DEFLECTION

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Can he pass through the river without getting wet on his foot ?

DEFLECTION is a SERVICEABILITY CONCERN

GENERAL

Before 60's

* Concrete with f_c' approximately 10.5 - 21 MPa, and reinforcement with f_y 230 - 280 MPa were predominant. The use of these materials with conservative allowable stress, along with the straightline working stress method, resulted in **large stiff sections having small deflection**.
* Ordinary reinforced concrete design involved **little concern for deflections**.

Today

* The common use of 400 MPa yield strength steel and of concrete with fc' 20 - 63 MPa permits **smaller sections** than those resulting from the use of lower strength.
* The permissible deflection is governed by the **serviceability requirement**.

* Both the **short-time** (instantaneous or immediate) and the **long-time** effects must be considered in deflection consideration.

$$\Delta_{total} = \Delta_{(i)} + \Delta_{(cs)}$$

Where :

Δ_{total} = total deflection

$\Delta_{(i)}$ = immediate (short-time) deflection

$\Delta_{(cs)}$ = deflection due to creep and shrinkage (= long-time deflection)

* The acceptable deflection depends on :
  - the type of building (warehouse, school, factory, residence, etc.)
  - the presence of plastered ceilings
  - the type and arrangement of partitions
  - the sensitivity of equipment to deflection
  - the magnitude and duration of live load.

* The general concepts dealt with in this topics are applicable to both **one-way** (beams and slabs) and **two-way** systems.

DEFLECTION CONTROL METHOD

For One-Way Structures :

A. MINIMUM DEPTH (h_{min})

B. CONTROLED BY ALLOWABLE DEFLECTION

For Two-Way Structures :

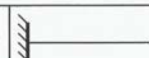
A. MINIMUM DEPTH (h_{min})

MINIMUM DEPTH

1. ONE-WAY STRUCTURES

The minimum depth (h_{min}) of one-way structures is defined as :

SNI Table 3.2.5(a)

								
f_y	400	240	400	240	400	240	400	240
Slab	L/20	L/27	L/24	L/32	L/28	L/37	L10	L/13
Beam	L16	L/21	L/18.5	L/24.5	L/21	L/28	L/8	L/11

Go to example

For those structures whose depth greater than the above requirement, its deflection were not to be check.

MINIMUM DEPTH - Cont'd.

2. TWO-WAY STRUCTURES

The minimum depth (h_{min}) of slab **without interior beam** :

SNI 3.2.5 (c)

Yield stress f_y (MPa)	Without Drop Panel			With Drop Panel		
	Exterior Panel		Interior Panel	Exterior Panel		Interior Panel
	Exterior Beam			Exterior Beam		
	Yes	No		Yes	No	
300	L/33	L/36	L/36	L/36	L/36	L/40
400	L/30	L/33	L/33	L/33	L/36	L/36

2. TWO-WAY STRUCTURES - Cont'd.

The minimum depth (h_{min}) of slab **with interior beam** :

$$h_{min} = \frac{L_n \left(0.8 + \frac{f_y}{1500} \right)}{36 + 5\beta \left[\alpha_m - 0.12 \left(1 + \frac{1}{\beta} \right) \right]} \quad \text{.... SNI 3.2.3.(3)}$$

But may not be smaller than :

$$h = \frac{L_n \left(0.8 + \frac{f_y}{1500} \right)}{36 + 9\beta}$$

And need not to be greater than :

$$h = \frac{L_n \left(0.8 + \frac{f_y}{1500} \right)}{36}$$

In all cases, the minimum depth of slab may not less than :

- 120 mm for $\alpha_m < 2.0$
- 90 mm for $\alpha_m \geq 2.0$

$$\alpha = \frac{E_{cb}}{E_{cs}} \left(\frac{b_w}{L} \right) \left(\frac{h}{h_f} \right)^3 f$$

Where :

α = relative stiffness ratio of beam and slab

α_m = average of α

f = constant from Graphic 2.6 or 2.7

SHORT-TIME (INSTANTANEOUS) DEFLECTIONS

$$\Delta_{(i)} = K \frac{5}{48} \frac{M L^2}{E_c I_e}$$

Where :

