COMPARATIVE STUDY OF REGULAR AND IRREGULAR PLAN GEOMETRIC DIAGRID STRUCTURE ON VARYING SOIL STRATUM UNDER LATERAL LOADING

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Abstract - *In present-days high rise multi-storey structures are expeditiously rising due to the fact that there is scarcity of land and quickly increasing population therefore, there is necessity for some advance techniques and technologies to be upheld to tackle with the present scenario. Structures providing appreciable efficiency, durability and safety are chief demand for a high rise structure. To fulfil all these demands adopting a structure with superior resistance to lateral loading will be advantageous. Study focuses on two factors namely (a) soil type- due to the fact that structures when subjected to numerous earthquake forces, they behave distinctly with change in soil type. (b) irregularity-as most of all structures relies on structural configuration and its geometry. In this thesis analysis of a G+16 storey diagrid structural system with a plan of 21x21m carrying geometric irregularity and symmetry, designed on varying soil stratum namely hard soil, medium soil and soft soil using E-Tabs (2017) software. The principal objective of the study is to distinguish the performance of diagrids with two dissimilar geometry when soil stratum is varied from hard to medium and from medium to soft considering seismic and wind loads. Equivalent static load method is employed for carrying out for seismic loading. Study develops a comparison premised on some prime parameters namely base shear, displacements and storey drift to determine the most suitable type of soil for high rise diagrid structural system.*

Key Words: Diagrid, Varying Soil, Lateral Loads, Plan Irregularity, Displacement, Storey Drift, Base shear.

1. INTRODUCTION

Diagrids can be described as the perimeter structural configuration formed by intersection of narrow grid of diagonal members intricated mainly in increasing the gravity and lateral resistance of the structure. The diagonal members in general are modelled as beams and on the basis of repetitive occurrence of stories they are subdivided into modules. Diagrid structural system are progressed from braced tube structures as the configuration of perimeter holds good for conserving the resistance to maximum bending and shear rigidity. Due to triangular arrangement of members the tilted diagonal segments behave both as inclined columns and as bracing components by sustaining gravity and lateral forces mainly concerning internal axial forces. Diagrids with the absence of exterior columns, interior columns are designed to carry only the gravity load.

Soil can influence the change in dynamic loading amplitude, its duration and frequency. This change is encountered by varying soil stratum, thickness of soil bed and dynamic property and also its relative layer depth. Effects of soil interaction can either increase or lower the intensity of seismic outcome of the structure under different earthquake loading when soil Stratum is varied.

1.1 OBJECTIVES

The prime objective of this study is to understand and analyse the behaviour of a regular and irregular plan geometric diagrid structure on a differing soil stratum namely hard soil, medium soil and soft soil conditions.

1. To model and investigate the response of regular and irregular plan diagrid structure under wind and seismic loading for varying soil stratum using E-Tabs.
2. To examine the effect of plan irregularities and differing soil types on diagrids by linear static method.
3. To emphasize comparison in terms of parameters such as maximum displacement, storey drift and base shear for both regular and irregular diagrid on varying soil types.

2. METHODOLOGY

Max displacement, storey drift and base shear are evaluated for two models namely regular and irregular diagrids on varying soil stratum as per Indian Standard codes by using E-Tabs software. Initial step is to Analyse two diagrid structures by considering its change in geometric configuration i.e., one with regular and other with irregular geometry and then carrying out the analysis on varying soil stratum such as hard, medium and soft soil stratum. Secondly, analysing the models with inclined diagrid members on the periphery when wind forces and seismic loads are applied on successive floors and at the edges of column joints both in X and Y directions. Lastly studying the variations in the plots corresponding to displacements, storey drift and base shear and procuring the reason for variation due to the influence of soil type and plan irregularity. All the columns are designed as concrete sections and all slab sections are assumed as shell thin element with meshing. Beams are assigned to be steel I sections and hollow mild steel pipe sections are taken into consideration for diagrid members.

Properties of soil and material properties are represented in the table1-2. Structural geometric details are illustrated in table 3. Member properties, loads considered, seismic forces and wind forces assumed for present study are displayed in the tables 4-7.

