# COMPARATIVE STUDY OF DIFFERENT TYPES OF FOUNDATION USING STAAD Pro.

A

Thesis

Submitted by

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UNDER THE GUIDANCE OF

Mr. Ajeet Pal

(Guest Lecturer)

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*for the award of the degree of*

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## CERTIFICATE

This is to certify that Ankit Yadav(1783900008), Arvind Yadav(1783900011), Asteek Raj (1783900014), Himanshu Yadav(1783900024), Irshad Ali Usmani(1783900026), Rashid(1783900041) has completed work on the major project. They have satisfactorily compiled the project work for B.Tech final year curriculum of Civil Engineering in this institute for the academic 2020-2021.

Mr. Ajeet Pal

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Place: Kannauj

Date

# DECLARATION

The satisfaction that accompanies any task would be incomplete without naming the people who made it possible and whose constant guidance and encouragement made the work seek perfection.

It's our pleasure to express deep gratitude and sincere and thanks to our major project guided by Mr. Ajeet pal, Civil Engineering Department for providing an opportunity of doing this important project under his guidance and sharing his experience and Knowledge with us.

Moreover, we would like to convey our sincere thanks to our guide for his constant motivation and for being supportive beyond comparisons.


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# ABSTRACT

A complete structure consists of two major components superstructure and substructure. Generally, when constructing a structure with large and complex load system various factors are considered for the selection of type of Foundation to be provided. Foundation is the main element of sub-structure that transfers entire load of whole superstructure to the ground, also provide resistance against overturning. Hence, a large amount of stress should be given on selection of type of Foundation to be used in the sub-structure.

In our study we have tried to determine which type of Foundation should be preferred if the loading conditions and bearing capacity of soil is same by using finite element analysis method using **STAAD Pro.** (STAAD Foundation).

This work will study the effects of soil-Foundation-structure interaction on the end bearing, bending moment and deflection response. Three types of Foundation with frequency-based design were analysed, including Isolated Foundation, Combined Foundation and mat Foundation. The finite element method using the STAAD Pro. program was first validated using experimental data. Recommendations were given to simplify the soil- Foundation structure interaction analysis of loading, deflection and moment. In this research work, we are comparing different shaped Footing for same loading condition also soil bearing capacity to determine the best suitable and stable type of Footing which can transfer load, bear deflection and moment. In this study is can be concluded that Combined Footing is comparatively more suitable and best in comparison with Isolated or mat Footing. The parameters used for analysis are selected such that they resemble the actual conditions. From the analysis, the method which gives the minimum ultimate bearing capacity for shallow Foundation on top of the slope may be recommended for further design.

**STAAD Pro.** (STAAD Foundation) is a structural analysis and design computer program originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineer International was bought by Bentley Systems.

The collected data is collected and a 3-D model is generated using STAAD Pro. and STAAD Foundation. The various loads acting on the structure is calculated and the structure is analysed for the various load combinations. Design of the building and various Foundation is done. The obtained results of various Foundation are analysed and compare with each other to Know which Foundation is Better in given condition.

**Key words:** Bearing Capacity, STAAD Pro., Foundation, Isolated, Combined, Mat.

# TABLE OF CONTENT

**LIST OF FIGURES** **Page No.**

**LIST OF TABLES** **Page No.**

**LIST OF GRAPHS** **Page No.**

# NOTATIONS & ABBREVIATIONS

| | |
|---|---|
| STAAD.Pro | Structure Analysis and Designing Program |
| IS | Indian standard |
| G+6 | Ground floor + 6 floors |
| DL | Dead load |
| LL | Live load |
| EQ | Earth quake |
| X | Transverse direction |
| Y | Longitudinal direction |
| 3D | Three dimension |
| Tv | Avg. Shear stress |
| SF | Shear force |
| $M_{umax}$ | Limiting moment of resistance |
| Mu | Governing moment |
| BM | Bending moment |
| Fck | Characteristics Strength of concrete |
| Fy | Yield Strength of steel |
| D | Effective depth |
| $K_{umax}$ | Limiting factor |
| C | Cohesion |
| FOS | Factor of safety |
| COF | Coefficient of friction |
| SBC | Soil bearing capacity |
| KN | Kilo Newton |
| M | Meter |
| GY | Global Y- direction |
| c/c | Centre to centre |

# CHAPTER-1

# INTRODUCTION

## 1.1 GENERAL

Engineering is a professional art of applying science to the efficient conversion of natural resources for the benefit of human. Engineering therefore requires above all creative imagination to innovative useful application for natural phenomenon.

Foundation is the lowest part of a structure below the ground level which is direct contact with ground and transmitted all the dead, live and other loads to the soil on which the structure rests.

## 1.2 MOTIVATION

- There is no provision in any IS code which explains the type of Footing to be used for a given load and soil characteristics.
- Study of effects of various types of Footing on a same type of soil will help us to know whether the Foundation will fail or sustain the loads applied.
- And which type of Foundation will be suitable under different loading and soil characteristics.
- To complete our project we should know some software which helps in calculations and analyzing our problems. These software plays a very important role in Civil engineering.
- They save our time and give as best techniques for solving Problem.
- In Comparative study of different types of Footing by using STAAD.Pro complex calculations and analyzing can be done easily, efficiently and accurately without any Human error.

## 1.3 OBJECTIVE

Objective of this Project is to know the effect of various types of Foundation for same building with same loading condition and analysis of various types of Footing using STAAD Pro. And STAAD Foundation software.

- To design a building (G+6) for providing the load to the Foundation.
- To analyse various types of Foundation for (G+6) building.
- Consideration of ethical standards, health and safety, and constructability.
- To design particularly three Footing Isolated, Combined and Mat Footing.
- Plot the graph of bending moment and shear force for the different types of Footing.
- To compare which Foundation is better for given condition of soil and loading to be constant.
- Comparative study of the bending moment and shear force for the different types of Footing.

- To determine the best suitable Footing type and shape for a considered soil property.
- By simplifying the effect, efficiency of Foundation so that selecting of type of Footing becomes easy if similar loading and soil conditions are faced, so to speed up the construction and minimize construction cost.

## 1.4 FOUNDATION

The Foundation or Footing is a very important part of a structure, which is located below the ground level. The Foundation transfer and spread load from column or wall into the ground soil evenly. It is otherwise called as sub structures.

Bearing capacity and settlement are two parameter requirements for the design of shallow Foundation. It is essential for engineers to estimate the Foundation's bearing capacity subjected to vertical loads.

Settlement of Foundation under load due to the movement of soil particle horizontally and vertically below the Footing.

All Footing are Foundation but all Foundation are not Footing.

### 1.4.1 FAILURE OF FOUNDATION

Most commonly Foundation failure is caused by the movement of expansive and highly plastic soils beneath different sections of the Foundation Footing. This movement of soil can be in the form of shrinkage, which causes settlement, or expansion, which causes heave. ... When moisture levels are high, soils swell.

#### 1.4.1.1 TYPES OF FOUNDATION FAILURE UNDER LOADS

Following are the different types of failure of Foundation:

a) Punching shear failure

b) One-way shear failure

c) Flexure failure of Foundation.

The above three modes of Foundation failure should be checked during design stage of concrete Foundation for the given load. Guidelines provided by standard codes of practice should be followed so that Foundation does not fail in any of the failure types as mentioned under any possible load combinations when structure is occupied.

#### (a) PUNCHING SHEAR FAILURE OF FOUNDATION

Punching shear failure is also Known as diagonal tension failure of Foundation. In this mode of failure, Foundation fails due to formation of inclined cracks around the perimeter of the column. The critical section for punching shear failure is taken at d/2 from the face of the column, where d is the effective depth of Footing. To avoid punching shear failure, the ultimate upward shear force at this section in the Foundation should be less than the shear resistance of concrete for the given percentage of concrete. Additional reinforcement should be provided to resist punching shear in case of shear resistance of concrete with reinforcement provided is not sufficient. The failure of Foundation in this mode appears as truncated cone or pyramid around the column, stanchion or pier as shown in figure below:

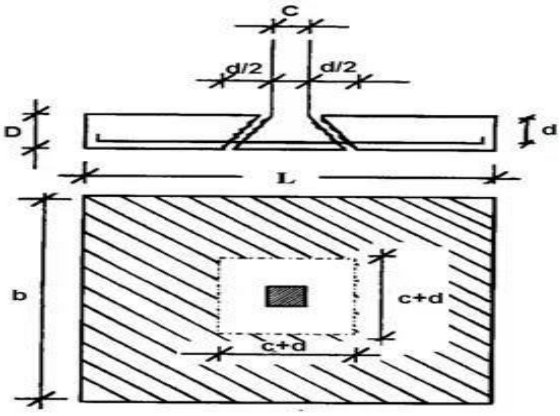



Fig-1

### (b) ONE-WAY SHEAR FAILURE OF FOUNDATION

Foundation in one-way shear failure fails in inclined cracks across full width of the Footing that intercept the bottom of the Footing slab at a distance d from the face of the column (called critical section), where d is the effective depth of Footing slab. In case where steel base plate is used under column directly on the Footing slab, the distance d is measured from a line halfway between the face of column and the edge of the base plate. To avoid one-way shear failure of Foundation, the shear stress at the critical section of Footing should be less than the shear strength of concrete with given percentage of reinforcement used. One way shear failure of Footing is shown in figure below:

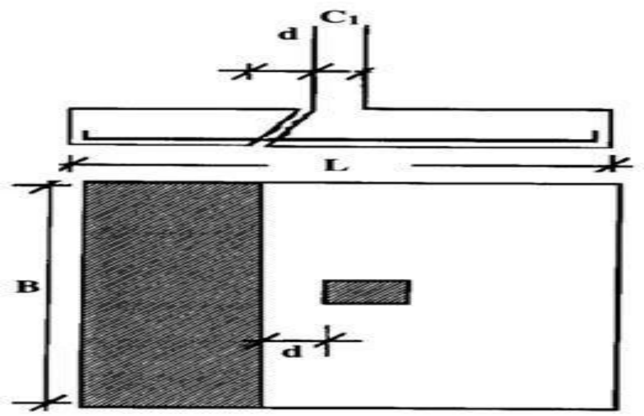



Fig-2

### (c) FLEXURE FAILURE OF FOUNDATION

During design of Footing, Mu/bd2 is calculated to get the percentage of reinforcement for the moment the Foundation is exposed to. Mu is the ultimate or factored moment; b is the width of Footing. The critical section for flexure is considered at distance d from the face of Footing. The standard codes take care of flexure failure during design by providing percentage of reinforcement required to resist the bending moment. But in case, when bending moment increases in Footing, the Footing fails as shown in figure below:

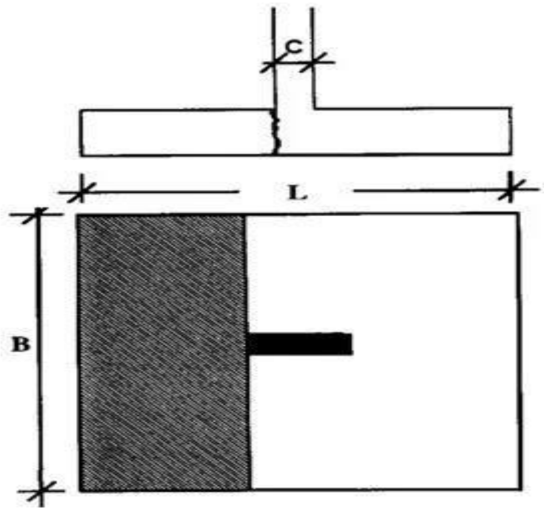



Fig-3

### 1.4.2 FUNCTIONS OF FOUNDATION

- It resists the lateral force such as wind, seismic etc.
- It resists the uplift force due to ground water.
- To provide a level surface for construction.
- To prevent the differential settlement of building.
- It provides good support for walls and columns.
- To distribute the weight of the structure over a large area in order to avoid overloading the underlying soil (possibly causing unequal settlement).

### 1.4.3 TYPES OF FOUNDATION

- **SHALLOW FOUNDATION**

Foundation with depth less than 3 meter are shallow Foundation. Such Foundation are used for structures that do not carry much load. They are also used in case the soil has a low weight bearing capacity.

Types of shallow Foundation are:

1. **Isolated Footing or Spread Footing:** A spread Footing also called as isolated Footing, pad Footing and individual Footing is provided to support an individual column.
2. **Combined Footing:** A combined Footing supports two columns. It is used when the two columns are so close to each other that their individual Footing would overlap.
3. **Mat/Raft Footing:** A mat or raft Foundation is a large slab supporting a number of columns and walls under the entire structure or a large part of the structure.
4. **Cantilever or strap Footing:** A strap (or cantilever) Footing consists of two isolated Footing connected with a structural strap or a lever.
5. **Wall Footing:** Wall Footing are used to support structural walls that carry loads for other floors or to support non-structural loads.

- **DEEP FOUNDATION**

Foundation with depth greater than 3 meters are deep Foundation. They are deep below the finished ground surface such that their base bearing capacity is not affected by surface conditions.

Types of deep Foundation are:

1. **Pile Foundation:** Pile Foundation are relatively long and slender members constructed by driving preformed units to the desired founding level, or by driving or drilling-in tubes to the required depth

2. **Piers:** A pier Foundation is a vertical column of relatively larger cross-section than a pile. The load coming from the superstructure is carried to the hard strata through these vertical columns.

3. **Caissons:** Caissons are hollow substructures designed to be constructed on or near the surface and then sunk as a single unit to their required level.

4. **Cylinders:** Cylinders are small single-cell caissons.

### 1.5 METHODOLOGY

i. Firstly, assign the loading over the building structure.
ii. Import the structure loading and generate the loading condition into STAAD Foundation.
iii. Design the isolated, combined and mat Foundation.
iv. Analyse and compare the Foundation.

## 1.6 OVERVIEW OF PROJECT:

Table - 1

| Sr.No. | Building Description | |
|---|---|---|
| **1** | Plan Area | 20m X 16m |
| **2** | Number Of Storey | G + 6 |
| **3** | Storey Height | 3m |
| **4** | Beam Dimension | 0.5mX0.5m |
| **5** | Column Dimension | 0.45mX0.45m |
| **6** | Slab Thickness | 0.15m |
| **7** | Bottom Support Condition | Fixed |
| **8** | Seismic Zone (According to IS 1893:2016) | $3^{rd}$ |
| **9** | Zone factor (According to IS 1893:2016) | 0.16 |
| **10** | Importance Factor (According to IS 1893:2016) | 1 |
| **11** | Response reduction factor (According to IS 1893:2016) | 5 |

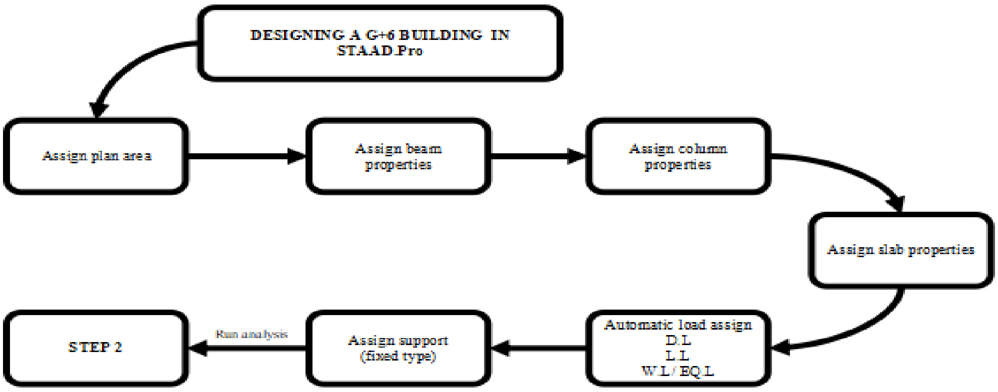
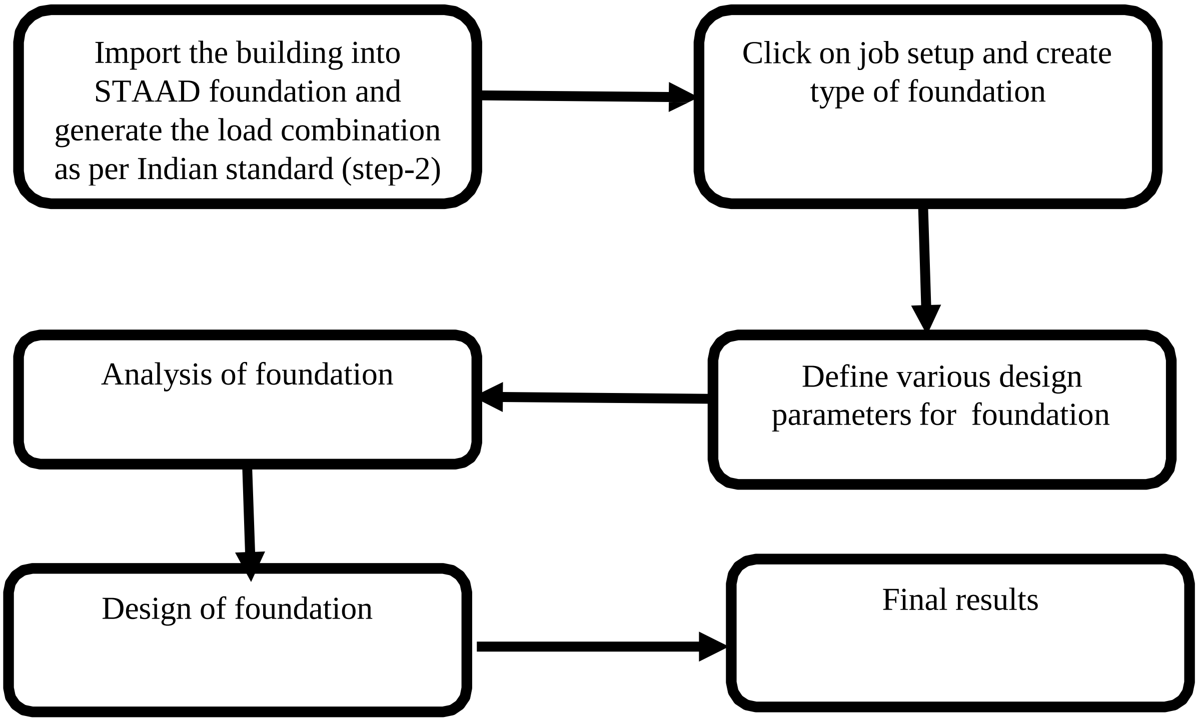



Table – 2

| S.No. | **Soil Description (**According to BS:8004-1986**)** | |
|---|---|---|
| **1** | Soil Type | Silty sand |
| **2** | Soil Density | 22 KN/$m^3$ |
| **3** | Soil Bearing Capacity | 150 KN/$m^2$ |
| **4** | Cohesion | 13 KN/$m^2$ |
| **5** | Subgrade Modulus | 18000 KN/$m^3$ |
| **6** | Coefficient of friction | 0.5 |
| **7** | Factor of safety against Overturning | 1.5 |
| **8** | Factor of safety against Sliding | 1.5 |



## 1.7 Organization of Project

**Chapter 1:** In this chapter, brief introduction about Foundation, functions of Foundation, failures in Foundation, types of Foundation, motivation and an overview of methodology and also the objectives of project.

