THE NEW SHEAR WALL WITH DRY FRICTION JUNCTIONS FOR EARTHQUAKE ENGINEERING

DEPREM MÜHENDİSLİĞİNDE
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ABSTRACT

Shear walls in frame buildings are used to provide horizontal stiffness and to reduce deflections under seismic actions. As opposed to solid precast shear walls connected with adjacent columns by on site welding or cast-in-place shear walls, in recent years increasingly more new designs of shear walls possessing the ability to adapt are developed. In doing so, junctions are artificially created where plastic deformations or dry friction can develop. Such designs result in intensive absorption of seismic energy. In the paper a new design of frictional shear wall patented by the author in Armenia is suggested. Investigation of the new shear wall was carried out and its performance was compared to that of a solid traditional shear wall under horizontal static loading.

STRUCTURAL CONCEPT OF THE FRICTIONAL SHEAR WALL

Frictional shear wall in the each floor consists of three parts within the limits of frames in the height of the building (Figure 1). The parts are: the basic middle precast R/C panel of trapezoid shape and two side cast-in-place panels of triangle shape, reinforced separately and concreted at the construction site. The basic middle precast R/C panel is mounted between two columns and has the slots along its inclined faces. There are slots also in the adjacent columns faces. These very slots prevent the triangular elements to come out from their plane at the horizontal loading. In the given design it is precisely these slots where dry friction occurring along them in the case of drift of the side elements, that are the junctions of seismic energy absorption. To make the downward shift of the side cast-in-place elements possible in vibrations of the building the gaps are created between their lower parts and the lower story slab.

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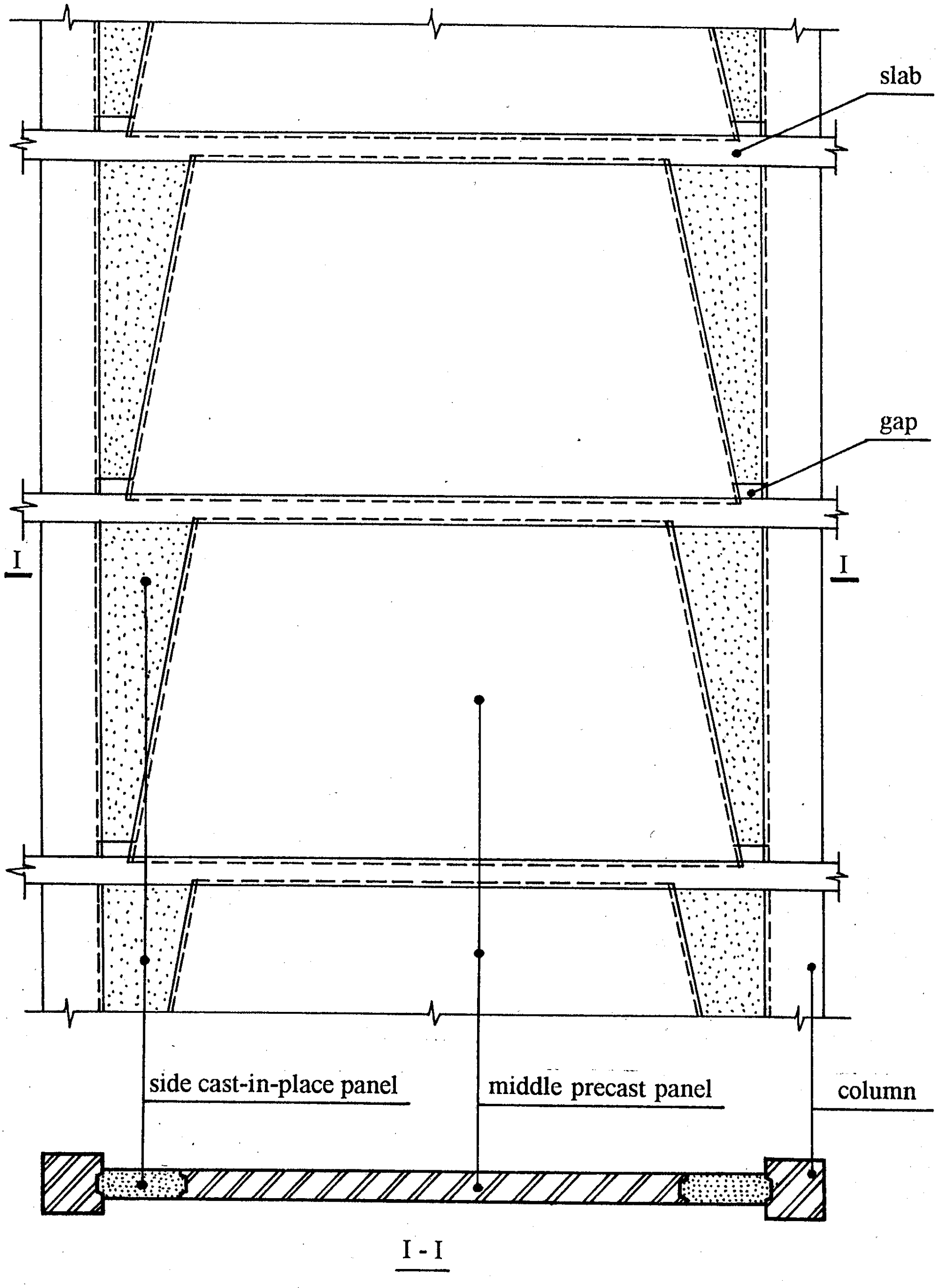

