"Effect of Pile Stiffness with Varying Diameter of Piles on Structure in Various Zones of Seismicity"

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Abstract - Pile foundations are commonly used for different structures on weak soil. Seismic design is extremely important to make sure efficient functioning of structure under sever seismic loading condition. The IS:1893 is should be used for analysis of seismic forces on a structure. This study includes selection of particular sort of building structure. itwill be shown that relation of building with and without pile foundation. Seismic behavior isn't similar for the various structures due to their varying characteristics. The effect of pile stiffness on the structure which is located in seismic zones is to be studied. The pile stiffness of pile foundation mayor may not effect on structure. With the rise in seismic activities there could also be need of efficient design of pile foundation to resist earthquake load & damage thanks to earthquake. This work is particularly consider comparing stiffness of pile with change in diameter and also zone.

Key Words- Pile Foundation, STADD-Pro, Structure, Stiffness, zone, Pile Cap, Load Estimation, Pile cap, Pattern of Pile.

1. INTRODUCTION

Pile foundation and their seismic design is extremely important structure to make sure efficient functioning of varied structures under various seismic loading conditions. during this process ground condition plays a crucial role in terms of foundation capacity. For this design Indian Standards are used. The finite element analysis is applied for seismic response of a foundation pile during a saturated coarse grained deposit. Through a series of centrifuge test, the seismic response of closely spaced group of piles in altered and unaltered soft clays was studied. Also a number of simplified methods, essential supported the Winkler soil model provide reasonably accurate solutions. during this project work we were getting to design building using STAAD-PRO software and designing pile foundation with varying diameter and ranging zone. It includes selecting various factors for the planning purpose estimating various sorts of load working on the structure depending upon the sort of the structure selected consistent with the advice made in IS Code. It also includes selecting various criteria for the planning of pile foundation and after designing the pile next stage is finding stiffness for all the inspiration

2. OBJECTIVES

a) To analysis and investigate the effect of pile stiffness with varying diameter of piles.
b) To analysis and investigate the effect of pile stiffness with varying zones of seismicity.
c) Validation of Results.

3. METHODOLOGY

1. General

In this project work we are getting to design building using STAAD-PRO software and designing pile foundation with varying diameter and ranging zone .It includes selecting various factors for the design purpose estimating various sorts of load working on the structure depending upon the sort of the structure selected consistent with the advice made in IS Code. It also includes selecting different criteria for the design of pile foundation and after designing the pile next stage is finding stiffness for all the foundation.

2. Flow Chart of Methodology:

Selection of Building

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Estimation of Load

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Design and Analysis of R.C.C. building by using STAAD-PRO

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Design of pile Foundation by varying Diameter of Piles by using STAAD-PRO

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Calculation of Stiffness Factor in various zones of Seismicity

3. Selection of Building

Combination of member selected together in such thanks to serve a use full purpose is named structure. There are differing types of the structure maintained as below

- **Rigid frame structure -**It is that sort of structure during which the members are joined together by rigid joint
- **Load bearing structure** – it's the structure during which wall carry all the load of roof and transfer that load to foundation strata uniformly.

4. Estimation of Load

There are various types of load acting on the structure such as dead load of the structure, live load, wind load, earthquake load. Load can be calculated based on height of building, it occupant, its use, and criteria given as per the various is code.

A. **Dead load -** Dead Loads are permanent or stationary loads which are carried by the structural member throughout their life span. In the calculation of dead load self-weight of the structure is taken. Self- weight of the slab, self-weight of column, beam, floor finish were taken. The brickwork is not included in the analysis and only the dead load of brickwork is considered. In this case, all the brick walls are assumed as 230 mm thick, though in practice the interior walls may have only 115 mm thickness.

B. **Live load** – Live load is movable loads without any acceleration or impact. These loads are considered to be produced by expected use or occupancy of the building, including the load of movable partition. live load for all the floors is equal and for roof it is different. Distribution of live load is similar to the distribution of self-weight of slab and floor load command is used in STAAD Pro for the same.