**Chapter 2:** In this chapter, we discuss the literature review (i.e., the previous work done), which has been reviewed to Know various important measures which can applied to our project. This chapter also includesaSummary of literature review.

**Chapter 3:** In this chapter, we discuss the theoretical information need in the project like Isolated, Combined, Mat Foundation and its types and also the information about the Software used (i.e. STAAD Pro and STAAD Foundation).

**Chapter 4:** This chapter contains the methodology which has been used to analyze & design the building and various types of Foundation.

**Chapter 5:** This chapter contains the results obtained from STAAD software, which includes Axial Force, Shear force and Bending Moment and also its graphical representation.

**Chapter 6:** This chapter concludes the study based on the results obtained and future scope of project is being mentioned.

# CHAPTER 2

# LITERATURE REVIEW

## GENERAL

Extensive literature review has been carried out in this study related to following and outcomes of different authors summarised below:

- **Won Taek Oh &Sai K. Vanapalli (2019)** in their study, proposed a methodology to estimate the bearing capacity and settlement in unsaturated sandy soils by predicting the stress versus settlement behavior. In addition, finite element analyses were also undertaken using the model Footing test results to simulate the stress versus settlement behavior.

- **Dineshh S.Patil and Anil S.Chander (2016)** Study a comparative of price of many kinds of Foundation as an example, Pad Footing, quadrangle Footing, Stepped Footing. These Foundation are accustomed estimate the cost of an optimized style of concrete Footing base on structural safety. Foundation is that the interface between the structure building and also the ground. Its task is to transfer safely the building load into the bottom and to stay settlement as tiny as potential.

- **Luévanos and Roja (2016)** comparative study for the planning of concrete isolated Footing that square measure rectangular or circular in form and subjected to axial load and moments in two directions victimization new models to get the foremost economical Footing. The new models take into consideration the important soil pressure working on contact surface of the Footing and this pressure is completely different all told the contact space, with a linear variation, this pressure is bestowed in terms of the axial load, the larger moment around the "X" axis and also the smaller moment around the "Y" axis, wherever the centre of mass axes are "X" and "Y" of the Footing.

- **R.K. Tripathi et.al. (2015)** experimentally studied the bearing capacity of square Footing on soft soil stabilized with rice husk ash. From the laboratory test considerable increase in UCS, BCR and reduction in settlements have been observed. 12 % rice husk ash has been observed as optimum dose for stabilizing the soft soil.

- **Bengt H. Fellenius et al. (2014)** investigated the results of finite element analysis of settlement for Footing of three sizes placed in two different sand types and conclude that the settlement in sand is a direct function of neither Footing size nor soil density, instead, the settlement should be related to the steady state line of the sand and to the upsilon distance of the sand, that is, the initial void ratio distance to the steady state line at equal mean stress and at homologous points.

- **Dewaikar et al. (2011)** (principle and numerical method of finite element method) observed on the model circular Footing with reinforced soil to study the load settlement behaviour. The study shows the provision of a single layer reinforcement, ultimate bearing capacity increases and settlement decreases. Further, in case of BCR and SRF rubber grid performed better than the geo-grid.

- **Nagaraj T.K. Ullagaddi (2010)** studied experimentally the effect of shape and size of Footing on sand Foundation. Using circular, square and rectangular model Footing of different area they concluded that square Footing shows better load settlement behaviour for a given settlement indicating higher load carrying capacity.

## SUMMARY OF REVIEW OF LITERATURE

After reading review of literature given above that the effect of shape and size of Footing on different types of soil, using circular, square and rectangular model of Footing of different area they concluded that square Footing shows better load settlement behaviour for a given settlement, indicating higher load carrying capacity.

They did comparative study for the planning of concrete isolated Footing subjected to axial load and moment in two directions, victimization new model to get the foremost economical Footing. They conclude that the contact space with a linear variation this pressure is bestowed in terms of axial load, the larger moment around X-axis and also the smaller moment around the Y-axis, where ever the centre of mass area X and Y of the Footing.

# CHAPTER-3

# THEORETICAL BACKGROUND

## 3.1 FOUNDATION DESIGN:

Foundation are the base and support in the structural system that transmit the superstructure's loads directly to the earth. All civil engineering structures require Foundation to keep the structure from leaning or buckling. Buildings bestow their weight and loading onto their Foundation; therefore, the Footing needs to be designed to withstand the weight of the building.

The Foundation design process cannot begin until the loads have been calculated. There are several different types of design loads including: normal loads, shear loads, moment loads, and torsion loads. Where weather is applicable, the bottom of the Foundation must be constructed below the frost line to prevent cracking from freeze-thaw cycles.

Since, Manual methods contain so many troubles in Calculations. So, we use Soft Computing Software STAAD Pro. and STAAD Foundation for Calculations and Analysis.

### 3.1.1 ISOLATED FOOTING

Isolated support the structural system of small to medium structures. These Footing are used to transmit a load from columns to the soil beneath it. If the soil supporting the column is weak or the column loading is too heavy, the isolated Footing needs to be designed a lot larger. Isolated Footing are more economical because less material is needed to create the Footing than a normal spread Footing.

The categories of isolated Foundation Footing are the following:

**1. Pad Footing**

A pad or flat isolated Footing is constructed by plain or reinforced concrete. Its thicKNess is constant and its shape can be circular, rectangular or square. It is economic and requires less excavation but its size is highly depended on the load and it is less resistant in lateral forces.

**2. Sloped Footing**

Sloped isolated Footing requires less concrete and reinforcements bars than pad Footing. It is constructed cautiously in order to maintain a 45-degree inclination from all sides. The concrete mix used must be stiff in order to avoid sustaining viscous deformation.

**3. Stepped Footing**

This type of Footing includes the construction of a Footing step by step until it reaches the desired width. This technique is mostly used in residential buildings but its utilization has been decayed over the last decades.

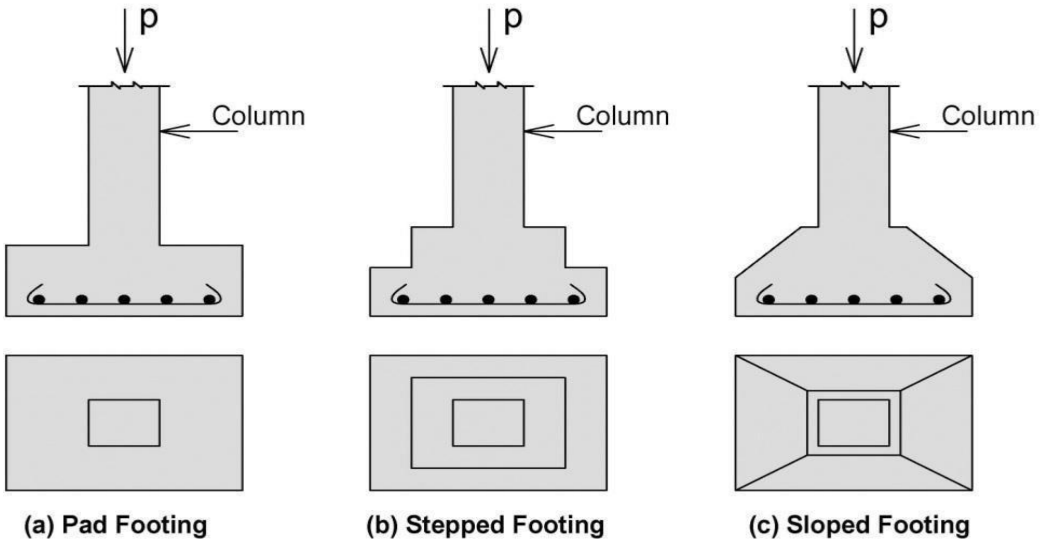



Figure-4 Isolated Footing

### 3.1.2 COMBINED FOOTING

Combined Footing receive loading from more than one column or load-supporting element. Each column applies their own individual loading to the Footing. The columns can be located at any distance from the Footing ends, however, they must lie on the center line along the longer axis of the Footing.

Combined Footing are most commonly designed with a rectangular or trapezoidal geometry.

- Rectangular Footing is provided when one of the projections of the Footing is restricted or the width of the Footing is restricted.
- Trapezoidal Footing is provided when one column load is much more than the other. As a result, the both projections of Footing beyond the faces of the columns will be restricted.

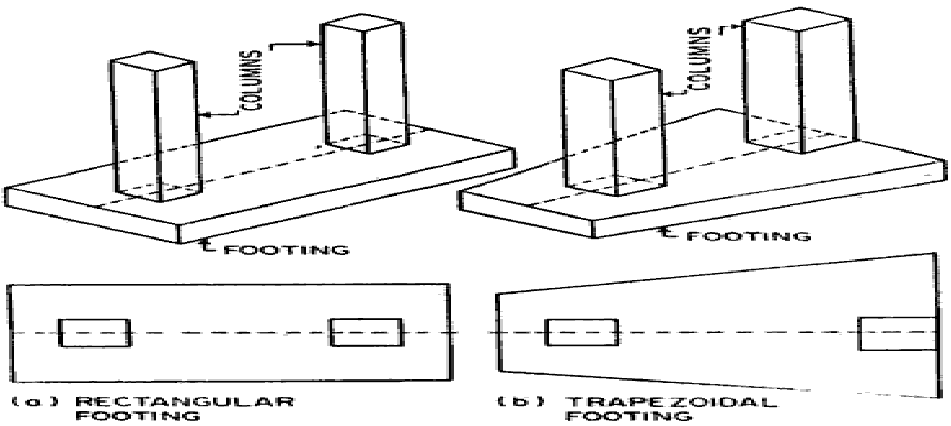



Figure-5 Combined Footing

### 3.1.3 MAT FOUNDATION

A raft or mat Foundation is a large continuous rectangular or circular concrete slab that carries the entire load of the superstructure and spreads it over the whole area beneath the building. It is considered as one type of shallow Foundation and is useful in controlling the differential settlement.

A mat Foundation spreads out under the footprint of the building and declines the contact pressure compared to conventional strip or trench Footing.

It is a suitable solution for low bearing capacity soil, spread Footing cover about 70% of the structure, high structure loads, soft pockets or cavities of in the soil to unKnown extent raft, and highly compressible soil that extends to a great depth.

**Functions of MAT Foundation:**

1. Transfer superstructure loads and spread it over the entire area of the building footprint.
2. Reduce differential settlement of structures constructed over weak soil.

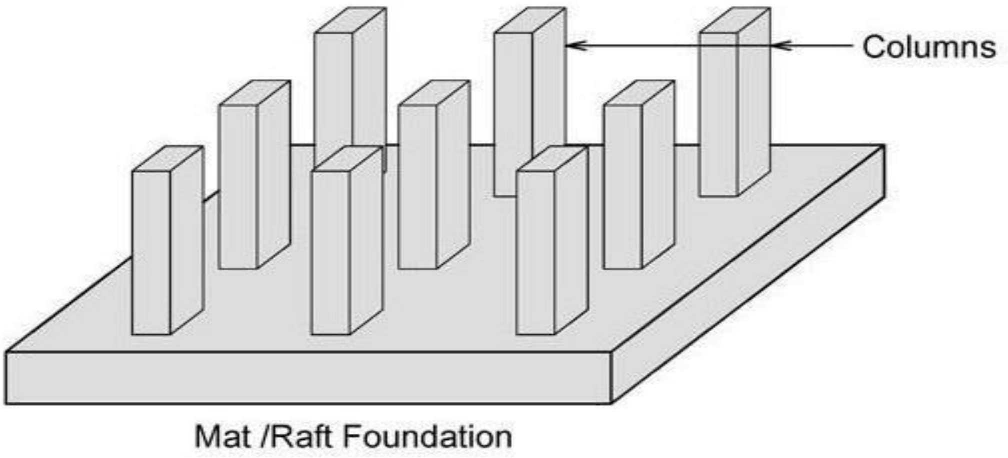



Figure-6

## 3.2 SOFTWARE USED

## 3.2.1 STAAD.Pro

STAAD Pro. is a structural design-oriented program with a user interactive interface which allows for the user working on it extremely easy.
It can be used for modeling, designing and analysing various structures and structural configurations.
STAAD Pro. programming is broadly utilized as a part of the structural analysis and designing structures – towers, buildings, bridges, transportation facilities, utility and industrial structures. Designs can include building structures incorporating culverts, petrochemical plants, bridges, tunnels, piles; and construction materials such as timber, steel, concrete, aluminium and cold-formed steel.
It is extremely useful for buildings and other such structures insignificant of their uses varying from residential to commercial to hospitals to offices. This software can be used for all kinds of buildings of various architectural drawings under a plethora of loads.

### 3.2.1.1 Features of this Software:

Features are given below on which STAAD Pro works:

1. **Model Generation:** Interaction based menu-driven model creation with concurrent 3D display 2Dand 3D graphics creation utilizing rectangular or polar coordinate frameworks Segments of redundant geometry used to produce complex structural models

2. **Model Verification:** On screen 3D/2D drawings and in addition to plotter/printer Full 3D shapes for outlines, components Isometric or any rotations for a full 3D view.

3. **Secondary Analysis:** Limited component capacities, concrete design, steel design and timber design. Displacements and forces at portions between nodes. Minimum and maximum force envelopes.

4. **Static Analysis:** The 2d/3d analysis in view of state-of-the-art Matrix strategy to deal with a substantial degree of the job. Linear, analysis of p-delta, non-linear examination with automatic load and stiffness amendment.

5. **Seismic/Dynamic Analysis:** Mass modeling, extraction of recurrence and mode shapes Response spectrum, time history examination Modal damping proportion for individual models.

### 3.2.1.2 Advantage of using STAAD Pro. Software :

- It is faster method of designing the structure
- It does not involve any manual calculation.
- It is suitable for all types material for designing i. e. Concrete, Steel, Aluminium etc.
- It shows accuracy in results i.e. Shear Force, Bending moment diagram for each and every beam and column of the structure.
- We can design structure for any type of load i. e. Dead load, Live load, wind load, snow load, area load, floor load etc.
- We can import designs from Auto CAD to STAAD Pro.using extension DXF .

#### 3.2.1.3 Limitations:

- It is not suitable for brick masonary work.
- It does not show the amount of material used.
- It can not be used for costing and estimating.
- In this software proper skill for typical designs is required.

### 3.2.2 STAAD Foundation

STAAD Foundation analysis and design software addresses the building, plant, and tower industries by offering basic Foundation such as isolated, combined, pile cap, and mat to specialized Foundation including horizontal vessel Foundation, tank annular ringwall, lateral analysis of pile/drilled pier, and state-of-the-art vibrational analysis of machine Foundation. STAAD Foundation offers advanced calculation reports with to-the-scale Footing sketches, graphs, and formulae with code reference along with CAD exportable detail, schedule, and general arrangement (GA) drawings.

#### 3.2.2.1 Integrates common Footing designs:

The software integrates all common Footing designs including isolated Footing, combined Footing, pile-cap arrangement and design, octagonal Footing, mat Foundation, vibrating machine Foundation, drilled pier Foundation, and guyed tower Foundation. The plant Foundation mode in STAAD Foundation contains vertical vessel, horizontal vessel Foundation with different shapes, and configurations along with annular ring Foundation for self or mechanically anchored tanks, and laterally loaded drilled pier analysis.

#### 3.2.2.2 Integrates with STAAD.Pro, ISM, and Microsoft Excel:

STAAD Foundation is seamlessly integrated with STAAD.Pro, ISM (Integrated Structural Modelling) and Microsoft Excel.

#### 3.2.2.3 Finite Element Method (FEM):

Analysis for Accurate and Economical Designs STAAD Foundation designs complex Foundation using its object-based modelling environment via the mat Foundation module.

#### 3.2.2.4 Includes Plan, Elevation, and Sectional Views STAAD Foundation:

Advanced generates detailed drawings that include plan, elevation, and sectional views with rebar marks.

#### 3.2.3.1 Analysis and Design:

- It supports both flexible and rigid methods.
- They include complex FEM static analysis for mat Foundation and dynamic analysis for machine Foundation powered by reliable STAAD analysis.
- It has unlimited number of load cases and load combinations.
- It is User-defined reinforcing zones and blocks for optimal reinforcement distribution.
- It can give slab design along any cut line to simulate manual mat design technique.
- It also gives Pedestal design.

**3.2.3.2 Design Codes:**

There are nine codes which are being supported by STAAD Foundation and all these are mentioned below:

- United States » ACI 318-2005 » ACI 318-2008 » ACI 318-2011
- United Kingdom - BS 8110
- India - IS 456-2000
- Australia - AS 3600-2004
- Canada - CSA A 23.3-04
- Chinese - GB50007-2002
- Euro - EN 1992-1-1-2004

**3.2.3.3 Output of STAAD Foundation:**

- It is found in DXF (format) which can be export into G.A drawing.
- It gives detailed structural drawing with customizable drawing options and labels.
- Base pressure and plate stress color contours are also formed.
- Step-by-step detailed calculation sheet with code clauses and equations to verify output.
- It gives bending moment and shear force graphs for combined Footing in calculation sheet for critical load case.

# CHAPTER-4

# METHODOLOGY

In this study, we are comparing different shapes of Footing for same loading conditions. Following steps are followed in a row to complete the study are as follows:

**Step-1** First step is to review the literature related to our work done in past to justify the scope of work and configure Indian codes for further steps.

