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Long-Time Deflection Analysis for Reinforced Concrete Floor Slabs under Working Loads

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Abstract

Herein we propose a modification of our previous method for predicting long-time deflections of floor slab systems of reinforced concrete. Improved are earlier *en bloc* treatments of slab stiffness reduced by partial cracking and of time-dependent portion of long-time deflections; respectively by accounting for local details of either crack or steel distribution over a whole member length, and also by introducing the existent concept of increased modular ratio, whereby to replace our prior resort of a single index of time-dependent multiplier.

Compared former test results occasional in the literature with our predictions are shown to refer to relative adequacy of our procedure.

1. Introduction

For the prediction of long-time deflections of reinforced concrete floor slab systems under working loads, while taking account of their immediate and time-dependent movements, we have presented an analytical method[1] in which the distribution of stiffness of a slab panel is only collectively considered on the assumption that it comprises segments of a pair of half column strips and a middle strip both with lengthwise invariable stiffness given in an empirically adjusted, averaged form even when affected by cracking.

At this time to consider stiffness distribution duly variable throughout the panel depending on local aspects of cracking and detail of reinforcement, we make an improved analysis wherein slab stiffness is treated at a difference mesh width strip level. In effect, at the mesh points of each such strip relevant sectional properties are modified as elastic difference analysis is iterated. This results in immediate deflections and, further, associated long-time predictions by using correspondingly modified concrete material properties.

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2. Method

2.1. Governing Equations and their Difference Expressions

Referring to a left hand x-y-z coordinate system, with x and y taken in respective directions of the short and the long edge of a slab and a uniformly distributed load of intensity p applied in the z-direction, the equation of equilibrium of the forces acting at (x, y) is expressed as[3)]

$$\frac{\partial^2 M_x}{\partial x^2} + \frac{\partial^2 M_y}{\partial y^2} + 2\frac{\partial^2 M_{xy}}{\partial x \partial y} + p = 0 \tag{1}$$

where M_x, M_y and M_{xy} are bending moments in x- and y-directions and torsional moment, respectively.

With D_x and D_y slab stiffness in respective x- and y-directions the relations between the above moments and deflection w are given by :

$$M_x = - D_x(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2}) \tag{2}$$

$$M_y = - D_y(\frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2}) \tag{3}$$

$$M_{xy} = -(1-\nu) D_{xy} \frac{\partial^2 w}{\partial x \partial y} \tag{4}$$

where $D_{xy}=\sqrt{D_x D_y}$ and ν=Poisson's ratio.

In case of subdividing a slab panel into equal meshes of widths $\varDelta_x$ and $\varDelta_y (=r\varDelta_x)$ in respective x- and y-directions with the system of numbering each mesh point laid out in Fig. 1, and then choosing $x=x_j$ and $y=y_i$ as coordinates of the origin of the usual finite difference pattern, referring to it difference expressions follow :

$$(\frac{\varDelta^2 M_x}{\varDelta x^2})_{0,0} = \frac{1}{\varDelta x^2}(M_{x0,1} - 2M_{x0,0} + M_{x0,-1}) \tag{5}$$

$$(\frac{\varDelta^2 M_y}{\varDelta y^2})_{0,0} = \frac{1}{r^2 \varDelta x^2}(M_{y1,0} - 2M_{y0,0} + M_{y-1,0}) \tag{6}$$

$$(\frac{\varDelta^2 M_{xy}}{\varDelta x \varDelta y})_{0,0} = \frac{1}{r \varDelta x^2}(M_{xy1/2,1/2} - M_{xy1/2,-1/2} - M_{xy-1/2,1/2} + M_{xy-1/2,-1/2}) \tag{7}$$

$$M_{x0,n} = - \frac{D_{x0,n}}{\varDelta x^2}\ [w_{0,n+1} - 2w_{0,n} + w_{0,n-1} + \nu (w_{1,n} - 2w_{0,n} + w_{-1,n})] \tag{8}$$

$$M_{ym,0} = - \frac{D_{ym,0}}{r^2 \varDelta y^2}\ [w_{m+1,0} - 2w_{m,0} + w_{m-1,0} + \nu (w_{m,1} - 2w_{m,0} + w_{m,-1})] \tag{9}$$

$$M_{xym/2,n/2} = - \frac{(1-\nu)}{4r \varDelta x^2}(D_{xy0,0} + D_{xy0,n} + D_{xym,n} + D_{xym,0})\ (w_{m,n} - w_{m,0} - w_{0,n} + w_{0,0}) \tag{10}$$

provided $m = -1$, 0 or 1 and $n = -1$, 0 or 1.