Table -1: Properties of Soil

Factors	**Hard soil**	**Medium soil**	**Soft soil**
Shear modulus G (KN/m^2)	2700	451.1	84.5
STP (N) value	30	6	3
Unit weight (KN/m^3)	20	18	16
Poisson's ratio	0.25	0.33	0.48

Table -2: Material Properties

Concrete grade	M30
Unit weight of concrete	$25kN/m^3$
Structural Steel grade	Fe-345
Modulus of elasticity (Fe345)	205GPa
Reinforcement grade	Fe-500
Unit weight of Steel	$78.50kN/m^3$
Poisson's ratio	0.2

Table -3: Structural geometric details

Plan dimension	21x21m
Pattern of model 1	Regular model
Pattern of model 2	Irregular model
No of storeys (both model's)	G+16
Building type	Commercial building
bottom storey height	3.5m
Typical storey height	3.6m
Spacing between frame (X direction)	3m
Spacing between frame (Y direction)	3m
End condition at base	Fixed support
Support condition for diagrid members	Pinned support

Table -4: Member properties

Column size	(450X450) mm
Beam type	ISMB 500
Slab thickness	120mm
Type of slab	Shell element
Diagrid size	350mm
Wall thickness for diagrid	12mm
Diagrid angle	67.4^0
Diagrid section	Hollow mild steel pipe

Table -5: Loads considered

Floor finish (IS 875 part 1)	$2.5kN/m^2$
Live load on terrace (IS 875 part 2)	$1.5kN/m^2$
Live load on floor (IS 875 part 2)	$4kN/m^2$

Table -6: Seismic Forces (IS:1893 (part 1)-2016)

Type of structure	SMRF
Importance factor, I	1
Response reduction factor	5
Seismic zone	III
Seismic zone factor	0.16
Soil type's	Hard, medium and soft

Table -7: Wind Forces (IS:875 (part 3)-1987)

Basic wind speed	39m/s
Wind location	Mangalore
Risk coefficient	1
Terrain category	Category 3
Structure class	C
Topography factor	1

E-Tabs (2017) software is used for current work. It is an innovative and most used software mainly to deal with the design of multi-storey structures which is otherwise heavy handed by manual design. The purpose of inducing irregularity in a structure especially in diagrid is to study the response of structure which completely relies upon structural configuration or arrangement of members in it. Secondly, to enhance its aesthetic look. The immensity of variation in reaction mainly relies on degree, location and kind of irregularity present. The optimum selection of these parameters while modelling the structure may improve the overall efficiency of the structure.

For present study we design two models of G+16 storey one with regular plan and other with irregular plan diagrid structure on differing soil types. Structure is assumed to be open hall assembly public building due to which there is no wall loads applied. Existing structure has absence of external columns which in turn are compensated by providing mild steel pipe inclined diagrid sections. 25 load combinations are assumed as per Indian standard codes. Plan and 3D view of diagrid models based on its plan geometry are represented in Fig 1-4.

