THE EFFECT OF CONFINEMENT OF SLAB REINFORCEMENT ON FLANGED SHEAR WALL DIAPHRAGM CONNECTION.

Sethuraman T.R.[1], **Annilet Sheeja L.**[2]

[1]Department of Civil Engg, Sivaji college of Engg & Tech
[2]Department of Civil Engg, Sivaji college of Engg & Tech

Abstract

The frequent occurrence of earthquakes in Indian subcontinent and its effects on various building stocks demand for the effective design and detailing of connections in buildings. In Indian Standard Code of practice (IS 456: 2000 and IS 13920: 1993), the joint is usually neglected for specific design and detailing of reinforcements. This may not be acceptable when the joint is subjected to reversible loads such as wind and seismic loads. Unsafe design and detailing within the joint region collapses the entire structure, even if other structural members conform to the design requirements. In the past three decades no significant research work has been carried out in the area of shear wall – diaphragm joint. Hence an attempt has been made to study the effect of various parameters on shear wall - diaphragm connection. In order to study the performance of exterior flanged shear wall-diaphragm joint, one six storey RC building has been analyzed and one of the exterior flanged shear wall - diaphragm joints is designed. Seismic analysis is performed using the equivalent lateral force method given in IS 1893 (Part 1): 2002. In the present study, it is proposed to study the behavior of the shear wall – diaphragm connection with respect to different parameters such as (i) the ratio of height of shear wall to effective width of the slab, (ii) the ratio of vertical reinforcement of the shear wall and (iii) the axial load. Analytical modeling of the shear wall – diaphragm joint was carried out using finite element software package ANSYS. The analysis has been carried out under axial load on the top of the shear wall and cyclic load at the end of the slab.

Keywords: Concrete, Seismic loading, Non linear Analysis

I. INTRODUCTION

Shear walls are specially designed structural walls incorporated in buildings to resist lateral forces that are produced in the plane of the wall due to wind, earthquake and other forces. The term "shear wall" is rather misleading as such wall behave more like flexural member. They act as a vertical cantilever in the form of separate planner walls, and as non planner assemblies of connected walls around elevator, stair and service shafts. The most important property of shear walls for seismic design is that it should have good ductility under reversible and repeated over loads. In planning shear walls, we should try as much gravity forces as it can safely take. They should be also laid symmetrically to avoid torsion stresses. Depending on the height - to - width ratio, a

II. MODELLING OF SHEAR WALL - DIAPHRAGM CONNECTION

The shear wall diaphragm connection has been modeled in ANSYS (version 10), introduces a three-dimensional element shear wall may behave as a slender wall, a squat wall or a combination of the two. Slender shear walls usually have a height - to - width ratio greater than two. They behave like a vertical slender cantilever beam. Squat shear wall shows significant amount of shear deformation as compared to bending deformation.

The forces are distributed to the shear wall of the building by the diaphragms and the shear wall transmits the loads down to the next lower storey or foundation. Diaphragm is a nearly horizontal structural unit that acts as a deep beam or girder when flexible relative to the support and as a plate when its stiffness is higher than the associated stiffness of the wall.

Solid 65 which is capable of cracking and crushing and is then combined along with models of the interaction between the two constituents to describe the behavior of the composite reinforced concrete material. Although the solid 65 can describe the reinforcing bars, this study uses an additional element, Link 8, to investigate the

III. FINITE ELEMENT MODELLING – ANSYS (Version 10)

In ANSYS, the finite element models can be created either using command prompt line input or the

Graphical User Interface (GUI). For the present study, the shear wall – slab connection was modeled using Graphical User Interface. For cyclic loading, the command prompt line input data was adopted.

A. Element Types

The elements used to develop this model are Solid 65 and Link 8. The Solid 65 element is used to model the concrete and stress along the reinforcement because it is inconvenient to collect the smear rebar data from solid 65. The material non linearity is taken into account for concrete. Link 8 element is to model the reinforcement.

(a) Solid 65 Element

Solid 65, an eight-node solid element, is used to model the concrete with or without reinforcing bars. The solid element has eight nodes with three degrees of freedom at each node translations in the nodal x, y, and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. The geometry and node locations for this element type are shown in Fig. 1.

