Standardization of Inserts for Precast Reinforced Concrete Units of Large Panel Residential Buildings

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PREFACE

Precast concrete is gaining increasing acceptance in Canada, having considerable potential compared to in situ concrete construction, particularly in providing wider possibilities for concrete construction in cold weather. The Division of Building Research has therefore been interested in precast concrete construction for some time and more recently has initiated an active research programme on the connections between precast concrete members, such connections representing one of the major problems of this method of construction.

Great efforts and advances have been made in this form of construction in other countries including those behind the Iron Curtain. In order to make information on these advances more readily available in Canada the Division of Building Research is providing translations of papers in this field in their series of Technical Translations.

The present paper from the U.S.S.R. reports on studies made there to attempt to standardize and economize on connection details for large panel residential construction in precast concrete. It is thought that similar problems may face designers in Canada.

The translation has been prepared by Mr. G. Belkov of the Translations Section of the National Research Council whose contribution is gratefully acknowledged.

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R.F. Legget
Director

NATIONAL RESEARCH COUNCIL OF CANADA

Technical Translation 1196

Title: Standardization of inserts for precast reinforced concrete units of large panel residential buildings

(Tipizatsiya zakladnykh detalei sbornykh zhelezobetonnykh elementov zhilykh krupnopanel'nykh zdanii)

Authors: M.I. Kholmyanskii et al.

Reference: Beton i Zhelezobeton, (8): 368-375, 1964

Translator: G. Belkov, Translations Section, National Science Library

STANDARDIZATION OF INSERTS FOR PRECAST REINFORCED CONCRETE UNITS OF LARGE PANEL RESIDENTIAL BUILDINGS

The correct choice of the type of inserts to be used in the designing of large panel buildings is of great importance. However, up to the present time there have been no unified initial data for selecting and calculating inserts and they are worked out by each designing organization by themselves. This has led to a large number of types of inserts being used at the present time. In the Moscow building material industry alone the number of insert types is more than 200. Under these circumstances there is no use talking about mechanization of quantity production of these parts. As a result their cost and labour consumption are high. The absence in our standards of the necessary calculation data results in the fact that inserts are designed in many cases with a large safety factor which brings about an overexpenditure of metal but does not eliminate the possibility of faulty designs. Two examples are given in Fig. 1. In the joint showed in Fig. 1a the concrete is subject to crushing stresses which leads to deformation and splitting of the concrete. In Fig. 1b a case is shown where there is a gap of 0.5 - 1 mm between the insert plates and the concrete. When forces are transferred to such a joint there is early breaking of the concrete due to splitting by the anchors.

The inserts should be standardized just as the precast parts of buildings were. Glavleningradstroi (Chief Leningrad Construction Enterprise) standardized the inserts for the basic types of buildings. It turned out that for all of the buildings it was quite sufficient to have 25 - 30 sizes and even less types of inserts. It is not difficult to imagine the effect of such a decrease in the number of inserts.

Having standard inserts of specific rigidity one can intelligently select the ratio between rigidity of the connections and the parts being joined.

The VNIIZhelezobeton and Mosproektstroiindustriya institutes in 1963 compiled an album of standard inserts based on the experimental and theoretical investigations of the embedding of reinforcement anchors in concrete as well as the testing of inserts.

The standardization of inserts is possible only if their size does not depend on the shape and size of the parts being joined. This conditions is fundamental. The part shown in Fig. 1a cannot be standardized since for all possible thicknesses of the parts being joined one would have to have different non-interchangeable inserts.

Standard types of inserts should include those which operate on axial forces, on any forces acting in a plane and on forces acting in any direction.

Since we are considering only the joining of panels it can be considered that in all cases the transfer of bending moment to the insert can be neglected.