And from the above the following equation with an unknown of deflection at each mesh point is derived by substitution of Eqs. (8) through (10) into Eqs. (5) through (7) and

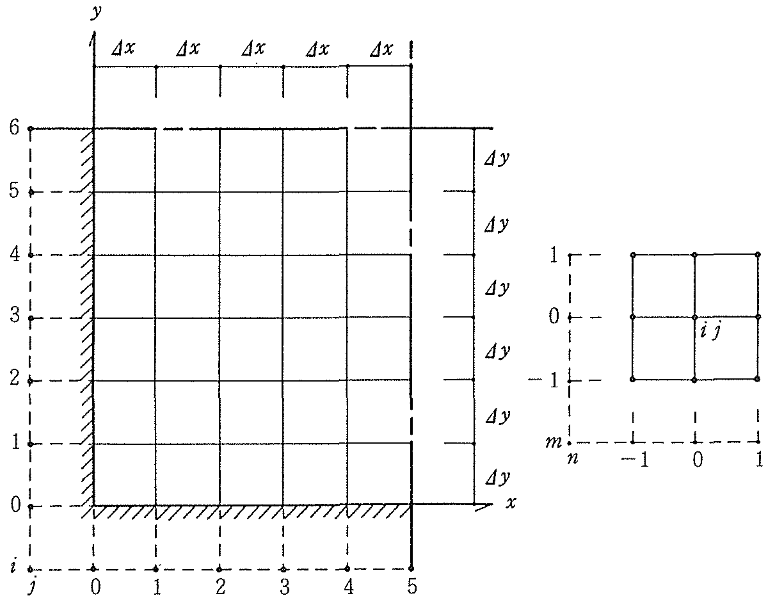

Fig. 1 Adopted Difference Subdivision of a Slab with Coordinate System of Numbering Mesh Points

subsequent summation.

$$\text{Eqs.}(5) + (6) + (7) + p = 0 \tag{11}$$

Because the boundary conditions for a built-in slab are $w = 0$ and $dw/dx = 0$ both for $x = 0$ the deflection at $x = x_{-1}$ becomes $w_{0,-1} = w_{0,1}$ from slope $(w_{0,1} - w_{0,-1})/2\Delta x = 0$; and at $x = 0$ in a simply supported case $w = 0$ and $M_x = 0$ or $d^2w/dx^2 = 0$, so that $w_{0,-1} = -w_{0,1}$ since bending moment $(w_{0,1} - 2w_{0,0} + w_{0,-1})/2\Delta x = 0$; such being the case also in the y-direction.

These operations let us eliminate imaginary exterior mesh points and set up Eq. (11), at each mesh point, using the slab stiffness ratio that is differently assumed depending on whether the considered deflection being of elastic, immediate or time-dependent type ; leading to a simultaneous system of such equations whose solution provides each type of deflection at any above point.

2.2. Effective Slab Stiffness

For a slab strip of one mesh width, relying on Branson's following equation :

$$I_{ex} = (M_{cr}/M_{ax})^4 I_{g0} + [1 - (M_{cr}/M_{ax})^4] I_{cr} \tag{12}$$

Effective stiffness D_{ex} in the x-direction at a mesh point is evaluated by

$$D_{ex} = D(I_{ex}/I_g) \tag{13}$$

provided that corresponding working moment M_{ax} at that point is not less than cracking moment M_{cr} ; with reference ratio of slab stiffness $D = E_c t^3/12(1-\nu^2)$, $E_c =$ elastic modulus of concrete, $t =$ slab thickness ; I_{g0} and I_{cr} = moments of inertia for an uncracked gross concrete section and a cracked transformed section, respectively. Otherwise in the above context the evaluation depends on :

$$D_{gx}=D\,(I_{gx}/I_{g0}) \tag{14}$$

using moment of inertia I_{gx} for the same uncracked slab strip including the effect of reinforcement.