Figure 1. The design concept of the frictional shear wall

In an earthquake in the junctions between the side panels and basic panel and columns attrition of the contact surfaces will take place, thus resulting in reduction of stiffness of the shear wall. However, simultaneously with it, as there are provided inclined faces and lower gaps, triangular elements will gradually move down to take up new position. In doing so, friction forces in the junctions hinder the movement, and, therefore, absorb some part of the energy of seismic action. Besides, sealing of junctions due to the wedge action takes place, the initial stiffness of shear wall thus being restored.

COMPARATIVE STUDY OF THE BEHAVIOR OF CONVENTIONAL AND FRICTIONAL SHEAR WALLS UNDER HORIZONTAL LOADING

The suggested structural concept of frictional shear wall was studied by testing the R/C model specimens scaled 1/2. The obtained results were compared to those of tests on conventional shear wall. The experiments were carried out according to technique at parallel gradual testing of twin specimens under horizontal static loading. The specimens presented one story one span frames with shear wall panels mounted in their plane.

Static hysteresis loops were obtained and analyzed for both types of shear walls tested up to the failure stage (Figure 2). Energy absorption factors, calculated from hysteresis loops, are equaled 1.59 in average for conventional shear wall and 2.0 for the frictional one. Stiffness of the frictional shear wall in elastic stage is greater than that of the conventional one by 64%, while the loading capacity is less by 40%. In order to explain the revealed difference, hysteresis loops and the mechanism of shear wall failure under static loading should be necessarily compared.

On the one hand, in the elastic stage the frictional shear wall, due to beams and triangle elements being cast-in-place, which fact provides close contact in all height of the columns, performs as a monolithic structure. On the other hand, in the conventional shear wall panel is connected with columns by welding only in three points. These namely circumstances result in difference between stiffness characteristics. Since in the design concept accepted for the given case, the basic panel has no reinforcing or other connection to the beams, it has been not efficiently involved into performance under horizontal loading and its loading capacity was underused. The basic middle panel has been insignificantly damaged (Figure 3), while as the loading level increased, plastic deformations concentrated in the triangular elements, due to which the frictional shear wall loading capacity was low as compared to the conventional one.

DISCUSSION

By comparing the hysteresis loops one may note that for conventional shear wall the parts of the loops corresponding to the maximum displacements are extended, whereas the middle parts are thinner. It means that the maximum energy absorption in conventional shear wall takes place in the zone of amplitude values of displacement.

