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Seismic Analysis of R.C. Structures with Fixed and Hinged Base for Different Soil Conditions

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ABSTRACT

Earthquakes have the potential to cause the utmost damages, among the other natural hazards. Structures are subjected to different earthquake loading, behaves differently with diversification in hard, medium and soft soil. Soil properties get affected drastically as seismic waves pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts with the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure. In this paper, G+5 RC building has been analyzed and compared for different seismic parameter with different types of base i.e. fixed and hinged base in different soil conditions (hard, medium and soft) as per IS 1893:2016.

Keywords: Seismic Performance, Fixed Base, Hinged Base, StoreyDrift, Storey Displacement, RC Structure, ETabs 2018 .

1.1 Introduction -

Most of the time earthquakes are caused by the slippage along a fault in the earth's crust. When the fault ruptures in the earth's crust, the seismic waves will travel away from the source known as focus, in all direction to the ground surface. As they travel through different geological materials, the waves are reflected and refracted. Throughout the whole journey from the bedrock to the ground surface, the waves may experience amplification. Seismic wave amplification may cause large acceleration to be transferred to the structures, especially when the resulting seismic wave frequencies match with the structure resonant frequencies. This phenomenon may result in catastrophic damages and losses. Thus, with respect to the possible risk of earthquake hazard, it is essential to estimate the peak ground acceleration at the ground surface in order to produce appropriate response spectra for the purpose of structural design and structural safety evaluation. An earthquake is a ground vibration due to the rapid release of energy. The vibration produced causing the ground to be in motion where such ground motion generates complicated transient vibrations in structures. The response of a structure under earthquake loading is directly associated with the response of soil to ground shaking. Thus, the extent and degree of damage during an earthquake is mainly influenced by the response of soil to ground vibrations. Therefore, it is vital to evaluate the response of soil due to ground vibration.

Though the structures are supported on soil, most of the designers do not consider the soil structure interaction and its subsequent effect on structure during an earthquake. Different soil properties can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure. Tall buildings are supposed to be of engineered construction in sense that they might have been analyzed and designed to meet the provision of relevant codes of practice and building bye-laws. IS 1893: 2016 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft soil.

2.Soil Structure Interaction

The soil-structure interaction refers to effects of the flexibility of supporting soil-foundation system on the response of RC frame structure. When earthquake force acts on these structural elements, neither the displacement of the structure nor the ground motion, are independent of each other. The phenomenon in which the response of both soil and structure caused due to earthquake are interdependent on each other is termed as Soil-Structure Interaction (SSI) or Soil-Foundation Structure Interaction (SFSI). Soil-structure interaction may not be considered in seismic analysis of structure supported on rock or rock like material at shallow depth. The response of a structure is affected by interactions between three linked systems under to earthquake load: the foundation, the structure, and the soil surrounding and underlying the foundation. Soil-structure interaction analysis evaluates response of these systems collectively to a specified ground motion.

3. Factors Affecting Soil Structure Interaction

The major factors which are conscientious in influencing the performance of framed structure foundation- soil interaction are

- Types of soil existing surrounding and below the foundation at different depths.
- Stiffness between footing and soil, and also among super-structure and footing.
- Size, shape and types of footing.
- Stress-stain relationship and soil non linearity of foundation soil.
- Type of loading:
  a) Static
  b) Dynamic
- Water table depth from surface.

4. Objective of the study

The purpose of this hypothetical study is to evaluate the seismic properties and & characteristics for regular structures with different base support conditions for different types of soil. The main aspect of this analysis is to obtain the sustainability of the building regarding the performance of the buildings by using the aid of capacity and the demand of the structure for a designed strong motion earthquake characteristics using the dynamic method of analysis.

