Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

Structural investigation on the seismic performance of precast mixed shear walls

H. Maniu
Building Research Institute, Department of Cluj, Romania

A. M. Ioani
Polytechnic Institute of Cluj, Romania

E. Tripa
Design Institute Hunedoara, Deva, Romania

ABSTRACT: Promoting in Romania a new type of 7 or 8 storey residential building, with a wholly precast structure, was preceded by an extensive program of theoretical analyses, structural and technological tests. The paper presents the characteristics of this new type of structure - already protected by an invention license - and it concentrates upon the way its seismic performances were evaluated. The experimental assemblage was achieved at a 1 to 2.5 scale, being tested under lateral alternate-reversed loadings, and both the up-to-failure behaviour and the work of column-column, column-panel and panel-slab-panel joints were studied. The test on the assemblage confirmed the good behaviour of the precast mixed shear wall, which allowed the use of this building system to the construction of over 1000 apartments in seismic areas.

1 THE NEW PRECAST SLAB STRUCTURE

In the attempt to solve the difficult problem of the construction of residential buildings, the correlation of the following factors has to be taken into consideration: the aesthetic architectural aspect, comfort and high-level facilities, changing of architectural layout, high quality of construction works and a lower cost. To meet these requirements, the Design Institute of Hunedoara proposed and obtained a license for this wholly-precast new constructive system of the slab structure type.

The structure consists mainly of long precast columns (a unit has between 5,40 to 11.40 m) and precast flat slabs. Promoting such a system in seismic areas was conditioned by the use of a certain number of shear walls, rarely distributed in the structure. In this solution, the structure, as a whole, can resist seismic lateral forces and meets the requirements for stiffness, ductility and energy dissipation, requested by the latest Romanian seismic design code, i.e. P 100-91 (1991).

In order to maintain the wholly precast character of the structure, the construction of the shear wall was accomplished by a R/C precast panel infill between the precast columns. The panels, by their vertical (column-panel) joints and horizontal (panel-flat slab-panel) joints, make up a mixed (dual) structure of the flange shear wall type. Due to its novelty, an experimental program was devised to test a large-size unit (2.02 × 1.62 × 5.95 m), consisting of two precast 5 storey mixed shear walls and of their precast flat.

2 TEST UNIT

The test assemblage was designed to model, at a 1 to 2.5 scale, the structural behaviour of a real precast shear wall with 8 storeys.

The unit elements are (figure 1):

- monolithic R/C foundation under each shear wall;
- precast columns, on 2 or 3 storeys each unit;

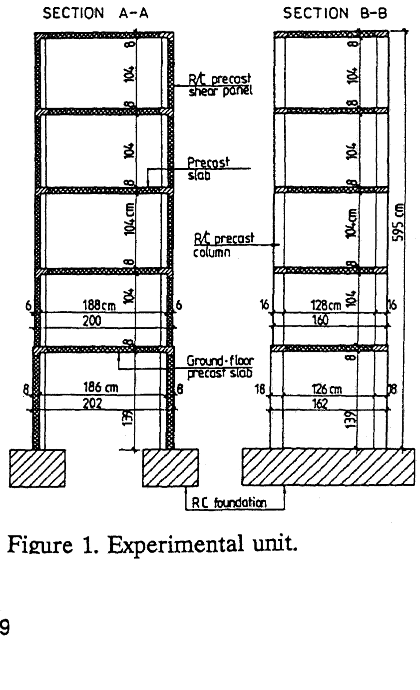

Figure 1. Experimental unit.

- shear wall panels precast on the height of a level;
- R/C precast floor slabs.

The material for the construction was fine concrete with 0-7 mm aggregate, with a cube compressive strength of 25 MPa. This material has the same properties and a resembling behaviour to that of the normal concrete, having the same modulus of elasticity and the same specific deformations (Domşa 1984). The reinforcement consisted of deformed reinforcing bars with 520 MPa and 370 MPa yield strength.

The vertical joints between the column and the shear wall web, as well as the horizontal ones between the panels, were achieved by splicing loops and longitudinal bars.

