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STRUCTURAL ANALYSIS OF MULTI STOREY RESIDENTIAL BUILDING WITH & WITHOUT RC SHEAR WALL

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Abstract:

There are several types of analysis methods available for analyzing shear walls of the building structures. Frame analyze is one of the methods and were used in this study to determine the ultimate strength of reinforced concrete coupled shear wall structures and its structural behavior under lateral loading. Staad Pro software which based on linear (first order elastic) analysis method were used to analyze the shear wall models. In this project we are analyzing the Multi floor Infrastructure build by Shear wall structure & Brick work framed structure, we obtaining the Area of Steel (AST) & Strength of the load bearing member (column) in Earthquake region. So we providing the difference between the Brick work Infrastructure & Shear wall Infrastructure.

1. Introduction:

General: High rise building is a structure vertically cantilevered from the ground level subjected to axial loading and lateral forces. It consists of frames, beams, shear walls, core walls and slab structures which interact through their connected edges to distribute lateral and axial load imposed to the building. Lateral forces generated either due to wind blowing against the building or due tothe inertia forces induced by ground shaking which tend to snap the building in shear and push it over in bending. These types of forces can be resisted by the use of shear wall system which is one of the most efficient methods of ensuring the lateral stability of tall buildings. For buildings taller than 10 stories, frame action obtained by the interaction of slabs and columns is not adequate to give the required lateral stiffness (Taranath 1998). It also has become an uneconomical solution for tall buildings. However it can be improved by strategically placing shear walls as it very effective in maintaining the lateral stability of tall buildings under severe wind or earthquake loading.

Analysis of Shear Walls: There are several types of analysis methods available for analysing shear walls structure. The analysis can be made in elastic, elasto-plastic and ultimate condition. However, due to uncertain and in-ability to analyse and interpret the post elastic behavior or possibly time constraint, the elastic method is preferred for its simplicity. This elastic method of analysis consists of Continuous Connection Method (CCM), Transfer Matrix Method, Wide Column Analogy (WCA) or frame analysis, Finite Element Method and Discrete Force Method. The Non-Linear Finite Element Analysis (NLFEA) can achieve excellent agreement with the test results (Driver et al., 1998). But this method is time consuming when relatively simple force distribution output is required. Frame analysis method offers the advantage of being simple and relatively accurate yet the results output are still acceptable by engineers. Thus, this study was carried out on shear wall structures adopted from research models by Marsono (2000) using frame analysis based software, to evaluate the accuracy of the methods.

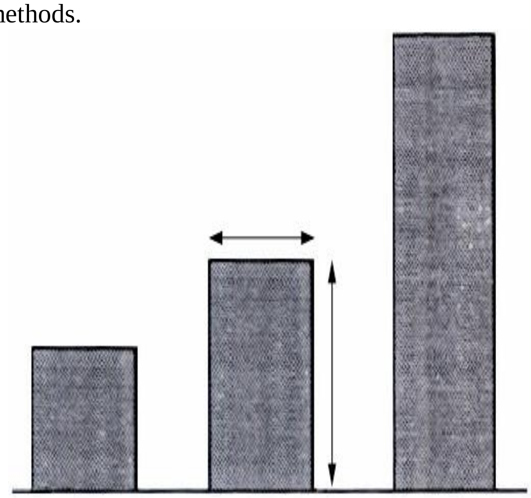


Figure 2.1: Shapes of shear walls

Previous Work: Previous researcher, Marsono (2000) has conducted an experimental work on small scaled model of various types of shear walls structure. Results from the experiment in the form of stresses and strains, crack distributions and ultimate strength then used to establish the analytical method (Continuous Connection Method, CCM) of analysis. The Non-Linear Finite Element Analysis (NLFEA) was performed as a tool to affirm the experimental results and the analytical mode of failure and ultimate strength predictions. The experimental and NLFEA results were in very close agreement in predicting the ultimate strength and mode of failure of coupled shear wall structure.

Objectives: The main objectives of the research are as follows:

- ✓ To carry out a frame analysis on shear wall models using Staad PRO V8i software.
- ✓ To check the reliability of frame analysis method compared to analytical Continuous Connection Method (CCM) and Non-Linear Finite Element Analysis (NLFEA) method.
- ✓ To approximately determine the crack formation and crushing of concrete at shear wall referring to the results obtained from the frame analysis.

