďƙƵǕƒ Ďƙ
. ŀʅƒƧƥ!ƒ ƯƒƧƷǊ Ŏ5ō Ǵďh ƒ ƒĂƤ!ƒ ǉŖǋ ǁĂǁʅ Ʃǂƶƙ ƘǴʅƒƧƥ Ƨ5ƒĂƙ Ďƥƶ! ǁ!ŖĂ ƥōƧhƙ!ƒĂ ǇǊōƤʅƙ!ƒ ǇǊď ƖƧƧǂƙď



[illegible] (5) [illegible]
(ISO 834) [illegible]

Structural Analysis [illegible] 2-5

[illegible] (S1) [illegible] (4,5,6) [illegible] 200,400,600 C° [illegible] (0.5 hr) [illegible] [3].

[illegible] (S1) [illegible] (7,8,9) [illegible] 200,400,600 C° [illegible] (0.5 hr) [illegible].

Conclusions

ǀ ƑƜƑŧdžŧ ƨ Ǘƹ .6

: ŧǒ!Ǵơ!ƒ ŧ ƪ ƒƨƥ!ƒ ýǘƤ ŧdžƥǀdž!ƒ ǋƑǴkǀj!ƒ ǨĂư Ĭ ǀƵ ŧǒkǗƒ ƘǴƞǴkǀjk ƪǗƒ Ĭ!ƒ ý ƮĂk!ƒ Ǆk ƥǀ!

ŧơǒ5ƮùĮƒ ǁdžùƪ ýǘƤ ĭƨƒƨơ!ƒ ƜƨƥǁĮƒ ýǒǀơk Ŏ5 ǀƥǒƞ ǀǴ5ŧ ƘƒƦ ǀƥƥơdž!ƒ ƘǴpĂƨ5!ƒ ŧǀǒƨƱ ƨǴhkƵǫ Ǉŧdžǒ -1

ŧùǀǒƨƱ ƥùƶk ǴùdžŧǑƑǴƮùǀjǗƒ ýǒǀơk!ƒ Ư ƒƨƺƒ Ŏ5k ǴdžhĂ ǀƨƒƨơ!ƒ ýǴǀkjƒ Ǉ Ƶ ǿơ ưƒĂ ǂƨĂƮk ŎƱƶk! ŧǒjǴƪƨƤ!ƒ

.ŧơǀƪdž!ƒ ŧŧǒdžƪ!ƒ ŧǒjǴƪƨƤ!ƒ ǑƑǴ5Ʈ!ƒ ýǒǀơk Ŏ5 ǀǴĂ5ŧ!ƒ ƾƒƨƱ!ƒ Ǉdž Ŏŧƨơ!ƒ ǴǴƤƨkƪǗƒ ŧǒjǀkĂ ǀƥƥơdž!ƒ ƘǴpĂƨ5!ƒ

Ǖ ƥùǒƨhk!ƒĂ ǇǒƤƪkǀ! Ʊ ƨƶk!ƒ ƘƒƨĂƥ ƥƥƵĂ ǀƨƒƨơ!ƒ ƘǴƞƨƥ ƥǴǒƥƨƒ ƴdž ŧǒjǴƪƨƤ!ƒ ŧơǒ5Ʈ!ƒ ǀǴǴƪƞ Ʊ5Ƥjk -2

ƥùǒƥơ ƱĂùƶk! ǁ!ƦĂ Ǖ ƥƮ!ƒ ƾǴƱǀj Ǉdž ư ǇǒƤƪk!ƒ Ʊǒǀƪk ŧ!Ǵơ Ŏ5 ǂƥĂƥơdž Ǵnj! ǄǛƵǕƒ ýdžơ!ƒ ƨƛdk Ĭǀhǒ Ǉŧ!Ă

ŧù!Ǵơ Ŏù5 Ǵùdžǁ . ǀƨƒƨơ!ƒ ƘǴƞƨƥ ƳǴ5kƨƒ ƨǭ ƥƮ!ƒ ŧǀƱǀjdž Ŏ5 ŧǀjǴƪƨƤ!! ǀƥĂǀ5dž!ƒ ƥƮ!ƒ ŧdžĂǴǀdž Ǉdž ǿưƶh ƱǒǀƪkĮƒ

