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Dynamic Analysis of Flanged Shear Wall Using Staad Pro

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ABSTRACT

Earthquakes demonstrate vulnerability of various inadequate structures, every time they occur. The lessons taught from the aftermath of earthquakes and the research works being carried out in laboratories give better understanding about the performance of the structure and their components. Damage in reinforced concrete structures was mainly attributed to the inadequate detailing of reinforcement, lack of transverse steel and confinement of concrete in structural elements. Typical failures were brittle in nature, demonstrating inadequate capacity to dissipate and absorb inelastic energy. This necessitates a better understanding of the design and detailing of the reinforced concrete structures under various types of loading. 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]. 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 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 Solid 65 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 Solid 65.

KEYWORDS: Dynamic Analysis, Flanged Shear Wall, Staad Pro

I. INTRODUCTION

A potentially limiting feature of reinforced masonry shear walls is the presence of a single line of vertical reinforcement along the wall length that cannot be effectively tied to delay buckling. Especially under cyclic loading, when opening and closure of wide cracks occurs, compression closure of the previous tension cracks causes all of the compressive stresses to be carried by isolated bars at the crack location. This situation affects the stability of the compression zone and may lead to out-of-plane buckling of the wall or local buckling of the reinforcement, which can lead to an accelerated degradation in strength due to increased damage.

This limitation may be avoided by using boundary elements at the end zones of the walls or by structurally connecting a linear wall to an intersecting wall which would limit the damage at the end zone of the wall, provide out-of-plane stability for the end of the wall, and delay buckling of the vertical bars. The experimental data presented is the first phase of an investigation of the response of flexural concrete masonry shear walls with various geometries at the ends of the walls.

The conditions studied are the effects of structurally connecting a flange to a linear reinforced masonry shear wall and of creating a boundary element at each end of the wall. The walls were tested under reversed lateral cyclic displacement simulating earthquake excitation. Details of the linear, flanged, and confined wall tests are presented in this paper. In general, high levels of ductility accompanied by relatively small strength degradation were observed for the test specimens with significant increase in ductility for the flanged and confined walls.

II. THE SHEAR STRENGTH OF SHEAR WALLS

The use of shear walls, as major lateral load resisting components in multistory structures is standard design procedure. The assessment of their required strength, likely behaviour and aspects of detailing are largely based on "good engineering practice. This draws from the analogy to other similar structures , such as reinforced concrete beams, and from the observed behaviour of structures which were exposed to seismic shocks. It is only recently that attempts were made to codify certain aspects of shear wall design. These recommendations were based on a limited amount of experimental evidence and presumably on some theoretical considerations. Some features of existing code rules will be discussed later. Because of the lack of factual information on many features of shear wall behaviour, understandably, code writers approach the problems with considerable caution or they do not mention them. A brief review of our present understanding of the shear resistance of reinforced concrete beams is presented to assist in the evaluation of the likely behaviour of shear walls. Certain features, such as the effect of cyclic loading, deep beam behaviour are discussed in greater detail. Much of this information was obtained from a continuing research project on shear walls at the University of Canterbury. It is attempted to interpret some of these findings in terms of likely shear wall behaviour. After a brief examination of code requirements a number of design recommendations are made. The emphasis is placed on various aspects of shear strength. The discussion of other equally important features of shear wall design is omitted.

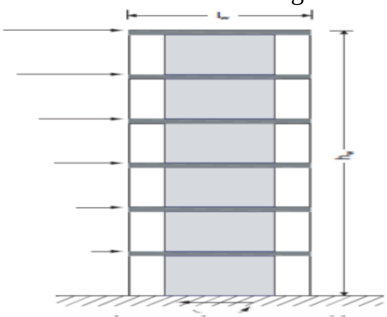

Fig 2.1 shear wall

III. BEAMS WITH WEB REINFORCEMENT

The mechanism of shear transfer, based on the analogy of a truss consisting of diagonal concrete compression members and tension members , formed by the web reinforcement, is familiar. This simple concept, introduced by Morsch at the turn of the century, has since been verified in numerous experiments. The web reinforcement engages in load resistance only after the formation of diagonal cracks. The load resisted by the truss mechanism is generally the load in excess of that which caused diagonal cracking.

