Analytical Study of Self-Centering Reinforced Concrete Shear Walls

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Abstract - *Self-centering systems are recent advancements in earthquake resistant structural systems. This paper introduces a new analysis form for prestressed reinforced concrete shear walls with horizontal bottom slits. Horizontal slits are placed symmetrically at the wall-foundation interface of prestressed shear walls by means of a separating steel plate, while the concrete in the middle of the wall width remains connected with the foundation. Unbounded prestressed tendons inside the wall are adopted to provide self-centering ability. This paper evaluated an analytical study on the seismic performance of 3 different shear walls; under quasi static reversed cyclic loading and a comparison was made among traditional shear wall and self-centering shear walls of different configurations . Analytical study reveals that there is significant increase in ultimate load carrying capacity of self centering reinforced concrete shear walls.*

Key Words: **Self-centering; Shear walls; Prestressed; Cyclic loading; Concrete structures.**

1.INTRODUCTION

Structures designed in accordance with even the most modern buildings codes are expected to undergo significant structural and non-structural damage during a severe earthquake. Damage to the structure may include yielding, buckling or fracture of structural elements and permanent horizontal displacements after the earthquake, referred to as residual drift. Concrete shear walls dissipate energy through yielding of reinforcing steel and crushing of concrete at the base of the wall. Shear walls are structural elements that are designed to provide lateral force resistance and drift control to buildings during seismic events. Conventional concrete shear walls that are a part of monolithic structures are expected to undergo significant structural damage in the form of flexural and shear cracking, toe crushing, and rebar fracture and buckling, as well as residual lateral displacement, in response to reversed cyclic loading during seismic events of design intensity or higher. Self-centring (SC) systems are recent advancements in earthquake resistant structural systems. The difference between conventional and SC structural systems is that critical connections in SC systems are designed to decompress at a specific level of lateral loading. This study expands the self-centring concept to cast-in-place concrete walls and presents an investigation into the seismic behaviour of self-centring shear walls with horizontal bottom slits. Horizontal slits are formed by inserting separating steel plates placed symmetrically at the wall-foundation joint of pre-stressed shear walls and keeping the reinforced concrete in the middle of the wall width connected with the foundation. Furthermore, unbounded pre-stressed tendons are used to provide self-centering ability. The structural deformation is concentrated at the wall-foundation joint by gap opening, allowing the wall to undergo large lateral displacements with little damage. The separating steel plates used as bottom slits in the shear wall weakened the connection at the wall-foundation joint so that the cracks could be easily formed at the joint by the guild of the steel plates. Because the inelastic deformation was primarily concentrated at the wall-foundation joint, the tension deformation and strain of the wall panel was significantly reduced to protect the wall from being damaged.

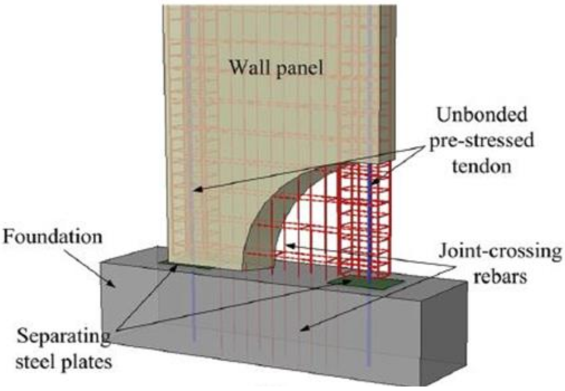

Figure 1: Schematic representation of self-centering wall with horizontal bottom slits [9]

The pre-stressed steel tendons were used to provide extra vertical restoring load to achieve self-centering capacity by eliminating the residual strain of the reinforcements crossing the wall-foundation joint. The joint crossing rebars in the shear wall could be used for energy dissipation, and these rebars casting together with the concrete could also provide additional dowel forces to prevent the slide of the shear wall panel. While aspects of the seismic response of the proposed walls are different from the traditional reinforced concrete shear wall, the components of their construction are conventional and standardized, not requiring special manufacturing. The benefits of self-centering ability and low damage of the wall panel can be achieved by utilizing currently available construction methods and materials.

The paper covers the finite element analysis of self centering reinforced concrete shear wall having precast post tensioned shear wall subjected to reversed cyclic loading. Static structural analysis in ANSYS workbench was used in this project. This study will be limited to the analysis of single storied shear walls.

