Numerical Analysis of Socket Connection between Precast Column and Footing by using various Parameters

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Abstract— Now days, precast concrete structures are used globally because it reduce construction period, reduce traffic congestion, cost efficiency and superior plant control of structural elements as compared to the conventional cast in place system. This paper focuses on the analysis of socket connection between precast column and cast in place footing by using various parameters. In this paper, it is planned to conduct a comparison between the socket connection with and without stiffener for improving the seismic performance of the socket connection between precast column and cast in place footing.

Key words: Socket Connection Between Precast Column–Footing Connection, Accelerated Bridge Construction (ABC), Stiffener

I. Introduction

Construction related delays can be reduced by precast the structural elements so that the connection between precast column and cast in place footing have the capability to transfer both gravity loads and lateral force safely to the footing. The socket connection between precast column and cast in place footing can be constructed by erecting the precast column and casting the reinforced concrete footing around it. Since there is no bar intersecting at the column – footing connection, so it provides better transfer of forces to foundation as compared to the conventional column – footing connection.

Fig. 1: Socket Connection

Now days, Accelerated Bridge Construction are widely accepted by the transportation agencies for reducing the amount of site work and also it reduce the environmental impacts. Accelerated Bridge Construction is constructed by using precast elements. This construction will improve safety for both motoring public and highway workers. Due to these reasons, Accelerated Bridge Construction is mostly used in many urban construction projects. This construction will save the time on site. The increasing in the cost of the project will be compensated by reducing the road user cost and also the economic loss to the affected communities. There are many benefits of using Accelerated Bridge Construction on site. They are Minimize traffic delays, Improve safety to workers, Quality of the work can be improved etc.

The socket connection between precast column and square footing has less capability to resist the deformation under monotonic analysis. In order to improve the seismic Performance of a structure, stiffener is used at the connection region. Stiffener consists of steel plate and bolts to connect the base plate to the top reinforcement of the footing. A circular steel plate at a height of 200mm and 4 triangular plates are provided on 4 sides are used for holding the base plate The cost of the steel plate with bolted connection can be offset by reducing the amount of steel in the column The advantages of using the stiffener at the connection region are,

- It will reduce the deformation of the column.
- It will greatly reduce the stress concentration at the connection region
- When the load acting on the column increases, the base plate or bolt may yield, it resulting in excessive deformation and reduced column load at failure.

II. Design of Socket Connection between Precast Column and Cast in Place Footing

Columns are the most important part for the structures like bridges, buildings etc. Columns are vertical compression members are used to transfer the loads of the structures to the foundation below. The function of a foundation is to safely transfer the loads from the superstructure to the ground. A foundation should be designed to transmit the load to the soil below, without exceeding the safe bearing capacity of the soil. The specimens are designed as per IS 475, IS 875, IS 800.

The precast circular column of diameter 285mm and the size of the footing is 2000mmx2000mm.Depth of footing is 650mm.the grade of concrete and steel is M20 and Fe415 respectively. Stiffener consists of base plate of size 380mmx360mm and 4nos of bolts are used to connect the baseplate to the footing. A circular plate of 200mm and 4 web plate are welded to the base plate for holding.

III. Finite Element Analysis

A. *Modelling*

ANSYS is most commonly used for the finite element analysis. With finite element analysis (FEA) tools, you can customize and automate your simulations, and parameterize them to analyze multiple design scenarios. ANSYS structural analysis software suite enables to solve complex structural engineering problems and make better, faster design decisions. In Finite element modeling (FEM), a complex domain is discretized in to elements of simple geometric shapes. The individual element in the system is linked by the assembly process.

In ANSYS Workbench 16.2, for modelling concrete, SOLID 65 elements .This element has eight nodes with three degrees of freedom at each node – translations in the nodal x, y, and z directions. For modelling reinforcements, BEAM 188 elements are used. All the structural properties of concrete and the reinforcement were suitably given in the ANSYS software. The Modeling of the socket connection between precast column and cast in place footing with and without stiffener is shown in the following figures.

