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Reinforced concrete shear walls stressed by horizontal loads

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ABSTRACT: The structures' protection against strong seismic strains requires the elaboration of scientifically substantiated antiseismic design conception.This supposes the knowing of the strain -structure relation and of the structures' optimal response to strains.One recommended method is to design the structures in a way that will enable them to have a ductil postelastic behaviour when stressed by strong seisms.This behaviour permits the dissipation of the energy induced by the seism in the structure,through the postelastic deformation of the elements,without important diminutions of the portant capacity or collapse. The main factors which influence this behaviour are the ductility and the energy absorption capacity. These factors are studied in the paper, based on results obtained through experimental researches on coupled shear walls, made of monolith reinforced concrete , submitted to cyclical - alternating horizontal loads.

1 INTRODUCTION

In the modern conception of structures design, the determination of the strains which correspond to the exhaustion stage of the bearing capacity, named yielding stage, is much sought after. This yielding stage of the structure can have an elastic or plastic character. Filimon and Ianca (1989) demonstrate in their paper that the elastic yielding of a statically undetermined structure takes place when, in the most stressed section of an element, the plastic bending moment is reached, the other sections having bending moments lesser than the one in the critical section.

The plastic yielding supposes that the structure exhausts its portant capacity only when it is transforming itself (totally or partially) into a "mechanism", as a result of the succesive plasticizing of the most stressed sections. The elastic yielding of a structure, or of an element has a fragile character, without the appearance of some warning specific phenomena (curve A from Figure 1). At elements which are in the postelastic range, the yielding is ductil and takes place progressively with great deformations, which warn over the collapse perill (curve B from Figure 1).

The design of the structures with reinforced concrete shear walls for seismic areas, is, in the conditions of an elastic behaviour in strong seisms, uneconomic and sometimes even impossible. Therefore, the structures design must consider the postelastic deformation capacity of the component elements, that is, the ductility and the energy absorption capacity of these elements.

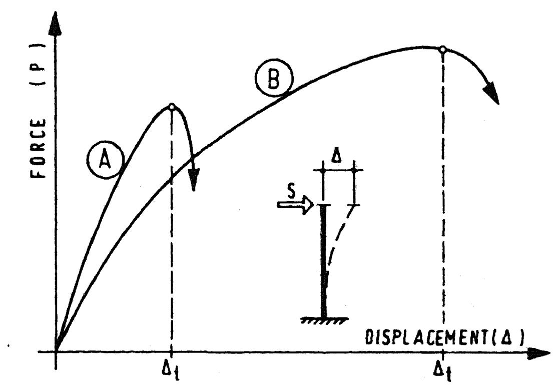

Figure 1. Elastic(A) and ductil (B) behaviour.

According to Paulay's observations (1981) and to Ianca's (1987) researches the structures' postelastic ductil behaviour in seismic strains admits some structural degradations by passing over the elastic behaviour limits, in the

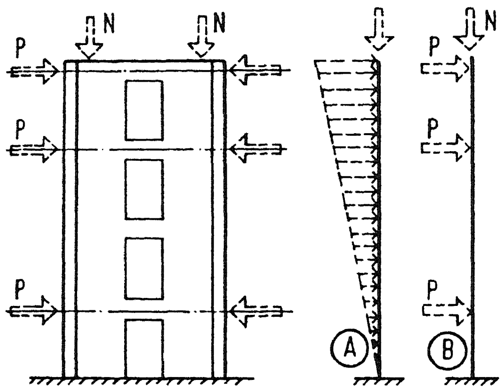

Figure 2. Testing principle (A-equivalent loading, B-real loading).

conditions of admissible conservation of the resistence and of structures yielding avoidance. In this mode, the security in exploitation of the constructions located in high intensity seismic areas increases and the seismic risk diminishes.

2 EXPERIMENTAL PROGRAM

In the experimental program that was conducted in Timisoara (Ianca 1987), the experimental elements were established starting from a shear wall currently used in the constructions of buildings with small number of levels. This chosen experimental "model " was a 4 level shear wall with door gaps simmetrically disposed. The 2 vertical walls have been endowed with bulbs at their exterior extremities of their section, and the coupling beams with rectangulary section (see Figure 2).

The experimental elements were made at reduced scale (1/2,75) compared to the real elements, and the materials used were the ones wich are currently used in constructions. The reinforcing mode of the "model" shear walls was made accordingly to the present reglementations from Romania (P.85-1982).

