

( / ) - :

:

-

*saker@yahoo.com*

( )

-

۳

(deflection)

:

-

.

-

(Service loads)

(Long-Term deflection)

( )

[ ]

( )

(Short- Term Deflection)

$\epsilon$  ...

Creep )

(and Shrinkage

[ ]

[ ]

[ ]

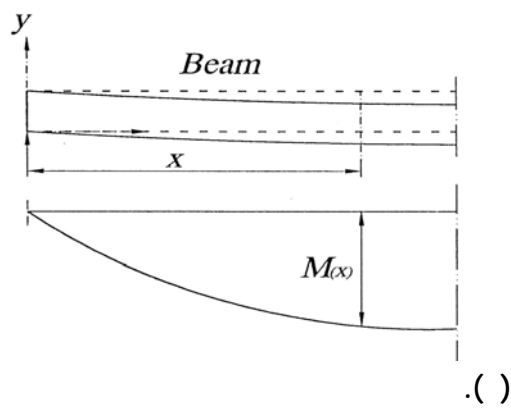
**(Short-Term Deflection)**

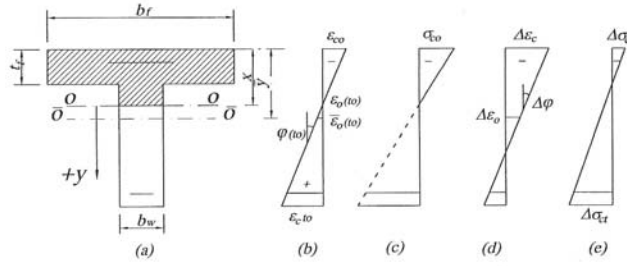
-

T

( ) M ( )

. ( )





( ) : ( )  
 . (t<sub>0</sub>) ( ) ( )  
 . (t, t<sub>0</sub>) ( ) ( )

:(M) (Curvature)

( ) 
$$\varphi = \frac{1}{\rho} = \frac{d^2 y}{dx^2} = \frac{M}{EI}$$

: ( )

( ) 
$$f = y = \iint \varphi_x dx$$

:

.( ) (x) ( ) (f) y  
 (t<sub>0</sub>)  $\varphi_x$

:( ) [ ]

( ) 
$$\varphi(t_0) = \frac{M}{E_c(t_0) I_{red}}$$

:

M

t<sub>0</sub>

.(t<sub>0</sub>) E<sub>c</sub>(t<sub>0</sub>)

v

...

O-O

$I_{red}$

. transformed section

( ) ( )

:

( $t_0$ )

( )

$$f(t_0) = \beta_a \frac{ML^2}{E_C(t_0)I_{red}} = \beta_a \cdot \varphi(t_0) \cdot L^2$$

:

L

...

$\beta_a$

$$\beta_a = \frac{5}{48} : ( )$$

.(

$$\beta_a = \frac{1}{4}$$

Bilinear )

:(equation

( )

$$f(t_0) = f_1 + \gamma f_2$$

( ) 
$$f_1 = \beta_a \cdot \frac{M_{cr} \cdot L^2}{E_c \cdot I_g}$$

$$f_2 = \beta_a \cdot \frac{(M - M_{cr}) \cdot L^2}{E_c \cdot I_{cr}}$$

$$f(t_o) = \beta_a \cdot \frac{M \cdot L^2}{E_c \cdot I_g} \text{ for } M \leq M_{cr}$$

( ) 
$$\gamma = \frac{2 + \lambda}{2}$$

$$\lambda = \frac{I_{cr}}{I_g}$$

( ) 
$$M_{cr} = \frac{(0.7 \sqrt{f'_c}) I_g}{y_t} \text{ (where } f'_c \text{ in MPa)}$$

( ) 
$$(\gamma f_2) \quad (f_1) \quad M_{cr}$$

( ) 
$$(1/\gamma) \quad E_c \cdot I_{cr}$$

Al-Zaid, Al-shaikh and )

(BU and BC)

( Abu-Hussein

[ ]

. ( )

