STATIC AND DYNAMIC ANALYSIS OF SHEAR WALL SUBJECTED TO LATERAL LOADS

IMAM MANSUR, PATVA VIVEK
P. G. Student, Department of Civil Engineering,SPCE,Visnagar-384215,Gujarat, India
Assistant Professor, Department of Civil Engineering,SPCE,Visnagar-384215,Gujarat, India

Abstract : Due to increase in population spacing in India is needed, especially in urban areas. Also due to increase in the transportation and safety measure the FSI (Floor Spacing Index) in Indian cities is increasing considerably. Structural engineers in the seismic regions across the world often face the pressure to design high rise buildings with stiffness irregularities, even though they know these buildings are vulnerable under seismic loading. Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high rise buildings. improving the structural systems of tall buildings can control their dynamic response. With more appropriate structural forms such as shear walls and tube structures and improved material properties. The general design concept of the contemporary bearing wall building system depends upon the combined structural action of the floor and roof systems with the walls. The floor system carries vertical loads and, acting as a diaphragm, lateral loads to the walls for transfer to the foundation. Lateral forces of wind and earthquake are usually resisted by shear walls which are parallel to the direction of lateral load. These shear walls, by their shearing resistance and resistance to overturning, transfer the lateral loads to the foundation. In the present study a 21 story high rise building, with podium up to 3rd floor level is considered.

IndexTerms - **Story Drifts, shear wall, Story Stiffness, base shear , ETAB 2016**

I. INTRODUCTION

In order to analyze the stress behavior of the shear wall structure, the finite element method is employed throughout the research. Two dimensional analysis is carried out and plane stress element is used to represent both the shear wall. Linear-elastic concept is employed instead of the more ideal non-linear analysis for the purposes of achieving an adequate level of performance under ordinary serviceability condition. Linear elastic analysis simply means that the design is based on the uncracked concrete structure and that the material is assumed to be linearly elastic, homogeneous and isotropic. It is adequate in obtaining the stress distribution for preliminary study or design purpose. A finite element model comprises shear wall from a case study will be created using ETABS software. Throughout this project, the ETABS Finite Element system is employed to carry out analysis on the vertical stress in wall, horizontal stress in wall, shear stress in wall, shear force in beam and bending moment in beam under both the vertical gravity load and lateral wind load. All these stress behavior of the shear wall-transfer beam interaction zone obtained from the analysis are then compared with those yielded through. Structures, 1997). From the comparison, conclusion will be drawn for the various stress behavior of the shear wall-transfer beam structure. The finite element analysis in this project is carried out in two separate cases. The first case is as though carried out where the model is solely subjected to vertical loads. The dead load is factored with 1.4 while the live load is factored with 1.6. In the second case, the similar shear wall-transfer beam structure is subjected to both vertical loads and lateral wind load, all of which being factored with 1.2. This creates a platform for observing the changes in stress behavior due to the wind load, which is not covered in the previous research. The strength, stiffness and ductility are the essential requirements of shear wall and need to be assessed for its structural performance (Derecho et al. 1979; Farvashany et al. 2008; IS 13920 1993; IS 4326 1993). Strength limits the damage and stiffness reduces the deformation in the shear wall. Ductility, defined as ability to sustain inelastic deformations without much strength and stiffness degradation, has been considered very essential requirement, especially under severe dynamic loading conditions.Shear walls in earthquake resistant structures are as follows: impart adequate stiffness to the building so that during moderate seismic disturbances, complete protection against damage, particularly to non-structural components, is guaranteed. provide adequate strength to building in order to ensure that an elastic seismic response does not result in more than superficial structural damage. provide adequate structural ductility to building in order to dissipate energy for the situation when the largest disturbance to be expected in the region does occur. Even the extensive damage, perhaps beyond the possibility of repair, is accepted under extreme conditions, but prevention of sudden collapse must be ensured under any dire circumstances.

Sometimes, shear walls are pierced with openings to fulfill the functional as well as architectural requirements of buildings. The structural response of shear wall may be influenced by the presence of openings, depending upon their sizes and their positions. The present study aims to accomplish this task by investigating the response of shear walls in the presence of openings.

