Seismic Response of High-Rise Building with The Effect of Soft Storey On Various Levels

V. Preetha, S. Gokul Prasath, S. Suresh Kannan, V. Senthil Kumar

Abstract: ***The high rise building mainly composed of open ground storey meant for car parking, reception lobbies and remaining floors with brick infill walls for occupancy. Due to congested population and high volume of vehicles, parking is a major constraint for the users. To manage the parking space in buildings, ground storey is usually allocated for parking facilities without in-filled masonry walls. The commercial buildings offer parking facilities at intermediate storey levels also due to space constraint. In this study, seismic analysis on building frames with soft storey effect on various levels considering G + 5 building model. The three dimensional building is modelled and analysed using STAAD PRO v8i software. The parameters involved for this study is floor height, and column stiffness. The results were attained based on variations of base shear, storey drift, storey displacement, mode shape, and frequency.***

Index Terms: ***High rise building, Soft storey, Storey drift, lateral force, base shear.***

I. INTRODUCTION

Soft storey buildings are characterized by having a storey which has a large open space for parking garages, or large retail spaces or floors as per IS 1893(part 1):2002, clause 4.20 [1]. Soft storey can be at any level of a high rise building to fulfil required functional necessity and serve various purposes [2].Soft storey buildings, having first storeys much less rigid than the storeys above are susceptible to earthquake damage because of large, unreinforced openings on their ground floors [3].This type of storey creates a major weakness during an earthquake. The large lateral displacements induced at the first floor level of such buildings yields large curvature in the ground storey columns. The bending moments and shear forces in that column are also magnified to a bare frame building (without a soft storey). The energy developed during earthquake loading is dissipated by the vertical resisting elements of the ground storey resulting in the occurrence of plastic deformations which transforms the ground storey into a mechanism, in which the collapse is unavoidable. The construction of open ground storey is very dangerous and the effect of placing is as shown in Fig: 1, if not designed suitably and with proper care.

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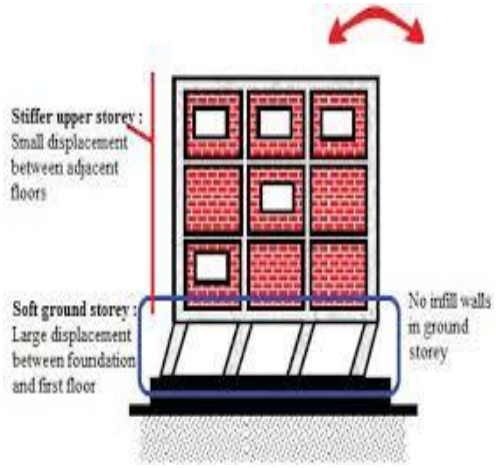

Figure: 1 Effect of soft storey building

II. BEHAVIOUR OF SOFT STOREY BUILDING

Open soft storey buildings are less resistance to earthquake loads and their performance is poor during earthquakes. The soft storey failure is due to strength demand on the column in that storey, where- in upper storey of the column, forces are reduced effectively due to presence of brick infill walls which share the forces so that the upper storey stiffer than the first soft storey[4]. Absence of infill wall in ground storey makes them the storey less stiff than the above storeys. For open soft storey building at ground floor, above storey moves all together as a single mass and large horizontal displacement of the building occurs at soft storey level as shown in Fig: 2. They may produce high stress in ground floor columns and if columns failed to take these stresses, get severely damaged. The Storey drift is the displacement of one level relative to the other level above or below. The lateral displacement of the whole structure is governed by the storey above the soft storey of the building.

