NIPES

Journal of Materials Engineering, Structures and Computation

Journal homepage: www.nipesjournals.org.ng

Investigation of Seismic Action on Frame Structure using Sap 2000

A.O. Ibrahim[1], M. Bello[2], F.O. Adeyemi[3], I.O. Salaudeen[4], K.A. Muhammad[5]

[1,2,4] Department of Civil engineering, Faculty of Engineering and Technology, University of Ilorin, University of Ilorin, Ilorin, Nigeria
[3]Department of Civil engineering, Faculty of Engineering and Technology, Ajayi Crowther University, Oyo, Nigeria
[4]Department of Building Technology, Abubakar Tafawa Balewa University, Bauchi, Nigeria
ibnibrohim88@gmail.com, mohammedbeldams@gmail.com,festusade4@yahoo.com, ibsalaudeen9@gmail.com
kamaluddeenkhas@gmail.com

ARTICLE INFORMATION

Article history:
Received 12 October 2022
Revised 16 November 2022
Accepted 25 December 2022
Available online 11 January 2023

Keywords:
Seismic Action, frame structure, earthquakes, concrete

https://doi.org/10.5281/zenodo.7524855

ABSTRACT

Earthquakes are considered one of the most deadly natural hazards to mankind, causing the death of thousands each year. This research aimed at gaining some insight into the real behaviour of reinforced concrete and frame structure under seismic excitation. The model of the reinforced concrete-steel frame structure was analyzed using the SAP 2000 software package. The P-Delta analysis is performed by subjecting the building to the pattern of loads increment representing the inertia forces which will be experienced by the building. As the magnitude of the load was increased gradually, the response of the building to the monotonically increasing load was observed at different points. The displacements observed were about 0.35m from joints on the first floor. The capacity curve obtained from static analysis of the building met the request curve near the elastic range at a displacement of 0.35m; this shows that the structure has good resistance to a spectrum acceleration of 0.11g which is equivalent to an earthquake of magnitude 5.2 (Mw).

1. Introduction

Natural disasters are events that occur suddenly in nature. The occurrences of these disasters have been as far as man can think of, the beginning of his existence on the planet earth [1]. Out of several natural disasters experienced on earth, earthquake is regarded as one of the greatest disasters that occur leaving human lives and properties hazarded based on how large it is in magnitude [1]. The continuous occurrence of earthquakes in different parts of the world has continued to be a source of concern to man, and experts have continued to research tirelessly to find ways to mitigate the aftermath such as damages and losses incurred from its occurrence [2]. According to [2], earthquakes occur as shakings. Most Seismic hazards can be defined as the probability of occurrence of a specific level in a given time interval like fifty years [3]. It also influences human life, buildings, bridges, railway strategic projects and structural man-made [4].
The peak ground acceleration and the peak ground velocity of the South-Western area of Nigeria ranges between 0.16 to 0.69 g and 18.0 to 58.3 m/s respectively [2].

The first quake ever in Nigeria occurred in 1939 in Ibadan, and the first tremor was recorded in Warri in 1933 [1]. Many other earthquakes have occurred after this. Recently on the 11th of September 2009 around 03:10:30am in Abeokuta, a quake with an intensity of VII and a magnitude of 4.8 was recorded [1]. Researchers from National Space Research and Seismic hazard are a source of a major threat to mankind [5]. Seismic hazards have the ability to cause notable and serious destruction and damage to biodiversity and man's immediate environment [6]. The effect of the resulting damage is not only limited to the moment of Seismic occurrence and can result in high consequences in terms of permanent damages or failures of buildings and structures. Effective mitigation of structures is of paramount importance in terms of structural resistance and physical integrity [1]. This can be achieved by designing the structures to be earthquake-resistant. The design of reinforced concrete structures is typically based on the prescriptive method of building codes. The loads on these structures are low and result in elastic behaviour [5]. Under a strong seismic action, a structure may be subjected to forces beyond its elastic limit. Although building codes can provide a reliable indication of the actual performance of individual structural elements, it is not within their scope to describe the expected performance of a 3-dimensional structure as a whole, under large forces [7]. With the availability of computers and design software packages, the expected seismic performance of a structure can be obtained. Structural engineers can observe and predict the expected performance of any structure under large forces and modify the design with the application of these software packages [8]. Nonlinear response history analysis is a possible method to predict structural response under strong seismic events. This method is not considered practical due to the large amount of data generated in the analysis. Performance-based seismic engineering usually involves nonlinear static analysis, also known as pushover analysis [7]. Structures may deform beyond the elastic limit when subjected to strong seismic events [2]. The seismic performance of structures should be conducted considering post-elastic behaviour [9]. Therefore, a nonlinear analysis procedure must be used to determine the response or behaviour of the structure under seismic load. Relevant information from past analytical and experimental studies on the seismic analysis of RC frame structures has been presented in this chapter.