ƱǒǀƪkĮƒ ƥǒƥơ ƥƶh! ǁ!ƦĂ Ǖ ƨǒhŧĂ ƱưƒĂ ýŧƮh Ʊ5Ƥjǒ ŧơǒ5Ʈ!ƒ ýdžơk Ǉ35 ƱǴƺưǀjǗƒ ƾǴƱǀj Ǉdž ư ǀƨƒƨơ!ƒ ƱǒǀƪK

Ǵùdžŧ ƱĂƶk Ǖ (Ʊƺư!ƒ ŧǀƱǀjdž) ǀƨƒƨơ!ƒ ƱǒǀƪK ŧǀƱǀjdž Ŏ5 ǀƨƨưkdž!ƒ ŧǀjǴƪƨƤ!ƒ ǇǁĂ . ǀƨƒƨơ!ƒ ƱǒǀƪK ŧǀƱǀjdž ǇƵ

. ƥƮ!ƒ ŧǀƱǀjdž Ŏ5 ǀƨƒƨơ!ƒ ƱǒǀƪK ŧ!Ǵơ Ŏ5 ýǴơ!ƒ ǋǒǀƵ ǇǴŧ

ƨƛdùk! ǁù!ƦĂ ƥƮù!ƒ ŧǀƱǀjdž Ŏ5 ǀƨƒƨơ!ƒ ƱǒǀƪK ƥǀƵ ƱưƒĂ Ăơǀj Ĭ ǀƵ ƾǀƮkǀ! ŧhhƪdž!ƒ ýdžơ!ƒ ŧdžǒƥ Ʊ5Ƥjk -3

. ŧǀjǴƪƨƤ!! ƥƮ!ƒ ŧdžĂǴǀdž!

References

ƥơƑƮǄǁƹ

1-Hand , F.R. , David , A. Recknold and William , C . S. , "Nonlinear layered analysis of RC plate and shells " , Journal of The Structural division , ASCE . , Vol . 99 , No. S . 7 , July 1973 , P. 1791

2-Spea , P .R. S . and Kemp , K . O . , " Shear deformation in elastic homogeneous and sandwich plates ,Pro . Inst . Civ . Engrs . , Part .2 Vol . 61 , Dec . 1976 , P . 697 .

3-ƥdžơ Ǖ ƥhƵ ŧơdžŧ!ƒ ǄǒŧĂ ƥǀơ ǕǀJƪơ Ǉ ƪơdž ƥdžơdž ". ƨǒƛdk ǀjǒƤƪk!ƒ ǇǀƵǀjdžǴĂƳ ǀjǴƪƨƤ!ƒ ǀƵ Ĭ " ŧǀhơ ǄƥǀdžƥǀƮƨǕ Ĭ ǀƶ!ǀ ƞǀƮùŧǕ

. ǇǒƥƺƒƨŦ!ƒ ŧƪƥǀjNj

4-Khan , M. R. and Royles, R., " Post heat exposure behavior of RC beam " , Magazine of concrete research , Vol. 38 , No . 135 , June 1986 , P.5

5-Huang , Z. , Burgess , L. W. and Plank , R. J. , " Nonlinear analysis of RC. Slabs subjected to fire " , ACI Structural Jour. Vol . 96 , No. 1 July 1999

6-Homles , M. , Anchore , R. D., Cook , G. M. E. and Grook , R. N. ," The effect of elevated temperatureon the strength properties of reinforcing and prestressing steel " , The Jour. of The Institution of Structural Engineers , Vol. 60 B , No. 1 , March 1982 , p . 7

-7 ǑǀjǴNj ƥdžơdž Ǒdžnj5 . Ă ƥdžơdž ƥǴhƪ Ǆƪ ǀDƶƥ . " ŧdžĂǴǀdž Ă ƮƨƨƸ ŧǀjǴƪƨƤ!ƒ ŧơǀƪdž!ƒŧdžƨưŧ !ǀơƨƒƨơ!ƒ ŧ!Ǵƶ!ƒ "

ǕƞǀŧǕ ŧǀǀjnj!ƥǀ ŧǀĂǀǀj ŧk!ƒ ǀǀǴƞǀǀjƒ Ǖ ƥƥƶ!ƒ 19 Ǖ ƒ 81

-8 ǑǀjǴNj ƥdžơdž Ǒdžnj5 Ă ƥdžơdžD ƘǒƒƥNj ƥdžơdž Ǖ " ƪǀǀĂǁ ǁǀǀǘƱǴƘ ŧǒjǴƪƨƤ!ƒ ŧơǀƪdž!ƒ ŧưƨdžƒ للحرارة العالية " ،
مجلة المهندس ، العدد 125 ä ، أذار 1996 ، ص 5

