

METHODS OF MONOLITHING JUNCTIONS IN EARTHQUAKE  
RESISTANT FRAMELESS LARGE PANEL BUILDINGS

by

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INTRODUCTION

Utilization of prefabricated reinforced concrete in construction is the basis of technical progress. For the last 10 years construction with the aid of large reinforced concrete panels has been practised on a large scale. Firm junctions present one of the most significant problems in prefab construction. It is especially important for the seismic areas where joints, apart from the strength of vertical load, wind, alterations in temperature or irregular setting are subjected to the influence of alternating loads.

Up till recently the junctions in large panel buildings have been executed by welding the laying parts. However, the experience showed that these parts are apt to corrosion, especially in outer wall junctions. Another fault of the junctions on laying parts lies in that when heat from arc welding is given off, temperature of laying parts is increasing more rapidly than that of concrete. This results in the pre-stressed condition arising from the contact of metal with concrete. This condition promotes separation of laying part from concrete.

Junctions on laying parts are also notable for low vibration strength. Economic indices of such junctions also leave much to be desired.

This is why, at present laying parts are used mainly as assemblage fastenings, while working couplings are executed by way of monolithing reinforcement edges from panels. The advantage of such couplings consists in that they are pliable, more

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economic and securely protected from corrosion.

#### DESIGN ASSUMPTIONS AND EFFORTS IN JUNCTIONS

The idea of joint action of carrying constructions for the seismic load secured by monolithing horizontal and vertical joints is basis of designing frameless large panel buildings for earthquake resistance (here and below buildings of up to five storeys with longitudinal and cross carrying walls will be discussed).

Taking into account that designing values of seismic load are rather approximate efforts in joints can be determined on the basis of assumptions considerably simplifying the design. Of particular importance is the assumption that, with the given direction of seismic load, the latter is translated in vertical diaphragms parallel to this direction.

The above-mentioned assumption provides for dealing with floors as non-deformed diaphragms distributing the load between walls in proportion to these rigidities. This is based on the presence of connections between the floor panels designed for displacement and normal efforts from seismic load, as well as on the close location of longitudinal and cross walls against which the floors rest and with which they are rigidly connected in outline.

Another simplifying assumption provides for each of the vertical diaphragms into which the building frame is divided to be considered as a cantilever mounted into the foundation and subjected to the action of horizontal loads on floor levels.

Displacement efforts are prevalent in frameless large panel buildings of up to 5 storeys in height. In vertical joints it is advisable to direct these efforts onto monolithed keys (Fig.1). With the presence of keys, formation of cracks resulting from the contact of concrete with panels does not interfere with the action of junction even if the cracks were formed all along the floor.

Key couplings in angles and wall intersections are of considerable importance. Their presence, in case they are designed for corresponding efforts. Allows to consider the cross walls as channel or tee-sections, formed by the cross wall and longitudinal wall parts adjoining it.

Arrangement of concrete keys for securing resistance of joints to displacement (in walls and floors) has been widely used in this country, as well as abroad (Japan, Roumania, Bulgaria etc.).

In horizontal joints arrangement of concrete keys for

perception of displacement efforts is not advisable. As was shown by investigation, firmness of concrete in panels manufactured in vertical position is as a rule less secure in its upper part than in the middle and lower parts.

Under these conditions arrangement of grooves for keys in the upper part of the panel is extremely undesirable, since packing of concrete under the keys is hampered which results in further deterioration of concrete quality in the upper part of the panel.

It is therefore that arrangement of keys in horizontal joints is not advisable. Displacement efforts in these joints should be perceived by vertical reinforcement connecting panels in height (Fig. 1) as well as by cohesion of mortar with account of friction forces, which is tolerated in the presence of vertical connections between the panels.

With large value of displacement efforts it may prove expedient to arrange a reinforced concrete projection in the upper part of the lower panel which engages a corresponding groove in the lower part of the upper panel (suggested by prof. S.V.Poljakov) (Fig. 2). Measures should thereby be taken to secure firmness of concrete in the upper part of the panel.

Normal straining efforts in horizontal joints, with the height of the building not exceeding five storeys, as a rule do not appear.

Appearance of normal efforts in vertical joints is determined by location of panels. In the joints of inner blind panels normal efforts from seismic loads can spring up as a result of unequal rigidity of panels. In all the joints of outer panels normal efforts may arise under the influence of alterations in temperature, while efforts of seismic load result from one presence of apertures in panels. In this case, when periaperture sections of adjoining panels are monolithed, piers are formed. Coupled with cross-pieces (lintels) form in their turn frame systems of posts-piers and collar-beam - lintels. It is the bending moment in frame posts from seismic load that causes normal efforts in vertical joints (Fig. 3).