II. LITERATURE REVIEW

***** TOPIC: Seismic Damage in Shear Wall-Slab Junction in RC Buildings
Snehal Kaushika* , Kaustubh Dasguptab

Most of the high-rise apartment buildings consist of spatial assemblies of shear walls and floor slabs. Due to strong earthquake shaking, the dynamic force may lead to high stress concentration at the shear wall-slab junction and subsequent localized failure. In the past, both experimental and analytical research have been carried out to simulate the nonlinear behaviour of concrete shear wall and steel/composite members [4, 11]. In the previous study the distribution of shear stresses at the slab wall junction was determined and concluded that the junction between the floor slab and structural wall is subjected to severe stress concentration [1]. It was also proposed that the design of slab-wall connection must be done considering the stress concentration to avoid redistribution of forces from walls to other elements not necessarily designed for lateral load resistance [10]. The floor slab – shear wall connection has also been investigated experimentally by considering different reinforcement detailing under combined gravity and lateral cyclic loading. It was observed that the wall – slab joint with slab shear reinforcement and bent 90° at the joint can be effective in moderate to high seismic risk region [2]. Considering the limited research carried out on seismic behaviour of wall-slab junctions, the purpose of this study is to investigate the damage caused at the shear wall slab junction due to earthquake shaking. Time history analysis of the RC shear wall- slab junction is carried out to observe the behaviour of wall-slab junction under the action of earthquake loading. To investigate the seismic behavior of the structure under earthquake action, a refined finite element model is developed using the computer program ABAQUS [5]. Nonlinear time history analyses are conducted using implicit integration method to study the tensile damage at the shear wall-slab junction.

***** TOPIC: Seismic Vulnerability Assessment of Concrete Shear Wall Buildings through Fragility Analysis
Yasamin Rafie Nazari, Murat Saatcioglu

A three-dimensional building model was created for each building using strength and stiffness quantities obtained from the structural design. Flexural yield moments for beams and columns were obtained by conducting sectional analyses using ETABS2016. The envelope curves for moment-rotation relationships were then generated by following the recommendations given in IS13920 for members without ductile detailing for all buildings as the frames were designed to be gravity-load carrying components. These members had linear behavior up to the yield point, with effective elastic rigidities (0.35 EI for beams and 0.7 EI for columns), followed by post-yield behavior until the onset of strength decay. The shear walls were the seismic force resisting elements, and were modelled with due considerations given to their post-yield behavior as governed by the detailing required in the applicable CSA Standard. The details of the shear wall models are presented in the next sub-section. The walls were considered to be fully fixed at the foundation level.

Shear wall element modelling

The response of buildings is primarily dominated by the behavior of the shear walls, which necessitates generating accurate and detailed analytical models. In PERFORM-3D, a fiber-discretized model is employed to simulate the wall behavior. The modeling of hysteretic behavior using the fiber model is considered to be more accurate than the assumption of a single element with concentrated hinges, as it will be able to simulate the progression of plastification within the plastic hinge region. The overall behavior of a wall section in fiber model is obtained from the integration of contributions coming from concrete and steel to sectional resistance. For ductile walls, confined concrete was used in modelling the wall boundary elements and unconfined concrete was used for the web. Confined concrete model developed by Saatcioglu and Razvi and unconfined concrete model developed by Hognestad were employed in sectional analysis. The confined concrete properties were computed based on the spacing and arrangement of boundary element transverse reinforcement. For non-ductile shear walls, concrete was modelled as unconfined in the entire wall section. Figure 2 demonstrates the concrete models implemented into the software. The stress-strain relationship of reinforcing steel in tension consists of three linear segments for elastic, yield plateau, and strain-hardening segments. The behavior in compression can be different depending on the tie spacing and the buckling characteristics of compression bars. The stress-strain relationship specified by Yalcin and Saatcioglu [20] was adopted to simulate the behaviour of reinforcement in compression. Accordingly, the reinforcement aspect ratio is defined as the ratio of tie spacing to bar diameter. Reinforcing steel aspect ratios higher than 8 result in bar buckling. In this case, the steel resistance drops linearly immediately after yielding with increasing compressive strains. For values of reinforcing steel aspect ratios between 4.5 and 8 the stress-strain relationship shows strainhardening lower than that corresponds to the tension curve. The decrease in aspect ratio results in the strain-hardening curve that approaches the relationship in tension. When compression steel aspect ratio is lower than 4.5, the behaviour of steel in tension and compression are symmetric. These behaviours are also captured by the linear approximation of segments used in PERFORM 3D software.