2. ANALYTCAL STUDY

2.1 General

The main objective of this project is to study analytically the performance of self-centering reinforced concrete shear walls. The analytical programme consists of modeling and analysis of shear wall with two different length of bottom slit with same prestressing. Again, it is compared with control shear wall with no prestressing strand and bottom slit. Analysis done on the basis of the journal "Experimental Study of Self-Centering Shear Walls with Horizontal Bottom Slits" [9]. Details of models are shown in table 1. The model dimensions of the shear wall panel being 2 m high 1 m long and 125 mm thick. Figure 2-4 shows reinforcement details of models

Table -1: Model description [9]

Model	Bottom slit length (mm)	Hoz.distance from steel strands to the centerline of the wall (mm)	Quantity of steel strands	Average initial prestress (Mpa)	Pre-stressing force (N)	vertical load applied (kN)
SW0	Null	-	-	-	0	370
SW1-1	180	420	2	465	65100	370
SW1-2	360	420	2	465	65100	370

2.2 Analytical modeling

Modeling and analysis performed using the software ANSYS17.0 WORKBENCH. M30 concrete and Fe415 steel are used for modelling. In ANSYS, concrete modeled using element SOLID65 and rebar modeled using LINK180 elements. Mesh size of 25 mm is selected and this size gives finer result in analysis.

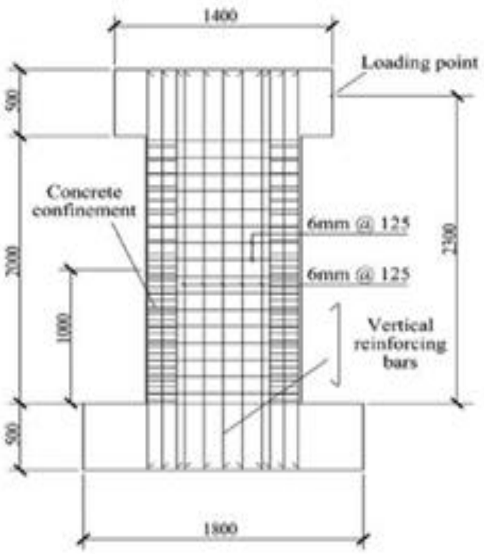

Figure 2: Reinforcement details of SW0

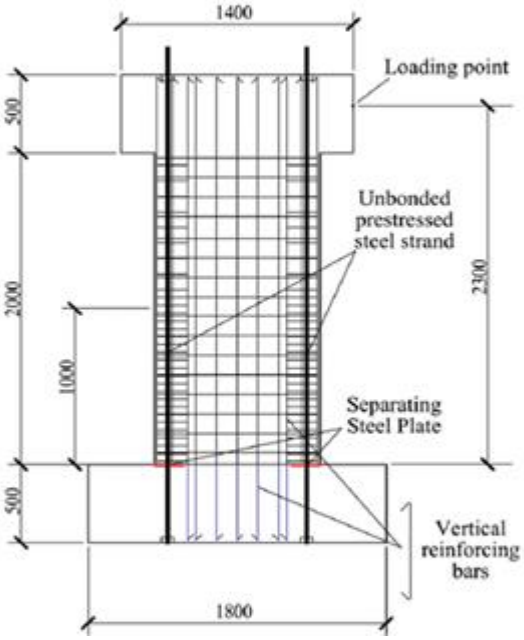

Figure 3: Reinforcement details of SW1-1

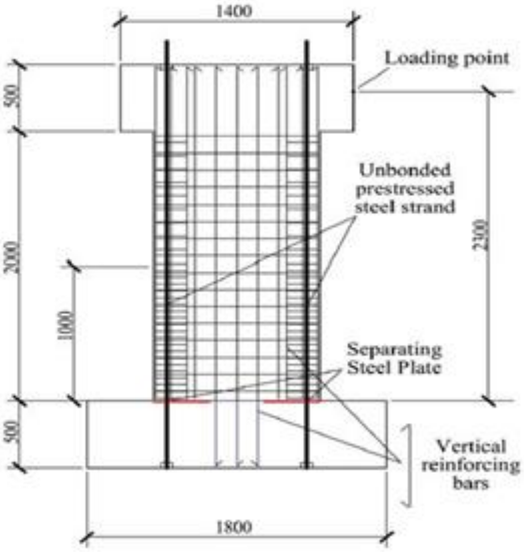

Figure 4: Reinforcement details of SW1-2

2.3 Loading pattern and boundary conditions

In order to impart earthquake loading in the prototype, quasi static cyclic loading was applied laterally at the surface of the loading beam. Loading is provided as displacement in ANSYS. The applied cyclic displacements were divided into a series of increments of 2.88 mm per load step and duration of one load step is 1 sec. The connections of foundation and shear wall are fixed. For imparting dead and live loads acting on the shear wall, a constant load of 370kN is applied on the top of beam in downward direction. A pre-stressing force is applied as pretention on both of the unbounded cables of different cases. Figure 5 below shows the loading pattern and boundary conditions applied.