C. **Wind Load**: Wind Load is a primary horizontal load caused by movement of air relative to earth. The design wind load is a function of design wing speed, risk coefficient, terrain roughness, aspect ratio of building and local topographical reason.

D. **Earthquake load or Seismic Load** –Earthquake loads are horizontal forces caused by earthquake and shall be computed in accordance with IS: 1893-2002. The resultant lateral force or seismic load is denoted by the force F. The force F is distinctly varies for the dead, live, snow, wind, and impact loads. The horizontal ground motion action is analogous to the effect of a horizontal force working on the building, hence the term Seismic load. As the base of the building moves in a particularly difficult manner, inertia forces are generated throughout the mass of the building. It is these opposite forces that caused the building to move and sustain damage or collapse. Additional vertical load effects are occurs on beams and columns due to vertical vibrations.

Analysis and Design of Building Using STADD-PRO Software:

In practice, multi-story buildings analyzed, designed, and detailed using commercially available software. The commercial software packages available in the market include STAAD Pro SAP 2000, ETABS, SAFE, Nastran, Midas NFX, ANSYS and STRUDS. In addition a number of free/open source programs are also available and include Open Sees, Frame3DD, and IDARC 2D. Many of these programs have analysis and design capability. Special structural design packages are also available and some engineers have developed their own spread sheets for the design of structural elements (e.g., FRAME, RC Slab, RC Beam and RC Foundation developed by Computer Design Consultants.

4. ANALYSIS OF G + 6 BUILDING

The seven storey RC building having three bays in one direction with spans of 8 m, 4m, and 8m and three equal bays of 5 m each in the other direction is considered in this case study. The other pertinent details required for the analysis and design are given below.

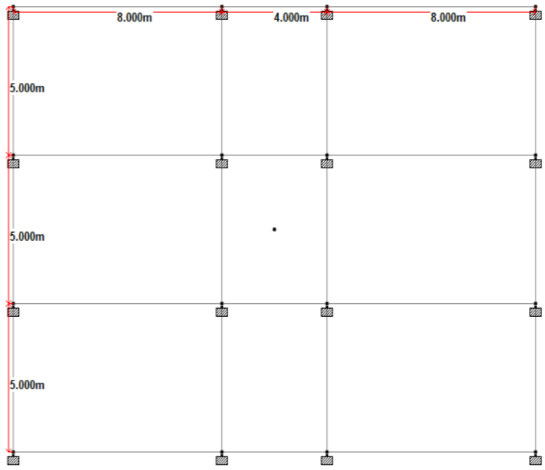

Fig. 1 Plan of Building

Details of Structure

- Details of Building = Ground + 6 story building
- Location = Mumbai
- Walls = 230 mm thick brick masonry
- Typical floor to floor height = 3000 mm
- Height of Plinth = 450 mm
- Depth of Foundation = 2000 mm below ground level
- Bearing capacity of soil = 400 kN/m2

Loading on Structure

- Dead Load
- Roof Finish = 1.5 kN/m2
- Floor Finish = 1.0 kN/m2
- Live Load Roof = 1.5 kN/m2
- Floor = 5.0 kN/m2
- Wind Load = Not considered for design
- Seismic Load = Seismic Zone II & III
- Type of soil = Medium Soil

Other Information

- Concrete Grade = M25
- Reinforcement Grade = Fe 415

- Exposure Condition = Very Severe(Clear Cover = 50)

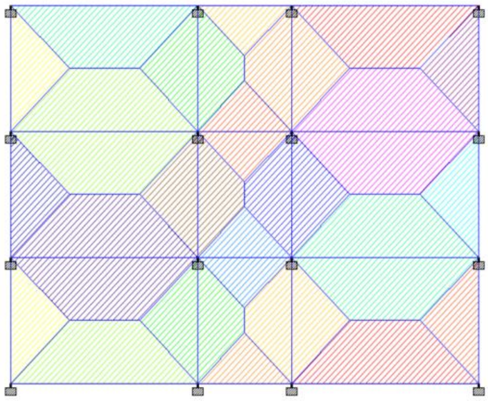

Fig.2 Typical distribution of slab loads on beams in STAAD.

