Predictive Calculation for Deflections of Reinforced Concrete Floor Slabs Part 2: Application of the Proposed Prediction System

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Predictive Calculation for Deflections of Reinforced Concrete Floor Slabs

Part 2: Application of the Proposed Prediction System

by Akira SUGINOME, Satoru INO and Yoshizo DOBASHI

Abstract

In Part 2 we initially examine how our method tolerably predicts r. c. floor deflections in practice. In an effort then needed to set measurement against prediction, as we earlier used test data on slab models, we here employ a field set of data which is rare but justifiably representative record of in-citu observation of chronic floor deflection progress, toward sagging damage, taken over several years on a spacious multistorey r. c. building having floor systems with a number of slab panels. And for the purpose of further similar comparison the same set of data is used by our method and by two others both proposed in major r. c. design codes.

The results of thus trying our procedure being substantially comparable to the measured set of data, we likewise examine several other reported cases of buildings with floor sagging injuries; whereupon partially inaccurate construction is rated as the main of their common causes. Also by our method we review the formula for limiting slab thickness prescribed in the domestic r. c. design code. Finally we suggest partial reconsideration of the equation.

1. Introduction

Earlier,[1] we noted that approximate prediction of longtime deflections of one- or two-way r. c. floor slabs may be feasible using our method then introduced to degrees reasonably comparable to actual test measurements. Now needed to be examined is its relative adaptability to more critical practical conditions incident to some floor structures sustaining cracking and/or sagging damage; where with less controllable concrete quality ordinarily attending their construction, notably the effect of bond-slip then can be a more significant consideration than in test models discussed already.

In this paper we will make the foregoing required effort in which deflection measurements taken on several cases of r. c. buildings with the above types of floor damage are to be compared with our corresponding follow-up calculations; and in one case, with appropriate predictions provided by the ACI and the CEB Code methods[2),3),4),5)].

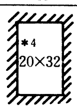
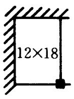
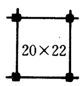
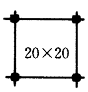
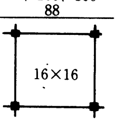
And with the result that estimation by our method practically suffices systematic calculation by using it of standard slab dimensions will be performed so as to utilize the result to check the current Japanese Code provisions for allowable slab thickness.

2. Applicabillty Check

In the following, five cases of buildings with more or less serious trouble of floor deflection damage will be treated. We adopt for the present prediction analysis the original design assumptions on loads, material properties and sectional detail unless thereof more reliable or realistic data are available.

Mainly considered in this context are differences of designed structural dimensions from those measured in situ referring to the concerned damage investigation. Additionally assumed for the analysis is a constant proportion, in principle 2. 1 times slab panel self-weight[7] as is customarily adopted, of construction-work load, or, construction load as may more usually be called.

Table 1 Results of Past Reported Field Investigatigations into Damaged Floor-Slabs and Predictive Assumptions for Concrete Properties and Load Intensities

