A REVIEW :Non Linear Dynamic Analysis of Vierendeel Girder System

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Abstract- *This paper evaluates the nonlinear procedures used for Performance Based Design, the Nonlinear dynamic procedure (time history).The purpose of this study is to determine in depth understanding of inelastic seismic response of rectangular Rcc buildings with diaphragram with openings. Non-linear time history dynamic analysis is performed using Elcentro data on typical modular structure to assess the seismic performance of these structures. The analysis accounts for their unique detailing especially to elements that contribute to energy dissipation during major seismic events. This study revealed significant global seismic capacity as well as a satisfactory performance at design intensity levels. This paper deals with an investigation carried out by the authors to study the behavior of simple parallel chorded reinforced concrete Vierendeel girders in their elastic as well as ultimate load conditions. Details of tests carried out on ANSYS along with measurements and observations made are fully described. The application of plastic analysis to reinforced concrete Vierendeel girders has been examined and shown to be feasible when the constituent members of the girders possess the desirable flexural characteristics. A simple method is suggested for predicting the exact mode of failure and to calculate the ultimate load. The predominating influence of depth span ratio of the girders over their behavior in service conditions has been demonstrated and the importance of selecting a proper depth span ratio so as to secure the desirable cracking characteristics and effective stiffness has been pointed out. The comparative behavior of Vierendeel girders designed on elastic theory and girders with arbitrary uniform reinforcements has also been investigated and their relative advantages discussed*.

Keywords- Response spectrum, IS 1893:2002 and 2016, Time History Analysis,Vineral Girder , ANSYS

I. INTRODUCTION

1.1 General:

The Belgian Engineer Arthur Vierendeel introduces the Virendeel Girder in 1896.Vierendeel frame or truss is a series of rectangular frames which achieves stability by the rigid connection of the vertical web members to the top and bottom chord. Vierendeel transfer shear from the chords by bending moment in the vertical webs .As a result, all members are combined stress member in which axial, shear, and bending stresses exist. The Vierendeel frame will be heavier than an equivalently loaded truss. Even though the diagonals are eliminated, bending in all members results in chord sizes and vertical webs significantly larger in cross-sectional area. Vierendeel appears highly advantageous where mechanical requirements are extensive and required to accommodate large duct work or elbow room to change direction. In a structural system, the Vieredeel gain tremendous rigidity with increase depth several stories of a Vierendeel grid linked together.

Safety in structural design is typically addressed by considering uncertainties in both the structure and the expected loads and introducing safety factors in the design process. A number of engineering failures, however, are related to accidental loading effects that are difficult to quantify and incorporate in the original design. Because the progressive collapse resulting from the gas explosion in the Ronan Point Apartment Building in England in 1968,1 widespread attention has been given to collapse-resistant performance of structures.2 The threat of terrorism has further highlighted the need to explicitly consider collapse resistance particularly for critical and public structures. Several existing British and U.S. codes provide limited guidelines for considering progressive collapse resistance of structures in the design process.

1.2 Motivation and Objectives

Although numerous publications have dealt with the behavior and design of concrete diaphragms, it is clear that there are several issues that have not yet been resolved.

Openings in diaphragms are often unavoidable and their presence can significantly modify the behavior of the diaphragm. At present and in many cases the designer assumes that the diaphragm is a rigid element, totally ignoring in-plane deformations – an assumption that can lead to erroneous results. Nor is it satisfactory to assume that the diaphragm acts as a continuous elastic beam over the shear walls and frames running in the transverse direction for low-rise rectangular

buildings with longer floor aspect ratios (greater than 3:1 ratio) without accounting for in-plane nonlinear deformation of the diaphragms. It is possible that the lateral load distribution of diaphragm inertia forces to the vertical frame elements may be compromised in a manner yielding an outcome contrary to what is assumed. This issue is considered vitally important, as it is the least understood subject in this area, since there is no quantification of the error in diaphragm and frame shears as a result of ignoring openings. Therefore, a systematic study of a set of carefully devised scenarios covering a spectrum of typical configurations is crucial where diaphragm in-plane deformations are incorporated in the analysis in order to capture the "real" behavior of the structural members as opposed to the "assumed" one.

Even though a total collapse of the diaphragm is unlikely to be the first major event in the failure of a building, a deterioration of its stiffness may result in a shift in the lateral loads distribution to the load carrying vertical elements causing some members to be overloaded resulting in a failure at that locality, thus jeopardizing the safety of the building structure and compromising the expected diaphragm action.

The proposed research will investigate the aforementioned issues in depth and will offer pertinent insights and better understanding of the structural behavior and design of RC buildings with floor diaphragm openings when subjected to strong ground motion. The main goal of this research effort is to gain in-depth understanding of inelastic seismic response of rectangular RC buildings with diaphragms with openings through the following

1.5 Aim and Objectives

Aim

This study aims for non linear dynamic analysis of vierendeel girder system using time history analysis.