***** TOPIC: The Influence of Single Shear Walls on the Behaviour of Coupled Shear Walls in High-rise Structures
J.C.D. HOENDERKAMPa

This paper presents a simple method of analysis to determine the influence of single shear walls (SSW) on the degree of coupling DoC and on the peak shear demand *PSD* for beams of coupled shear walls (CSW) in mixed shear wall structures (MSW). Non-coupled lateral load resisting structures such as singular planar walls will reduce primary bending moments in the coupled shear walls of MSW structures thereby increasing the degree of coupling. They will also change the location and magnitude of the maximum shear in and rotation of the coupling beams. These changes in the coupled wall bents may increase the demand on their performance beyond capacity. It is therefore important to have an indication of the change in the coupling beam design parameters at an early stage of the design. The proposed graphical method is based on the continuous medium theory and allows a rapid assessment of the structural behavior of coupled shear wall bents in mixed shear wall structures that are subject to triangularly distributed horizontal loading.

The proposed analysis is based on the continuous medium theory as applied to coupled wall structures and therefore only applicable to high-rise structures. This theory allows a MSW structure to be represented by two characteristic non-dimensional parameters, *k*2 and *k*□*H,* which define its overall structural behavior. The parameter *k*□*H* allows rapid graphical assessments of five important design parameters for the coupling beams: peak shear demand, peak rotation demand, maximum shear force, maximum rotation and their location up the height of the structure. In general, an increase in *k*□*H*: increases the peak shear force in the coupling beam, decreases the beam rotation and moves the location of peak shear and rotation downward to the base of the structure. The range of the peak shear demand and peak rotation demand factors is between 1.24 and 1.52. The method of analysis is restricted to structures in which the structural floor plan arrangement is symmetric. The theory is based on the assumption of,
and therefore is accurate only for, structures that are uniform through their height. It may be used, however, to obtain approximate values for the design parameters for comparison between practical structures whose properties vary with height.

***** TOPIC: Effect of Shear Wall on Seismic Performance of RC Open Ground Storey Frame Building
Ashwani Singh, P.W.Chanvhan

The Open Ground Storey buildings are very commonly found in India due to provision for very much needed parking space in urban areas. However, seismic performance of this type of buildings is found to be consistently poor as demonstrated by the past earthquakes. Some of the literatures indicate that use of shear walls may enhance the performance of this kind of buildings without obstructing the free movement of vehicles in the parking lot. The present study is an attempt in this direction to study the performance of Open Ground Storey buildings strengthened with shear walls in a bay or two. In addition to that, the study considers a different scenarios of Open Ground storey buildings strengthened by applying various schemes of multiplication factors in line with the approach proposed by IS 1893 (2002) for the comparison purpose. Study shows that the shear walls signi_cantly increases the base shear capacity of OGS buildings however the comparative cost is slightly on the higher side.

OGS frames strengthened with shear wall The maximum capacities of base shear and roof displacement of the OGS frame strengthened with shear wall is increased by about 93% and 40% The maximum capacities of base shear and roof displacement of the OGS frame strengthened with shear wall is increased by about 5% and 37% respectively compared to a RC frame in_lled in all storeys. OGS frames re-designed with shear wall The maximum capacities of base shear and roof displacement of the OGS
frame re-designed with shear wall is increased by about 91% and 42% respectively. The maximum base shear capacity of the OGS frame re-designed with shear wall is decreased by about 16% and the displacement capacity is increased by about 39% compared to a RC frame in_lled in all storeys. The maximum base shear capacity of the OGS frame re-designed with shear
wall is decreased by about 20% and the displacement capacity is increased by about 4% compared to an OGS frames re-designed with shear wall. The maximum base shear to cost analysis ratio for OGS frames strengthened with shear wall is more by about 9 times that of OGS frame.The maximum base shear to cost analysis ratio for OGS frames re-designed with shear wall is more by

about 8 times that of OGS frame.The strengthening schemes in line with IS code procedure of applying multiplication factor could achieve only a maximum base shear to cost ratio of 3 times that of OGS frames.