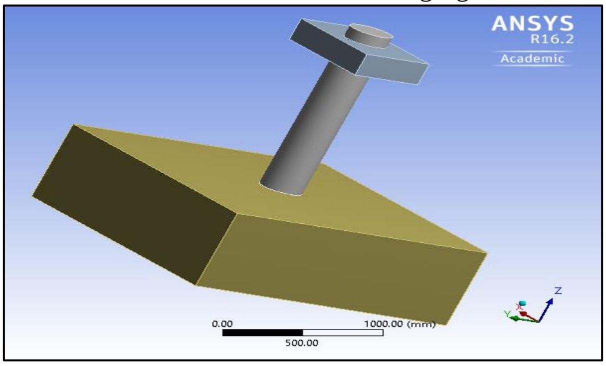

Fig. 2: Model showing the precast circular column and square footing without stiffener

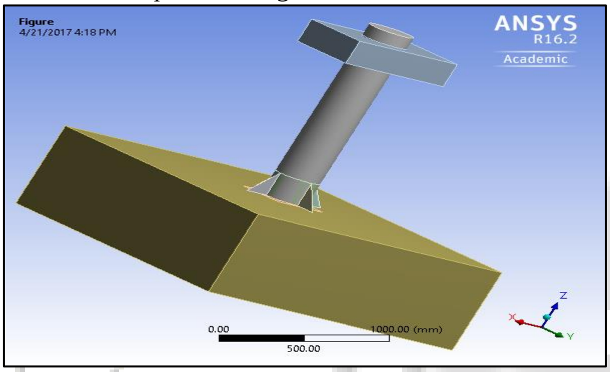

Fig. 3: Model showing the precast circular column and square footing with stiffener

B. Material Properties

Properties	Value
Grade of concrete	M_{20}
Poissons ratio of concrete	0.15
Poissons ratio of steel	0.3
Density of concrete	2300 Kg/m^3
yield strength of concrete	20Mpa
yield strength of steel	415 Mpa
Density of steel	7850 Kg/m^3

Table 1: Material Properties

C. Meshing of Socket Connection between Precast Column and Cast in Place Footing

In FEA, the model is divided into small elements. These elements must agree with the geometry of the structure and correspond to the geometry and the mechanical properties in the regions. Parallel meshing is available without any additional cost or license requirements. It is better to use the elements size smaller enough to succumb the good results and yet largely reduces the computational time.

ANSYS Meshing chooses the most appropriate options based on the analysis type and the geometry of the model. ANSYS Meshing to automatically take advantage of the available cores in the computer to use parallel processing and thus significantly reduce the time to create a mesh. Parallel meshing is available without any additional cost or license requirements. Meshing of the entire arrangements was done in ANSYS by giving the appropriate size of mesh.

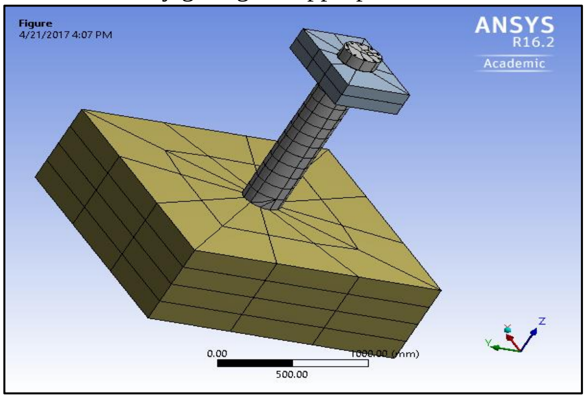

Fig. 4: Meshed model of the precast circular column and square footing

D. Support Condition and Loading

Since the footing was provided in the ground and it is surrounded by the soil. So the footing was given with the fixed support condition.

After providing the support condition to the foundation, loading arrangement was given to the column. In loading there are two types of loads, one is the vertical load that acted vertically to the column and another one is the earthquake loading that is acted horizontally along the loading plate that was provided at the column. The vertical loads are taken from the design data and the lateral load is taken from the cyclic lateral load analysis that is acting in positive and negative direction. In cyclic lateral load analysis, the lateral load corresponding to the maximum deformation is in negative direction. So the lateral load is provided in negative direction during the monotonic analysis.