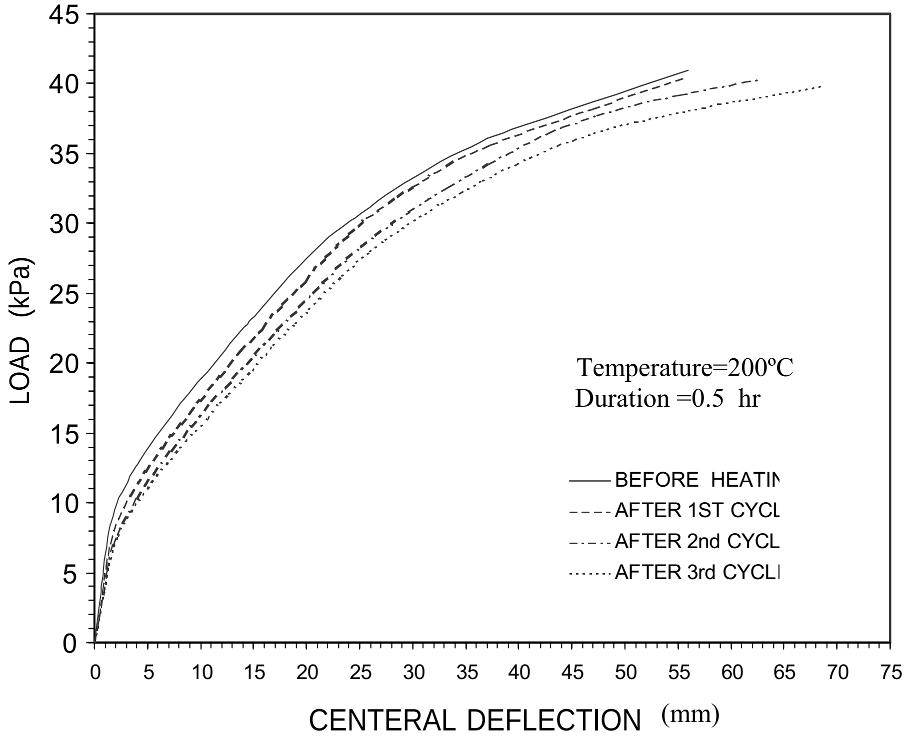
9-Mäkeläinen , P. , Outinun , J. and Kesti , J. ," Fire design model for structural steel S420 M based onTransient–State tensile test result " , Journal of constructional steel , Vol . 48 , No . 1 , Oct . 1998 , P . 47

10- Liu, T.C.Y. , Nilson , G.W. and Slate , F.O. , " Biaxial stress – strain relation for concrete " , ASCE . Journal of structural division , Vol . 98 , No. ST5 , May , 1972 , P. 1025

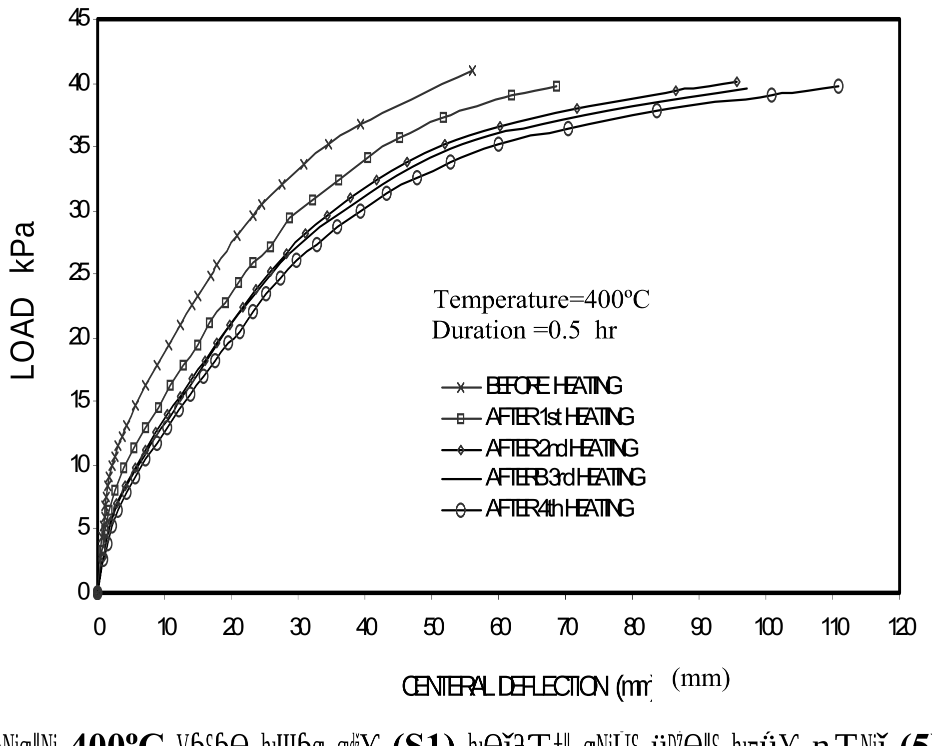
11- Vcchio , F. J. and Collins , M.P. , " The modified compression – field theory of rei - nforced concrete element subjected to shear " , ACI . Jour. Proc. , Vol . 83 , No. 2 ,March – April , 1986 .

