REINFORCED CONCRETE SHEAR WALL: STRUCTURAL ELEMENT - FINITE ELEMENT

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Abstract. The contribution deals with reinforced concrete shear wall model. On the base of experimental testing data is created a single degree of freedom nonlinear finite element. The nonlinear finite element is represented by parallel ordered spring and friction elements. The stiffness reduction in the sequence of load cycles is taken into account in the element with help of limit friction force in each friction element which gradually reject the parallel springs. The developed element is able to simulate the stress-strain relation of reinforced shear walls during loading including the complex destructive phenomena of concrete cracking, interaction effects between steel and concrete, steel yielding and concrete crushing. The derived finite element has a significance and application in model simplification of concrete civil structures.

1 INTRODUCTION

Reinforced concrete shear walls are frequently used in civil engineering as structural elements resisting horizontal forces acting on the structure. Horizontal forces issues from wind loading and earthquake respectively.

The reinforced concrete is a composite consisting of concrete with nonlinear behavior from the beginning of the loading and steel reinforcement characterized by yielding point and mesh geometry. The stress-strain relation of reinforced shear walls during loading is not easy to describe theoretically due to complex destructive phenomena including concrete cracking, interaction effects between steel and concrete, steel yielding and concrete crushing in compression [3], [4], [5], [6].

On the base of wall geometry (it means ratio between length and height, length and thickness) theory distinguishes high-rise shear walls and low-rise shear walls. High-rise shear walls are governed by flexural behavior similar to a cantilever beam. The flexural behavior of reinforced concrete walls has been examined and it is in literature theoretically well described. The behavior of low-rise shear walls is governed mainly by shear behavior. The research of low-rise shear walls is still in progress because their use in nuclear power plants.

The most objective information is obtained from experimental testing. The paper focuses on the behavior of the low-rise reinforced concrete shear wall under cyclic horizontal loading.

2 EXPERIMENTAL TESTING

Experimental testing shows the real behavior of the shear wall [1]. The numerical modeling described in the paper have used data from experimental testing carried out by ELSA at JRC in Ispra, Italy.

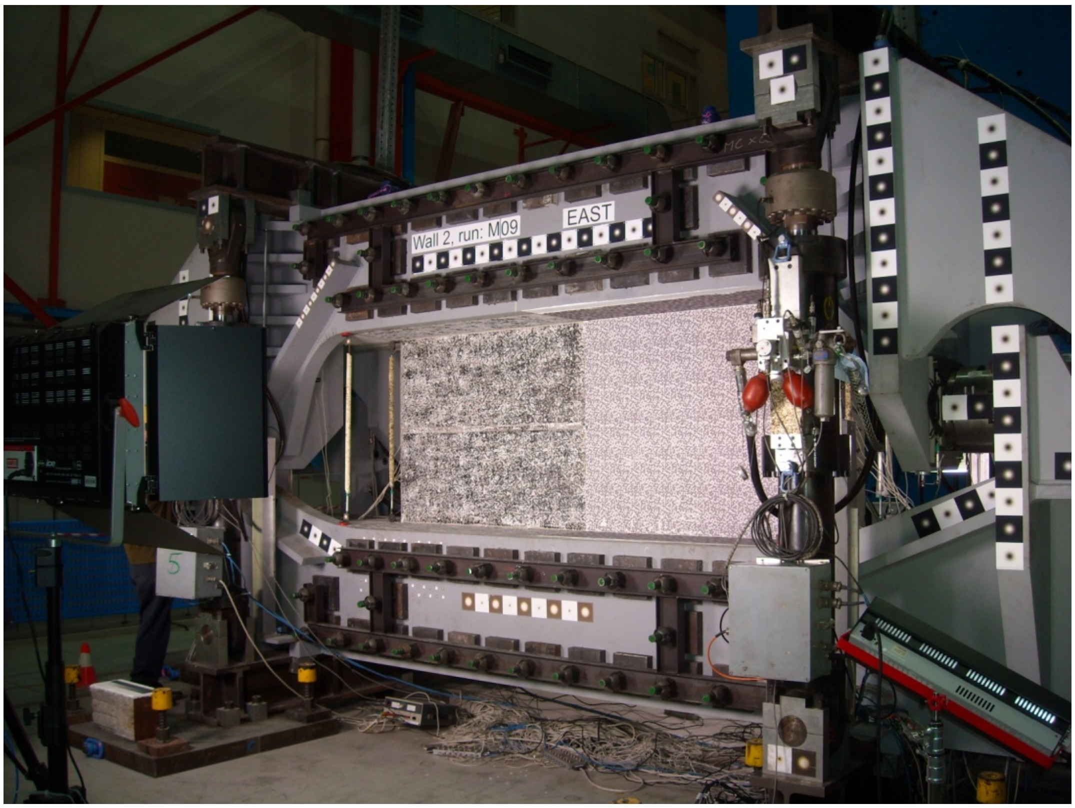

Figure 1: The reinforced concrete shear wall testing at the ELSA laboratory (IRIS project)

2.1 Testing

The specimen was loaded by horizontal cyclic quasi-static force. The force was transferred from the loading machine to the upper boundary of the wall. The bottom of the specimen was fixed. The “pure” shear (no bending) was simulated. The force and the displacement were measured on the top of the specimen.

