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# Analytical Prediction and Finite Element Simulation of Steel Tubular Pier with Stiffener

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***Abstract:** Hollow steel tubular members are extensively used in multi storey car parks, bridge piers, building columns, offshore structures and subway columns. An earthquake of moderate intensity can result in extensive damage and potential collapse of bridges. During a large earthquake, traditional seismic lateral resisting system can experience significant damage and it cause residual drifts. Thus, a suitable strengthening or retrofitting technique needs to be developed for minimising structural damage and human casualty due to imposed lateral impact loading. The steel shell acts as longitudinal and transverse reinforcement. The primary role of stiffeners is to prevent local buckling prior to overall buckling and to increase overall buckling strength. In seismic applications, an additional, yet equally important role of stiffeners is to increase ductility of the cross section under cyclic loading. Stiffeners are the secondary plate or sections which are attached to web or flanges to stiffen them against out of plane deformation. This paper presents the research work on analytical prediction and finite element simulation of steel tubular pier with stiffeners. A non-liner 3D model was developed using ANSYS programme.*

***Keywords**: Finite element analysis, ANSYS, Stiffener*

## I. INTRODUCTION

Thin-walled steel box columns have wide application in piers of urban highway bridges, and in towers of suspension and cable stayed bridges. In modern days, building design emphasizes on enhancing flexibility of the floor space by reducing the cross section of column size. The steel shell acts as longitudinal and transverse reinforcement. The primary role of the stiffener is to prevent local buckling prior to overall buckling and to increase overall buckling strength. In seismic applications, an additional, yet equally important role of stiffeners is to increase ductility of the cross section under cyclic loading. Natural disasters such as tsunamis, earthquakes and accidental impacts can damage or destroy deficient structures in a matter of seconds. The majority of older buildings and bridges were constructed according to older design codes. These structures are vulnerable during extreme events and need to be retrofitted to meet the current codes and standards. Traditional retrofit techniques include concrete and steel jacketing. These methods are time consuming and labour intensive. They also increase the cross-sectional area of the structural column member. An earthquake of moderate intensity can result in extensive damage and the potential collapse of bridges. Since any damage to the transportation system could have significant impacts on society, the need for the design and development of new bridge components and systems with damage avoidance mechanism has been increasingly highlighted over recent years.

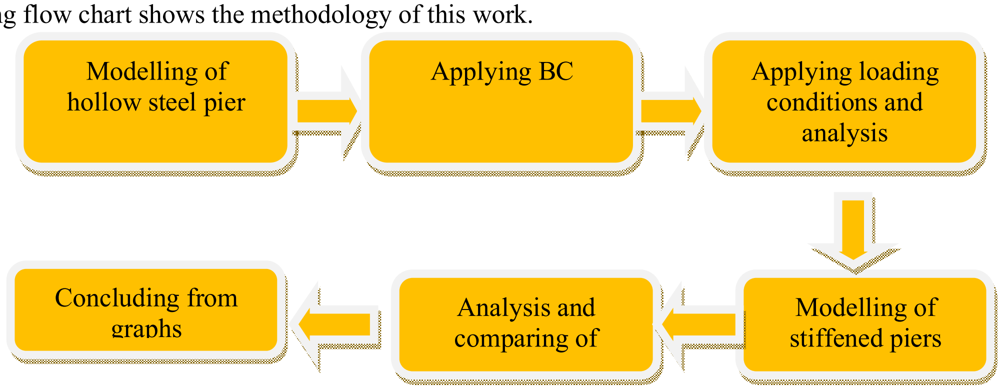
### *A. Objectives*

The following are the objectives of this study,

1) To study the load carrying capacity of stiffened sections.
2) To analyse the energy absorption capacity of stiffened pier.

### *B. Methodology*

The following flow chart shows the methodology of this work.