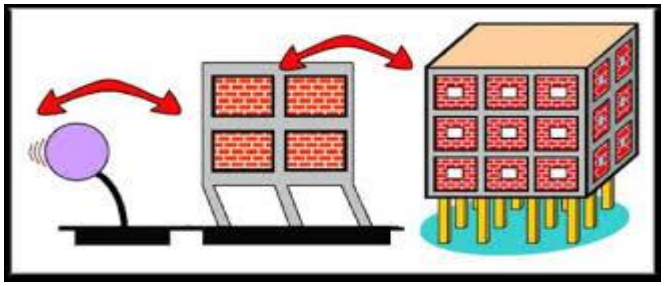

Figure: 2 Behaviour of building with open ground storey

III. MODELLING DESCRIPTION

The building model created for the analysis is of Ground + 5 storey ordinary moment resistant frame having the plan dimensions of 16 m x 18 m with the length of bay is of 4 m x 4.5 m. The soft storey height adopted as 4m at every level in each models and remaining storey height maintained as 3.5m. The columns of size 500mm x 500mm and beams of uniform size 300mm x 450mm with slab thickness of 150mm throughout the building. The structure is modelled as 3D frame using STAAD Pro., software and the masonry infill is modelled as quadrilateral shell element of uniform thickness of outer wall as 230mm and inner wall as 115mm. The study involves various seismic zones as zone II, III, IV and V. The geometrical parameters of the multi-storey frame are shown in Table: 1. The cases adopted for analysis are as follows

Model 1: Building with soft storey of 4m height at ground floor

Model 2: Building with soft storey of 4m height at first floor

Model 3: Building with soft storey of 4m height at second floor

Model 4: Building with soft storey of 4m height at third floor

Model 5: Building with soft storey of 4m height at fourth floor

Model 6: Building with soft storey of 4m height at fifth floor

Table: Geometric parameters of the building

Description	Values
Depth of the foundation	1.5m
Height of each storey	3.5m
Height of the soft storey	4m
No.of storey	G+5
Length of Bay on X - direction	4m
Length of bay on Z-direction	4.5m
Live Load on floors	4.75kN/m^2
Live Load on roofs	1kN/m^2
Floor Finish	1kN/m^2
Importance Factor ,I	1.0
Damping	5%
Soil Type	Medium soil