In vertical joints of outer and inner panels normal efforts may also arise due to considerable length of compartments (commensurable with the length of seismic waves), stipulating the possibility of differential soil motions, when different parts of buildings oscillate in different phases.

#### INFLUENCE OF ALTERATIONS IN TEMPERATURE ON BEHAVIOUR OF PANELS AND JOINTS BETWEEN THEM

Behaviour of panels is subjected to strong temperature influence. Alterations in temperature serve to cause continu-

ous reversible deformations that make joints now open now thicken. Of considerable importance for the south of the USSR where most of the seismic areas of the country are concentrated is the winter temperature overfall when the difference between the outside and inside air temperature can go up to 25-30°.

Under these conditions, caving inside the premises is the prevalent mode of deformations, the medium part of the panel pressing itself to the floor, while the ends are withdrawn from the floor, thus opening the floor from the outside. This results in the appearance of displacement efforts over the upper side of the panel. These efforts are the stronger, the larger the elasticity modulus is of the panel concrete. In this respect, utilization of light concrete for manufacturing of outer wall panels is advantageous.

Displacement efforts resulting from temperature alterations cannot be perceived by the forces of friction and cohesion between mortar and concrete in joints only, especially in upper storeys. To perceive these efforts, connections between the outer panels, as well as between the panels and inner partitions in vertical joints and floor panels in horizontal joints, are engaged into action.

Connections of wall panels with cross partitions and with floor panels are designed to prevent the wall panel from caving inside the premises when being cooled outside. Caving of the panel is thereby changed in proportion to the square of panel length, while the turning angle changes in proportion to its first degree. That's why manufacturing of considerable length panels should be avoided.

To lessen the caving in of panels, as well as of their end turning angle, the connections that hamper these deformations should be rigid enough. Rigidity of connections secures to increase hermeticity of joints, to raise durability of large panel buildings and to improve their operation qualities.

It should be noted that, no matter how secure and firm the connections are, the joints in junctions between the outer panels, as well as between the outer and floor panels, will be broken through a number of reasons. This will inevitably be accompanied by appearance of cracks over the contact between the filling concrete and the panel. However, as was shown by nature observations, breakage of junctions occurs mostly on the outer side. It is quite natural, since the deformations, stipulated by cooling the outer surface of the panel cause the opening of vertical joints outside. Under these conditions, cracks on the inner side of the panel will be closed. In case the junction could be securely hermetized from the outside with the aid of, say, some elastic "non-aging" materials possessing durable qualities of mechanical compensation, cavings of the panel inside the premises would not be endanger

the security of junctions. As for the existing methods of hermetizing junctions, the deformations of panels should be limited in every way. This can be reached with the aid of connections between the outer panels with floor panels and inner panels.

#### NUMBER OF CONNECTIONS BETWEEN PANELS OVER HEIGHT OF FLOOR

Conjugate panels in separate sparsely located points create extremely undesirable dangerous concentration of efforts. Even in non-seismic areas not less than three connections are planned over the floor height.

Location of junctions in 3-4 levels answers the requirements of uniform distribution of efforts in junction and thus ensure the secure perception of temperature tensions.

In addition to that, the reinforcement edges closely and uniformly located over the height of joint secure to increase firmness of contact between the new and old concrete.

Of no small importance is the above-mentioned location of connections in respect to the resistance of buildings to irregular precipitation, since in this case equal firmness of junction and panel can be reached more easily.

If we take into account that normal efforts with elastic action of the junction occur in accordance with the triangle law, the strongest efforts should be perceived by connections most remote from the middle of the panel height. That is way carrying capacity of these connections should be much more considerable than that of the intermediate connections. To facilitate the assembly, intermediate connections can be executed by mounting the reinforcement ends (loops, anchors etc.) into concrete without connecting them to each other.

#### REQUIREMENTS OF MONOLITHED JUNCTIONS

Based on the above-given considerations, as well as on the experience of designing, construction and operation of large panel buildings, the following requirements can be shaped of monolithed junctions in earthquake resistant large panel buildings.

I. The designing displacement efforts should be conveyed to keys, chequered surface etc. in vertical joints, to the edges of vertical reinforcement, with 7-8 seismicity force, in horizontal joints, while, with larger seismicity, the efforts will be directed both to reinforcement edges and to reinforced concrete projections in the upper parts of the panels.