The test of the experimental elements was made with gravitational loads (N) and cyclical-alternating horizontal loads (P). The vertical loads introduced a 1,5 N/mm^2 constant compression stress in the walls. The horizontal loads (P) were applied in the form of 3 concentrated loads, in the coupling beams' axis from level 1; 3 and 4. Thus, the P loads simulated a seismic type conventional load, with a triungular distribution on the shear wall height (see Figure 2).

3 EXPERIMENTAL RESULTS

From the testing of 9 experimental elements

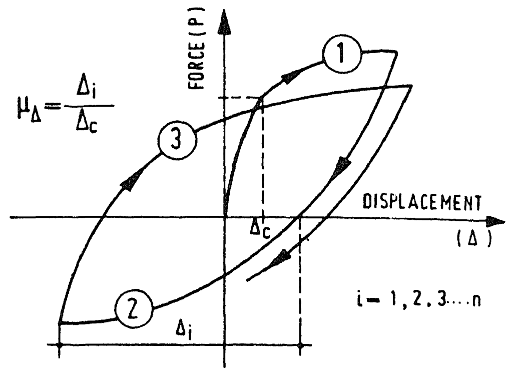

Figure 3. Force-Displacement diagram.

which were strained until yielding occured, there were obtained important results regarding the factors which influence the coupling shear walls' postelastic behaviour. There were also established the ductility and the capacity to absorb the energy induced in the elements by the strains and the relation between these.

The ductility of a section, or of a construction element permits a global evaluation of the possibility of the element to postelastic adaptation to powerfull strains. This can be measured through the ductility coefficients, defined as the ratio of the last limit deformation and the deformation corresponding to the elements passages in the postelastic behaviour range.

In the case of the experimental elements, wich were tested with cyclical-alternating horizontal loads, the force-displacement diagram (P-Δ) was made in the form of hysteretic curves (see Figure 3). The displacement ductility coefficient (μ_Δ) was calculated based on relation (1), presented by Dumitrescu and Postelnicu (1979) :

$$\mu_{\Delta i} = \frac{\Delta_i}{\Delta_c} \qquad (1)$$

where Δ_i is the maximum displacement at the elements vertex in the "i" loading cycle and Δ_c is the displacement (at the same level) registered in the moment of the first plastic articulation apparition in the most strained section of the element.

For the shear wall type reinforced concrete elements which are strained by seismic forces, the ductility doesn't characterizes in all cases correctly the energy absorption capacity, because this capacity is strongly influenced by the "repeated shear" phenomena and by the

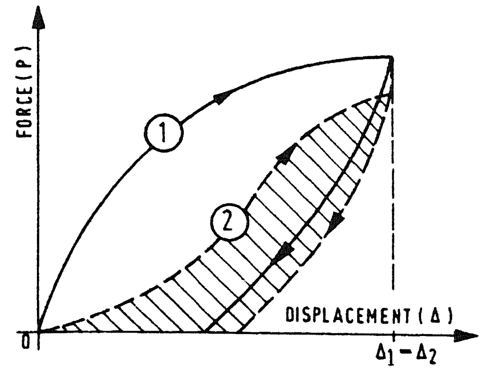

Figure 4. Ductil behaviour types.

number of incursions made by the element in the postelastic range. As an example, in Figure 4 is illustrated a hysteretic curve for 2 types of elements : curve 1 is the optimal response of a well elaborated element, which is not prematurely affected by the shear force, and curve 2 represents the response of an element whose rigidity diminishes a lot in the first loading cycles under the effect of the shear forces.

Although both curves have the same limit displacement ($\Delta_1=\Delta_2$) and hence closed ductility coefficients, the energy absorbed by the type 2 element is a lot more lower than the one absorbed by the element with an elasto-plastic behaviour, as type 1.

The amount of energy absorbed by the tested elements was determined by adding the areas of the experimentally obtained hysteretic curves (the area between the P-Δcurve and the Δ axis) and by their transformation into mechanical work units (kN·mm).

The space of this paper doesn't permit the presentation of the values obtained experimentally for ductility and absorbed energy, but it permits the presentation of a qualitative relation between the 2 characteristics. Thus, Ianca (1987) proposes the definition of an "energy absorption capacity factor", noted with $\bar{E}_{ab}$, represented by the ratio of the amount of absorbed energy through postelastic deformations ($E_{ab,p}$) and the energy totally absorbed by the experimental element ($E_{ab,t}$) :

$$\bar{E}_{ab} = \frac{E_{ab,p}}{E_{ab,t}} \qquad (2)$$

The $\bar{E}_{ab}$ factor, defined by relation (2) represents, for the cyclical-alternating type strains, a more correct measure to characterize the postelastic response of the reinforced concrete elements, than the ductility factor.

