iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: VIII Month of publication: August 2019

DOI: http://doi.org/10.22214/ijraset.2019.8055

Structural Analysis of Diagrid and Regular Building Structure by Using Staad-Pro

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Abstract: The latest trend in high rise building is diagrid structures because of structural and architectural effectiveness. In the study previous literatures are studied for Flat-slab Building and detailed analysis is carried out to check the behaviour of flat-slab buildings with and without diagrid. It is very important that the selected structural system is such that the structural elements are utilized effectively while satisfying design requirements. Recently diagrid structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Structural design of high-rise buildings is governed by lateral loads due to wind or earthquake. Lateral load resistance of the structure is provided by interior structural system or exterior structural system. Due to inclined columns lateral loads are resisted by axial action of the diagonal in diagrid structure compared to bending of vertical columns in conventional building. This paper also reviews the studies on the comparison of diagrids with regular configuration and diagrids with varying angles. The analysis and comparison of diagrid and conventional structural system on the basis of consumption of steel, structural weight and displacement are also highlighted.
Keywords: Diagrid building, conventional building, Tall Buildings, Storey Displacement, Diagrid Structures, Storey Displacement.

I. INTRODUCTION

Tall building development involves various complex factors such as economics, aesthetics look, technology, municipal regulations, and politics. Among these, economics has been the primary governing factor. For a very tall building, its structural design is generally governed by its lateral stiffness. Comparing with conventional orthogonal structures for tall buildings such as framed tubes, diagrid structures carry lateral wind loads much more efficiently by their diagonal member's axial action. A Diagrid structure provides great structural efficiency without vertical columns have also opened new aesthetic potential for tall building architecture. Diagrid has a good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduces the number of structural elements required on the façade of the buildings, therefore less obstruction to the outside view. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, and therefore, allowing significant flexibility with the floor plan. "Diagrid" system around perimeter saves approximately 20 percent of the structural steel weight when compared to a conventional moment- frame structure. The diagonal members in diagrid structural systems carry gravity loads as well as lateral forces due to their triangulated configuration. Diagrid can save up to 20% to 30% the amount of structural steel in a high- rise building. The term "diagrid" is a combination of the words "diagonal" and "grid" and refers to a structural system that is single-thickness in nature and gains its structural integrity through the use of triangulation. Diagrid systems can be planar, crystalline or take on multiple curvatures, they often use crystalline forms or curvature to increase their stiffness. Perimeter diagrids normally carry the lateral and gravity loads of the building and are used to support th floor edges. This paper presents a comparative study of both diagrid and regular structure building system. The main objective of this analysis is to study the performance of grid system in an irregular building and to find out the response of the structure towards lateral load resistance.

II. METHODOLOGY

In this study comparison of diagrid and regular building structure system is compared in terms of displacement, with increasing height of building.

Following steps are adopted in this study.

1) *Step 1:* Selection of building geometry and modelling of diagrid, hexagrid and conventional structural system using Staad-Pro software for the same plan.
2) *Step 2:* Selection of site condition and seismic zone.
3) *Step 3:* Application of loads and load combination to the structural model according to the standard codes.
4) *Step 4:* Analysis of each building frame models.
5) *Step 5:* comparative study of results in terms of storey displacement, storey drift, storey shear and time period.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue VIII, Aug 2019- Available at www.ijraset.com

III. STRUCTURAL MODELLING AND ANALYSIS

A 12 storied steel framed structure with different plan dimensions up to certain storey levels is chosen. Height of each storey is 45.5 m. plan dimensions are 18 m x 18 m for 12 stories building structure with diagrid and regular building. Fig.1 shows the elevation selected for building.