***** TOPIC: Natural convection flows along a 16-storey high-rise building

Yifan Fan , Yuguo Li , Jian Hang , Kai Wang , Xinyan Yang

The flow caused by natural convection adjacent to a heated vertical wall (wall flow) is an important mechanism in the creation of wind flows in a city when the background wind is weak. The wall flows along a 16-storey building were measured in Guangzhou, China. Fourteen three-dimensional ultrasonic anemometers were installed on three floors to study the boundary layer structure. Continuous measurements were taken during three test periods. The Rayleigh numbers were approximately 10^{13}, 10^{13} and 10^{14} at the height of the 5th, 10th and 14th floors, respectively. The diurnal changes in the velocity of the wall flows, the wall surface temperature and the ambient air temperature were analysed. Our new experimental data support the theory that the natural convection boundary layer has a three layer structure, i.e. an inner viscous layer, a transition layer and an outer turbulent layer, as first proposed theoretically by Wells and Worster. The outer turbulent layer is governed by the law of plumes with a Gaussian profile. The vertical velocity changes with g04=9x1=3 along the vertical wall, where g0 is the buoyancy force and x is the coordinate along the vertical wall. It was noted that only the building's roof was significantly cooler than the ambient air at night, due to the sky radiation effect, so no downward flow adjacent to the wall caused by the cooling plate effect was found in our field measurements.

The wall flows (natural convection flows) along a 16-storey high-rise building were measured. The knowledge of real building scale turbulent flow was broadened. The results can be used to model urban canopy layer ventilation. Based on the existing theory, the laboratory experimental data and the results of these in situ measurements, the following conclusions can be drawn.

The turbulent boundary layer of natural convection along a high rise building wall can be divided into an layer and an outer turbulent layer. The flow in the outer turbulent layer is governed by the rule of plumes with a Gaussian profile across the outer turbulent layer. Theverticalvelocityalongthewallincreaseswithg04=9x1=3 .The widths of the boundary can be approximated as the plume widths at a certain height. The widths of the boundary layers have an order of 6 m, 7 m and 8 m at 5F, 10F and 14F, respectively, when the Rayleigh numbers are on the order of 10^{13},10^{13} and 10^{14} at the corresponding heights. The flow in this experiment is in Region II, where the buoyancy instability criterion holds true when the Rayleigh number is on the order of 10^{14}. Only the roof of the building might be significant cooler than the ambient air due to the sky radiation effect. There is no downward flow adjacent to the vertical wall caused by the 'cooling plate effect' analogous to down slope flow.

TOPIC: Wind loading on high-rise buildings and the comfort effects on the occupants

Authors: Ramtin Avini, Prashant Kumar, Susan J. Hughes

Research highlights

- Wind loads for tall buildings studied by codes and Computational Wind Tunnel (CWT)
- Design Standards gave rise to larger surface pressures than CWT estimates
- Complex terrain led to more fragmented vortices in New York City
- Shielding effect was crucial for depleting the mean component of the load

The design of low to medium-rise buildings is based on quasi-static analysis of wind loading. Such procedures do not fully address issues such as interference from other structures, wind directionality, across-wind response and dynamic effects including acceleration, structural stiffness and damping which influence comfort criteria of the occupants. This paper studies wind loads on a prototype, rectangular cross-section building, 80m high. Computational Wind Tunnel (CWT) tests were performed using Autodesk Flow Design with the buildings located in London and New York City. The analysis included tests with and without the surrounding structures and manual computation of wind loads provided data for comparison. Comfort criteria (human response to building motion) were assessed from wind-induced horizontal peak accelerations on the top floor. As expected, analytical methods proved conservative, with wind pressures significantly larger than those from the CWT tests. Surrounding structures reduced the mean component of the wind action. As for comfort criteria, across-wind direction governed the horizontal accelerations with wind targeted on the building's narrow face. CWT tests provide a cheaper alternative to experimental wind tunnel tests and can be used as preliminary design tools to aid civil engineers, architects and designers with high-rise developments in urban environments.