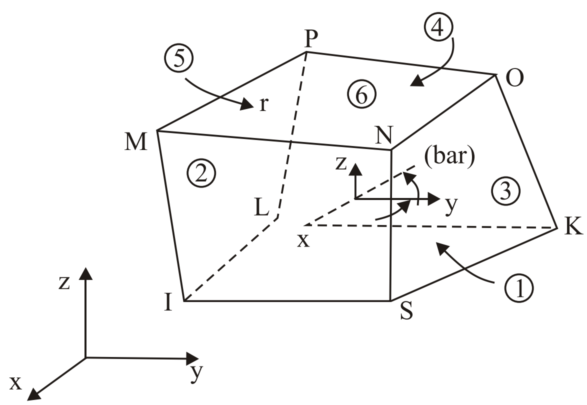

Fig. 1 Solid 65 Element - ANSYS (Version 10)

(b) Link 8 Element

Link 8 element, the three-dimensional spar element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y and z directions. As in a pin-jointed structure, no bending of the element is considered. The element is also capable of plastic deformation, stress stiffening, and large deflection. The geometry, node locations and the coordinate system for this element are shown in Fig. 2.

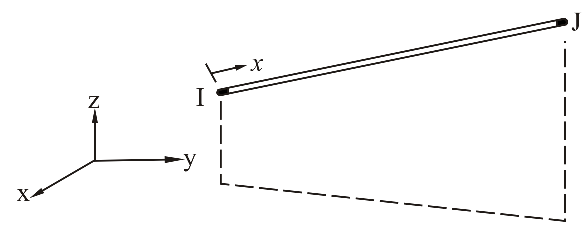

Fig. 2 LINK 8 Element - ANSYS (Version 10)

B. Sectional Properties (Real Constants)

The parameters to be considered for Solid 65 element are material number, volume ratio, and orientation angles (in X and Y direction). Since there is no rebar data required for Solid 65 element with discrete reinforcement, the volume ratio and orientation angle for real constant set 1 are set to zero. The parameters to be considered for Link 8 element are cross sectional area and initial strain. The values were entered for solid 65 element as shown in Table 1.

C. Material Properties

The material properties defined in the model are given in Table 2. Material Model Number 1 and 2 refers to the Solid 65 element and Link 8 Element, respectively. For Solid 65 element, it is necessary to input the multilinear isotropic material properties to properly model concrete. The multilinear isotropic material uses the Von Mises failure criterion along with the Willam and Warnke (1974) model to define the failure of the concrete. EX is the modulus of elasticity of the concrete (Ec), and PRXY is the Poisson's ratio (í). The characteristic strength of the concrete and the Poisson's ratio considered was 30 N/mm^2 and 0.3. The multilinear isotropic stress-strain curve for the concrete under compressive uniaxial loading was obtained using Eq. 1 (a) (Macgregor 1992).

$$f = \frac{E_C \varepsilon}{1 + (\varepsilon \varepsilon_0)^2} \quad \text{...(1 (a))}$$

$$\varepsilon_0 = \frac{2 f_{ck}}{L_C} \quad \text{...(1 (b))}$$

where, f = stress at any strain ε, ε = strain at stress f, ε 0 = strain at the ultimate compressive strength

Table 1. Real Constants For Concrete (Solid 65 Element)

Real constants set	Element type	Particulars	Constants		
			Real constants for Rebar 1	Real Constants for Rebar 2	Real Constants for Rebar 3
1	Solid 65	Material Number	2	2	2
		Volume Ratio	0.009	0.00785	0.00349
		Orientation Angle	90	0	0
		Orientation Angle	0	90	90

Table 2. Material Properties

Material Model No	Element Type	Material Properties	
1	Solid 65	**Concrete**	
		Shear transfer coefficients for an open crack	0.2
		Shear transfer coefficients for a closed crack	0.9
		Uniaxial tensile cracking stress	3.78e6 N/m^2
		Uniaxial crushing stress	30e6 N/m^2
2	Link 8	**Linear Isotropic**	
		Ex	2.1×10^{11} N/m^2
		PRXY	0.3
		Bilinear Isotropic	
		Yield Stress	415×10^{6} N/m^2
		Tang Modulus	842×10^{6} N/m^2

D. Analytical Modeling

For carrying out the parametric study, the flanged shear wall – diaphragm joint has been modeled in ANSYS (Version 10). Shear wall of dimensions of 2 m × 3.5 m × 0.3 m, the flange dimensions of 0.25 m × 0.5 m on each end and slab dimensions of 2.5 m × 2 m × 0.25 m is taken for analysis. The element used to develop this model is Solid 65. The material properties adopted for the model are defined in the table 2. The sectional properties are described in Table 3.