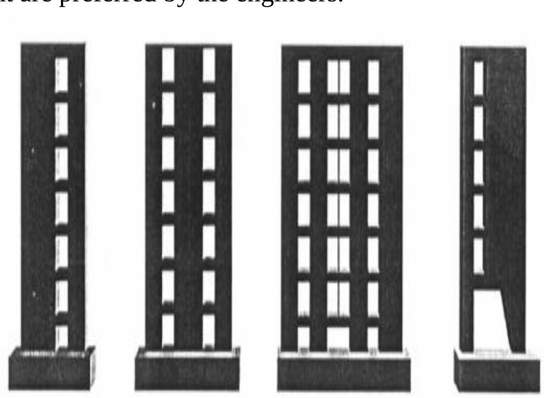
2. Literature Review:

General: The following is a review on shear wall structural systems, modes of failure for shear wall and coupling beam, method of analysis that available for analyzing shear wall structure and background of the Staad PRO V8i software.

Shear Wall Systems: Shear walls have been the most common lateral force resisting elements for tall buildings besides frame systems. It is an efficient method of ensuring the lateral stability of tall buildings and also efficient against torsional effects when combined together with frame structures. Their stiffness is such that sway movement under wind load can be minimized.

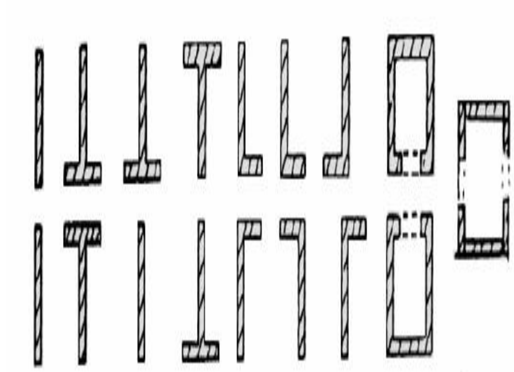
Structural forms of shear wall are commonly used in buildings of 10 to 30 storeys. Monolithic shear wall can be classified as short, squat or cantilever as in Figure 2.1 according to their height/depth ratio (Irwin, 1984). The walls may be planar, flanged or core in shape.

Coupled Shear Walls: Coupled shear wall is a continuous wall with vertical rows of opening created by windows and doors, coupled by connecting beams. When two or more shear walls are interconnected by a system of beams or slabs, the total stiffness of the system exceeds the summation of the individual wall stiffness because the connecting slab or beam restrains the individual cantilever action by forcing the system to work as composite unit. Such an interacting shear wall system can be used economically to resist lateral loads in buildings up to about 40-stories (Taranath 1998). Shear wall may come in many forms and there are various types of opening shape due to architectural and planning requirement as in Figure 2.2. However due to ease of analysis, design and construction, regular shapes with openings throughout the height are preferred by the engineers.



Single Band Staggered Band of Openings

(a)



(b)

Figure 2.2: a) Typical arrangement of elevation and b) Plan shapes of shear wall structures

Modes of Failure for Shear Wall: At loaded state, shear wall is subjected to tension and compression along the height. It may fall in flexure, shear or combined action of flexure and shear. Primarily, the failure of shear wall structure can be identified by the three main

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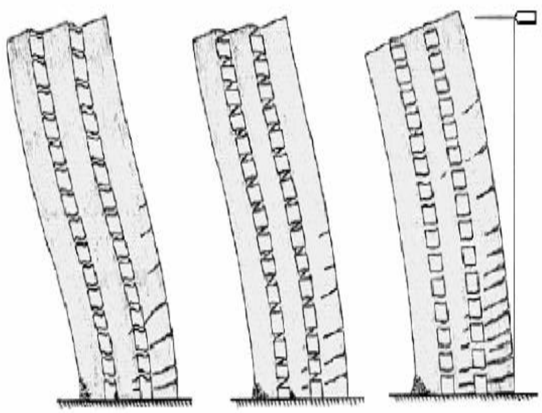
cases that highly dependent on the effectiveness of the coupling beams. The first two modes of failure are caused by the flexible coupling action in shear wall structures. Referring to Figure 2.3, the modes of failure of shear walls are;

- ✓ **Mode of Failure 1 – Flexural Mode of Failure:** This mode of failure is identified by flexural failure of coupling beams. It happens with relatively shallow coupling beams and reinforced with the small amount of main bars.
- ✓ **Mode of Failure 2 – Shear Diagonal Splitting Mode of Failure:** This mode of failure is characterized by the failure of coupling beams in shear or diagonal splitting mode. Major shear or diagonal splitting concrete cracks across the compression diagonal developed at the failed beams.
- ✓ **Mode of Failure 3 – Rigid Actions:** The rigid actions of coupling beams will cause this mode of failure occurs to shear walls. Some partial flexural cracks will develop at the coupling beams while a large number of cracks will develop on the tension side of the wall, and it will bend in a cantilever mode. The wall will fail with the crushing of the concrete at the highly stressed compression corners.