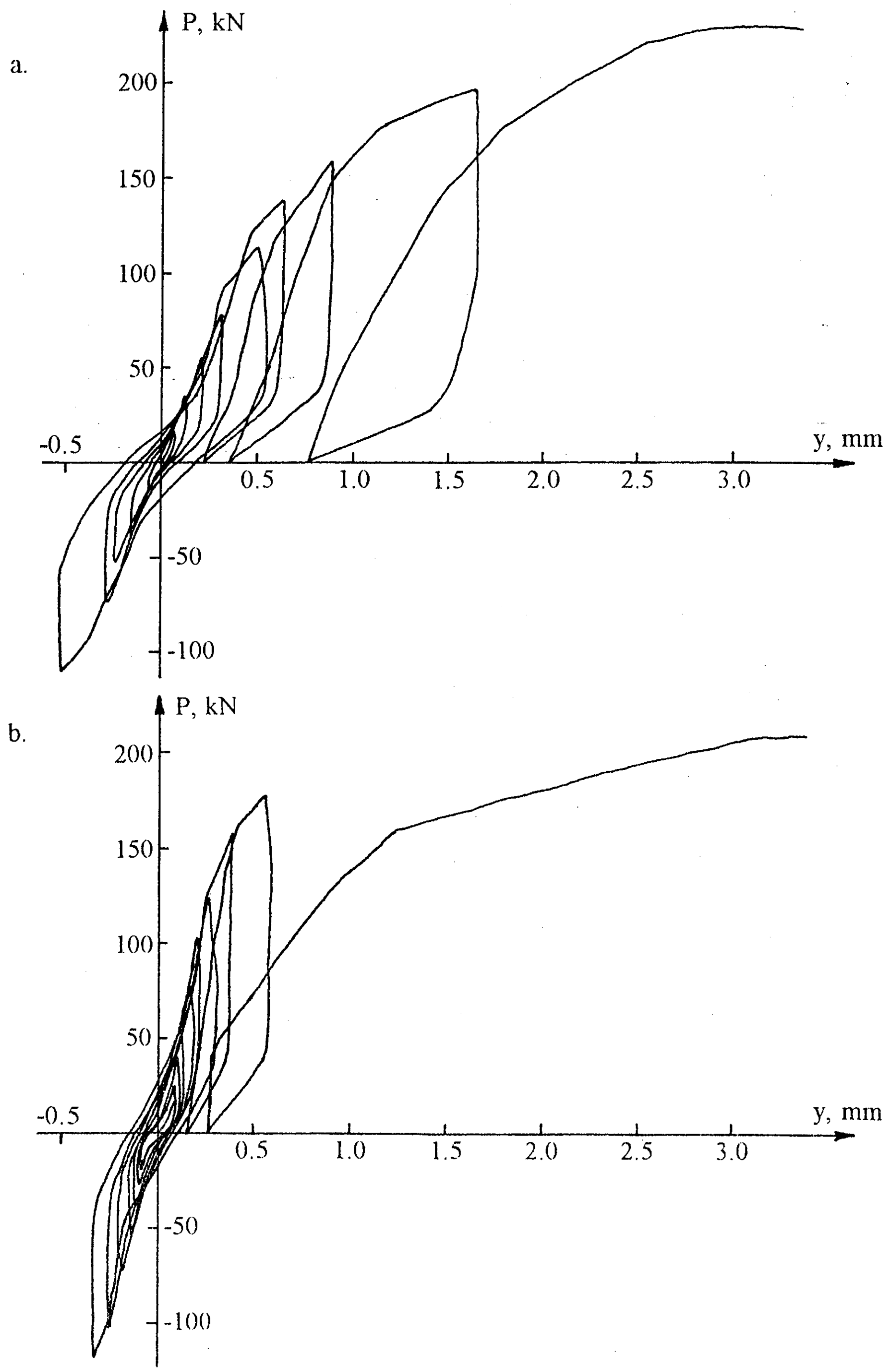

Figure 2. Restoring force characteristics of the conventional (a) and frictional (b) shear walls