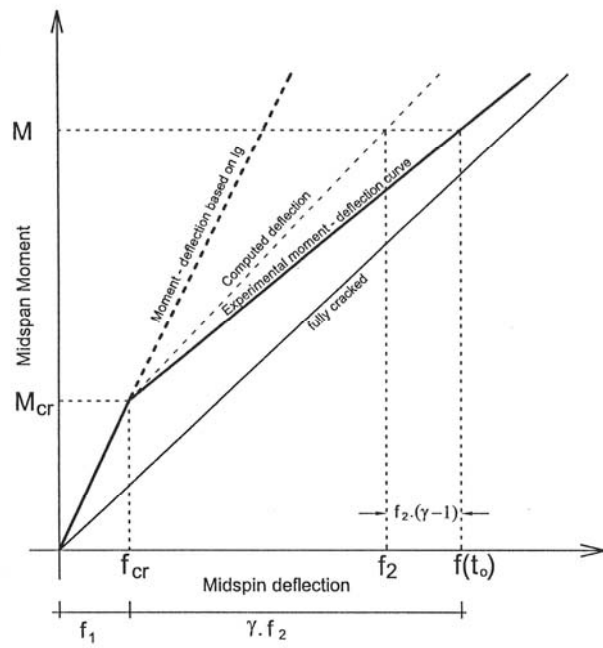
[ ]

[ ]

(CEB-FIP)

(ACI318-95)

. (BC)



. ( )

(Long-Term deflection)

-

$t > t_0$        $t_0$        $t$

( )       $\Delta\phi$

Creep and ( )

(Shrinkage)

$$\phi(t, t_0) = \phi(t, t_0) \phi(t_0) \quad t_0 \quad ( \quad )$$

$$\varepsilon_{sh} \quad \Delta\phi$$

$$\phi(t_0) \quad E_c(t_0)$$

$$) \quad ( \quad ) \bar{E}_c(t, t_0)$$

$$n \quad ($$

$$: [r, \gamma] \quad \bar{n} = E_s / \bar{E}_c(t, t_0)$$

$$( \quad ) \quad \Delta\phi = - \frac{\Delta M}{\bar{E}_c(t, t_0) \bar{I}_{red}}$$

$$. ( \quad )$$

BU					BC				
M/M <sub>cr</sub>	f(t <sub>0</sub> )	f(t <sub>0</sub> )	f(t <sub>0</sub> )	f(t <sub>0</sub> )	M/M <sub>cr</sub>	f(t <sub>0</sub> )	f(t <sub>0</sub> )	f(t <sub>0</sub> )	f(t <sub>0</sub> )
	[ ]	CEB-FIP <sup>[1]</sup>	:	ACI <sup>[1]</sup>		[ ]	CEB-FIP <sup>[1]</sup>	:	ACI <sup>[1]</sup>
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
,	,	,	,	,	,	,	,	,	,
E <sub>c</sub> = 29.6 GPa; M <sub>cr</sub> = 5.2 kN.m I <sub>g</sub> = 140x10 <sup>6</sup> ; I <sub>cr</sub> = 38x10 <sup>6</sup> mm <sup>4</sup> [ ]					E <sub>c</sub> = 29.6 GPa; M <sub>cr</sub> = 5.3 kN.m I <sub>g</sub> = 140x10 <sup>6</sup> ; I <sub>cr</sub> = 38x10 <sup>6</sup> mm <sup>4</sup> [ ]				



Age- ) AAEM  $\bar{E}_c = \bar{E}_c(t, t_o)$   
 .(Adjusted Effective Modulus Method  
 $\Delta M$   
 age-adjusted  $\bar{I}_{red}$   
 $\bar{O}-\bar{O}$  transformed section

$\bar{B}_{red} = 0$

( )  $\Delta M = -\bar{E}_c \left\{ \phi \left[ \bar{B}_c \bar{\epsilon}_o(t_o) + \bar{I}_c \phi(t_o) \right] + \epsilon_{sh} \bar{B}_c \right\}$   
 : [ ] ( ) ( )

( )  $\Delta \phi = \frac{\phi \left[ \bar{B}_c \bar{\epsilon}_o(t_o) + \bar{I}_c \phi(t_o) \right]}{\bar{I}_{red}} + \frac{\epsilon_{sh} \bar{B}_c}{\bar{I}_{red}}$   
 : ( )