Designation		A (Condominium)	B (Elem. School)	C (Office)	D (Office)	E (Office)
	Locality Structure; Storey Exec./Investgtd. in	Sapporo, Hokkaido St. Framed; 9-S. 1973/1981	Furano, Hokkaido RC; 9-S. 1973/1978	Sapporo RC; 3-S. 1960/1967	Kitami, Hokkaido RC; 2-S. 1959/1976	Sapporo RC;5-S.with Bsmt. 1960/1967
Designed Slab Dimensions	Cent.-to-Cent. Span m Effective Span m Slab Thickness mm	4,700×7,300 4,400×7,000 130	4,500×6,700 4,150×6,450 120	5,400×6,000 5,000×5,600 120	6,000×6,000 5,650×5,650 140	7,300×7,300 6,900×6,900 150
Measrd. Slab Dimensions (Range of Msrmnt.)	Base Mortar Thcknss. mm Slab Thickness mm Eff. Depth of Top St. mm Measred. Deflection mm	— 119(90~160) 65(47~ 97) 35(22~ 50)	82(68~ 96) 102(99~108) 54 27(12~ 38)	17(13~ 30) 129(111~153) 57(39~ 87) 49(34~ 64)	23(20~ 26) 156(141~164) 91(85~ 99) 40	34(8~ 87) 157(107~207) 97(66~125) 55(34~ 71)
Slab Reinforcement	Middle Strip, Short Edge, End: Top St.mm Botm. St.mm	13,9ϕ @150 9ϕ @250	13,9ϕ @150 9ϕ @300	13,9ϕ @240 9ϕ @240	13ϕ @200 9ϕ @400	13,9ϕ @100 9ϕ @200
	Middle Strip, Short Edge, Cent.: Top St.mm Botm. St.mm	— 9ϕ @250	— 9ϕ @150	— 9ϕ @235	— 13.9ϕ @200	— 9ϕ @100
	Middle Strip, Long Edge, End: Top St.mm Botm. St.mm	13,9ϕ @200 9ϕ @400	13,9ϕ @200 9ϕ @400	9ϕ @350 9ϕ @350		
	Middle Strip, Long Edge, Cent.: Top St.mm Botm. St.mm	— 9ϕ @200	— 9ϕ @200	— 9ϕ @290		
	Col. Strip, Short Edge: Top St.mm Botm. St.mm	9ϕ @200 9ϕ @200	9ϕ @200 9ϕ @400	13,9ϕ @350 9ϕ @450	9ϕ @400 9ϕ @400	9ϕ @200 9ϕ @400
	Col. Strip, Long Edge: Top St.mm Botm. St.mm	9ϕ @250 9ϕ @250	9ϕ @300 9ϕ @600	9ϕ @400 9ϕ @600		
Colmn./Girder Sections & Floor Height	Colmn.: Upper Flr. mm Lower Flr. mm		500 × 500 500 × 500	500 × 500 600 × 600	400 × 500 400 × 500	600 × 600 600 × 600
	Floor Height m	2,700	3,600	3,400	3,600	3,600
	Girder for: Short Span mm Long Span mm		200 × 1,500 300 × 800	400 × 500 400 × 500	350 × 500 350 × 500	400 × 550 400 × 850
Reinforcement of Girders in Directions of:	Short Span, Inner End: Top St.mm Botm. St.mm		2−22ϕ 2−22ϕ	3−22ϕ 2−22ϕ	4−22ϕ 2−22ϕ	6−22ϕ 2−22ϕ
	Short Span, Center: Top St.mm Botm. St.mm		2−22ϕ 2−22ϕ	2−22ϕ 2−22ϕ	2−22ϕ 3−22ϕ	4−22ϕ 4−22ϕ
	Long Span, Both Ends: Top St.mm Botm. St.mm		4−22ϕ, 3−22ϕ 3−22ϕ, 2−22ϕ	5−22ϕ 4−22ϕ		
	Long Span, Center: Top St.mm Botm. St.mm		2−22ϕ 3−22ϕ	2−22ϕ 3−22ϕ		
Concrete Properties	Compr. Strngth. kg/cm² Tens. Strngth. kg/cm² Avrg. Bond Stress kg/cm²	180 18 10.8	188 18.8 11.3	150 15 9	180 18 10.8	210, 180, 150 21, 18, 15 12.6, 10.8, 9
	Other Material Properties	Elastic Modulus=210,000 kg/cm² (except E Using Code Values); Modular Ratio =10; Poisson's Ratio=0.2; *2 Creep Coef. =4.4 for Slabs & 3.8 for Girders; *2 Shrinkage Strain=0.0005 for Slabs and 0.00042 for Girders; Conc. Slump=20 cm				
Loads *3	Longtm. Impsd. kg/m² Finishing Matrls. kg/m²	60 40	80 184	100 56	100 66	100, 200, 300 88
Note; with Illustration of Idealized Systems	*1 Measrd. Spacings Used for Case C alone; Others as Desgnd.; *2 Assumed Rel. Humid.=55%; *3 Const. Load as in text; *4 Nr. of Difference Subdivision					

2.1 A Long Observed Case of Floor Construction with Sagging Damage

This is such a rare instance of deflection damage to the floor systems of a public service office building in Sapporo, Hokkaido, as was fortunately able to be observed for about six years following the year after its execution.[8), 9)]

In Table 1 are shown on its floor slabs, referring to Case E therein, design details on material properties and both overall and sectional dimensions together with in-situ measurements correponding to them.

According to our investigation a wide scattering is noticed of slab thickness and end top reinforcement level. Also actual imposed live load amounts were significantly different from a floor or floor section to another depending on what type of service had occupied it. Connectedly as varied were degrees of deflections of its slab panels as imposed load amount. The predictive calculation assumed, other than the above-mentioned construction load, alternative amounts of live load of 100 and 300 kg/sqm for sustained longtime use.