This has been observed in a very large number of test beams. However, no satisfactory theory has been put forward so far to explain why the diagonal cracking load, and not a force substantially different from this, can be sustained by the mechanisms other than the web reinforcement. It is now an accepted design practice to allocate a fraction of the external shear to the "concrete" and the remainder to the web reinforcement. However, the share of the concrete is assessed rather conservatively^' .

An important role of the web reinforcement, generally overlooked in the relevant literature, is that of crack control. Within the elastic range the web reinforcement inhibits the excessive opening of diagonal cracks and by doing so it preserves the integrity of those mechanisms which sustain shear in a beam without web reinforcement. Stirrups arrest excessive crack propagation into the web or along the flexural reinforcement and thus enable aggregate interlock and dowel actions to remain operative. Alternatively, for short beams, they enable effective arch action to be maintained by preventing a diagonal splitting failure.

When the ultimate strength of the web reinforcement is attained these secondary, but by no means unimportant, effects cease to function. After yielding of the stirrups the diagonal cracks open very rapidly. In normal beams shear capacity due to aggregate interlock or crack friction is lost, and sudden collapse follows. Only negligible ductility can be observed. For this reason the web reinforcement must be so proportioned that it operates in the elastic range when the ultimate flexural capacity of the member is being approached.

In short beams the ultimate shear strength may be in excess of the sum of the diagonal cracking load and the strength of the web reinforcement. This excess strength may be derived from arch action when the loads are introduced suitably. However, arch action may tax the flexural strength of the beam by imposing large diagonal compression forces at the sections of maximum moments. In thin webbed beams with flanges the diagonal compression, which is at least twice as much as the nominal shear stress corresponding with the shear force across the truss, may lead to diagonal crushing. Therefore an upper limit must be set to the desired web steel content in the same way as in the case of flexure, when a primary compression failure is to be avoided.(Fig.3.1)

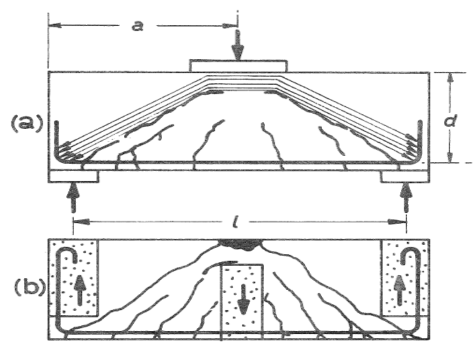

Fig 3.1 Arch Action as Affected by the Introduction of Load into a Beam.

IV. REPEATED AND CYCLIC LOADING

Most of the shear research was concentrated on simply supported beams under static loading. For this reason little information exists on those aspects which are particularly important in the assessment of seismic behaviour. In the extensive research projects of Leonhardt and W a l t h e r ^ the development and possible widening of diagonal cracks for different types and amounts of web reinforcement was also observed. Several load repetitions , up to and above full dead and live load intensity, indicated that the load-stress pattern of stirrups becomes stable after a few load applications, and that a fraction of the shear can always be sustained by mechanisms other than the web reinforcement. This indicates that the important contribution of aggregate interlock action does not deteriorate as long as the web and flexural reinforcement do not yield. Recent tests at the University of Canterbury, specifically designed to explore aggregate interlock action, verified this behaviour. After a certain amount of permanent shear displacement shear stresses of the order of 700 psi across a preformed crack were attained ten times without significant additional deformations. It is important to note, however, that this can be achieved only if cracks are prevented from opening. Therefore it may be said that, within the elastic performance of the reinforcement in a beam, the three components of shear resistance, as outlined previously, remain operative even after several repetitions of high load intensity.