* TOPIC: Analysis Method of Reinforced Concrete Shear Wall Using EBCS

Authors: Dr. Suresh Borra1, P.M.B.RajKiran Nanduri2, Sk. Naga Raju3 Girma Bitsuamlak

Concrete shear walls or structural walls are often used in multistory buildings to resist lateral loads such as wind, seismic and blast loads. Such walls are used when the frame system alone is insufficient or uneconomical to withstand all the lateral loads or when partition walls can be made load bearing, replacing columns and beams. The analysis and design of buildings with shear walls became simple using commercially available computer programs based on the finite element method (FEM) and subsequent implementation of stress integration techniques to arrive at generalized forces (axial, shear, and moments). On the other hand, design engineers without such facilities or those with computer facilities lacking such features use simple method of analysis and design by taking the entire dimensions of the walls. This is done by considering the shear walls as wide columns of high moment of inertia and following the same procedure as for columns. The primary purpose of this paper is believed that structural engineers working in the analysis and design of high- rise buildings will be benefited from the design shear wall by using EBCS: 2-1995 and EBCS:8-1995codes and its results. are studied. ETABS 15 is being used for the modeling of RC bare frames and to analyze the structure. This project focuses on the study of effect of wind response on different irregular shapes with gust response factor and without gust response factor method and also the variation of wind response factor for the irregular shaped RC structures in various wind zones and for different terrain category. In this present analysis, the variation of wind forces on particular RC bare frames at different wind zones, at different heights and also at different terrain category are shown. The effect of variation in terrain category is the major factor in this work because as the height increases the wind speed increases so the displacement increase as the storey height increases but as the terrain category varies from 1-4 the obstruction for the wind flow increases so the effect of wind force decreases on the particular High Rise Structure, when the wind load is applied in both X & Y-direction. The analysis has been done by considering Static and Dynamic cases.

III. CONCLUSION

- The main objective of this study has been to investigate the effectiveness and applicability of size of openings and their locations on the static and dynamic response of the shear wall with different damping characteristics. To achieve this objective, an analytical finite element model to predict the static and dynamic behavior of Reinforced Concrete (RC) shear wall was developed.
- Since the behavior of RC shear walls is highly complex under the influence of severe lateral loads arising due to wind and earthquake, the response of shear wall no longer remains elastic and therefore, finite element method was needed to predict the behavior of shear wall in both linear and non-linear regimes under static and dynamic loading conditions.
- Though the non-linear static analysis (pushover analysis) of shear wall is performed to obtain the lateral force-displacement characteristics, it does not represent true dynamic characteristics of shear wall subjected to seismic loading, nor does it capture the effect of higher modes on its structural response.
- The finite element program developed in FORTRAN was capable of capturing the non- linearity due to material characteristics (material non-linearity) that incorporates macro material model for concrete and steel. The non-linearity considered in the present study includes concrete cracking, yielding of steel & concrete and tension stiffening caused by bond slip between steel and concrete, aggregate interlock and the dowel action of reinforcement steel. Also, for the dynamic analysis,
- Finite element model based on implicit solution algorithm was employed to study the nonlinear dynamic response of RC shear walls. It is well documented in literature that the nine-noded Lagrangian degenerated shell element with assumed strain approach does not suffer from spurious energy modes and locking and performs well in thin as well as thick situations with reasonable accuracy for static and dynamic analyses. The sensitivity analysis carried
- In order to validate the program for both static and dynamic response of shear walls, three shear wall problems were selected. For the validation of program under static loading, the squat shear wall with top and bottom beams was

considered. The displacement at the middle of the top slab was evaluated under monotonically increased lateral loading applied at the middle of the top beam. The load-displacement response as well as crack & yield patterns of shear wall have been found to be in close agreement with the experimental results published in literature.