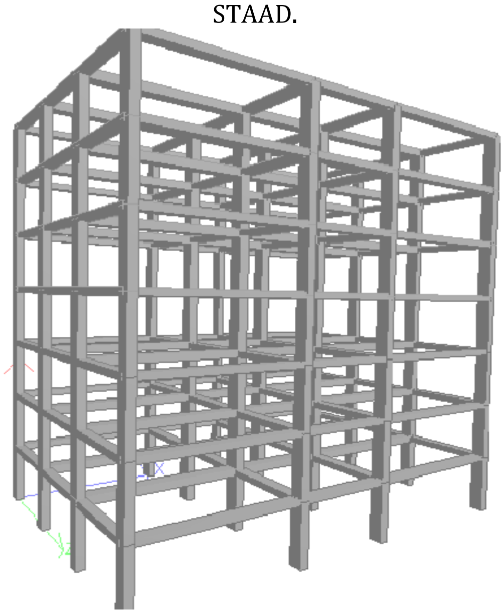

Fig.3 Beam Column Frame structure

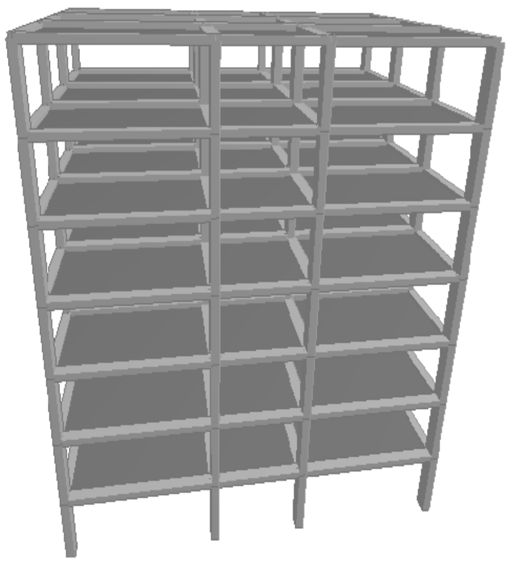

Fig.4 Slab Plates

Result of Beam Design

Beams are designed in its STAAD.Pro through its in built program. IS 13920 is used for the design and result of beam. The length of beam is 5000 mm and size of beam is 400 mm X 600 mm. The cover required for beam is 50mm. The area required for top reinforcement for section 5000 mm is 2604.17 mm2. The area required for bottom reinforcement for section 5000 mm is 1579.55mm2. Shear reinforcement are provided in the form of stirrups. Two legged 8mm diameter stirrups are provided @ 130 mm c/c. Shear result of design at 740 mm away from face of support is also taken. For this shear reinforcement, two legged 8mm diameter stirrups are provided @ 190 mm c/c.

Result of Column Design

Columns are designed in its STAAD Pro through its in built program. IS 13920 is used for the design and result of column. STAAD Pro number for column is 15. The length of column is 3000mm and cross section of column is 400 mm X 700 mm. The cover required for column is 50mm. The required steel area of column is 1816.55 m2. The required concrete area is 358183.44 m2. The main reinforcement required for column is equally distributed. It is reinforced with 12-20 diameter of bar. The shear reinforcement can be referred to with tie reinforcement, hoop reinforcement. In confining reinforcement, 12 mm diameter of rectangular ties @ 100mm c/c over mm length 800 is provided. It is provided from each joint face towards mid span as per Clause 7.4.6 of IS 13920. Three number overlapping hoop along with crossties are provided along Y direction as per Clause 7.3.2 IS 13920. Also three number overlapping hoop along with crossties are provided along Z direction as per Clause 7.3.2 IS 13920. Rectangular ties of 8 mm diameter @ 225 mm c/c are provided. The interaction ratio is 0.99 as per clause 39.6 IS 456:2000.