Naturally the same holds in the y-direction, replacing suffix x above by y.

2.3. Effect of Bond-Slip of Reinforcement Anchorage

The angle of rotation, θ, of a slab at its built-in-edges due to the bond-slip, u, of the top steel anchorage may reasonably be estimated by :

$$\theta= u/(1-c)\,d \tag{15}$$

with $c=$ relative depth of neutral axis, here regarded as the center of the above rotation, as part of effective depth of a slab.

Additional deflections of a slab owing to the bond-slip of the anchorage may be regarded as resulting from forcing the above rotation, worked out along the edges in a cracked region at each of its mesh points, back again at them on tentatively assuming the edges to be simply supported.

And the simultaneous equation system then needed is provided by putting $p = 0$ in Eq. (11) and eliminating the terms concerning exterior points, using : $(w_{i,1} - w_{i,-1})\ /\ 2\Delta x = \theta_x$ or $(w_{1,j}-w_{-1,j})\ /\ 2\Delta y= \theta_y$ and $w_{i,-1}= -\ w_{i,1}$ or $w_{-1,j}= -\ w_{1,j}$, respectively in cracked and uncracked regions.

2.4. Effective Concrete Modulus

Adopted currently are the fundamentals of the well-documented increased modular ratio method[4] for our inclusively calculating the long-time deflection, Δ_{i+cp} or $\Delta_{i+cp+sh}$, affected by creep alone or both creep and shrinkage, in lieu of our earlier explicit separation of elastic or immediate and time-dependent portions to add up to the relevant deflection. This approach permits its prediction in a similar way to that of elastic or immediate deflection through an introduced formal elastic modulus of the concrete generally called effective modulus. In the case of including the creep effect alone the effective elastic modulus of the concrete, E_{ct} and n_t are written as follows :

$$E_{ct} = E_c\ /\ (1 + \phi_t) \tag{16}$$

$$n_t = n(1 + \phi_t) \tag{17}$$

where ϕ_t = creep coefficient of the concrete and n = modular ratio of the steel.

In the other case of our considering both effects of creep and shrinkage we will resort to the following equation proposed by Yu and Winter[5] whereby to obtain effective modulus E'_{ct} and modular ratio n_t' and calculate the long-time deflection in the same manner as in the former case.

$$E'_{ct}= E_c/(1+ 0.93\ \alpha\ E_c Y t^{1/3}\ /\ a^{0.4}) \tag{18}$$

$$n'_t = E_s/E'_{ct} \tag{19}$$

where : Y= multiplying factor due to years of duration of loading[6], t = days of duration of loading provided t= constant for t more than a year, a = concrete age in days at the start of loading, α = coefficient we have introduced depending on the slump of concrete at placing[7] and E_s= elastic modulus of reinforcement.

3. Procedure

The following steps are taken in the course of the present deflection analysis :

1) Subdivide a slab panel with a reference stiffness ratio D into equal meshes in the orthogonal directions, calculate elastic deflection $\varDelta_e$ under sustained loads, and therefrom bending moments, under construction loads, whereby to determine effective slab stiffness ratios, D_{ex} and D_{ey} over cracked regions of the panel ;
2) Make deflection analysis of a slab with slab stiffnesses D_{ex} or D_{ey} and D_{gx} or D_{gy} respectively in cracked and the other regions so as to obtain bending moments M_x and M_y under construction loads ;
3) Obtain additional amounts of both deflections and bending moments using slab edge moments provided in step 2), to modify slab stiffness in cracked regions by summing additional moments and either of M_x and M_y worked out in that step ;
4) Iterate steps 2) and 3) until convergence of slab stiffness at each mesh point, thus to attain immediate deflections $\varDelta_i$ and those additional $\varDelta_s$ under long-time sustained loads ;
5) Perform analysis of step 2) using time-dependent values of concrete elastic modulus and steel modular ratio to result in long-time deflections $\varDelta_{i+cp}$ and $\varDelta_{i+cp+sh}$, with D_{ex} and D_{ey} then caused by bending moments under construction loads ; and lastly
6) Calculate total deflections $\varDelta_s + \varDelta_{i+cp+sh}$.