4.1 Determining the Depth of an Earthquake

Earthquakes can occur anywhere between the Earth's surface and about 700 kilometres below the surface. For scientific purposes, this earthquake depth range of 0 - 700 km is divided into three zones: shallow, intermediate, and deep. Shallow (crustal) earthquakes are between 0 and 70 km deep; intermediate earthquakes, 70 - 300 km deep; and deep earthquakes, 300 - 700 km deep. In general, the term "deep-focus earthquakes" is applied to earthquakes deeper than 700 km. All earthquakes deeper than 700 km are localized within great slabs of shallow lithosphere that are sinking into the Earth's mantle. The most obvious indication on a seismogram that a large earthquake has a deep focus is the small amplitude of the recorded surface waves and the uncomplicated character of the P and S waves.(Fig.4.1)

(a)

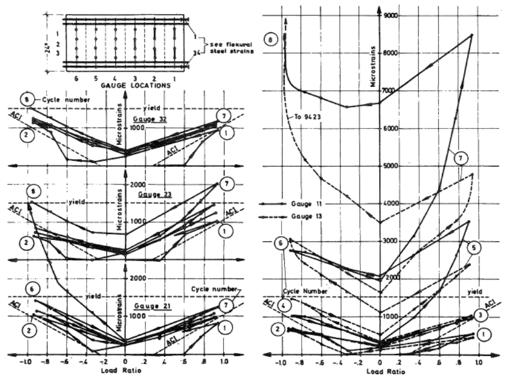

Fig. 4.1. The Load-Strain relationship for the (a) stirrups

V. DESIGN RECOMMENDATIONS

1 From the foregoing discussion certain design recommendations, with respect to the shear strength of shear walls, suggest themselves

2 The careful consideration of shear strength should not distract from the attention to be paid to flexure. The strength and the post elastic performance of shear wall must be governed by flexure. In this respect walls with H/D larger than 2 are likely to behave as large doubly reinforced concrete beams with ample ductility.

3 The benefit that may be derived in deep beams from arch action, as a major shear resistant mechanism after cracking, should be disregarded. The shear resistance of various mechanisms , other than the web reinforcement, should be assessed as in an ordinary beam, i.e. V c = 2bd>/f^. Web (horizontal) reinforcement should be provided for the remainder of the seismic shear.

4 The combined shear resistance, i.e. V u = V c + Vs , should be larger than the shear generated at the attainment of the maximum moment. Yielding of the web reinforcement should not occur.

5 Where diagonal cracks could open, as a consequence of yielding in the flexural reinforcement, the whole of the seismic shear should be resisted by suitable shear reinforcement. The height of the shear wall affected by this requirement could be equal to its depth.

6 Vertical reinforcement placed in the core of shear walls, irrespective of this being nominal or not, must be included in the assessment of the ultimate flexural strength, at its true yield strength, to ensure that the shear strength provided is not exceeded. Apart from improving crack control and providing dowel resistance, vertical web reinforcement in shear walls is not likely to contribute towards shear strength.(Fig.5.1)

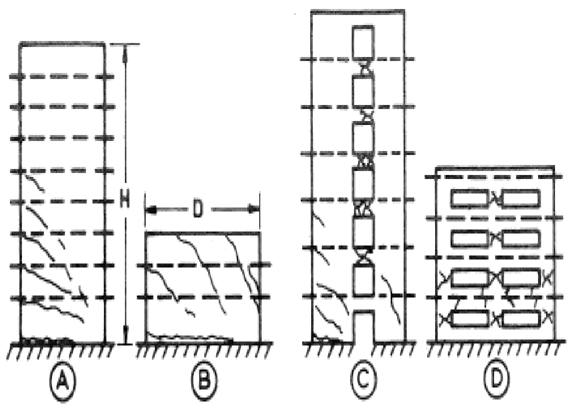

Fig.5.1 Vertical web reinforcement in shear walls

VI. RESEARCH SIGNIFICANCE

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 modelling are discussed and it is shown that satisfactory results may be obtained from relatively simple and limited models. He took a simply supported reinforced concrete beam subjected to uniformly distributed loading has been analyzed. P. 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 Solid65 element in ANSYS.

The internal reinforcements were modelled using three dimensional spar elements with plasticity, Link8, embedded within the solid mesh. Finite element models of ordinarily reinforced concrete beams and post- tensioned concrete beams, developed in ANSYS using the concrete element (Solid 65) have accurately captured the nonlinear flexural response of these systems up to failure. Anthony J. Wolanski, B.S (2004) did research on the flexural behaviour of reinforced and prestressed concrete beams using finite element analysis.

The two beams that were selected for modelling were simply supported and loaded with two symmetrically placed concentrated transverse loads. Qi Zhang (2004) presented the application of finite element method for the numerical modelling of punching shear failure mode using ANSYS. The author investigated the behaviour of slab-column connections reinforced with Glass Fibre Reinforced Polymers (GFRPs). SOLID65 and LINK8 elements represented concrete and reinforcing steel bars respectively.