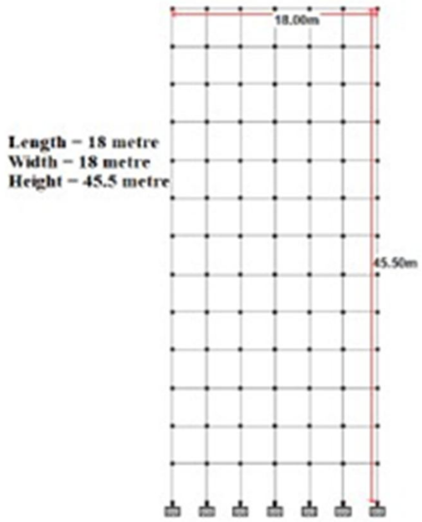

Figure 1: Regular Building Structure

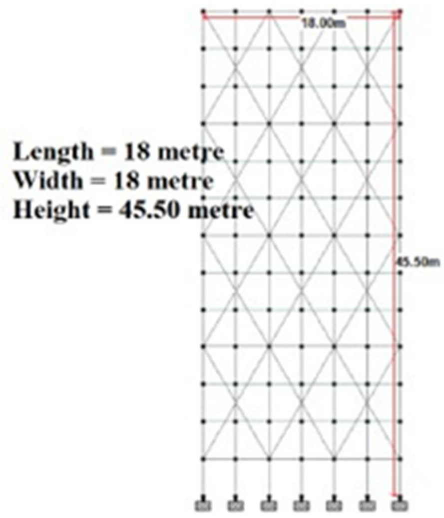

Figure 2: Diagrid Building Structure

IV. STRUCTURAL MODELS

A Model of G+12 storeyed is developed, analysis and design using STAAD-Pro software. A regular floor plan of 18m x 18m is considered in both buildings. Storey height is 45.50 m. The angle of inclined column(45°) is kept constant throughout the height. The design dead load and beam load are 4.5 kN/m2 and 4 kN/m2 respectively. Exterior wall load is taken negligible in both the buildings. Both the building frames are analysed for dead load, beam load and floor load.

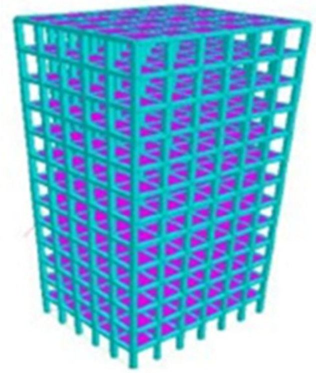

Figure 3: 3D model of conventional building

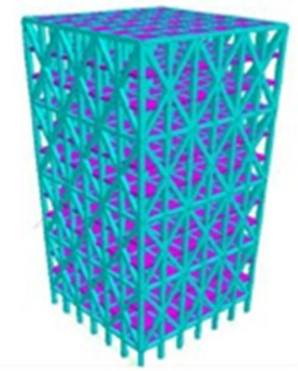

Figure 4: 3D model of diagrid building

1) *Self-weight:* The self-weight of the building can be designed by STAAD-Pro with the self-weight command in the load case column.
2) *Supports:* The base supports of the structure are assigned as fixed. These values are provided as an input to the STAAD-Pro software for drawing, analysis and designing purposes.
3) *Dead Load from Slab:* Dead load from slab can also be produced by STAAD-Pro by denoted the floor thickness and the load on the floor per sq. m. computation of the load per sq. metre was completed considering the weight of beam, weight of column, weight of RCC slab, weight of terracing, external walls, internal walls and parapet over roof.

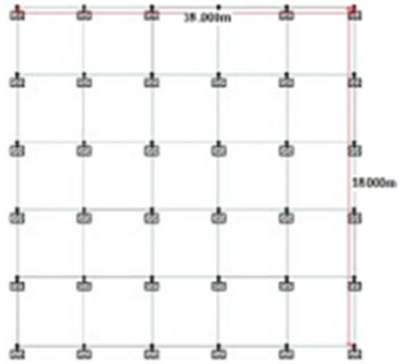

Figure 5: RCC building frame with fixed ground support

4) *Loading:* The loadings were optimized partially manually and remaining was analysed using STAAD-Pro load generator. The loading cases were considered as: -

a) Dead load
b) Beam load
c) Floor Load

V. RESULTS & DISCUSSIONS

For the parametric comparison, a symmetrical building is selected. Seven steel buildings for different heights are modelled, analysed and designed in ETABS for two structural systems; diagrid and conventional frame. Analysis and design are carried out for dead load, beam load and Floor load. For conventional and diagrid building, both static and response spectrum analysis are done. To consider extreme conditions of lateral loads, the buildings are considered to belocated in Zone V. The parameters selected for the comparison are fundamental time period, maximum top storey lateral displacement with combinational load and maximum storey displacement.