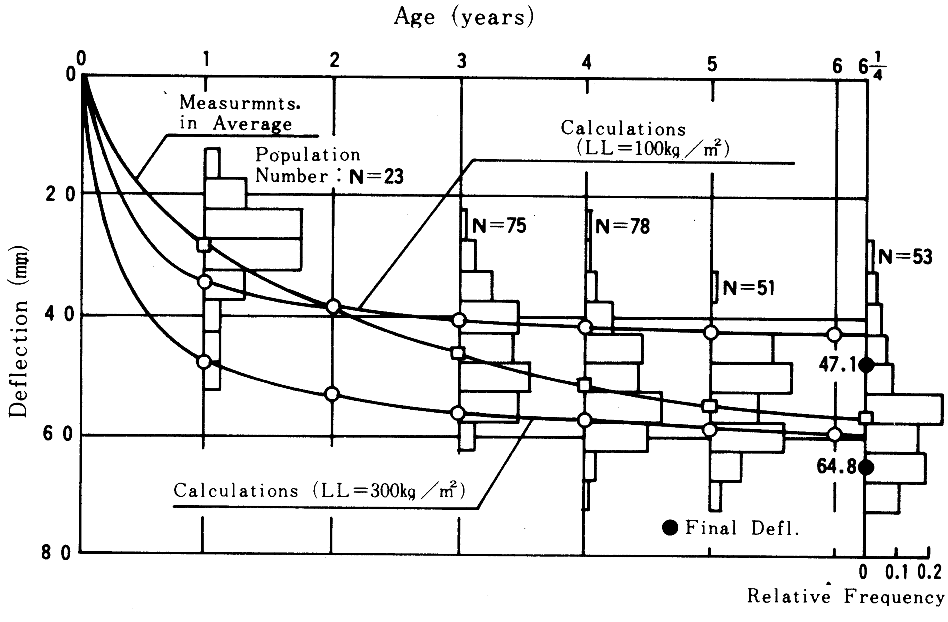


Fig. 1. Measured and Calculated Progress of Midpanel Deflection of a Floor Slab in an Office Building; with Population Number as Investigated Total

The annual distributions of frequency of measured deflection values are diagrammed and the corresponding average points plotted in Fig. 1, along with the interpolation curves drawn through them; though the distribution ranges are varied due to unstable latitude given in our selecting accessible part of the floor spaces in service.

Duly to be provided for this predictive trial is that all the related assumptions are made again the same as were in Part 1 on analyzing the test results; the eventual prediction data are to serve for the following observations.

As concerns the observed deflection progress set against its follow-up counterpart the overall degree of agreement between both types of data is seen in Fig. 1 to be comparable fairly to that in the three prior test examples. Likewise the agreement tends to be much better in later part of loading periods than in earlier stage as appreciably true of Figs. 6 through 8 of Part 1.[1)]

2.2 Comparison with Prediction by Code Methods

Respecting all the cases of structure we have so far discussed Table 2 compares measurements of their terminative longtime deflection, experimentally here regarded as those at the end of long-term loading, with the equivalent calculations by our current method, and with predictions by two major building code methods from the ACI's and CEB's appropriate design manuals.

In contrast with our predictions the two latter sets of estimation are considerably lower than the measured values. The difference is considered to be caused by the ruled out bond-slip effect in the code methods. And accordingly, the corresponding results obtained by our method ignoring that type of effect are found, also occupying Table 2 in parentheses, to be practically of the order of the measurements. The slight difference may be owing to the disparity between such basic sets of design assumptions in our procedure and the quoted code methods as of orthogonal anisotropy, effective width of T-beams or others.

2.3 Examining Reported Cases of Damaged Foor Structure

Our initially intended prediction analysis of damaged practical examples is to be made while mainly assuming observed construction inaccuracies and the customarily adopted amounts of construction load.

2.3.1 Objects and Main Analytical Detail

The introduced cases, each from five r. c. or steel framed r. c. buildings here labeled alphabetically A through E, all consisting of slab-girder floor systems without beams, built into multistorey main girder-column frames.

These past instances have any of the usual types of structural defects inhering in both their de-

Table 2 Measured Floor Deflections on First of Discussed Buildings; as against Predictions by Authors' Method and those by Two Code Methods

Objects in Comparison		Age (days)	Rel. Humidity (%)	Measrd. Deflection (mm)	Predictions (mm) by Method of: Authors *2	ACI	CEB
Tested Slabs in Part 1.	One-Way by Ohbayashi Lab	∞	40 80	19.0 *1	23.5(14.2) 15.8(9.3)	11.2 7.3	12.4 8.5
	Two-Way (A) by Tokyu Lab.	560 ∞	70	14.5 —	17.6(10.5) *3 21.1(12.7)	8.3 10.0	9.6 11.2
	Two-Way (B) by Tokyu Lab.	560 ∞		20.0 —	20.6(13.5) *3 24.9(16.5)	11.8 14.6	11.1 13.3
	Two-Way by B. C. S.	245 ∞	65	6.3 —	6.4(4.9) 9.5(7.4)	5.0 7.7	4.3 6.4
Field. Struct.	Damaged *4 Slabs	∞	55	56 (31∼71)	47.1(32.7) 64.1(44.7)	26.9 40.7	32.7 37.0