In horizontal joints, with insufficiency of reinforcement

edge sections, mortar cohesion with concrete, as well as friction force, may be taken into account.

To increase the section and rigidity of reinforcement which perceives displacement in horizontal joints, some additional slanting rods should be welded to the main rods. The welding is done when assembling the reinforcement of upper panel (Fig.4).

Normal efforts both in horizontal and vertical joints should be conveyed to reinforcement edges connected with each other in this or that way.

2. With due account of the fact that interstorey floors will secure invariability of the building outline in the plan and distribution of seismic load between vertical diaphragms, the connections of floors with each other, as well as with wall panels, especially outer ones apt to temperature deformations, should possess high firmness and inconsiderable deformativity.

3. Connections between the panels should be, if possible, direct and one-stepped. The fault of multi-stepped connections lies in slipshod operation and increased deformativity.

4. To avoid perilous concentration of tensions in connections and to promote contact between new and old concrete thus securing equal firmness of junction and panel, the connections should be located not less than in three-four levels over the height of the floor.

5. The junction working zone must be situated on the inner part of the outer panel where contracting tensions arise, when the panel is cooled.

6. The conjugate structure should not hinder free filling of junction with concrete.

7. To secure continuous transmission of efforts within the confines of the building in horizontal and vertical directions, the reinforcement edges in junctions, with seismicity strength of 8 and 9, should present extension of panel reinforcement (Fig.5). For this purpose, to reinforce the panels, frames should be used located in accordance with location of connections and equally firm with the latter.

With seismicity strength 7, utilization of "floating" connections is tolerated, on condition that they are securely fastened in panels (Fig.1).

8. Horizontal joints between panels should be executed on mortar. To secure compact filling of joint with mortar, the ineffective and labour consuming manual way of laying the mortar

should be replaced by mechanized operation, particularly by the method of humid guniting elaborated, tested and inculcated industrially in the USSR by "Industrojprojekt".

It goes without saying that measures on increasing firmness of junctions should be accompanied by entire complex of protective measures which secure normal action of junctions as well as proper operation qualities of the building.

Selection of the most rational types of monolithed conjunctions should be done on the basis of the above-mentioned premises.

At the same time, these conjunctions should answer the requirements of technology and assembly convenience.

The two above-mentioned requirements very often run counter to each other.

Seeking to simplify as far as possible manufacture of panels, we sometimes get conjunctions comparatively complicated in assembly. And on the contrary, at the expense of more complicated manufacture of panels the conjunctions more convenient in assembly can be obtained. It seems that the second way has been given preference in pre-fab construction of factory-made panels.

So, these are the requirements to be answered by monolithed junctions of frameless large panel buildings.

The main requirement to be answered is that conjunction should correspond to its basic designation, i.g. ability to resist the designing efforts of displacement and tension. From this point of view the junction between the reinforced concrete panels should also be made of reinforced concrete so that straining efforts could be conveyed from iron to iron, while contracting efforts from concrete to concrete. The displacement efforts can thereby be perceived by concrete keys, reinforcement edges etc.

A junction with reinforced edges connected by welding is a typical reinforced concrete junction.

Junctions like this are provided for in the joints of large panel buildings designed in the USSR for the city of Kabul (Afghanistan) (Fig.6).

In reinforced concrete welded junctions the straining efforts are conveyed from rod to rod either directly or with the aid of laps, the junction in this case being considered as direct, one-stepped junctions. This is the advantage of reinforced concrete junctions. Another advantage lies in their high resistance to displacement. In case the joint has no keys, the action of the junction for displacement is secured by re-

sistance of reinforcement edges considered as cross rods (yokes) of the beam (with sufficient number of reinforcement edges).

With the presence of keys in junctions, concrete resists the displacement, the reinforcement, prior to appearance of cracks from concrete section, increasing resistance of the junction to displacement efforts, while after the crack have appeared, retaining ability of the junction to partially perceive these efforts. To increase resistance of concrete to displacement, reinforcement frames are mounted into the keys, as it was done, for instance, with Kabul junctions (Fig.6).

Taking into account that junctions on welded reinforcement edges have advantage over other types of junctions, they should be used wherever high firmness and reliability is required and wherever the welding can be executed in position ensuring its quality.