Analysis and Design of Building Foundation Using STADD-PRO Software

Design of piles:

Step 1: structure run in STAAD foundation

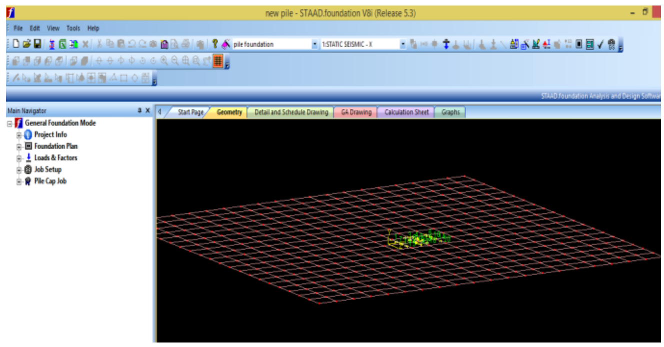

Fig.5 Foundation arrangement in STADD-Pro

Step 2: Generate the load combination

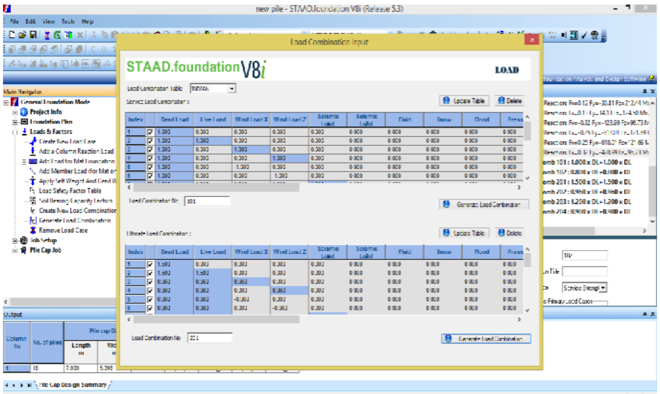

Fig.6 Load Generation

Step 3: To create the job setup

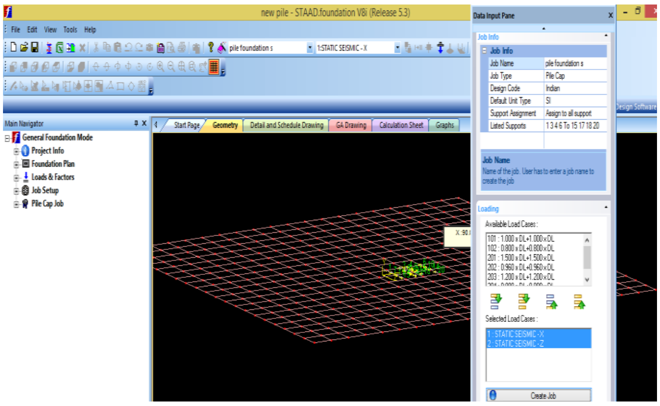

Fig.7 Job Setup Creation

Step 4: Input the design parameter

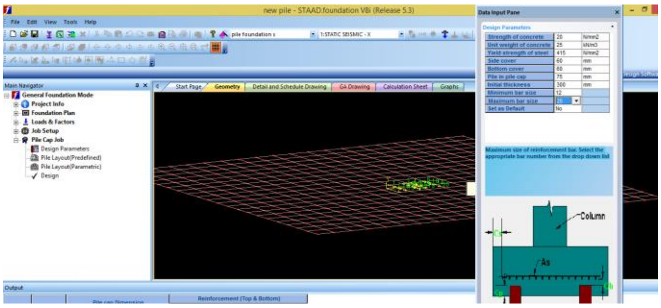

Fig.8 Input the design parameter

Step 5: Input the pile details

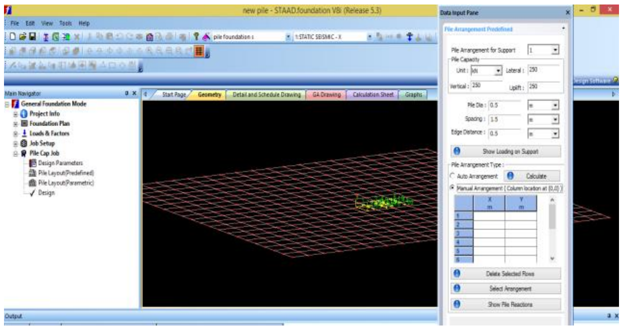

Fig.9 Pile arrangement

Step 6: Selection pile arrangement

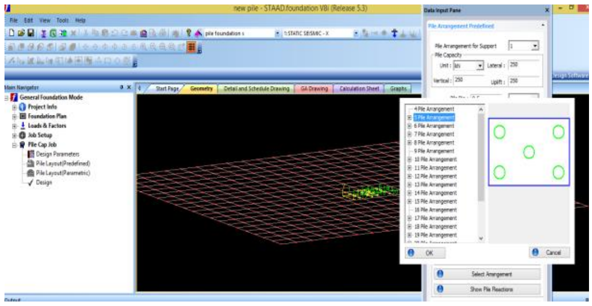

Fig.10 Selection of Pattern

Step 7: pile layout

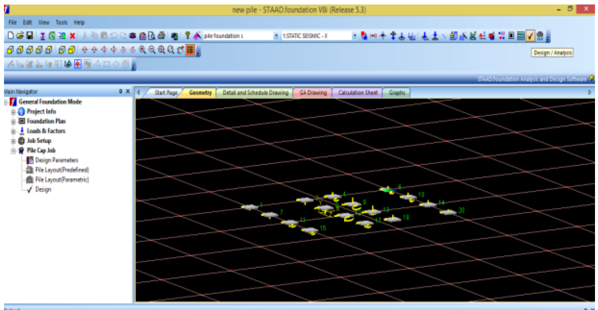

Fig.11 Pile Layout

Step 8: calculation sheet of pile after design