Δ_i = instantaneous/ immediately deflections

L = span length

K = coefficient based on load and support condition

I_e = effective moment of inertia

E_c = modulus of elasticity of concrete

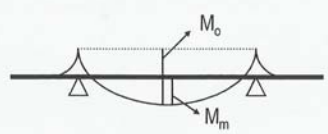
= $4700 \sqrt{f_c'}$ MPa

COEFFICIENT K

2.0

1.0

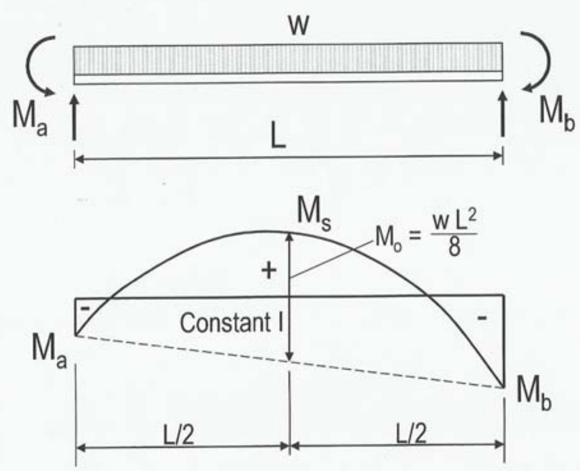
0.6



$$1.2 - 0.2 \frac{M_o}{M_m}$$

0.8 midspan
0.74 max

DEFLECTION FOR ELASTIC SECTIONS



$$\Delta_{max} = \beta_a \frac{M L^2}{E I_c}$$

Where :

Δ_{max} = maximum deflection in an elastic member

M = bending moment

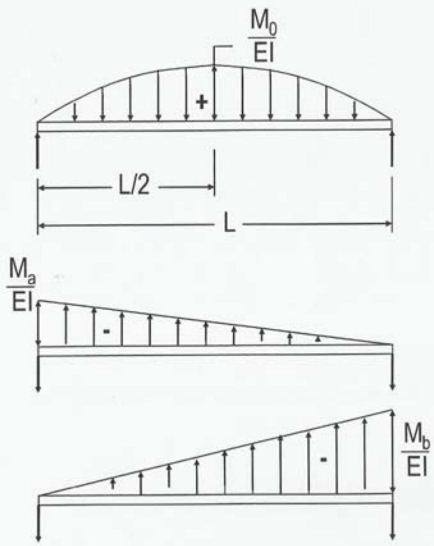
L = span length

E = modulus of elasticity

I_c = moment of inertia of section

β_a = a coefficient that depends on the degree of fixity at supports, the variation in moment of inertia along the span, and the distribution of loading.

Component conjugate beams



The total midspan deflections, Δ_m is :

Due to uniform load : $\Delta_s = \dfrac{5 M_0 L^2}{48 EI}$

Due to left/right end moment :

$$\Delta_a = \Delta_b = \frac{- M_{(a \text{ or } b)} L^2}{16 EI}$$

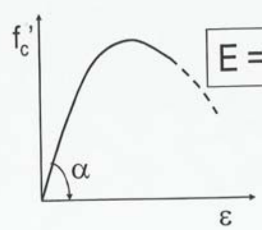
$$\Delta_m = \Delta_s + \Delta_a + \Delta_b$$

$$= \frac{L^2}{48 EI} [5M_0 - 3 (M_a + M_b)]$$

and, $M_s = M_0 - ½ (M_a + M_b)$,

then : $$\Delta_m = \frac{5 L^2}{48 EI} \left(M_s - \frac{1}{10} (M_a + M_b) \right)$$

MODULUS OF ELASTICITY



$E = tg\ \alpha$

* For homogeneous material :
  E in tension $\approx$ E in compression

* In a reinforced concrete :
  - **Creep** affects the E in compression zone
  - **Crack** affects the E in tension zone

* In both tension and compression zone, E varies not only with the magnitude of stress from top to bottom at a section but also along the span.

* Further, creep and shrinkage over a period of time effectively reduce E and will generally **magnify deflections** by a factor of two or three.