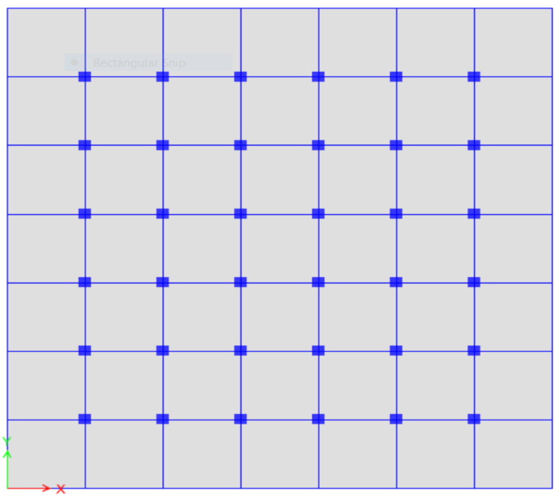

Fig -1: Plan view of Regular Diagrid Structure

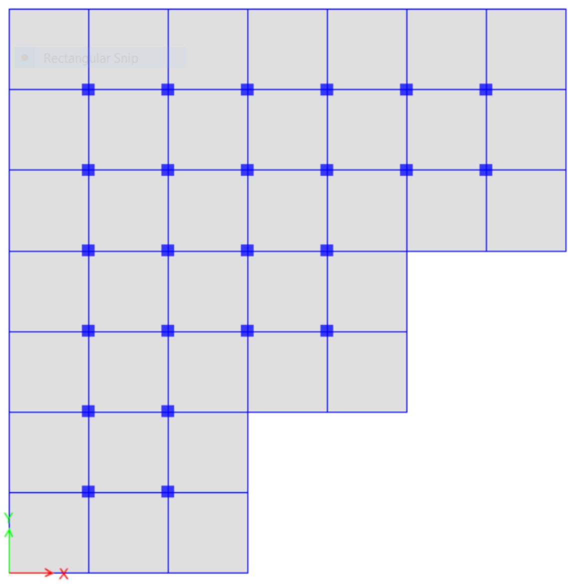

Fig -2: Plan view of Irregular Diagrid Structure

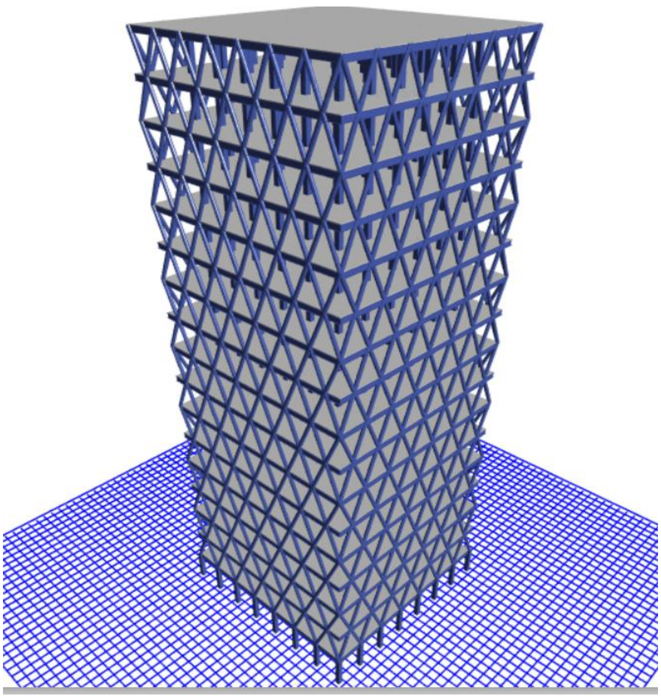

Fig -3: 3D view of Regular Diagrid Structure

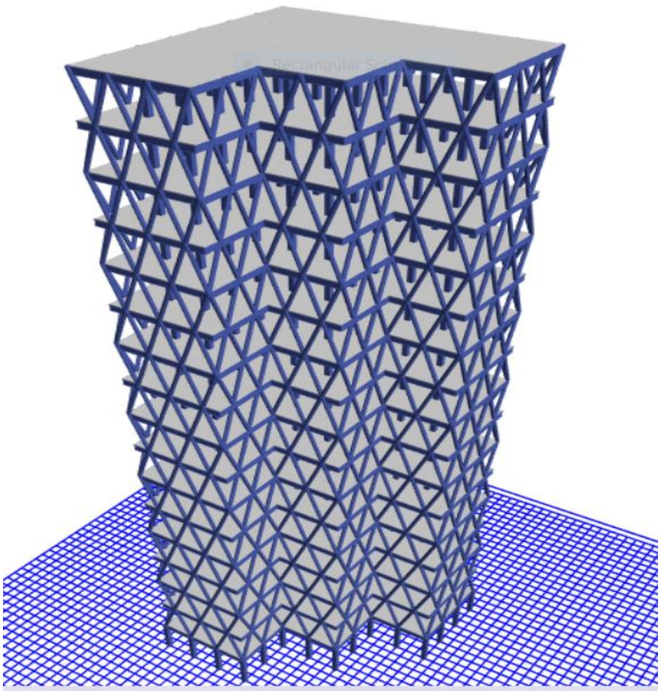

Fig -4: 3D view of Irregular Diagrid Structure

Model works on the simple technique by computing design base shear V_B for complete structure and then dispersing along the entire height. Acquired lateral force at successive floor level are transmitted to each component that can withstand lateral load.