12- Abrishami , H. R. and Denis , M. , " Influence of splitting cracks on tension stiffening " , ACI . Structural Journal .Vol . 93 , No. 6 , Nov . – Dec. 1996 .

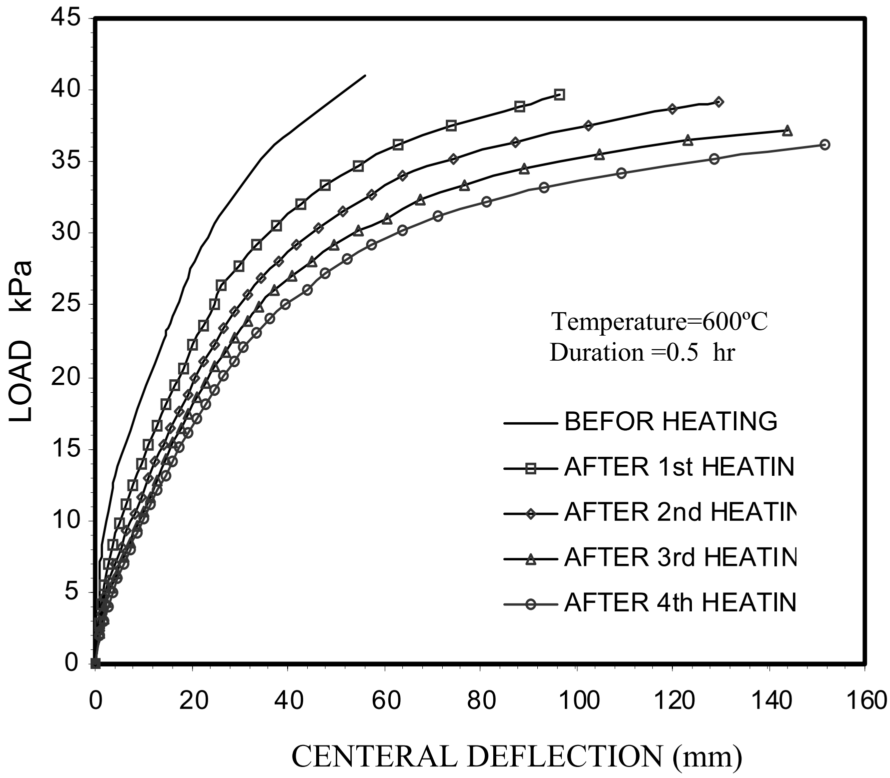
13- Lin , T.D. , Zwiers, R.I., Shirley , S.T. and Burg , R.G. ," Fire test of concrete slab reinforced with Epoxy- coated bars " , ACI . Structural Journal , Vol. 86 , No. 2 March – April 1989 , P . 156 .