- the dynamic response of shear walls, the flanged shear walls and rectangular shear walls were considered under simulated earthquake ground motion applied at the base of shear wall. The flanged shear wall is squat in nature whereas the rectangular shear wall is of slender type. The time history responses have been plotted at the top level of shear wall. It was found that the maximum displacement response as well as the profile of time history response was found to be satisfactory.
- The focus of the present study is to investigate the influence of openings on the structural response of slender (10-storeyed) and squat (5-storeyed) RC shear walls under non-linear static and dynamic loading conditions. In order to determine the load carrying capacity and ductility, the non-linear static analysis of shear wall was carried out considering material non-linearity.

References

1) Lefas, I.D., Kotsovos, M.D., and Ambraseys, N.N. (1990). "Behavior of reinforced concrete structural walls: Strength, deformation characteristics, and failure mechanism." ACI Structural Journal, 87(1), 23-31.
2) IS 1893 (2016). Criteria for earthquake resistant design of structures, BIS, New Delhi
3) IS 13920 (1993). Code of practice for ductile detailing of reinforced concrete structures.
4) IS 1786 Foundation Movement
5) Dr H.J SHAH Design of Rcc Structure
6) S Ramamurthy Structure Design
7) Apurba Mondal, Siddhartha Ghosh, and GR Reddy. Performance-based evaluation of the response reduction factor for ductile rc frames. Engineering structures, 56:1808{1819, 2013.
8) CVR Murty. IITK-BMTPC Earthquake Tips: Learning Earthquake Design and Construction. National Information Centre of Earthquake Engineering, Indian Institute of Technology Kanpur, 2005.
9) Bungale S Taranath. Reinforced concrete design of tall buildings. CRC Press, 2009.
10) CVR Murty, Rupen Goswami, AR Vijayanarayanan, and Vipul V Mehta. Some concepts in earthquake behaviour of buildings. Gujarat State Disaster Management Authority, Government of Gujarat, 2012.
11) CVR Murty and Sudhir K Jain. Bene cial in uence of masonry in ll walls on seismic performance of rc frame buildings. In 12th World Conference on Earthquake Engineering (Auckland, New Zealand, January 30), 2000.
12) Robin Davis, Praseetha Krishnan, Devdas Menon, and A Meher Prasad. E ect of in ll sti ness on seismic performance of multi-storey rc framed buildings in india. In 13 th World Conference on Earthquake Engineering. Vancouver, BC, Canada, 2004.
13) Hemant B Kaushik, Durgesh C Rai, and Sudhir K Jain. Stress-strain characteristics of clay brick masonry under uniaxial compression. Journal of materials in Civil Engineering, 19(9):728{739, 2007.
14) Santiago Pujol, Amadeo Benavent-Climent, Mario E Rodriguez, and J Paul Smith-Pardo. Masonry in ll walls: an e ective alternative for seismic strengthening of low-rise reinforced concrete building structures. In 14th World Conference on Earthquake Engineering (Beijing, China, Unknown Month October 12), 2008.
15) GV Mulgund and AB Kulkarni. Seismic assessment of rc frame buildings with brick masonry in lls. International Journal of advanced engineering sciences and technologies, 2(2):140{147, 2011.
16) J Prakashvel, C UmaRani, K Muthumani, and N Gopalakrishnan. Earthquake response of reinforced concrete frame with open ground storey. Bonfring International Journal of Industrial Engineering and Management Science, 2(4):91{101, 2012.
17) N Sivakumar, S Karthik, S Thangaraj, S Saravanan, and CK Shidhardhan. Seismic vulnerability of open ground oor columns in multi storey buildings. International Journal of Scienti c Engineering and Research (IJSER), 2013.
18) MS Lopes. Experimental shear-dominated response of rc walls: Part i: Objectives, methodology and results. Engineering Structures, 23(3):229{239, 2001.
19) Rahul Rana, Limin Jin, and Atila Zekioglu. Pushover analysis of a 19 story concrete shear wall building. In 13th World Conference on Earthquake Engineering Vancouver, BC, Canada August 1-6, 2004 Paper No, volume 133, 2004.
20) Han-Seon Lee and Dong-Woo Ko. Seismic response characteristics of high-rise rc wall buildings having di erent irregularities in lower stories. Engineering structures, 29(11):3149{3167, 2007.
21) O Esmaili, S Epackachi, M Samadzad, and SR Mirghaderi. Study of structural rc shear wall system in a 56-story rc tall building. In The 14th world conference earthquake engineering, 2008.
22) YM Fahjan, J Kubin, and MT Tan. Nonlinear analysis methods for reinforced concrete buildings with shear walls. 14th econference in Earthquake Engineering, 2010.
23) H Gonzales and Francisco Lopez-Almansa. Seismic performance of buildings with thin rc bearing walls. Engineering Structures, 34:244{258, 2012.