3. RESULTS AND DISCUSSION

3.1 LATERAL DISPLACEMENT

Lateral displacement is the most significant parameter to suspect the influence of diagrid structure from lateral loads such as wind and seismic forces. Lateral displacement mainly counts on the height of the structure i.e., higher the stories more the structure turns unsafe and flexible for resisting and transferring lateral loads.

For each story from storey 1 to 16 all the values extracted for displacement along X and Y direction for both regular and irregular geometric diagrid model with respect to different soil types are evaluated and corresponding graphs are plotted based on the extracted values. Displacement of regular diagrid structure both in X and Y direction are represented in chart 1 and chart 2.

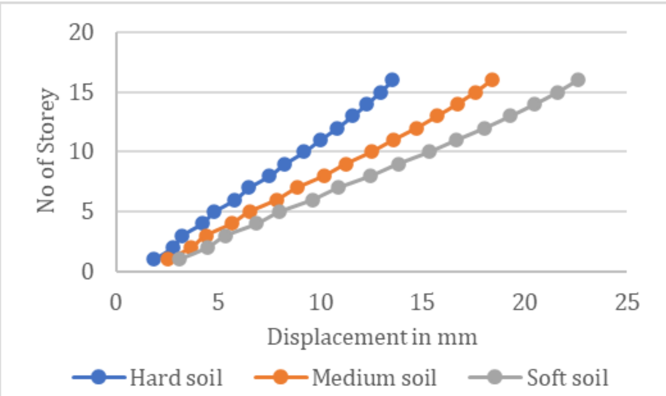

Chart -1: Storey vs displacement in EQX direction for regular diagrid structure on varying soil stratum.

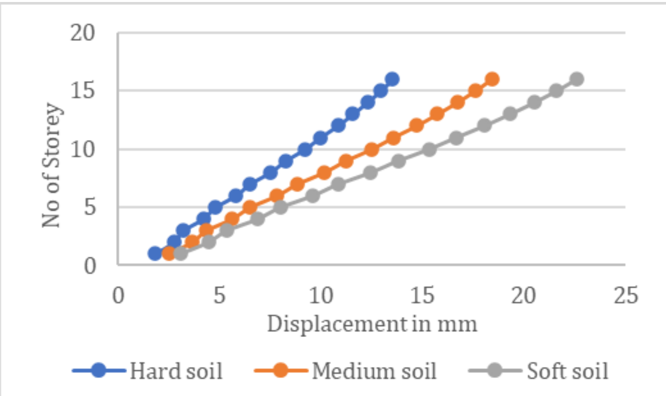

Chart -2: Storey vs displacement in EQY direction for regular diagrid structure on varying soil stratum.

Displacement of irregular diagrid structure both in X and Y direction are represented in chart 3 and chart 4.

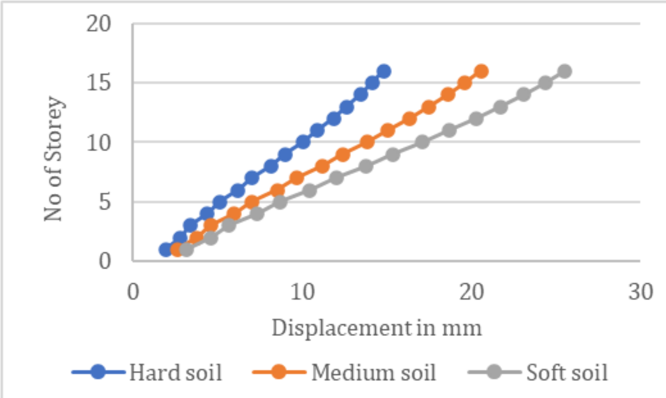

Chart -3: Storey vs displacement in EQX direction for irregular diagrid structure on varying soil stratum.

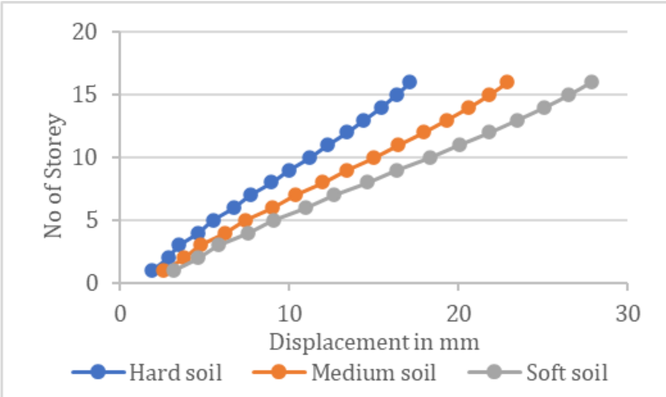

Chart -4: Storey vs displacement in EQY direction for irregular diagrid structure on varying soil stratum.