Proceeding from the above-mentioned considerations, welding of reinforcement edges is absolutely necessary in horizontal joints where it can most securely ensure vertical connections between the panels and action of reinforcement for displacement. It also enables to calculate friction forces in those floors where connections are to be formed capable of stiffening floors as diaphragms. Friction forces are also calculated in the connections of floors with outer walls to secure non-deformity of the building outline, as well as perception of temperature efforts.

Special firmness and reliability of connections between the floors and walls is of considerable significance also because, when coupled with welding in horizontal joints and in the junctions of floor panels, it ensures connection between the carrying constructions of the building and, thanks to it, enables to lower to some extent the requirements to be answered by arrangement of junctions in tight, almost inaccessible vertical joints.

To ensure proper quality of welding in joints like this, is much more difficult. That is why here the welding of reinforcement edges in deep key grooves should be done only under strong designing efforts.

Under the more moderate efforts, junctions in vertical joints should be executed by reinforcement edges mounted into the junction concrete. In case the concrete has not been reinforced, the edges are connected to each other, as it was done when erecting first pre-fab buildings in Tokyo. The edges may not be connected to each other at all, if the junction concrete has been reinforced, for instance, with a spiral all through the height of the floor, as it is done in the buildings erected by the french Kameau company (Fig.7).

Reinforcement can also be let out of the panel in the shape of loops connected to each other in different ways.

In the loops do not project over the side of the panel, connections should be arranged of either yokes and rods or elastic pins mounted into the openings at intersections of yokes with loops (Fig.8). The loops projecting over the panel side can be connected by vertical rods mounted into the openings at intersections of loops (Fig.9), by short spirals screwed on the loops (as was suggested in the USSR by Candidate technical sciences J.A.Izmajlov) (Fig.10) etc.

The authors of the report have devised universal junctions on edges of loops, connected by welding under strong designing efforts and by short spirals under less considerable efforts.

In panels manufactured with high precision (for instance, by vibro-rolling) the junctions can be executed on bolts.

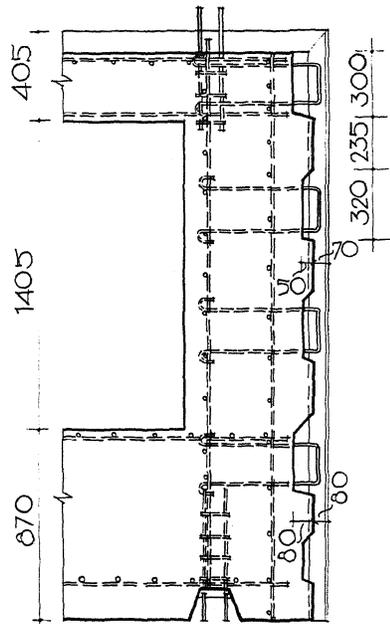


Fig. 1 PANEL WITH KEY GROOVES AND REINFORCEMENT EDGES

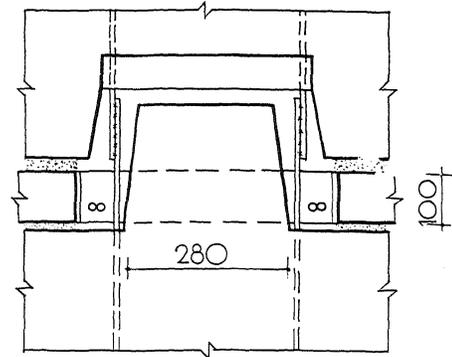


Fig. 2 REINFORCED CONCRETE PROJECTIONS IN PANELS

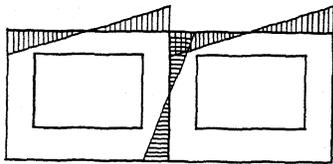


Fig. 3 BENDING MOMENTS IN PANELS WITH SEISMIC LOADS

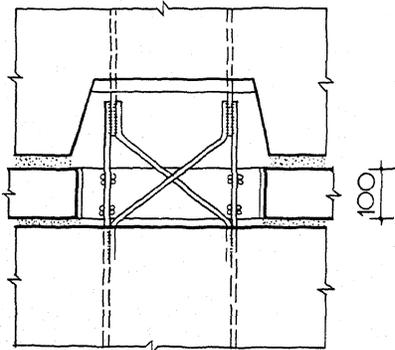


Fig. 4 STRENGTHENING OF REINFORCEMENT EDGES IN HORIZONTAL JUNCTIONS BY CROSS RODS.

