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ANALYTICAL STUDY ON FLANGED SHEARWALL UNDER LATERAL LOADING

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ABSTRACT:

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 and it should be adequately designed and detailed. An analytical study has been made of the behavior of laterally loaded flanged shear wall in building with cross-shear wall. Particular attention is paid to the modeling of reinforced concrete rectangular shear wall with boundary elements. The objective of this work is to discuss the possibilities of modeling reinforcement detailing of reinforced concrete models in practical use. It reports the results of some analyses performed using the reinforced concrete model of the general-purpose finite element code ANSYS Version 10. The reinforced concrete model in ANSYS 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 nonlinear finite element analysis of the reinforced concrete wall modeled with smeared reinforcement as well as discrete reinforcement detailing subjected to lateral static loading.

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 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.

LITERATURE REVIEW

Can Balkaya et al. (1993) studied about the shear wall dominant structures. Shear-wall dominant buildings are the prevailing multistory 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. The consequences of small changes in modeling are discussed and it is shown that satisfactory results may be obtained from relatively simple and limited models. He took a simply supportedreinforced concrete beam subjected to uniformly distributed loading has been analyzed. Fanning (2001) did research on non-linear models of reinforced concrete beams. The requirement to include the nonlinear response of reinforced concrete in capturing the ultimate response of ordinarily reinforced beams demands the use of the dedicated Solid 65 element in ANSYS. The internal reinforcements were modeled using three dimensional spar elements with plasticity, Link 8, embedded within the solid mesh. Anthony J Wolanski (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.

REINFORCED CONCRETE MODELING

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 concretestructures is presented in excellent state ofthe-art reports by the American Society of Civil Engineers in 1982 (ASCE, 1982). The results from the FEA are significantly relied on the stress-strain relationship of the materials, failure criteria chosen, simulation of the crack of concrete and the interaction of the reinforcement and concrete. Because of these complexity in short- and long-term behavior of the constituent materials, the ANSYS finite element program introduces a three dimensional element 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 stress along the reinforcement because it is inconvenient to collect the smear rebar data from Solid 65.

Modelling of Shear Wall – ANSYS

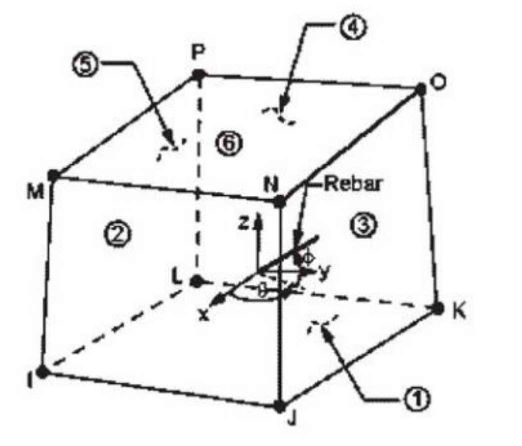
The Shear Wall has been modeled in ANSYS (Version 10), introduces a three dimensional element Solid 65 which is capable of cracking and crushing and is then combined along with models of the interaction between the two constituents to describe the behavior of the composite reinforced concrete material. Although the Solid 65 can describe the reinforcing bars, this study uses an additional element, Link 8, to investigate the 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.

Element Types

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

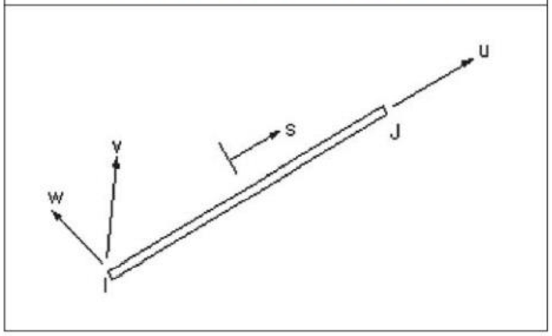
Figure 1: Solid 65 Element (ANSYS)



in Figure 1. Shear wall of dimensions of 2.5 m x 3.5 m x 0.3 m is taken for analysis and modeled by selecting smeared rebar property of SOLID 65 Element and also modeled by using discrete reinforcement to study the variation of stresses along the reinforcement. The diameter of vertical reinforcement is taken as 16 mm @150 mmc/c, horizontal reinforcement is 12 mm @ 200 mm c/c and shear reinforcement is provided as 8 mm @150 mm c/c. Meshing has carried out. Shear wall is fixed at bottom. Static analysis of shear wall has been carried out.