## II. FINITE ELEMENT MODELLING

To simulate the cyclic and dynamic behaviour of the specimen, three-dimensional FE model were developed using ANSYS mechanical APDL. The finite element modelling is a powerful tool that would be an alternative for the experimental tests which are both time and labour consuming. It is considered a powerful tool in analysis and design of slender steel sections once the model is verified with experimental work. The commercial finite element package ANSYS has been used for simulating the hinged-hinged supported shell slender plate columns. This software has proven its reliability in many benchmark studies and was considered suitable for the current task. The finite element model was developed using quadrilateral element (shell 181) which gives more accuracy in buckling problems. The length of the pier taken for the analysis is 3m and diameter is 900mm with thickness of steel plate is 16mm. Boundary condition is fixed support at bottom. Various loading conditions are applied i.e., axial loading and seismic loading. Fig.1 shows the mesh model of steel hollow tubular pier in ANSYS.

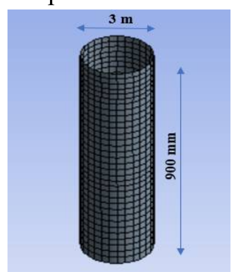



Fig. 1 Mesh model of hollow steel pier

Stiffeners are secondary plate or sections which are attached to web or flanges to stiffen them against out of plane deformation. Almost all main bridge beams will have stiffeners. However, most will only have transverse web stiffeners, i.e., vertical stiffeners attached to the web. Deep beams sometimes also have longitudinal web stiffeners. Stiffeners are employed to resist lateral loading of the plate and are usually made from the rolled shapes integrally welded to the plate. Fig-2 shows the mesh model of stiffened pier with various number of stiffeners. The material properties used for modelling is shown in below table-1.

with 2 stiffeners with 5 stiffeners with 10 stiffeners

Fig. 2 Mesh model of stiffened piers

TABLE I

MATERIAL PROPERTIES

| Material | Young's modulus (GPa) | Poisson's ratio | Density (kg/m^3) | Yield strength (MPa) | Thickness (mm) |
|---|---|---|---|---|---|
| Steel | 200 | 0.3 | 7850 | 250 | 16 |
| Stiffener | 200 | 0.3 | 7850 | 250 | 10 |

## III. ANALYSIS

Three dimensional SOLID 185 element, which has eight nodes, each having three transitional degree of freedom, was used to mesh the piers. Size of the mesh is 100 mm. for axial loading, a remote force of 81420 N is applied at the top of the specimen as shown in fig-3. A pushover analysis is carried out to find the energy absorption capacity of stiffened steel tubular sections. The specimen is fixed to the base. To apply loads, LINK180 elements with a rigid behaviour were used to connect the point of loading to the top nodes of pier. Fig.3 shows the loading and support conditions. Fig.4 shows the loading diagram for seismic loading.

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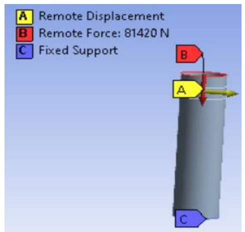



Fig. 3 loading and support condition

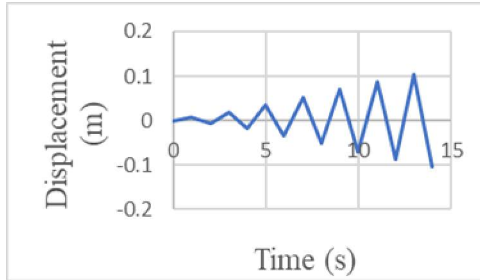



Fig. 4 loading diagram

## IV. RESULTS AND DISCUSSIONS

Strengthening implies the addition of structural material in order to achieve adequate stability, member resistance or stiffness. This may be achieved by adding material to increase load carrying capacity, stiffening the member or introducing additional restraint to the original section thereby increasing its overall resistance reducing susceptibility to buckling. In recent years, challenging steel structures are required to withstand the needs of economic and uneconomic constructions. Therefore, a proper understanding of the structural behavior of those structure is a must. Fig.4 to fig.7 shows the contour plot of deflection and load deformation graph for hollow steel pier with axial and seismic loading.