Objective:

1. To enhance IDARC2 [56] -developed in 1988- to account for RC buildings with diaphragm openings. Special attention will be given to the algorithms used in obtaining the in-plane idealized moment-curvature curves from the current fiber model.
2. To investigate the influence of estimated hysteretic parameters for slabs with openings.
3. To investigate the applicability of rigid floor assumption (neglecting their in-plane deformations) to modeling of floor diaphragms with openings of various sizes placed in symmetric and asymmetric plan locations. Also, to investigate the influence of floor diaphragms on the distribution of lateral loads among the frames and shear walls considering the floors' inelastic-in-plane deformations. This will result in establishing a criterion as to when floor diaphragm openings in earthquake resistance design of RC rectangular buildings with shear walls can be ignored.

Hence, by using a suite of actual earthquake accelerations as ground motion input for the dynamic analysis, the true behavior of the diaphragm will be better captured, which will lead to a deeper understanding of diaphragm behavior during a seismic event in RC buildings with flexible (elastic and inelastic) diaphragms with openings. It will also provide a timely and enhanced computational tool for the research community to use.

II. LITERATURE REVIEW

2.1 Lei Zhang1 , Hailong Zhao1,2,* , Tiecheng Wang1,2 and Qingwei Chen1 'Parametric Analysis on Collapse-resistance Performance of Reinforced-concrete Frame with Specially Shaped Columns Under Loss of a Corner Column' 2016:

A finite element model is verified accurate enough to simulate the static test of one reinforced-concrete frame with specially shaped columns subjected to the loss of a ground corner column. As the frame sustained loads primarily depending on the beam resisting mechanism in the test, four related parameters, namely the height of beam section, rebar ratio of beam, rebar ratio of slab and limb length of specially shaped column are chosen for parametric analyses respectively. It is indicated that the collapse resistance capacity remarkably increases with the increasing of the height of beam section and rebar ratio of the lower steel bars of beam. The increase of the rebar ratio of slab and upper steel bars of beam could enhance the stiffness and collapse-resistance capacity slightly. The lengthening of the limb of specially shaped column only increases the stiffness of the frame. According to an equivalent method, the rectangular column frame is obtained to compare collapse-resistance performance with the specially shaped column frame. It is concluded that the frame with specially shaped columns could maintain the equivalent collapse-resistance capacity while reduce the lateral stiffness compared with the rectangular column frame

2.2 Jun Yu and Kang Hai Tan 'Experimental study on catenary action of RC beam-column sub-assemblages' 2010:

Catenary action is considered as the last defense of a structure to mitigate progressive collapse, provided that the remaining structure after an initial damage can develop alternate load paths and a large deformation has occurred in the affected beams and slabs. As a result, catenary action requires high continuity and ductility of joints. To investigate whether current RC structures designed according to ACI 318-05 could develop catenary action under column removal scenarios, two one-half scaled beam-column sub-assemblages with seismic and non-seismic detailing were designed and tested to complete failure, i.e. rebar fracture. The sub-assemblage consists of two end column stubs, a two-bay beam, and one middle beam-column joint at the junction of two single-bay beams. To ensure sufficient horizontal resistance, the sizes of end columns were enlarged to be rather stiff. To simplify the boundary conditions in the first batch of tests of our ongoing project and to make the test system statically determinate, two end column stubs were supported onto two horizontal restraints and one vertical restraint to simulate the encased supports. A concentrated load was applied vertically by a hydraulic actuator on the top of the middle joint using displacement control until the whole system eventually failed. The loading rate was controlled manually to simulate quasi-static structural behavior. The study provided insight not only into catenary action of sub-assemblages, but also the performance and failure mode of the middle joints, as well as the influence of two different detailing requirements. During the whole loading history, the cross-sectional internal forces at any beam locations can be evaluated according to the measured reaction forces. Finally, a simple analytical model will be used to check the mechanism of catenary action.

2.3 E. Wahyuni, Y. Tethool' Effect of vierendeel panel width and vertical truss spacing ratio in staggered truss framing system under earthquake loads' June 2015:

The purpose of this study is to determine the effect of vierendeel panel width and vertical truss spacing ratio in an inelastic behavior of the STF system due to earthquake loads. The STF system is applied to a six-storey building that serves as apartments. The STF system is used in the building in the transverse direction (N-S direction), while in the longitudinal direction (W-E direction) the building system uses the special moment resisting frame. The structural behavior was evaluated using nonlinear pushover and time history analyses. The results showed that by increasing the ratio of vierendeel panel width and vertical truss spacing, the ductility of the structure was increased. Based on the performance evaluation, the ratio of the vierendeel panel width and vertical truss spacing on the STF buildings that provided satisfactory performance was more or equal to 1.6. The ultimate drift obtained from non-linear time history analysis was smaller than the pushover analysis. This result showed that the static nonlinear pushover analysis was quite conservative in predicting the behavior of the six-storey building in an inelastic condition.