A quarter of the full-size slab-column connections, with proper boundary conditions, were used in ANSYS for modelling. The author reported that the general behaviour of the finite element models represented by the load-deflection plots at centre show good agreement with the test data. However, the finite element models showed slightly higher stiffness than the test data in both the linear and nonlinear ranges.

VII. DESIGN AND DETAILING OF FLANGED SHEAR WALL

71 Structure and analytical model

A six storey RC building in zone III on medium soil is analyzed using the software STAAD – PRO. The analytical model is shown in Figure 1. It is assumed that no parking floor for the building. Seismic analysis is performed using Equivalent lateral force method given in IS 1893:2002 and also by dynamic analysis.

Description of Structure

- No of bays in X direction = 3 m
- No of bays in Y direction = 3 m
- Story height = 3.5 m
- Column size = 0.45 m x 0.3 m
- Beam size = 0.3 m x 0.45 m
- Density of concrete = 25 kN/m3
- Live load on roof = 1.5 kN/m2
- Live load on floors = 3 kN/m 2
- Floor finish = 1 kN/m2
- Brick wall on peripheral beams = 230 mm
- Brick wall on internal beams 150 mm
- Density of brick wall 20kN/m3

7.2 Computation of design forces

The shear forces, bending moments and axial forces at the bottom of the shear wall for the 13 load combinations (IS 1893(Part 1): 2002) are obtained. Seismic analysis is performed using Equivalent lateral force method and also by dynamic analysis.

7.3 Design of Flanged Shear Wall

The design moment, shear and axial force at the base of the flanged shear wall for a length of 2.5 m obtained from the analysis are 4532.97 kN-m, 285.28 kN and 2038.74 kN respectively. The flanged shear wall is designed for these critical forces as per IS 13920:1993-Annexure I. Reinforcement details of shear wall are shown in Table7.1 and Figure.7.1

Table 7.1: Reinforcement details of flanged shear wall

Shear wall (Web)	Vertical bars	16 mm bars @ 200 mm c/c.
	Horizontal bars	10 mm bars @ 200 mm c/c.
	Lateral ties	8 mm bars @ 300 mm c/c.

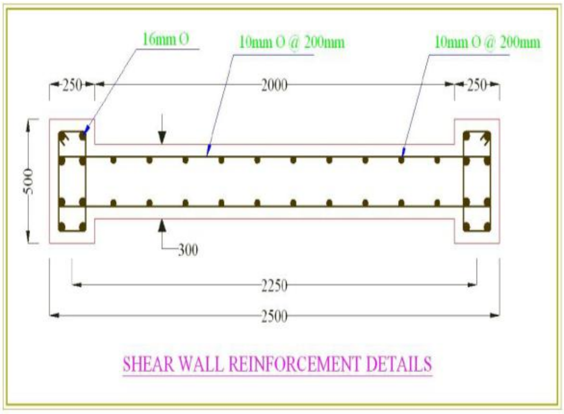

Figure 7.1 Reinforcement details of shear wall

VIII. Finite Element Analysis

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 was modelled using Graphical User Interface. For carrying out the seismic analysis, the command prompt line input data was adopted. For carrying out the analysis, the command prompt line input data is adopted.

The convergence criteria used for the analysis are displacement with the tolerance of 0.001. The analysis has been carried out for the shear wall subjected to reversible cyclic loading. The axial load of 0.5 T is applied on top nodes of the shear wall. Lateral cyclic load is applied at the top nodes in plane with the shear wall. The displacement cycle adopted for the analysis is shown in Figure.8.1