1.2 Nonlinear Static Analysis of Reinforced Concrete Structure

Several methods can be used in the design of structures under seismic actions with different accuracy to describe the structural seismic response [2]. The most realistic method is the non-linear dynamic analysis which focused on structural behaviour time variation, materials and geometry. Nonlinear dynamic analysis requires costly computational resources and takes a long period of time to interpret the results [10].
However, structural engineers require intuitive tools to predict the structural response under seismic actions.

2. Methodology

The P-Delta analysis is performed by subjecting the structure to a monotonically increasing pattern of loads representing the inertia forces which would be experienced by the structure when subjected to lateral loading. Under increasing loads, various structural elements may yield sequentially. Using the P-Delta analysis, the characteristic nonlinear force-displacement relationship is determined.

2.1 Load Data

Number of bays: three (3) i.e 7m, 9m, 6m along the x-axis
Number of bays: two (2) i.e 7m and 8m along the y-axis
Slab thickness: 150mm, beams 450 x 225, wall thickness: 225mm. steel beam angle iron, steel column: Universal column
 Floor Load
Dead load: 3.6kN/m^2

Live load: 1.5kN/m2 (BS6399 Pt1, BS 8110)
 Roof Load
Dead load: 3.6kN/m2
Live load: 1.5kN/m2 (BS6399 Pt3, BS 8110)
 Static Wind Load
1st floor: 15kN,2nd floor, 10kN, 3rd floor:5kN
Applied code: Eurocode1:2004
Terrain Category: II
3 Fundamental Basic Wind Velocity (Vb): 26m/s
 Seismic Parameters
Applied code: Eurocode8:2004
Ground Type: B
Ground Acceleration: 0.10g
Behaviour Factor (q): 1.5: Importance Factor (I): 1.2

2.2 Procedure for P-Delta Analysis in SAP2000

1. Complete static analysis

2. Input control data for P-delta analysis

3. Input P-delta Load Case

4. Define Hinge Data

5. Assign Hinge Data to the members

6. Perform P-delta analysis

7. Check the analysis results

2.2.1. Step-by-Step Procedure of P-Delta Analysis in SAP2000

The P-Delta analysis of the reinforced concrete frame structure was performed as follows:

Step 1: Static Analysis

The steps involved in modelling and static analysis of the structure (multi-storey building) are as follows:

a. Open to the GUI, set the units and coordinates

b. Input Material Properties and Section Data

c. Create the Structural Model

d. Define the Support Condition

e. Define and Assign the loads

f. Set analysis Option and run Static Analysis

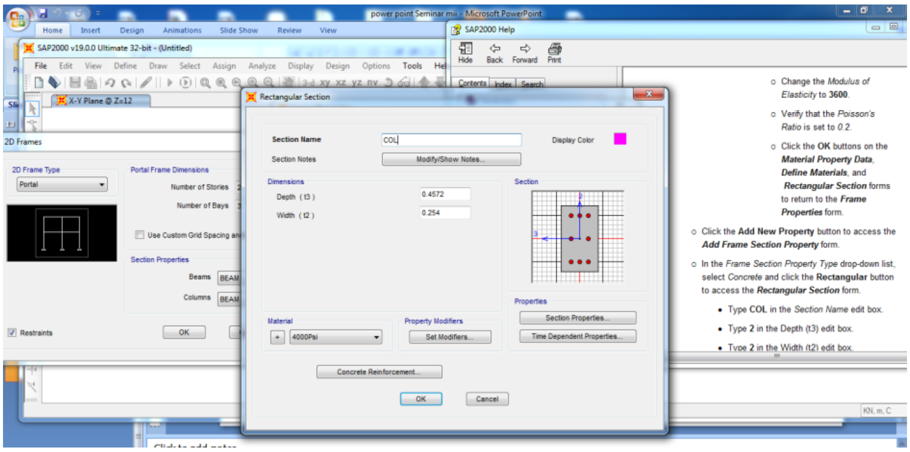

Figure 1: Preliminary Settings

Figure 1 shows the graphic user interface was displayed showing the settings of the coordinates and the unit system.

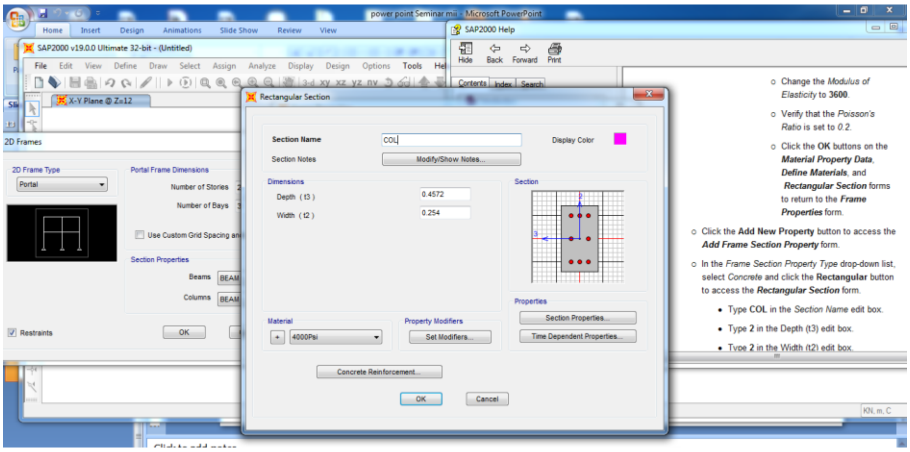

Figure 2: Material and Section properties input

Figure 2 shows the properties of the structural elements (i.e., material, section and thickness) that were defined. After defining the dimensions of the beam, the basic dimensions of the Column are defined: Firstly, give the section name then select the material used. After this, provide the dimensions (depth & width).

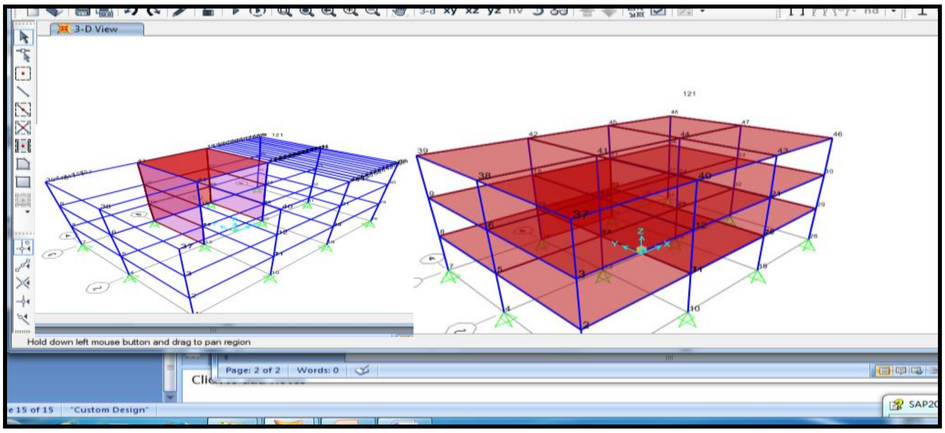

Figure 3: Create the Ground floor elements using Frame Wizard in the X-Y plane

Figure 3 shows the ground floor which was generated from the model menu through structure wizard and finally select frame.