**Step-2** Second step is to use STAAD Pro. for design and analysis of Building (super structure).

a) Entering the STAAD Pro. Interface we have made some Important settings like Length units, Force units and select the Space and Add beam,

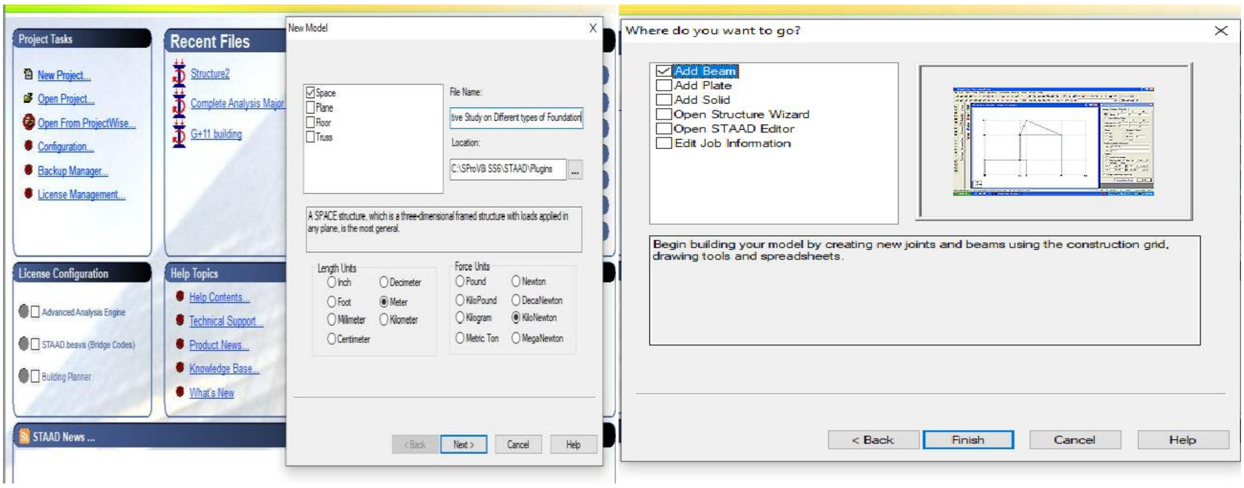



Figure-7: selecting the space and add beam option

b) Plan and Isometric view of building which further being analysed,

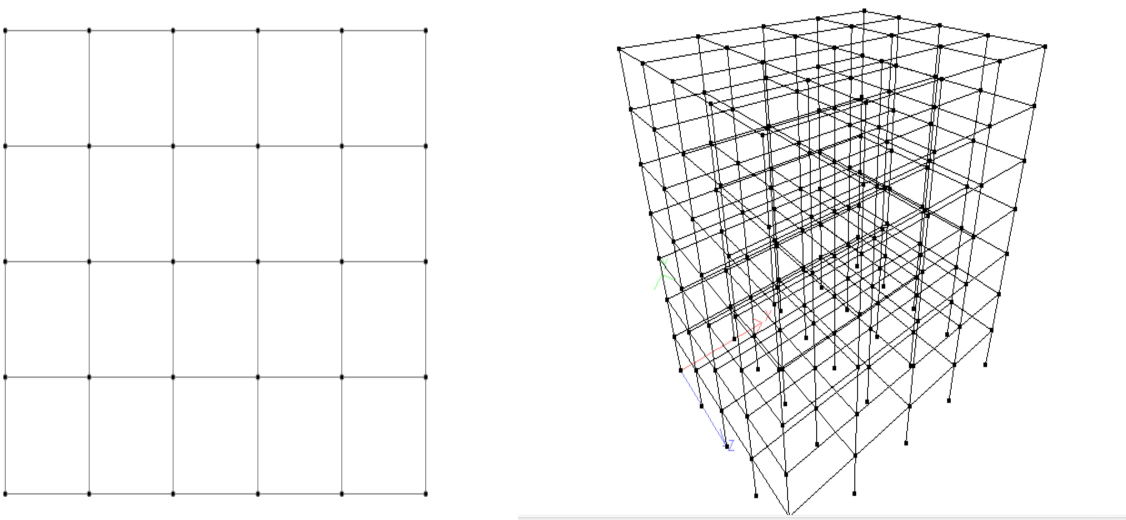


Figure-8 : Plan and isometric View of building

c) Used beam and column cross-section in building;

| Beam properties: | Column properties: | Slab properties: |
|---|---|---|
| Dimension (0.5m X 0.5m) | Dimension (0.45m X 0.45m) | Dimension (0.15m) |
| Material: Concrete (M30) | Material: Concrete (M30) | Material: Concrete (M30) |

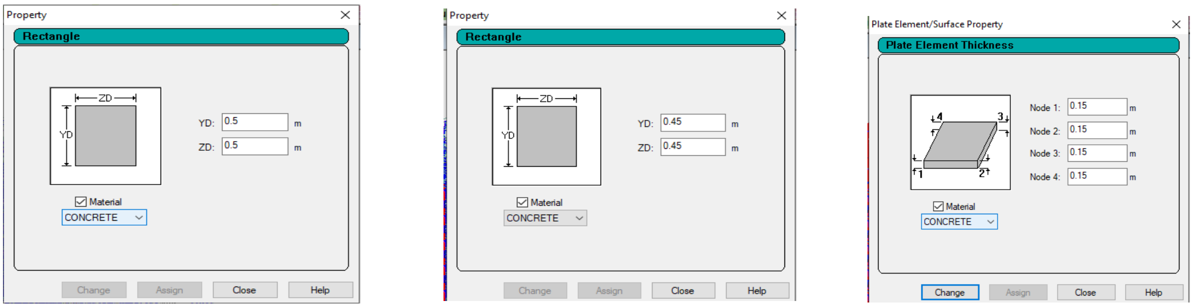



Figure-9: beam, column, slab properties

d) Beam, Slab and Column properties are being assigned,

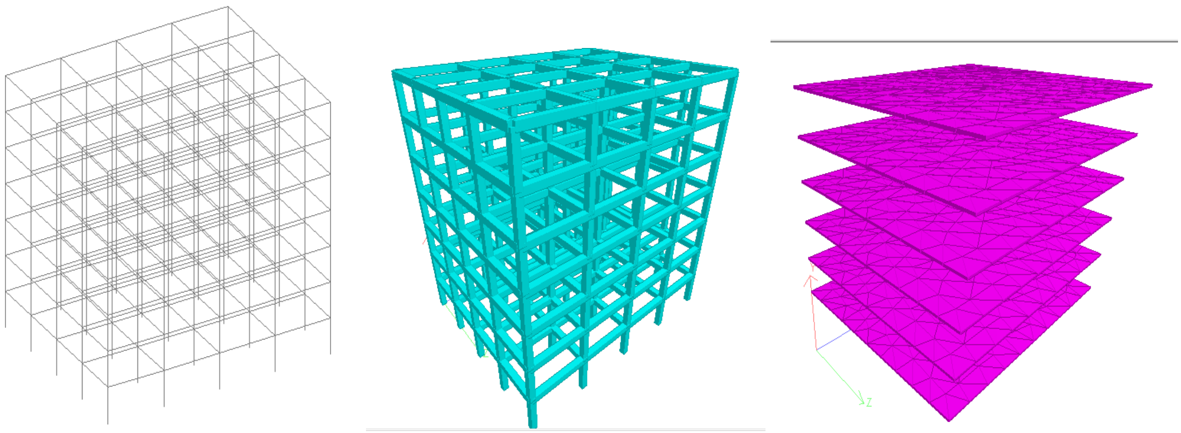


Figure-10: After assigning beam column and slab properties

e) After assigning the properties of beam, column and slab, fixed support is being provided,

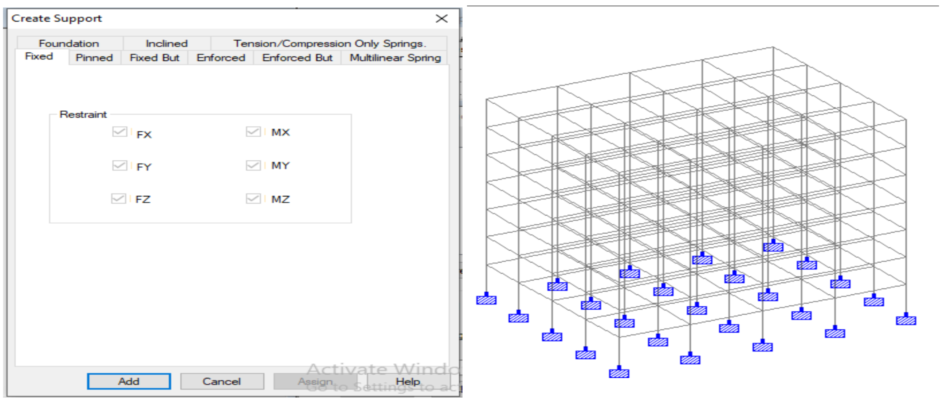



Figure-11: Assigned Fixed support to structure

f) Various load cases applied in building ;

(1) Seismic(Eq -X) - IS 1893:2016
(2) Seismic(Eq -Z) - IS 1893:2016
(3) Dead Load – IS 875-Part1
Selfweight-Y(-1)
Floor Load (GY-2.5KN/$m^2$)
Member Load (GY-7.5KN/m)
(4) Live Load – (GY-3KN/$m^2$) IS 875-Part 2

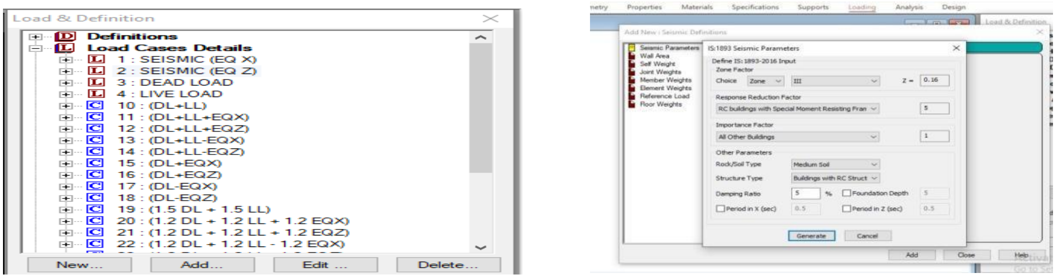



Figure-12: Various load cases applied to structure

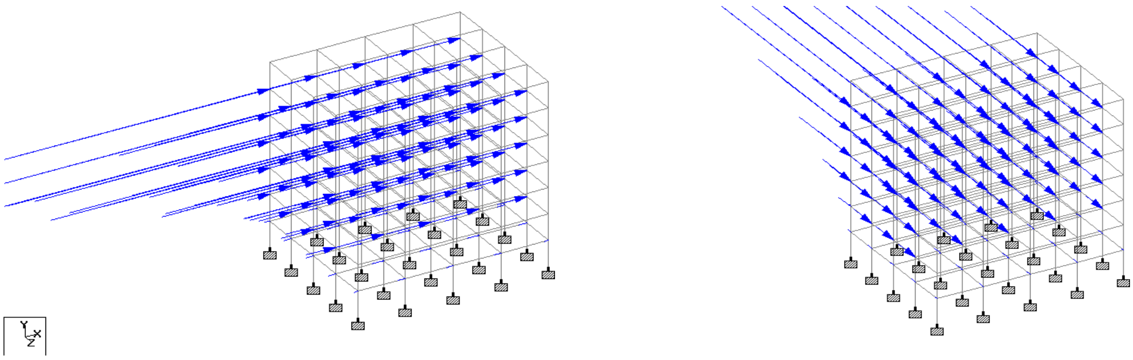


Figure -13 Seismic(Eq -X) assigned to structure Seismic(Eq-Z) assigned to structure

- Dead Load = (Breadth X Height)of member X unitweight of concrete

= (0.5x0.5)x25 = 6.25 KN/m

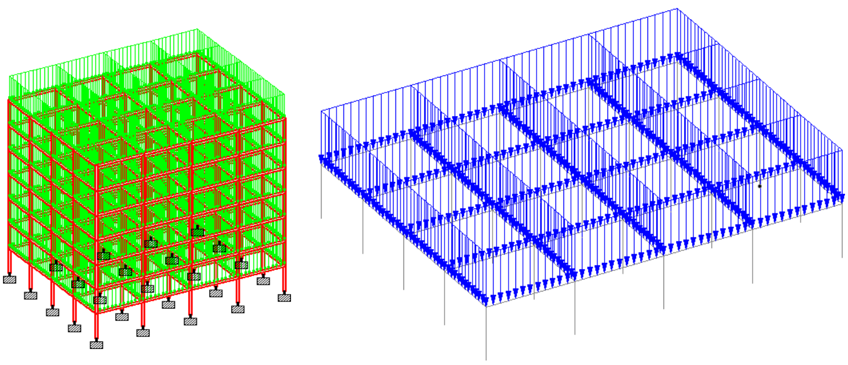


Figure-14: Dead load on the building

- Live Load : from IS code 875-Part 2 for Assembly Buildings / Hostels/ Hospitals/ Residential Buildings = 3KN/m$^2$.

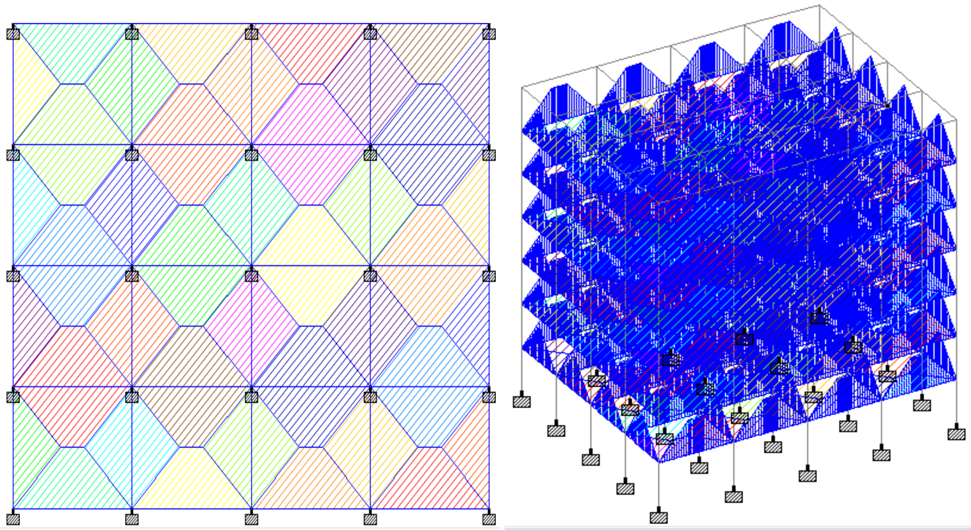


Figure-15: Live load on the building

g) After, applying the dimension properties and Load cases we analysed the structure.

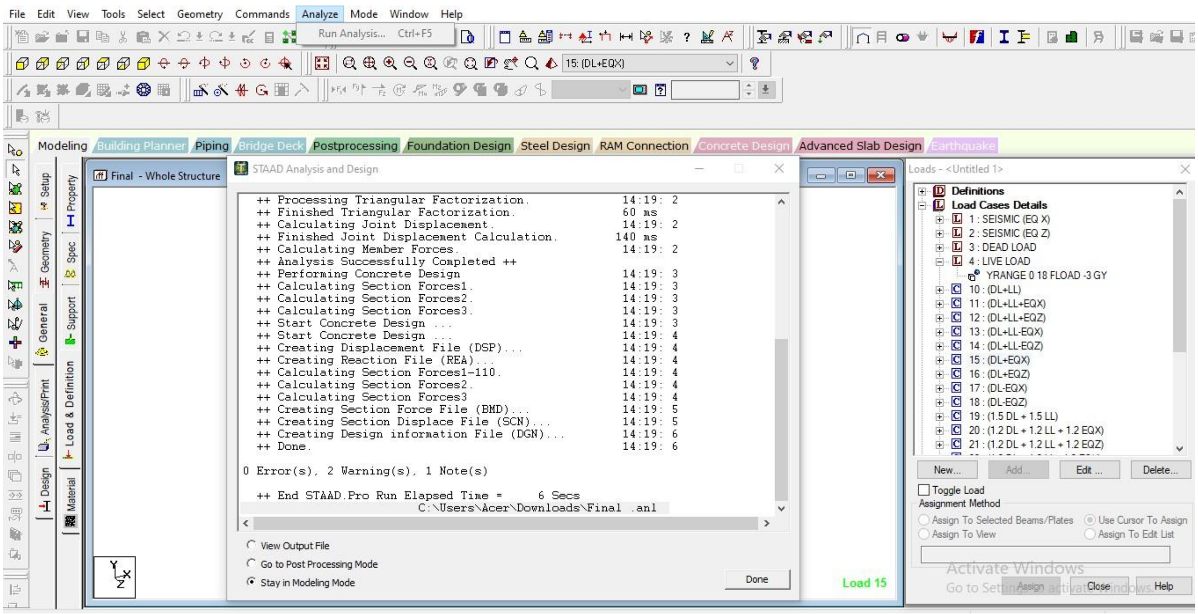



Figure-16: Analysis of the building

**Step-3** After analysing the structure, we import the structure into STAAD Foundation for designing the Footing and generate loading combination based upon Indian code.