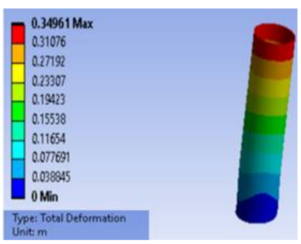



Fig. 4 contour plot of deflection of hollow steel pier with axial loading

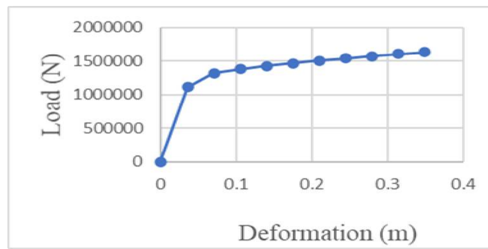



Fig. 5 Load deformation graph of hollow steel pier with axial loading

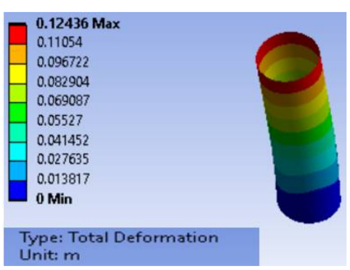



Fig. 6 Contour plot of deflection of hollow steel pier for seismic loading

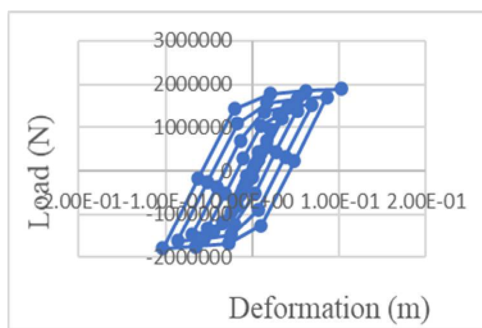
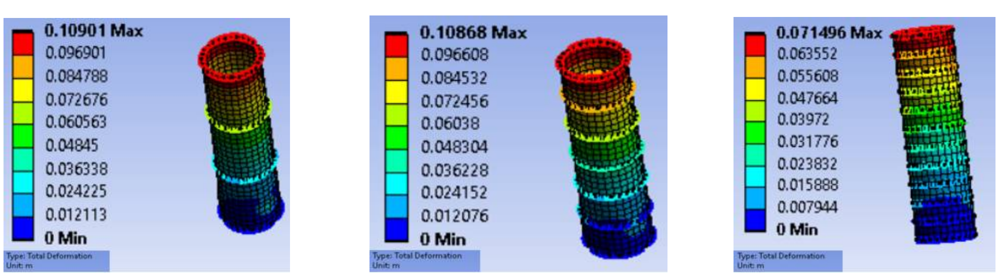