( )  $\bar{\epsilon}_o(t_o) = \phi(t_o) (\bar{y} - x)$   
 : ( ) ( )

( )  $\Delta \phi = \frac{\left[ \bar{B}_c (\bar{y} - x) + \bar{I}_c \right] \phi \phi(t_o) + \frac{\bar{B}_c}{\bar{I}_{red}} \epsilon_{sh}}{\bar{I}_{red}}$   
 : ( )

( )  $\Delta \phi = \bar{\omega}_{cr} \phi \phi(t_o) + \bar{\omega}_{sh} \epsilon_{sh}$   
 or  
 $\Delta \phi = \Delta \phi_{cr} + \Delta \phi_{sh}$

( )  $\Delta \phi_{cr} = \bar{\omega}_{cr} \phi(t, t_o) \phi(t_o)$

( )  $\Delta \phi_{sh} = \bar{\omega}_{sh} \epsilon_{sh}$

$t \quad t_0 \quad \varepsilon_{sh}(t, t_0) = \varepsilon_{sh}$

.Free Shrinkage

. Creep Coefficient  $\phi(t, t_0) = \phi$   
 $\bar{I}_c \quad \bar{B}_c$

( )  $\bar{\omega}_{cr} = \frac{\bar{O} - \bar{O}}{\bar{I}_{red} \left( \bar{B}_c (\bar{y} - x) + \bar{I}_c \right)}$

( )  $\bar{\omega}_{sh} = \frac{\bar{B}_c}{\bar{I}_{red}}$

$t_0$

:

( )  $f(t, t_0) = f_{cr}(t, t_0) + f_{sh}(t, t_0)$

:

( )  $f_{cr}(t, t_0) = \bar{\omega}_{cr} \phi(t, t_0) f(t_0)$

( )  $f_{sh}(t, t_0) = \alpha \bar{\omega}_{sh} \varepsilon_{sh} L^2$

:[ ]

$\alpha$  :

, =  $\alpha$  , =  $\alpha$

, =  $\alpha$

. , =  $\alpha$

L

( )

( )

: (t)

( )  $f(t) = f(t_0) + f(t, t_0)$

[ ] ACI318-95

$f(t_0)$

( )

$$\lambda = \frac{\xi}{1 + 50\rho'} = k_r \xi$$

:

$\xi$  :

.( - )

Alternate

[ ]

Procedures

: [ ] Branson

( )

$$f(t, t_0) = f_{cr}(t, t_0) + f_{sh}(t, t_0)$$

:

( )

$$f_{cr}(t, t_0) = k_r \phi(t, t_0) f(t_0)$$

( )

$$f_{sh}(t, t_0) = \alpha k_{sh} \epsilon_{sh} L^2$$

:

$$. ( \quad ) - \alpha$$

-  $k_r$

( )

$$k_r = \frac{0.85}{1 + 50\rho'}$$

: [ ]

: [ ]

$K_{sh}$

( - )

$$k_{sh} = \frac{1}{h} \quad \text{for } (\rho - \rho') > 3\%$$

$$( - ) \quad k_{sh} = 0.7 \frac{(\rho - \rho')^{\frac{1}{3}}}{h} \left( \frac{\rho - \rho'}{\rho} \right)^{\frac{1}{2}} \text{ for } (\rho - \rho') \leq 3\%$$

( t )

(Effective Moment of Inertia)  $I_e$

:( )

$$( ) \quad f(t) = f(t_0) + f(t, t_0)$$

( )

(ACI Committee)

( )

.