(a) (b) (c)

Figure 2.3: Modes of failure of shear walls. a) Mode of failure one, b) Mode of failure two &, c) Mode of failure three.

Coupling Beams: Coupling beams are defined as a connector between two or more vertical shear walls separated by regular openings created by windows or doors at each storey level along the shear wall height. It may be shallow or deep beam type, however the most common type used is a deep beam type. The ACI Code 318-89 defines a deep beam as a beam in which the ratio of the clear span l to the overall depth d is less than the limits 1.25 for simple spans and 2.5 continuous spans. While the CIRIA Guide 2 state deep beam as a beams having an effective span/depth ratio l/d of less than 2 for single span and less than 2.5 for continuous beams.

At lateral loaded state, shear walls undergo different movement between supporting ends. The coupling beams in between are actually constraint the walls to deflect similarly and will be subjected to flexural, shear or combination of both types of deformation, as the beams are required to connect the walls and transfer process between them. Local failure of coupling beams may lead to a more serious global failure of the whole lateral load resisting systems of the building. The main characteristics of the coupling beams that can be observed at failure are:

- ✓ Formation of initial flexural cracks at fixed end supports
- ✓ Formation of major diagonal cracks
- ✓ Concrete crushing at two ends of diagonal cracks

There are several modes of failure on coupling beams considered as flexural, shear and combined action of flexure plus shear (Marsono 2000)

Flexural Mode of Failure: In flexural mode of failure, coupling beams are deformed in double curvature of bending.

Pure Shear Mode of Failure: Pure shear deformation will occur when top and bottom reinforcement along the beam length is in tension. It can be characterized by the extension of diagonal cracks to the position of main reinforcement diagonally opposite and by the crushing of concrete at its end.

Flexure Plus Shear Mode of Failure: The characteristic of failure are the formation of major flexural cracks along the fixed end and a major diagonal crack on the web section. There are signs of crushing concrete occurs at two ends of the diagonal that act as a hinge.

Method of Analysis of Shear Wall Structures: Analysis on shear wall structures can be made in elastic, elasto-plastic and ultimate condition. Due to its simplicity, elastic analysis is still widely in use today in the design offices.

Finite Element Analysis: In finite element method, the main idea is to discrete a complex region defining a continuum into simple geometric shapes called finite elements. The material properties and the governing relationships are considered over these elements and expressed in terms of unknown values at element corners. This is may be due to geometric nonlinearities, material nonlinearities and the contact of bodies with geometric and material nonlinearities. It also virtually may include various geometrical shapes of structures. Factors that usually considered for nonlinear concrete material model used in the analysis are includes of:

- ✓ Nonlinear behavior in compression at materials including hardening and softening

- ✓ Fracture of concrete in tension based on nonlinear fracture mechanics
- ✓ Biaxial strength failure criterion
- ✓ Reduction of the shear stiffness after cracking

Non linear finite element analysis (NLFEA) make possible for us to analyze models real-life conditions on the desktop. The analysis can be made in elastic, elasto-plastic and ultimate conditions. Results obtained could offer very good alternatives to experimental results.

Continuous Connection Method (CCM): Continuous connection method is an analysis where the coupling beams of shear wall structure are replaced by continuous connected media along its height. Several problems may arise when obtaining the solution to the equation if unusual base forms, irregularities of openings, such that new boundary conditions that has to be applied to the equation.

Equivalent Frame Analysis: Frame analysis may also be called wide frame analogy. It is a simple method and can be used in plan frame programs. This method treats the walls and lintel beams as discrete frame members. Walls and connecting beams are replaced by the line element of stiffness equal to those of the units they replaced.