From chart1-4 it is suspected that the max displacement value for soft soil strata is clearly higher than hard and medium soil. As the stiffness of the soil reduces or if the flexibility of the soil increases then displacements will be substantially larger. As a result, soft soil strata generate high displacement in comparison to hard or medium soil condition. The max displacement occurs in irregular diagrid structure with the displacement value of 27.848mm which in higher than 22.594mm for regular diagrid structure respectively. This is due to the regularity of the diagrid structure which permits balanced and equal no of members to displace when exposed to lateral loads.

3.2 STOREY DRIFT

when there is some sort of variation between two successive stories by lateral loads it leads to storey drift. structural and non-structural components play significant role in holding drifts within permissible limits.

For each story from storey 1 to 16 all the values extracted for storey drift along X and Y direction for regular and irregular geometric diagrid model with respect to different soil types are evaluated and corresponding graphs are plotted based on the extracted values. Storey drift for regular diagrid structure both in X and Y direction are represented in chart 5 and 6

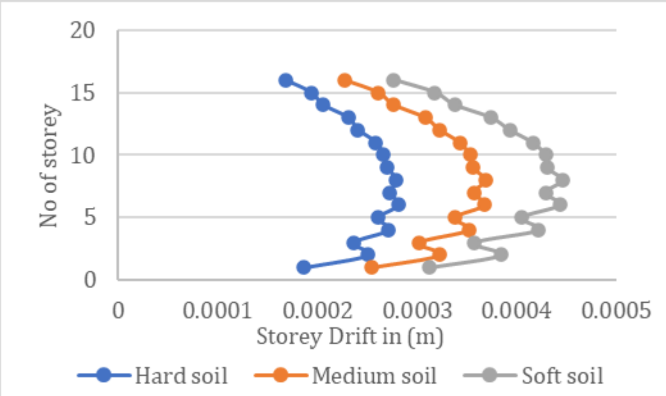

Chart -5: Storey vs Storey drift in EQX direction for regular diagrid structure on varying soil stratum.

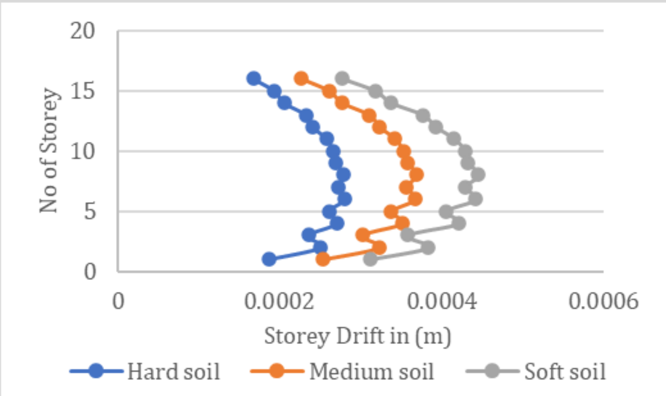

Chart -6: Storey vs Storey drift in EQY direction for regular diagrid structure on varying soil stratum.

Storey drift for irregular diagrid structure both in X and Y direction are represented in chart 7 and 8.

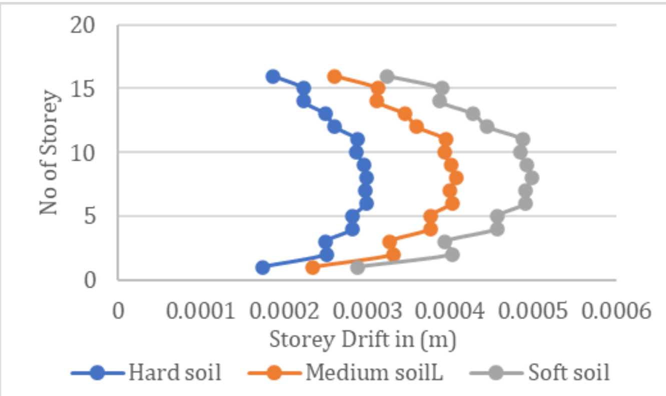

Chart -7: Storey vs Storey drift in EQX direction for irregular diagrid structure on varying soil stratum.