IV. PLAN OF THE STRUCTURE

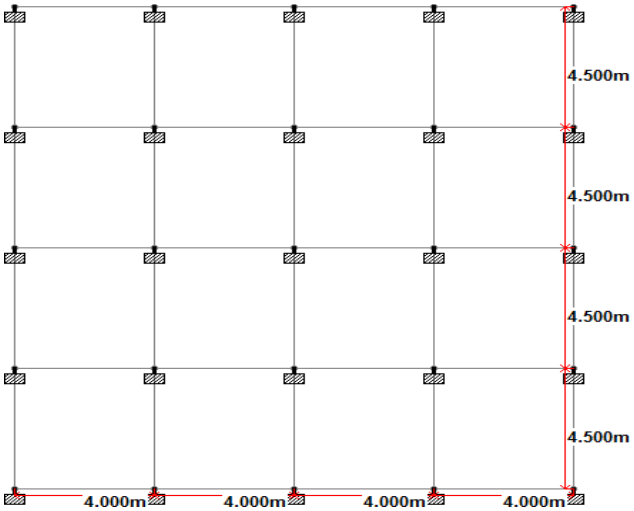

Figure: 3 Plan of the Building

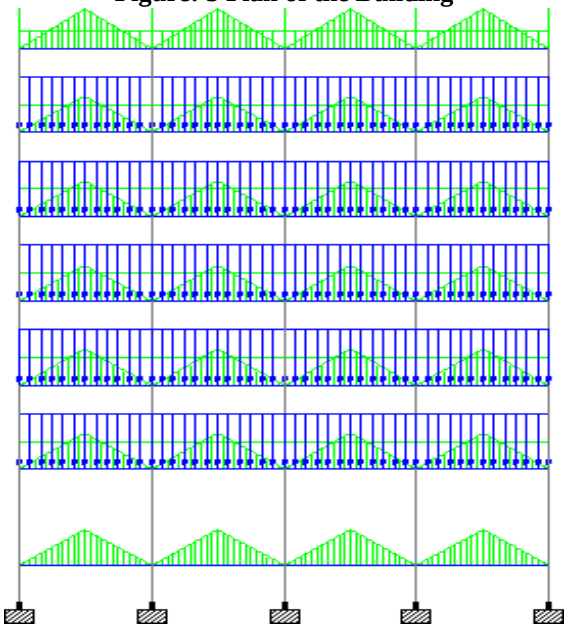

Figure: 4 Soft storey on ground floor

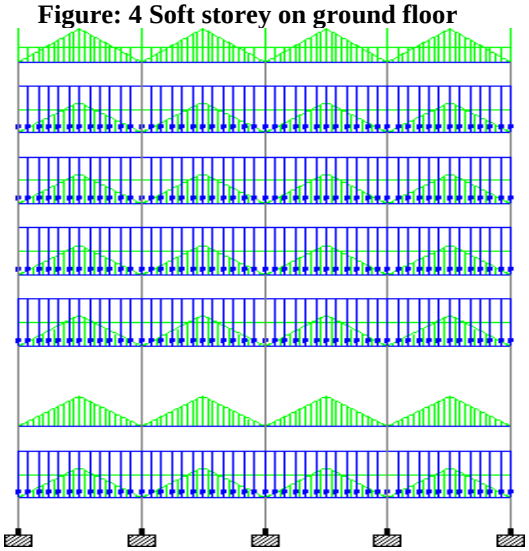

Figure: 5 Soft storey on First floor level

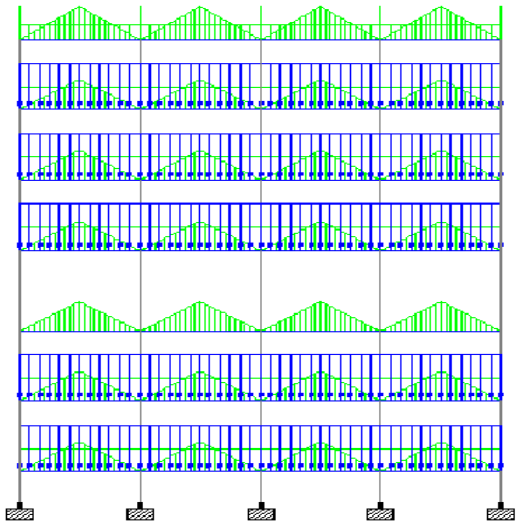

Figure: 6 Soft storey on second floor level

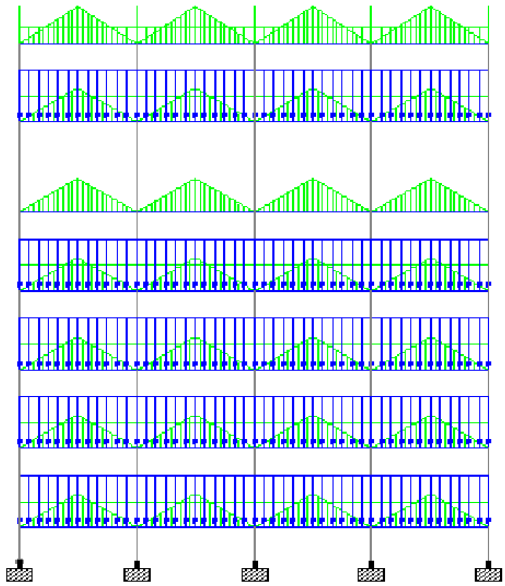

Figure: 7 Soft storey on third floor level

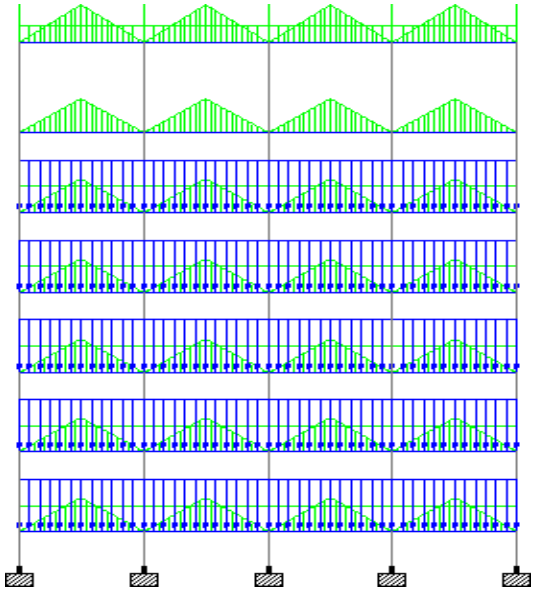

Figure: 8 Soft storey on fourth floor level

V. RESULTS AND DISCUSSION

The behavior of soft storey building having soft storey at different levels under various seismic zones has been analysed. The variations of base shear for six different models are compared based on their effect of soft storey at different levels as shown in Table: 2. The variations of base shear increases with increase in seismic zones as shown in fig: 9.