Staad Pro V8i: STAAD or (STAAD.Pro) is a structural analysis and design computer program originaaly developed by Research Engineers International at Yorba Linda, CA in 1997. In late 2005, Research Engineers International was bought by Bentley Systems. The commercial version, STAAD.Pro, is one of the most widely used structural analysis and design software products worldwide. It supports several steel, concrete and timber design codes. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis

Co-Ordinate Systems: Since STAAD uses the Matrix Displacement Method of structural analysis, there are 2 Cartesian coordinate systems – the local and the global.

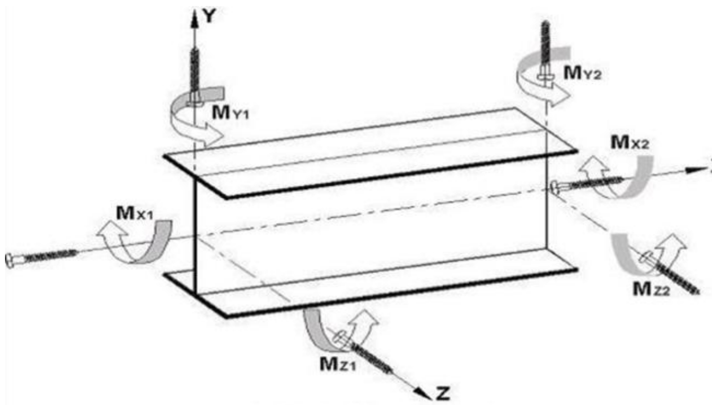


Figure 2.10: Staad Sign Convention For End Moments

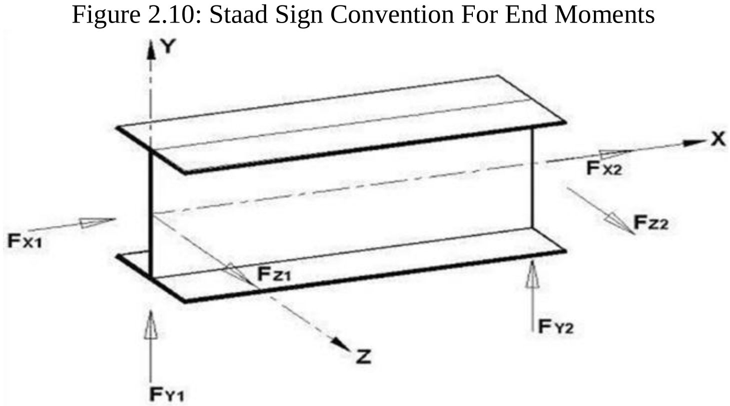


Figure 2.11: Staad Sign Convention for End Forces

Forces Acting on a Member's End: In STAAD this is called the "MEMBER END FORCES"

Fundamental Analysis Commands: Regardless of the structure being analyzed, the following are fundamental steps and STAAD command keywords shown in the brackets:

- ✓ Define whether the problem is 2D or 3D (STAAD PLANE or SPACE)
- ✓ Define the length and force units (UNITS)
- ✓ Define the nodes and their locations (JOINT COORDINATES)
- ✓ Define the member and their nodes (MEMBER INCIDENCES)
- ✓ Define the section properties of the members, I_x, etc (MEMBER PROPERTY)
- ✓ Define the mechanical properties of the members such as the Young's modulus, density, etc (CONSTANTS)

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- ✓ Define the support conditions (SUPPORTS)
- ✓ Define the load cases (LOAD)

These commands are stored automatically in STAAD in a file with the extension .std. This file is formatted as an ASCII text file which means that it can be edited outside of STAAD with a word processor or any other text editor. STAAD also creates certain other output files for its internal use. STAAD creates a database for your analysis, .dbs, and files for the bending moments .bmd, displacements .dsp, reactions .rea among others. The aforementioned STAAD commands are incomplete by themselves – they are the keywords of the commands.

Continuum Structures – Static Loads: Continuum structures (plates, slabs, walls, shells, tanks, etc) are modeled in STAAD by using finite elements. The following is with respect to the element of the STAAD library which can be quadrilateral or triangular. Common rules for the use of finite element modeling apply and will not be repeated here and it is presumed that section1.0 has been covered.

