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Behaviour of semi-rigid prestressed connections of concrete structural elements under cyclic loading

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ABSTRACT: Concrete prefabricated skeleton, stiffened by shear walls to accept horizontal force influences, has presented itself as a very convenient structure for building in seismic regions. Characteristic way of column and floor-slab joint by prestressing enables elegant, secure and permanent joint under the influence of static and dynamic loadings. Numerous objects, built in Yugoslavia, survived without damages, the earthquake of 8^{o} and 9^{o} MKS. This paper describes the series of testings on the models where the concrete elements - column and floor slabs (beams) - were connected by prestressing and loaded by cyclic load to determinate the behaviour of this type of the joint.

1 INTRODUCTION

The prefabrication of a load-bearing structure consisted of precast reinforced concrete elements is conditioned by the existence of offective means for connecting of elements. For that reason, the connections are specially tested and analized. The stability of the structure assembled of precast elements to a great extend depends of the safety of connections. As a rule, the safety factor of a joint ought to be higher or at least the same as the safety factor of structure elements.

Prestressing is one possible way to achieve satisfactory connection between concrete precast elements. In Yugoslavia, as well as in some other countries, prefabricated concrete skeleton structure is readily employed in highrise building constructions. The joints in this building system, between columns, slabs and beams, are formed by the use of prestressing. In each floor plane, in both orthogonal directions, steel cables are placed to span the building from one side to the other, as they are being led through the ducts in column and the free space between adjacent floor-slabs, or frame's beams. The contact zone between floor-slabs and column is filled with rapid hardening mortar prior to tensioning of the cables. It is very important to understand the behaviour of this type of the structure: a precast concrete frame, where the prestressing is used as a tool for connectioning the precast elements. Playing with the intensity of the prestressed force it is possible to limit or obtain desired stiffeness of the joint. For this reason we have conducted a series of tests on models of that type of the joint in full size scale.

2 DESCRIPTION OF THE MODEL AND LOADING

The model concept chosen for the experiments was to fulfill the requirements for an easy unambigous analysis of the column-slab join functioning, for a number of different loading cases applied as: bending moment only, torsion moment only and simultaneous acting of both bending and torsion moments.

The joint model was the portion of the complete precast frame structure. It was consisted of a column element with a 3o/3o cm cross section stiffened by the 15 cm thick concrete wall (to avoid the influences of the column flexure) and the section of the floor-slab structure with corresponding edge girders. The floor-slab structure consists of two parts of 2o cm thick coffered floor-slabs with hollow bodies made out of rigid polystyrene foam to form the top slab 4 cm

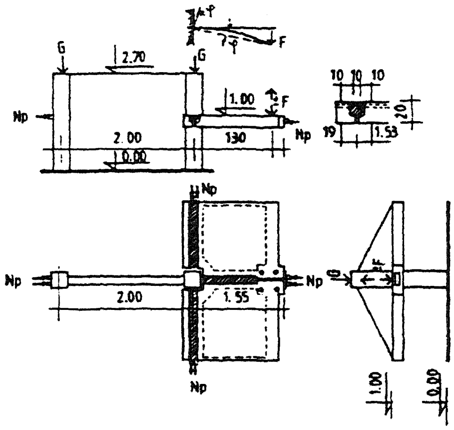


Figure 1. Disposition of the model

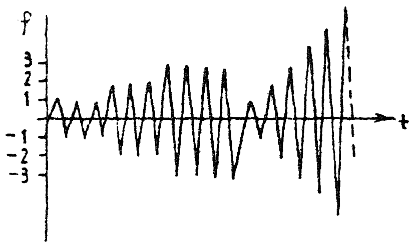


Figure 2. The treatment of the loading

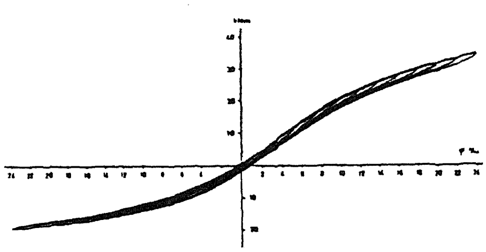


Figure 3. The hysteretic loop of bending moments

thick and the bottom slab 3 cm thick. The selected model provided the options of connecting floor-slabs with column by means of prestressing cables orthogonally to the wall or in the direction of the wall, or in both directions simultaneously. The position of the force acting on the joint was determined to provide the wanted loading: bending moment, torsion moment or both. Making use of measuring devices and the loading equipment, it was possible to keep the record of the force (moment) and deflection (rotation) changes. The model is conceptualized as the cantilever structure.