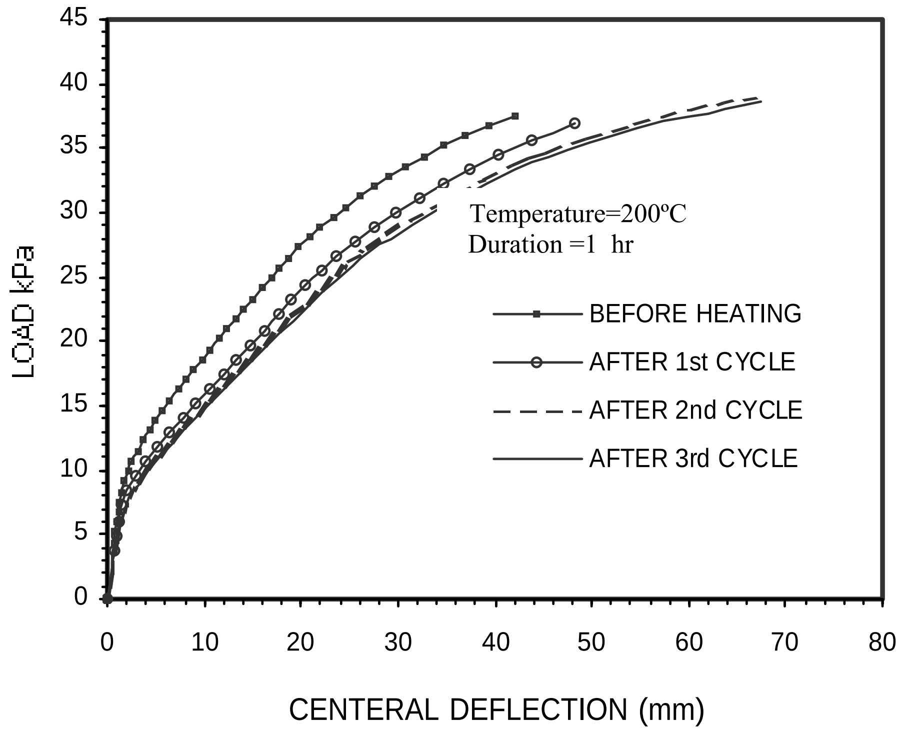
ץםץ ﻻ ξϸǸןןǸן **200ºC** ץϸξϸθ ƖШϸם םǘץ **(S1)** ƖθĭƧƬǂ םǸǗξ - üĎĞθǁξ ƖυƽǘƔ ƞƮǸĭ **(4)** üǀƪǁξ
. םƪǁξ ƼƒƯǘ ĎĎĞƮ ĎĭĨםƨǂξ ĎĎĞ



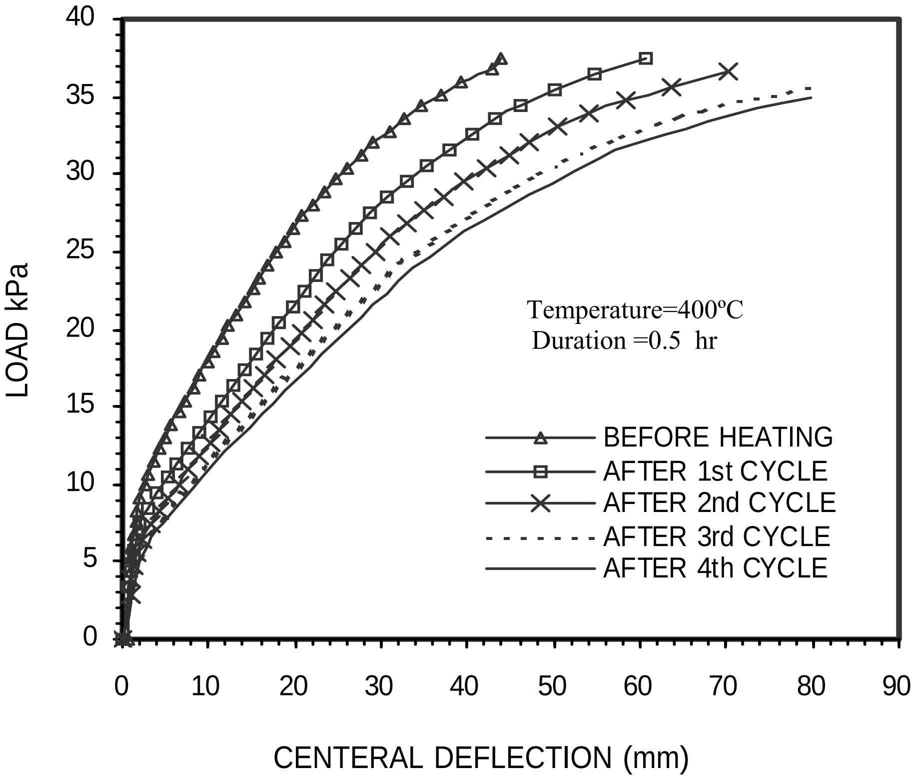
ץםץ ﻻ ξϸǸןןǸן **400ºC** ץϸξϸθ ƖШϸם םǘץ **(S1)** ƖθĭƧƬǂ םǸǗξ üĎĞθǁξ ƖυƽǘƔ ƞƮǸĭ **(5)** üǀƪǁξ
םƪǁξ ƼƒƯǘ ĎĎĞƮ ĎĭĨםƨǂξ ĎĎĞ