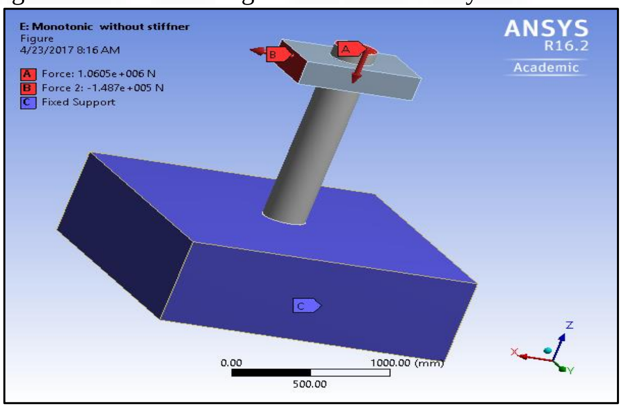

Fig. 5: Boundary condition and load application

IV. Analysis of the Structure using ANSYS

After the preprocessing techniques are done, the next stage is post processing that is analyzing the Connection against the given fixity and the loads that is provided. In this paper, monotonic analysis is conducted. Monotonic analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. Monotonic load is the load corresponding to the previous of maximum deformation that is obtained when the cyclic lateral load analysis is conducted. The load corresponding to the previous of maximum deformation is in negative direction.

A. Analysis of Socket Connection between Precast Column and Cast in Place Footing with and Without Stiffener

The analysis is done to determine whether the seismic performance improving or not when the stiffener is used at the connection region. The deformation and frictional stress diagram of the socket connection footing with and without stiffener as shown in the following figures.

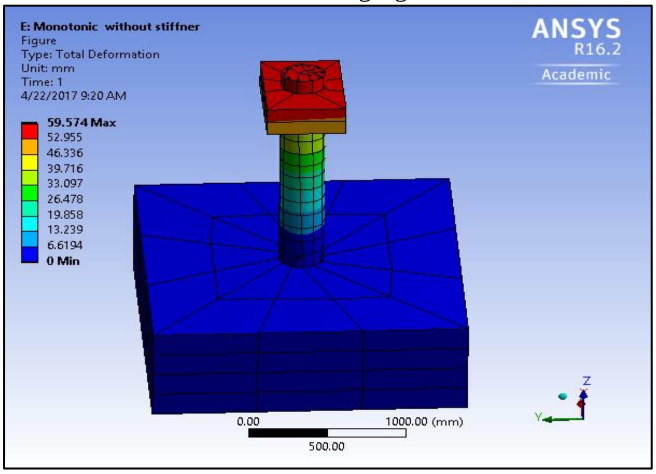

Fig. 6: Total Deformation of precast circular column and square footing without stiffener

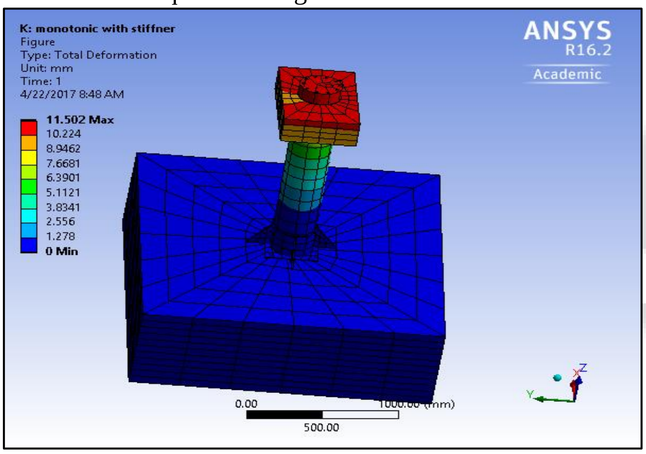

Fig. 7: Total Deformation of precast circular column and square footing with stiffener

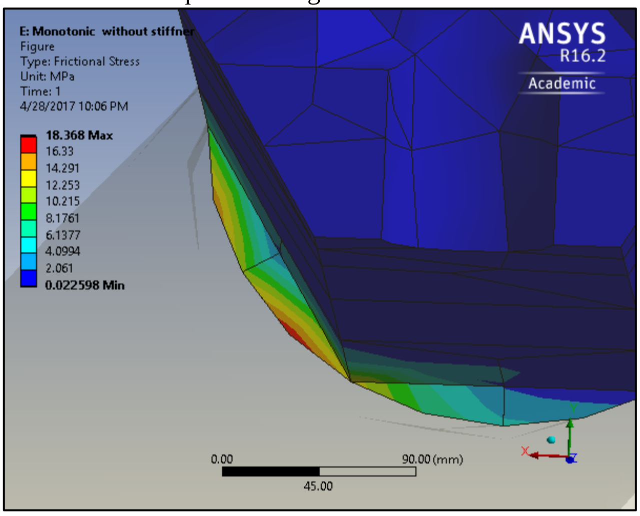

Fig. 8: Frictional Stress of precast circular column and square footing without stiffener