Table 3. Real Constants for Solid 65 element for Type 1 and Type 2 Model

Real Constant Set	Particulars	Constants		
		Real Constant for Rebar 1	Real constant for Rebar 2	Real Constant for Rebar 3
1	Material Number	2	2	2
	Volume Ratio	0.014	0.007506	0.001222
	Orientation Angle θ1	90	90	0
	Oreintation Angle Φ1	0	– 90	– 180
2	Volume Ratio	0.015047	0.007064	0.001744
	Orientation Angle θ1	90	90	0
	Orientation Angle Φ1	0	– 90	– 180
3	Volume Ratio	0.016094	0.0030152	0.0020106
	Orientation Angle θ1	90	90	0
	Orientation Angle Φ1	0	– 90	– 180
4	Volume Ratio	0.0038912	0.003664	–
	Orientation Angle θ1	0	90	–
	Orientation Angle Φ1	0	– 90	–
5	Volume Ratio	0.0030152	0.003664	–
	Orientation Angle θ1	0	90	–
	Orientation Angle Φ1	– 180	– 90	–

The shear wall is fixed at the bottom end. All the degrees of freedom are constrained except in-plane displacement and rotations θ_x and θ_z at the end of the diaphragm. The axial load and the moment that comes above the shear wall are distributed at the top surface of the wall. The modeling details of Type 1 and Type 2 model are as shown in Figure 3 to Figure 6.

IV. FINITE ELEMENT ANALYSIS

The finite element analysis has been carried out for the shear wall-diaphragm joint subjected to cyclic lateral drift histories so as to provide the equivalent of severe earthquake damage. The Modified Newton Raphson method was adopted for the solution. The loading is controlled by displacement cycles for all types of model as shown in Figure 7

V. RESULTS

The analysis results are presented in the form of ultimate load carrying capacity, drift - load hysteretic curves, envelope curves for drift – load and energy dissipation curves.

A. Ultimate load carrying capacity

The variation in ultimate load carrying capacity for the models for positive and negative direction of loading is shown in Table 4. It is observed

B. Load – Displacement Hysteretic loops

The hysteretic loops of the load - displacement relationship for two types of specimens are shown in Figure 8 and

C. Energy Dissipation Capacity

The dissipated energy is determined by integrating the areas bounded by the hysteretic loops in each cycle. Cumulative energy absorbed during each that the ultimate load is higher for Type 2 models.