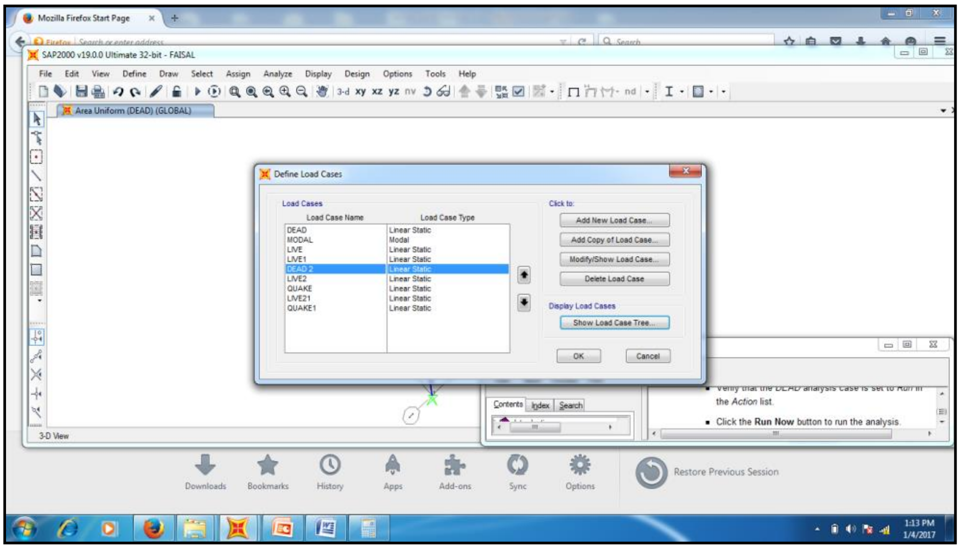

Figure 4: Define static loads, load cases and combination

The static loads were defined by clicking on the load option from the main menu, select the static load cases and fill the required information as shown in Figure 4. After the first entry (dead load) the remaining load cases can be added by clicking the add button.

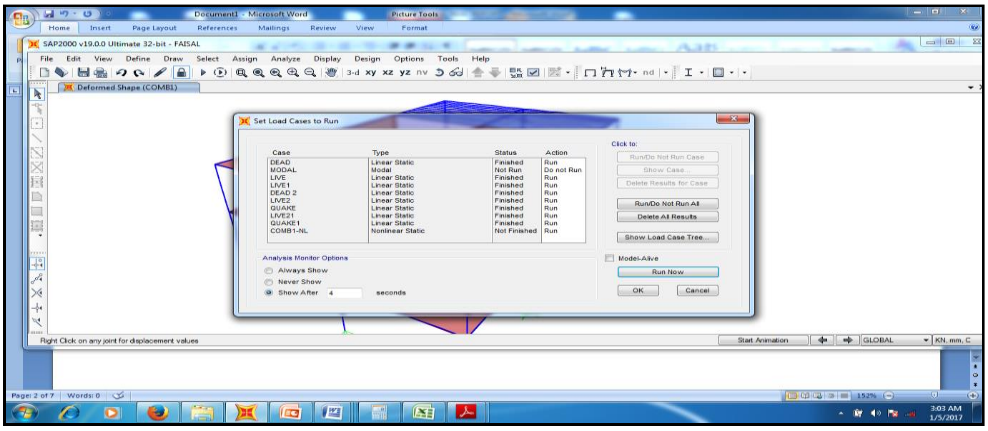

Figure 5: Assigning the floor load, wind, and earthquake load on the structure.