In parts operating on axial forces the direction of the anchor should correspond or be close to the direction of the application of force. Let us compare two cases of the operation of the same insert which we will call a table. If the force is directed along the anchor (Fig. 2b) the anchor can be embedded in panels of any thickness; if the force is perpendicular to the anchor (Fig. 2a) the strength and give of the anchor is greatly reduced and will depend on the value of C - the distance from the anchor to the edge of the panel. When the value of C is small even the strongest reinforcement will not prevent lateral splitting off of the concrete under small loads.

Calculation for lateral spalling off of the concrete is almost impossible since the least change in shape of the panels introduces large complications. If the panels carry forces in a plane of unknown direction one must have two anchors perpendicular to each other, and in designing for space force one must have three orthogonal anchors.

The anchors of an insert should operate if possible in tension rather than compression. There are important defects in the operation of anchors in compression. Unavoidable random eccentricities result in the concentration of stresses where the anchor enters the concrete. If the concrete panel is thin, the concrete may split off resulting in loss of stability of the anchor. An anchor operating on tension does not have these defects. It has the property of automatically equilibrating random eccentricities and has greater rigidity. The operation of a panel with anchors in tension is more specific since forces are transferred only through the anchors and not through the anchors and plate, as for example in the case shown in Fig. 1b. At the present time we cannot determine directly the forces acting at panel joints in buildings of different types. Consequently for this purpose some other method must be used to take advantage of the extensive experience acquired in the construction of large panel buildings. The most specific characteristic of insert is the diameter of the anchor. It should be used as a basis for designing standardized inserts.

Inserts should have a rather specific displacement under load. This is possible only if the anchors are made of deformed bars.

The anchors of inserts should not be allowed to receive ever-increasing loads up to their failure. This could lead to overloading of the joined panels and putting the joints out of operation. The ideal working diagram for joints is one of elastic-plastic deformation. The material for anchors should be steel of sufficient plasticity.

Most of the precast units used in present-day large panel construction of buildings are plane, thin-walled panels operating under forces acting in their plane. Figure 3 shows schematic diagrams of possible joints of panels; there are comparatively few of them. The variety of inserts should, first of all, provide for these types of joints. The joining of parts that are subject to bending as a rule does not require additional types of inserts.

The factors considered above were basic for developing the range of designs of inserts.

The design schematics of the inserts were such as to ensure a good joint for all cases shown in Fig. 3. For this purpose seven types of inserts are required. The number of sizes of inserts was determined by several gradations of strength and the necessity of providing for the use of inserts in concretes of different types. For anchors we used deformed reinforcing steel type St. 5, 10 and 12 mm in diameter, and for plates we used plate steel or strip steel type St. 3, 6 and 8 mm in thickness.

The characteristics of the inserts for standardization of types are shown in Table I. For each type of insert an indication is given of the bearing capacity for use with concretes of the following (cube) strengths 50, 75, 100 and 200 kg/cm^2. Consideration was given only to normal weight concrete, slag concrete and expanded clay concrete prepared according to the existing engineering specifications. Inserts with 1 and 2 anchors with lap welds are intended for receiving forces acting in the plane of the panel. The position and shape of the anchors are determined by the following considerations.

In type (a) Fig. 4, the anchor is placed in the same direction as the force, the anchor operates in tension and the concrete is not split off.

In type (c) the anchors are perpendicular to the force and the joint has high deformability and the concrete is subject to lateral forces. Type (b) on first glance differs little from type (a), however the insert in this case has greater pliability and reduced strength of the welded joint which operates not only to counteract shear as in (a), but on pulling away also (Fig. 5). The best is type (a).

Inserts T 11 and T 12 are designed for forces in one direction. So that they could sustain small forces perpendicular to the plate the anchors have a short bend (5 cm long) at an angle of 90° around a radius of D = 2.5 d. Inserts T 13 and T 14 with 2 and 4 anchors respectively are also designed for forces acting in one direction, namely axial force causing tension of the anchors.

The distance between the anchors is 60 mm as a minimum at which the load carrying capacity of the anchor in the concrete is not reduced by their proximity.