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 Figure 2.

Figure 2: Link Element (ANSYS)



SECTIONAL PROPERTIES (REAL CONSTANTS)

The real constants considered for Solid 65 element were volume ratio and orientation angles (in X and Y direction). Shear wall with discrete reinforcement is considered for thepresent study. Hence the smeared reinforcement capability of the Solid 65 element turned off for real constant set 1 (volume ratio and orientation angle were set to zero). The parameters considered for Link 8 element were cross sectional area and initial strain. The real constant values for Link 8 element used for modeling the specimens are as given in the Table 1.

MATERIAL PROPERTIES

The material properties used in the model are given in Table 2. The average 28-day cube strength (fck) of the specimens used for modeling was 37.76 MPa. The multilinear isotropic material uses the Von Mises failure criterion along with the William 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. Ec = 5000 √f ck = 3.0724 x 1010 N/m2 The uniaxial tensile cracking stress of concrete (t f) is determined using Equation (1)

$$f_t = 0.623\sqrt{f_c'}$$

Table 1: Real Constants for Steel Reinforcement (Link 8 Elements)

Real Constant Set	Element Type	Particulars of the Specimen	
1	Link 8(Vertical reinforcement of shear wall)	Cross sectional Area (m^2)	$201X10^{-6}$
		Initial Strain	0
2	Link 8(Horizontal reinforcement of shear wall)	Cross sectional Area (m^2)	$78.54X10^{-6}$
		Initial Strain	0
3	Link 8(Stirrup in shearwall)	Cross sectional Area (m^2)	$50.26X10^{-6}$
		Initial Strain	0

where, ' c f is the cylinder strength of the test specimen. The multilinear isotropic stress-strain curve for concrete under compressive uniaxial loading was obtained using Equation (3) (Desayi and Krishnan, 1964), for modeling concrete.

$$f = \frac{E_C\,\varepsilon}{1+\left(\varepsilon/\varepsilon_0\right)^2}$$

$$\varepsilon_0 = \frac{2 f_{ck}}{E_C}$$

where, f = stress for strain ε, ε = strain at stress f, ε0 = strain at the ultimate strength.

MODELING OF SHEAR WALL

The shear wall was modeled in two ways, such as (i) shear wall with discrete reinforcement; (ii) Shear wall with smeared reinforcement. The sectional properties and material properties adopted for modeling are discussed in the earlier sessions. Shear wall is subjectedto a lateral load at the top of the wall in the in plane direction of the wall. The maximum lateral deflection and the corresponding stresses are found. The modeling details are shown in Figures 3 to 7.

Table 2: Material Properties Defined in Model

Material Model No.	Element Type	Material Properties	
1	Solid-Concrete65	Linear Isotropic	
		EX	3.0724×10^{10} N/m^2
		PRXY	0.15
		Concrete	
		Shear transfer coefficient for open crack	0.2
		Shear transfer coefficient for closed crack	0.9
		Uniaxial tensile cracking stress	3.71×10^6 N/m^2
		Uniaxial crushing stress	-1
2	Link-Spar8	Linear Isotropic	
		EX	2.1×10^{11} N/m^2
		PRXY	0.3
		Bilinear Kinematic	
		Yield stress	432×10^6 N/m^2
		Tangent Modulus	847×10^6 N/m^2

FINITE ELEMENT ANALYSIS

The finite element analysis has been carried

Figure 3: Reinforcement Configurations – Discrete Model (Top View)