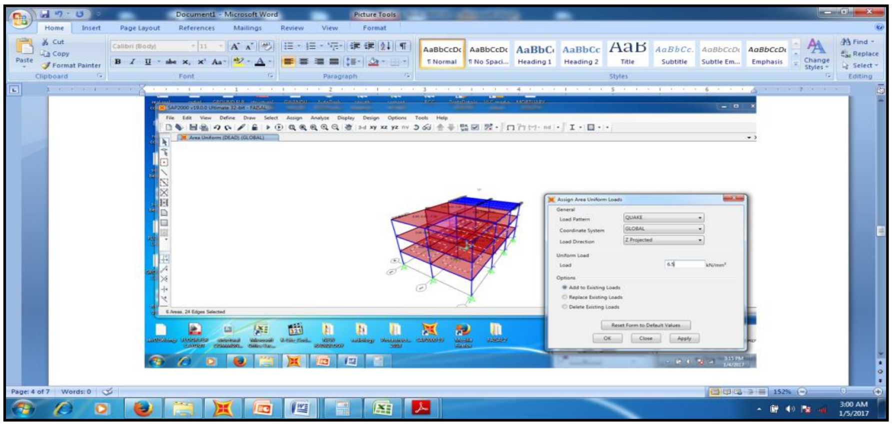

Figure 6: Perform static analysis

3. Results and Discussion

This chapter presents the results of the P-Delta analysis of the two (2) storey buildings. Analysis of the RC frame structure under the P-Delta has been performed using the SAP2000 software package. This is presented in Figure 7-12.

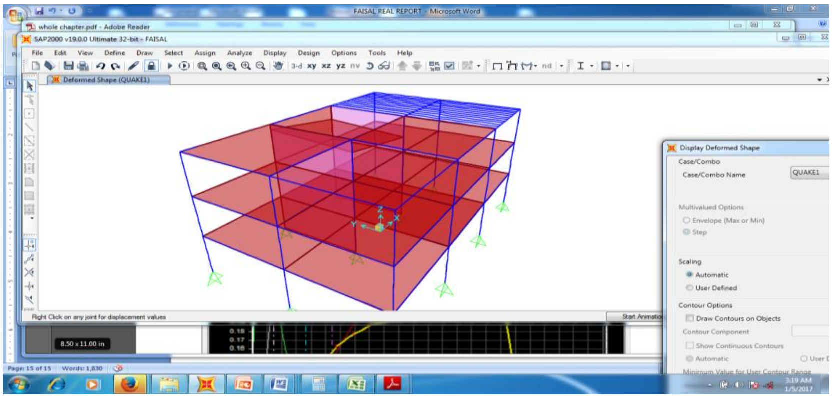

Figure 7. Shows deformed shape under Earthquake load

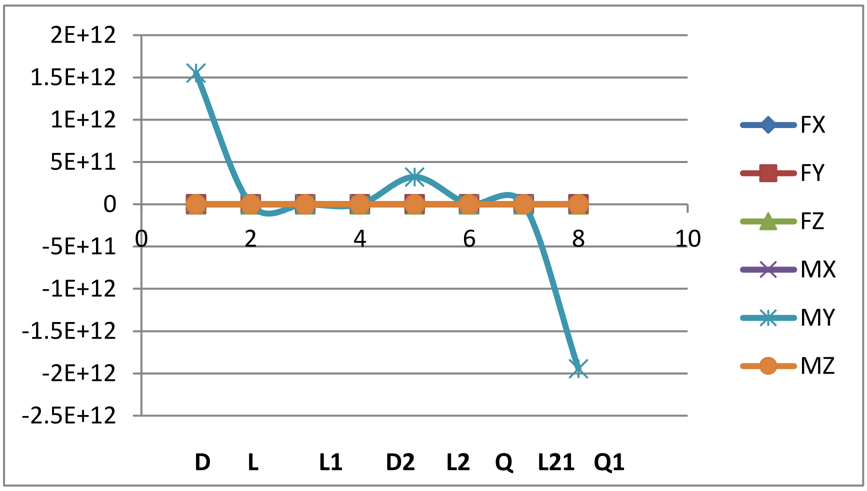

Figure 8. Graph of forces and moments against load type

Figure 8 shows the graph of forces and moments against load type. The maximum moment was observed when a dead load was applied. This means the effect of gravity load is more when compared with the lateral load. And the minimum moment was observed when the earthquake load was applied at 7.5m in the building.