-

( )

:T

$$t_f = 100, b_w = 250, b_f = 1450, h = 600\text{mm}, M = 600\text{kN.m},$$

$$[ ] A_s = 40\text{cm}^2, A_s' = 6\text{cm}^2$$

[ ] ( - )

(Step-by-Step)

[ ]

( )

( - )

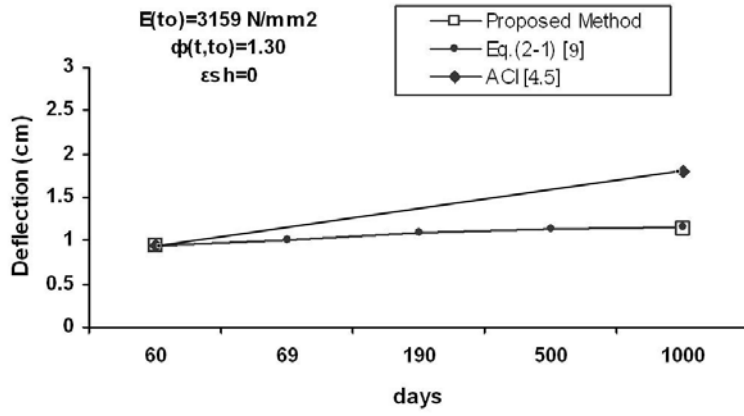
( )

$$f(t=1000 \text{ days})$$

,

.

...



. ( )

$$\bar{\omega}_{sh} \quad \bar{\omega}_{cr} \quad k_{sh} \quad k_r \quad [ \quad ] \quad ( \quad )$$

(  
.) ( )

$$k_r \quad ( \quad ) \quad ( \quad )$$

$$( \rho' )$$

$$\bar{\omega}_{cr}$$

(  $\rho, \rho', \phi(t, t_0)$  and Age - adjusted transformed section ... )

$$\bar{\omega}_{cr}$$

$$k_r$$

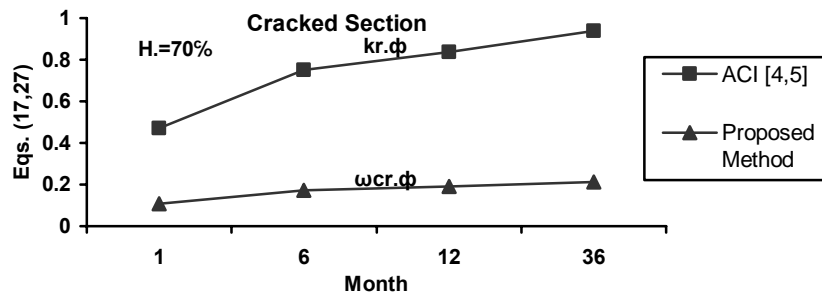
Uncracked

[ ]

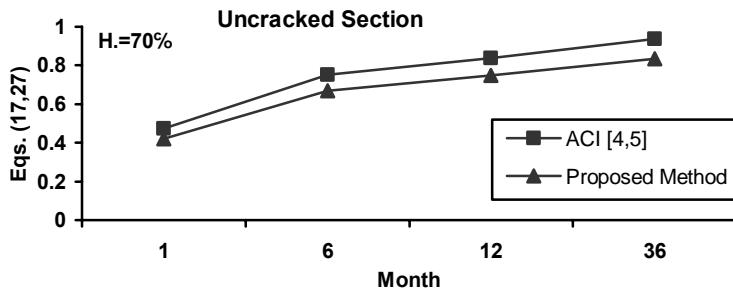
cracked section

section

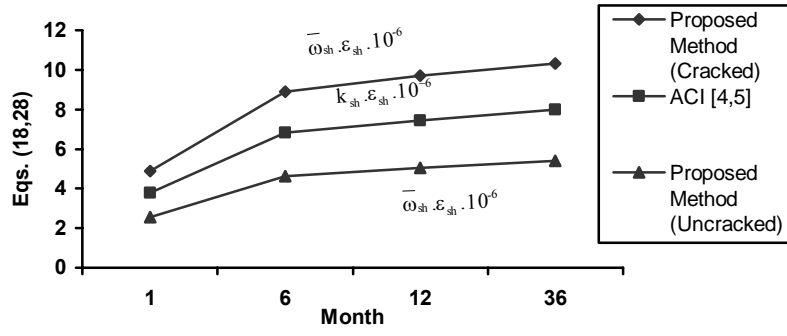
$$k_{sh} = \frac{\bar{\omega}_{sh}}{\bar{\omega}_{sh} + \rho + \rho'}$$



$$-k_r \bar{\omega}_{cr} \quad (.)$$



$$-k_r \bar{\omega}_{cr} \quad (.)$$



$\bar{\omega}_{sh} \quad k_{sh} \quad .( )$

)

