Research Article

CALCULATION OF SHORT-TERM DEFLECTION FOR FIXED SUPPORTED TWO-WAY RC SLABS

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ABSTRACT

In limit state design method the serviceability criteria are important because thickness depends on it. The economy of design depends upon the thickness of slab. Hence deflection control, directly effects economical design of RC slabs. At present, in different relevant codes clauses are there to control deflection. IS 456-2000 also deal with estimation of short-term and long-term deflections in RC members in general, but there is no particular formula for estimation of short-term and long-term deflections in fixed supported two-way RC slab in particular. This paper reviews the methods for estimation of deflections in RC members, suggested by IS 456, and reviews the literature pertaining the same, highlighting need of revision in the codal provisions. The paper gives rational approach for estimating of short-term deflection in fixed supported two-way RC slabs. The method considers load on the slabs as obtained by Rankin- Grashoffs' methods. The deflection calculated in this way is found to be more accurate as compared to other available methods. The results obtained have been found to be comparable with experimental results available in the literature. The method has been designated as equivalent load method and found to be more realistic for calculating short term deflection for fixed supported two way RC slabs.

KEYWORDS: Short-term deflection, Two-way RC slab, Equivalent load, Codal provisions.

INTRODUCTION

The deflections calculations in RC slabs are difficult due to the non-homogeneity of the material, the effects of cracking, and the time-dependent nature of material response. In order to minimize the adverse effects of deflections, different codes of practice specify the deflections limits in RC slabs. In the various building codes such as IS 456, ACI 318, AS 3600, BS 8110, EC 2, etc., gives the method to calculate the deflections of RC beams and one way slab, but that the calculated values lie within permissible limits specified by codes. The type of slab and support conditions plays important role in serviceability requirement of the slab i.e. deflection. The serviceability criterion for both the slabs is same. But for same loading and span, deflection is more for one way slab. Deflection of one way slab can be calculated using the formulae available in different codes. But no direct formula is given in any of the code for calculating deflections of two way slabs. Moreover the formula given in IS 456 does not specify the span and the loading to be considered for calculating deflections in two way slab. The work reviews the procedures for estimation of short-term deflections in fixed supported two-way RC slabs.

LITERATURE REVIEW

Varma and Pendharkar (2010) presented a rational approach for estimating short-term deflection in two-way RC slabs. The approach has been designated as Equivalent Load Method. The deflections calculated by this approach are found to be more accurate as compared to those calculated by the other available methods. Also the results obtained from Equivalent Load Method have been found to be comparable with experimental results. Sarkar P.G. (2008) had also studied the different codal provisions and they calculate the values of deflection for two-way RC slabs using IS 456-2000. They had also shown that the code provisions are not adequate to estimate deflection of two-way RC slabs and that there is an urgent need to modify to these provisions. Kollar L.P. (2004) had given the new simple method for deflection calculation of one-way RC slabs, rectangular beams etc. but the method is not applicable for two-way slabs.

Indian Standards Provision (IS 456-2000):

The IS 456-2000 gives the specification for calculating total deflection of RC members as the sum of short-term deflection and long-term deflation in general. The total deflection shall be taken as the sum of the short-term deflection determined in accordance with Eqn. 1 and long-term deflection, in accordance with. Eqn. 2 and Eqn. 3.

1 Short-term deflection

The short-term deflection may be calculated by the usual methods for elastic deflection using the short-term modulus of elasticity of concrete, E_c and an effective moment of inertia I_{eff} give by the following equation:

$$I_{eff} = \frac{I_r}{1.2 - \frac{M_r}{M}\frac{z}{d}\left(1 - \frac{x}{d}\right)\frac{b_w}{b}} \text{; but} \qquad (1)$$

Where,

I_r = Moment of inertia of the gross section, M_r = cracking moment, equal to $\frac{f_{cr} \times I_{gr}}{y_t}$ where f_{cr} is the modulus of rupture of concrete, I_{gr} is the moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and y_t is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fiber in tension, M = Maximum moment under service load, z = Lever arm, x = Depth of neutral axis, d = Effective depth, b_w = breadth of web, and b = Breath of compression face.