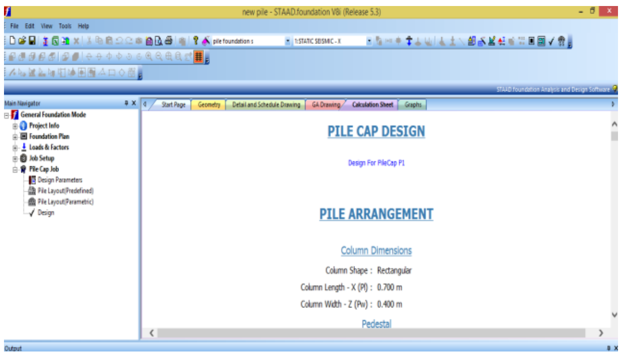

Fig.12 Design Result

Step 9: GA drawing of pile

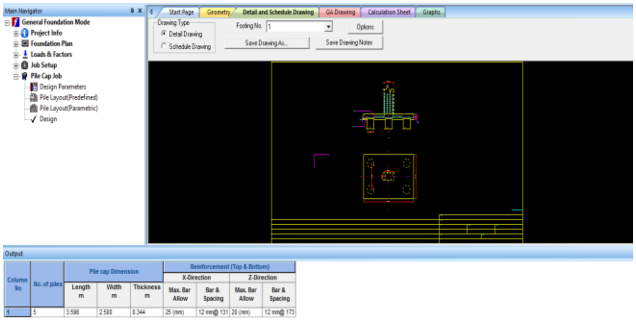

Fig.13 Drawing of Pile, Column

5. RESULT AND DISCUSSION

5.1. PILE DESIGN

Arrangement of pile is such that it consist of five piles under one column. Shape of column is rectangular its length is 700mm and width is 400mm, pile spacing is 1500mm is taken also the pile edge distance is 500mm and pile diameter is 1000mm .piles consist of pile cap in which pile cap length is 3598mm and pile cap width is 2500mm the thickness of pile cap is 300m axial capacity of pile is 250kn, lateral capacity of pile is 250kn and uplift capacity of pile is 250kn. Bottom clear concrete cover for pile is 60mm and side clear concrete cover is 60mm. Grade of concrete used m25 and grade of steel is 415 . Shape of pile cap is rectangular its width is2500 mm and its length is 3598mm.