Sign Convention: The sign convention is as follows:

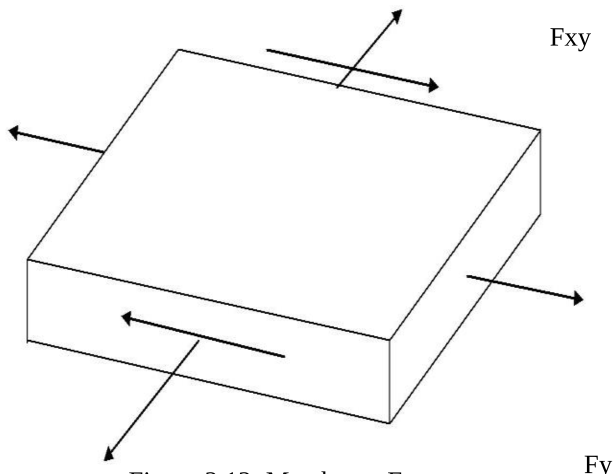

Figure 2.12: Membrane Forces

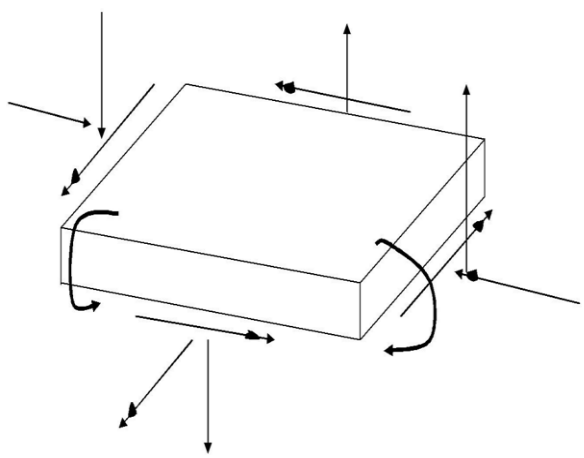

Figure 2.13: Bending Moments & Transverse Shear

Hence the axial direct forces: tension is positive, for bending moments: hogging is positive, and for transverse shear: down-to-the-left and up-to-the-right is positive. Element Force outputs are available at the center node of the element, all corner nodes of the element, and at any user-specified point within the element. The items included in the Element Force output are:

QX, QY Transverse shear forces stated as force per unit length per unit element thickness.

FX, FY, FXY Membrane forces stated as force per unit length per unit element thickness.

MX, MY, MXY Bending moments stated as moment per unit length.

SMAX, SMIN Principal stresses stated as force per unit area.

Fundamental Commands: The fundamental commands for finite element analysis using STAAD closely follow those for the skeletal or frame member analysis. The following are the essential differences:

- ✓ ELEMENT INCIDENCES command.
- ✓ ELEMENT PROPERTY command.

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Both frame members and finite elements can be used together in STAAD but the Element Incidences command must immediately follow the MEMBER INCIDENCES command.

The self weight of the finite elements is converted to joint loads at the connected nodes and is not used as an element pressure load.

Skeletal Structures – Dynamic Load:

Fundamental Commands: The reader must fire complete section 1.0. Only Time History dynamic analysis by the application of forcing functions to nodes or members is covered in this section (i.e. not ground motion time history dynamics). There are 2 issues to consider in the use of STAAD for dynamic analysis – how STAAD idealizes the distribution of mass and how to apply the forcing function. STAAD distributes the mass via the SELFWEIGHT command. When this is done, the mass is lumped at the nodes. If this is an inadequate model of the mass idealization, the member concentrated load command CON can be used to tell STAAD that significant masses are located there and their values. Also, the user can split the member into shorter lengths by inserting nodes along the member. In this case, the user can use the JOINT LOAD command to tell STAAD that a significant mass is located there and its mass. The SELF WEIGHT command is placed as the first line (or lines) of the commands under the relevant LOAD command. If the CON or JOINT LOAD commands are used, it is placed after the SELFWEIGHT command. You can then use the TYPE "i" FORCE command along with its particular syntax requirements. Finally, under the relevant LOAD command and after the mass idealization commands (i.e. SELFWEIGHT, CON, JOINT LOAD), you use the TIME LOAD command. You can only use the TIME LOAD command in one load case.

3. Research Methodology

General: The research methodology was start with problem identification and difference of strength and AST on reinforced concrete shear with normal brick wall structure and setting up the objectives and scope of study. Then all the related background information were collected and studied for the literature review for knowledge updating.

Modelling and Analyzing the Shear Wall Models: Generally there are several steps in modeling and analyzing the shear walls. First is by installing the section properties for every part of the shear walls using section marker in Staad PRO. Followed by building the frame models for every shear walls in Staad PRO and all the section properties and restraints are assigned to the respective part of the structure. Then applying the structure with load and analyzed it to obtain all the results.

