DESIGN OF A HYPERBOLIC PARABOLOID FOOTING

Ramesh.J, Aswini Vasudevan, Manishaa.S

Ramesh.J (Assistant Professor), Civil Department, Prince Shri Venkateshwara Padmavathy Engineering College, Ponmar, Chennai – 600127, Tamil Nadu, India
Aswini Vasudevan (U.G. Student), Civil Department, Prince Shri Venkateshwara Padmavathy Engineering College, Ponmar, Chennai – 600127, Tamil Nadu, India
Manishaa.S (U.G Student), Civil Department, Prince Shri Venkateshwara Padmavathy Engineering College, Ponmar, Chennai – 600127, Tamil Nadu, India

ABSTRACT

Shell foundations are the development of hyperbolic shell roofs. Hypar shells are suited for supporting single-column loads, because of their single point of discontinuity. The most versatile aspect its geometry is its straight-line property, which gives it all the advantages of a shell and at the same time that of a plain surface Plane foundations were replaced by shell foundations to transfer eccentric and large amount of loads safely into soil. It is prescribed for weak soils also. It is comparatively more stable than conventional footing. It reduces the amount of steel and concrete used and so is cost effective. Hence shell foundations are found to be suitable for weaker soils, large scale constructions, special constructions and cost effective works.

Keyword: - *Hyperbolic shell, Shell foundation, Hyperbolic paraboloids*.

---

1. INTRODUCTION

In a hypar foundation, the forces in the ridge beams boundary members will be acting from the lower to the higher points along the ridge beams so that the ridge will be in compression. The total force in each ridge beam will be the sum of these forces in each shell on its sides. The forces in the edge beams will be the forces acting along the edge beam of each shell (and valley beams of multiple shells).This force in the edge beam will be equal to the sum of the shear forces along the edge of these members and it will obviously be in tension. Thus, we have tension and compression in the shell proper, compression in the ridge beam and tension in the edge beams. Shell footings are admirably suited to resist small eccentricities of applied load, even when they are designed for central vertical loads. The changing the rise of hypar shell and thickness will affect the structural properties of the shell. Variation in soil affects the load –deflection characteristics. Shells which act mostly in tension or compression will be more efficient and economical in such situations. Even in smaller foundations, the amount of materials that is necessary for a shell to carry a load will be considerably less than that required for bending members such as beams and slabs. However, the labour involved in shell construction (in forming the shell surface, fabricating steel, supervision, etc.) will be more than that is necessary in conventional type of foundations. Thus, in such special situations, one can consider the use of shells as foundations.

2. COMPONENTS OF SHELL FOUNDATION

The following are the components of shell foundation,

- Shell proper
- Ridge beam
- Edge beam
- Valley beam

Shell proper: It is provided for the extension of ridge beams in which tension and compression acts.

Ridge beam: Four inclined ridge beams are in compression and their vertical component of compression should carry the column. Their breath is made equal to the size of the column

Edge beam: Edge beams at the base are in tension. The thickness of the edge beams is made half the size of the column. Its depth should be about 1/6 the total length of the two hypar which form the base length.

Valley beam: Valley beams are used only in combined footings and raft footings.