The result of the testing was the hysteresis defining the force and displacement relation during the testing.

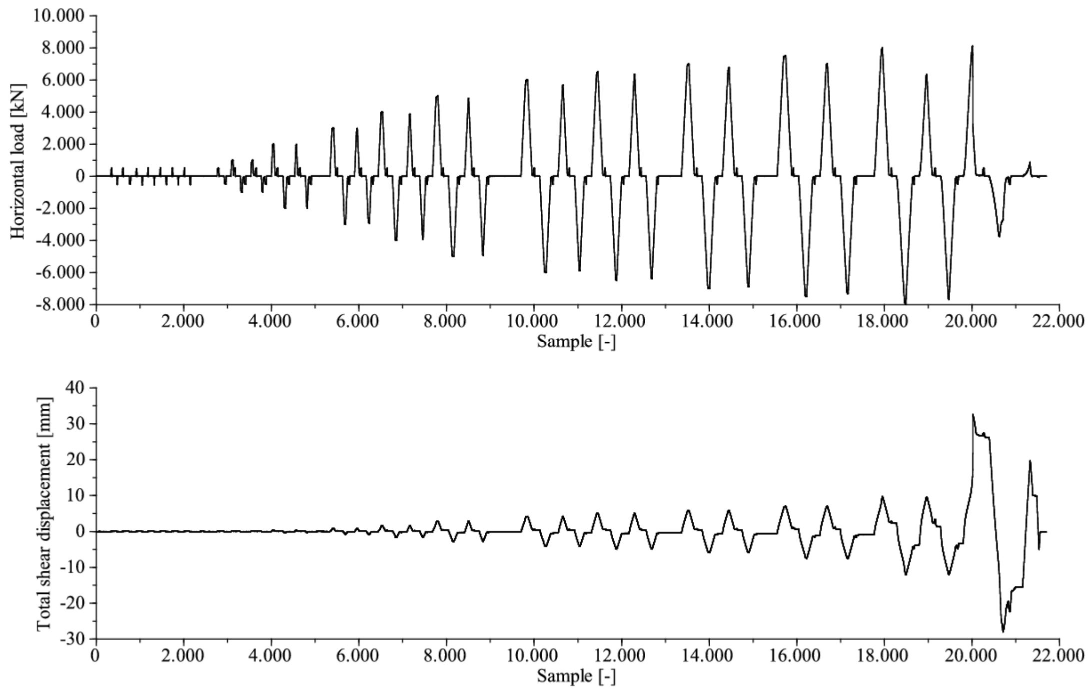

Figure 2: Horizontal forces and horizontal displacements during testing

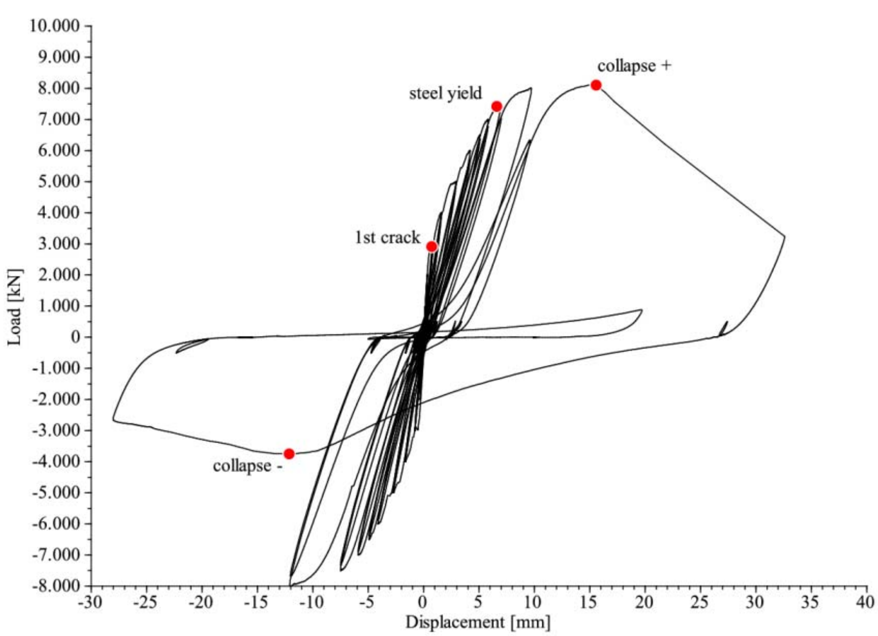

Figure 3: Hysteresis: horizontal forces vs. horizontal displacements

2.2 Behavior of the shear wall

The behavior of the shear wall during testing we can comment on the base of following sources: visual records (camera recorded the crack development on the wall surface), shear force vs. time record, horizontal displacement vs. time record and hysteresis – shear force vs. horizontal displacement.

On the base of visual observation during the testing we noticed an oblique crack formation in one direction. By change of the shear force orientation the originally cracks were closed gradually and mirror cracks were opened. The higher damage degree was registered when two surfaces of the crack slides were not able to close when moving back.

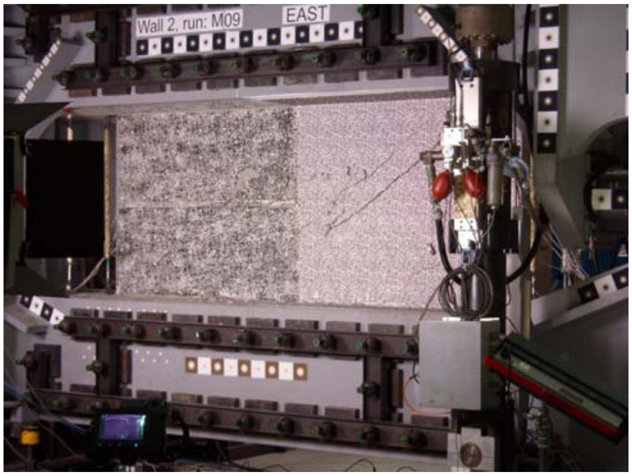