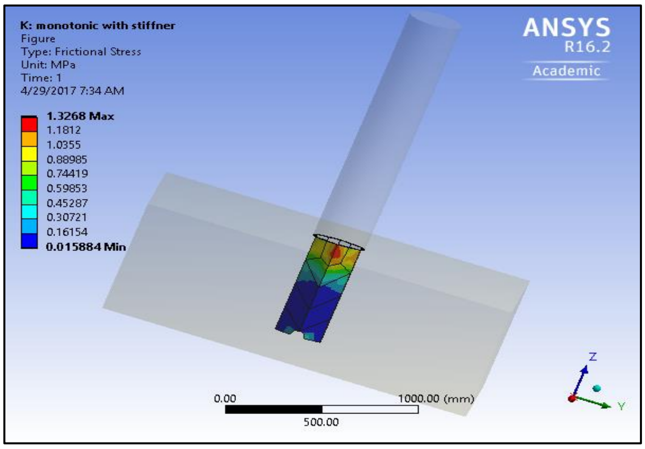

Fig. 9: Frictional Stress of precast circular column and square footing with stiffener

By comparing the existing socket connection and socket connection with stiffener, it shows that

1) Existing socket connection
   – Frictional Stress - 18.368 Mpa
   – Total Deformation - 59.574mm
2) Socket connection with stiffener
   – Frictional Stress - 1.3268Mpa
   – Total Deformation - 11.502 mm

By providing the stiffener at the connection region, we can reduce the deformation of the structure and the stresses are acting in between the connection region can also reduce as compared to the socket connection between precast column and cast –in-place footing without stiffener. From the results, it can be inferred that socket connection between precast column and footing with stiffener can improve the seismic performance.

B. Analysis of Socket Connection between Precast Column and Cast in Place Footing with Stiffener and Conventional Column – Footing Connection

The analysis is done to determine whether the seismic performance improving or not as compared to the conventional column – footing connection. The value of total deformation and frictional stress of precast circular column and square footing with stiffener as shown in above fig7 and fig 9.The total deformation and frictional stress of conventional column-footing connection as shown below. The design of conventional column – footing connection is designed as per as per IS 475, IS 875,IS 800.

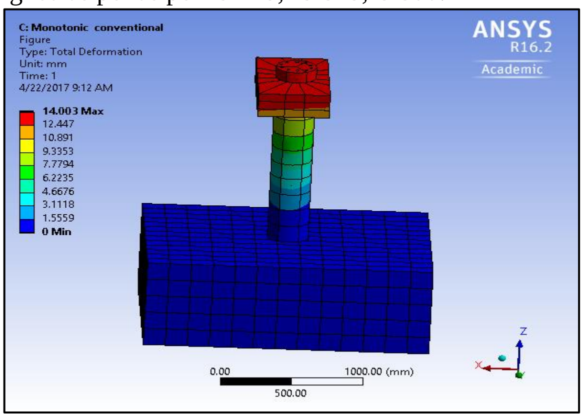

Fig. 10: Total Deformation of conventional column-footing connection

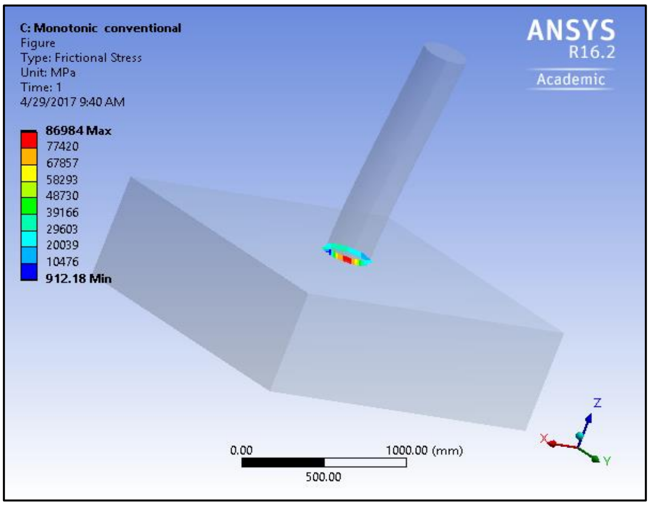

Fig. 11: Frictional stress of conventional column-footing connection

By comparing the conventional cast in place system and socket connection with stiffener, it shows that

