SEISMIC BEHAVIOUR OF SHEAR WALL - SLAB CONNECTION

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ABSTRACT

Reinforced concrete structures are largely employed in engineering practice in a variety of situations and applications. In most cases these structures are designed following simplified procedures based on experimental data. Although traditional empirical methods remain adequate for ordinary design of reinforced concrete members, the development of the finite element method have provided means for analysis of much more complex systems in a much more realistic way. The main obstacle to finite element analysis of reinforced concrete structures is the difficulty in characterizing the material properties. Much effort has been spent in search of a realistic model to predict the behaviour of reinforced concrete structures. Due mainly to the complexity of the composite nature of the material, proper modeling of such structures is a challenging task. The objective of this work is to explore the various detailing, adopted for the connection of shear wall to floor slab. It reports the results of analyses performed using the reinforced concrete model of the general purpose finite element code ANSYS (Version10). Its reinforced concrete model consists of a material model to predict the failure of brittle materials, applied to a three dimensional solid element in which reinforcing bars may be included. The material is capable of cracking in tension and crushing in compression. This paper presents the results of the three-dimensional non-linear finite element analysis of the shear wall-slab connection under seismic loading.

KEYWORDS: Concrete, Seismic loading, Non linear Analysis

1. INTRODUCTION

The frequent occurrence of the major earthquakes in the Indian subcontinent, and construction of tall buildings, especially over the last two decades demands for the construction of earthquake resistant buildings. Shear wall is one of the best lateral loading systems. In the wake of the devastating earthquakes in the recent past and the trend in Civil Engineering construction, to go for tall buildings, the shear wall- slab connection should be adequately designed and detailed.

An extensive description of previous studies on the underlying theory and the application of the finite element method to the linear and nonlinear analysis of reinforced concrete structures is presented in excellent state of-the-art reports by the American Society of Civil Engineers in 1982 [ASCE 1982]. Because of these complexity in short- and long-term behavior of the constituent materials, the ANSYS finite element program introduces a three-dimensional element Solid65 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 Solid65 can describe the reinforcing bars, this study uses an additional element, Link8, to investigate the stress along the reinforcement because it is inconvenient to collect the smear rebar data from Solid65.

2. LITERATURE REVIEW

Can Balkaya et al (1993) studied about the shear wall dominant structures. Shear-wall dominant buildings are the prevailing multi-story RC buildings type particularly in the regions prone to high seismic risk. To identify their most essential design parameters, dynamic and inelastic static pushover analyses were conducted on the backbone of performance based design methodology.

Antonio F. Barbosa et al (2000) presented a paper considering the practical application of nonlinear models in the analysis of reinforced concrete structures. The results of some analyses performed using the reinforced concrete model of the general-purpose finite element code ANSYS are presented and discussed. The differences observed in the response of the same reinforced concrete beam as some variations are made in a material model that is always basically the same are emphasized.

Anthony J. Wolanski, B.S (2004) did research on the flexural behavior of reinforced and prestressed concrete beams using finite element analysis. The two beams that were selected for modeling were simply supported and loaded with two symmetrically placed concentrated transverse loads.

Joel. M. Barron and Mary Beth D. Hueste (2004) studied the diaphragm Effect in Rectangular Reinforced Concrete Building. Under Seismic Loading, floor and roof systems in RC building acts as diaphragms to transfer lateral earthquake loads to the vertical lateral force resisting system. The impact of in- plane diaphragm deformation on the structural response of RC building is evaluated using a performance-based approach.

3. DESIGN AND DETAILING OF SHEAR WALL – SLAB CONNECTION

A six storey RC building in Zone III on medium soil was analyzed and the shear forces, bending moments and axial forces around the wall-slab interface due to different load combinations were obtained. Seismic analysis is performed using equivalent lateral force method given in the Indian Standard Code IS 1893:2002. One of the exterior shear wall-slab connections was designed and detailed as per the design criteria of IS 456:2000 and IS 1893:2002 incorporation of the ductile detailing as per IS 13920:1993. The details of the reinforcements provided for shear wall and slab are shown in Fig.1 and Fig.2, respectively.