Insert T 15 is intended to receive equal forces in two directions: in the plane and perpendicular to the plane of the plate. There are two types of anchors with lap and butt type welds.

Inserts T 16 and T 17 with 3 and 2 anchors are designed for equal forces in 3 and 2 perpendicular directions.

For the first inserts of each type (when they are used in lightweight concrete with a strength of 50 and 75 kg/cm^2) the anchors are headed at the ends. The heading is carried out without changing the length of the anchor rods. To form the head the length of rod required is 2.5 d.

The use of standardized inserts, applicable to the diagrams shown in Fig. 3, are given in Fig. 6. The schematic 3a corresponds to Fig. 6a. On making the joint, inserts of type T 11 or T 12 can be used at the top and on the sides. Schematic 3b corresponds to Fig. 6b. The joint at the top can be made with insert T 17 preventing shift and breaking away of the panel. The lateral joint should be made with inserts fulfilling the same function as insert T 17. To prevent rotation of the panels with respect to each other inserts T 12 are placed on the outside. Schematic 3d corresponds to Fig. 6c. For joining at the top inserts T 13 or T 14 are placed in the middle of the through panel and T 12 in the butting ends. For lateral joints insert T 12 is used in the butt ends (by analogy with schematic 3a) and in the middle inserts T 13 (T 14) are used. In this case the location of anchors of inserts T 13 (T 14) standing opposite each other is more complicated. If the panels are relatively thin the anchors of adjoining inserts should be welded together. For schematic 3f insert T 16 is used if the panel is thin and T 17 if the panel is thick. The joint is made with one metal plate. The remaining schematics of joints are solved by analogy with those described above.

To decrease the length of the metal plates the insert should be located as close as possible to the end of the panel but so that the distance from the edge of the concrete to the rod bent to an angle of ninety degrees is not less than about 30 mm.

The connecting plates should be as thin as possible so that if the panels shift from the plane the plates will not transfer to the inserts forces perpendicular to the plates.

The inserts are selected with respect to strength and rigidity. The characteristic of strength is the calculated resistance N_p; of rigidity - the displacement of the insert Δ under a force equal to the calculated resistance.

The value of N_p is taken to be the least of those obtained by calculation for rigidity and strength of the anchor in the concrete; the strength of the anchor itself; the tearing out strength of the anchor along with the surrounding concrete.

For standardized inserts the first case is used for calculation (of the rigidity of the anchor fixed in concrete).

As a normal displacement for the inserts the value of Δ = 150 microns is taken.

The calculated value for displacement is determined from the formula

$$\Delta_p = \Delta \cdot c \cdot k_1,$$

where c - the uniformity coefficient of the concrete which according to Table IV of SNiP II-A.10-62 is equal to 0.45 when the concrete is subject to forces of tension;

k_1 - a design coefficient taking into account the pliability of the metal plate of the insert, which from experimental data is taken to be 0.80.

The rigidity of the inserts is calculated from graphs showing the dependence of displacement Δ on forces P constructed for anchors of the A-II* class of various diameters and for various strengths of concrete.

The strength of the embedding is determined from graphs showing the dependence of the maximum stresses σ_{max} on the depth of embedding l.

The calculated load on the inserts P_p is determined by the formula

$$P_p = N_p \cdot m_1 \cdot m_2,$$

where m_1 and m_2 are coefficients of operating conditions. The coefficient m_1 is taken to depend on the angle φ between the direction of the force acting and the direction in which the concrete was placed; coefficient m_2 is taken to depend on the place where the concrete was prepared.

The operation of the inserts is determined in the first place by properties of the embedding of the anchors in the concrete. The determination of strength and pliability of the inserts does not involve any difficulty** if the physical constants (α and B) are known, which characterize the interaction between the anchor and the concrete.

The experimental determination of these constants for a number of important cases was carried out at the institute of NIIZhelezobeton by

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* Translator's note: Probably T 11.