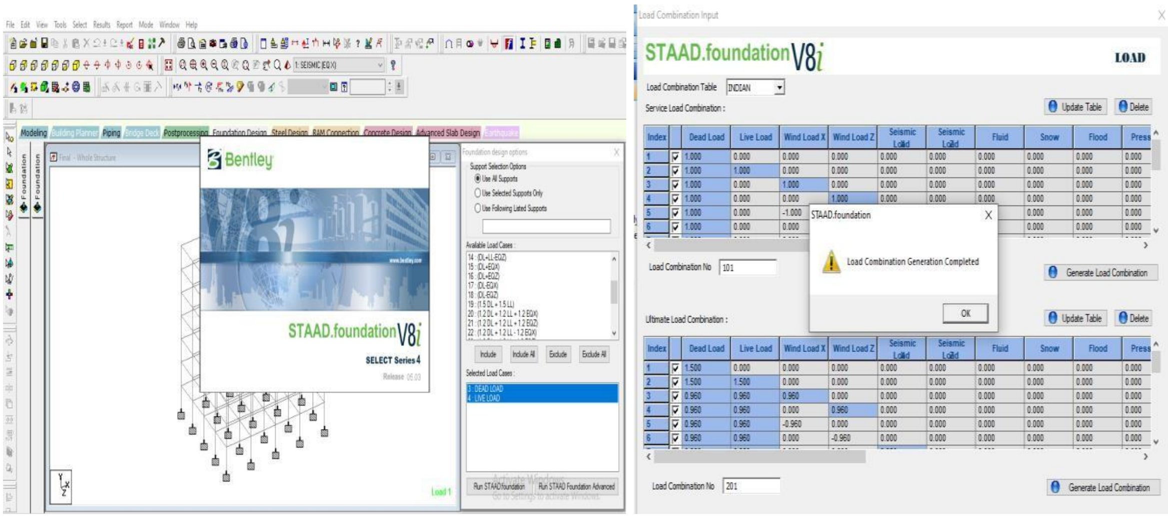



Figure-17: Importing file and Load generation STAAD Foundation

**Step-4** Fourth step is to use STAAD Foundation for design and analysis of various types of Foundation.

**4.1 Isolated Footing design:** for designing of Isolated Footing, we should have to define various parameters like;

**Concrete and rebar:**

Strength of concrete = 30 KN/$m^2$
Yield of concrete = 500KN/$m^2$

**Footing Geometry:**

Footing Type = Uniform ThicKNess
Length/Breadth = 2

**Cover and Soil:**

Soil Type = Silty Sand (Drained Condition)
Clear Cover = 50 mm
Soil Bearing Capacity = 150 KN/$m^2$
Cohesion = 13 KN/$m^2$

**Sliding and Overturning Factors:**

Factor of Safety against Sliding = 1.5
Factor of Safety against Overturning =1.5
Coefficient of friction = 0.5

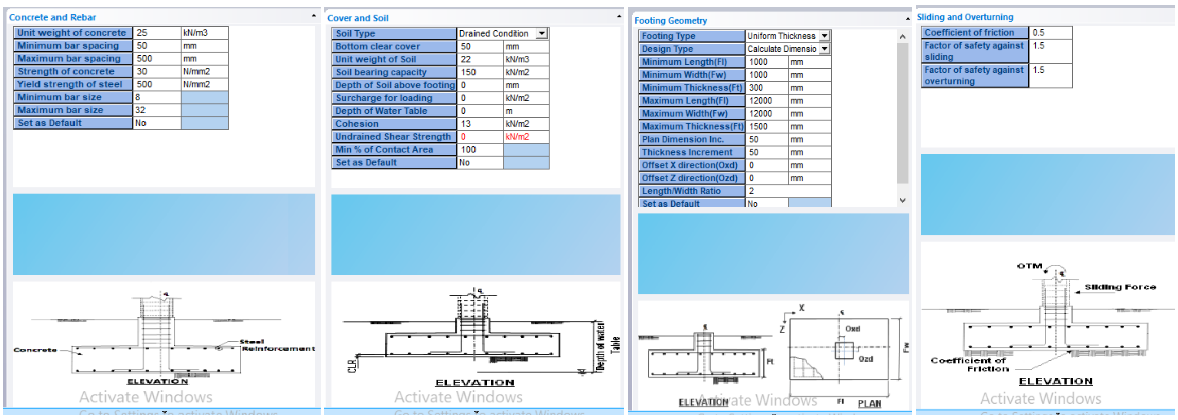



Figure-18: Defining various parameters of Isolated Footing

- After defining the design parameters, we analyze /design the isolated Foundation,

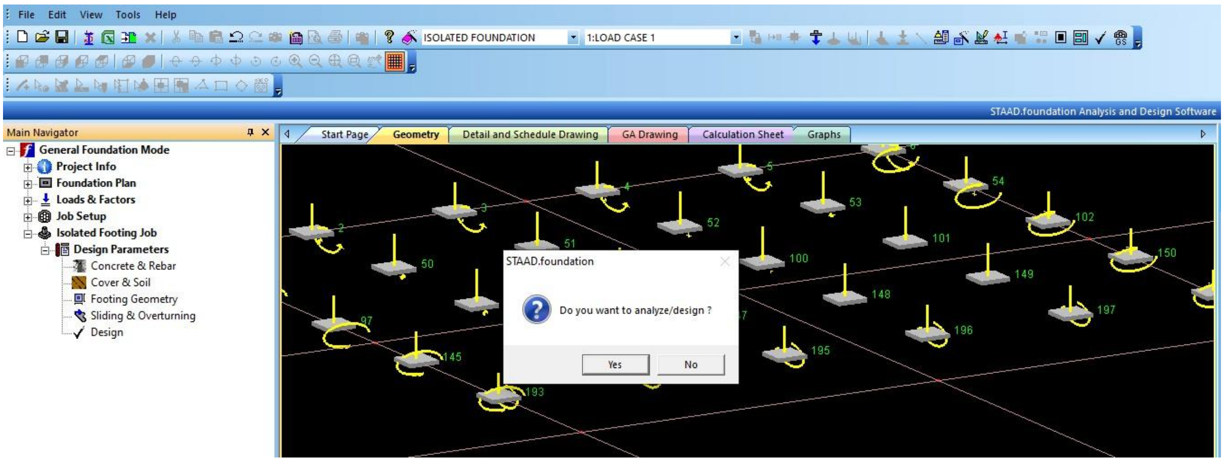


Figure-19: Analysing the Isolated Footing

**4.2 Combined Foundation design:** for designing of Combined Footing, we should have to define various parameters like;

a) Concrete and rebar
b) Cover and Soil
c) Footing Geometry

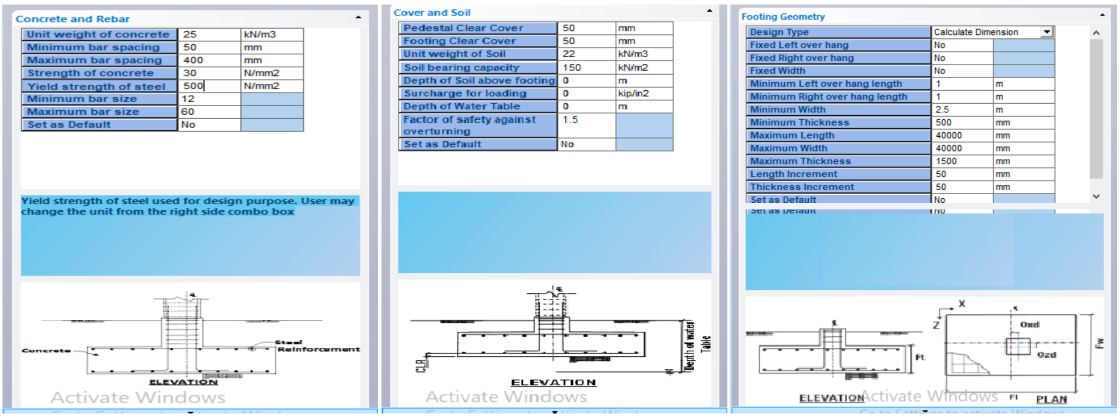


Figure-20: Defining various parameters of Combined Footing

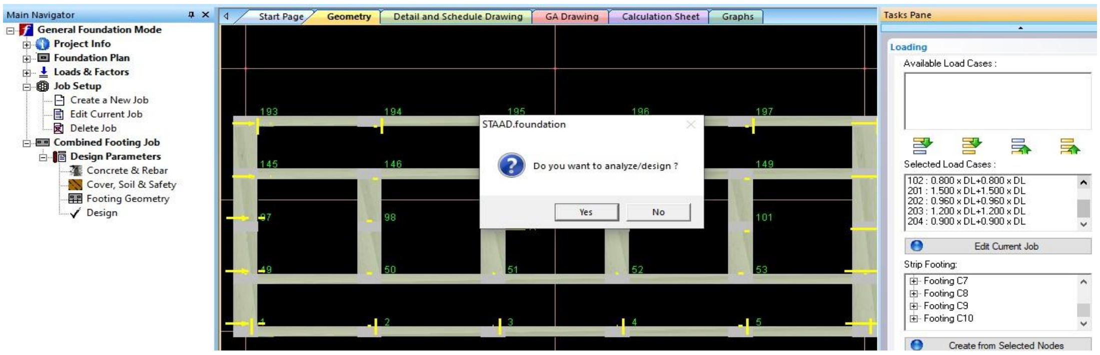


Figure-21: Analysing the Combined Footing

**4.3 Mat Foundation design**: For designing of MAT Footing, we should have to define various parameters like;

a) Default properties
   Slab thickness = 600 mm
   Subgrade Modulus = 18000 KN/$m^3$

b) Mesh Generation
   i. Define Rectangular Region
   ii. Meshing Setup

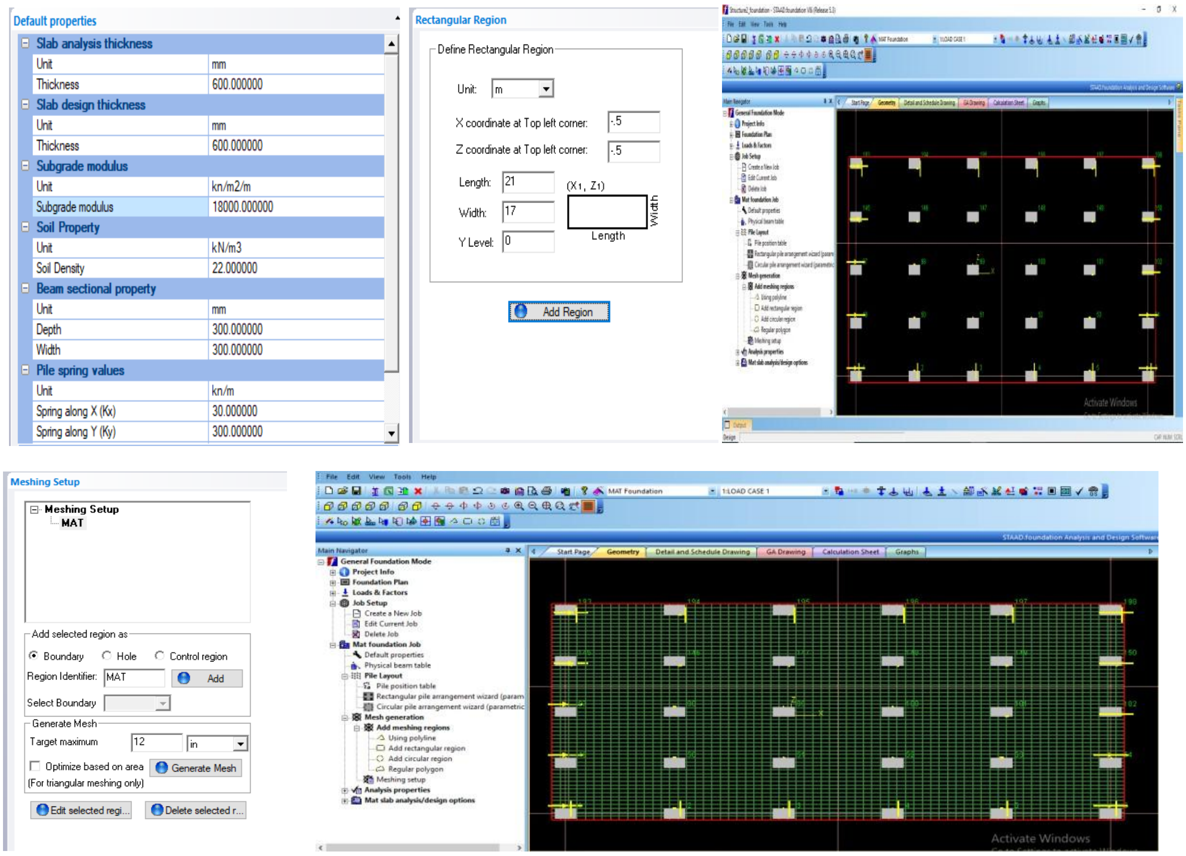



Figure-22: Defining parameters and mesh generation

c) Analysis: After mess generation we analyse the Foundation,

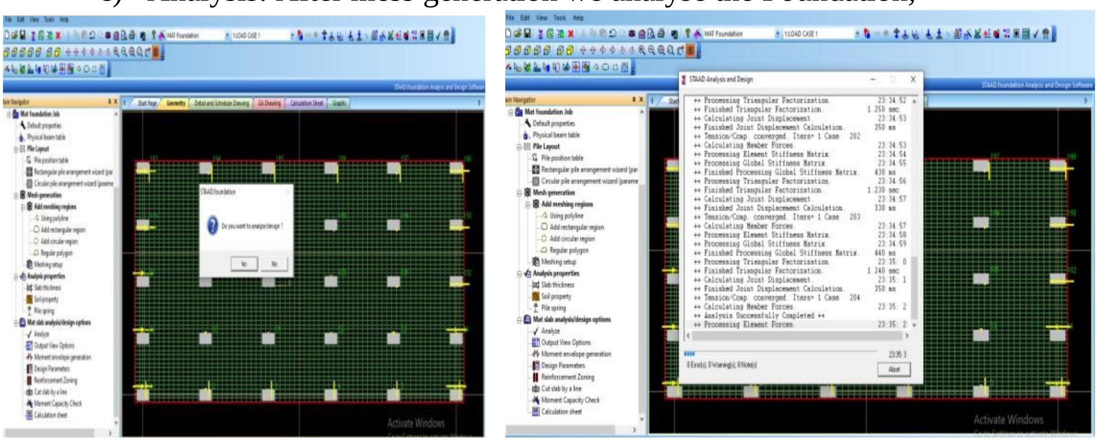


Figure-23: Analysing the Mat Footing

d) Design: After analysing the Foundation, we generate moment envelope over Foundation and design Mat Slab after defining design parameters.

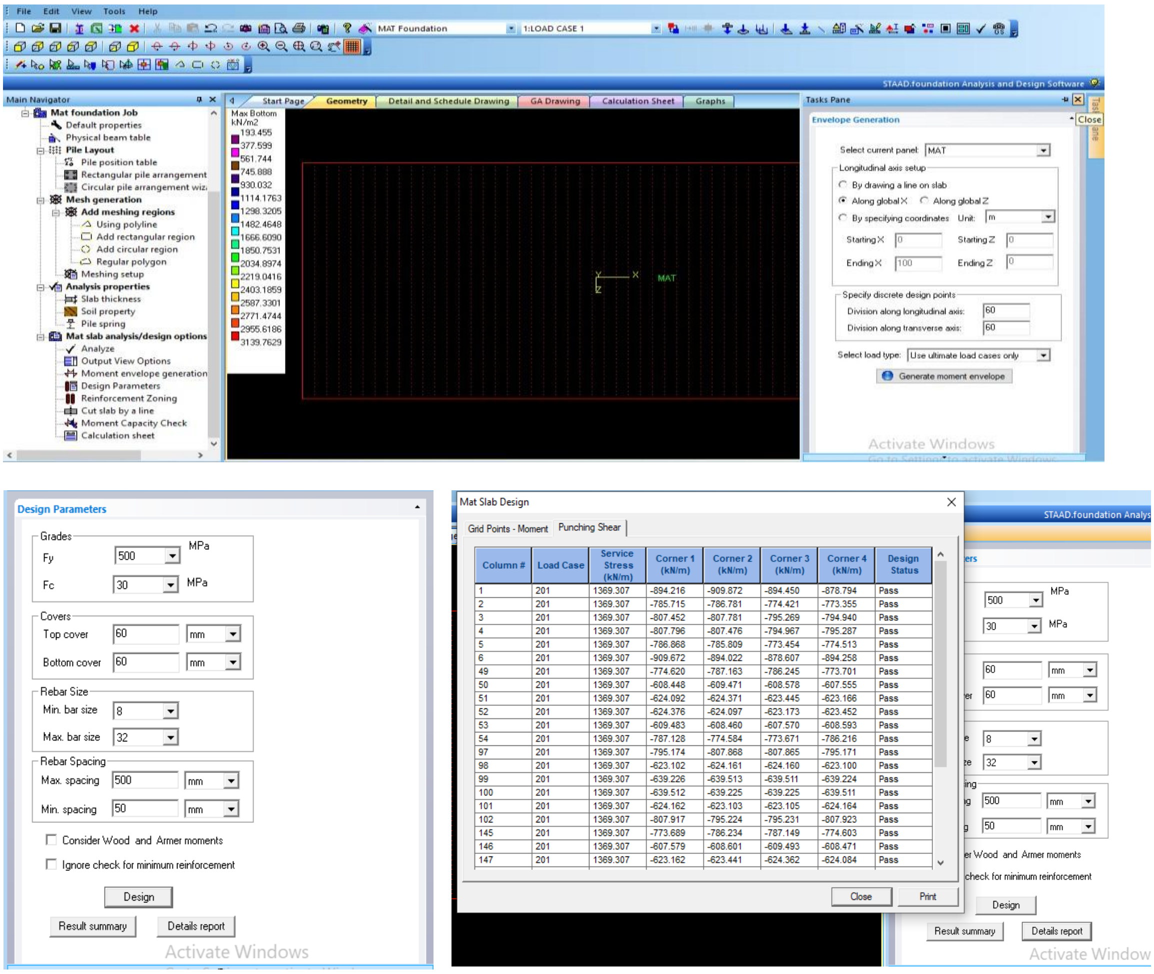



Figure-24: Defining parameters and design of mat slab

**Step-5** We Conclude and Compare our various Foundation Design Results.

# CHAPTER-5

# RESULT AND DISCUSSION

## RESULT

Result of all three Footing has been shown according to the STAAD outputs, the results shown consist value of Axial load, shear stress and bending moment shown graphically and in tabular form. Later value of Axial load, Shear stress and Bending moment of each Footing of a particular Foundation is plotted on a graph separately so that the maximum value reached Footing of each Foundation can be taken to compare with other Foundation.

### 1) ISOLATED FOOTING:

These are the plan and elevation of considered isolated Foundation in which Footing depth soil depth Footing width and critical section of the Footing is clearly shown.