Installing the Section Properties: To compute deflections and stresses in the structure, it is necessary to know all the material properties and dimensions of the section used in the structure. The line element has a same stiffness with the unit they replaced and will represent the actual behavior of the structure. This same stiffness can be achieved by assigning the actual material and section properties to the line element. For this study, all the section properties were newly define in the Section Maker since it do not use the standard section provided in the Section Library. All the steel reinforcement was being assigned compositely with the concrete member referring to the reinforcement detail and cross section of every part of the structure. For the purpose of modeling the narrower wall (180mm) was named by 'Wall 1' and the wider wall (280 mm) named by 'Wall 2' for every models. These walls contain same vertical steel reinforcement throughout the height. However, the horizontal reinforcements are different at certain part. There are two different steel which are 6mm diameter steel used at middle span of the wall and 8mm diameter steel respectively.

Table 3.2: Material Properties

For Floor	Concrete			Steel			
	Characteristic Strength, *fcu*^{2} N/mm	Splitting Strength, *fst* ^{2} N/mm	Modulus of Elasticity, *Ec* ^{2} kN/mm	Diameter Mm	Cross Sectional Area 2 mm	Yield Strength, *fy* 2 N/mm	Modulus of Elasticity, *Es* 3 kN/mm
Ground Floor	52.75	3.42	28.9	6 8 10 16	28.27 50.27 78.54 201.06	280.2 416.4 381.9 542.2	208.8 216.8 212 215
First to Tenth Floor	52.18	4.22	23.99	6 8 10 16	28.27 50.27 78.54 201.06	280.2 416.4 381.9 542.2	208.8 216.8 212 215

All the coupling beams were named by 'Beam' and the base of the wall as 'Base'. Since the existence of the horizontal bars have to be included in the analysis, every part of the structure is to be split into two section properties and it was differentiated by the name of 'with links' or 'without links'. These section properties will be shown in Table 3.1. The type of material for each shape of section can be chose from the range of mater. All the material properties assigned to the models were obtained from the laboratory test has been carried out during experimental study as in Table 3.2.

4. Data Collection & Analysis

General: In this first we have given the loads to the structure and the load is calculated using thumb rule formulae. The step by step analysis given to the structure is shown below.

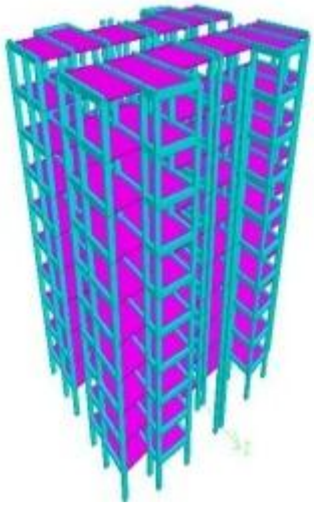

Figure 4.1: Loads to the Structure

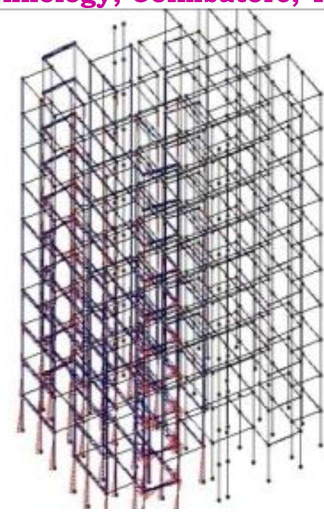

Figure 4.2: Deflection to the structure

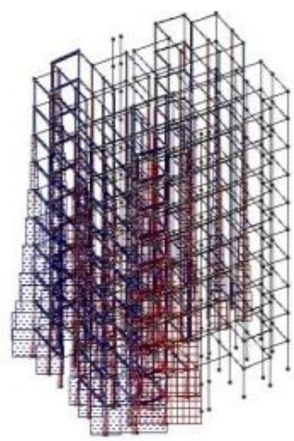

Figure 4.3: BM to the structure

5. Conclusion:

In this report we have studied about the shear walls located at many places in many zones. We have giving the exterior walls with shear wall completely and the loads, deflection and bending moment have given to the structure. In the next report we will continue with the analysis of the structures and will compare about the brick wall structures and the shear wall structures.

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