** M.M. Kholmyanskii. Calculation of centrally reinforced prisms for bond. Trudy NIIZhelezbetona, no.4, 1961.

V.M. Kol'ner, Sh. Aliev and B. Gol'dfain. Table II gives the values of α and B for conditions under which the calculated loads and displacements were computed.

Determination of the strength σ_{max} of the anchor in the form of a straight deformed bar from the depth of embedding is carried out with the graph showing the dependence of σ_{max}/k on l/a shown in Fig. 7. The auxiliary parameters k and a are expressed by α and B, the diameter of the reinforcing rod D, and the modulus of elasticity of the steel E, and are obtained with formulae:

$$k = \sqrt{\frac{4BE}{\alpha D}}; \quad a = \frac{E}{\alpha k}.$$

In Fig. 7 the dotted line shows the theoretical curve, the solid line the curve adjusted with respect to experimental results (see above-mentioned investigations of V.M. Kol'ner et al.).

The characteristics of Δ_a, the pliability of the insert, can be determined by the relationships between σ_0/k and l/a for different values of $\alpha\Delta_a$ shown in Fig. 8 and perfected by the above-mentioned experiments.

When a head is set on the end of the rod its effect is taken into account by the parameter β which characterises the operation of a rod with a head.

Experiments shows that the greatest rigidity is ensured by rods with smooth rounded heads. Since the setting of a head of a required shape does not present any difficulties one should plan on barrel-shaped heads. The value of beta for heads of this shape were determined experimentally by E. Gol'dfain. Table III shows the value of β for heads with a set of C = 5 mm.

Knowing α, B and β, one can determine Δ_a from Table IV where the values of $\alpha\Delta_a$ depending on σ_0/k are given for 11 values of β and 6 values of l/a.

If heads are formed on the ends of anchors a check should be made of the strength with respect to pulling out of the anchors along with the concrete. As a rough approximation one can take the angle of 45° as a safety value for the slope of the cone.

The experimental checking of the operation of the standardized inserts was started in 1962 and is continuing at the present time.

Preliminary results of testing of specimens are shown in Table V.

Since the resistance to forces acting perpendicular to the plate did not evoke any doubt, all inserts were tested for displacement with the purpose of determining the effect of the value of C - the distance from the edge of the concrete to the axis of the anchor - on rigidity and strength. Values used ranged from 50 to 290 mm.

In the first two series a check was made of the strength of concrete R and the depth of embedding l. Specimens of the third series differed in that before the usual test (by the schematic shown in Table V) the inserts connected by metal plates were subjected to displacement along the plane perpendicular to the plate.

For analysis of the results of the test they were compared with the results of the calculations. Here the following suppositions were made.

Forces are distributed between the anchors uniformly; the depth of embedding of the anchors is equal to their free length, i.e. it is measured from the end of the welded joints; the plates of the insert are not deformable.

As seen from Fig. 9a and b the experimental relationship between the maximum load and strength of the concrete and depth of embedding are very close to the theoretical values. Attention is drawn to the high strength of the inserts with long anchors.

Figure 10a, b, and c show graphs of the relationship between the displacement of the inserts Δ and forces P for three series of specimens. In most cases the actual pliability of the inserts is somewhat greater than the calculated value.

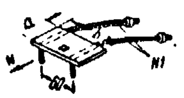
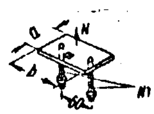
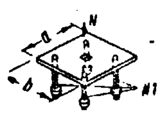
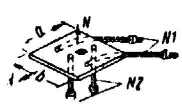
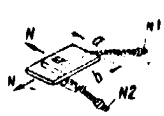
Testing of specimens of the third series show that the preliminary displacement of the insert does not cause any deterioration in the operation of the anchors. As seen from Fig. 10c, even with a relative displacement reaching a value of 12 - 15 mm there was no noticeable decrease in the rigidity.