4. Compared Adaptability of Procedure

Intended to be helped by them to examine the adaptability of our method to experimental or practical cases so far reported, comparisons are now attempted of available test and field measurements in the literature with our correspondingly obtained follow-up calculation results. Adopted in this respect are eight cases of long-term test slabs and five examples of damaged field structures.

4.1. Calculation Outlines

In the case of two-way floor slabs, all assumed to be all-edge-built-in, their calculated deflections are added to those of beams or girders supporting them[8], with their span accordingly taken between centers of such supports. Connectedly used is a difference subdivision of their short span into ten parts and mesh forms nearest to squares. For one-way structures, span length are defined within a relatively well-used range depending on the supporting conditions in each case ; and assumed is the same subdivision number as above.

On calculating the long-time deflection, $\varDelta_{i+cp+sh}$, including effects of creep and drying shrinkage, influence coefficient α for effective modulus E'_{ct} is chosen to be 1.25, 0.75 and 1.0 for respective slumps over 15 cm, under 5 cm and otherwise.

For damaged field slabs, construction accuracy is considered in the same calculation, when use is made of in-situ measurements on slab thickness, steel level, steel spacing each in average form. Relatedly chosen is the construction load amount as an alternative to the largest load in the unavailable actual loading history, while one third of the design live load is used as long-time sustained load.

Construction load intensity, taken as usual to be 2.1 times slab self-weight in normal cases, is otherwise calculated as slab self-weight for the considered floor plus 1.1 times the weight of that next upper, using either the design thickness of its slabs or the measured thickness average in respective cases of the latter thickness short of the former or not. Only for the second-floor slab in a two-storeyed system we assumed a construction load of slab self-weight plus roof loads plus form self-weight ($80kg/m^2$), which relates with the most adverse condition of the first floor when it supports the whole upper floor construction load via the shoring. The modulus of rupture of concrete is assumed to be 1.8 $\sqrt{F_c}$ as a rule and 1.2 $\sqrt{F_c}$, respectively suggested in Ref. [18] to be a standard and a practical lower limit. The latter is tried on the domestic one-way test models uncracked analytically alone when depending on the former ; with the recalculation result that the alteration, within the reported low moment ranges, only brings virtually indifferent deflection values of such structures whether they actually crack as in the test or not.

4.2 Examined Adaptability

In Table 1 are entered the considered details of the test models as well as their reported deflection measurements and our predictions. Floor slab models restrained by beams or girders are all treated using both lengths of a span taken between centers of those supports and an effective span except in calculating additional deflections of Δ_s when only the latter is used.

Shown in Fig. 2 are the predictions versus the measurements of deflection, respectively plotted for the abscissas and ordinates, regarding each of the treated slab types, of the corresponding diagrams.

There, respecting the damaged field structures set against the others, noted above all are significantly larger amounts of difference between measured and predictive values ; which may reasonably be attributed to the observed excessive lowering of top reinforcing bars of field slabs to which deflections are generally sensitive and increasingly more as its degrees become larger. For example, as to the floor slab designated A) of a condominium in Table 1, where large discrepancies are noted between measurements and predictions, calculated deflections are respectively 25.6 and 38.2mm assuming an effective depth of 55 or 45mm instead of the reported 65mm when based on effective spans ; and 30.3 or 43.5mm due to center-to-center spans ; while ratios of measured to calculated values, $\Delta_m/(\Delta_s+\Delta_t)$, are 1.35 or 0.91 in the former case and 1.15 or 0.8 in the latter. The above trial estimates seem to help interpret the noticed large degrees of scattering of the measured values in Fig. 2.