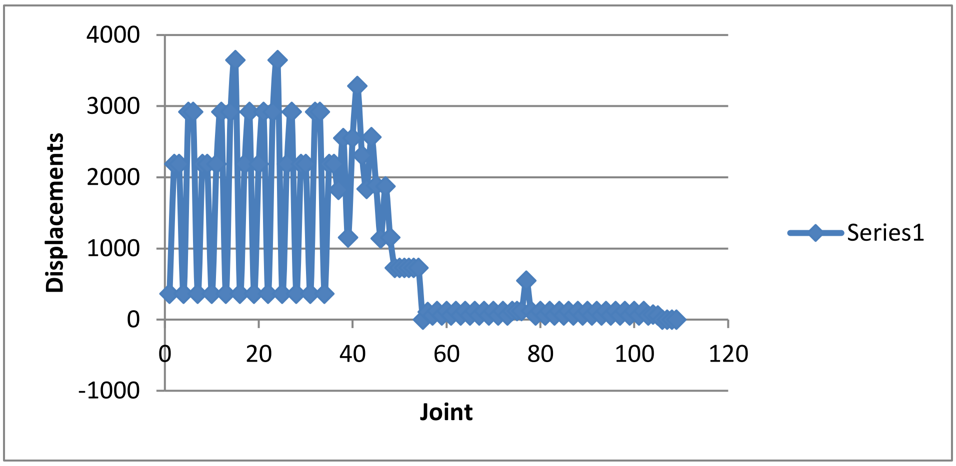

Figure 9: Shows deformed shape under earthquake load

The figure shows the deformed shape under earthquake load. The displacement was 3800E-2 mm at joints 10 and 24 which are very close to the base. This implies the effect of the earthquake load was intense at the base of the building.