Table No.1.Loading applied at the top of Cap

Load Case	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
1	90.552	240.850	0.216	0.226	0.000	-233.221
2	0.324	428.991	96.732	185.091	0.000	-0.350

Pile Cap Design Calculation

Total pile number N = 5

Table No.2.Pile Reaction

Pile No.	Arrangement		Reaction		
	X(m)	Y(m)	Axial (kN)	Lateral (kN)	Uplift (kN)
1	-1.299	-0.750	0.000	18.111	-15.339
2	-1.299	0.750	0.000	18.111	-15.533
3	0.000	0.000	0.000	18.111	34.678
4	1.299	0.750	-15.533	18.111	0.000
5	1.299	-0.750	-15.339	18.111	0.000

Reinforcement Calculations

Maximum bar size allowed along length 25 mm
Maximum bar size allowed along width 20 mm
Bending Moment at Critical Section= 137.812 kNm (Along Length)
Bending Moment at Critical Section=160.299 kNm (Along Width)
Pile Cap thickness = 0.294 m
Selected bar size along length 12 mm
Selected bar size along width 12 mm
Selected bar spacing along length = 81.66 mm
Selected bar spacing along Width = 105.03 mm
Pile Cap Thickness Check
Calculated thickness (t) = 0.294 mm

Check for Moment (Along length)

Critical load case for thickness is reported only when required thickness is more than the given minimum thickness.

Table No.3.Moment (Along length)

Pile No.	Moment along x1-x1(kNm)	Moment along x2-x2(kNm)
1	136.266	0.000
2	0.805	0.000
3	0.414	0.414
4	0.000	0.969
5	0.000	136.429

Check for Moment along Width

Critical load case for thickness is reported only when required thickness is more than the given minimum thickness.

Table No.4.Moment along Width

Pile No.	Moment along y1-y1(knm)	Moment along y2-y2(knm)
1	78.974	0.000
2	0.000	0.467
3	2.257	2.257
4	0.000	0.562
5	79.068	0.000

Governing moment (Mu) =160.299 kNm

Check for one way shear (along length)

Table No.5.one way shear (along length)

Pile No.	Shear Force x1-x1(kN)	Shear Force x2-x2(kN)
1	143.591	0.000
2	0.849	0.000

3	0.000	0.000
4	0.000	1.021
5	0.000	143.763
TOTAL	144.440	144.784

Design Shear Force for One-Way Action

Vu= 144.784 kN

Check for one way Shear (along width)

Table No.6.one way Shear (along width)

Pile No.	Shear Force y1-y1(kN)	Shear Force y2-y2(kN)
1	128.873	0.000
2	0.000	0.762
3	10.665	10.665
4	0.000	0.916
5	129.028	0.000
TOTAL	268.566	12.343

Design Shear force (Vu) = 268.566kN

Check for two way shear (along length)

Table No.7.Two way shear

Pile No	Two-way Shear at column face (kN)
1	143.591
2	0.849
3	6.132
4	1.021
5	143.763
TOTAL	295.356

Design Two-Way Shear force= 295.356 kN

Calculation of maximum bar size (along length)

Selected maximum bar size = 25 mm

Bar diameter corresponding to max bar size (db) =25 mm

As Per IS 456-200Cl.No 26.2.1

Development Length(ld) = $\frac{0.87 \times d_b \times f_y}{4 \times \tau_{bd}}$

Where, fy=strength of steel

db= bar diameter,Tbd= bond stress =1.126m

Allowable Length(ldb) = $0.5 \times (B - b) - C_s$

Where, B= width of column

Cs= side cover, ld= desirable length.

=1.389M ldb >ld hence, safe

Along width

Selected maximum bar size = 20 mm

Bar diameter corresponding to max bar size (db) = 20mm As Per IS 456-2000 Cl.No 26.2.1

Development Length(ld) = $\frac{0.87 \times d_b \times f_y}{4 \times \tau_{bd}}$

Where, fy=strength of steel

db= bar diameter,Tbd= bond stress = 0.901M

Allowable Length(ldb) = $0.5 \times (H - h) - Cs$

Where, H= Height of column

Cs= side cover, ld= desirable length. = 0.990M

ldb >ld hence, safe

Top reinforcement is provided same as bottom reinforcement.