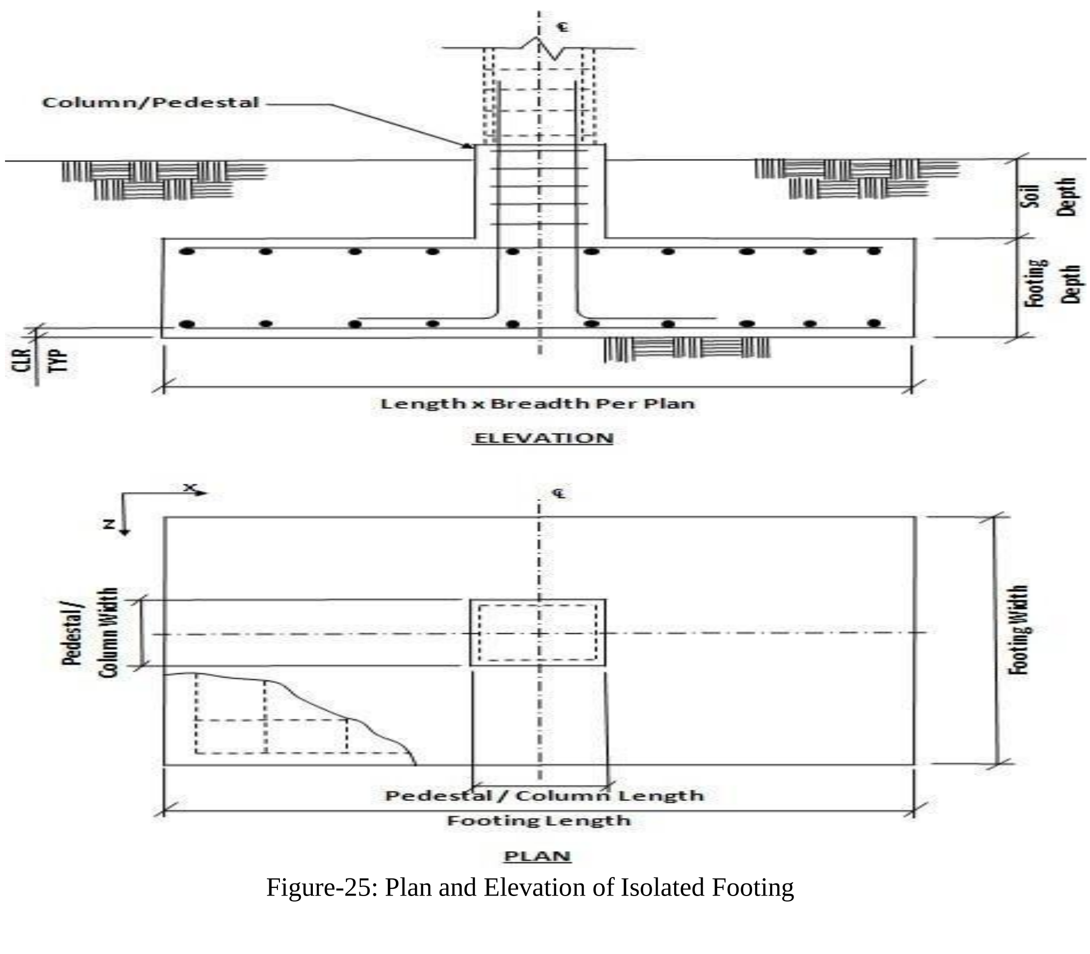



Figure-25: Plan and Elevation of Isolated Footing

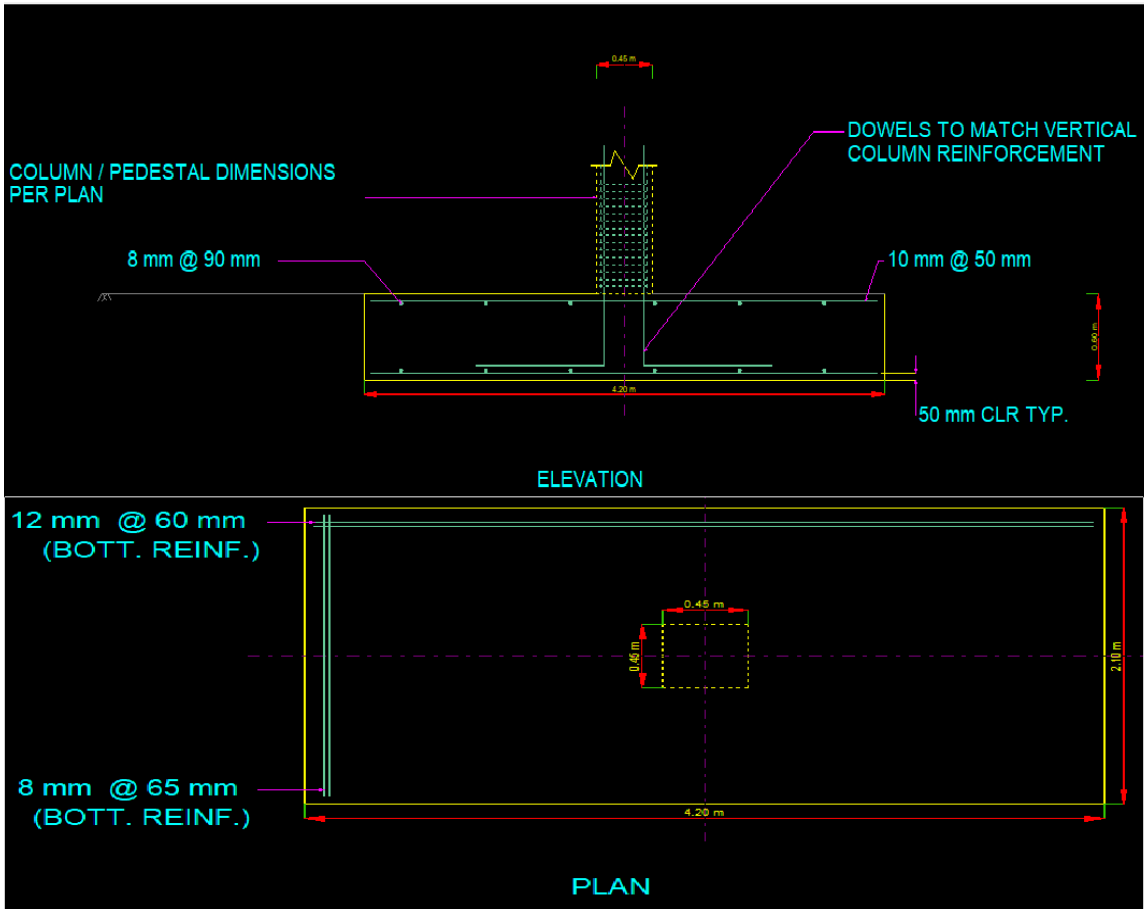



Figure-26: Plan and Elevation of critical (73) Isolated Footing

A total of 25 isolated Footing was designed and analysed by the STAAD Foundation for the provided plan area, building load and soil conditions.

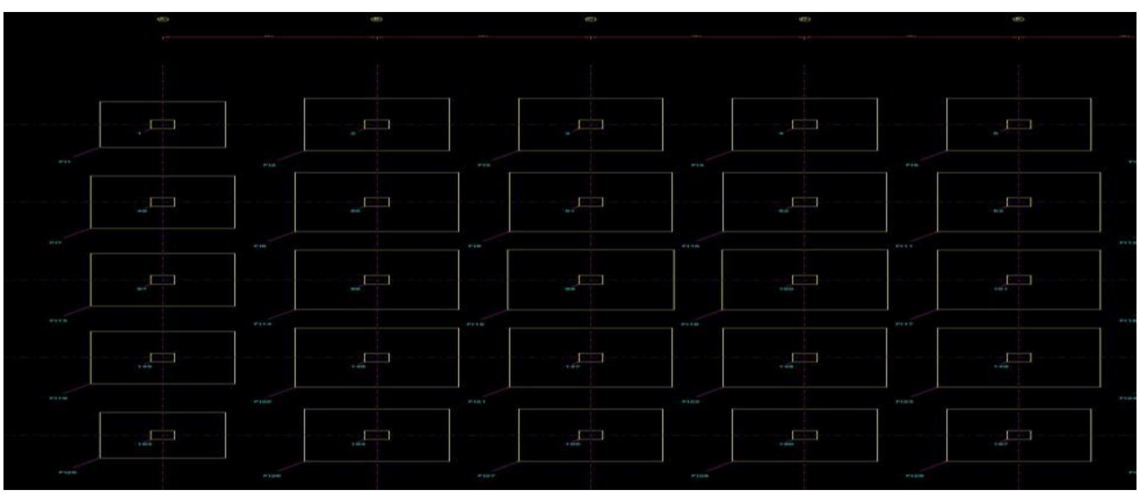


Figure-27: Plan of Isolated Foundation

Out of 25 Footing the Footing with maximum value of shear stress (Footing NO-73) is considered for comparison with shear stress of other types of Footing.
The moment of this Footing is also used for comparison with moment of other type of Footing.
The number of different load combinations applied by the STAAD software are shown in the table below:

Table -3 Load Combinations

| **Load Combination/s- Strength Level** | | |
|---|---|---|
| **Load Combination Number** | **Load Combination Title** | **Axial Load (KN)** |
| 3 | DEAD LOAD | 909.710 |
| 4 | LIVE LOAD | 361.859 |
| 201 | 1.500 x DL+1.500 x LL | 1907.353 |
| 202 | 0.960 x DL+0.960 x LL | 1220.706 |
| 203 | 1.200 x DL+1.200 x LL | 1525.882 |
| 204 | 0.900 x DL+0.900 x LL | 1144.412 |

Here we can observe that Load combination number 201 is proving to be the critical load combination. Hence the calculation of shear stress and moment of this Footing is done by using the load combination 201.

The area and dimensions of Footing are calculated by STAAD that could bear the applied load of the building.

The pressure at four corners of the Footing is checked for any uplift pressure adjustment, so that it can be made sure that whole area of Footing is in contact with the soil surface.

Pressures at Four Corner

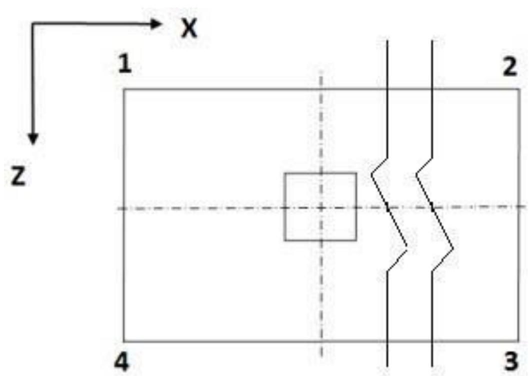



Figure-28: Plan of Isolated footing showing pressure

Table-4 Pressure at corners

| Load Case | Pressure at corner 1 ($q_1$) (KN/m2) | Pressure at corner 2 ($q_2$) (KN/m2) | Pressure at corner 3 ($q_3$) (KN/m2) | Pressure at corner 4 ($q_4$) (KN/m2) | Area of Footing in uplift ($A_u$) ($m^2$) |
|---|---|---|---|---|---|
| 101 | **148.7267** | 148.7267 | 148.7267 | 148.7267 | 0.000 |
| 101 | 148.7267 | **148.7267** | 148.7267 | 148.7267 | 0.000 |
| 101 | 148.7267 | 148.7267 | **148.7267** | 148.7267 | 0.000 |
| 101 | 148.7267 | 148.7267 | 148.7267 | **148.7267** | 0.000 |

Overturning and sliding of Footing in X and Z direction is checked by the STAAD software

Table -5 Sliding and overturning check

| - | Factor of safety against sliding | | Factor of safety against overturning | |
|---|---|---|---|---|
| Load Case No. | Along X-Direction | Along Z-Direction | About X-Direction | About Z-Direction |
| 3 | N/A | N/A | N/A | N/A |
| 4 | N/A | N/A | N/A | N/A |
| 101 | N/A | N/A | N/A | N/A |
| 102 | N/A | N/A | N/A | N/A |

Moment in X and Z directions is calculated according to the critical load case 201.

Similarly, one way shear and two-way shear are calculated for the critical load case 201. And we consider 2way shear for the comparison with different Footing.

## DISCUSSION

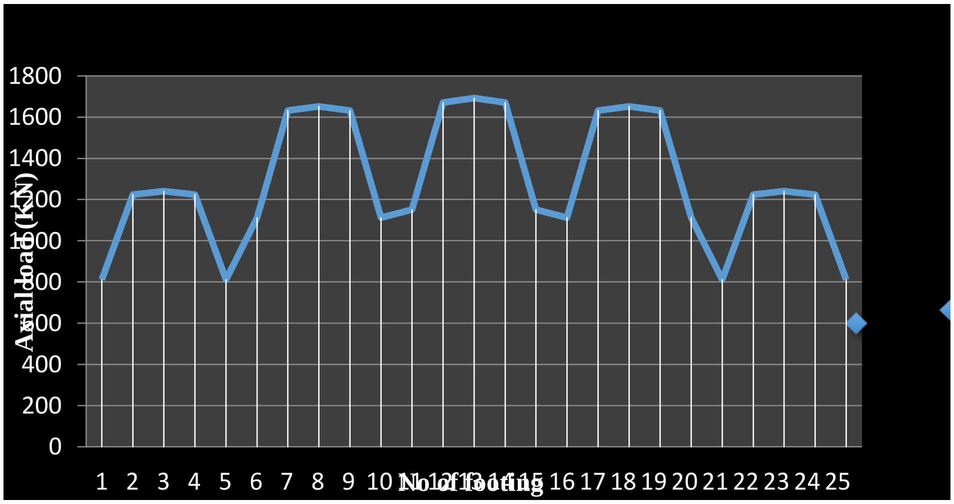
The values of Axial load, shear stress and moment according to load case 201 can be observed by the table below here the Footing showing the maximum value of axial load, shear stress and moment (highlighted) and this maximum value is taken into consideration when comparing with the Axial load, shear stress and moment of other Footing.

Table -6 Axial load, shear stress and moment

| Axial load KN | Shear stress KN/$m^2$ | Moment KN-m |
|---|---|---|
| 810.749 | 735.932 | 269.419 |
| 122 3.654 | 765.519 | 494.777 |

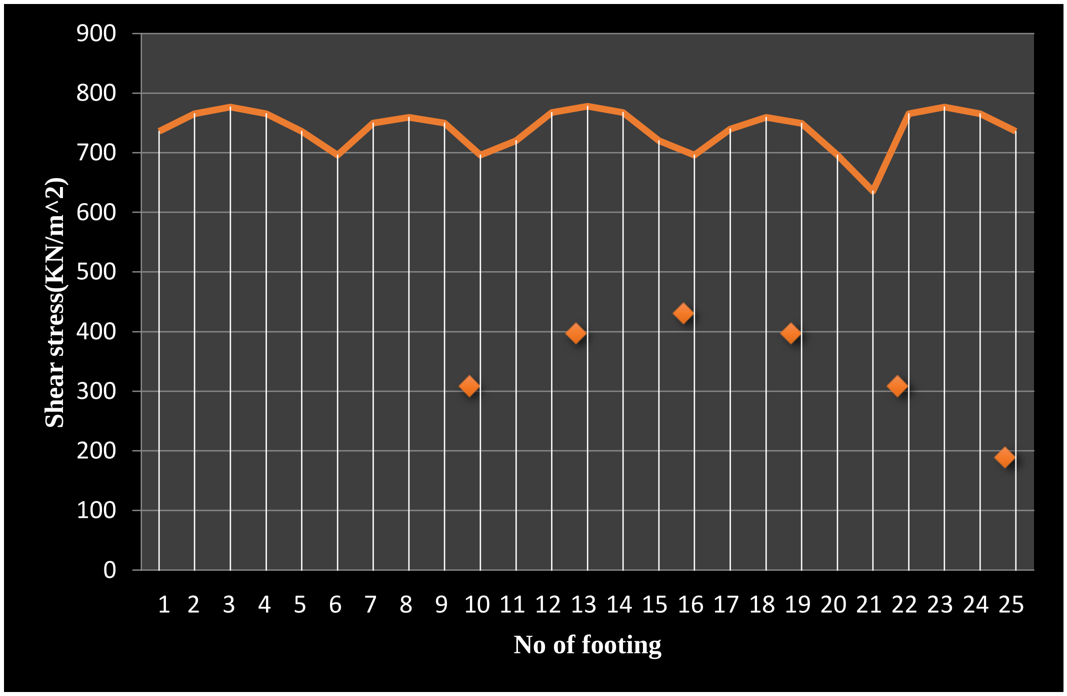
| | | |
|---|---|---|
| 1241.691 | 776.803 | 501.95 |
| 1223.654 | 765.519 | 494.777 |
| 810.749 | 735.932 | 269.424 |
| 1112.658 | 696.079 | 431.714 |
| 1631.297 | 749.935 | 769.4 |
| 1652.887 | 759.856 | 779.43 |
| 1631.297 | 749.931 | 769.41 |
| 1112.658 | 696.079 | 431.721 |
| 1151.303 | 720.256 | 459.153 |
| 1670.169 | 767.8 | 787.738 |
| 1692.826 | 778.216 | 798.264 |
| 1670.169 | 767.8 | 787.738 |
| 1151.303 | 720.256 | 459.16 |
| 1112.658 | 696.079 | 431.714 |
| 1631.297 | 739.931 | 769.4 |
| 1652.887 | 759.856 | 779.43 |
| 1631.297 | 749.391 | 298.155 |
| 1112.658 | 696.079 | 431.721 |
| 810.75 | 635.932 | 269.419 |
| 1223.655 | 765.519 | 494.777 |
| 1241.691 | 776.803 | 501.95 |
| 1223.655 | 765.519 | 494.778 |
| 810.749 | 735.932 | 269.424 |

- The graph of Axial load VS number of Footing (25) in isolated Foundation is shown.



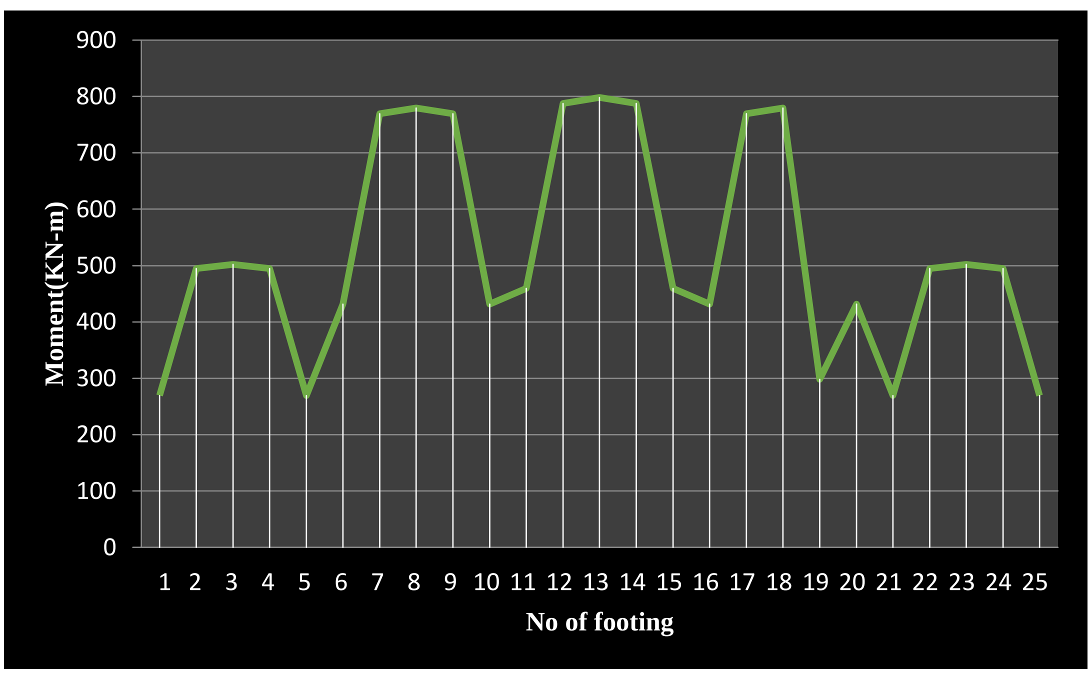

Graph 1: Axial load VS number of Footing

- The graph of Shear stress VS number of Footing (25) in isolated Foundation is shown.