For continuous beam, deflection shall be calculated using the values of I_r, I_{gr} and M_r modified by the following equation:

$$X_e = k_1\left[\frac{X_1 + X_2}{2}\right] + (1 - k_1)X_o \qquad (2)$$

Where Xe = Modified value of X, X_1, X_2 = Values of X at supports, X_o = Value of X at mid span, k_1 =

Coefficient given in table 1, and X = Value of I_r, I_{gr} or M_r as appropriate.

Note – k_2 is given by

$$k_2 = \frac{M_1 + M_2}{M_{F1} + M_{F2}} \quad (3)$$

where M_1, M_2 = Support moments, and M_{F1}, M_{F2} = Fifed end moments.

Table 1 Values of Coefficient, k_1

k_2	0.5or less	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
k_1	0	0.03	0.08	0.16	0.30	0.50	0.73	0.91	0.978	1.0

2 Deflection due to shrinkage

The deflection due to shrinkage a_{cs} may be computed from the following equation:

$$a_{cs} = k_3 \, \Psi_{cs} l^2 \quad (4)$$

Where k_3 is a constant depending upon the support conditions, 0.5 for cantilevers, 0.125 for simply supported members, 0.086 for members continuous at one end and 0.063 for fully continuous members.

Ψ_{cs} is shrinkage curvature equal to

$$k_4 \frac{\varepsilon_{cs}}{D} \quad (5)$$

Where ε_{cs} is the ultimate shrinkage strain of concrete

$$k_4 = 0.7 \times \frac{p_t - p_c}{\sqrt{p_t}} \leq 1.0 \, for \, 0.25 \leq p_t - p_c < 1.0 \quad (6)$$

$$= 0.65 \times \frac{p_t - p_c}{\sqrt{p_t}} \leq 1.0 \, for \, p_t - p_c \geq 1.0 \quad (7)$$

Where,

$$P_t = \frac{100 A_{st}}{bd} \text{ and } Pc = \frac{100 A_{sc}}{bd} \quad (8)$$

and D is the total depth of the section, and l is the length of span.

3 Deflection due to creep

The creep deflection due to permanent loads $a_{cc(perm.)}$ may be obtained from the following equation:

$$a_{cc(perm.)} = a_{i,cc(perm.)} - a_{i(perm)} \quad (9)$$

Where, $a_{i,cc(perm.)}$ = Initial plus creep deflection due to permanent loads obtained using an elastic analysis with an effective modulus of elasticity,

$$Ece = \frac{E_c}{1+\theta}; \quad (10)$$

θ being the creep coefficient, and $a_{i(perm)}$ = short-term deflection due to permanent load using E_c.

PROPOSED METHOD: EQUIVALENT LOAD METHOD.

Is 456-2000 has given formulae for calculating deflection in RC slabs. Pradip Sarkar, et. al. (15) had revised the various methods and compares the results with codal provisions. They had specified that the use of formulae available in IS 456-2000 for calculating deflection in RC two-way slabs results in prediction of higher deflection than actual. In the following section IS code method has been used for calculating deflection in RC two-way slabs and three different cases have been considered. In CASE-I, Total load has been considered to be acting along longer span, in CASE-II, Total load has been considered to be acting along shorter span and finally in CASE-III, equivalent loads consider to be acting along longer and shorter span simultaneously. The deflection calculation with equivalent load on shorter span has been categories as CASE-III A and similarly deflection calculation with equivalent load on longer span has been designated as CASE-III B. This load in which equivalent loads have been considered and deflections have been calculated using IS codal formulae is designated as Equivalent Load Method. The equivalent loads along the two spans have been calculated using Grashoff-Ranhine method. The loads calculated along shorter span and along longer span are given by following equations

$$w_x = \frac{w}{1 + \left(\frac{l_x}{l_y}\right)^4}$$

$$w_y = \frac{w}{1 + \left(\frac{l_y}{l_x}\right)^4}$$

The three cases have been illustrated for fixed supported two-way RC slab, the CASE-III has been found be more near to practical values. The third case is designated as Equivalent Load Method for calculating the deflection in two-way RC slabs.

Example 1

Unyielding fixed supported slab of overall size 2314 mm × 2314 mm × 63.5 mm. On this slab I calculate the deflation for deferent load as 20 KN/m^2, 40 KN/m^2, 60 KN/m^2, 80 KN/m^2, and 100 KN/m^2**.**

1 CASE-I Total load along longer span

Deflection formula for simply supported and for UDL. Eqn. 13

$$\partial_{x1} = \frac{1}{384} \frac{w l_x^4}{EI_{eff}}$$

Where,

w = Uniform distributed load, l_x = longer span, E_c= Modulus of elasticity of concrete, and defined by

$E_c = 5000\sqrt{f_{ck}}$ As per IS 456-2000,

I_{eff} = Effective moment of inertia as per Eqn. 1.