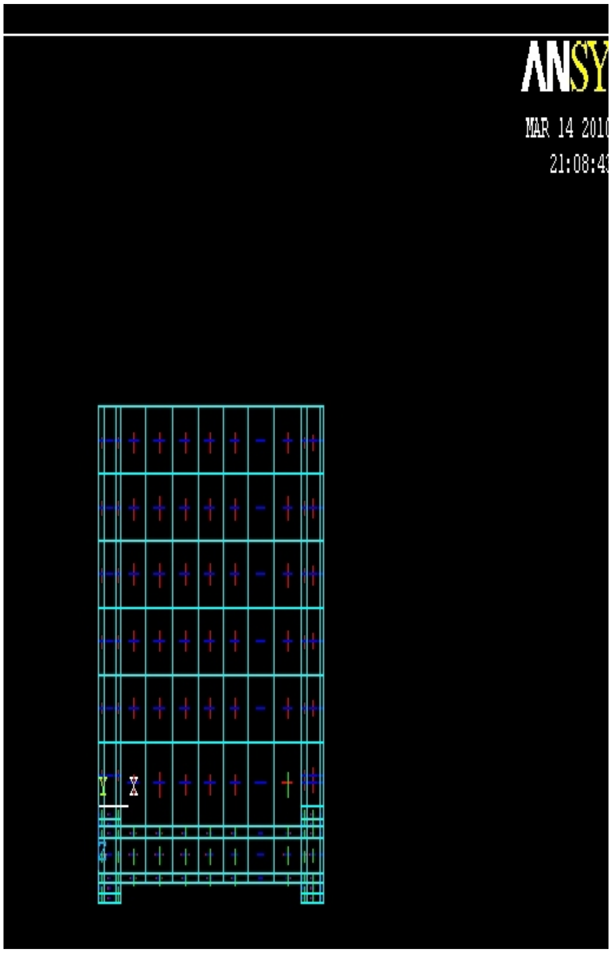

Fig. 3. Reinforcement configuration sneared model (top view)

Table 4 Ultimate load carrying capacity

	Ultimate Load (kN)		
Designation of specimen	Positive direction	Negative direction	Average (P_U)
Type 1	24.520	23.152	23.836
Type 2	26.862	26.675	26.768

**cycle of loading is plotted against corresponding cycle for Type 1 and Type 2 models as shown in Figure 10.

It is observed that Type 2 specimen had exhibited higher ultimate strength and energy dissipation capacity when compared to Type 1 specimen. Hence further parametric study has been carried out by varying the ratio of vertical reinforcement of flanged shear wall and the axial load for Type 2 specimen only.

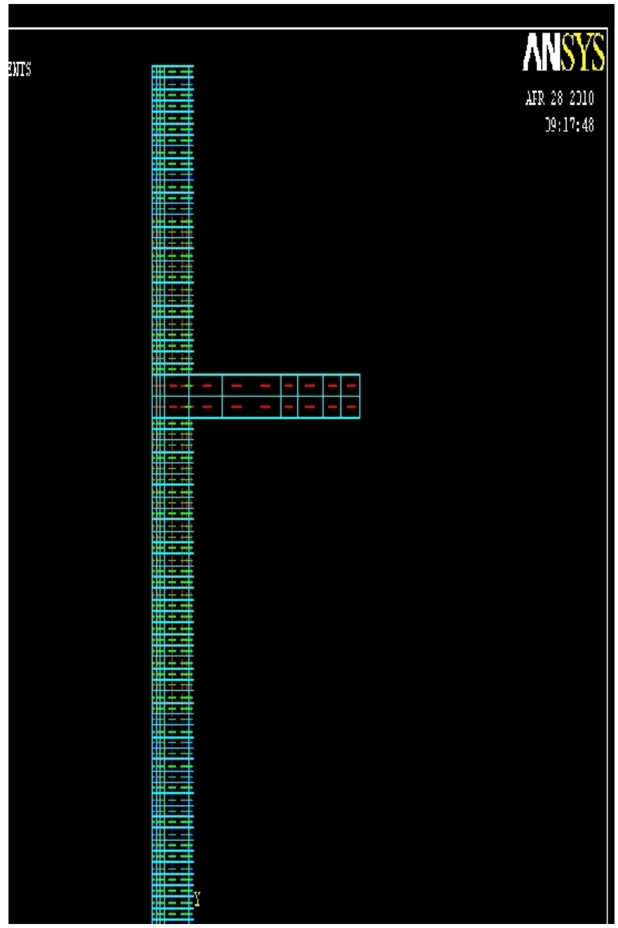

Fig. 4. Shear wall diaphragm connection side view

VI. CONCLUSION

Following are the conclusions drawn based on the and analytical modeling carried out to study the behavior of shear wall-diaphragm joint under cyclic loading.

(i) From the parametric study it is found that the model has exhibited higher ultimate strength and deformation capacity when the confining U hooks were extended for an effective length of 2.8 Hw (Type 2 model) when compared with 2.25 Hw (Type 1 model).

(ii) Spindle-shaped hysteretic loops were observed with large energy dissipation capacity for Type 2 models compared to Type 1 model.

(iii) It is also observed that the ultimate strength increases with increase in reinforcement ratio but the deformation capacity gets increased for models with $\rho = 0.02$ when compared to $\rho = 0.025$.