Graph 2: Shear stress VS number of Footing

- The graph of Moment VS number of Footing (25) in isolated Foundation is shown.




Graph 3: Moment VS number of Footing

## DESIGN OF FOOTING

This column contains the geometry of isolated Foundation like value of length, width and thickness of all Footing i.e., isolated Foundation.

Table – 7 Geometry of foundation

| **Footing No.** | **Foundation Geometry** | | |
|---|---|---|---|
| | Length | Width | Thickness |
| 1 | 3.100 m | 1.550 m | 0.401 m |
| 2 | 3.700m | 1.850m | 0.501 m |
| 3 | 3.700m | 1.850m | 0.501 m |
| 4 | 3.700m | 1.850m | 0.501 m |
| 5 | 3.100 m | 1.550 m | 0.401 m |
| 36 | 3.500 m | 1.750m | 0.501 m |
| 37 | 4.200 m | 2.100 m | 0.602 m |
| 38 | 4.200 m | 2.100 m | 0.602 m |
| 39 | 4.200 m | 2.100 m | 0.602 m |
| 40 | 3.500 m | 1.750 m | 0.501 m |
| 71 | 3.600 m | 1.800 m | 0.501 m |
| 72 | 4.200 m | 2.100 m | 0.602 m |
| 73 | 4.200 m | 2.100 m | 0.602 m |
| 74 | 4.200 m | 2.100 m | 0.602 m |
| 75 | 3.600 m | 1.800 m | 0.501 m |
| 106 | 3.500 m | 1.750 m | 0.501 m |
| 107 | 4.200 m | 2.100 m | 0.602 m |
| 108 | 4.200 m | 2.100 m | 0.602 m |
| 109 | 4.200 m | 2.100 m | 0.602 m |
| 110 | 3.500 m | 1.750 m | 0.501 m |
| 141 | 3.100 m | 1.550 m | 0.401 m |
| 142 | 3.700 m | 1.850 m | 0.501 m |
| 143 | 3.700 m | 1.850 m | 0.501 m |
| 144 | 3.700 m | 1.850 m | 0.501 m |
| 145 | 3.100 m | 1.550 m | 0.401 m |

This table contains the value of top and bottom reinforcement required for each and every Footing of isolated Foundation in both the direction, symbol shown like first value shows no. of reinforcement bars and second value shows diameter of reinforcement bars.

Table – 8 Reinforcement detail

| **Footing No.** | **Footing Reinforcement** | | | |
|---|---|---|---|---|
| | Bottom Reinforcement ($M_Z$) | Bottom Reinforcement ($M_X$) | Top Reinforcement ($M_Z$) | Top Reinforcement ($M_X$) |
| 1 | Ø10 @ 60 mm c/c | Ø8 @ 100 mm c/c | Ø10 @ 70 mm c/c | Ø8 @ 135 mm c/c |
| 2 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 3 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 50 mm c/c | Ø8 @ 115 mm c/c |
| 4 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 5 | Ø10 @ 60 mm c/c | Ø8 @ 100 mm c/c | Ø10 @ 70 mm c/c | Ø8 @ 135 mm c/c |
| 36 | Ø10 @ 55 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 60 mm c/c | Ø8 @ 115 mm c/c |
| 37 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 38 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 39 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 40 | Ø10 @ 55 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 60 mm c/c | Ø8 @ 115 mm c/c |
| 71 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 72 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 73 | Ø12 @ 60 mm c/c | Ø8 @ 65 mm c/c | Ø10 @ 50 mm c/c | Ø8 @ 90 mm c/c |
| 74 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 75 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 106 | Ø10 @ 55 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 60 mm c/c | Ø8 @ 115 mm c/c |
| 107 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 108 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 109 | Ø12 @ 65 mm c/c | Ø8 @ 65 mm c/c | Ø12 @ 65 mm c/c | Ø8 @ 100 mm c/c |
| 110 | Ø10 @ 55 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 60 mm c/c | Ø8 @ 115 mm c/c |
| 141 | Ø10 @ 60 mm c/c | Ø8 @ 100 mm c/c | Ø10 @ 70 mm c/c | Ø8 @ 135 mm c/c |
| 142 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 143 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 50 mm c/c | Ø8 @ 115 mm c/c |
| 144 | Ø10 @ 50 mm c/c | Ø8 @ 80 mm c/c | Ø10 @ 55 mm c/c | Ø8 @ 115 mm c/c |
| 145 | Ø10 @ 60 mm c/c | Ø8 @ 100 mm c/c | Ø10 @ 70 mm c/c | Ø8 @ 135 mm c/c |

We have previously defined the parameters based on that the,

Check for Maximum value of Bending Moment,

**(Along X - Axis):**

Assume, effective Depth = $D-(cc+0.5\times d_b)$ = 0.546 m

Governing moment (Mu) = 309.088 KN-m

As Per IS 456 2000,

Limiting Factor1 ($K_{umax}$) = $\frac{700}{1100+0.87f_y}$ = 0.456

Limiting Factor2 (Rumax)= $0.36 \times f_{ck} \times k_{umax}(1 - 0.42 \times k_{umax}) =$ 3981.77 KN/m2

Limit Moment Of Resistance ($M_{umax}$) =$R_{umax} \times B \times d_e^2$=2492.72 KN-m

**Mu <= $M_{umax}$**

Hence**, Safe .**

**(Along Z-Axis) :**

Effective Depth =$D - (cc + 0.5 \times d_b)$=0.546m

Governing moment (Mu) = 798.26KN-m

As Per IS 456 2000,

Limiting Factor1 ($K_{umax}$) = $\frac{700}{1100+0.87f_y}$ = 0.456

Limiting Factor2 (Rumax) = $0.36 \times f_{ck} \times k_{umax}(1 - 0.42 \times k_{umax})$ =3981.77 KN/m2

Limit Moment Of Resistance ($M_{umax}$) =$R_{umax} \times B \times d_e^2$=4985.44 KN-m

**Mu <= $M_{umax}$**

hence, **Safe.**

**Check value for Maximum value of shear force,**

For two-way shear:

Shear Force(S) = 1692.826 KN

Shear Stress ($T_V$) = 778.216 KN/m$^2$

As Per IS 456 2000 Clause 31.6.3.1

Ks =min $[(0.5 + \beta), 1]$= 1.000

Shear Strength (Tc)=$0.25 \times \sqrt{f_{ck}}$= 1369.3064 KN/m2

Ks x Tc = 1369.3064 KN/m2

**Tv<= Ks x Tc**

hence**, Safe.**

## 2) COMBINED FOOTING:

Combined Foundation made by using STAAD Foundation, the placement of Footing in the plan area can be observed by below STAAD output.

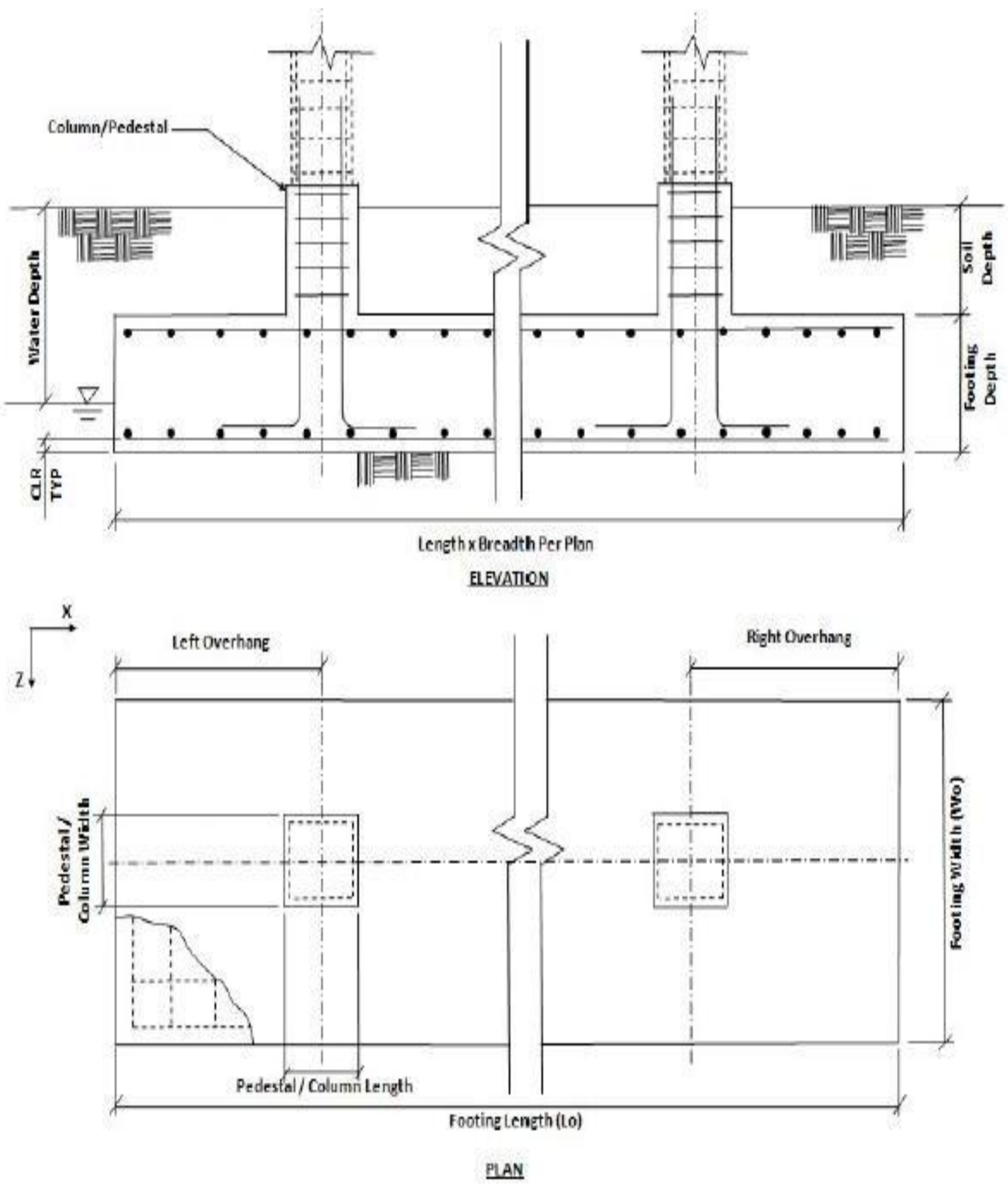



Figure-29: Plan and elevation of combined Footing

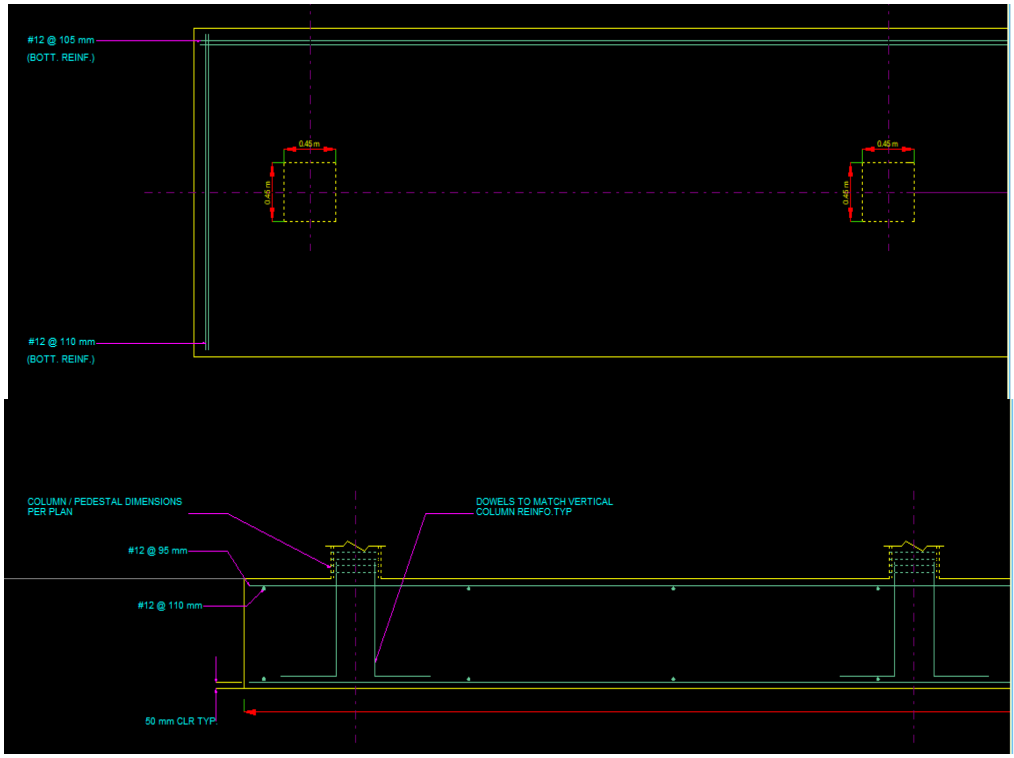
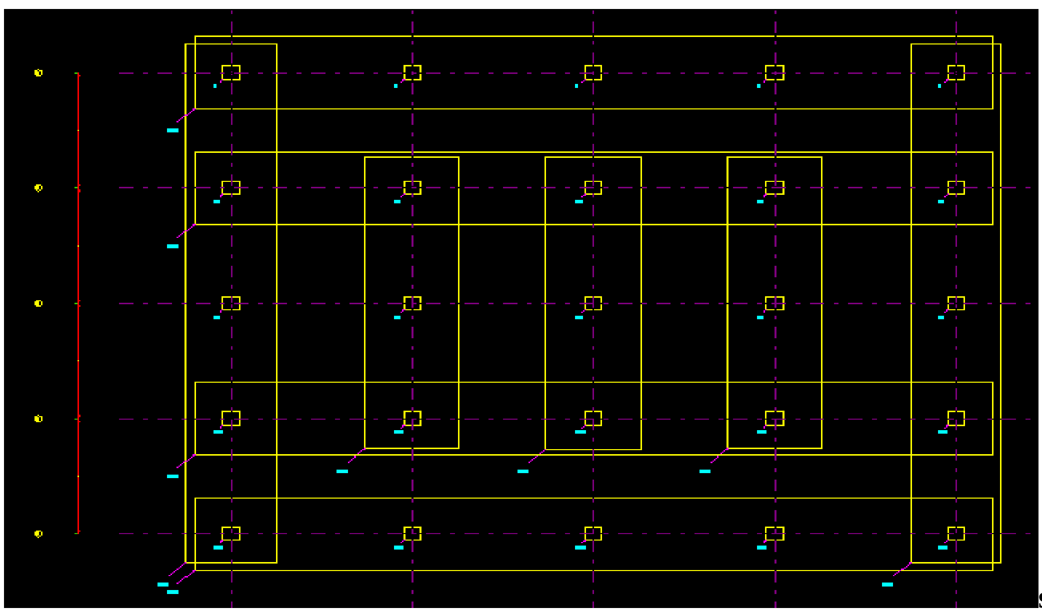



Figure-30: Plan and elevation of combined Footing (9)



**s**

Figure-31: Plan of combined Foundation

A total of 9 combined Footing was designed and analysed by the STAAD Foundation for the provided plan area, building load and soil conditions.

Out of 9 Footing the Footing with maximum value of shear stress is considered for comparison with shear stress of other types of Footing.

The moment of this Footing is also used for comparison with moment of other type of Footing.

Each combined Footing is made by two or more columns having same base to rest on.

Footing NO-9 consist of five individual columns namely column no-106, 107, 108, 109, 110.

The number of different load combinations applied by the STAAD software on both of the columns are shown in the table below,

Table – 9: Load combination shear force and shear stress

| **Applied Loads - Strength Level** | | | | | |
|---|---|---|---|---|---|
| **LC** | **Axial (KN)** | **Shear X (KN)** | **Shear Z (KN)** | **Moment X (KN-m)** | **Moment Z (KN-m)** |
| Column Number : 106 | | | | | |
| 3 | 675.694 | -4.755 | 0.161 | 0.196 | 4.736 |
| 4 | 177.969 | -3.267 | 0.133 | 0.145 | 3.255 |
| 201 | 1280.495 | -12.033 | 0.441 | 0.512 | 11.987 |
| 202 | 819.517 | -7.701 | 0.282 | 0.328 | 7.672 |
| 203 | 1024.396 | -9.626 | 0.352 | 0.410 | 9.589 |
| 204 | 768.297 | -7.220 | 0.264 | 0.307 | 7.192 |
| Column Number : 107 | | | | | |
| 3 | 887.559 | -0.042 | 0.161 | 0.196 | 0.106 |
| 4 | 337.792 | -0.060 | 0.248 | 0.270 | 0.104 |
| 201 | 1838.026 | -0.152 | 0.612 | 0.699 | 0.315 |
| 202 | 1176.337 | -0.098 | 0.392 | 0.447 | 0.201 |
| 203 | 1470.421 | -0.122 | 0.490 | 0.559 | 0.252 |
| 204 | 1102.816 | -0.091 | 0.367 | 0.419 | 0.189 |
| Column Number : 108 | | | | | |
| 3 | 896.057 | 0.000 | 0.161 | 0.196 | 0.000 |
| 4 | 345.511 | 0.000 | 0.255 | 0.278 | 0.000 |
| 201 | 1862.353 | 0.000 | 0.624 | 0.711 | 0.000 |
| 202 | 1191.906 | 0.000 | 0.399 | 0.455 | 0.000 |
| 203 | 1489.882 | 0.000 | 0.499 | 0.569 | 0.000 |
| 204 | 1117.412 | 0.000 | 0.374 | 0.427 | 0.000 |
| - | | | | | |

| Column Number : 109 | | | | | |
|---|---|---|---|---|---|
| 3 | 887.559 | 0.042 | 0.161 | 0.196 | -0.106 |
| 4 | 337.792 | 0.060 | 0.248 | 0.270 | -0.104 |
| 201 | 1838.026 | 0.152 | 0.612 | 0.699 | -0.315 |
| 202 | 1176.337 | 0.098 | 0.392 | 0.447 | -0.201 |
| 203 | 1470.421 | 0.122 | 0.490 | 0.559 | -0.252 |
| 204 | 1102.816 | 0.091 | 0.367 | 0.419 | -0.189 |
| | | | | | |
| Column Number: 110 | | | | | |
| 3 | 675.694 | 4.755 | 0.161 | 0.196 | -4.736 |
| 4 | 177.969 | 3.267 | 0.133 | 0.145 | -3.255 |
| 201 | 1280.495 | 12.033 | 0.441 | 0.512 | -11.987 |
| 202 | 819.517 | 7.701 | 0.282 | 0.328 | -7.672 |
| 203 | 1024.396 | 9.626 | 0.352 | 0.410 | -9.589 |
| 204 | 768.297 | 7.220 | 0.264 | 0.307 | -7.192 |

Here we can observe that Load combination number 201 is proving to be the critical load combination. Hence the calculation of shear stress and moment of this Footing is done by using the load combination 201.