2.4 Wei-Jian Yi, Qing-Feng He, Yan Xiao, and Sashi K. Kunnath 'Experimental Study on Progressive Collapse-Resistant Behavior of Reinforced Concrete Frame Structures' AUG, 2008:

A static experimental study to investigate progressive failure of a reinforced concrete frame due to the loss of a lower story column is described. A four-bay and three-story one-third scale model representing a segment of a larger planar frame structure was tested. A constant vertical load was applied to the top of the middle column by a servo-hydraulic actuator to simulate the gravity load of the upper floors and the failure of the middle column of the first story was simulated by unloading a mechanical jacking system. The frame collapse, defined in this study as the rupture of tension steel bars in the floor beams, occurred at a vertical unloading displacement of 456 mm (18 in.) that corresponds to a beam drift angle (rotation with respect to the horizontal) of 10.3 degrees. Based on the experimental observations, the mechanical behavior of the model frame is analyzed and the redistribution and transition of the load resisting mechanisms is discussed. It is concluded that the calculated capacity of the frame based on the plastic limit state was approximately 70% of the tested failure capacity if catenary effects are also included.

2.5 Marin Lupoae, Cătălin Baciu, Patricia Murzea, Dan-Ilie Buliga 'Progressive Collapse Evaluation of an Industrial Building':

The paper presents the evaluation of the potential of occurrence and propagation of the progressive collapse for an industrial building made of precast and cast in place elements. The performed experimental tests aimed to initiate the collapse by destroying, through explosion, a column situated at the ground level, on the contour of the building, at half the distance of the long side of the construction, using charges placed in boreholes. A model was developed for the numerical evaluation using the method of applied elements and a demolition scenario was used through which the column was instantaneously removed. The analysis of the numerical and experimental results showed that there is a good concordance between the displacements on the vertical direction of the node located above the removed column. Using these results the potential of occurrence and development of collapse was studied, using scenarios of column removal in according to GSA 2003 as well as scenarios in which two or three columns

were removed. The evaluation was based on the determination of the rotations of the beam ends. The obtained results highlighted the importance of the manner in which the structure is designed and built, of the height regime and structural conformity, on the collapse.

2.6 Trevor E KELLY and Jonathan D CHAMBERS 'ANALYSIS PROCEDURES FOR PERFORMANCED BASED DESIGN' 2000:

This paper evaluates the two nonlinear procedures used for Performance Based Design, the nonlinear static procedure (pushover) and the nonlinear dynamic procedure (time history). Two buildings damaged during the Northridge and Kobe earthquakes were used as case studies. The evaluation showed that the pushover procedure could provide a reasonable estimate of maximum response provided the hysteretic damping was conservatively calculated. The pushover procedure is less intensive in terms of computer resources than the time history method but it does require extensive calculations to account for directional effects and mass eccentricities. The paper concludes that the earthquake engineering profession should be making efforts to move toward the time history procedure for performance based design

2.7 Y.S. Salem, K. Sham 'Nonlinear Time-History Analysis of Modular Structures Isolated by Sliding Plates under Seismic Loads' 2012:

Modular steel structures are the common method of construction in the arctic region where they are largely used by the oil and gas industry to support and enclose process equipments. Non-linear time history dynamic analysis is performed on typical modular structure to assess the seismic performance of these structures. The analysis accounts for their unique detailing especially to elements that contribute to energy dissipation during major seismic events. Maximum inter-story drift and peak global roof drift were adopted as critical response parameters. This study revealed significant global seismic capacity as well as a satisfactory performance at design intensity levels. Special attention needs to be considered for the detailing of the interface between the super structure and the pile foundation.

2.8 Marko Đuran, Ivan Lukačević, Darko Dujmović 'LINEAR AND NON-LINEAR ANALYSES OF CABLE-STAYED STEEL FRAME SUBJECTED TO SEISMIC ACTIONS' 2017:

In this study, linear and non-linear dynamic analyses of a cable-stayed steel frame subjected to seismic actions are performed. The analyzed cable-stayed frame is the main supporting structure of a wide-span sports hall. Since the complex dynamic behavior of cable-stayed structures results in significant geometric nonlinearity, a nonlinear time history analysis is conducted. As a reference, an analysis using the European standard approach, the so-called linear modal response spectrum method, is also performed. The analyses are conducted for different seismic actions considering dependence on the response spectrums for various ground types and the corresponding artificially generated accelerograms. Despite fundamental differences between the two analyses, results indicate that the modal response spectrum analysis is surprisingly consistent with the internal forces and bending moment distributions of the nonlinear time history analysis. However, significantly smaller values of bending moments, internal forces, and displacements are obtained with the response spectrum analysis.

