Seismic Behavior of Stone Column in the RC Frame Structure

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Abstract - *In this research paper, we have created four models of the stone column and it is used in the RC structure. Model-01 has a simple stone column in the medium soil type, Model-02 have also a simple stone column but is used in the Hard soil, Model-03 has a stone column with reinforcement in the medium soil type, and Model-04 have also a stone column with reinforcement but it is used in the hard soil. All four models are used in the RC frame structure with different soil properties, and these models will be analyzed with help of the ETABS software by using the Time history analysis, and code is used for the analysis of these models is Indian Standard Code 1893 part-01:2016. We will analyze the structure by taking some important seismic parameters such as base shear, natural period, storey drift, Column force, and displacement.*

Key Words: Stone Column, RC Column, RC frame structure, Seismic Behaviour, Dynamic Analysis, Time history analysis, ETABS

1. INTRODUCTION

Stone columns are a type of ground improvement technology that uses a network of compacted stone columns to stabilise the soil. Stone columns are used to decrease settlement and increase load-bearing capacity, as do other ground improvement procedures. The drainage ability of the granular material within the columns, which function as pore or water pressure evacuation sites, also helps to speed up soil consolidation. By enhancing shear strength inside the soil, stone columns are particularly efficient in strengthening slope stability and preventing liquefaction.

Figure-1: Stone Column

1.1. Basic Principle of Stone Columns Rigid Inclusions

These vertical inclusions, which can be formed of stone or sand, are laid out in a grid pattern beneath the structure in the soft soils. Stone columns, also known as aggregate piers, are ideal for improving soft or loose soils because they generate vertical inclusions that are stiff, shear strength, and drain well. The Stone Columns boost bearing capacity while also lowering total and differential settlements.

1.2. Type of stone Column

1. Aggregate Column
2. Granular Piles
3. Vibro Stone Column
4. Rammed Stone Column
5. Compacted Stone Column
6. Aggregate Piers
7. Sand Compaction Piles
8. Geotextile Encased Columns
9. Grout Stone Columns

2. METHODOLOGY

For the analysis of these four models, we used some methods such as Dynamic Analysis, ETABS Software and Indian Standard code 1893 part-1:2016. Dynamic Analysis is a method of the analysis of the structure when the variation of the load concerning the time is more, according to the IS code 1893 part-1: 2016, clause 7.7.3 dynamic analysis is classifieds into two types:

i. Time History Method
ii. Response Spectrum Method

2.1 Time History Method

According to clause 7.7.4 from IS code 1893 part-1: 2016, the time history method shall be based on appropriate ground motion and shall be performed using the accepted principle of earthquake structural dynamics. The data of the time history is taken from "EL CENTRO". The time history method comes under the dynamic analysis where the variation of the lateral force concerning time is maximum, if the variation of the lateral force concerning the time is low then we should use the static analysis method. Etabs software is developed by the CSI company and is used for both analysis and designing of the structure.

3. MODELLING

In this paper, there are four models in the first model (Model-01) Stone Column without reinforcement in RC frame structure in the medium soil type, in the model second (Model-02) Stone Column without reinforcement in RC frame structure in the hard soil type, in the third model (Model-03) Stone Column with reinforcement in RC frame structure in the medium soil type, and in the fourth model (Model-04) Stone Column with reinforcement in RC frame structure in the hard soil type.

All parameters (material, building configuration, seismic) of this Stone Column in RC frame structure with and without reinforcement at different soil type in the building is given below in detail:

3.1 Material Parameter

In this parameter, we give the details about the material which is used in Stone Column in RC frame structure with and without reinforcement at different soil types and the material parameter is given below in the table:

Table -1: Material Parameter.

S. No	Material	Grade
1.0	Concrete	M30 & M25
2.0	Longitudinal Bar	Fe415
3.0	Stone	

3.2 Building Parameter

In this parameter, we provide the information about structure parameter such as size of beam, size of column, and slab is given below in table:

Table -2: Building Parameter

S.No	Building Parameter	Value
01.	Beam	240mm*360mm
02.	Column	230 mm*360mm
03.	Slab	160mm
04.	Span of Beam	3.25m
05.	Height of building	39 m
06.	Floor height	3 m
07.	Ground storey	3 m

3.3 Seismic Parameter

In this factor, we were given the factor of the seismic where the model is assumed to construct such as seismic zone factor, Importance factor, etc

Table -3: Seismic Parameter

S.No	Seismic Parameter	Value
01.	Seismic Zone Factor (Z)	0.24 (Forth Zone)
02.	Response Reduction Factor (R)	5
03.	Importance factor (I)	1.2
04.	Soil type	2nd or 3rd
05.	Eccentric ratio	5%

3.4 Load Parameter

The load which is acting on the model such as Imposed load is given in the table:

Table -4: Load Parameter

S.No	Load Parameter	Value
01.	Live load	3.0KN/m^2
02.	Dead load	Automatic through software
03.	Load distribution wall	14.0KN/m

4. DETAILS VIEW OF ALL MODELS

In the details view of the models, we will see the details plan, elevation, three-dimensional view, and cross of every stone column.