*1 Measured Values at 3000 days of Age

*2 Parenthethized referring to Ignored Bond-Slip

*3 Predictions given as Averg. for Two Different τ_b Values

*4 Prediction assuming 100 and 300 kg/m^2 of Live Loads for respective Upper and Lower of Paired Entries

sign and the effected construction process, including excessively lowered end-top reinforcement as in cases A through E, slab panels executed with less than design thickness for A and B, overthickness of mortar base for finishing materials, as to B, and partly curtailed required additional reinforcement as observed in case C; hence being chosen here to be typical of floors with comparatively aggravated degrees of deflection damage.

The designed and partly observed structural detail on all the slab panels in point are shown in Table 1 as explained in Section 2.1 likewise about case E.

Calculating their initial deflections heeding flexural cracking and effect of their continuity to adjoining structural elements assumes their boundary conditions as illustrated at the foot of the table, with fixity and continuity respectively marked by shade and thick lines.

Otherwise a column top and bottom are treated as being rigidly fixed at both foor levels just above and below the considered adjoining slab. Working out initial deflections, those due to bond-slip of the steel and those owing to the creep and shrinkage effects presupposes longtime sustained loads of Table 1, while both flexural and torsional stiffnesses of slab and beam elements taking account of their flexural cracking are decided on the basis of the effective moment of inertia obtained by use of a construction load taken as the available maximum reading of corresponding records of loading hysteresis envelopes.

A construction load is assumed herein at the introduced amount as a rule unless its more detailed treatment is possible. Then, such a load is supposed to be slab self-weight for the considered floor plus 1.1 times that for the next upper, using its designed or measured average slab thickness respectively when the latter thickness is smaller than the former or not.

Notably, for the second-floor slabs in a two-storey case a construction load of slab self-weight plus roof load plus form self-weight amounting to 80 kg per sqm which corresponds to the most adverse condition possible of the first floor when it undergoes the whole upper floor construction loads via the shoring.

2.3.2 Discussion on Calculation Results in Comparison

In Table 3 are shown predicted causally different portions of the longtime deflection obtained using average measured slab thickness and taking account of observed construction accuracy. and also entered beneath parts of them are their equivalents obtained for three cases with differing values of the cited factors in question, for the purpose of examining the effect, on relevant predictions, of comparatively scattered degrees of construction inaccuracy in the case of building A and the changes in concrete strength and in amount of construction or longtime sustained load in case E construction. As for case B structre, where relatively thin slabs have thick mortar layers, en-

Table 3 Predicted Deflections taking account of Inaccurate Construction

Structure	Measurements		Concr.	Load		Elastic	Initial Deflection		Longtime Deflection		Final Deflection
	Slab Thick-ness mm	Effectv. Depth of Top Steel mm	Compr. Strgth. kg/cm²	Constr. Load kg/m²	Long-Time Sust. kg/m²	Deflec-tion $\triangle_e$ mm	Cracking Effect $\triangle_i$ mm	Bond Slip Effect $\triangle_s$ mm	Creep Effect $\triangle_{cr}$ mm	Shrinkage Effect $\triangle_{sh}$ mm	$\Sigma\triangle=\triangle_i+\triangle_s+\triangle_{cp}+\triangle_{sh}$
A	130	105	180	655	412	0.9	1.2	0.5	6.0	3.4	11.1
	130	80		655	412	0.9	1.1	1.6	9.5	3.4	15.6
	130	55		655	412	0.9	1.1	5.8	24.1	3.4	34.4
	115	55		619	376	1.2	1.8	4.8	22.9	4.1	33.6
	100	55		583	340	1.6	3.0	4.2	24.8	5.0	37.0
B	102	54	188	613	509	2.7	5.0	6.4	38.3	4.8	54.5
	184	54				0.6	0.8	6.2	23.4	2.2	32.6
C	129	57	150	650	464	2.1	5.7	7.3	38.0	4.4	55.4
D	156	91	180	829	541	1.7	2.6	4.5	23.8	4.0	34.9
E	157	97	210	791	565	3.2	4.4	1.9	23.3	7.4	37.0
			180	791	565	3.4	5.4	2.0	27.6	7.4	42.4
			150	791	565	3.7	7.1	2.4	35.2	7.4	52.1
			180	659	565	3.4	4.9	1.9	24.9	7.4	39.1
			180	923	565	3.4	6.0	2.4	35.3	7.4	51.1
			180	791	665	4.0	6.7	2.4	33.6	7.4	50.1
			180	791	765	4.6	8.7	2.5	41.3	7.4	59.9