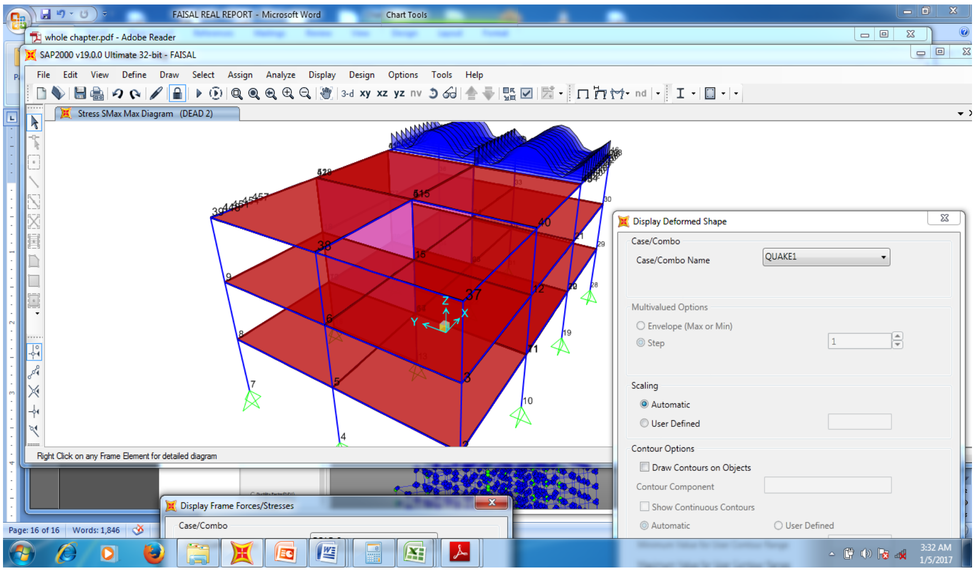

Figure 10: Shows deformed moment shape under Earthquake load

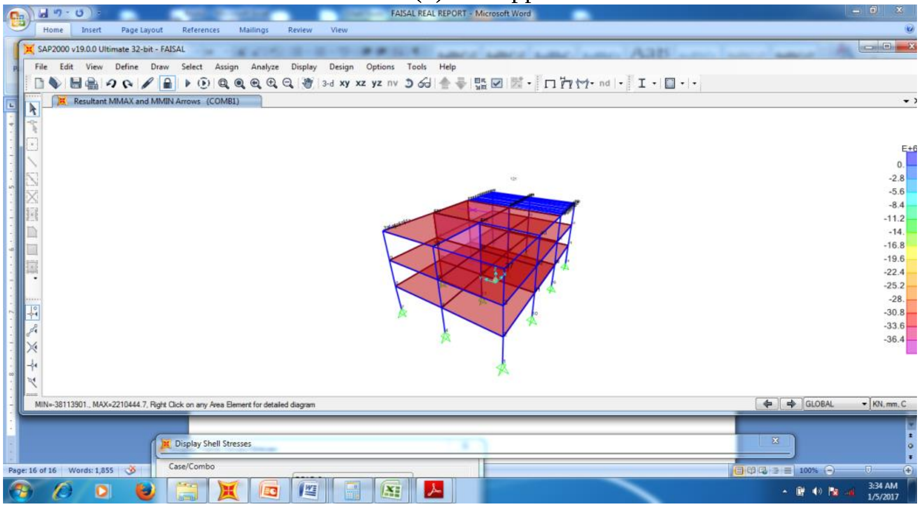

Figure 11: Shows deformed moment shape under earthquake load (member and shell)

It was observed that the maximum moment was at the lowest part of the structure due to the intense load there.

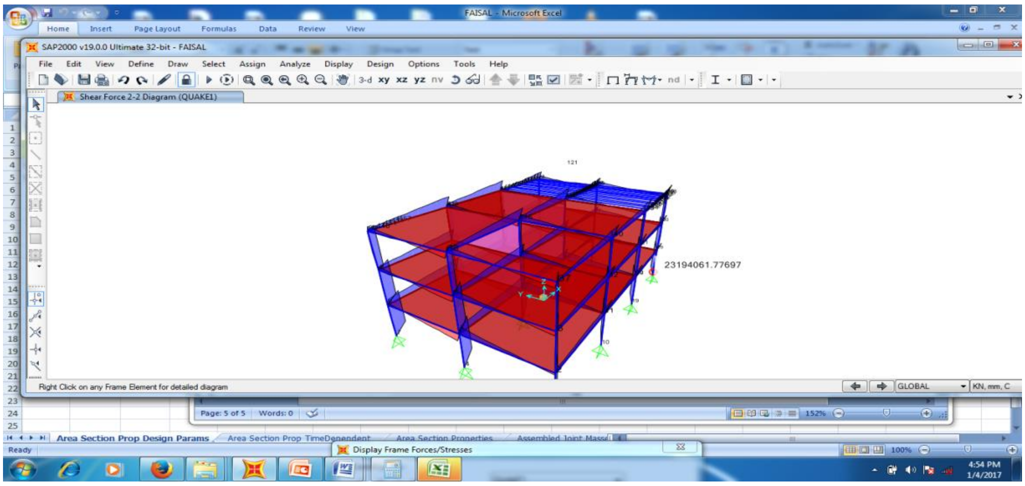

Figure 12: Shows deformed shear force shape under earthquake load (member and shell)

As the magnitude of the load was increased gradually, the response of the building to the monotonically increasing load was observed at different points. The displacement observed was about 0.35m from joints on the first floor.

4. Conclusion

The seismic capacity of the frame structure was investigated by performing static analysis using the SAP2000 software package. The capacity curve obtained from static analysis of the building was found to meet the demand curve near the elastic range at a displacement of 0.35m; this shows that the structure has good resistance to a spectrum acceleration of 0.11g which is equivalent to an earthquake of magnitude 5.2 (Mw). However, as the load increases, the joints of the structure display rapid degradation showing some damages at the first and second storey. From this observation, it could be deduced that the structure can resist minor to moderate earthquakes, but the performance of the structure under severe earthquakes may be poor. The results obtained in terms of shear forces and moment distribution gave an insight into the real behaviour of the structure.

Nomenclature

D	Dead Load
L	Live Load
Q	Earthquake load

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