Table 2 Base Shear variation for different zones

Base shear (Vb)	ZONE II	ZONE III	ZONE IV	ZONE V
Model 1	778.12	1243.34	1863.62	2796.82
Model 2	753.84	1204.54	1805.47	2709.56
Model 3	753.84	1204.54	1805.47	2709.56
Model 4	753.84	1204.54	1805.47	2709.56
Model 5	753.84	1204.54	1805.47	2709.56
Model 6	753.84	1204.54	1805.47	2709.56

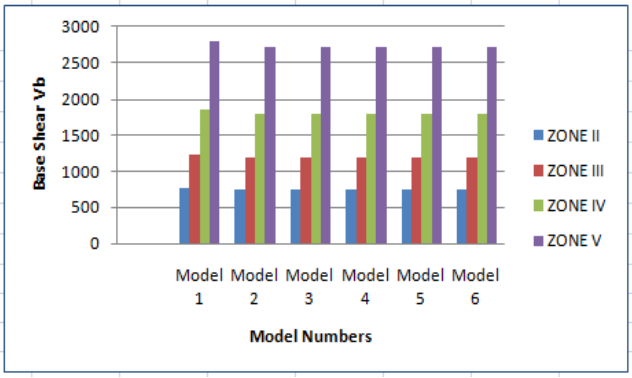

Figure 9 : Variation of base shear for different zones

The variations of storey drift in both X and Z direction for various models are predicted for various zones. The drift increases when there is a soft storey effect in between the floor levels. The displacement of particular floor moves suddenly due to large accumulation of stresses. The graph clearly shows the variation of storey drift for model 1 to 6 in Figure 10 to 17 irrespective of seismic zones.