Table 1: Total Deformations of buildings due to Dead load, Beam load and Floor Load

Building Types	Total Def. Dead Load	Total Def. Dead Load + Beam Load	Total Def. Dead Load + Beam Load + Floor Load
Diagrid Building	4.398	5.994	7.068
Regular Building	8.775	10.301	11.328

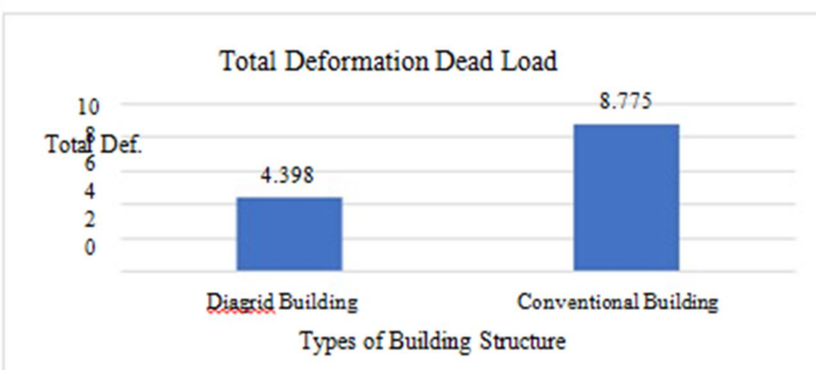

Figure 6: Total deformation b/w conventional and diagrid buildings due to dead load

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
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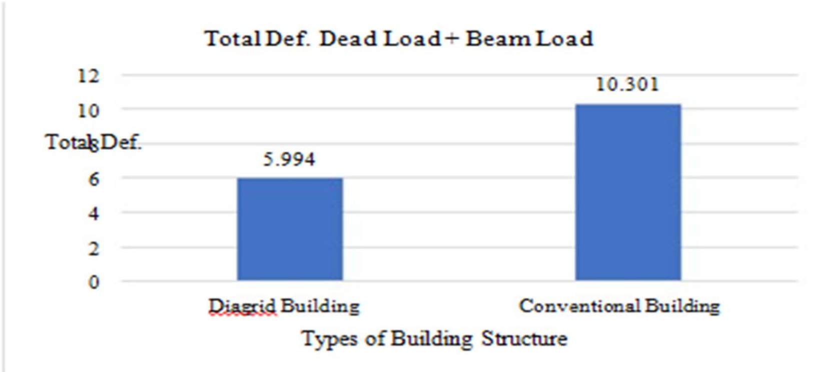

Figure 7: Total deformation b/w conventional and diagrid buildings due to dead load and Beam Load

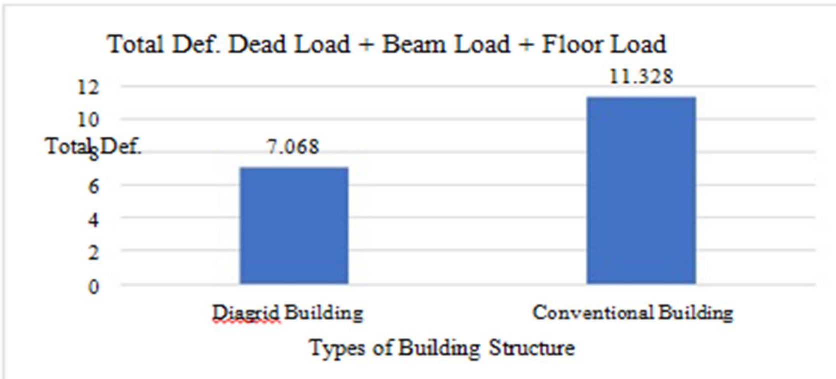

Figure 8: Total deformation of buildings due to dead load and Beam Load with Floor Load

Table 2: comparison deflections of Diagrid building due to increase of storey level

Diagrid Building Design results			
Deflections in mm			
Storey Numbers	Dead Load Diagrid	Dead Load +Beam Load Diagrid	Dead Load +Beam Load + Floor Load Diagrid
Ground Floor	0.902	1.096	1.19
1	1.264	1.535	1.665
2	1.614	1.963	2.13
3	1.946	2.371	2.574
4	2.25	2.744	2.98
5	2.532	3.093	3.361
6	2.79	3.414	3.712
7	2.988	3.659	3.978
8	3.162	3.876	4.214
9	3.308	4.061	4.418
10	3.395	4.168	4.533
11	3.455	4.244	4.615
12	3.487	4.287	4.663

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Table 3: comparison deflections of conventional building due to increase of storey level