(

. ( )

[ ]

4.267m(14ft)

:

(6 ft from supports )

$h = 350.52(13.8in), d = 317.5(12.5in), b = 180.34(7.1in)$

$\rho = 1.42 \% \text{ (deformed steel)} \quad t_0 = 28days$

$M_{max} = 31.761kN.m$

( )

t=360days

$\lambda$

(ACI318 – 95)

(Eq.23)  $\xi$

( )

[ ]

( )

t=360days

( )

Samra and Ghali ) [ ] CEB-FIP

[ ] ACI318-95

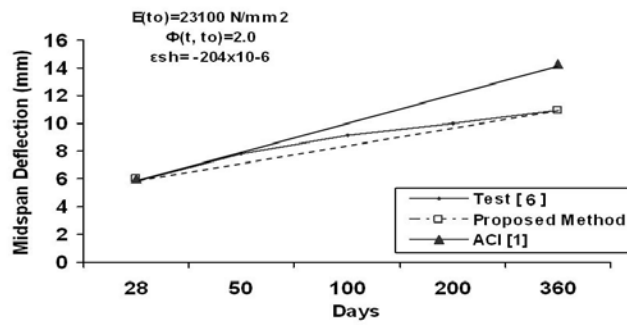
t = 2.5years

( [ ] Azarnejad

[ ] Washa and Fluck

( )

.( )



.( )



$f_c(t_0)$

$f_c(t)$

$f_c(t_0)$								
	$f_c(28)$ , MPa	$\rho$ , Percent	$\dot{\rho}$ , Percent	Measured [ ]	CEP- FIP [ ]	ACI [ ]	Samra [ , ]	( )
A1/4	,	,	,	,	,	,	,	,
A2/5	,	,	,	,	,	,	,	,
A3/6	,	,	,	,	,	,	,	,

$f_c(t, t=t)$

$f_c(t)$

$f_c(t)$								
	$f_c(28)$ , MPa	$\dot{\rho}$	Measured [ ]	Ghali+ Azarnejad [ ]	CEP- FIP[ ]	ACI[ ]	Samra [ , ]	( )
A1/4	,	$\rho$	,	,	,	,	,	,
A2/5	,	(0.5p)	,	,	,	,	,	,
A3/6	,	( )	,	,	,	,	,	,

$f_c(t)$

	CEP-FIP[ ]	ACI[ ]	Samra[ , ]	( )
$f_c(t)$	,	,	,	,
$f_c(t, t=t)$	,	,	,	,

( )

(ACI318-95)

(Deflection)

**ACI Committee 318**, “*Building Code Requirements for Structural Concrete (ACI 318-95) and Commentary (318R-95)*,” American Concrete Institute, Farmington Hills, Mich (1995). [ ]

**Saker, W.**, Change of deflection in the time for multilayer reinforced concrete structures”, *The Roads J.*, **No.5** (1999). [ ]

**Saker, W.**, Time-Dependent Effects in Continuous Composite “Concrete-Concrete” Beams, *J. King Abdulaziz University: Engineering Sciences*, (Under Publication). [ ]

**ACI Committee 209**, *Prediction of creep, shrinkage, and Temperature Effects in concrete structures*, Detroit, ACI (1971). [ ]

**ACI Committee 435**, Proposed revisions By committee 435 to ACI Building code and commentary provisions on Deflections, *ACI. J. Proceedings*, **75**, June (1978). [ ]

**Neville. A.M.** and **Dilger, W.**, *Creep of Concrete : Plain, Reinforced, and* [ ]

*Prestressed*, North-Holland Publishing Company- Amsterdam (1970).