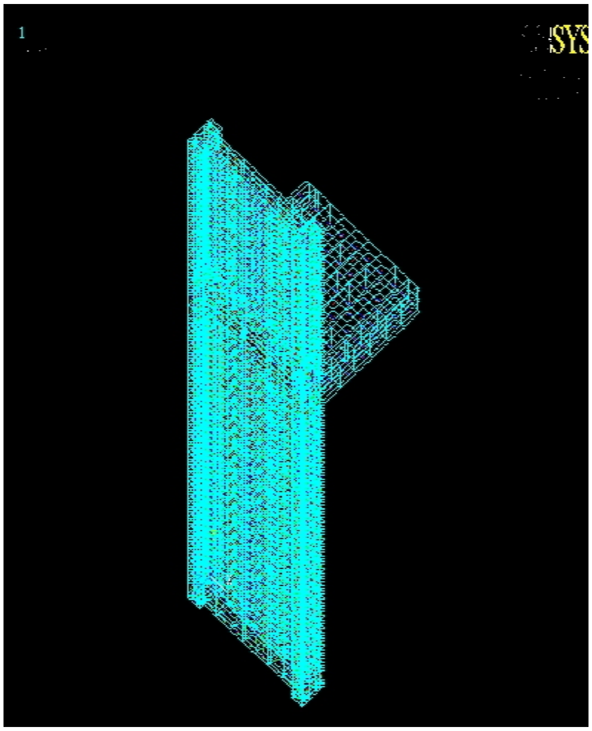

Fig. 5. Shear wall diaphragm model

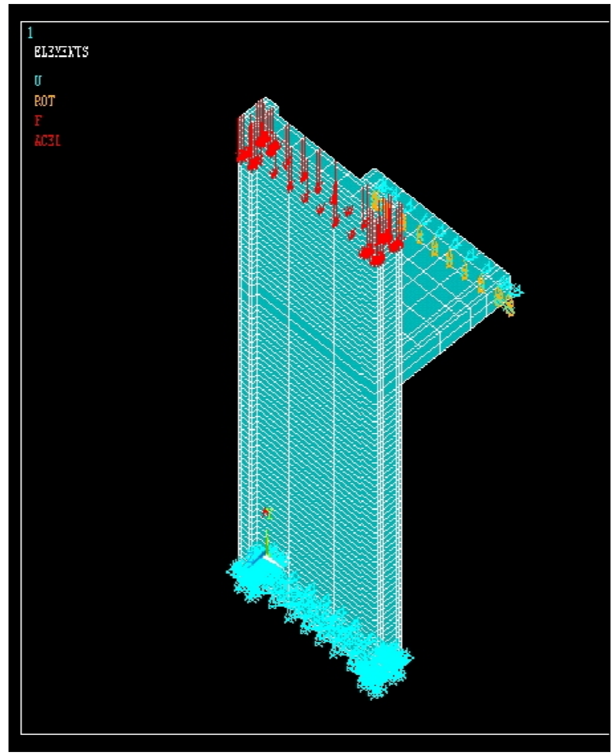

Fig. 6. Sheat wall diaghragm model with loading and boundary condition

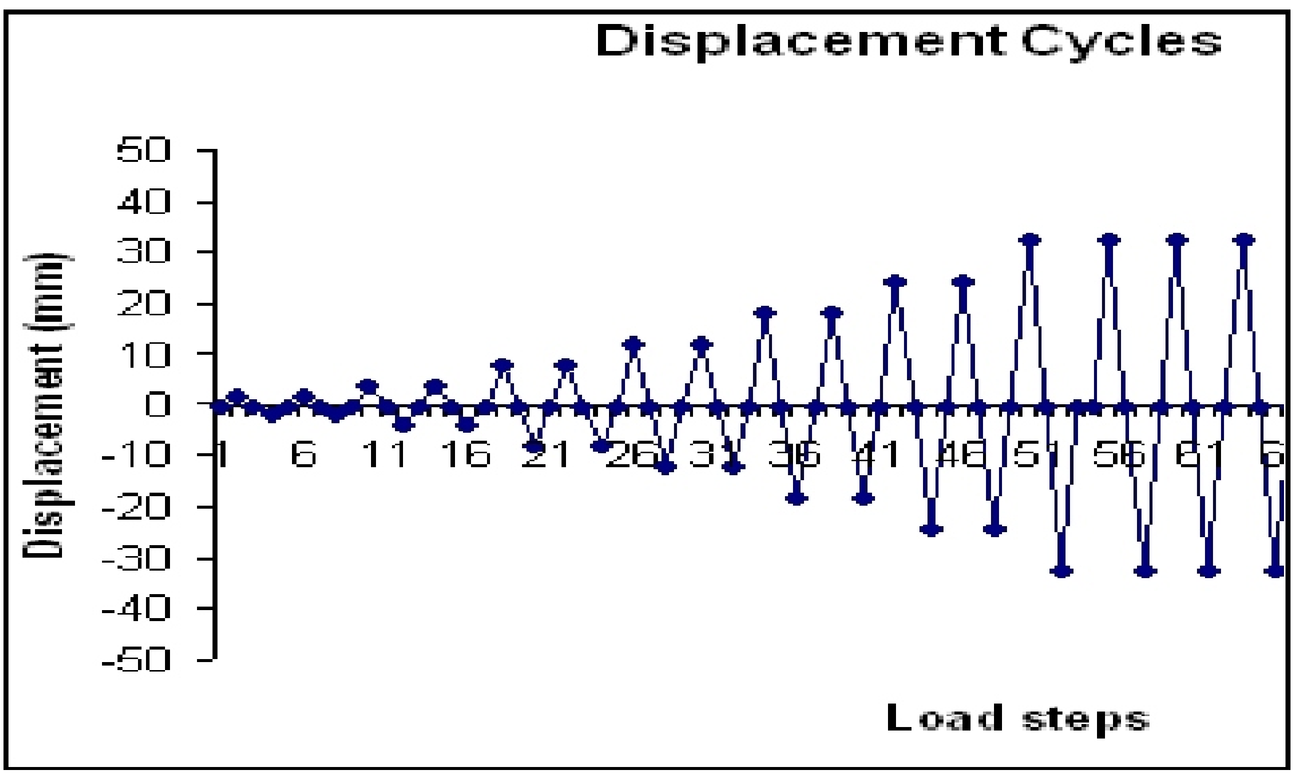

Fig. 7. Displacement Cycles

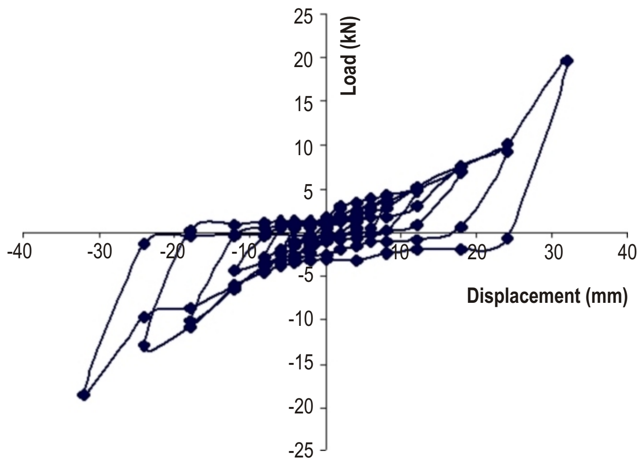

Fig. 8. Load displacement curve for Type 1 model

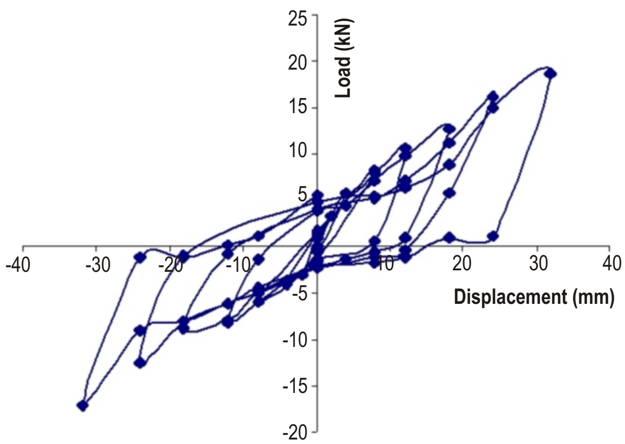

Fig. 9. Load displacement curve for type 2 model

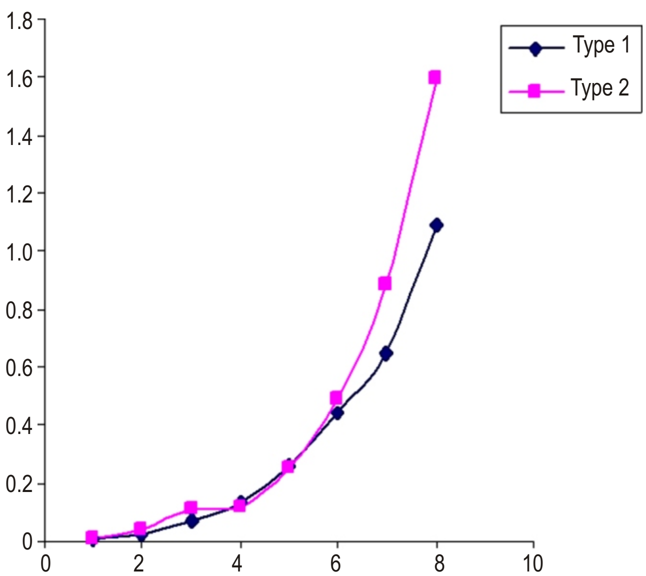

Fig. 10. Cumulative energy dissipation curves of models

(iv) The ultimate strength and energy dissipation increased drastically for the models with axial load 0.1 P when compared to models with P.

(v) Further, the joint shear capacity of the Type 2 model has improved when compared to Type 1 model.

REFERENCES