4.1. Stone Column with RC Structure in Medium Soil Structure (Model-01)

The plan, elevation and three-dimensional view of the model-01(where) are given below:

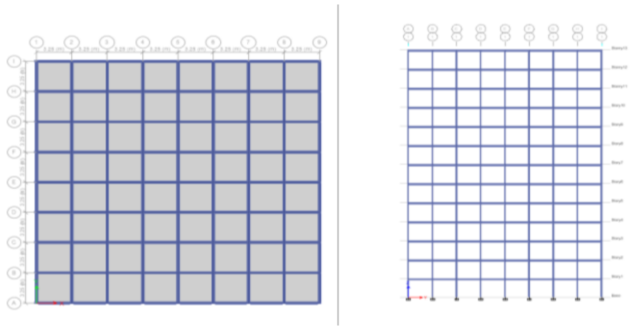

Figure-02: Plan and Elevation of Model-01

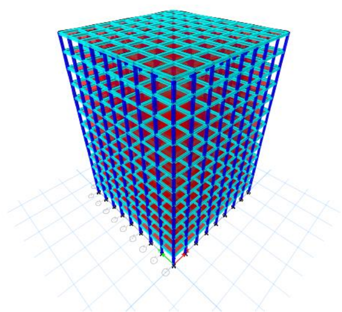

Figure-03: 3D View of Model-01

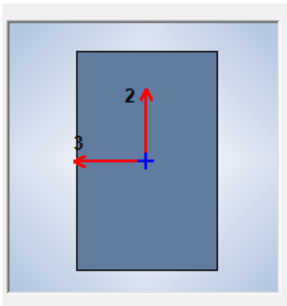

Figure-04: Cross-section of Column of Model-01

4.2. Stone Column with RC Structure in Hard Soil Structure (Model-02)

The plan, elevation and three-dimensional view of model-02 are the same as model-01.

4.3. Stone Column with Reinforcement with RC Structure in Hard Soil Structure (Model-03)

The plan, elevation and three-dimensional view of the model-03 are same as model-01, but the cross-section of the column is different which are given below:

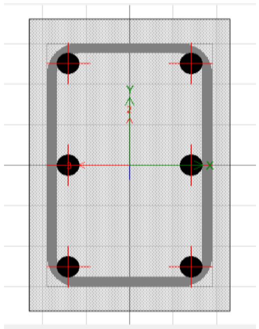

Figure-05: Cross-section of Columns of Model-03 and Model-04

4.4. Stone Column with Reinforcement with RC Structure in Medium Soil Structure (Model-04)

The plan, elevation and three-dimensional view of the model-04 are same as model-01, but the cross-section of the column is also the same as model-03:

5. CALCULATION AND ANALYSIS

After analyzing all these four model, there are following result come out and we have taken some parameter to compare the value of these three models, such parameter is the storey drift, base shear, storey overturning moment, and maximum storey displacement.

5.1. Base Shear

According to the Indian standard code 1893 part-1:2016, the base shear is defined as the lateral force at every storey due to seismic force. The graph of the base shear of every model is given below:

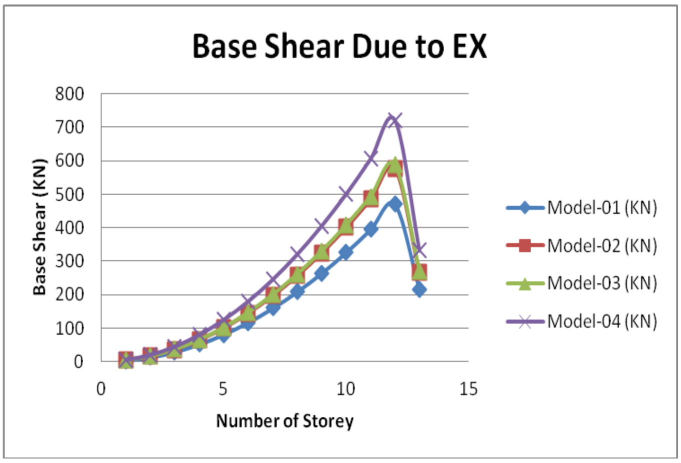

Figure-06: Base Shear of Models due to EX

From the above graph, the maximum value of the base shear is acting in model-04 as compared to the other three models.

5.2. Storey Drift

According to the Indian Standard Code 1893 part-01:2016, the storey drift is defined as the relative displacement between two floors which may be the upper or lower floor. The maximum value of the storey drift should not exceed 0.004h, where h is the height between floors. The graph of the storey drift is given below at the load case EX:

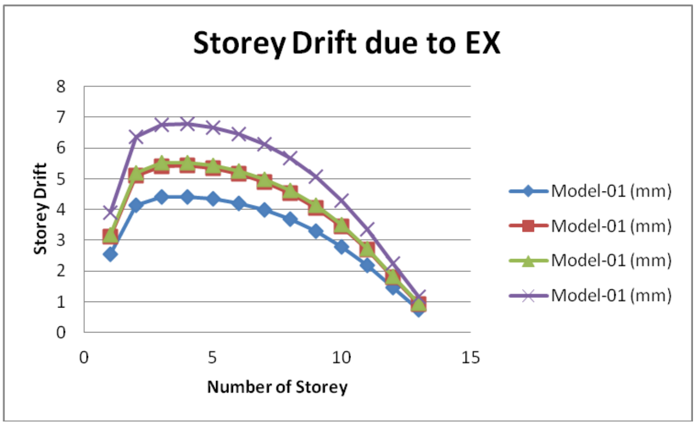

Figure-07: Storey Drift of Models due to EX

The maximum value of the storey drift is acting in model-04 as compared to the other three models.