To sustain this affirmation, Ianca (1987) calculated and represented graphically (for a simple system, with 1 freedom degree) one connection relation between the E_{ab} factor and the μ_Δ coefficient, obtaining the following equation :

$$\bar{E}_{ab} = \frac{2\,(\mu_\Delta - 1\,)}{2\,\mu_\Delta - 1} \qquad (3)$$

Representing graphically the equation (3), the diagram from Figure 5 resulted, showing (theoretically) the dependence $\bar{E}_{ab}=f(\mu_\Delta)$ for a simple structural system.

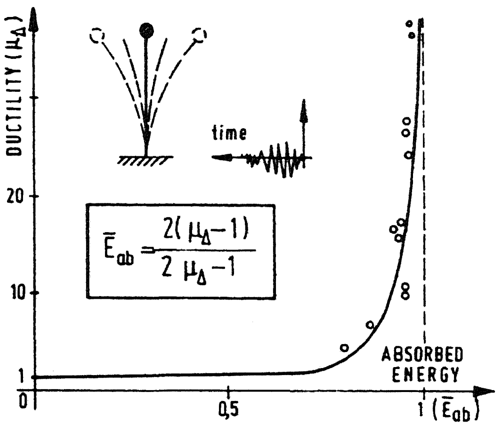

Figure 5. Ductility-absorbed energy relation.

For the tested experimental elements, the results that were obtained were marked on the theoretical diagram in Figure 5 (with circles). It can be remarked the fact that the experimental values confirm the correctness of relation (3) and the good postelastic behaviour of the experimental elements.

4 PROPOSALS FOR THE DUCTILIZATION OF THE COUPLED SHEAR WALLS

Analysing the elaboration mode of the experimental elements and the tests' rezults (Ianca 1987), there can be made several recommandations regarding the correct elaboration of the coupled shear walls, made of reinforced concretes, to obtain a ductil response to seismic strains and an increased energy absorption capacity.

The ductilization of the coupled shear walls can be made by actioning on the shear wall in this whole, on its component elements (walls and coupling beams) or on the materials (concrete and reinforcement). Thus, the main costructive measures, recommended for the coupled shear walls design, are :

- to complicate the fracturing mechanism by designing shear walls with connection reserves, which consume the seisms energy when yielding occurs. Thus, a " ductil guarding line " against violent seismic strains is obtained ;
- to conduct the shear walls yielding mechanism in such away the coupling beams will enter the postelastic range before the walls do, because the coupling beams are easier to repair and to consolidate after their damage ;
- to limit to a superior value the longitudinal reinforcement coefficient of the walls in the streched areas, because the exaggerated increase of this coefficient can lead to an abrupt yielding of the element through the crushing of the compressed concrete ;
- to develop the compressed areas of the walls section as bulbs or plates and their confinement through transversal reinforcement (stirrups) to increase the resistence to compression ;
- to ductilize the coupling beams by disposing the longitudinal reinforcements in their diagonal directions, in the form of a frame with dense stirrups or with spiral reinforcement ;
- to use steel, with a ductil behaviour, as reinforcements.

5 CONCLUSIONS

The reinforced concrete shear walls have a low capacity to absorbe energy from seismic strains through elastic deformations. The greatest amount of energy is consumed through postelastic deformations, mainly through the plastic yield of the streched reinforcement in the plastic hinge areas of the elements. The designers must have in view the achievement of structures which are capable to be have in a ductil way to powerfull strains and which will dispose of a high capacity to absorb and dissipate the energy induced by the strains. This characteristics must not be ensured by neglecting other important ones, as resistence and rigidity.

The correct design supposes not only an adequate calculus but also the adoption of constructive measures as the ones presented in paragraph 4 (and others) which will offer the structure an increased security to seismic actions, ensuring its survival and the avoidance of causing victims and exagerated damages.

REFERENCES

Dumitrescu, D. and Postelnicu, T. 1979. Explanations regarding the reinforced concrete structures ductility notion in seismic areas. Constructions Journal 1.

Filimon, I. and Ianca, S.I. 1989. Contributions to the ductility and energy absorption capacity calculus of the reinforced concrete elements used in the antiseismic structures. Studyes and Researches of Applied Mechanics. Volume 48/2 : 201-218.

Ianca, S.I. 1987. Contributions to the reinforced concrete shear walls ductility study, for buildings. Doctors' Degree Thesis. Technical University of Timisoara.

Paulay, T. 1981. The design of reinforced concrete ductile shear walls for earthquake resistance. Research Report 81-1, Department of Civil Engineering. University of Canterbury.

P. 85- 1982. Technical instructions for the design of constructions with concrete shear walls structure. Constructions' Bulletin 6.