From Fig. 9c it can be seen that the strength of the insert depends primarily on the value of C. This relationship is such that for the conditions under consideration (approximately when C = 130 mm) the strength of the insert equals the bearing capacity of the anchor metal. When C is decreased there is a sharp decrease in strength.

In Fig. 11 the results of the testing of the break-away detail for shear strength are compared with the results of testing the displacement detail. In all cases the displacement detail, as could be expected, turned out to be more rigid. Increasing the value of C leads to some decrease in pliability. However, when C = 270 mm the pliability of the break-away detail is approximately twice that of the displacement detail.

Table I

Characteristic inserts

Name of insert	Diagram of insert	No. of insert	Plate (Steel 3) a in mm	Plate (Steel 3) b in mm	Plate (Steel 3) δ in mm	Anchor (Steel 5) ø	Anchor Length l_1 in mm	Anchor Length l_2 in mm	At R kg/cm² 50 N, kg	At R kg/cm² 75 N, kg	At R kg/cm² 100 N, kg	At R kg/cm² 200 N, kg	Weight of insert in kg
T11		1	60	60	6	10п	260	—	400	450	550	1200	0,320
		2			8	12п	260	—	—	—	750	1850	0,457
T12		1	60	100	6	10п	260	—	660	740	900	2050	0,607
		2			8	12п	260	—	—	—	1250	3100	0,839
T13		1	60	100	6	10п	180	—	660	740	900	2050	0,501
		2			8	12п	180	—	—	—	1250	3100	0,689
T14		1	100	100	6	10п	180	—	1100	1250	1500	3350	0,907
		2			8	12п	180	—	—	—	2100	5150	1,250
T15		1	100	100	6	10п	200	180	660	740	900	2050	0,937
		2			8	12п	200	180	—	—	1250	3100	1,290
T16		1	60	100	6	10п	200	180	400	450	550	1200	0,640
		2			8	12п	200	180	—	—	750	1850	0,889
T17		1	60	100	6	10п	260	200	400	450	550	1200	0,568
		2			8	12п	260	200	—	—	750	1850	0,786

<u>Note</u> In light concretes of 50 and 75 kg/cm² anchors with set heads are used.

Table II

Distance of rods in mm	Cube strength of concrete in kg/cm²							
	Light concrete				Normal concrete			
	50		75		100		200	
	α	B	α	B	α	B	α	B
10	87	63	137	96	43	77	121	154
12	-	-	-	-	54	97	152	193

Table III

Distance of rod in mm	Cube strength of concrete in kg/cm²			
	Light concrete		Normal concrete	
	50	75	100	200
10	0.10	0.12	0.36	0.43
12	-	-	0.22	0.26

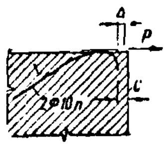
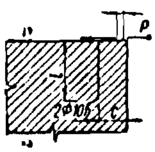
Table IV

Value of $\alpha\Delta_a$

σ_0/k	l/a \ β	0,0	0,2	0,4	0,6	0,8	1,0	2,0	3,0	4,0	5,0	10,0
0,5	0,5	–	1,75	1,05	0,79	0,67	0,59	0,42	0,37	0,34	0,32	0,26
	1	–	1,13	0,85	0,73	0,67	0,63	0,53	0,49	0,47	0,47	0,44
	1,5	1,10	0,83	0,75	0,69	0,67	0,65	0,69	0,58	0,56	0,55	0,55
	2,0	0,77	0,72	0,70	0,67	0,67	0,65	0,62	0,61	0,61	0,60	0,60
	3,0	0,68	0,65	0,65	0,65	0,65	0,65	0,65	0,64	0,63	0,63	0,63
	4,0	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
1,0	0,5	–	4,65	2,48	1,97	1,47	1,28	0,88	0,76	0,69	0,63	0,56
	1,0	–	4,11	2,35	1,85	1,61	1,49	1,19	1,10	1,04	0,96	0,94
	1,5	–	3,44	2,20	1,79	1,69	1,59	1,39	1,32	1,28	1,24	1,23
	2,0	–	2,64	2,07	1,82	1,73	1,73	1,51	1,49	1,46	1,44	1,43
	3,0	2,00	1,85	1,83	1,73	1,73	1,73	1,70	1,67	1,65	1,65	1,65
	4,0	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73	1,73
1,5	0,5	–	–	4,00	2,88	2,32	2,00	1,37	1,17	1,07	0,99	0,86
	1,0	–	–	4,28	3,16	2,73	2,41	1,88	1,74	1,62	1,49	1,46
	1,5	–	–	4,47	3,47	3,05	2,78	2,31	2,19	2,10	1,99	1,98
	2,0	–	–	4,40	3,61	3,25	3,10	2,64	2,54	2,47	2,41	2,38
	3,0	–	–	4,0	3,75	3,40	3,38	3,20	3,15	3,08	3,05	3,00
	4,0	–	3,87	3,68	3,61	3,50	3,42	3,41	3,40	3,40	3,40	3,40