2.9 M.A. Basher, N.E. Shanmugam_, A.R. Khalim 'Web openings in horizontally curved composite plate girders' 2009:

The paper is concerned with the effects of circular or square web openings on the ultimate strength of horizontally curved composite plate girders. Finite element analysis using the computer package LUSAS has been employed to investigate the behavior and ultimate strength capacity of the girders with web openings of different proportions. The opening sizes and their locations within the web panels have been studied in detail, and the results are presented in the form of load deflection and load opening size plots. An approximate method to determine the ultimate strength capacity of horizontally curved composite plate girders accounting for the presence of web openings and composite action between the steel girder and concrete slab is presented. The accuracy of the method is established by comparing the predicted strength with the corresponding values predicted by the finite element method.

2.10 M.F. Hassanein 'Shear strength of tubular flange plate girders with square web openings' 2013:

In this paper, the influence of square opening sizes on the shear behavior of hollow tubular flange plate girders (HTFPGs) is investigated. A three-dimensional finite element (FE) modelling using the ABAQUS computer package has been employed to analyze HTFPGs containing central web openings at end panels. The results of the HTFPGs with web openings are analyzed and then compared with equivalent plate girders (IPGs) with such openings. The collapse behavior of such girders is examined considering the following parameters: the flange type; the flange size; the type of the

web (solid web or web with opening); the web plate slenderness (hw/tw) and the relative opening depth to the web depth (do/hw). The results indicate that employing the HTFPGs with unreinforced central web opening without curved corners instead of the corresponding IPGs with the similar weight and the web opening size is a high performance solution to avoid the reduction in shear resistance due to the presence of web openings. An optimum web opening depth (do,op) for a HTFPG with a slender web is additionally recommended at which its shear strength becomes higher than the corresponding value of the similar weight IPG with solid web. It is furthermore found that the design strength of such girders should consider the sum of the contributions of both the web and the tubular flanges. However, new conclusions on the shear strength and behaviour of HTFPGs with web openings are presented.

2.11 P. C. VARGHESE, T. P. GANESAN, H. ACHYUTHA 'Strength and Behaviour of Reinforced Concrete Vierendeel Girders' 1972:

This paper deals with an investigation carried out by the authors to study the behaviour of simple parallel chorded reinforced concrete Vierendeel girders in their elastic as well as ultimate load conditions. Details of tests carried out along with measurements and observations made are fully described. The application of plastic analysis to reinforced concrete Vierendeel girders has been examined and shown to be feasible when the constituent members of the girders possess the desirable flexural characteristics. A simple method is suggested for predicting the exact mode of failure and to calculate the ultimate load. The validity of the method has been demonstrated from the experimental results. The predominating influence of depth span ratio of the girders over their behaviour in service conditions has been demonstrated and the importance of selecting a proper depth span ratio so as to secure the desirable cracking characteristics and effective stiffness has been pointed out. The comparative behaviour of Vierendeel girders designed on elastic theory and girders with arbitrary uniform reinforcements has also been investigated and their relative advantages discussed.

Summary of Literature:

After going through all the research papers, I have got the quality knowledge about The Vierendeel structural system. I have listed all the research papers and summarized above. Now, I am giving a small summary of all papers collectively.
1. Vierendeel beams with semi-rigid joints structural solution is a more economic structure,as semi-rigid joints are cheaper and the structure is lighter.
2. The fully in filled Vierendeel girder shows better results than other girders. But the girder with opening at compression side is more efficient than the girder with opening in tension side. The infill girder with center openings was less efficient than other in filled girders whereas girder without infill gives perform lower compare to the other girders

III. CONCLUSIONS

In this paper the RCC vineral girder is analysed and compared with conventional building both static linear and dynamic non linear analysis is done using FEA tool ANSYS. Following conclusions can be made up to now

- The normal stress is 45% less in vineral gireder as compared with conventional beam.
- The total deformation due to elcentro is 34%% less in vineral gireder as compared with conventional beam.
- The shear stress is 31% less in vineral gireder as compared with conventional beam.
- The equivalent stress is observed19% less in vineral gireder as compared with conventional beam.

IV.FUTURE STUDY

Following parameters are proposed for further work

- The validation of present case study with experimental model
- The analytical comparison using ANSYS for various span to depth ratio as per code provision subjected to Dynamic load

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