The prestressing cables, two in either of directions, were 4Ø7 mm wires made of steel 17oo/154o N/mm^2, the concrete compressive strength was 42 kPa and the prestressing force in each of the cables at the time of the tensioning was 18o kN. Model was equiped with the adequate measuring devices to record the deflections in defined points. The treatment of cyclic loading is presented schematically in the figure 2.

3 TESTS UNDER BENDING MOMENTS

The series of tests featuring the bending moment, caused by the cyclic loading, was conducted on models where the prestressing is achieved in the direction of concrete wall only, while the sideways prestressing was not introduced. During the tests all significant changes on the model was recorded. The cracks that had appeared in the slab for rotation values less or equal to +/- o.oo4 rad, would readily close as the structure has been unloaded. Beyond this limit value of the cracks would remain stable. The maximum rotations acquired were o.o25 rad. the cracks widths were around 5 mm, while the joint was still functional. The joint entered the plastic region for rotation values of o.oo2 rad. and the moment continued to increase until the rotation reached the values of o.oo8 to take the maximum of around 5o kNm, in the case where the force was in the gravity direction. For the case in the opposite direction, the same phenomena was noted to around 3o kNm. The recorded difference in maximum values of moments may be explained by the fact that the loading "neutral" point did not coincide with the loading "starting" point.
The hysteretic loop has a typical "S" shape as the envelope of the maximal bending moments. The maximal theoretical and experimental bending moments are very corresponding.

4 TESTS UNDER TORSION MOMENTS

For tests under torsion moments the position of loading was not altered, only the cables were tensioned in sideways direction relative to the wall. The difference in results were obvious considering the shape of hysteretic loop and the maximum value of torsional moment applied to the joint. Hysteretic loop acquired showed greater inclination toward the rotation axes, while maximum value of

Figure 4. The hysteretic loop of torsional moments

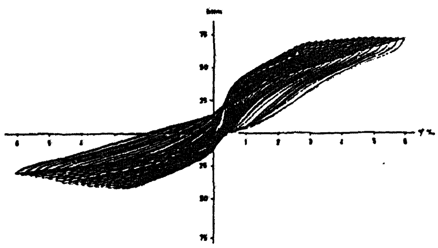


Figure 5. The hysteretic loop of simultaneous acting bending torsional moments

torsional moment, in case of the force acting in direction of gravity loads, amounted to 2o kNm, while in the opposite direction went as 3o kNm.

The appearance of cracks is characterised by their disposition. For the great values of rotations, cracks have appeared parallel to the connection between the floor-slab and the concrete cast in situ and even on the column. The plastic hinge was formed as the cylinder-like surface which represented the center point to the floor-slab rotation. The maximal values of theoretical and experimental torsion moments were corresponding satisfactorly.