Table V

Characteristics of specimens and results of tests for strength

Series	Schematic of test	No. of specimen	R in kg/cm	l in mm	c in mm	δ in mm	h in mm	P_{max} in kg	Reason for failure
I		1	340	150	40	8	75	9300	Split off of concrete prism
		2			40			8360	Ditto
		3			40			10500	"
		4			40			8780	"
		5	140		45			5480	"
		6			45			4560	"
		7			60			5550	"
II		1	225	75	30	8	30	1200	Split off of concrete prism
		2		75			30	1400	Ditto
		3		150			60	6860	"
		4		150			60	6650	"
		5		250			100	10900	"
		6		250			100	8550	"
		7		350			140	12600	"
III		1	220	150	20	6	75	10200	Split off of concrete prism
		2						6500	Ditto
		3						8550	"
		4	100					4560	"
		5						4350	"
		6						5150	"
IV		1	200	190	50	8	—	865	Split of concrete
		2			50			1250	Ditto
		3			70			1970	"
		4			70			1760	"
		5	300		50			1100	"
		6			50			2150	"
V		1	140	150	270	10	—	7420	Failure at weld joint of rod
		2			270			8500	Ditto
		3			290			6340	"
		4			275			6860	"
VI		1	270	150	160	10	—	8050	"
		2			145			6300	No failure
		3			145			7500	Rod failure
		4			145			10400	Ditto
		5			95			6850	Concrete failure
		6			75			2490	Ditto

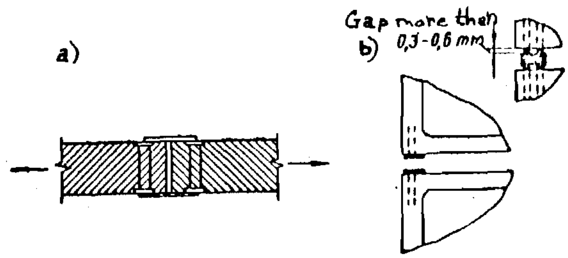


Fig. 1

Examples of joints

a) concrete under anchor subject to crushing
b) there is a gap between concrete and anchor plate