24) Luca Martinelli, Paolo Martinelli, and Maria Gabriella Mulas. Performance of ber beam{column elements in the seismic analysis of a lightly reinforced shear wall. Engineering Structures, 49:345{359, 2013.
25) C Todut, D Dan, and V Stoian. Theoretical and experimental study on precast reinforced concrete wall panels subjected to shear force. Engineering Structures, 80:323{338, 2014.
26) Xinzheng Lu, Linlin Xie, Hong Guan, Yuli Huang, and Xiao Lu. A shear wall element for nonlinear seismic analysis of super-tall buildings using opensees. Finite Elements in Analysis and Design, 98:14{25, 2015.
27) John B Mander, Michael JN Priestley, and R Park. Theoretical stress-strain model for con ned concrete. Journal of structural engineering, 114(8):1804{1826, 1988.
28) J Enrique Mart nez-Rueda and AS Elnashai. Con ned concrete model under cyclic load. Materials and Structures, 30(3):139{147, 1997.
29) M Menegotto. Pinto,(1973), pe, method of analysis for cyclically loaded reinforced concrete plane frames including changes in geometry and non-elastic behavior of elements under combined normal force and bending. In IABSE Symposium on the Resistance and Ultimate Deformability of Structures Acted on by Well-De ned Repeated Loads, Lisbon, 1973.
30) Filip C Filippou, Egor Paul Popov, and Vitelmo Victorio Bertero. E ects of bond deterioration on hysteretic behavior of reinforced concrete joints. 1983.
31) Francisco Javier Crisafulli. Seismic behaviour of reinforced concrete structures with masonry in lls. 1997.
32) Michalis Fragiadakis and Manolis Papadrakakis. Modeling, analysis and reliabilityof seismically excited structures: computational issues. International Journal of Computational Methods, 5(04):483{511, 2008.
33) Antonio A Correia and Francisco BE Virtuoso. Nonlinear analysis of space frames. In III European Conference on Computational Mechanics, pages 107{107. Springer, 2006.
34) E Spacone, V Ciampi, and FC Filippou. Mixed formulation of nonlinear beam nite element. Computers & Structures, 58(1):71{83, 1996.
35) Ansgar Neuenhofer and Filip C Filippou. Evaluation of nonlinear frame nite-element models. Journal of Structural Engineering, 123(7):958{966, 1997.
36) ETABS Version. 13.1.4, 2013. Computers and Structures, Inc., Berkeley, California.
37) Indian Standard. Criteria for earthquake resistant design of structures. Indian Standards Institution, New Delhi, IS 1893 (Part 1), 2002.
38) IS Code. Code 456-2000 code of practice for plain and reinforced concrete bureau of indian standards. New Delhi.
39) IS BIS. 13920 ductile detailing of reinforced concrete structures subjected to seismic forces{code of practice. New Delhi (India): Bureau of Indian Standards, 1993.
40) SeismoSoft. Seismostruct v7.0.0 - a computer program for static and dynamic nonlinear analysis of framed structures. 2014