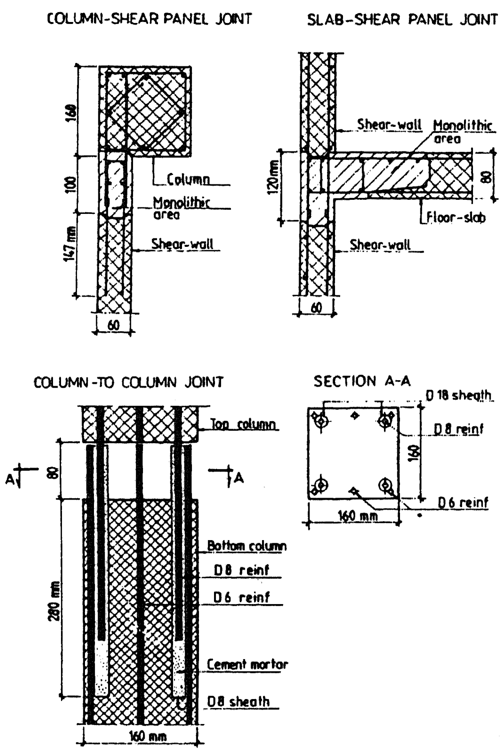

Figure 2. Joint details.

The joint between the columns, at the third level of the structure, was carried out by the penetration of 4 bars of the top column into the sheath of the bottom column, previously filled with cement mortar (Figure 2). The technologic concerns of this joint and the tests under alternate axial cycles were the object of a previous, successfully completed experimental program.

3 TEST PROCEDURE FOR UNIT

The loading of the model was accomplished with vertical forces (dead load), to obtain, at each level, the same compressive stress as in the real 8 storey shear wall. The vertical force N_1 (Figure 3) compensates, in the model, the effect of the reduction of the upper 3 level of the real shear wall. The horizontal force H is applied at the level of the uppermost floor slab and corresponds to a horizontal force applied in the real shear wall at two-thirds of its height.

These adjustments from the real structure did not alter the results of the test. On the maximum interest part (the lower third of the shear wall), the bending moments are practically equal and the shear force is generally slightly higher, compared to the real state. In the same time, from previous tests (Wang 1975) it is known that the crack area does not exceed the lower third of the shear wall. Two main objectives were taken into consideration:

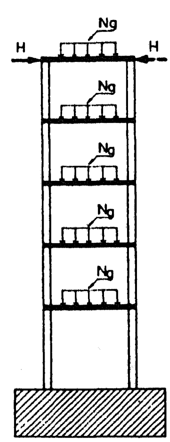

Figure 3. Loading condition.

- the general behaviour of the shear walls under static, alternate-reversed loadings in all ranges: elastic, cracking, post-elastic and failure;
- the behaviour of the joints between the precast elements, due to the particular way of achievement and to the extremely high shear forces induced by the seismic action.

The horizontal load was applied in alternate cycles, on the principle on imposed displacements (Figure 4), Δ_y is the top displacement at the first yield of steel reinforcement. Aspects during the tests are presented in Figure 5.

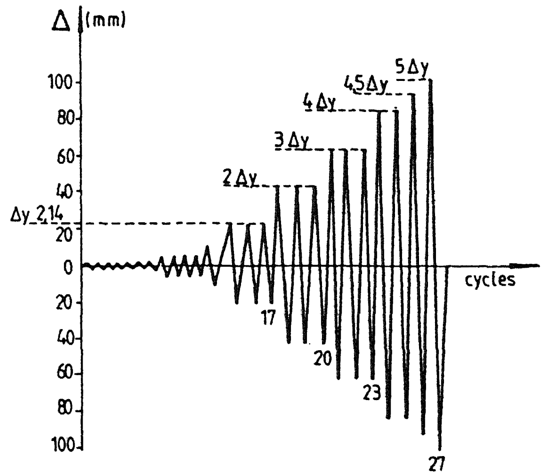

Figure 4. Loading history.

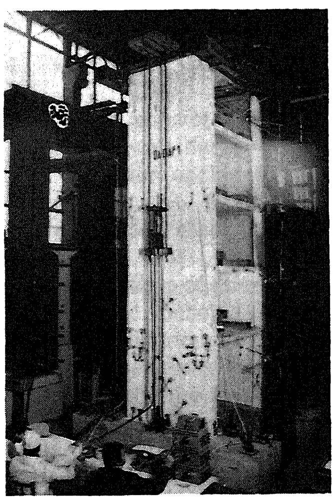

Figure 5. Aspects during the tests.