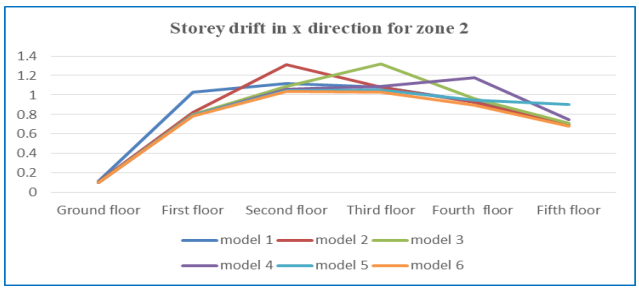

Figure 10 Storey drift in x direction for zone 2

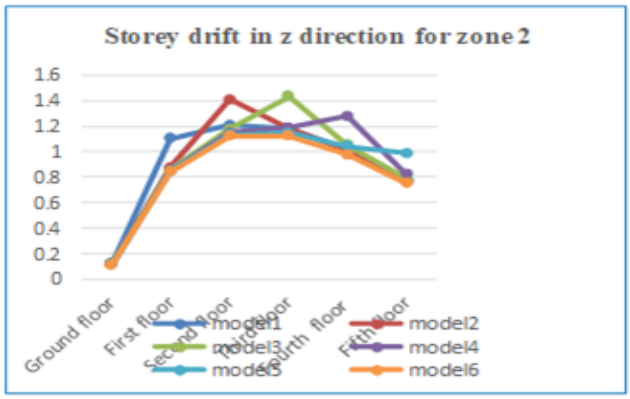

Figure 11 Storey drift in Z direction for zone 2

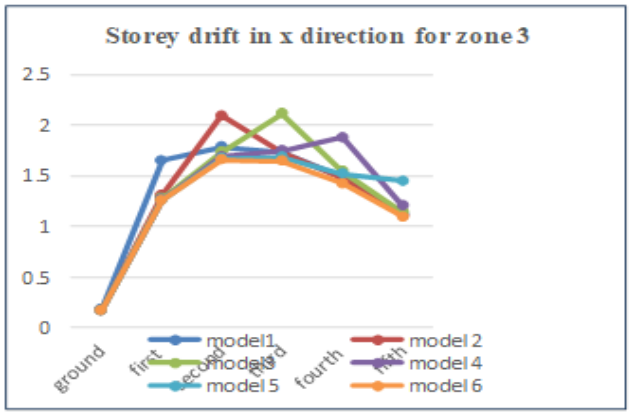

Figure 12 Storey drift in X direction for zone 3

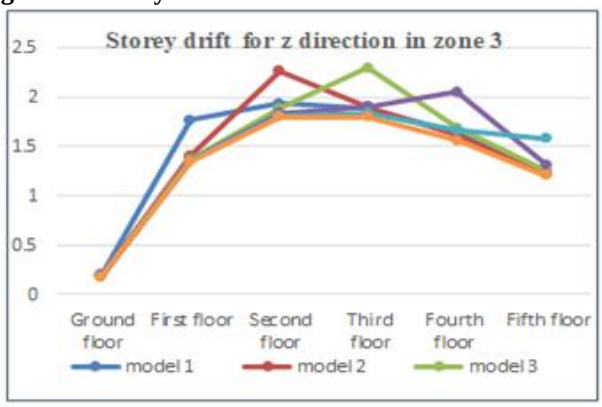

Figure 13 Storey drift in Z direction for zone 3

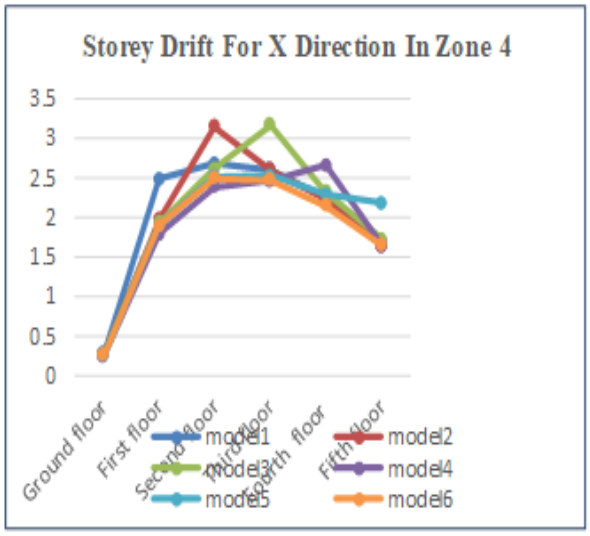

Figure 14 Storey drift in X direction for zone 4

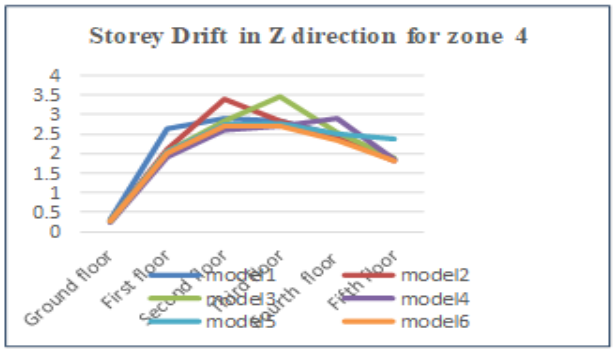

Figure 15 Storey drift in Z direction for zone 4

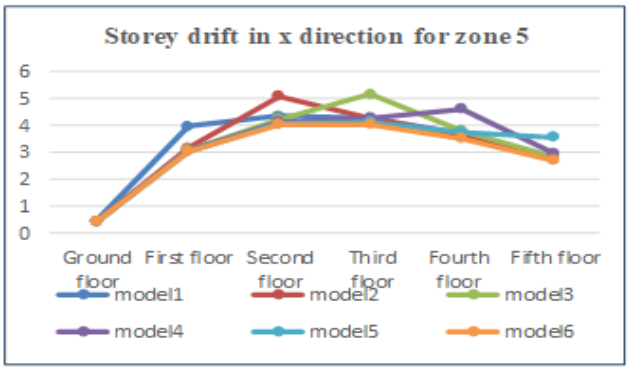

Figure 16 Storey drift in X direction for zone 5

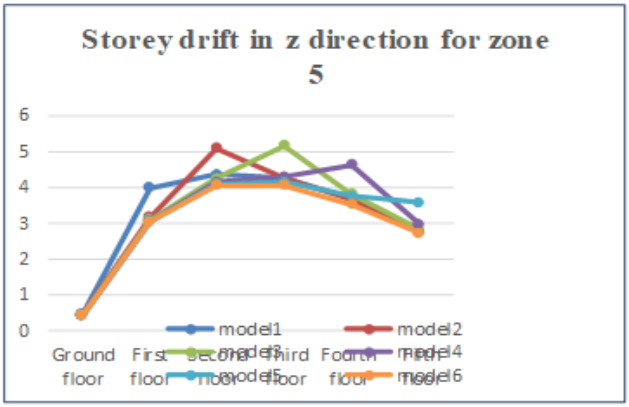

Figure 17 Storey drift in Z direction for zone 5

The storey displacement increases with increase in seismic zones that are shown in fig: 18. The displacement is high at the soft storey adopted whereas in other floors it is slightly reduced.