Table 1 Compared Measured with Predicted Deflections of Long-Term Test Slabs and Field Floor Slabs ; their Referential Identities and Details

Workers*1 [Ref. Nos.]; General Description ; Yr. of Construction/ Investigation	Original Designations	Major Slab Dimensions*2 $L_x \times L_y$ or L_x (m)	T (mm)	d (mm)	Main Reinforcement*3 with its Spacing (mm) in Directions of: Short Edge	Long Edge	Concrete Properties*4 (kg/cm²) F_c	E_c (×10⁵)	${}_c\sigma_t$	Loads (kg/m², kg/m)*5 Constr. Load	Finishes	Long-Time Imposed	Age at Mmt. in days	Deflections (mm) Measurements Δ_m	Predictions: Elastic Δ_e	Immediate Δ_i	Bond-Slip Δ_s	Time-Depnd. Δ_t	Final $\Delta_s+\Delta_t$	Rel. Vals. $\Delta_m / (\Delta_s+\Delta_t)$
Yamamoto-Shirato [9]; Square Panels; Restrained of All Edges	A	4.80×4.80 4.50×4.50	120	95	D10 @200 D10 @200	D10 @200 D10 @200	69.4	1.96	15.0	576 (2)	—	144 (14)	560	20.0	1.2 0.9	1.5 1.1	2.7 2.7	16.1 12.4	18.8 15.1	1.06 1.32
	B	4.80×4.80 4.50×4.50	120	95	D10 @200 D10 @200	D10 @200 D10 @200	69.4	1.96	15.0	576 (2)	—	144 (14)	560	14.5	1.0 0.8	1.3 1.0	2.7 2.7	14.8 11.4	17.5 14.1	0.83 1.03
B.C.S.[10]; Rectanglr.Pnls.;do.	RSL	4.60×5.80 4.30×5.50	130	100	D10 @150 D10 @150	D10 @150 D10 @150	223	2.22	22.3	655 (14)	—	117 (28)	245	6.3	1.0 0.8	1.0 0.8	0.0 0.0	6.7 4.9	6.7 4.9	0.94 1.58
[1];Condominm.; 9-s. R/C(Steel-Frmd.);1973/1981	Structure (A)	4.70×7.30 4.40×7.00	119	65	13,9φ @125 9φ @250	13,9@200 9φ @200	180	2.10	18.0	629 (14)	40	60		35 (22-50)	1.5 1.1	2.6 1.8	5.1 5.1	18.8 14.8	23.9 19.9	1.46 1.76
[1]; Elementary School; 2-Story R/C; 1973/1978	do. (B)	4.50×6.70 4.15×6.45	102	54	13,9φ @150 9φ @150	13,9φ @200 9φ @200	188	2.10	18.8	613 (14)	184	80		32 (12-38)	2.7 2.0	5.2 3.4	7.8 7.8	31.6 24.1	39.4 31.8	0.81 1.01
[1]; Business Office; 3-Story R/C; 1960/1967	do. (C)	5.40×6.00 5.00×5.60	129	57	13,9φ @240 9φ @235	9φ @350 9φ @290	150	1.82	15.0	650 (14)	56	100		49 (34-64)	2.4 1.8	3.8 2.4	25.8 25.8	27.6 19.6	53.4 45.4	0.92 1.08
[1]; Business Office;2-Story R/C; 1959/1976	do. (D)	6.00×6.00 5.65×5.65	156	91	13φ @200 13,9φ @200	13φ @200 13,9φ @200	180	2.10	18.0	829 (14)	66	100		40	1.9 1.5	3.0 1.8	12.0 12.0	20.7 13.9	32.7 25.9	1.22 1.54