1) Conventional cast in place system
   - Frictional Stress - 86984Mpa
   - Total Deformation - 14.003mm
2) Socket connection with stiffener
   - Frictional Stress - 1.3268Mpa
   - Total Deformation – 11.502 mm

From the results, it is inferred that the value of frictional stress in conventional column-footing connection is very large due to the intersection between the column reinforcement and the footing reinforcement. But the deformation is very more at the connection region as compared to the socket connection with stiffener. The value of deformation of the socket connection with stiffener is less. So this new system is suitable to construct in India.

V. RESULTS AND DISCUSSIONS

A. Comparison of Socket Connection between Precast Column and Cast in Place Footing with and without Stiffener

The comparison of socket connection between precast column and cast in place footing with and without stiffener is done to determine the improved seismic performance.

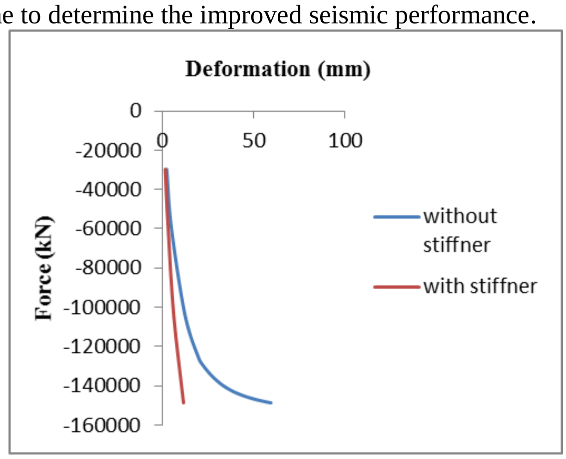

Fig. 12: Graph showing the comparison of precast circular column and square footing with and without stiffener

From the graph, it can be inferred that the precast circular column with square footing without stiffener shows high value of deformation and the curve of the structure without stiffener bends and shows little failure behaviour.

B. Comparison of Socket Connection between Precast Column and Cast in Place Footing with Stiffener and Conventional Column – Footing Connection

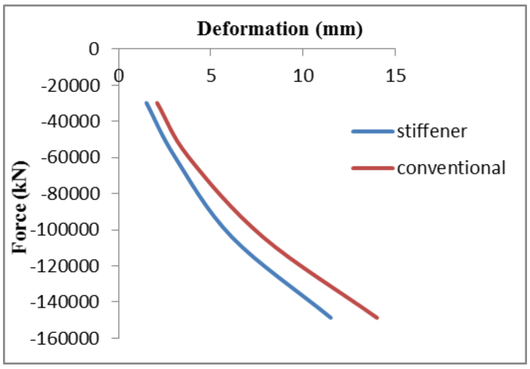

Fig. 13: Graph showing the comparison of precast circular column and square footing with stiffener and conventional column – footing connection

From the graph, it can be inferred that the value of deformation is more than the precast circular column and square footing with stiffener. In conventional column-footing connection, the cracks at the connection region are more and it is very difficult to repair the cracks. The socket connection with stiffener is very easy to construct on site. So it saves construction time on site

VI. CONCLUSIONS

The socket connection between precast column and footing are better than other connection between precast column and footing because no bars projecting from the bottom of the column and also there is no intersection between the column reinforcement and the reinforcement of the footing. In this connection, the stresses are concentrated less at the connection region. So it is very easy to transfer the loads at the connection region. The Socket connections are very excellent in resisting the different loads. Socket connection between precast column and footing with stiffener shows improved seismic performance as compared to the conventional column footing connection as well as the Socket connection between precast column and footing without stiffener the socket connection between precast column and cast in place footing can be adopted in India.

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