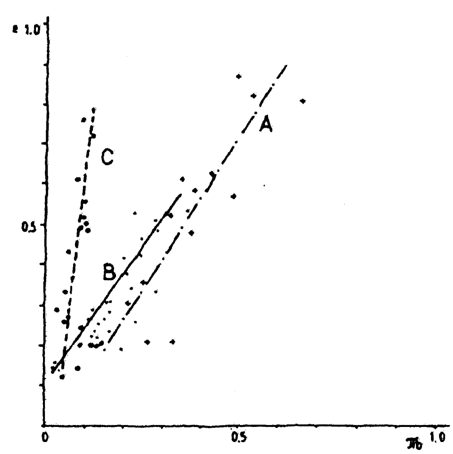
5 TESTS WITH SIMULTANEOUS TORSIONAL AND BENDING MOMENTS

Those tests were made on the models prestressed in both directions. The loading regime was equivalent to ones in the previous series of testing. Maximum values of moment was acquired for the rotation value of o.oo6 rad. and it amounted to 8o kNm in the case of loading acting in gravity direction. In the opposite direction the maximal value was 45 kNm for the rotation of o.oo5 rad. The maximal moment kept this values for rotations o.oo8-o.ol rad. and it decreased to 7o kNm (4o kNm) for rotations equal to +/- o.ol5 rad. The hysteretic loop describes the behaviour of the typical prestressed joint in precast frame as response of the cyclic loading. Even during the extreme rotation the functioning of the prestressed joint was preserved. This acquired rotation is the equivalent to the relative horizontal displacement in a single storey frame of 4.2 cm, while in lo storeys frame displacement of the top floor relative to the ground floor would amount to 42 cm.

The hysteretic loop characteristics, acquired from simultaneous action of bending and torsional moment, which is at the same time the realistic manner of the joint loading, point out to the significant capability for the energy dissipation during the cyclical loading. The diagram of correlation between the dissipated energy and rotation shows the satisfactory increasing in cases of cyclic loading with torsion moments and simultaneous, acticn of the torsion and bending moments. The same conclusion could be made for correlation between ductility and rotation. The certain plastic characteristic of the joint it is shown on the diagram of correlation between coeficient e, representing relation of dissipated energy and elastic work and plastic excursion which represent relation between plastic deformation and maximal plastic deformation of one cycle.

6 CONCLUSION

1. The shear bearing capacity of the joint,

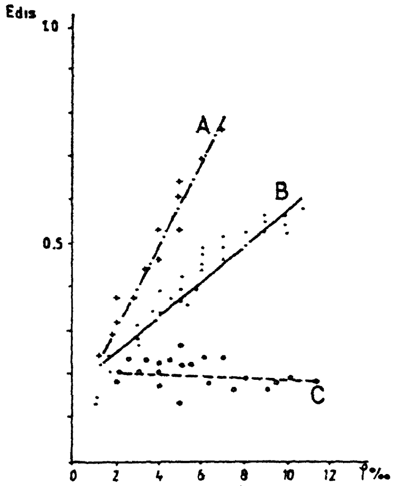


A - bending moment

B - torsional moment

C - bending and torsional moment

Figure 6. Diagram of correlation e - d



A - bending moment
B - torsional moment
C - bending and torsional moment

Figure 7. Anveloop of moments

meaning the capacity to accept vertical reactions, does not depend of the contact surface between concrete elements, but only on the existence and intensity of the horizontal forces - prestressing.

2. The tests with simultaneous action of both moment, torsion and bending, show quite bigger bearing capacity of the joint in the limit states which is more than the simple addition of separate action of the torsion and bending moments.

3. Using the energy parameters given from the analysis of the hysteretic loops, it proved that this type of prestressed joint has the necessary ductility for aseismic design; in the limit states has capability of necessary energy dissipation and has characteristics of a semi-rigid joint.

REFERENCES

Dimitrijević, R.: TECHNOLOGIA DE CONSTRUCCION IMS EN LA PRACTICA HOY, Proceding, XX Convencion Union Pan-americana de Asociaciones de Ingenieros, Habana, 1988

Dimitrijević, R.: PREFABRICATED PRESTRESSED SKELETON SYSTEM AS SEISMIC STRUCTURE IN HOUSING, Proceding, Catastrofes y sociedad, Madrid, 1989

Jurukovski, D.; Petrovski, J.; Bouwkamp, J.: FORCED VIBRATION FULL-SCALE TESTS ON FIVE BUILDINGS CONSTRUCTED BY INDUSTRIALIZED METHODS, Closing symposium on research on the field of earthqake resistan design of structure, Proceding, Dubrovnik-Cavtat, 1978

Petrović, B.; Petrović, S.: TESTING FULL-SCALE MODELS OF JOINTS BETWEEN FLOOR-SLAB AND SHEAR WALL DONE BY PRESTRESSING UNDER CYCLIC LOAD, Proceding, Congress FIP, London, 1978

Petrović, B.: TESTING OF MODELS OF SOME IMS ELEMENTS AND THEIR JOINTS, Proceding, Closing symposium on research on the field of earthquake resistent design of structure, Proceding, Dubrovnik-Cavtat, 1978