With requirement of high infrastructure increasing day by day, more amounts of high rise structures have been designed and analyzed. The research works were undertaken with various issues related to seismic analysis of such structures in severe seismic zones. Regarding to such studies, following conclusions have been drawn in this study to overcome the problem -

- To study the response of buildings subjected to seismic forces with Fixed and Hinged support at base.
- Multi storied buildings with fixed and hinged support subjected to seismic forces were analyzed and compared under different soil conditions like hard, medium and soft strata.
- To compare seismic performance of Fixed and Flexible base foundations in severe seismic zone as per IS 1893:2016.
- To identify the economy of structure under fixed and hinged base.

5. Methodology

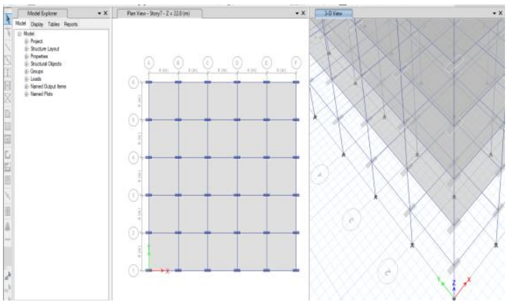
In this present section, the 3 D model of reinforced cement concrete structure building of G+5 storied building have been modelled. The linear dynamic analysis as response spectrum analysis been performed for RCC building model using IS 456:2000 and IS 1893:2016 with the help of ETABS Software. The following models are analyzed in this work.

Model 1 – Regular Frame with Hinged Base in Seismic Zone II with hard soil
Model 2 – Regular Frame with Hinged Base in Seismic Zone II with medium soil
Model 3 – Regular Frame with Hinged Base in Seismic Zone II with soft soil
Model 4 – Regular Frame with Hinged Base in Seismic Zone V with hard soil
Model 5 – Regular Frame with Hinged Base in Seismic Zone V with medium soil
Model 6 – Regular Frame with Hinged Base in Seismic Zone V with soft soil
Model 7 – Regular Frame with Fixed Base in Seismic Zone II with hard soil
Model 8 – Regular Frame with Fixed Base in Seismic Zone II with medium soil
Model 9 – Regular Frame with Fixed Base in Seismic Zone II with soft soil
Model 10 – Regular Frame with Fixed Base in Seismic Zone V with hard soil
Model 11 – Regular Frame with Fixed Base in Seismic Zone V with medium soil
Model 12 – Regular Frame with Fixed Base in Seismic Zone V with soft soil
The general specification used in building for analysis shown in table below.

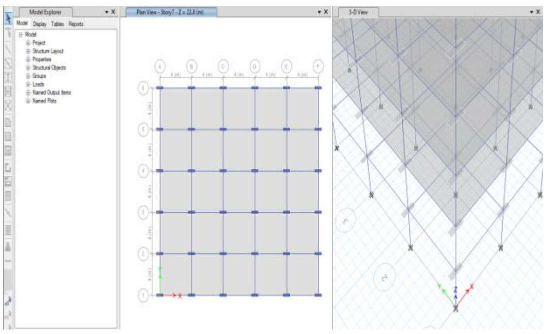
General Properties	
No. of storeys	G+5
Typical Storey Height	3.3 m.
Size of Column	300 mm x 900 mm
Size of Beam	300 mm x 600 mm
Thickness of Slab	150 mm.

Thickness of Wall	230 mm.
Material Properties	
Grade of Concrete	M 30
Grade of Steel Rebar	Fe 500
Type of Loading	
Wall Load	13.5 KN/m
Live Load	3 KN/m^2
Floor Finishing	1.2 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	II & V
Zone Factor	0.1 & 0.36
Importance Factor	1
Type of Soil	I (Hard), II (Medium) & III (Soft)
Building Type (R)	5 (SMRF)