Conventional Building Design results			
Deflections			
Storey Numbers	Dead Load Regular	Dead Load +Beam Load Regular	Dead Load +Beam Load + Floor Load Regular
Ground Floor	1.017	1.193	1.3
1	1.968	2.31	2.518
2	2.855	3.35	3.653
3	3.67	4.307	4.697
4	4.41	5.174	5.645
5	5.071	5.949	6.491
6	5.65	6.629	7.232
7	6.146	7.211	7.868
8	6.558	7.695	8.395
9	6.885	8.079	8.813
10	7.126	8.363	9.121
11	7.281	8.546	9.318
12	7.348	8.626	9.403

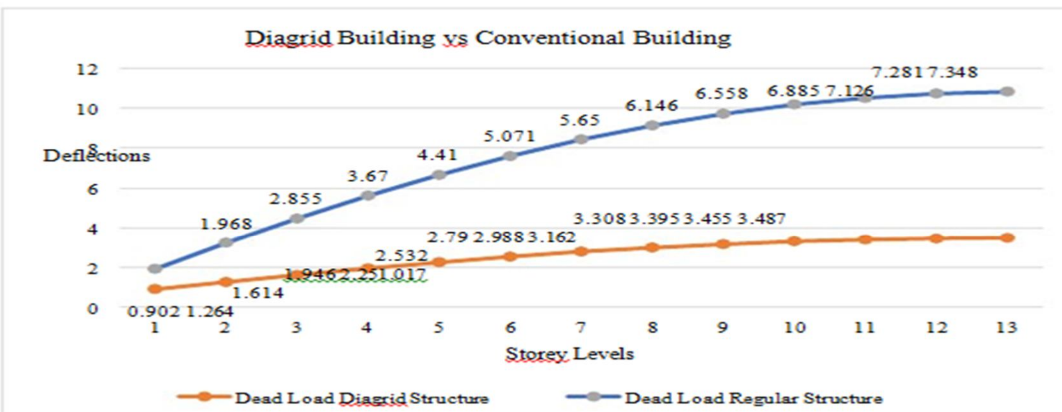

Figure 9: comparison of structure deflections due to Dead load

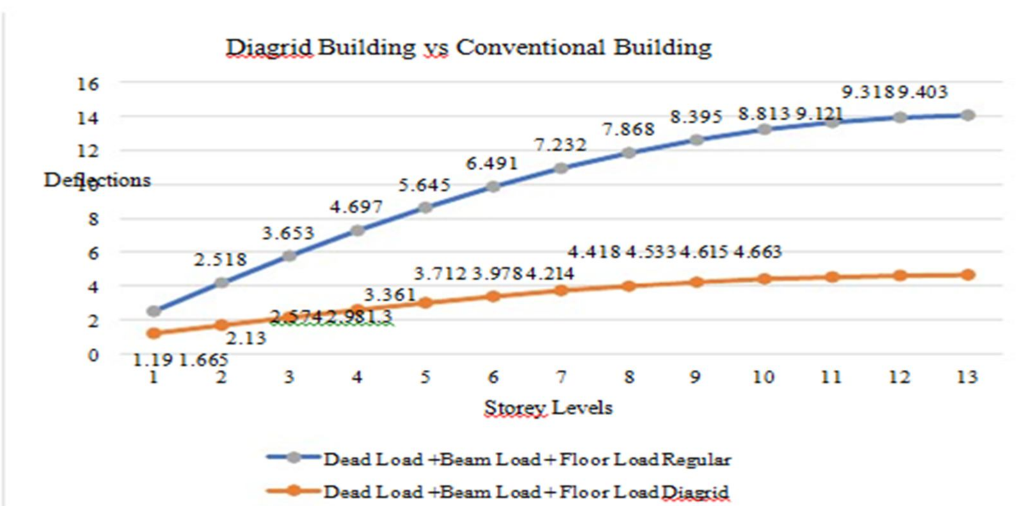

Figure 10: comparison of structure deflections due to Dead load, beam Load with floor load

VI. CONCLUSION

STAAD PRO is multipurpose analysis tool used to analysed structure and has the potential to compute the reinforcement required for any concrete element, to estimate lateral deflection caused by dead load, Beam load and floor load. Several structural behaviours are considered on building elements such as axial, flexure, torsion etc as per to their behaviour. After analysing and designing all the structures, the governing loads for each building for both diagrid and conventional frame systems are tabulated in the Table 2. It is observed that in diagrid system earthquake forces are predominant up to 16 storeys and in conventional frame upto 12 storeys. This means wind forces are predominant after 16 storeys in diagrid system and 12 storeys in conventional frame system. It can be concluded that diagrid system resists wind forces up to higher heights than conventional frame system. Further it is important to note that the section for conventional frame is not possible from feasibility and practicability point of view.
The dead load, Beam load and floor loads are analysed for G+12 RCC framed structure. Conclusions based on the optimized results are described below:

A. The dead load and beam load increases with height of structure.
B. Floor loads are more critical for tall structures but it is higher in conventional building structure than diagrid structure.
C. Buildings should be designed for loads optimized in both directions separately for deflection and stresses in buildings.