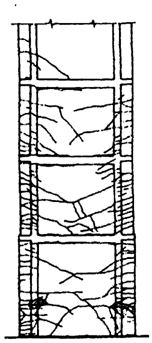

Figure 6. Cracking pattern.

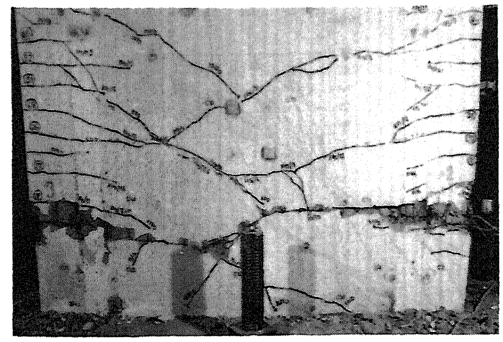

Figure 7. Unit after failure.

4 TEST RESULTS FOR UNIT

The cracking process extended on the height of 3 storeys. Although wholly precast, the mixed shear wall behaved at cracking as a monolithic shear wall, the cracks of the columns being continuous through the joint and through the precast panel (Figure 6). The cracks are typically "of bending". The main cracks, which finally led to the failure, developed only after the imposed $3\Delta_y$ cycle. In the monolithic area, the cracks were narrower (0.20 mm) during the whole test. The very good behaviour of the column-column joint is to be emphasized, where the cracks were insignificant (in 2 joints) or were totally absent (in 2 joints).

The failure of the assemblage occurred due to concrete spalling and crashing in the compressed area and due to the failure of a few column reinforcement bars (Figure 7), which after 26 cycles presented local buckling between the hoops. The ultimate theoretic capacity was by 2% smaller than the experimental one (360 kN·m vs. 354 kN·m).

The hysteretic loop of horizontal force-top displacement (Figure 8), by its convex aspect shows a behaviour characteristic to long shear walls subjected mainly to bending moment. There was no "pinching" in the last cycles, which reveals a good behaviour between the precast elements. Moreover, joint slipping was not noticed only after the cycle $1\Delta_y$, and the maximum values attained in the cycle $4\Delta_y$ did not exceed 0.3 mm in the vertical column-panel joint and 0.1 mm in the horizontal panel-panel joint.

The area of the hysteretic loops reveals o large energy-absorption capacity (1.26×10^6 daN·cm). The loops are stable, the stiffness reductions after 3-4 cycles under the same imposed displacement, do not exceed 10% (Figure 8). The experimental displacement corresponding to the design code force (52.8 kN) was in a good agreement (5% higher)

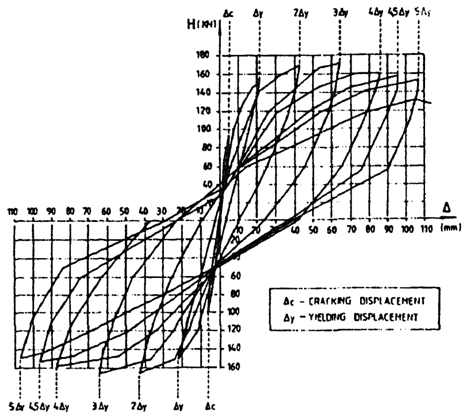

Figure 8. Horizontal force - top displacement diagram: envelope curves.

versus the theoretical one. The ultimate attained ductility (Δ_u / Δ_y) during the test was 5.25, the structural assemblage proved good behaviour from this point of view, too. After 23 cycles, at the $4\Delta_y$ imposed displacement, the recorded storey drift at the uppermost level was 1/205.

5 CONCLUSIONS

The test on the subassemblage confirmed the good behaviour of the precast mixed shear wall (load-bearing capacity, stiffness, ductility, cracking).

The types of connections proved suitable, providing a behaviour for the precast subassemblage, similar to the monolithic solution.

Due to its functional and technical advantages, to a high productivity and low costs, the constructive system was used in over 1000 apartments, with real possibi-lities of extension in seismic areas.

REFERENCES

P 100 - 91. Romanian seismic design code. 1991. Ministry of construction. Bucharest

Domşa, Julietta. 1984. The use of micro-concrete to model R/C elements and structures. PhD Thesis. Polytechnic Institute of Cluj-Napoca. Cluj-Napoca

Wang, T.Y., Bertero, V.V. & Popov, E.P. 1975. Hysteretic behaviour of reinforced concrete framed walls. Report EERC 75-23. University of California, Berkeley.