PLAN OF THE BUILDING



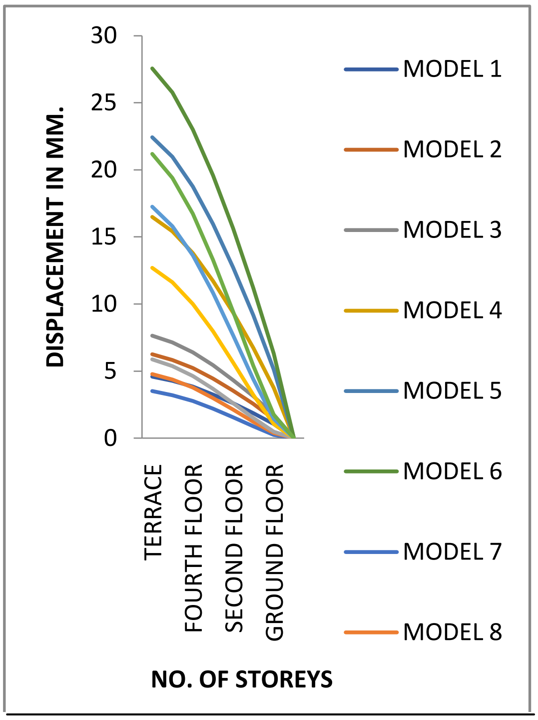
Model 1 to Model 6 with different properties of soil and zone factor

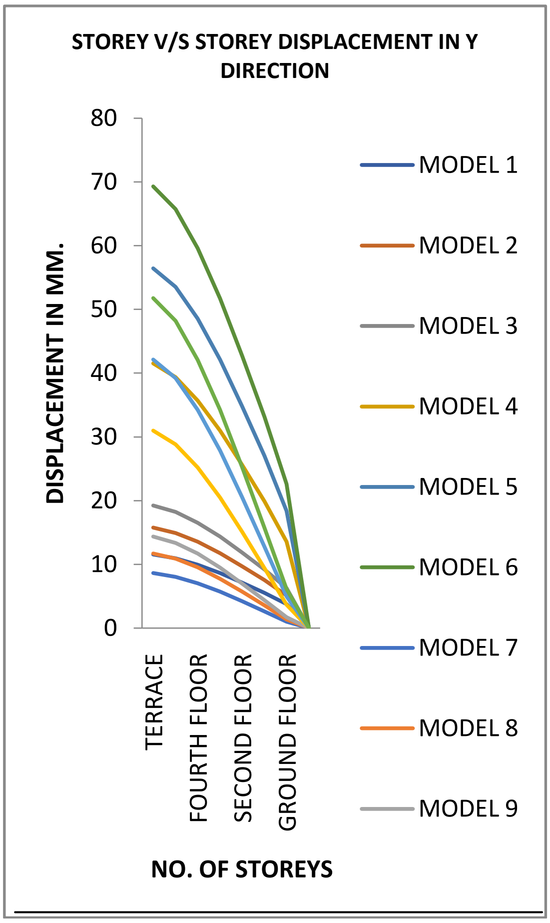


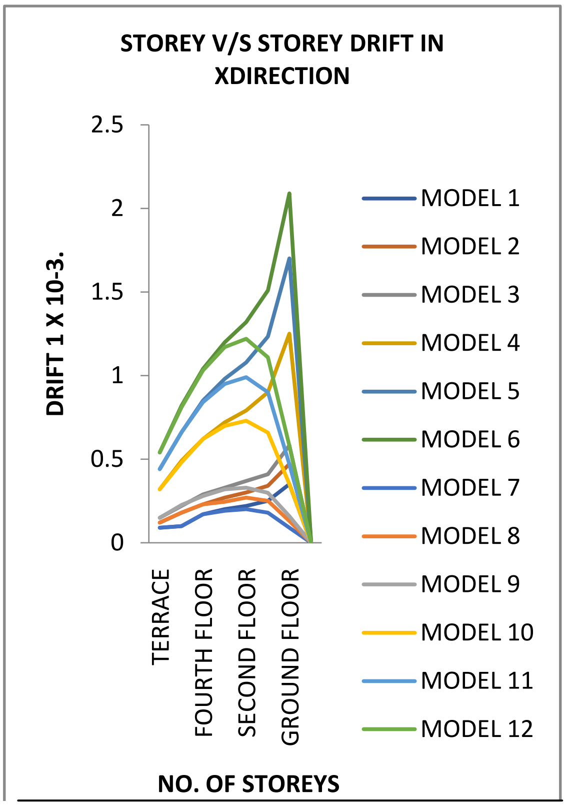
Model -7 to Model 12 with different properties of soil and zone factor