tries are made of calculated deflection values using an assumed slab thickness with depth of base mortar counted in it, though serving as simplified criteria for upper bounds on those effects of added stiffness owing to that nonstructural material which otherwise would have to account for its own strength and bonding property.

In Figs. 2 and 3, using buildings A and E as typical examples the plotted degrees of respective effects of construction accuracy, slab thickness, both for case A, and concrete strength as well as construction- and longtime-load intensities, for case E, on the predicted deflection values are comparatively reviewed, with the result that difference in top reinforcement level has the most marked influence.

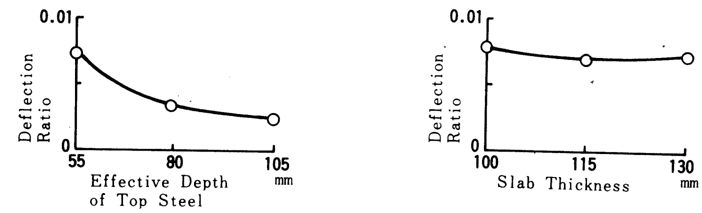


Fig. 2. Effect of Construction Inaccuracies on Floor Slab Deflections for Case A

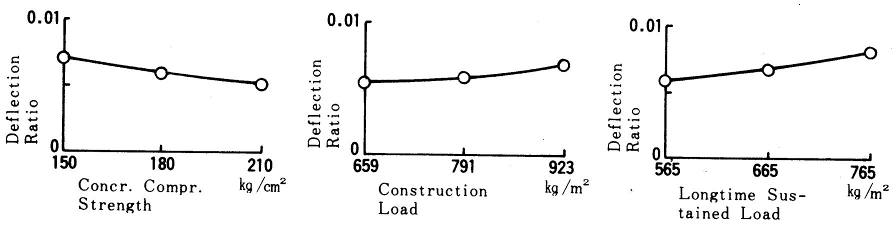


Fig. 3. Effect of Variations in Concrete strength and Load Intensity on Floor Slab Deflecitions for Case E

3. Checking Japanese R. C. Code Provisions for Slab Thickeness

The requirements for floor slab thickness in the latest revised code[6] by Architectural Instute of

Table 4 Dimensions of Model Slabs used for our Reviewing Domestic Code's Slab Thickness Provisions

Slab Dimensions			Tens. Steel %				Elastic Deflection	Initial Deflection		Longtime Deflection		Final Deflection
Short Span	Aspect ratio	Thickness	Short Edge Direction		Long Edge Direction			due to Cracking	due to Bond Slip	due to Creep	due to Shrinkage	$\Sigma\triangle=\triangle_i+\triangle_s+\triangle_{cp}+\triangle_{sh}$
lx: m	λ	t : mm	End	Cent.	End	Cent.	$\triangle_e$: mm	$\triangle_i$: mm	$\triangle_s$: mm	$\triangle_{cr}$: mm	$\triangle_{sh}$: mm	
3.500	1.0	85	0.40	0.31			0.60	0.6	1.0	5.8	2.6	10.0(4.6)
	1.5	105	0.37	0.28	0.25	0.25	0.62	0.7	0.6	4.6	2.4	8.3(2.7)
	2.0	105	0.40	0.30	0.26	0.20	0.72	0.9	0.7	5.7	2.3	9.6(3.1)
4.000	1.0	100	0.34	0.27			0.69	0.7	0.8	5.7	2.8	10.0(3.7)
	1.5	120	0.32	0.25	0.22	0.18	0.78	0.9	0.7	6.0	2.6	10.2(3.3)
	2.0	125	0.33	0.25	0.22	0.17	0.82	1.0	0.7	6.4	2.4	10.5(3.2)
4.500	1.0	120	0.28	0.22			0.72	0.8	0.7	5.5	2.7	9.7(3.2)
	1.5	140	0.28	0.21	0.19	0.15	0.87	1.0	0.8	6.8	2.1	10.7(3.7)
	2.0	145	0.38	0.29	0.19	0.15	0.93	1.2	0.5	6.5	2.8	11.0(2.4)
5.000	1.0	135	0.25	0.20			0.84	0.9	0.7	6.3	2.8	10.7(3.5)
	1.5	160	0.32	0.25	0.21	0.17	0.98	1.2	0.5	6.5	2.9	11.1(2.4)
	2.0	165	0.34	0.25	0.20	0.16	1.06	1.4	0.5	7.3	2.7	11.9(2.5)
5.500	1.0	150	0.30	0.24			0.96	1.1	0.5	6.1	3.2	10.9(2.4)
	1.5	180	0.29	0.22	0.19	0.15	1.10	1.4	0.6	7.5	3.0	12.5(2.9)
	2.0	185	0.30	0.22	0.18	0.14	1.20	1.7	0.7	8.8	2.8	14.0(3.2)
6.000	1.0	170	0.26	0.21			1.02	1.2	0.5	6.6	3.2	11.5(2.5)
	1.5	200	0.34	0.21	0.22	0.15	1.23	1.6	0.5	7.9	3.0	13.0(2.3)
	2.0	210	0.34	0.21	0.21	0.14	1.28	1.9	0.5	9.3	2.8	14.5(2.6)