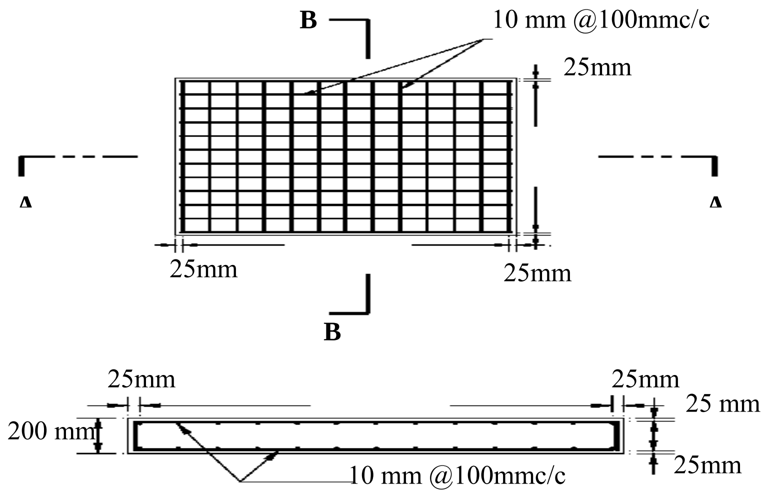


Fig.1 - Slab reinforcement details – Top View and Section AA

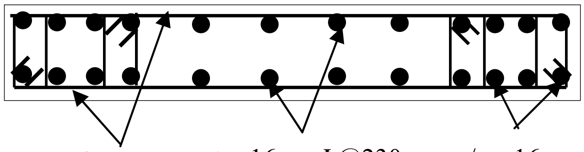


Fig.2 - Shear wall – reinforcement details

3.1 Detailing of Shear Wall - Slab connection

The main objective of the present study is to identify the optimum connection detailing of slab to shear wall. There are three patterns of detailing were adopted for the shear wall to slab connection, such as,

(i) ***Type I Connection (90 degree bent at the connection):*** In an external shear wall-slab connection, both the top and bottom bars of the slab were extended towards the exterior face of the shear wall and provided with anchorage length, beyond the face of the shear wall, equal to the development length plus 10 times the bar diameter as shown in Fig.3. This type of connection is referred as Type I connection in the following discussion.

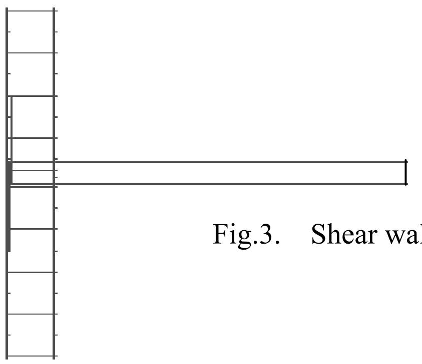


Fig.3. Shear wall – slab connection for 90 degree bent configuration

(ii) ***Type II Connection (45 degree cross-reinforcement):*** The type II connection is of non-conventional in nature. The non-conventional detailing is provided as diagonal cross bracing reinforcement at the connections along with the longitudinal bars as shown in Fig.4.

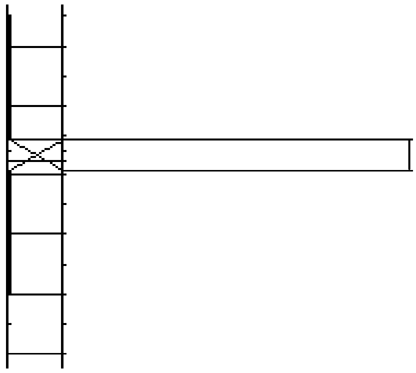


Fig.4. Shear wall – slab connection for 45 degree cross bars configuration (Type II)

(iii) ***Type III Connections (Hook Bars):*** Additional U hooks were provided at the connection region along with the normal slab reinforcements. The additional hooks are of 8 mmΦ @100 mm c/c. The details are shown in Fig.5.

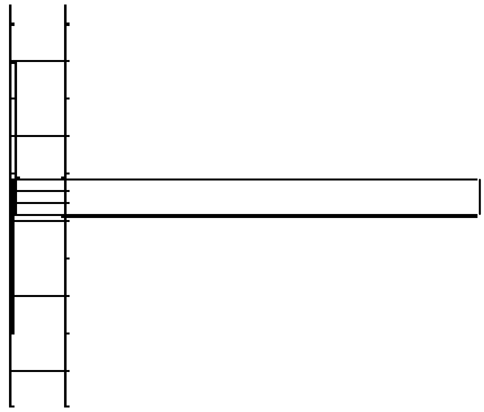


Fig.5. Shear wall – slab connection for additional U hook bars (Type III)

4. FINITE ELEMENT MODELLING OF SHEAR WALL – SLAB

The slab of dimensions 2m x 2m in plan and 0.2 m thick supported on a shear wall of dimensions 3.5m x 2.5m x 0.3m .The elements used were SOLID 65 for concrete and LINK 8 for reinforcement modeling. The properties of both the elements were defined. The shear wall was fixed at the bottom and at the slab end; all the degrees of freedoms were constrained except in-plane displacement. The dead load that comes above the shear wall was distributed as a point load at each node on the top surface of the wall.