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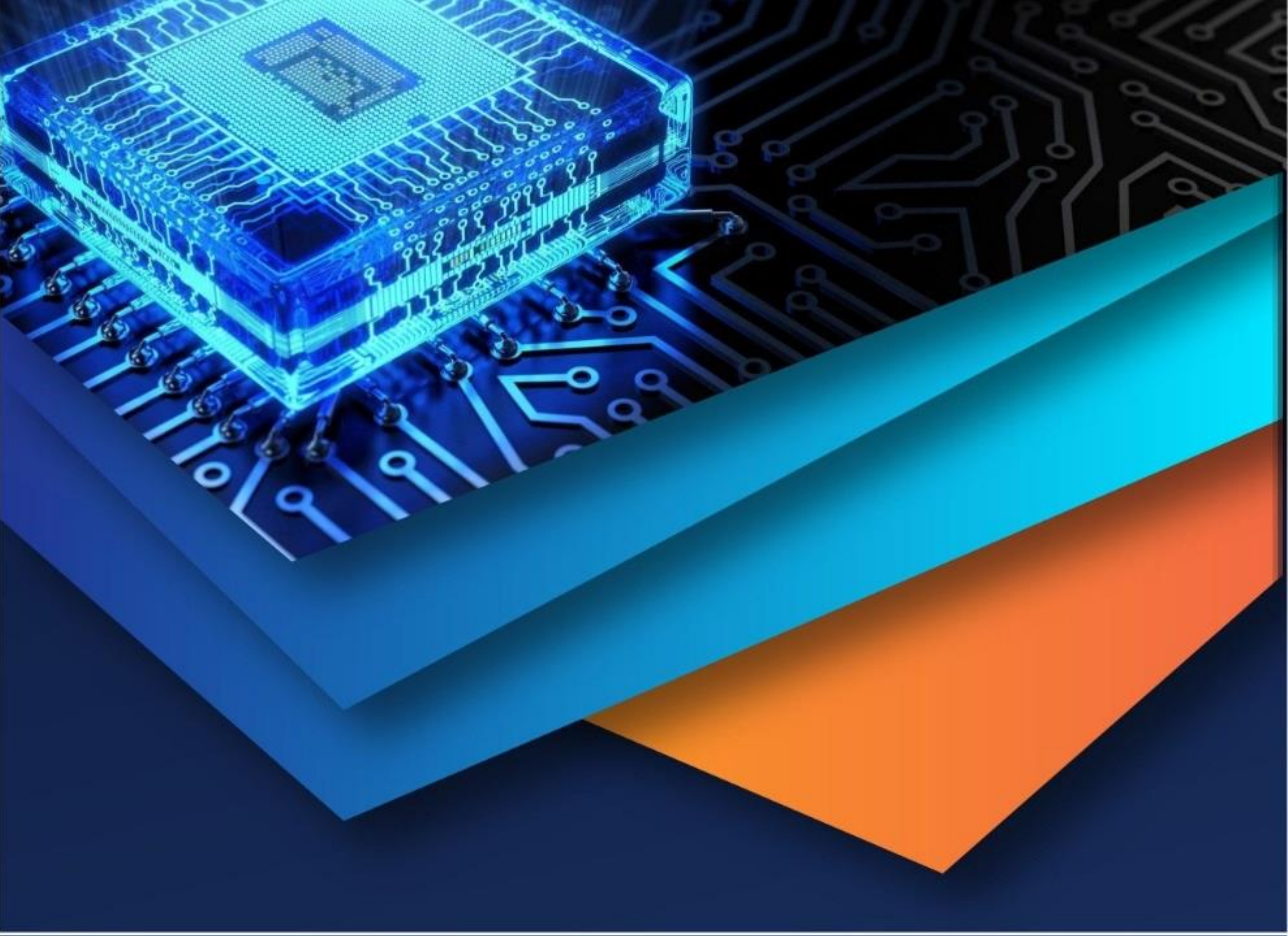

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