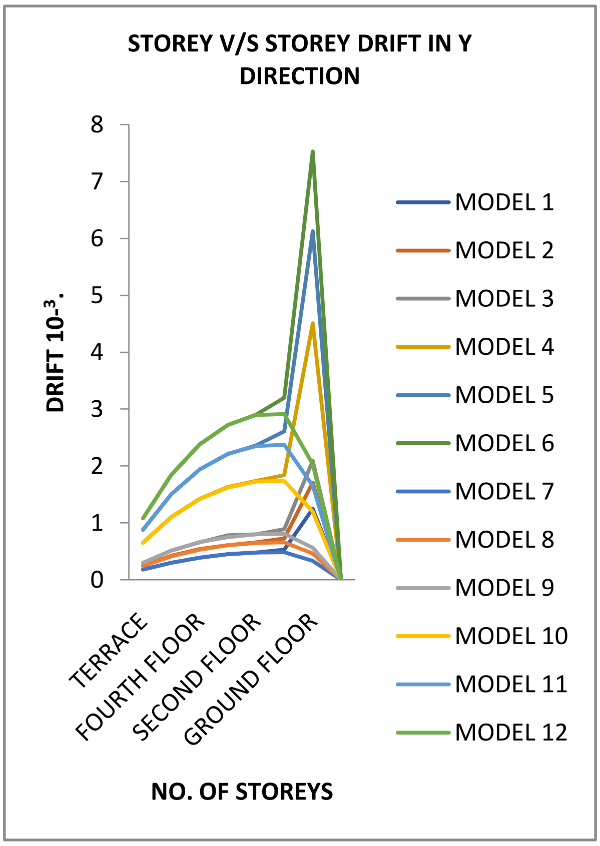
6. Results

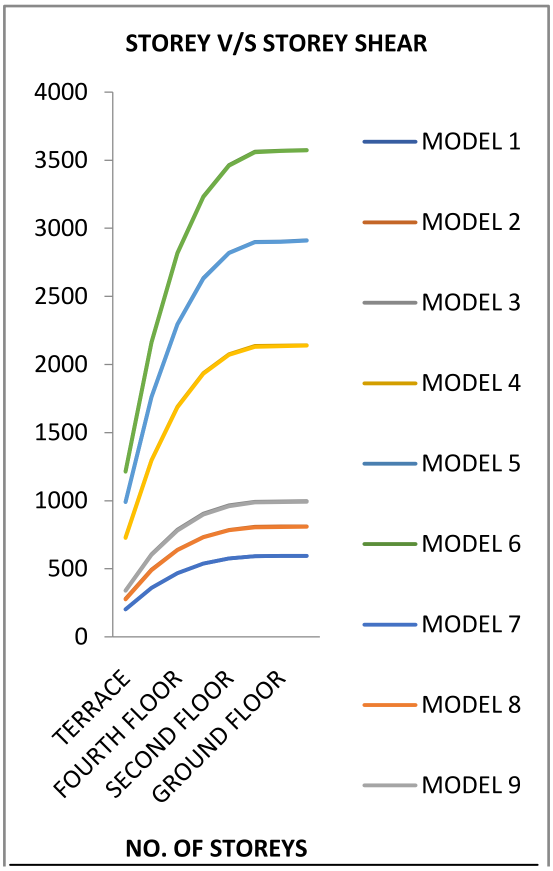
The detailed analysis has been done for the various conditions for regular RC structure and outputs have been carried out in the tabular form and have been plotted. The results which have been plotted give an idea about the comparison between different types of buildings. The output parts contain Time Period, Mass Participating ratios, drift, displacement and base shear and have been discussed below.