4.1 Element Types

The element types and modeling method adopted are discussed in the following sessions. The elements used to develop this model were Solid 65 and Link8. The Solid65 element was used to model the concrete and Link 8 element was to model the reinforcement.

Solid65, an eight-node solid element, is used to model the concrete with or without reinforcing bars (shown in Fig.6) . The solid element has eight nodes with three degrees of freedom at each node translations in the nodal x, y, and z directions.

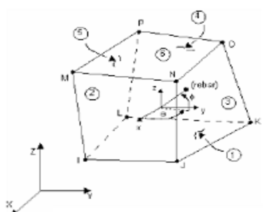


Fig.6 - Solid 65 Element -ANSYS

Link8 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 shown in Fig.7. As in a pin-jointed structure, no bending of the element is considered.

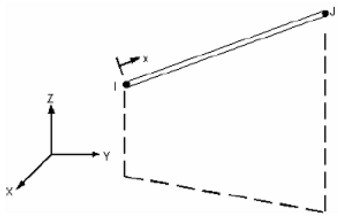


Fig.7 - Link 8 Element - Ansys

4.2 *Sectional Properties (Real Constants)*

For the shear wall with discrete reinforcement, smeared reinforcement capability of the Solid65 element turned off for real constant set 2, 3, 4 and 5. Values for cross-sectional area and initial strain were entered for Link 8 element corresponding to the reinforcements in shear wall and slab.

4.3 *Material Properties*

The Solid65 element requires linear isotropic and 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. The characteristic strength of the concrete considered was 25 N/mm^2 and the Poisson's ratio was 0.3.

$$Ec = 5000 \sqrt{f_{ck}} = 2.5 \times 10^{10} \text{ N/m}^2$$

The multilinear isotropic stress-strain curve for the concrete under compressive uniaxial loading was obtained using Eqn.1.3 a and Eqn.1.3 b (Macgregor 1992).

$$f = \frac{E_C \varepsilon}{1 + (\varepsilon/\varepsilon_0)^2} \quad \text{(Eqn. 1.3 a)}$$

$$\varepsilon_0 = \frac{2 f_{ck}}{E_C} \quad \text{(Eqn. 1.3 b)}$$

where, f = stress at any strain ε, ε = strain at stress f, ε_0 = strain at the ultimate strength

5. FINITE ELEMENT ANALYSIS

The analysis has been carried out for the shear wall – slab connection subjected to four earthquakes loading. The convergence criteria used for the analysis is displacement with the tolerance of 0.001.For carrying out the seismic analysis, the command prompt line input data is adopted. The analysis was carried out with acceleration time history data of three earthquakes by mentioning the number of data points and time interval.

6. RESULTS AND DISCUSSIONS

From the Time History analysis of three earthquakes, the absolute maximum displacements and von mises stresses were found. The absolute maximum displacements and von mises stresses for the shear wall – slab connection subjected to El Centro, Northridge and Loma Prieta earthquakes were shown in Table.2 and the responses for the shear wall – slab connection with hooks due to El Centro earthquake loading were shown in Fig.8 and Fig.9. It was found that the absolute maximum displacements for the shear wall- slab connection subjected to Northridge earthquake loading was 75% more when compared to El Centro earthquake as shown in Table 1. Comparative studies for the responses are shown in Fig.10 and Fig.11.

Table.1. Absolute Maximum Displacement and Von Mises stresses

Configuration	**90 degree bend**		**Cross reinforcement**		**Hook connection**	
Earthquake	Absolute maximum displacement, (mm)	Von Mises Stress,MPa	AbsoluteMaximum Displacement,mm	Von Mises Stress,MPa	Absolute Maximum Displacement, (mm)	Von Mises Stress,MPa
El-Centro (1940)	2.1243	230837	2.1228	231189	2.2571	230601
Northridge (1994)	3.7174	402455	3.7137	403073	3.7622	406447
Loma Prieta (1989)	3.5750	298210	3.5601	298361	3.5823	298828

7. CONCLUSION

The scope of the present work was to find the proper connection detailing of shear wall to the diaphragm. The dynamic analysis was carried out for three configurations of shear wall- diaphragm connection subjected to El Centro, Northridge and Loma Prieta earthquakes. It was noticed that the difference in maximum displacements for the three configurations of the shear wall- slab connection for El Centro earthquake loading were within 6%. For Northridge and Loma Prieta earthquake the variation was within 2 %. It was found that, within the allowable deflection (H/425), the shear wall- diaphragm connection with hook deflects more when compared to the other two configurations. Hence, the shear wall- diaphragm connection with hook was more efficient under dynamic lateral loadings.