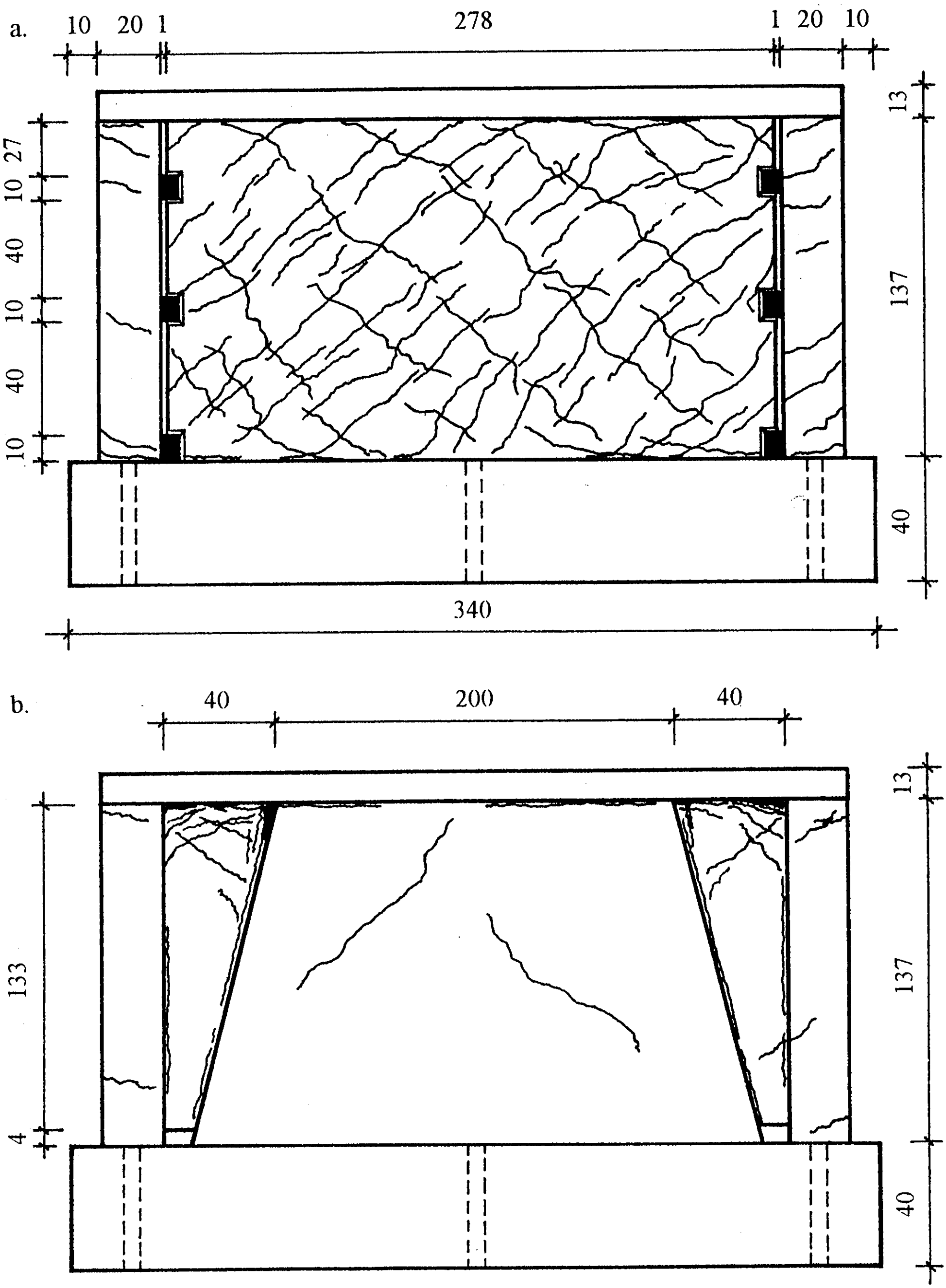

Figure 3. Distribution of damage in conventional (a) and frictional (b) shear walls after testing under horizontal static load

For frictional shear wall, vice versa, hysteresis loops are extended in the middle, in the zone of small displacements, when the structure passes through the initial equilibrium state. The matter is that at low level loading, when triangular elements (side panels) work in the elastic stage, rotation of these elements takes place alongside with horizontal displacement of the top of structure. Rotation is accompanied by non uniform opening of crack in junctions between the triangular elements and basic trapezoidal panel. Thus, a certain part of energy of external action is absorbed.

During the unloading triangular elements tend to return to the initial position, due to which not only the cracks in junctions are closed, but, what is more important, intensive friction, that prevents the elements from returning to the initial position, occurs in them. Simultaneously, in the state close to that of initial equilibrium, triangular elements are shifted down under their own weight. Additional energy is expended on these deformations, which is the obvious cause for extension of loops in the middle, as well as for the fact that energy absorption by frictional shear wall is by 26% greater.

Experiments have confirmed also the hypothesis that the frictional shear wall structure is able to restore its stiffness. It is easily seen from the plot of frictional shear wall performance, where inclination of hysteresis loops up to the plastic deformation stage remains almost the same. Contras tingly, as differentiated from conventional shear wall, the envelop curve for the frictional shear wall can be presented as a bilinear one.

At high level of horizontal loading in triangular elements along of their junctions with beam plastic deformations develop. Further, cracks occur also along the whole junction of the basic trapezoidal panel with the upper beam. This being so, in order to increase the loading capacity of the frictional sear wall in the future, structural connections of the basic trapezoidal panel to the beams should be necessarily provided. It will allow to increase the efficiency of the frictional shear wall, to transfer the most part of horizontal loading to the basic trapezoidal panel, the triangular elements functioning as zones of intensive absorption of seismic energy.

CONCLUSIONS

In R/C buildings together with conventional sear walls, as well as alone, frictional shear walls can be used, in which, due to artificially created zones, dry friction occurs in vibrations, thus bringing to increased dissipation of seismic energy.

Stiffness of the frictional shear wall in elastic stage is greater than that of the conventional one by 64%, while the loading capacity is less by 40%.

Frictional shear wall is able to restore stiffness close to initial one up to the moment when in triangular elements plastic deformations start to develop.

Loading capacity of the frictional shear wall is conditioned by strength of the side elements and horizontal junctions between the beams and the basic middle panel. Lack of reinforcement connection in these junctions results in the panel offering smaller resistance to horizontal load.

In order to increase the loading capacity of the frictional shear wall reinforcing connections between the basic trapezoidal panel and the beams should be provided.

The energy absorption coefficient of the frictional shear wall is greater than that of the conventional one by 26%.

Absorption of energy by frictional shear walls occurs not only at the expense of opening and closing of cracks in junctions between the side triangular elements and basic middle panel and columns, but essentially at the expense of dry friction occurring in these junctions when the structure passes through the initial equilibrium position.

The envelop curve of the frictional shear wall can be presented as bilinear with hardening, while of the conventional one as trilinear.