The area and dimensions of Footing are calculated by STAAD that could bear the applied load of the building.

The pressure at four corners of the Footing is checked for any uplift pressure adjustment, so that it can be made sure that whole area of Footing is in contact with the soil surface.

## Calculated Pressures at Four Corners

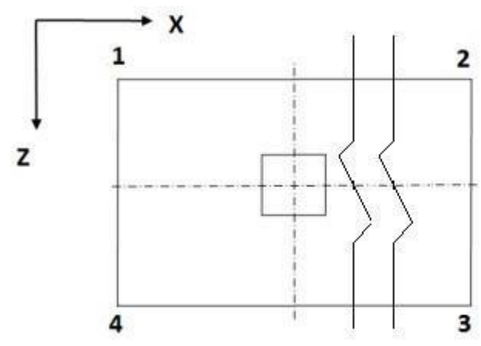



Fig 32: Pressure at four corners

Table 10: Pressure at four corners

| Load Case | Pressure at corner 1 (q1) (KN/m^2) | Pressure at corner 2 (q2) (KN/m^2) | Pressure at corner 3 (q3) (KN/m^2) | Pressure at corner 4 (q4) (KN/m^2) | Area of Footing in uplift (Au) (sq. m) |
|---|---|---|---|---|---|
| 101 | 89.7068 | 89.7068 | 95.6462 | 95.6462 | 0.000 |
| 101 | 89.7068 | 89.7068 | 95.6462 | 95.6462 | 0.000 |
| 101 | 89.7068 | 89.7068 | 95.6462 | 95.6462 | 0.000 |
| 101 | 89.7068 | 89.7068 | 95.6462 | 95.6462 | 0.000 |

Overturning and sliding of Footing in X and Y direction is checked by the STAAD software.

Table 11: Sliding and overturning check

| Load Case | Moment X(KN-m) | Moment Z(KN-m) | Resisting Moment X(KN-m) | Resisting Moment Z(KN-m) | Ratio X | Ratio Z |
|---|---|---|---|---|---|---|
| 3 | 1.383 | 0.001 | 5550.362 | 48843.187 | 4013.249 | 78150524.664 |
| 4 | 1.616 | 0.000 | 2243.511 | 19742.894 | 1388.118 | 126356829.370 |
| 101 | 2.999 | 0.001 | 7271.623 | 63990.282 | 2424.493 | 102386320.859 |
| 102 | 2.399 | 0.001 | 5921.748 | 52111.385 | 2468.025 | 83379737.867 |

The Footing is then designed for flexure in longitudinal direction (sagging and hogging) and transverse directions and checked whether the moment for each direction is not exceeding the maximum limiting moment for the Footing.

Moment in X and Z directions is calculated according to the critical load case 201.

Similarly, one way shear and two-way shear are calculated for the critical load case 201. And we consider 2-way shear for the comparison with different Footing.

Bending Moments and Shear Force Graphs of Combined Footing as given by the STAAD software output.

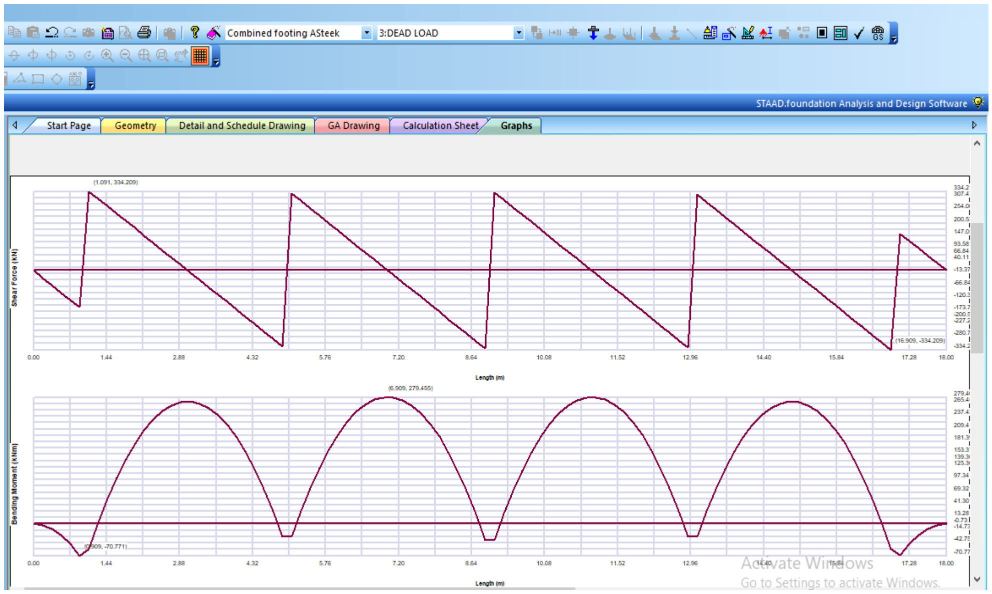



Figure-33: Shear stress and moment of combined Footing (9)

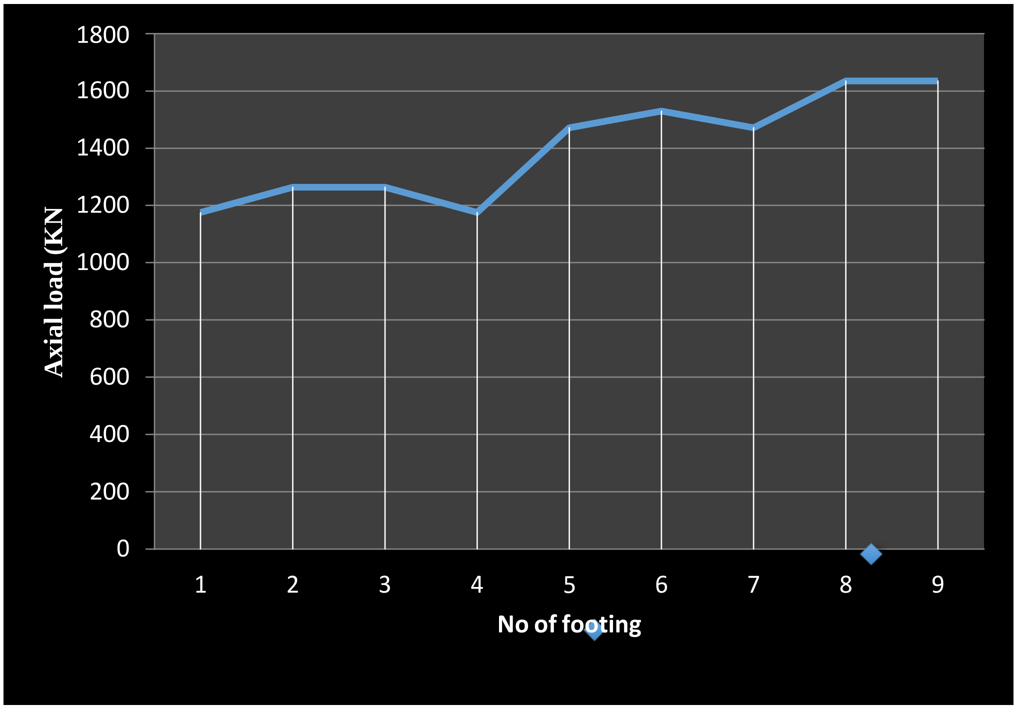
## DISCUSSION

The values of Axial load, shear stress and moment according to load case 201 can be observed by the table below here the Footing showing the maximum value of axial load, shear stress and moment (highlighted) and this maximum value is taken into consideration when comparing with the Axial load, shear stress and moment of other Footing.

Table -12: Axial load, shear stress and moment

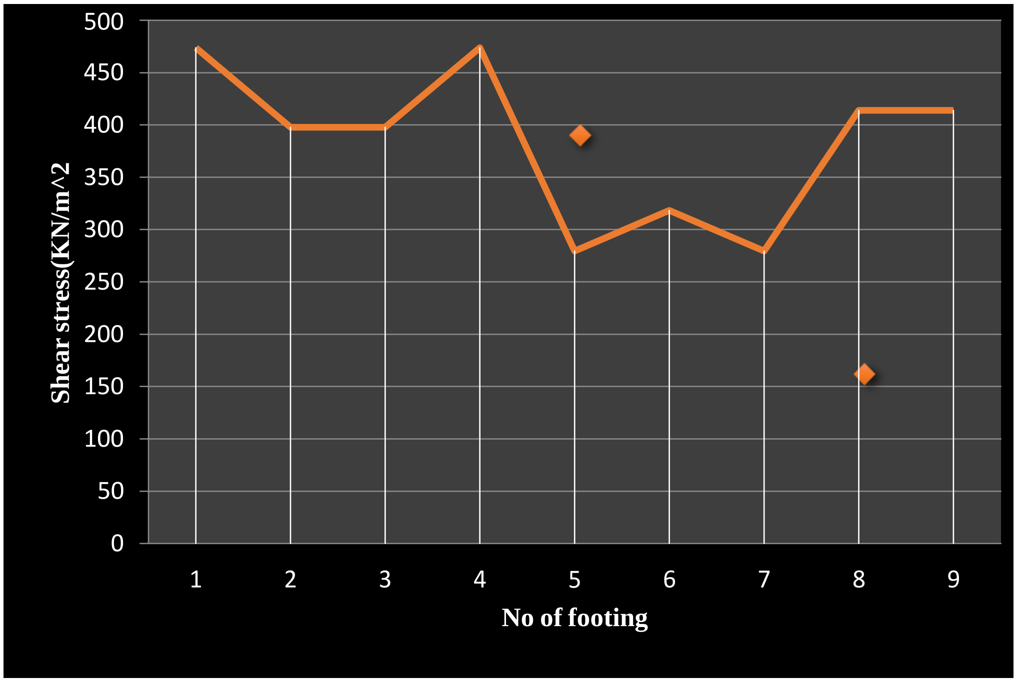
| S.No | Column No. | Axial load KN | Shear stress KN/m^2 | Moment KN-m |
|---|---|---|---|---|
| 1 | 1 | 1175.013 | 473.692 | 1206.704 |
| 2 | 2 | 1262.785 | 397.634 | 1270.592 |
| 3 | 3 | 1262.785 | 397.634 | 1270.592 |
| 4 | 4 | 1175.013 | 473.692 | 1206.704 |
| 5 | 5 | 1470.542 | 279.372 | 1235.135 |
| 6 | 6 | 1529.125 | 318.16 | 1285.786 |
| 7 | 7 | 1470.542 | 279.372 | 1235.135 |
| 8 | 8 | 1634.46 | 413.688 | 1701.854 |
| 9 | 9 | 1634.46 | 413.688 | 1701.854 |

- Graph of Axial load VS number of Footing(9) in isolated Foundation is shown.



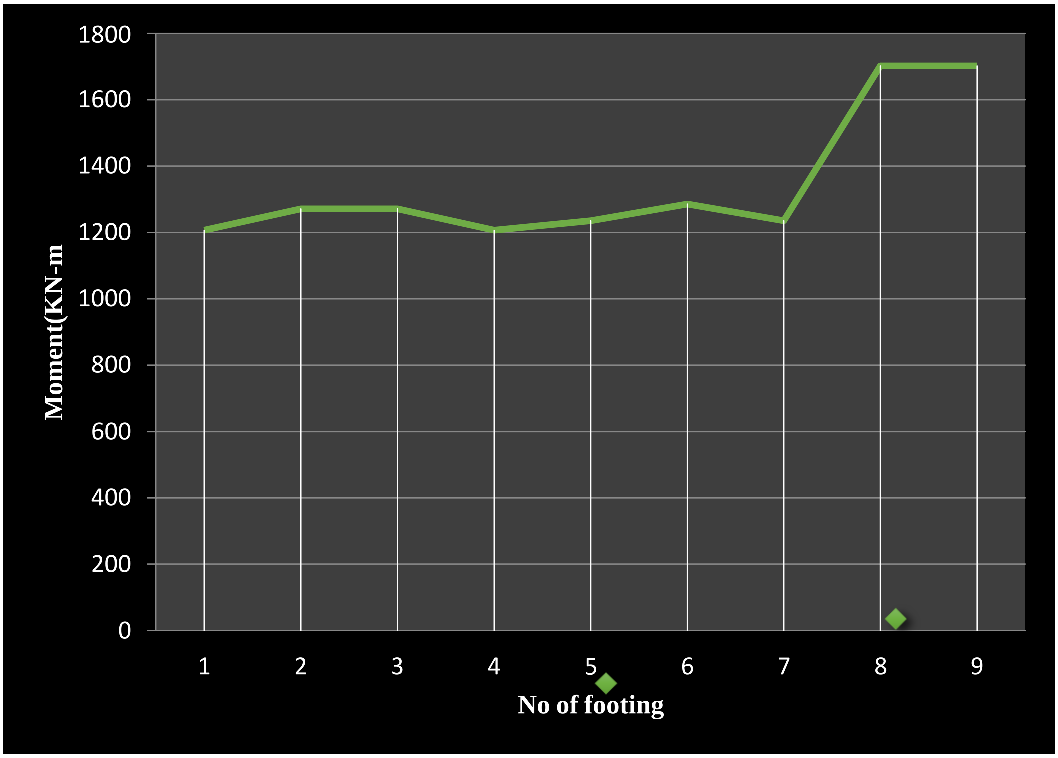

Graph 4: Axial load VS number of Footing

- The graph of Shear stress VS number of Footing(9) in isolated Foundation is shown.




Graph 5: Shear stress VS number of Footing

- The graph of Moment VS number of Footing (9) in isolated Foundation is shown.



Graph 6: Moment VS number of Footing

## DESIGN OF FOOTING

### Design for Flexure

### Sagging moment along length:

Critical load case: 201
Effective Depth $= D - (cc + 0.5 \times d_b)$= 0.794 m
Governing moment (Mu) = 293.189 KN-m
As Per IS 456 2000,

Limiting Factor1 ($K_{umax}$) = $\frac{700}{(1100 + 0.87 \times f_y)}$ = 0.456026
Limiting Factor2(Rumax)=$0.36 \times f_{ck} \times k_{umax}(1 - 0.42 \times k_{umax})$=3981.77 KN/m^2
Limit Moment of Resistance (Mumax) =$R_{umax} \times B \times d_e^2$= 6275.522457 KN-m
**Mu<= $M_{umax}$**
hence, **Safe.**

### Hogging moment along length:

Critical load case : 201
Effective Depth $= D - (cc + 0.5 \times d_b)$= 0.794 m

Governing moment ($M_u$) = 967.475 KN-m
As Per IS 456 2000,
Limiting Factor1 ($K_{umax}$) = $\frac{700}{(1100 + 0.87 \times f_y)}$ = 0.456026
LimitingFactor2(Rumax)= $0.36 \times f_{ck} \times k_{umax}(1 - 0.42 \times k_{umax})$ = 3981.77 KN/m^2
Limit Moment Of Resistance ($M_{umax}$) =$R_{umax} \times B \times d_e^2$= 6275.522457 KN-m
**Mu <= $M_{umax}$**
hence, **Safe.**

**Transverse direction:**

Critical load case: 201
Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.794 m
Governing moment ($M_u$)= 1701.854 KN-m
As Per IS 456 2000,
Limiting Factor1 ($K_{umax}$) = $\frac{700}{(1100 + 0.87 \times f_y)}$= 0.456026
Limiting Factor2($R_{umax}$)=$0.36 \times f_{ck} \times k_{umax}(1 - 0.42 \times k_{umax})$=3981.77 KN/m^2
Limit Moment of Resistance ($M_{umax}$) = $R_{umax} \times B \times d_e^2$= 55224.599228 KN-m
Mu<= Mumax
hence, **Safe.**

**<u>Check trial depth for two-way shear</u>**

Critical Load case for Punching Shear Check: 201
For Column 2
Shear Force(S) = 1610.133 KN
Shear Stress(Tv) = 413.688KN/m^2
As Per IS 456 2000 ,
Ks=min $[(0.5 + \beta), 1]$= 1.000
Shear Strength(Tc)=$0.25 \times \sqrt{f_{ck}}$ = 1369.3064 KN/m^2
Ks X Tc = 1369.3064 KN/m^2
**Tv<= KsX Tc**
hence, **Safe** .

## 3. MAT FOUNDATION :

Mat Foundation made by using STAAD Foundation, the placement of Footing in the plan area can be observed by below STAAD output.

Mat Footing is designed as a whole consisting 30 columns having common base and analysed by the STAAD Foundation for the provided plan area, building load and soil conditions.

The moment of this Footing is also used for comparison with moment of other type of Footing.

The number of different load combinations applied by the STAAD software and load case 201 is considered to be critical.