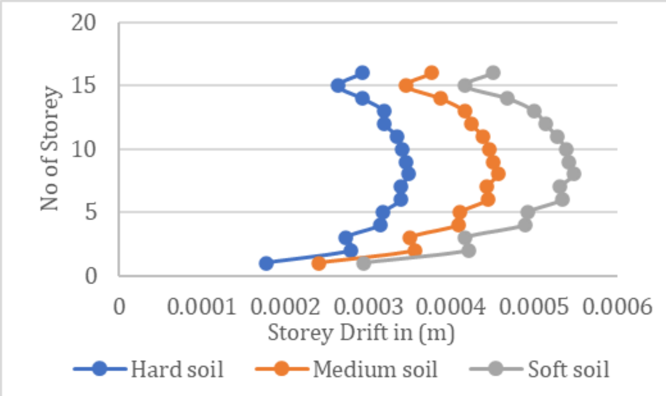

Chart -8: Storey vs Storey drift in EQY direction for irregular diagrid structure on varying soil stratum.

From the above charts 5-8 it is suspected that the max value of storey drift was encountered to be considerably higher for soft soil conditions both for regular and irregular diagrid structure. Storey drift values clearly increases based on the soil flexibility. Study states that increase in flexibility of soil leads to rise in storey drift. It is noticed that the drift values for soft soil condition corresponding to 8th storey was evaluated to be 0.000548m for irregular diagrid structure which was higher than 0.000446m corresponding to 8th storey of regular diagrid structure. Therefore, performance of the regular diagrid structure in terms of drift is more effective than irregular geometric diagrid structure.

3.3 BASE SHEAR

If the structure is not suspected to be exposed to seismic forces in its past then the resulting base shear values will be lower. Due to the earthquake ground motion, lateral forces that eventuate at the base of the structure are termed as base shear. Soil type plays prominent role in the fluctuation of base shear values.

Base shear values extracted from the base of the regular and irregular geometric diagrid model with respect to different soil types along EQX and EQY direction are displayed in the below chart 9-12.

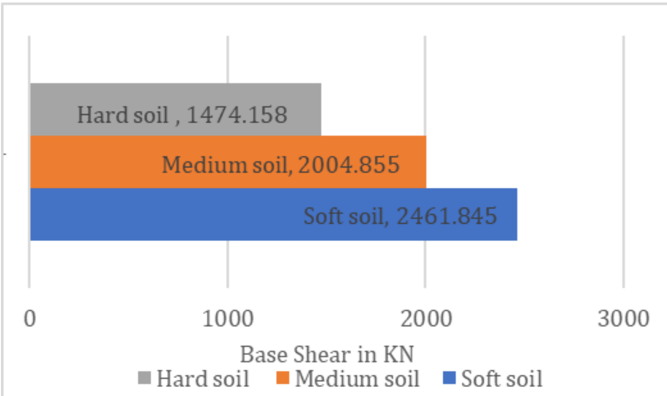

Chart -9: Base shear in EQX direction for regular diagrid structure on varying soil stratum.

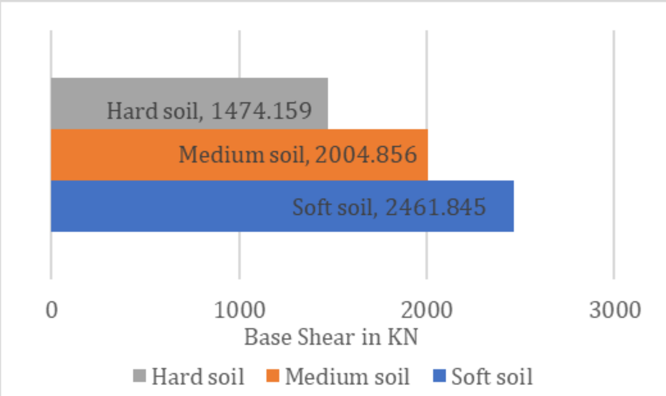

Chart -10: Base shear in EQY direction for regular diagrid structure on varying soil stratum.