Note - - The above prediction assumes:

1) deformed steel rods of combined D13 and D10 ;
2) distance d'=35m from extreme compression/tension fiber to centroid of compress./tension steel;
3) parenthesized values due to bond-slip, including its secondary effect on creeping, i.e., $\triangle_s+\triangle_{cp}\cdot\triangle_s/(\triangle_i+\triangle_s)$;
4) construction load=2.1 times slab self-weight;
5) longtime sustained load = actual imposed load of 60kg/m² plus weight of finishing materials of 80kg/m² ;
6) for concrete: compr. strength 210kg/cm², tesile strength 21kg/cm², average bond stress 21kg/cm², elastic modulus 210000kg/cm², Poisson's ratio 0.2, modular ratio 10, creep coefficient 4.4 and shrinkage strain of 0.0005 ; and
7) difference subdivision; into squares; numbering 20 for short edge of slab panel.

Japan (A. I. J.) have been improved as compared with its earlier versions, respecting how slab panels of comperatively large span and structures under a large amount of live load should be treated, generally being based on the design concepts of serviceability limits of deflections. However, it has been known there can be cases of limiting thickness getting smaller than the corresponding earlier code values when it comes to floor slabs of dwelling use sustaining relatively small amounts of live load and having panel span length less than 4.5 m. Also in one of our already presented report notice was taken of a case of highrise steel framed r. c. condominium[7] whose floor slabs suffered deflection damage in spite of their panel width being relatively small and their panel thickness conforming to the existing relevant Code limitations.

In order to serve for their reviewal implied just above the corresponding efforts will now be made to examine the longtime deflections of floor slabs designed and executed in compliance with them.

3.1 Calculation

In a trial calculation complying with the existing Code requirements slab thickness and reinforcement are worked out as shown in Table 4 for slab panel examples for residential use which implies their being notably sensitive to the limiting conditions for their serviceability.

Herein referred to as standard slabs, the sample structures number eighteen in total with their short-edge length ranging from 3.5 to 6.0 m at 0.5 m intervals, each variety having three aspect ratios of 1.0, 1.5 and 2.0. At the same time such effects as of lowered reinforcement due to construction inaccuracy or of increases in both reinforcement ratio and slab thickness are examined, by way of deflection damage prevention, on two standard slabs with an aspect ratio of 1.5 and respective short-edge lengths of 4.0 and 5.5 m, with both above parameters given three reference values. The associated calculation of terminative longtime deflection, hereafter simply quoted as final deflection, assumes all-edge built-in slabs and either loads acting thereon or physical properties of the used materials defined in the footnote to Table 4.

3.2 Examining Calculated Results in Comparison

As seen in that table, with increases in short-span length, merely called span or span length from now on, or in aspect ratio, values of final deflection tend to increase gradually, however for smaller span lengths the correlation between relative or absolute slab proportions and final deflection is not always distinct owing to the pertinent design's rounding off slab thickness and bar spacing for fractions respectively below 10 and 100mm. Especially for spans less than 4.5 m, for which the latest Code provisions remain the same as earlier, there seems no noticeable interdependence between the aspect ratio and the final deflection and hence considerations here will be limited mainly to span/deflection concerns.