Figure 4: Crack formation

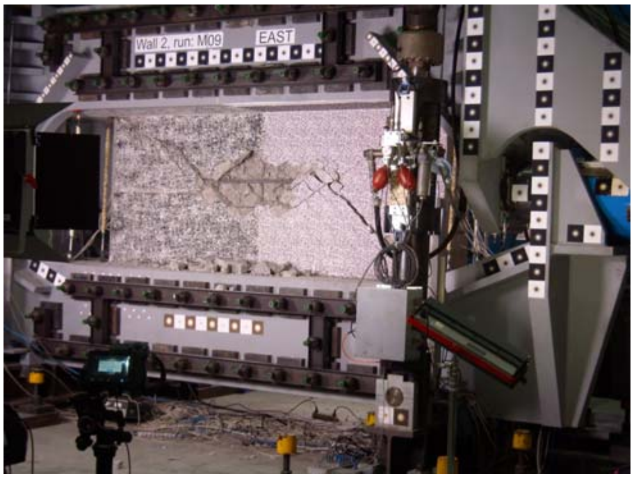

Figure 5: Damaged shear wall

The stiffness degradation is visible from hysteresis slope sinking. The areas defined by cycles show the dissipated energy – range of nonlinearity.

3 THE FINITE ELEMENT

The obtained hysteresis as the result of the testing is applied for derivation of the nonlinear spring element with single degree of freedom. The nonlinear finite element is represented by parallel ordered spring and friction elements. The stiffness reduction in the sequence of load cycles is taken into account in the element with help of limit friction force in each friction element which gradually reject parallel springs. Friction forces and stiffness of springs are determined from the test hysteresis. The pinching effect is taken into account with help of additional spring and slider connected in series to the rest of the element model.

The features of the derived element are specific for reinforced concrete: include the concrete cracking, pinching, the stiffness degradation and yield effects.