5.3. Storey Overturning Moment

According to the Indian standard code 1893-part 01:2016, the storey overturning moment is defined as the moment generated at each storey of the building due to the effect of seismic force. At the top storey, the value of the storey overturning moment always zeros.

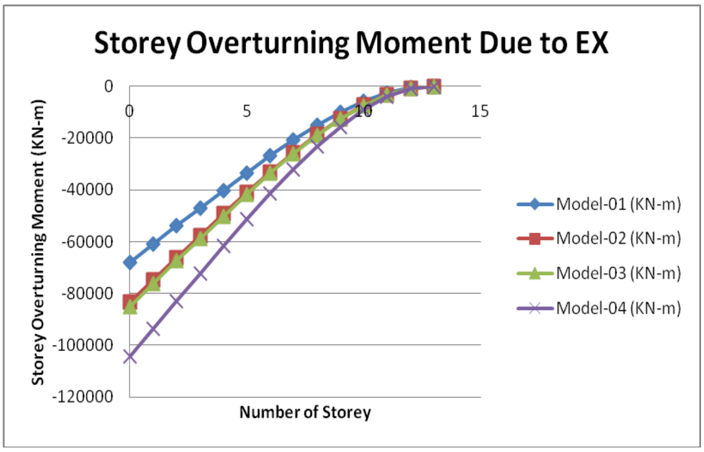

Figure-08: Storey Overturning Moment of Models due to EX

From the above graph of the storey overturning moment, the maximum value of the storey overturning moment acting in model-04 as compared to the other three models.

5.4. Storey Displacement

According to the Indian Standard Code, storey displacement is defined as the displacement of the upper or lower storey concerning another storey due to seismic force. If the height of the floor is 3m, then the maximum displacement should not be greater than 12mm. The graph of the storey displacement of all models at load case EX is given below:

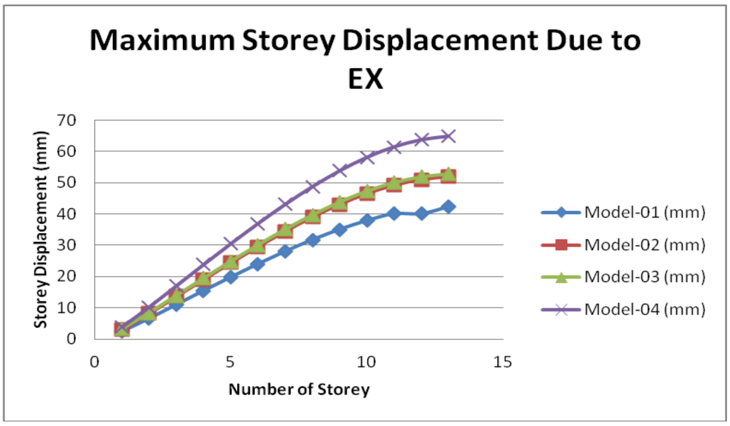

Figure-09: Maximum Storey Displacement of Models due to EX

From the above graph of the storey displacement, we found that maximum displacement occurs in model-04 as compared to the other three models.

6. CONCLUSION

After analysing all these models with the help of the ETABS software by using Time history analysis, and IS code 1893 part-01: 2016, we found some results which are given below:

The value of the base shear is maximum in model-04 where the reinforcement provided in the stone column in the RC frame building at the hard soil, which is approximate 19% higher than model-03, 20% higher than model-02, and 35% approximately higher than model-01. The stability of the resisting the lateral force due to seismic effect in the building is in the model-04.

According to the Indian Standard code 1893 part-01:2016, the value of the storey drift should not exceed 0.004h, where "h" relative height between two floors. In this research work, take the height of every floor is 3m, so storey drift should not exceed 12mm relative between two floors. All value of the storey drift is less than 12mm so we can say that all models are in the safe condition, but the maximum value of the storey drift exists in the model-04 where the reinforcement provided in the stone column in the RC frame building at the hard soil, that is 6.782mm.

According to the Indian Standard code 1893 part-01:2016, the value of the maximum storey displacement should not be exceeding than H/250, where "H" is the total height of the building. In this research work, take the total height of the building is 39m, so the maximum storey displacement should not exceed 156 mm from the ground to the top floor. The value of the maximum storey displacement is less than 156 mm so we can say that all models are in the safe condition, but the maximum value of maximum storey displacement exists in the model-04 where the reinforcement provided in the stone column in the RC frame building at the hard soil, that is 64.845 mm at the top floor.

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