2 CASE-II Total load along shorter span

Deflection formula for simply supported and for UDL. Eqn. 14

$$\partial_{y1} = \frac{1}{384} \frac{w l_y^4}{EI_{eff}}$$

3 CASE-III-A Equivalent load along longer span

Deflection formula for simply supported and for UDL. Eqn. 15

$$\partial_{x2} = \frac{1}{384} \frac{w_x l_x^4}{EI_{eff}}$$

Where,

w_x = Equivalent Uniform distributed load, As per Eqn. 11

4 CASE-III-B Equivalent load along shorter span

Deflection formula for simply supported and for UDL. Eqn. 16

$$\partial_{y2} = \frac{1}{384} \frac{w_y l_y^4}{EI_{eff}}$$

Where,

W_y = Equivalent Uniform distributed load, As per Eqn. 12

The results for the example for the three cases have been tabulated in Table 2. The test results available for example and hence the example have been considered Table 2 shows the deflection for different load intensities on two-way simply supported RC slabs for three cases and corresponding test results. The load intensities considered for all the three cases in example are 15 KN/m^2, 30 KN/m^2, 45 KN/m^2, and 60 KN/m^2. The table 3 shows the percentage difference among calculated values of example for three cases at different loads, with test values. The comparison of results of the example for the three cases with test values has been presented in fig. 1

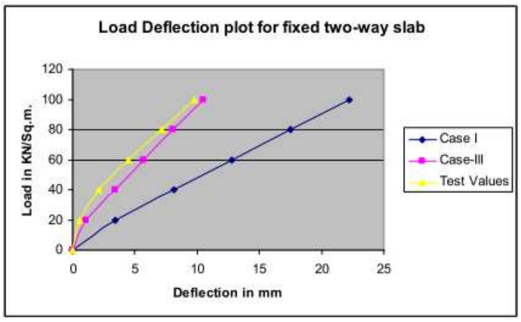
Table No. 2 Deflection for Fixed supported two-way slab

Loading Condition	Loading on slab in KN/m^2				
	20	40	60	80	100
Case-I	3.42mm	8.12mm	12.8mm	17.5mm	22.2mm
Case-III	1.03mm	3.38mm	5.74mm	8.1mm	10.5mm
Test values	0.6 mm	2.1 mm	4.46 mm	7.2 mm	9.77 mm

Table No. 3 Percentage difference of deflection for Fixed supported two-way slab

Sr No	Loading Condition	Percentage difference				
		20 KN/m^2	40 KN/m^2	60 KN/m^2	80 KN/m^2	100 KN/m^2
1.	Case-I	470%	286.7%	186.9%	143.1%	127.23%
2.	Case-III	71%	60.9%	28.7%	12.45%	7.47%

Fig 1. Deflection for two-way Fixed supported RC slab



CONCLUSION

The comparative study shows that there are large differences in the various recommendations to calculate short-term deflection for RC two-way slabs. The deflection calculation procedure based on effective moment of inertia with different load condition for three examples, procedure covered by various codes and experimental results are discussed and compared with each others. The main outcome form present studies are:

1. The deflection calculation results by effective moment of inertia with equivalent load along longer span are nearer to experimental values for all ranges of loading considered.
2. There is wide difference among the experimental values and the recommendations given by various codes for fixed supported slabs.
3. Although all the national and international codes give suggestions for deflection calculation of two-way RC slabs, but overall procedure is not clearly spelt out.

NOMENCLATURE

I_{eff} = Effective moment of inertia
I_g = Gross moment of inertia
E_c = Modulus of elasticity of concrete
f_{ck} = Characteristic strength of concrete
f_{cr} = modulus of rupture of concrete
M_{cr}= Cracking moment per unit width
M_{xx} = Maximum moment in the short span
M = Maximum moment under service load
z = Lever arm
x = Depth of neutral axis
d = Effective depth
b_w = breadth of web
b = Breath of compression face
δ = deflection of the plate/slab
ℓ = longer span length
w = uniform transverse load

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