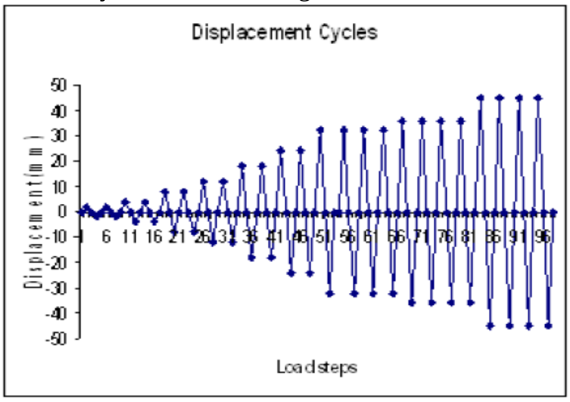

Figure 8.1 Displacement cycle

IX. Displacement Analysis

The load Vs displacement hysteretic loops for the models are shown in Figure. For the smeared model, spindle-shaped hysteretic loops were observed with large energy dissipation capacity when compared to the discrete model. Here the ductility is increased without compromising the stiffness. The displacement envelope curve for both the models is shown in Figure.9.1

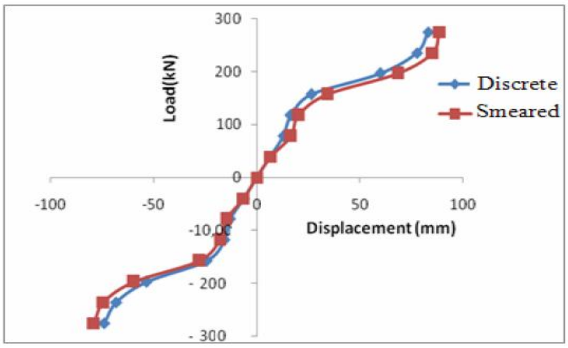

Figure 9.1 Load - displacement envelope curve for models

X. ANALYSIS RESULTS

Analysis results are shown in fig.10.1,Fig.10.2 & Fig.10.3

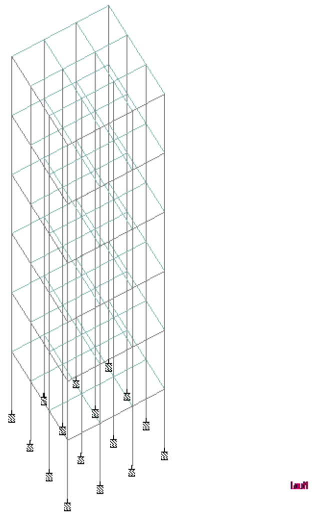

Fig 10.1 Whole Structure

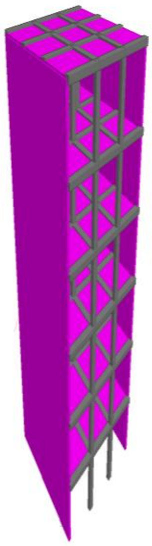

Fig 10.2 Rendering View

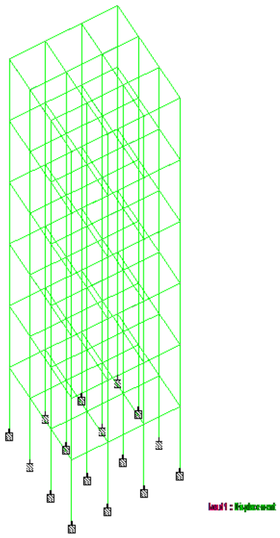

Fig 10.3 Whole Structure Displacement

XI. CONCLUSIONS

In seismic zones, a structure can be subjected to strong ground motions, and, for economical design, a structure is considered to undergo deformations in the inelastic range; therefore, in addition to strength requirement, the structure should undergo these inelastic deformations without failure. From the literature reviewed it is clear that paucity of information exists in the area of modeling of reinforced concrete structures.

In the present study two types of models are analysed, (i) smeared model and (ii) discrete model. Both the models were analysed for cyclic loading. The analytical results are compared with the empirical relations in ACI 318 (2002). From the analytical results, following conclusions are drawn.

It is noticed that the smeared model exhibited higher ultimate strength compared to that of discrete model. There is 10 % increase in ultimate strength for smeared model than that of discrete model. It is also observed that smeared model has higher average ductility than their counter parts (discrete model). The enhancement in deformation capacity for smeared model is 2.5 % than that of discrete model.

Spindle-shaped hysteretic loops are observed with large energy dissipation capacity for smeared model compared to discrete model. The enhancement in energy dissipation for smeared model is observed to be 7.5 % higher than that of discrete model. Further, the ultimate shear capacities of both the models were observed to be matching with the empirical relation as per ACI 318.

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