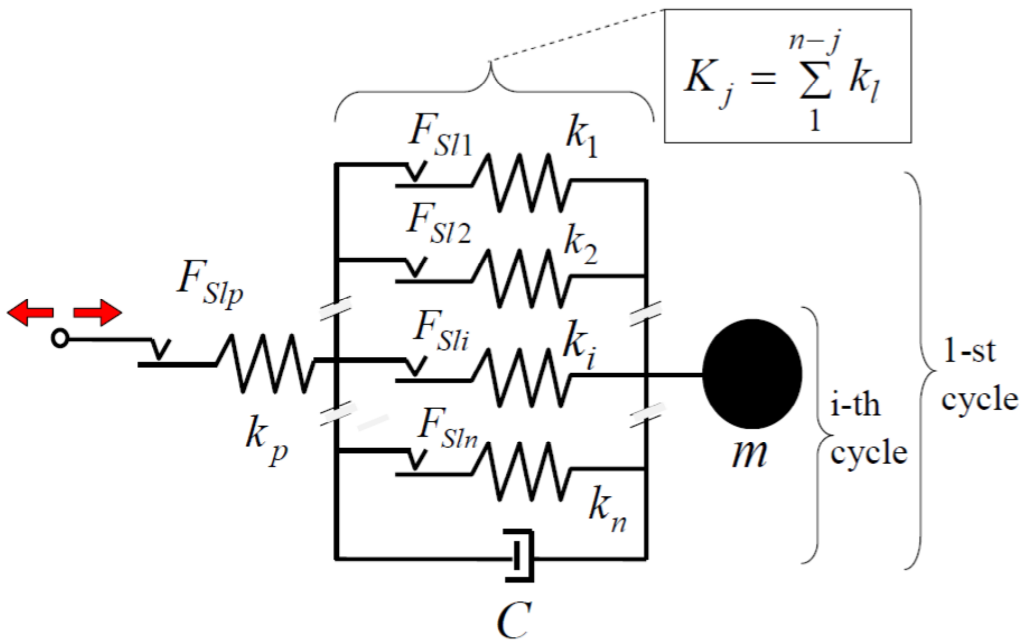

Figure 6: Finite element - model of the shear wall

The derived element can be built in the arbitrary finite element model of the structure [2], [7]. Application of the mentioned SDOF element instead of FE model of the whole wall decreases the system matrix size and improves the efficiency of the analysis.

The application of the derived element is suitable for nonlinear mechanics.

The advantage of the reinforced shear wall model with single degree of freedom is that the whole shear wall is represented by only one element and provides a global view on this structural part of the civil structure.

The example presented below shows the hysteresis from numerical simulation of arbitrary (time dependent) loading compared to the test hysteresis from cyclic loading.

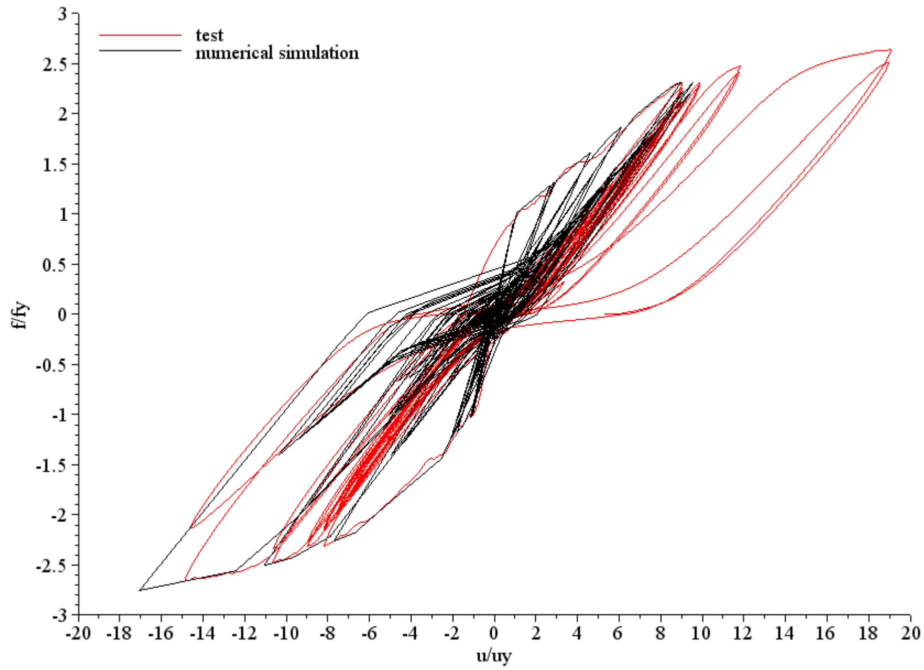

Figure 7: Hysteresis from numerical simulation of arbitrary (time dependent) loading and test hysteresis from cyclic loading

4 CONCLUSIONS

- The reinforced concrete shear wall - nonlinear finite element is created on the base of experimental testing data.
- The stiffness reduction in the sequence of load cycles is in the element taken into account with help of limit friction force in each friction element which gradually reject parallel springs.
- The developed element is able to simulate the stress-strain relation of reinforced shear walls during loading including the complex destructive phenomena of concrete cracking, pinching, interaction effects between steel and concrete, steel yielding and concrete crushing.
- Application of the mentioned SDOF element instead of FE model of the whole wall decreases the system matrix size and improves the efficiency of the analysis.
- The derived finite element has a significance and application in model simplification of concrete civil structures loaded with horizontal forces (e.g. earthquake, wind).

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