- Washa, G.W.** and **Fluck, P.G.**, Effect of Compressive Reinforcement on the Plastic Flow of Reinforced Concrete Beams”, *ACI Structural Journal*, **49**(2): 1952. [ ]
- Al-zaid, R.Z.**, **Al-shaikh, A.H.** and **Abu-hussein, M.**, Effect of Loading Type on the Effective Moment of Inertia of Reinforced Concrete Beams, *ACI Structural Journal*, **88**(2), Mar.-Apr. (1991). [ ]
- CEB-FIP Model Code 1990, *Model Code for Concrete Structures (MC-90)*, **CEB**, Thomas Telford, London (1993). [ ]
- Dan E. Branson**, Instantaneous and Time-dependent deflections of simple and continuous reinforced concrete beams, *HPR Publication 7*, Part 1 , Alabama Highway Dept., Bureau of Public roads, Ala., Aug. (1963). [ ]
- Dan E. Branson**, Compression Steel Effect on Long-Time Deflection”, *ACI Journal*, **68**(Aug.): 1971. [1 ]
- Gilbert, R.I.**, Deflection Calculation for Reinforced Concrete Structure –Why Sometimes Get it Wrong, *ACI Structural Journal*, **96**(6) Nov.-Dec. (1999). [ ]
- Samra, R.M.**, Predicting Deflections of Reinforced Concrete Beams Analytically, *Journal of Structural Engineering*, **115**(5): 1989. [ ]
- [14] **Ghali, A.** and **Azarnejad, A.**, Deflection Prediction of Members of Any Concrete Strength, *ACI Structural Journal*, **96**(5) Sept.-Oct. (1999). [ ]
- Samra, R.M.**, Renewed Assessment of Creep and Shrinkage Effects in Reinforced Concrete Beams, *ACI Structural Journal*, **94**(6) Nov.-Dec. (1997). [ ]

( )

Stress-Strain Relation of Concrete

0.4  $f_{cm}(t_0)$

: [ ]  $t_0$

( - )

$$\epsilon_c(t, t_0) = \frac{\sigma_c(t_0)}{E_c} \phi(t, t_0)$$

:

$\phi(t, t_0)$

.  $t_0$

t

$E_c$

Principle of

.Superposition

: [ ]

$$( - ) \quad \epsilon_c(t) = \sigma_c(t_0) J(t, t_0) + \int_{t_0}^t J(t, \tau) \frac{\partial \sigma_c(\tau)}{\partial \tau} d\tau + \epsilon_{sh}(t)$$

(age- adjusted effective modulus method)

: [ ]

$$( - ) \quad \epsilon_c(t) = \frac{\sigma_c(t_0)}{E_{c,ef}(t, t_0)} + \frac{\sigma_c(t) - \sigma_c(t_0)}{E_c(t, t_0)} + \epsilon_{sh}(t)$$

Free) t  $t_0$

$\epsilon_{sh}(t)$

.(shrinkage

. creep function

$J(t, t_0)$

:

$E_{c,ef}(t, t_0)$

$$( - ) \quad E_{c,ef}(t, t_o) = \frac{1}{J(t, t_o)} = \frac{E_c(t_o)}{1 + \left( \frac{E_c(t_o)}{E_c} \right) \phi(t, t_o)}$$

age- adjusted effective modulus )

$$\bar{E}_c(t, t_o)$$

:( method

$$( - ) \quad \bar{E}_c(t, t_o) = \frac{E_c(t_o)}{1 + \chi(t, t_o) \left( \frac{E_c(t_o)}{E_c} \right) \phi(t, t_o)}$$

$$\cdot t_o \quad E_c(t_o)$$

aging coefficient  $\chi$

, - ,

· ,

## **Time Effects on Deflection of Reinforced Concrete Beams. Does the Code Reflect this Effect Precisely?**

**Wael Mounir Saker**

*Studies Branch, P.O.Box.12760, Damascus, Syria.*

*w\_saker@yahoo.com*

*Abstract.* The aim of this work is to demonstrate the effects of creep and shrinkage on long-term deflection of reinforced concrete beams, and provide a practical equation for the calculation of deflection in reinforced concrete structures based on linear creep theory. To this end, the simplified equations used in the ACI code and in other methods are evaluated and compared.

The proposed method is found simple to use, can be programmed on small calculators, and agree well with experimental results. It is concluded that the proposed equations are suitable for adoption in practice.