Along Length

As Per IS 456-2000 Cl.No 26.5.2.1

Minimum Area of Steel (Astmin) = $0.12\% \times B \times h_{cap}$

Where, Where, hcap =height of pile cap,

B=width of column, = 868.500 mm2

As Per IS 456-2000annex G,G-1.1 b

Area of steel required (Asq)

$$= 0.5 \times \left(\frac{f_c}{f_y}\right) \times \left(1 - \sqrt{1 - \frac{4.5977 \times M_u}{f_c \times b \times d \times d}}\right) \times b \times d$$

Where, fc=compressive strength of concrete

Mu= ultimate moment

fy= strength of steel = 3340.172 mm2

Area of steel provided (Ast) = 3340.172mm2

Astmin<= Ast

Steel area is accepted.

Minimum spacing allowed (Smin) = 40 + db= 52 mm

Selected spacing (S) = 81.66 mm

Smin <= S <= 450 mm

selected bar size < selected maximum bar size

Along width As Per IS 456-2000 Clause 26.5.2.1

Minimum Area of Steel (Astmin)= $0.12\% \times B \times h_{cap}$

= 1230.516 mm2

Where, hcap =height of pile cap,

B=width of pile cap

As Per IS456 -2000 annex G,G-1.1 b

Area of steel required (Asq)= -

$$0.5 \times \left(\frac{f_c}{f_y}\right) \times \left(1 - \sqrt{1 - \frac{4.5977 \times M_u}{f_c \times b \times d \times d}}\right) \times b \times d$$

Where, fc=compressive strength of concrete

Mu= ultimate moment

fy= strength of steel = 3750.902 mm2

Area of steel provided (Ast) = 3750.902 mm2

Astmin<= A st

Steel area is accepted

Minimum spacing allowed (Smin) = 40 + db = 52.00 mm

Selected spacing (S) = 105.03 Mm

Smin <= S <= 450 mm

Where, smin= Minimum spacing, S= spacing allowed

The reinforcement is accepted

selected bar size < selected maximum bar size

5.2. Result of Stiffness Calculation

5.2.1 Pile stiffness in zone 3 by pile diameter changing

a) Diameter of pile = 500mm

Area of pile = 0.196 m2, Length of pile = 3.598m,

Modulus of elasticity = 29580 N/mm2

Moment of inertia = 3.06 x 10-3 m4

Stiffness Calculation

Refer IS 2911 Part1/Sec 2 2010 Annex C Cl.6.5.2,

For piles in sand and normally loaded clays

Stiffness factor = (EI/K1)1/5

Where,

E = Young"s modulus of pile material

I = Moment of inertia of the pile cross section

K1 = Modulus of subgrade reaction

Solving above Stiffness factor = 1.767

As, IS 2911 Part1/Sec 2 2010 Annex C Cl.3

L ≤ 2T: Indicates short (rigid) pile

L ≥ 4T: Indicates long (flexible) pile
From above, pile stiffness in zone 3 with pile diameter 500mm is 1.767.It satisfies the condition L ≤ 2T, so it is a case of rigid pile behaviour.
b)**Diameter of pile = 700 mm**
Area of pile = 0.384 m2
Length of pile = 3.598m
Modulus of elasticity = 29580 N/mm2
Moment of inertia = 0.0117 m4
Stiffness Calculation
As, IS 2911 Part1/Sec 2 2010 Annex C Cl.6.5.2.
For piles in sand and normally loaded clays
Stiffness factor = (EI/K1)1/5
Where,
E = Young‟s modulus of pile material
I = Moment of inertia of the pile cross section
K1 = Modulus of subgrade reaction
Solving above Stiffness factor = 2.311
As, IS 2911 Part1/Sec 2 2010 Annex C Cl.3.
L ≤ 2T: Indicates short (rigid) pile
L ≥ 4T: Indicates long (flexible) pile
From above, pile stiffness in zone 2 with pile diameter 700 mm is 2.311.It satisfies the condition L ≤ 2T, so it is a case of rigid pile behavior.