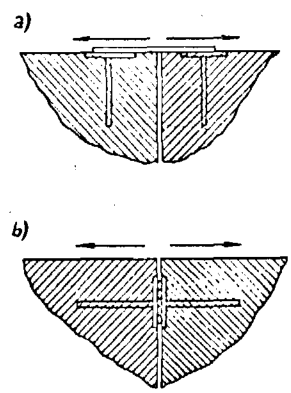


Fig. 2

Two cases of transfer of forces to inserts of the "table" type

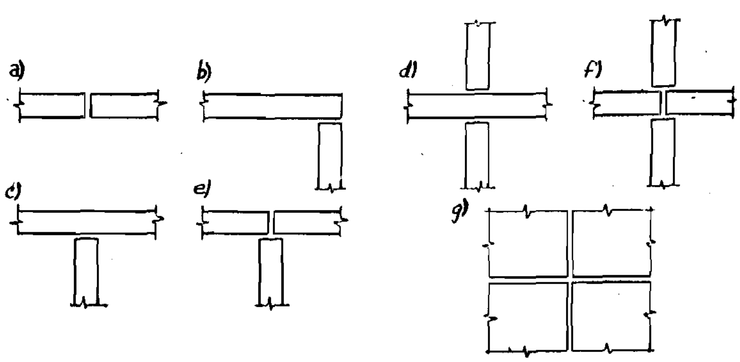


Fig. 3

Schematics of possible large-panel joints

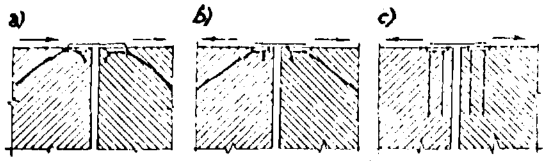


Fig. 4

Types of corner joints

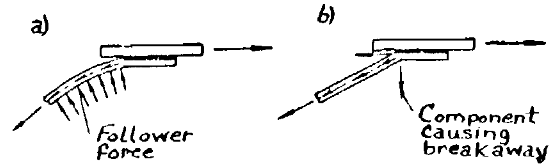


Fig. 5

Two types of anchors

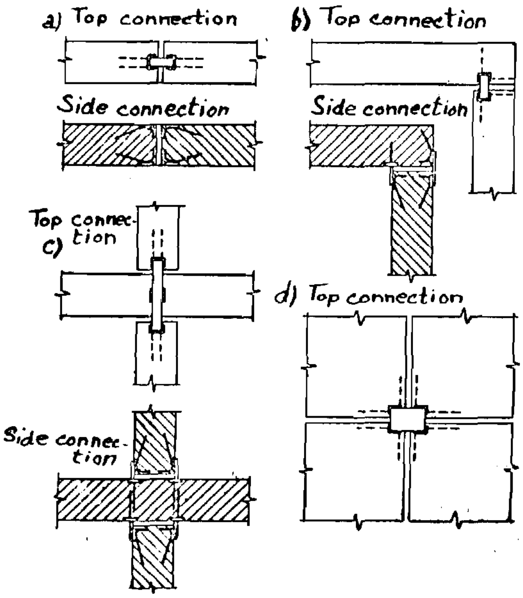


Fig. 6

Examples of joints using standardized inserts