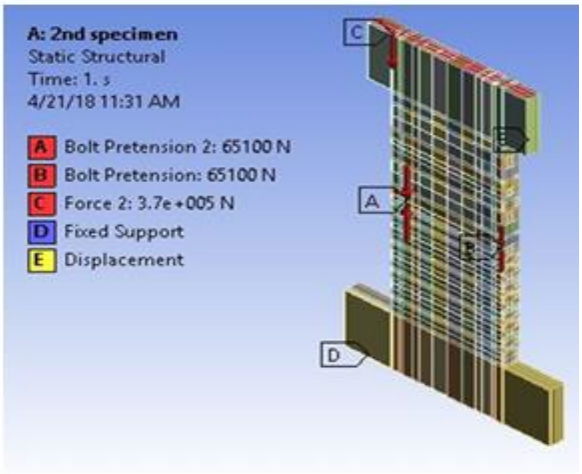

Figure 5: Loading Pattern & Boundary Conditions

Figure shows the ANSYS model of each specimen.

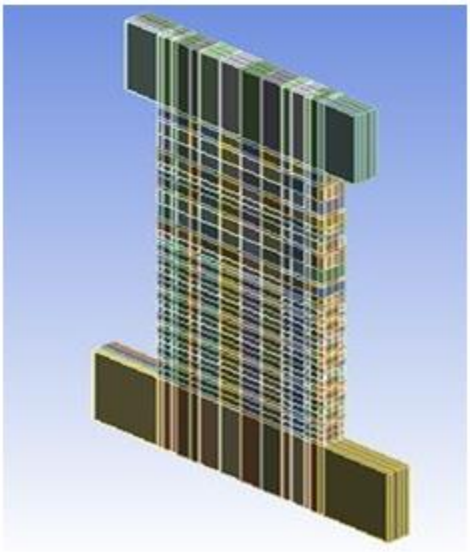

Figure 6: shear wall model geometry ANSYS model

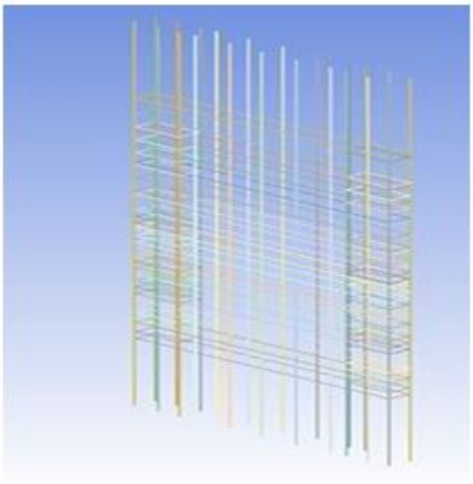

Figure 7: Rebar model of SW0

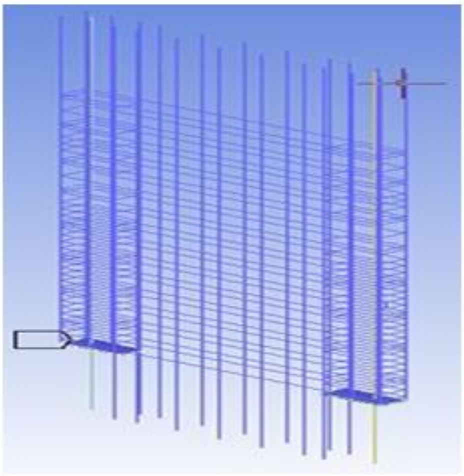

Figure 7: Rebar model of SW1-1

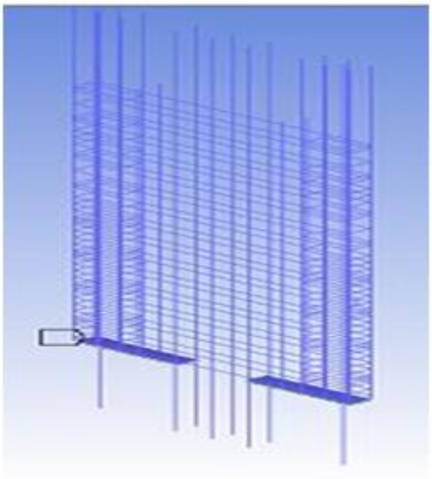

Figure 8: Rebar model of SW1-2

4. RESULTS AND DISCUSSIONS

Performance of shear wall is discussed in terms of displacement.