[1]; Post Office 5(4)-Story R/C; 1960/1967	do. (E)	7.30×7.30 6.90×6.90	157	97	13,9φ @100 9φ @100	13,9φ @100 9φ @100	180	2.10	18.0	791 (14)	88	200		55 (34-71)	4.1 3.1	7.1 5.0	5.9 5.9	41.8 34.2	47.7 40.1	1.15 1.37
Washa-Fluck[11]; One-Way, Simply Supported	C1,C4	6.3(0.305)	127	102	4-#4 (4-#4) 4-#4 (4-#4)		208	1.88	26.0	—	—	29 (14)	900	80.0	20.0	42.9	—	74.8	74.8	1.07
	C2,C5	6.3(0.305)	127	102	4-#4 (2-#4) 4-#4 (2-#4)		208	1.88	26.0	—	—	29 (14)	900	100.6	21.4	44.2	—	92.7	92.7	1.09
	C3,C6	6.3(0.305)	127	102	4-#4 (—) 4-#4 (—)		208	1.88	26.0	—	—	29 (14)	900	140.7	23.2	46.1	—	160.0	160.0	0.88
	D1,D4	3.8(0.305)	127	102	4-#4 (4-#4) 4-#4 (4-#4)		205	1.85	26.0	—	—	248 (14)	900	27.7	7.4	15.7	—	27.2	27.2	1.02
	D2,D5	3.8(0.305)	127	102	4-#4 (2-#4) 4-#4 (2-#4)		205	1.85	26.0	—	—	248 (14)	900	33.0	7.9	16.3	—	33.7	33.7	0.98
	D3,D6	3.8(0.305)	127	102	4-#4 (—) 4-#4 (—)		206	1.92	26.0	—	—	248 (14)	900	44.5	8.3	16.5	—	58.3	58.3	0.76
	E1,E4	5.3(0.305)	76	59	4-#3 (4-#4) 4-#3 (4-#4)		210	1.88	26.1	—	—	1 (14)	900	124.0	22.9	52.8	—	103.0	103.3	1.20
	E2,E5	5.3(0.305)	76	59	4-#3 (2-#4) 4-#3 (2-#4)		210	1.88	26.1	—	—	1 (14)	900	128.8	24.2	53.9	—	124.0	124.0	1.04
	E3,E6	5.3(0.305)	76	59	4-#3 (—) 4-#3 (—)		210	1.88	26.1	—	—	1 (14)	900	184.9	25.7	55.3	—	193.5	193.5	0.96
Washa-Fluck[12]; One-Way, Two-Span Continuous	Y1,Y4	6.3(0.305)	127	102	5-#5 (5-#5) 4-#4 (4-#4)		236	2.04	27.7	—	—	124 (14)	900	46.0	13.5	27.0	—	47.3	47.3	0.97
	Y2,Y5	6.3(0.305)	127	102	5-#5 (5-#5) 4-#4 (2-#4)		236	2.04	27.7	—	—	124 (14)	900	49.8	14.1	27.5	—	53.5	53.5	0.93
	Y3,Y6	6.3(0.305)	127	102	5-#5 (5-#5) 4-#4 (—)		236	2.04	27.7	—	—	124 (14)	900	59.9	14.8	28.1	—	72.8	72.8	0.82
	Z1,Z4	5.3(0.305)	76	59	4-#4 (5-#4) 4-#3 (4-#3)		232	2.10	27.4	—	—	45 (14)	900	58.9	15.7	34.8	—	66.0	66.0	0.89
	Z2,Z5	5.3(0.305)	76	59	4-#4 (5-#4) 4-#3 (2-#3)		232	2.10	27.4	—	—	45 (14)	900	67.8	16.2	35.2	—	73.8	73.8	0.92
	Z3,Z6	5.3(0.305)	76	59	4-#4 (5-#4) 4-#4 (—)		232	2.10	27.4	—	—	45 (14)	900	79.8	16.7	35.7	—	95.4	95.4	0.84
Iwahara[13-14]; One-Way Slab Strips	SL-1	3.0(0.40)	130	100	2-D10(—) 2-D10(—)		278	2.96	20.0	—	—	172 (35)	140	17.0	14.3	3.7	—	16.2	16.2	1.05