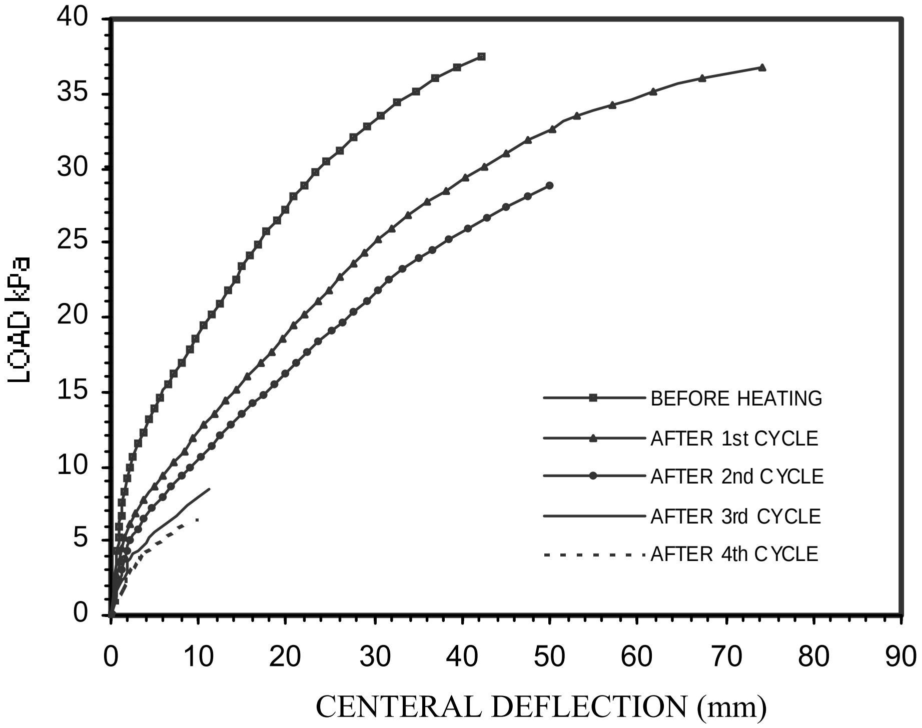
l ɛþǸǰǭ Ɣǭyǁǹǰ **600ºC** ƔþɛþΘ ƕШþǭ ǭǳƳ **(S1)** ƕΘǏƻƬǂ ǭǸǓɛ üǅΘǁɛ ƕƽǘƳ ηƮǸǐ **(6)**ü l ƪǁɛ
ǛƑƸƮǳǓɛ ƼƑƯǳ ǅǅƮ ǅǐǖƨǂɛ ǅǅ



ǅǅ l ɛþǸǰǭ Ɣǭyǁǹǰ **200ºC** ƔþɛþΘ ƕШþǭ ǭǳƳ **(S1)** ƕΘǏƻƬǂ ǭǸǓǫ üǅΘǁɛ ƕƽǘƳ ηƮǸǐ **(7)**ü l ƪǁɛ
ǛƑƸƮǳǓɛ ƼƑƯǳ ǅǅƮ ǅǐǖƨǂɛ



ƔơƳ ǀ ƐƥǊơǁǊ **400ºC** ƔƥƐƥƟ ƕƜƥơ ơǆƳ **(S1)** ƕƟǏƸƬǂ ơǊǙƐ ǖǄƟǁƐ ƕƽǕƳ ƞƬǊǏ **(8)**ǖǀ ƪǁƐ
. ƯƒƩƬǆǙƐ ƼƒƯǆ ǄǆǄƬ ǄǏơǀƨǂƐ ǄǆǄ



ǀƥƵ ƘƒƧǍƥǃǍ **600ºC** ǀƧƒƧơ ƗƞƧƥ ƥǈƵ **(S1)** ƗơǏƽƬǃ ƥǍǕƊ ǉǆơǃƒ ƗƿǕƵ ƠƯǍǒ **(9)**ǉǂƬǃƒ
ƱƓƺƯǈǕƒ ƾƓƱǈ ǇǆƯ ǇǒƤƪǃƒ ǇǆƵ