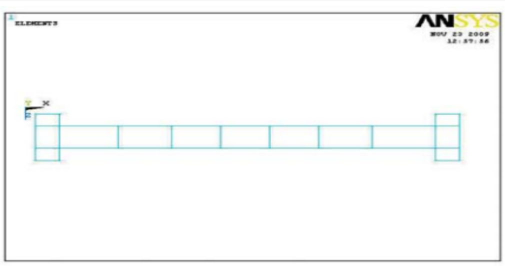


Figure 6: Shear Wall with Smeared Reinforcement

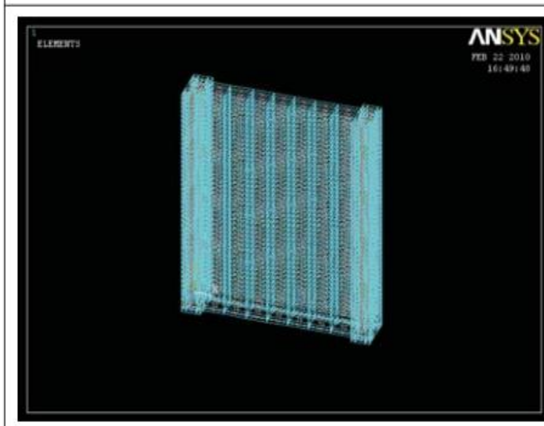


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Figure 4: Reinforcement Configuration - Smeared Model (Top View)

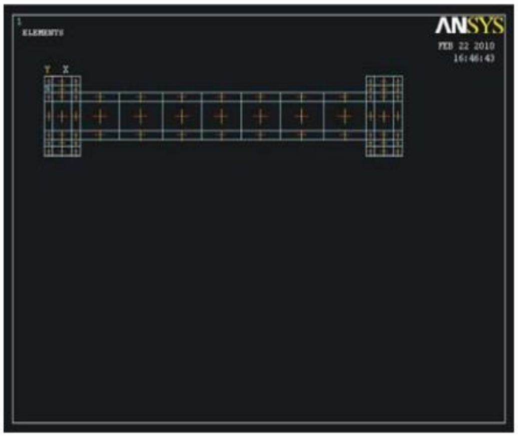


Figure 7: Shear Wall Model with Loading

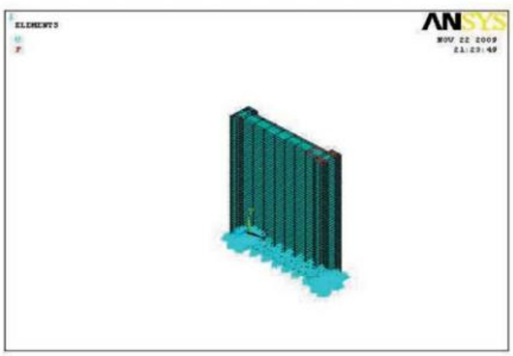
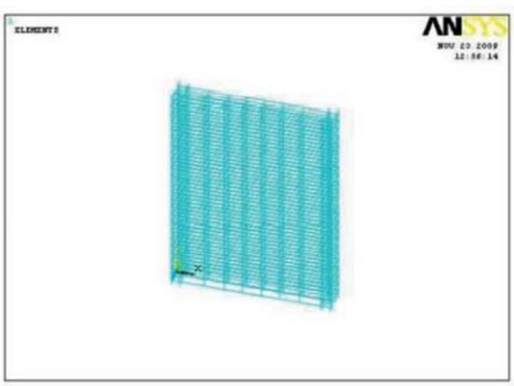


Figure 5: Shear Wall with Discrete Reinforcement



out for the shear wall subjected to static loading. The graphical user interface was adopted for applying the load. The loading was applied in 10 load steps with the convergence of 0.001. The Modified Newton Raphson method was adopted for the solution

RESULTS AND DISCUSSION

Results from finite element analysis of shear wall under structural loading. The top of the flanged shear wall was subjected to a lateral load of 50 kNThe maximum deformation were observed for the top surface of shear wall and it's gradually reduced towards the bottom. The deformed shape under lateral loading was

Figure 8: Deformed Shape (Discrete Model)

Figure 9: Deformed Shape (Smeared Model)