5.2.2 Pile stiffness in zone 2 by pile diameter changing.

a) **Diameter of pile = 500mm**
Area of pile = 0.196 m2, Length of pile = 3.598m
Modulus of elasticity = 29580 N/mm2
Moment of inertia = 3.06 x 10-3 m4
Stiffness Calculation
Refer IS 2911 Part1/Sec 2 2010 Annex CCl.6.5.2.
For piles in sand and normally loaded clays
Stiffness factor = (EI/K1)1/5
Where,
E = Young‟s modulus of pile material
I = Moment of inertia of the pile cross section
K1 = Modulus of subgrade reaction
Solving above Stiffness factor = 1.767
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L ≤ 2T: Indicates short (rigid) pile
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From above, pile stiffness in zone 2 with pile diameter 500 mm is 1.767.It satisfies the condition L ≤ 2T, so it is a case of rigid pile behaviour.
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Stiffness Calculation
Refer IS 2911 Part1/Sec 2 2010 Annex C Cl.6.5.2.
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I = Moment of inertia of the pile cross section
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From above, pile stiffness in zone 2 with pile diameter 700 mm is 2.311.It satisfies the condition L ≤ 2T, so it is a case of rigid pile behaviour.

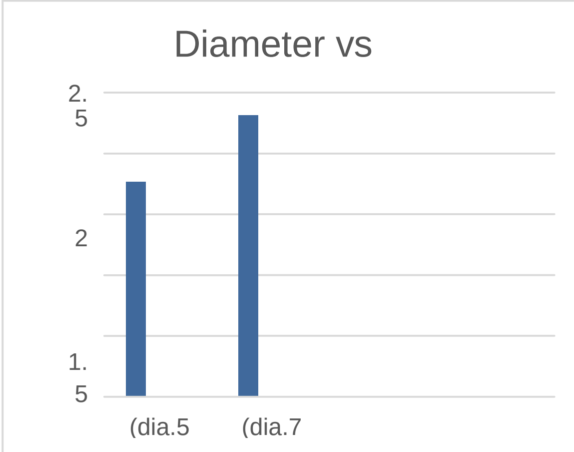

Chart 1 Graph of Stiffness Vs Diameter in Zone II

From above graph shows that stiffness of 500mm diameter pile is 1.76 and 700mm diameter pile is 2.31 hence rigidity of pile increase to in the same zone, When zone changes there is no change in stiffness as rigidity of pile remains same.

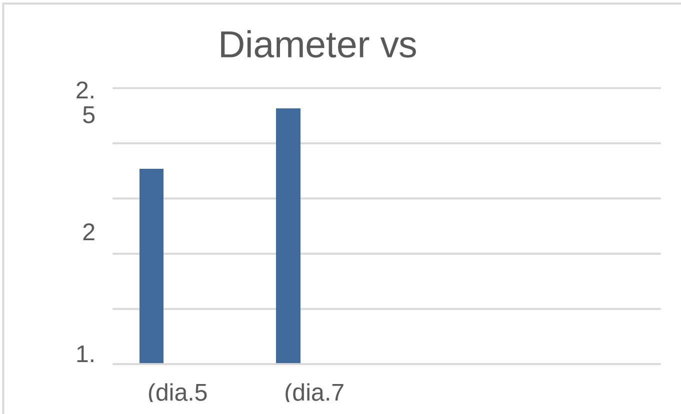

Chart- 2 Graph of Stiffness Vs Diameter in Zone III

6. CONCLUSIONS

1) It is observed the pile cap has a good contribution against the lateral load.
2) By changing the zone there is no change stiffness of pile.
3) By changing the diameter of pile from 500 mm to 700 mm there is change in stiffness of 32 % in same zone.
4) The different factor like length of pile, position of pile cap from ground level implies lateral resistance of pile cap.

5) The pile stiffness is directly proportional to modulus of elasticity of pile, the higher the modulus of elasticity of pile, higher is the pile stiffness. The material of pile and cap influences the pile cap stiffness.
6) Pile nature is rigid so behaviour of structure is also rigid against seismic response.
7) It is also represented highlighting the key points to be considered for seismic design of pile foundation.

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