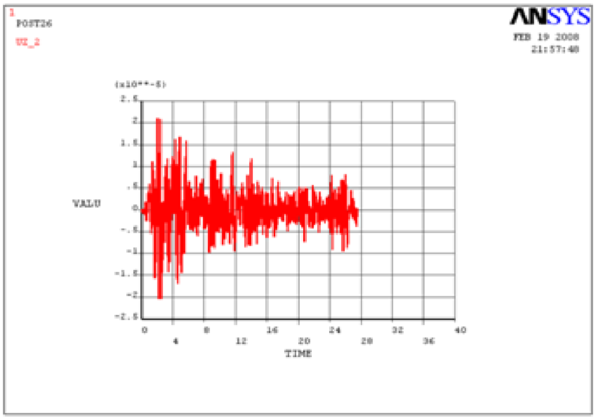


Figure 8. Displacement response of shear wall-diaphragm connection with hook under El Centro Earthquake

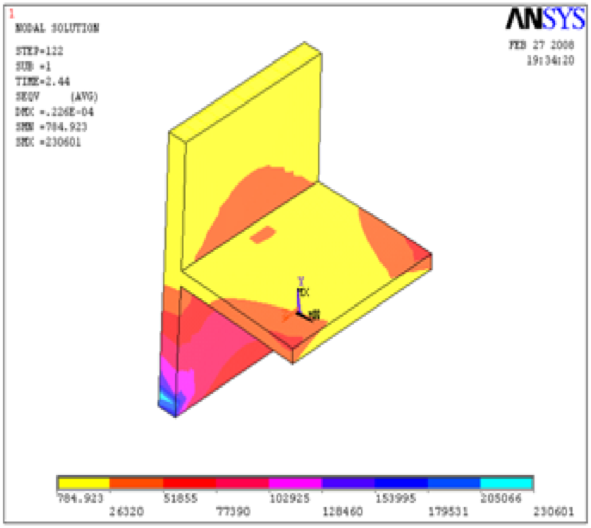
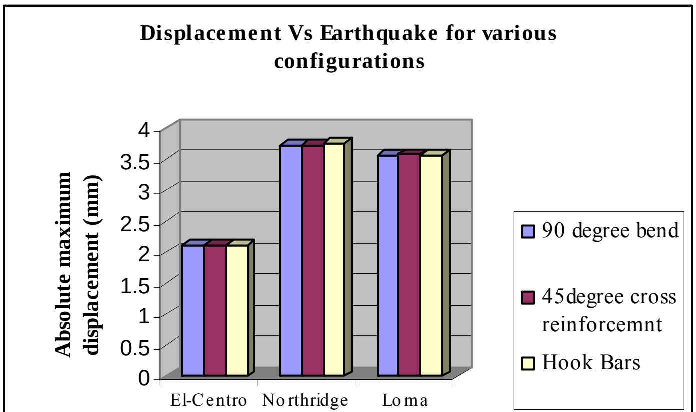


Figure 9. Von Mises stress of shear wall-diaphragm connection with hook under El Centro Earthquake



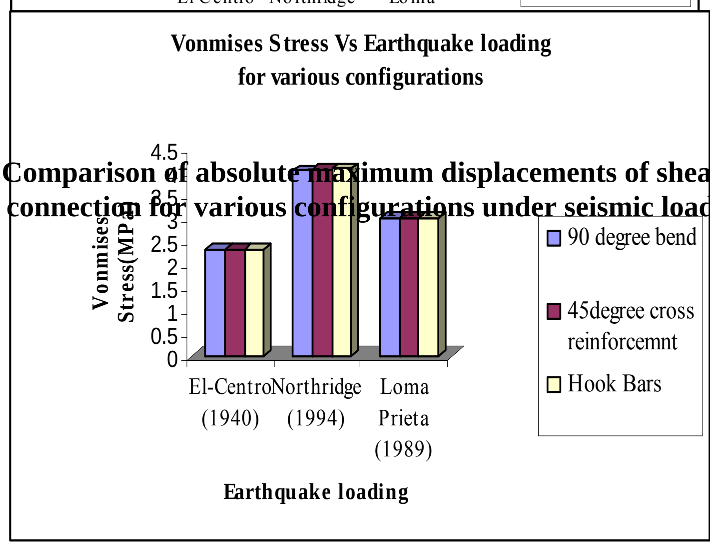


Figure 10. Comparison of absolute maximum displacements of shear wall-diaphragm connection for various configurations under seismic loading.

Figure 11. Comparison of vomises stress of shear wall-diaphragm connection for various configurations under seismic loading.

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