Figure 10: VonMises Stress for Shear wall with Discrete Reinforcement under Static Loading

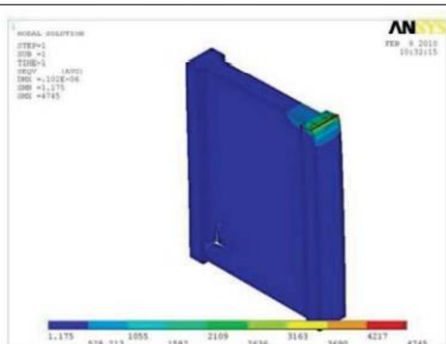
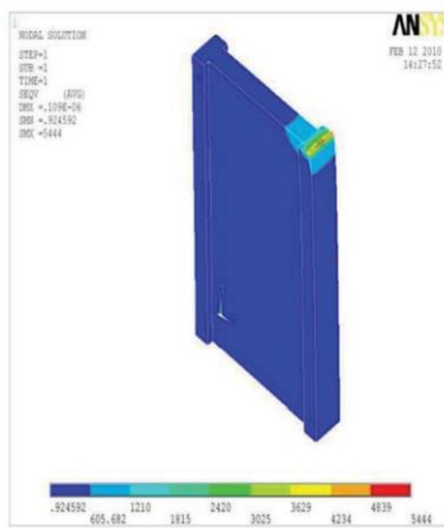


Figure 11: VonMises Stress for Shear Wall With Smeared Model Reinforcement Under Static Loading



shown in Figures 8 and 9. Von Mises stress contour was shown in Figures 10 and 11 and it was observed that the maximum stress is at the bottom of shear wall. The possibility of modeling the flanged shear wall can be extended for modeling all the reinforced structures under lateral cyclic loading.

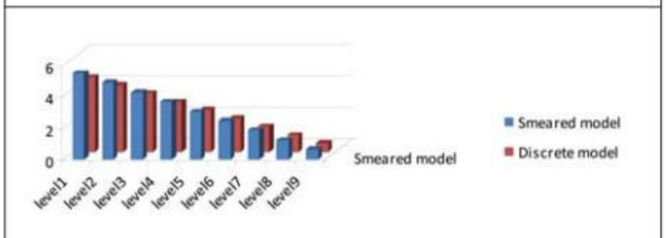
NUMERICAL RESULTS AND DISCUSSION

The modeling and analysis of shear wall has been carried out with two different conditions, such as (i) Shear wall with smeared reinforcement subject to in-plane static loading, (ii) shear wall with discrete reinforcement subject to in plane static loading. According to the Von Mises theory, at the plastic limit, the elastic energy of distortion reaches a constant value, which is equal to the distortion energy in simple tension at yield. Energy of distortion is equal to the total strain energy minus elasticenergy of volume dilatation. For ductile material, this theory expresses the equation of the limiting surface of yielding. The lateral deflection of shear wall with discrete reinforcement is noted to be same as that of the shear wall with smeared rebar property as shown in Table 4. Similarly, the Von Mises stresses for wall with smeared reinforcement are almost same as that of the wall with discrete

Table 4: Lateral Deflection and Von Mises Stresses

Description	Lateral Deflection	Von Mises Stress (N/mm^2)
Shear wall with smeared reinforcement (in plane static loading)	0. 5256	5.45
Shear wall with discrete reinforcement (in plane static loading)	0.5221	4.75

Figure 12: Comparison of Vonmises Stress for the Two Models



reinforcement as shown in Figure 12 and the maximum variation in Von Mises stress is within 15%

CONCLUSION

The major objective of the present study is to explore the possibility of modeling reinforced concrete shear wall with discrete reinforcement for the nonlinear analysis. The shear wall was modeled with smeared reinforcement property using Solid 65 element and the same was modeled with discrete reinforcement using Link 8 element. It is observed that the lateral deformation is almost same for both the cases. Similarly, the Von Mises stresses for the discrete reinforcement model are also matching with that of the model with smeared rebar property. Hence, it is proposed to use discrete reinforcement detailing for the dynamic analysis.

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