	SL-2	3.0(0.40)	130	100	2-D10(—) 2-D10(—)		278	2.96	20.0	—	—	15 (35)	140	5.5	0.7	0.7	—	4.5	4.5	1.22
	SL-3	3.0(0.40)	130	120	2-D10(—) 2-D10(—)		278	2.96	20.0	—	—	172 (35)	140	9.0	1.4	3.2	—	12.8	12.8	0.70
	SL-4	3.0(0.40)	130	80	2-D10(—) 2-D10(—)		278	2.96	20.0	—	—	172 (35)	140	19.2	1.5	4.1	—	20.6	20.6	0.93
	SN-1	4.0(0.45) 3.6	137	100	3-D10(3-D10) 3-D10(—)		204	2.32	17.1	—	—	282 (30)	856	22.2	1.3 0.9	9.1 6.5	3.3 3.3	16.1 10.7	19.4 14.0	1.14 1.59
	SN-2	4.0(0.45) 3.6	135	100	3-D10(3-D10) 3-D10(—)		204	2.32	17.1	—	—	22 (30)	856	—	0.5 0.4	0.5 0.4	0.0 0.0	4.0 2.7	4.0 2.7	— —
	SN-3	4.0(0.45) 3.6	135	115	3-D10(3-D10) 3-D10(—)		204	2.32	17.1	—	—	283 (30)	856	15.7	1.3 0.9	7.1 5.4	2.5 2.5	12.7 9.7	15.2 12.2	1.03 1.29
	SN-4	4.0(0.45) 3.6	133	80	3-D10(3-D10) 3-D10(—)		204	2.32	17.1	—	—	283 (30)	856	17.8	1.4 1.0	15.1 11.3	6.6 6.6	22.6 15.0	29.2 21.6	0.61 0.82
Yamamoto[15]; One-Way Slab Strips	S1	5.3(0.40) 5.0	130	104	2-13φ(2-13φ) 2-13φ(—)		306	2.42	21.0	—	—	106 (56)	350	23.0	2.7 2.1	14.9 12.5	6.3 6.3	19.8 15.6	26.1 21.9	0.88 1.05
	S2	5.3(0.40) 5.0	130	104	2-13φ(2-13φ) 2-13φ(—)		306	2.42	21.0	—	—	106 (56)	350	20.0	2.7 2.1	14.9 12.5	6.3 6.3	19.8 15.6	26.1 21.9	0.77 0.91
	S3	4.0(0.40)	130	104	2-13φ(—) 2-13φ(—)		306	2.42	21.0	—	—	70 (56)	350	32.5	3.5	8.3	—	27.8	27.8	1.17
	S4	4.0(0.40)	130	104	2-13φ(—) 2-13φ(—)		306	2.42	21.0	—	—	70 (56)	350	30.5	3.5	8.3	—	27.8	27.8	1.17
Matsuzaki[16]; One-Way Slab Strips	A1	4.2(1.00) 3.8	120	95	7-D10(5-D10) 5-D10(—)		168	1.85	15.6	—	—	288 (30)	350	16.0	1.8 1.2	7.6 4.9	2.0 2.0	14.1 8.9	16.1 10.9	0.99 1.47
	A2	4.2(1.00) 3.8	120	95	7-D10(5-D10) 5-D10(—)		168	1.85	15.6	—	—	180 (30)	350	11.6	1.5 1.0	4.7 2.9	1.2 1.2	11.1 7.0	12.3 8.2	0.94 1.42
	A3	4.2(1.00 3.8	120	95	7-D10(5-D10) 5-D10(—)		168	1.85	15.6	—	—	0 (30)	350	8.2	0.9 0.6	1.0 0.6	0.0 0.0	5.4 3.1	5.4 3.1	1.52 2.65
Komori[17]; One-Way Slab Strips	S1-A	5.3(0.25) 5.0	100	70	1-9φ(—) 1-9φ(—)		205	1.62	17.2	—	—	0 (56)	90	63.0	3.9 3.1	33.8 29.3	20.5 20.5	35.6 26.4	56.1 46.9	1.12 1.34
	S1-B	5.3(0.25) 5.0	100	70	1-9φ(—) 1-9φ(—)		205	1.62	17.2	—	—	0 (56)	90	46.0	3.9 3.1	31.6 28.3	19.6 19.6	35.0 25.9	54.6 45.5	0.84 1.01