In practice, the taken average of final deflection values obtained for any three standard structures with an equal span and different aspect ratios of 1.0, 1.5 and 2.0 was plotted for each preceding varied span length to result in Figs. 4 through 7, in which, as a result of deflection values, once scattered due to the cited rounding of design dimensions, being now levelled off the following relations has been indicated between the span length and the predicted final deflection.

First of all may be that as span lengths get smaller so do final-deflection values as shown in Fig. 4. Next, on the contrary, the ratio of final deflection to span length or to elastic deflection increases with decreasing span length as noted in Figs. 5 and, causing this tendency, the last is that with the smaller span length, i. e., with decreasing slab thickness, the greater becomes the ratio re-

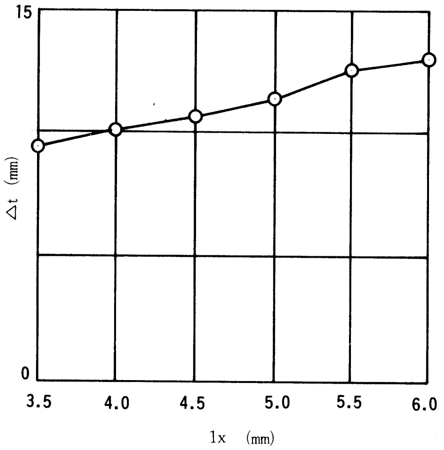


Fig. 4. Final Deflections plotted against Varied Short Span Length

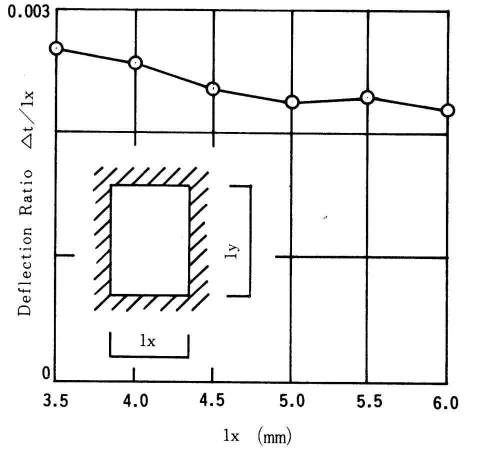


Fig. 5. Deflection Ratios plotted against Varied Short Span Length

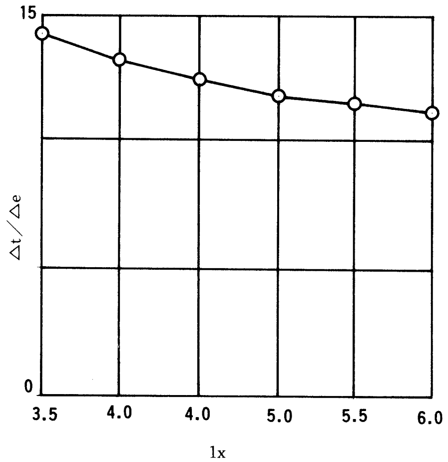


Fig. 6. Ratio of Final to Elastic Deflection, given relatively to Varying Short Span

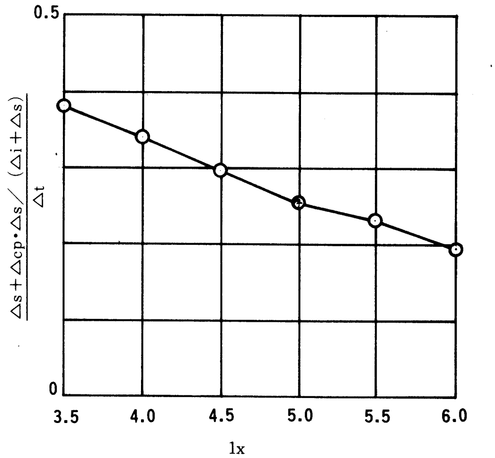


Fig. 7. Ratio of Deflection due to Bond-Slip of Reinforcement to Final Deflection, relative to Varying Short Span

lative to a final deflection of that portion of it associated with bond-slip of reinforcement; which inclination is observed in Fig. 7.