Table 3 Storey displacement variation for different zones

Storey Displacement	ZONE II	ZONE III	ZONE IV	ZONE V
Model 1	5.8	9.4156	14.12	21.185
Model 2	5.83	9.3404	14.01	21.015
Model 3	5.90	9.4544	14.18	21.272
Model 4	5.92	9.4569	13.33	21.278
Model 5	5.71	9.2791	13.91	20.871
Model 6	5.52	8.843	13.26	19.896

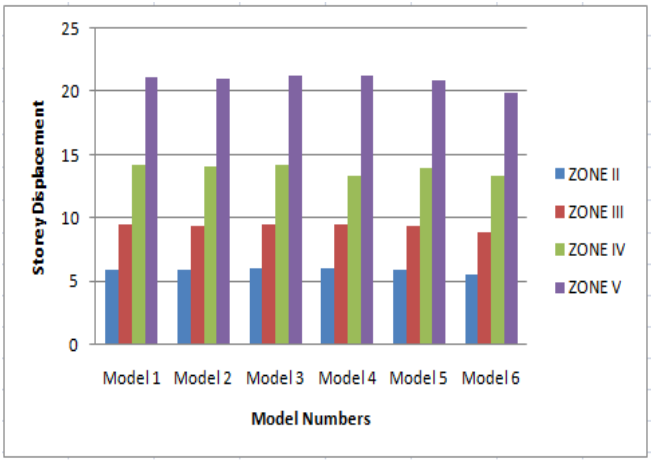

Figure 18 Variation in Storey displacement

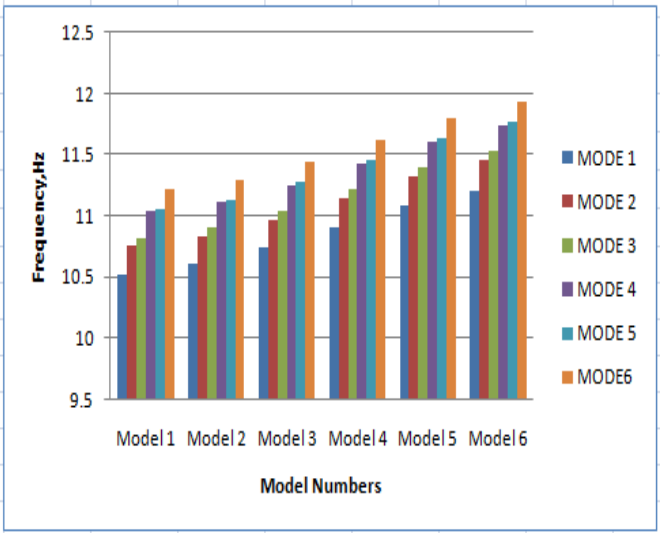

Fig 6 Variation in Frequency for different modes

VI. CONCLUSION

The seismic behavior of G+5 building under various seismic condition involving soft storey effect at different floor levels are studied and results were determined. The lateral strength of high rise building mainly depends upon the stiffness and strength. It is found that the earthquake response is maximum in the model 1(i.e with soft storey at ground floor) and minimum in the model 6 (i.e with soft storey at the top floor). The base shear values are increased as the zone increases considerably. Displacement and relative storey drifts are mainly affected by the structural irregularities. The drift is maximum for the floors where there is soft storey when compared to other floors without soft storey and it also increases as the zone level increases. The storey drift of each soft storey also depends up on the seismic and geometric parameters. The value of storey displacement is ranging high for increasing zone levels. The frequency increases as the number of modes increased. A failure of soft story building can be reduced by placing shear wall to ensure stability and to attract more stresses as a matter of earthquake engineering design. The soft-storey floor will have very determinant effect on structural behavior of building and the design should be made as per capacity based design in unavoidable soft storey conditions.

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