Note

*1 Field Structures Labelled (A) through (E) as in Ref.[1]; See it for Edge Restraint; Structures of [11] & [12] Treated there were Wide-Flat Beams;
*2 L_x = Span : Those Measured Center-to-Center in Upper and Effective Spans in Lower Entries with Panel Widths Parenthesized ; T = Slab Thickness ; d = Effective Depth of Top Steel ; L_y = Lateral Span ;
*3 Upper Enries refer to End Top Steel and Those Lower to Midspan Bottom Steel with Compression Steel in Parentheses ;
*4 F_c = Compression Strength of Concrete ; E_c = its Elastic Modulus ; ${}_c\sigma_t$ = Modulus of Rupture of Concrete ;
*5 Parenthesized are Durations of Loading in Days ; Load Intensities Put in Different Units, per Length and Area for respective One- and Two Way Systems.

5. Summary and Conclusion

Through this report we have proposed a renovated method, as a modification of our earlier procedure, for analytically predicting immediate and long-time deflections of floor slab systems with ununiform distribution of stiffness due to their partial cracking.

Comparing with the above prior approach generally based on the ACI Code method[1], in which a slab panel is simplified to comprise a few rows of slab strips each with a uniform stiffness over the length, while time-dependent deflections hinge on a sole multiplier, we have shown by using examples the presented alternative serves to account more reasonably for r/c slab deflections including cases of actual damaged construction.

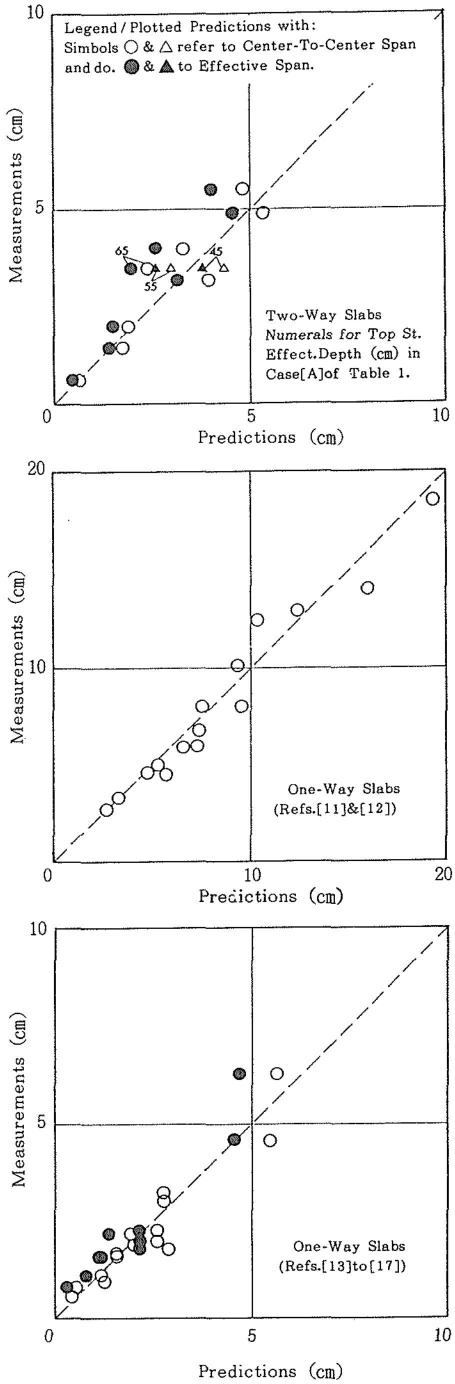

Fig. 2 Examined Degree of Agreement between Measured and Predicted Deflection Values

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