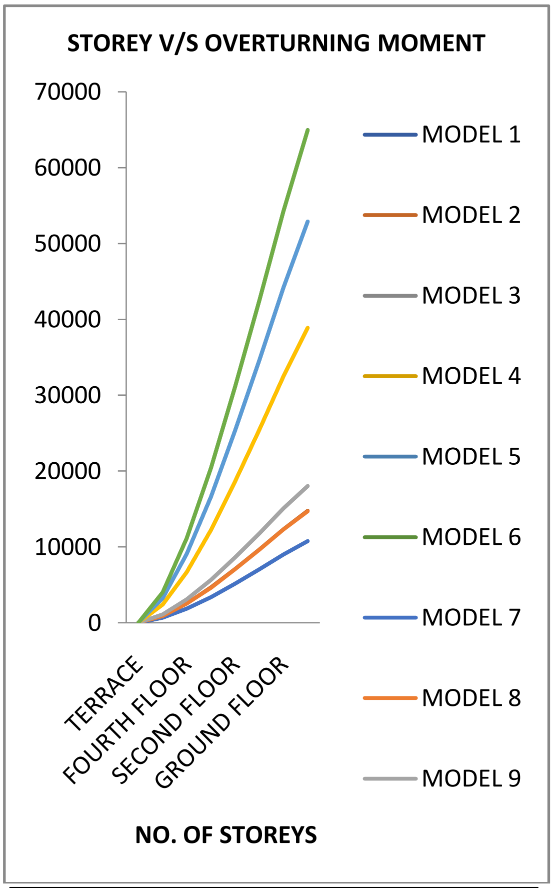

30
25
20
15
10
5
0
DISPLACEMENT IN MM.
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8

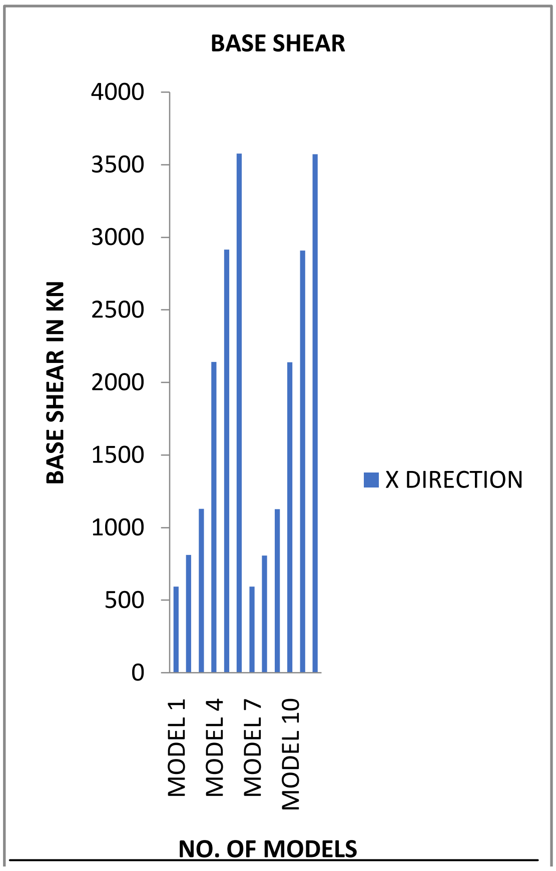

STOREY V/S STOREY DISPLACEMENT IN Y DIRECTION
80
70
60
50
40
30
20
10
0
DISPLACEMENT IN MM.
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9