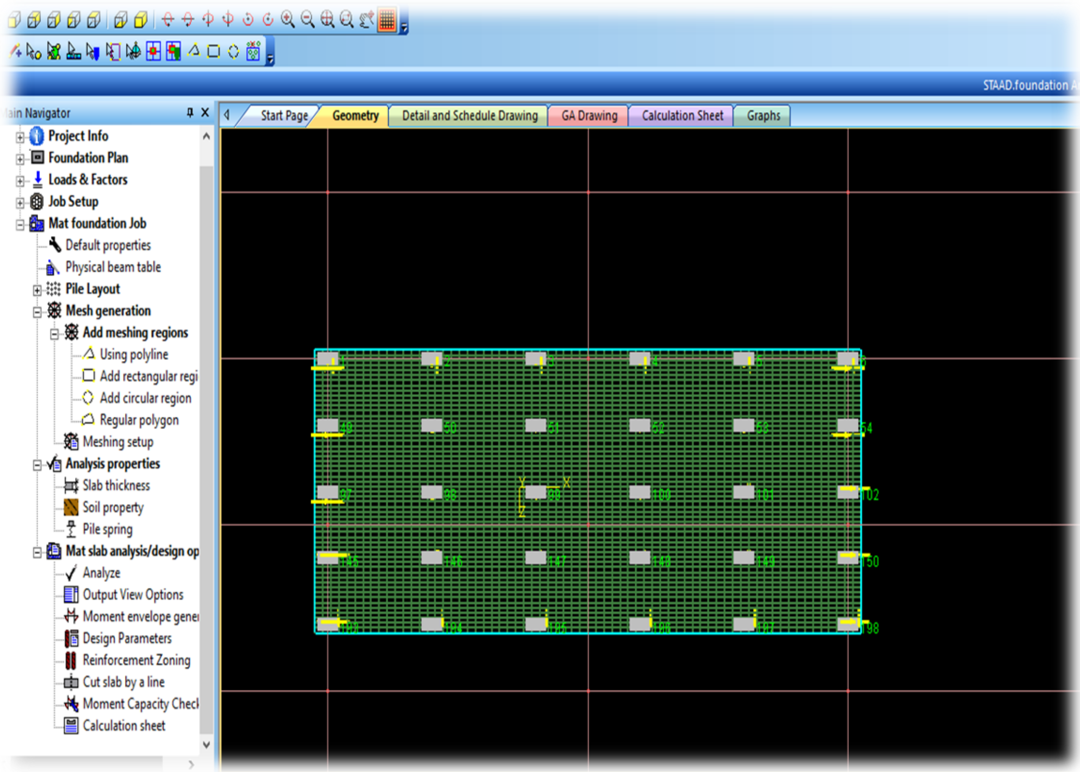



Figure-34: Plan of mat Foundation

For critical load case bending moment and shear stress for mat Foundation is calculated.

The pressure at four corners of the Footing is checked for any uplift pressure adjustment, so that it can be made sure that whole area of Footing is in contact with the soil surface.

Table 13: Pressure at four corners

Contact Area

| Load Case | Area in Contact (m2) | % Of Total Area | Area out of Contact (m2) | % Of Total Area |
|---|---|---|---|---|
| **3** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **4** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **101** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **102** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **201** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **202** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **203** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |
| **204** | 356.99998 | 100.00000 | 0.00000 | 0.00000 |

Bending Moment Distribution in X-Y plane ($M_{xy}$) of MAT Foundation Using STAAD Foundation,

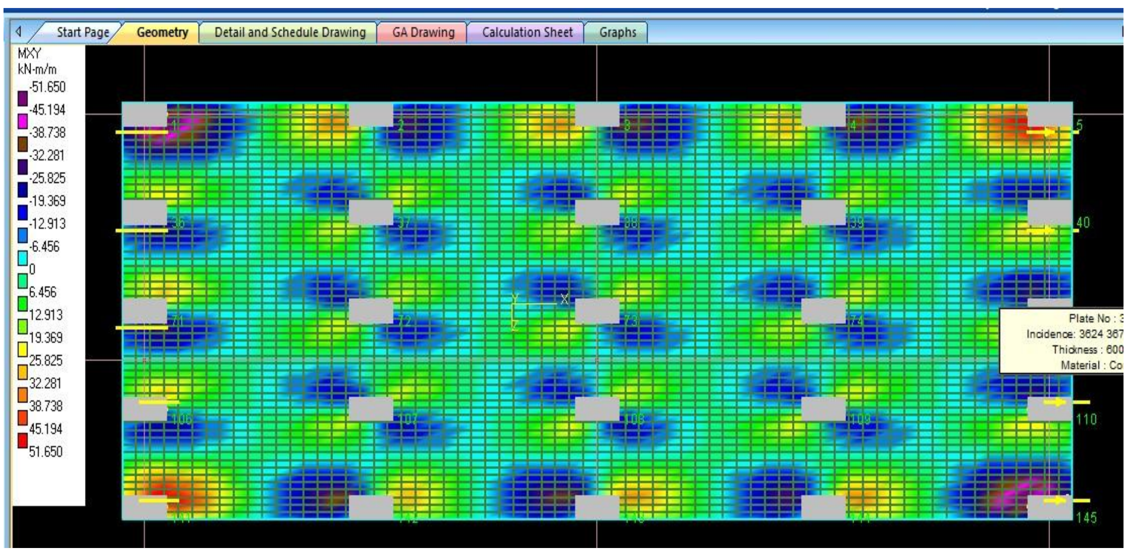


Figure-35: Bending Moment Distribution of MAT Foundation

Shear Force Distribution (SQY) of MAT Foundation Using STAAD Foundation,


Figure-36: Shear Force Distribution of MAT Foundation

Settlement of mat Foundation can be observed by the following table-

Table 14: Node displacement

| - | Node Number | Load Case | Dx(m) | Dy(m) | Dz(m) | Rx (Rad) | Ry (Rad) | Rz (Rad) |
|---|---|---|---|---|---|---|---|---|
| **Max Dx** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Max Dy** | 844 | 4 | 0.00000 | -0.00076 | 0.0000 | 0.00000 | 0.000 | -0.00001 |
| **Max Dz** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Max Rx** | 124 | 201 | 0.00000 | -0.01066 | 0.0000 | 0.00134 | 0.000 | -0.00164 |
| **Max Ry** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Max Rz** | 192 | 201 | 0.00000 | -0.01079 | 0.0000 | 0.00122 | 0.000 | 0.00180 |
| **Min Dx** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Min Dy** | 2 | 201 | 0.00000 | -0.01191 | 0.00000 | -0.00129 | 0.0000 | -0.00176 |
| **Min Dz** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Min Rx** | 74 | 201 | 0.00000 | -0.01066 | 0.0000 | -0.00134 | 0.000 | -0.00164 |
| **Min Ry** | 1 | 3 | 0.00000 | -0.00668 | 0.0000 | -0.00076 | 0.000 | 0.00101 |
| **Min Rz** | 70 | 201 | 0.00000 | -0.01079 | 0.0000 | -0.00122 | 0.000 | -0.00180 |

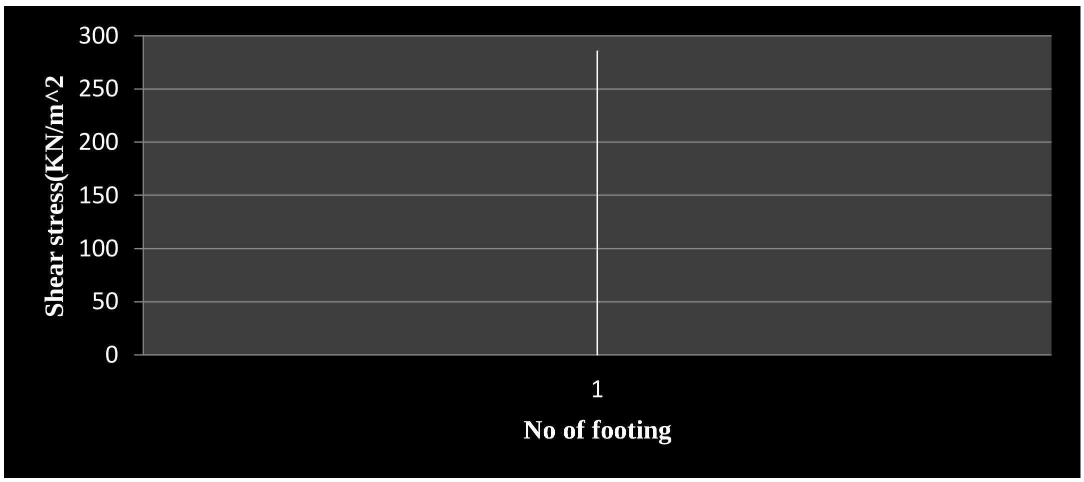
## DISCUSSION

The values of Axial load, shear stress and moment according to load case 201 can be observed by the table below here mat Foundation has only one Footing showing the value of axial load, shear stress and moment and this value is taken into consideration when comparing with the Axial load, shear stress and moment of other Footing.

Table 15: Shear stress and moment

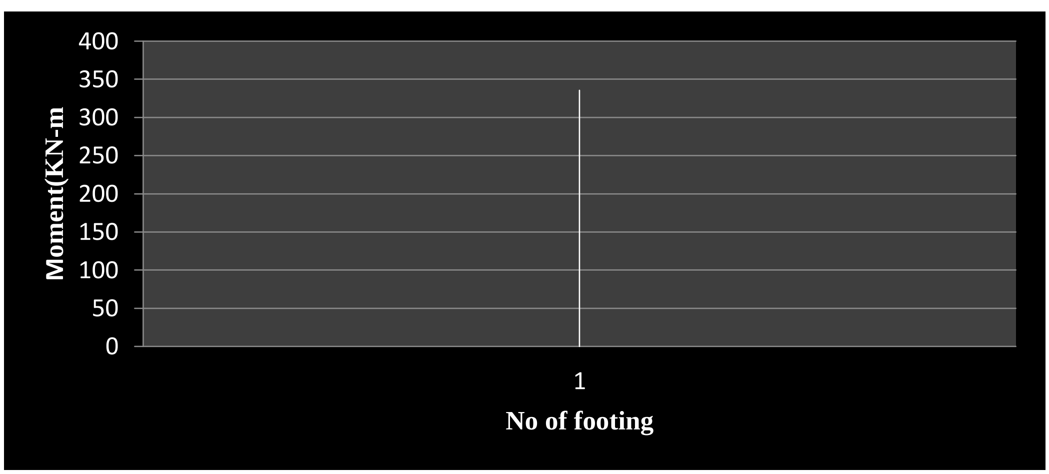
| S.No | Column No. | Shear stress KN/m$^2$ | Moment KN-m |
|---|---|---|---|
| 1 | 1 | 285.65 | 335.571 |

- The graph of Shear stress VS number of Footing (1) in isolated Foundation is shown.




Graph 7: Shear stress VS number of Footing

- The graph of Moment VS number of Footing (1) in isolated Foundation is shown.




Graph 8: Moment VS number of Footing

## Design of Footing

**Properties Details:** Table 16: Slab properties

| **Region** | **Thickness(m)** | **Material** |
|---|---|---|
| **MAT** | 0.600 | Concrete |

**Soil Details:** Table 17: Soil details

| **Boundary** | **Subgrade Modulus** | **Soil Density** | **Soil Pressure** |
|---|---|---|---|
| **MAT** | 18000.000 $KN/m^2/m$ | 22 $KN/m^3$ | 150 $KN/m^2$ |

Zone Distribution of MAT Foundation based on Moment resisting capacity,

i) Zone 1

ii) Zone 2

iii) Zone 3 (Critical Zone)


Figure-37: Zone Distribution of MAT Foundation

**Zone: - 3**

Governing Moment (MGOV) = 335.571(KN-m/m)

For FC <4.0

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.536 (m)

Limit Moment of Resistance (Mumax)= $R_{umax} \times B \times d_e^2$ =989.513 (KN-m)

MGOV<= Mumax **hence, OK.**

## Steel Required

Calculated Area of Steel = 1838.722 ($mm^2$)

Minimum Area of Steel = 720.000 ($mm^2$)

Provided Area of Steel = 1838.722 ($mm^2$)

# CHAPTER-6

# SUMMARY AND CONCLUSIONS

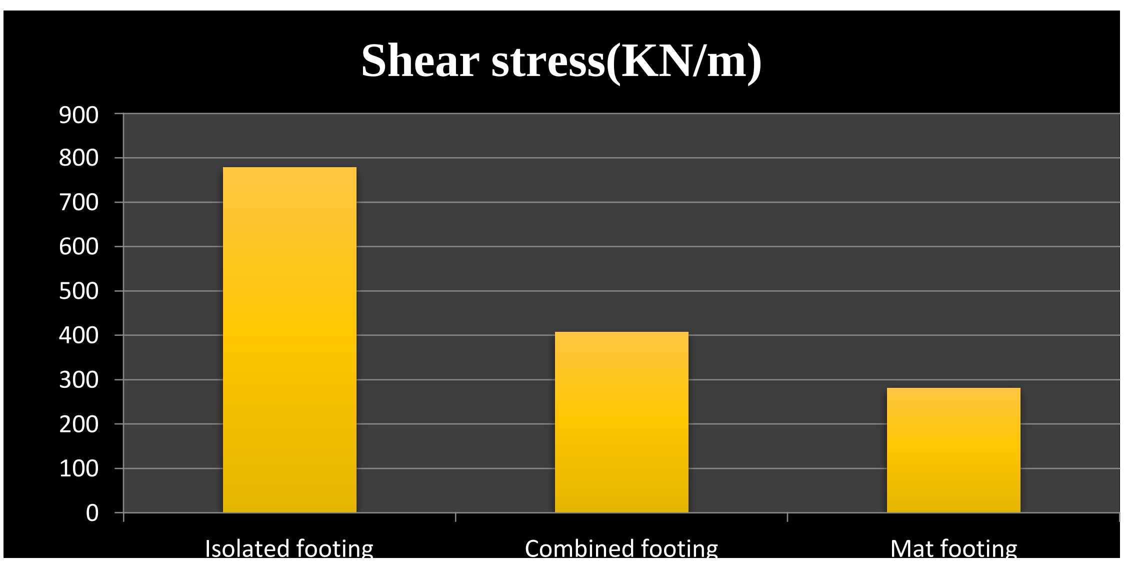
## 6.1 SUMMARY

Results of all three Footing are compared for **critical load case 201** by comparing maximum shear force and moment for each of the Footing for same load of G+6 building over the Footing.

Table 18: Comparison between Isolated, Combined and Mat foundation

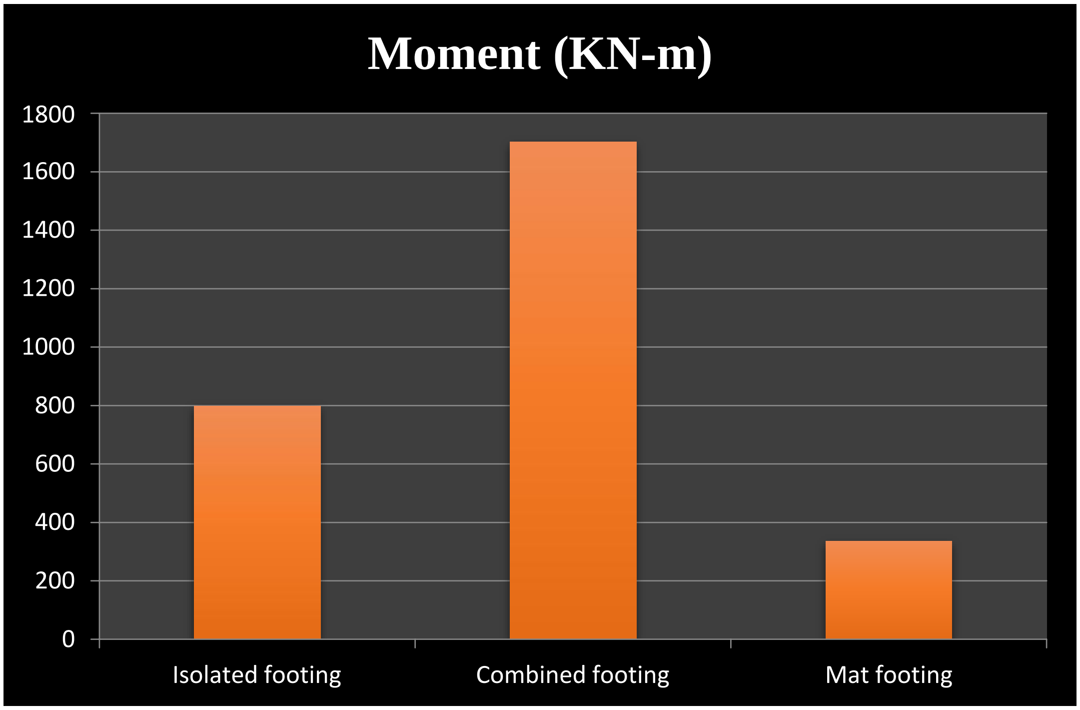
| ISOLATED FOOTING | COMBINED FOOTING | MAT FOOTING |
|---|---|---|
| A total 25 isolated Footing specimen were tested by STAAD Pro. and the results were recorded.<br><br>Isolated Footing attain average shear stress 778.216 KN/$m^2$.<br><br>Isolated Footing attains a moment of 798.16 KN-m. | A total 9 combined Footing specimen were tested by STAAD Pro. and the results were recorded.<br><br>Combined Footing attain average shear 407.531 KN/$m^2$.<br><br>Combined Footing attains a moment of 1701.854 KN-m. | STAADPro.Foundation analysed entire load over Foundation plan area with a single Footing like a large raft.<br><br>Mat Footing attain average shear stress of 281.65110 KN/$m^2$.<br><br>Mat Footing attains a moment of 335.571 KN-m. |

- A comparative graph of shear force of Isolated, Combined and Mat Footing can be observed to be as follows:




Graph 9: Shear stress VS types of Foundation

- A comparative graph of Moment of Isolated, Combined and Mat Footing can be observed to be as follows-




Graph 10: Moment VS types of Foundation

## 6.2 CONCLUSIONS

- Mat footing attains 64% less average shear stress as compared to isolated footing and 31% less average shear stress than combined footing. Mat footing is far better than combined and isolated footing.
- It can be clearly shown in above table in combined footing; moment generated is high comparatively to other two.
- Combined footing can resist 53% more moment than isolated footing and 80% more moment than mat footing.

## 6.3 FUTURE SCOPE

Present application and future scope are as follows:

- Used Footing should be able to sustain all the loads, moments and induced reactions within the safe bearing capacity of the soil.
- The settlement of the structure should be within the tolerable limits.
- In this project a multi-storey building rests on particular soil condition has been considered for further experimental investigations different combinations of soil conditions can be carried out.
- In this project the soil in and around the Foundation has been considered the effect of shear and bending for further study torsion effects can also be considered.
- This project can model by using different software like ANSYS, SAP2000 and ETABS or inelastic continuum method.
- The soil is considered as single media but layered soil types exist below is not single, so different linear equilibrium effects can also be considered.

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