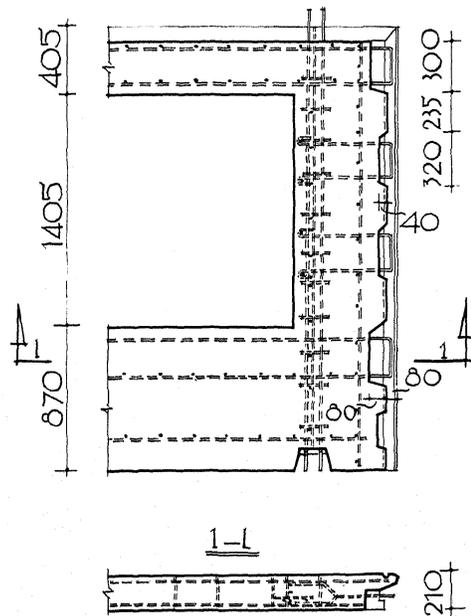


Fig. 5 PANEL WITH THROUGH REINFORCEMENT

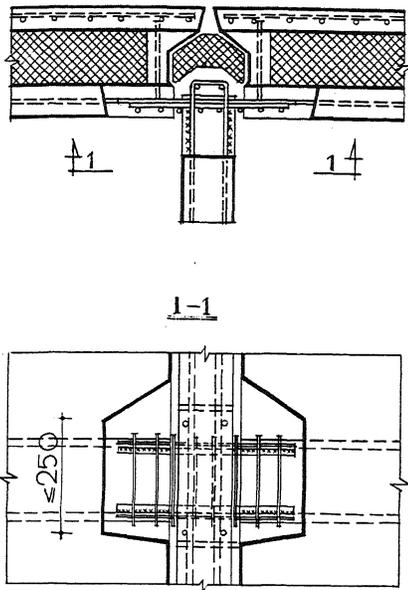


Fig. 6 JOINTS ON WELDING OF REINFORCEMENT EDGES

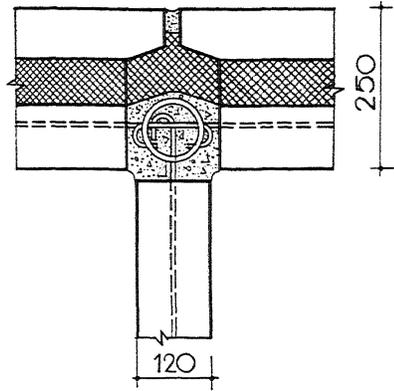


Fig. 7 JOINT OF KAMEUE TYPE

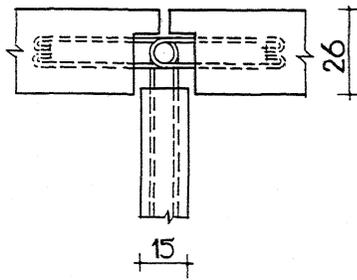


Fig. 9 JOINT WITH OVERLAPPING LOOPS

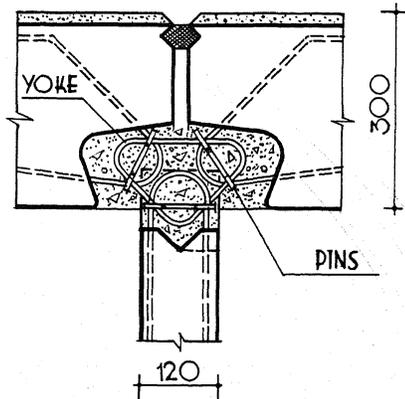


Fig. 8 JOINT WITH YOKE AND PINS

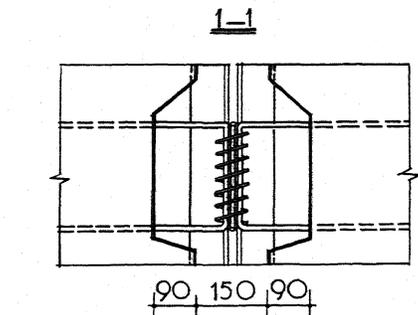
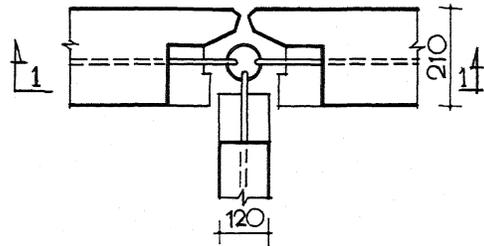


Fig. 10 JOINT WITH LOOPS CONNECTED BY Y.A. IZMAILOV SPIRALS