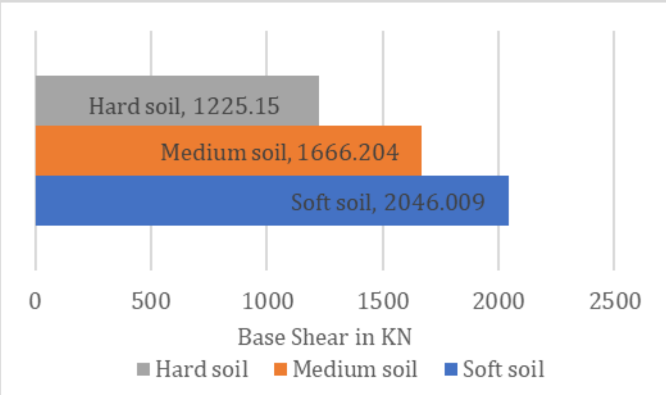

Chart -11: Base shear in EQX direction for irregular diagrid structure on varying soil stratum.

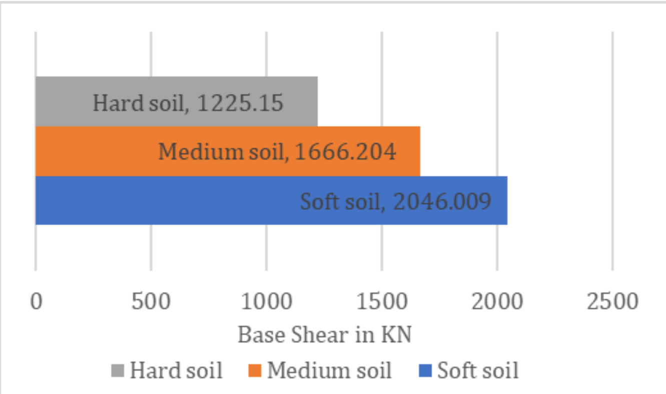

Chart -12: Base shear in EQY direction for irregular diagrid structure on varying soil stratum.

It is observed from chart 9-12 that soft soil has higher base shear both in x and y direction. This is mainly because of the stiffness of soil. If soil tends to be less stiff then there is increase in base shear. Max base shear of irregular diagrid structure is 2046.009 kN which is less than 2461.845kN for regular diagrid structure because base shear depends on the amount of strength and ductility affiliated with respect to structural configuration and whole mass of structure.

4. CONCLUSIONS

Numerous conclusions that are extracted from the study by comparing diagrids premised on parameters such as displacements, storey drift and base shear are as follows:

1. It was witnessed from the outcome of displacement values that top storey displacement for soft soil stratum was considerably higher than hard and medium soil stratum. This was due to fact that lateral displacement will be substantially larger if stiffness of soil reduces or if soil flexibility is exceeding.

2. Equal number of members displace when exposed to lateral loads because of the regularity in structural geometry, top storey displacement for regular geometric diagrid structure was detected to be appreciably lower than irregular diagrid structures.

3. It was observed that storey drift corresponding to soft soil stratum was substantially greater than hard and medium soil stratum for both regular and irregular diagrid structures since, storey drift values clearly depends on soils flexibility and increases with rise in soils flexibility.

4. Member stiffness offered by regular geometric diagrid structure is considerably high as a result performance of regular diagrid structure in terms of drift is more effective than irregular geometric diagrid structure.

5. Lateral forces that eventuate at the base of the structure due to earthquake ground motion will be high in soft soil as it tends to be less stiff and possess low shear strength therefore base shear for soft soil stratum is comparatively higher than medium and hard soil.

6. Response of irregular diagrid structure is effective when base shear is taken into account.

7. In order to facilitate the comparison most of the factors are kept identical for both models. From the above observations that are extracted from present study we can conclude that hard soil and medium soil strata are ideal choice for high rise diagrid structural systems in comparison to soft soil.

8. Regular geometric model turns out to be appreciably efficient than irregular geometric model in terms of displacement and storey drift.

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