Fig. 7 Hysteresis graph of hollow steel pier for seismic loading




with 2 stiffeners with 5 stiffeners with 10 stiffeners

Fig. 8 contour plot of deflection of stiffened pier for axial loading

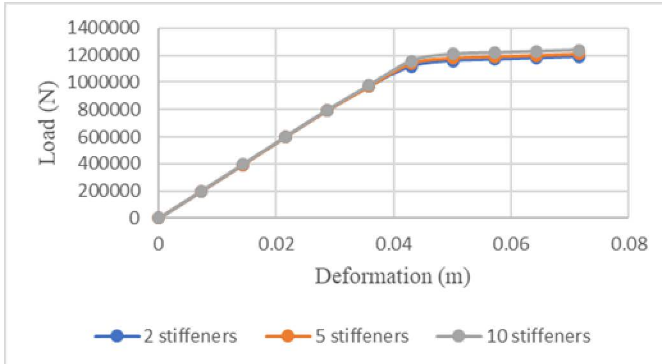
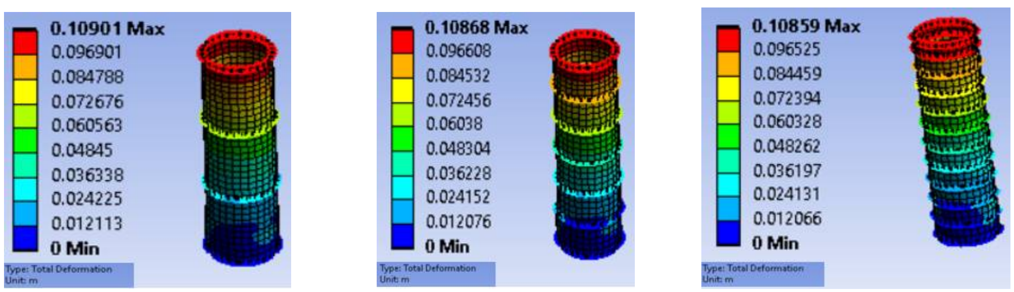
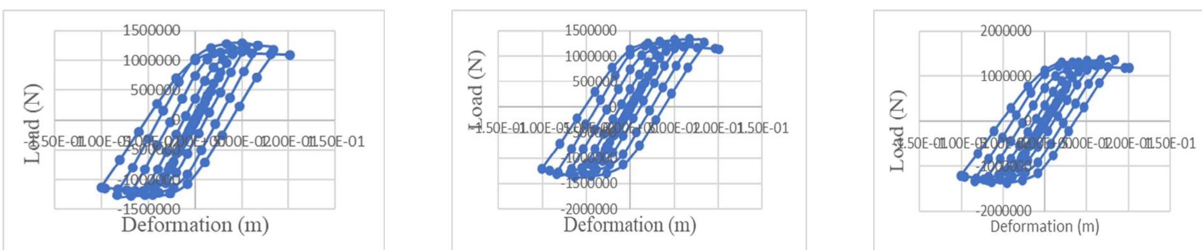



Fig. 9 Load deformation graph of stiffened pier for axial loading




with 2 stiffeners with 5 stiffeners with 10 stiffeners

Fig. 10 Contour plot of deflection of stiffened pier for seismic loading




with 2 stiffeners with 5 stiffeners with 10 stiffeners

Fig. 11 Hysteresis graph of stiffened pier for seismic loading

From the above figures and graphs, we can conclude that stiffened pier has higher energy absorption capacity and load carrying capacity Therefore, it is economic at seismic prone areas. The failure load of unstiffened pier is 1115.1 kN. But the stiffened pier has the failure loads of 1120kN, 1140kN, and 1160kN which is greater than the unstiffened pier. Fig-8 to fig-11 shows the contour plot of deflection and load deformation graph for stiffened pier with axial and seismic loading.

TABLE II
summary of results

| **Material** | **No. of stiffeners** | **Axial loading** | | **Seismic loading** | |
|---|---|---|---|---|---|
| | | Deformation (mm) | Failure load (kN) | Deformation (mm) | Energy absorption capacity (J) |
| Hollow tubular steel pier | - | 0.3496 | 1115.1 | 0.1243 | $1.85x10^3$ |
| Stiffened steel pier | 2 | 0.1090 | 1120 | 0.1090 | $1.95x10^3$ |
| | 5 | 0.1086 | 1140 | 0.1086 | $2.06x10^3$ |
| | 10 | 0.0714 | 1160 | 0.1085 | $6.04x10^3$ |

As we can see from the above results, the strength of hollow section is enhanced by providing stiffeners. The load carrying capacity of tubular section is enhance by increasing number of stiffeners.

## V. CONCLUSIONS

This paper presents a study on stiffened steel tubular pier under axial and seismic loading. The following conclusions can be drawn from this study,

*A.* The stiffened pier has higher load carrying capacity and energy absorption capacity.
*B.* As the number of stiffeners increase, the energy absorption capacity also increases.
*C.* The load carrying capacity of tubular section is enhance by increasing number of stiffeners.
*D.* Transverse stiffeners are vital in slender sections.

## VI. ACKNOWLEDGMENT

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