[1] Willam, K.J. and Warnke, E.P, 1974, "Constitutive Model for Triaxial Behaviour of Concrete," Seminar on Concrete Structures Subjected to Triaxial Stresses, International Association of Bridge and Structural Engineering Conference, Bergamo, Italy, p.174.

[2] Antonio F, Barbosa and Gabriel O Ribeiro, 2000, "Analysis of Reinforced Concrete Structures Using ANSYS Non Linear Concrete Model", Computational Mechanics, New Trends and Applications, Barcelona, Spain.

[3] P. Fanning, 2001, "Nonlinear Models of Reinforced and Post-tensioned Concrete Beams", Electronic Journal of Structural Engineering, Vol.2, pp 111 - 119.

[4] Anthony J, Wolanski B.S, 2004, "Flexural behavior of reinforced and prestressed concrete beams using finite element analysis ", A Thesis submitted to the Faculty of the Graduate School, Marquette University. Milwaukee, Wisconsin May, 2004.

[5] ANSYS, "ANSYS User's Manual Revision 10", ANSYS, Inc; 2006.

[6] A. Coull and Y.C. Wong, 1985, "Local elastic wall deformations on the interaction between floor slab and flanged shear walls" *ASCE*, Vol.20, No.3, pp 169-179.

[7] Joel. M. Barron and Mary Beth D.Huste, 2004, "Diaphragm effect in rectangular reinforced concrete building". *ACI*, Vol 101, pp 615-624.

[8] Doran, 2003, "Indian institute of science Elastic-plastic analysis of R/C coupled shear wall :the equivalent stiffness ratio of the tie elements". Indian Institute of Science, Vol 83, pp 87-94.

[9] Alexander Coul, 1983, "Design of Floor Slabs Coupling Shear Walls" ASCE Vol-109, pp. 109-125.

[10] Saatcioglu. M, Derecho A.T, Corley. W.G, 1987, "Parametric Study of Earthquake-Resistant Coupled Walls" *ASCE* Vol-113 (1), pp.141-157.

[11] Alex Coull, 1984, "Influence of door openings on effective slab width". *ASCE*, Vol 10, No.10, pp. 2531-2535.

[12] Md. Safil Bari, 1995, "Nonlinear, finite element study of shear wall – floor slab connections". *CE* Vol 24, No.2. pp 137-145.