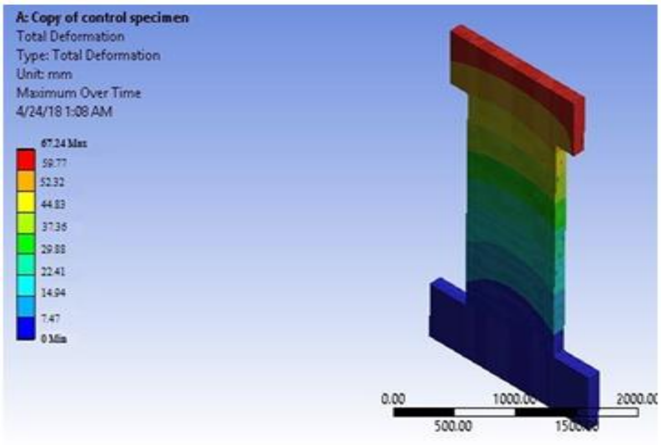

Figure 9: Total deformation of SW0

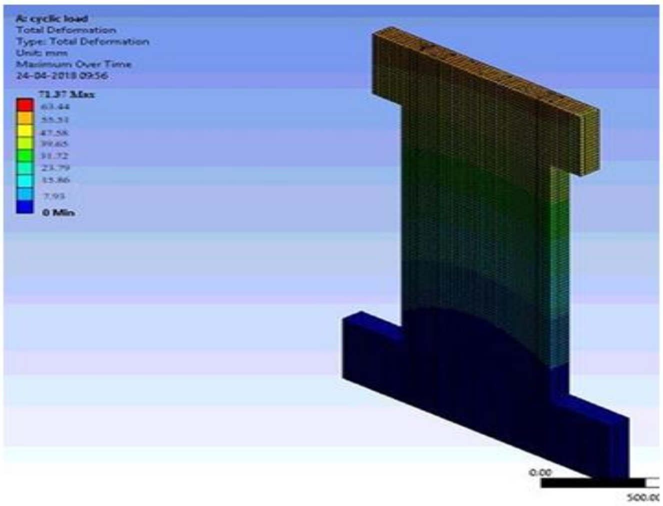

Figure 10: Total deformation of SW1-1

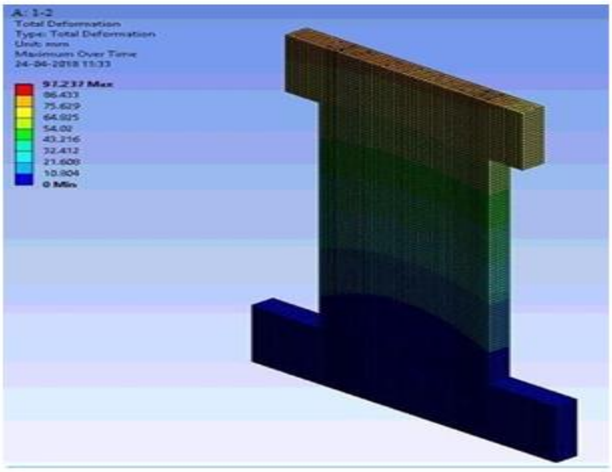

Figure 11:deformation of SW1-2

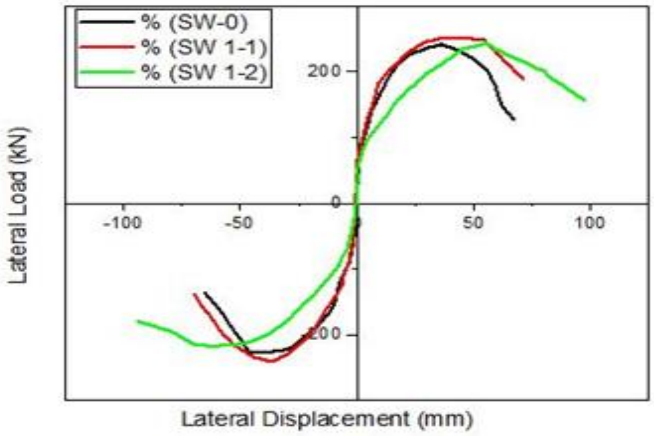

Figure 12: Load v/s Deformation graph

5. CONCLUSIONS

Based on the finite element study, the following conclusions can be drawn:

- There is significant increase in ultimate load carrying capacity of self centering reinforced concrete shear walls.
- SW1-1 shows maximum ultimate load with minimum deformation.
- As the length of steel plate increases deformation also increases.

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