Fig. 8 gives a typical example of what degree of influence the preceding lowering of end-top reinforcement might have on the final deflection. Increased values of final deflection of standard slabs e. g. of 120 and 180 mm thickness due to a 30 mm lowering of end-top reinforcement come up to respectively ca. 2.7 and a little less than 1.3 times those amounts for their normally rein-

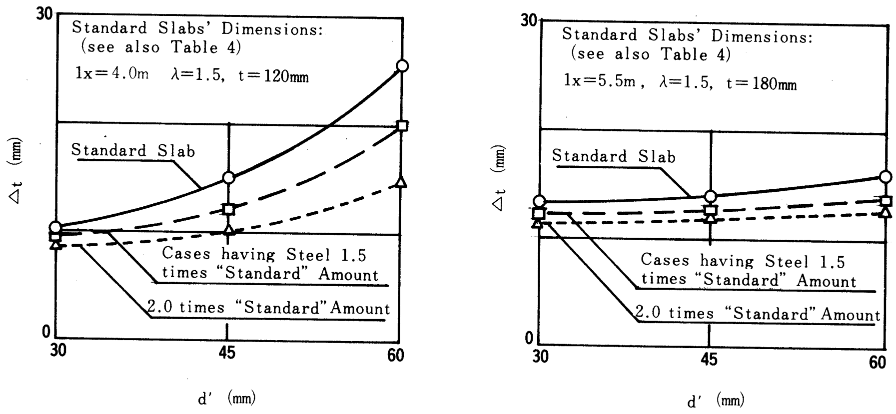


Fig. 8. Effect of Steel Ratio and Lowered Top Steel Level on Final Deflection

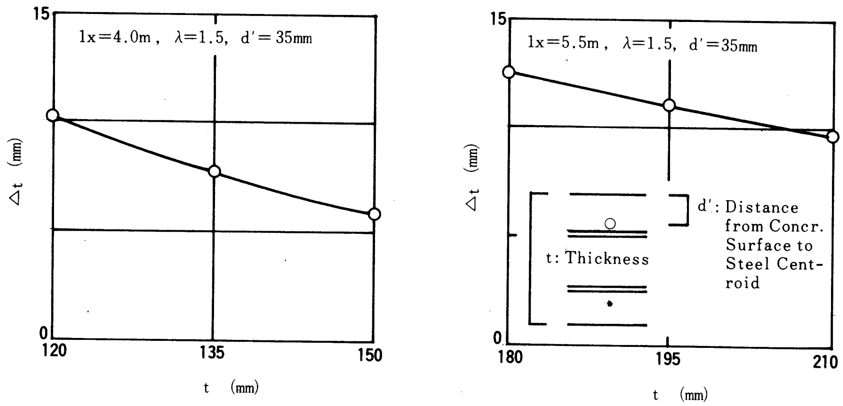


Fig. 9. Effect of Slab Thickness on Final Deflection

forced correspondents, indicating the deflection comes to be more sensitive to a change in reinforcement level the smaller the thickness becomes.

3.3 Observed Irrelevancy of Code Thickness Formula in Practice

The ratio of a final deflection to its immediate elastic portion tends to increase as the span length decreases, because the attendant reduction in the effective depth of end-top reinforcement facilitates its bond-slip.

Accordingly, if the final deflection is predicted to be its elastic portion multiplied by a constant factor, ruled by the present Code principle, the final deflections of floor slabs with comparatively small spans are liable to be underestimated, the result being the likelihood of a designed floor panel with a limiting slab thickness smaller than practically needed.

Moreover, thinner floor slabs are more sensitive to the lowering of reinforcement, having the possibility that a small amount of construction inaccuracy may cause their deflection damage. Thus its prevention should be assured by such means as maintaining normal top reinforcement levels using bar supports or chairs and, in case of using the code formula for the limiting thickness of a slab, introducing any factor affecting its design thickness depending on the intended use of the floor space in consideration.

For two cases of standard slabs of relatively large and small proportions how their final deflections decrease is followed as their thicknesses gradually increase and its consequence shown in Fig. 9. Therefrom it ensues that only a slight increase in slab thickness can result in a substantial decrease in the value of the final deflection.

Also as effective is using a larger amount of the end-top reinforcement than that designed in the case of structures with smaller spans in order to refrain the bond-slip effects beforehand (e. g. see Fig. 8).

While in some r. c. design codes in other countries deflection limits provided for for floor panels to be used under comparatively exacting conditions are set half these values for the same structures for general use it seems necessary for the discussed code to introduce similar measures to those above against hazards of deflection damage at least for certain types of buildings sensive thereto including ones having spacious public rooms of Japanese style.

4. Conclusion

It has been shown through our reports that floor slab deflections have come to be more reasonably estimated, including those on a floor construction subject to cracking and/or deflection damage, than by the methods most frequently in use which tend to underestimate the deflection.

In conclusion it may be said that our analytical procedure can help account for the causes of usual types of slab deflection injuries by numerically simulating in substance their experimental treatment which is discouragingly difficult for economic and other crucial reasons to reproduce and in the main has been replaced by their occasional field observation alone.

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