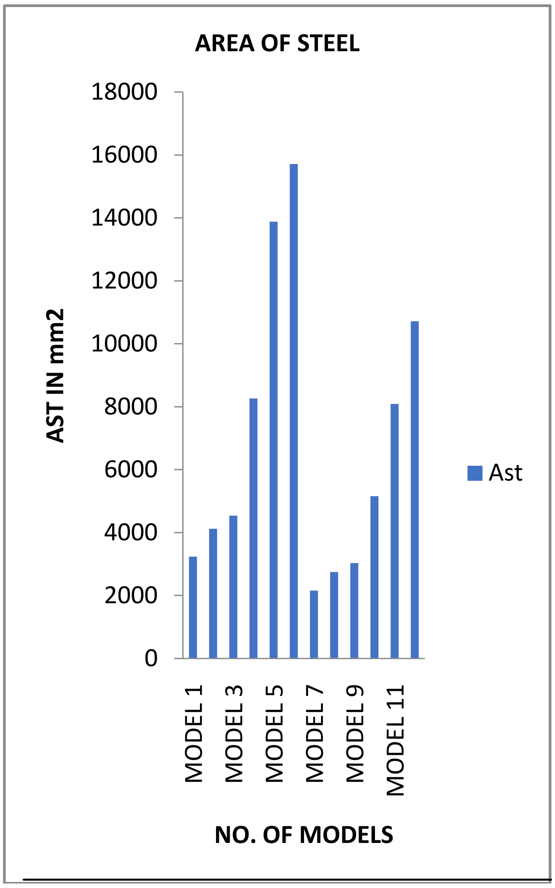

STOREY V/S STOREY DRIFT IN XDIRECTION
DRIFT 1 X 10-3.
2.5
2
1.5
1
0.5
0
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9
MODEL 10
MODEL 11
MODEL 12


STOREY V/S STOREY DRIFT IN Y DIRECTION
DRIFT 10-3.
8
7
6
5
4
3
2
1
0
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9
MODEL 10
MODEL 11
MODEL 12


STOREY V/S STOREY SHEAR
4000
3500
3000
2500
2000
1500
1000
500
0
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9


STOREY V/S OVERTURNING MOMENT
70000
60000
50000
40000
30000
20000
10000
0
TERRACE
FOURTH FLOOR
SECOND FLOOR
GROUND FLOOR
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6
MODEL 7
MODEL 8
MODEL 9


BASE SHEAR
BASE SHEAR IN KN
4000
3500
3000
2500
2000
1500
1000
500
0
MODEL 1
MODEL 4
MODEL 7
MODEL 10
X DIRECTION
NO. OF MODELS


AREA OF STEEL
AST IN mm2
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
MODEL 1
MODEL 3
MODEL 5
MODEL 7
MODEL 9
MODEL 11
Ast
NO. OF MODELS

6. Conclusions

In the present project report seismic design analysis of a symmetrical plan building is carried out. Multi storied building frames with fixed and hinged base subjected to seismic forces were analyzed and designed for different soil conditions.12 buildings models are analyzed in the software ETABS with the configuration as shown above.

1. Lateral deflection values increases when the type of soil changes from hard to medium and medium to soft for fixed and hinged base buildings.
2. Lateral deflection values of fixed base building were found to be lower as compared to hinged base building.
3. Lateral deflection values increases when the type of zone changes from zone2 to zone5
4. Base shear values increases when the type of soil changes from hard to medium and medium to soft for fixed and hinged base buildings.
5. Base shear values of fixed base building was found to be same as compared to hinged base building.
6. Base shear values increases when the type of zone changes from zone2 to zone5
7. Storey drift values increases when the type of soil changes from hard to medium and medium to soft for fixed and hinged base buildings.
8. Storey drift values of fixed base building were found to be lower as compared to hinged base building.
9. Hence suitable soil condition has to be adopted along with the type of foundation while designing building for Earthquake resistant.
10. Storey drift values increases when the type of zone changes from zone2 to zone5
11. Area of steel in columns for fixed base building is less as compared to hinged base building.

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