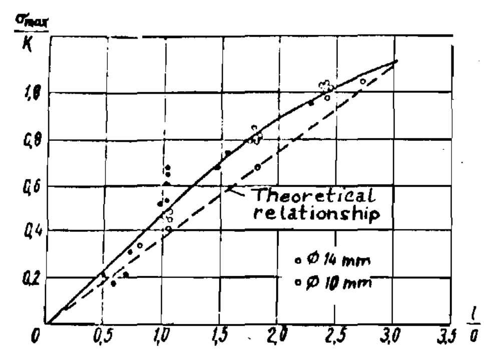


Fig. 7

Strength of anchor embedding

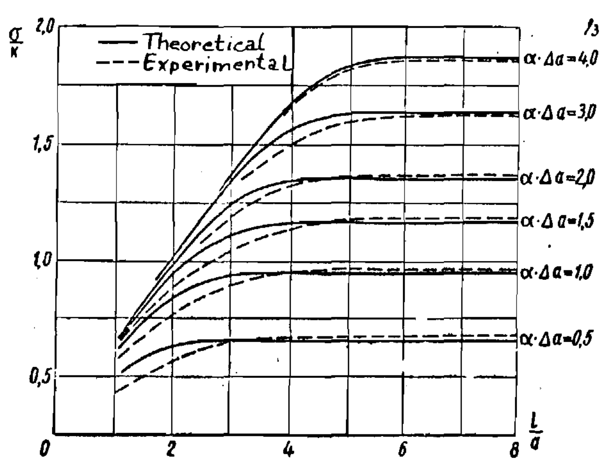


Fig. 8

Graphs for determining pliability of anchor embedding in concrete

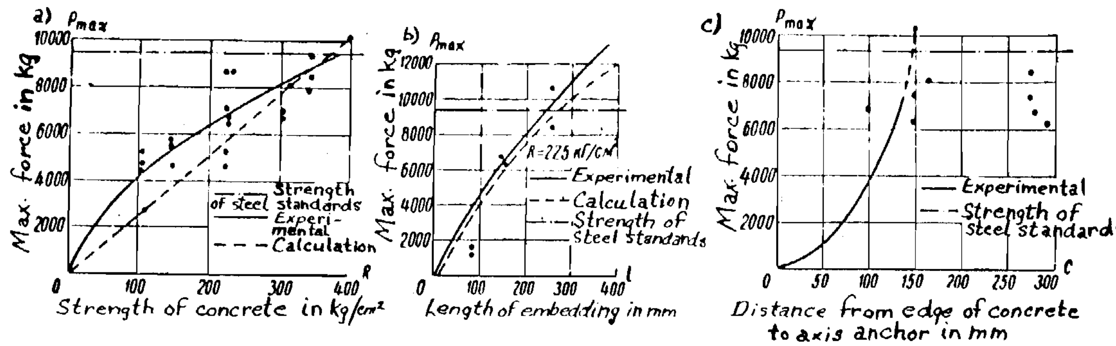


Fig. 9

Load-carrying capacity
of inserts

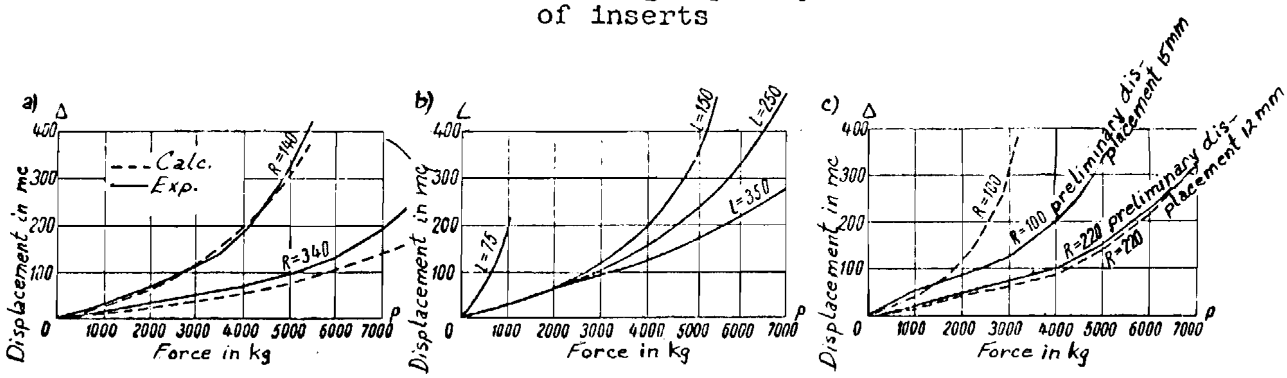


Fig. 10

Rigidity of inserts

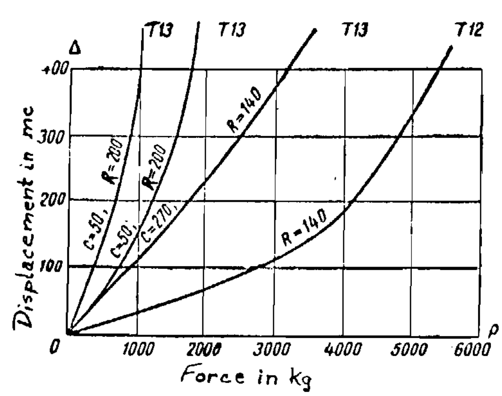


Fig. 11

Comparison of T 12 and T 13
for shear