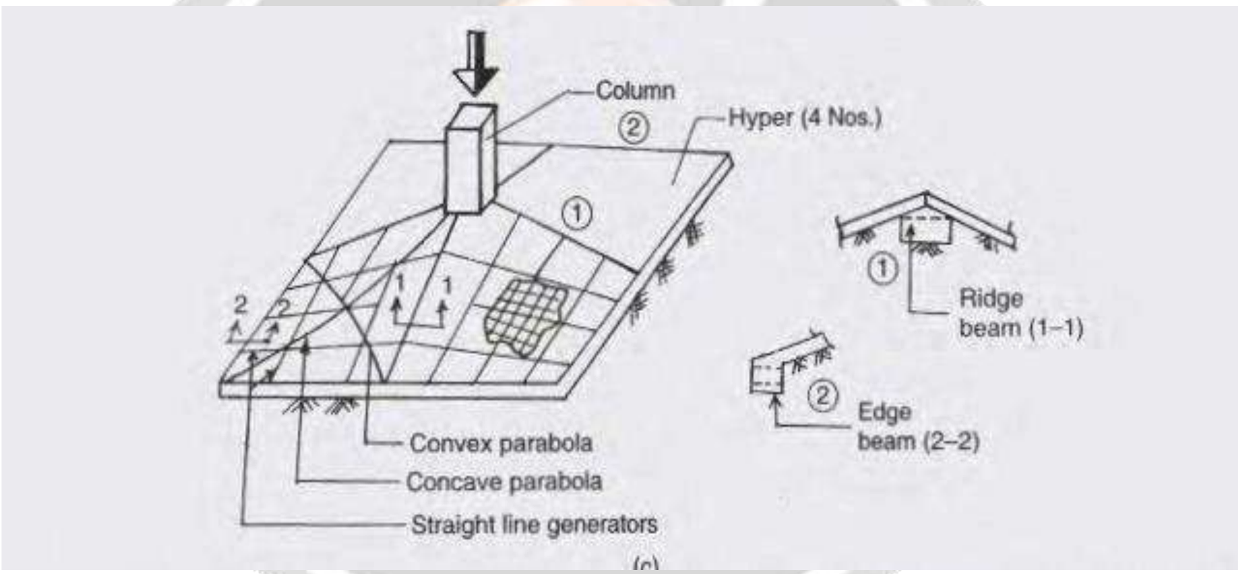


Fig-1: Formation of hypar shell by four hypars, (1) Ridge beam (2) Edge beam

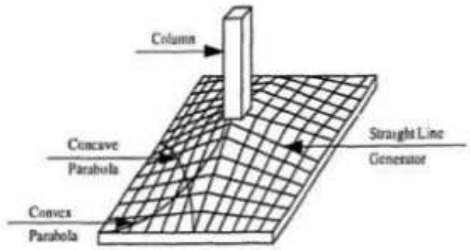


Fig-2: Hypar shell foundation

3. DESIGN OF SHELL FOUNDATION

The following shell foundation was designed for an aquatic centre with a hyperbolic paraboloid roof . the total area is with circular columns each with individual shell foundation.

Step 1: Dimensions of the shell

Load on footing transferred through the column = 161.67kN

Safe bearing capacity, SBC = 200kN/m^2

Required base area = $\frac{load}{SBC}$ = $\frac{161.67}{200}$ = 0.81 m^2

Hence, a = 0.9m

b = 0.9 m

Adopt 4 hypar shells, each of 0.2025 m size to form a column.

Let rise, h = 1 in 2

So, h = $\frac{0.2025}{2}$ = 0.10125m

Wrap of shell = $\frac{rise}{area}$ = $\frac{0.10125}{0.2025\times0.2025}$ = 2.469 m^{-1}

Base pressure = $\frac{load}{area}$ = $\frac{161.67}{0.90\times0.90}$ = 200 kN/m^2

Step 2: Membrane shear

Factored shear, q = 1.5 × 200 = 300 kN/m^2

Membrane shear = $\frac{q}{2\times wrap}$ = $\frac{300}{2\times2.469}$ = s = 60.75kN/m

Let thickness of shell = 120mm

Use 10mmØ with 50mm cover on both sides.

Shear stress, $\tau = \frac{s \times load}{thickness\ of\ shell} = \frac{60.75 \times 161.67}{120 \times 1000}$ = 0.508 N/mm^2

Allowable shear for M20= 2.8 N/mm^2.
However, we have to provide for the tension and compression produced by the shear along the Diagonals.

Step 3: Design of steel:

Design the steel in shell (Find area of steel for tension due to shear)
Tension = Shear = 60.75 kN/m.

Thickness = 120 mm

Steel required = $\frac{60.75 \times 1000}{0.87 \times 415}$ = 168.26mm^2

Percentage tension, pt = $\frac{168.26 \times 100}{1000 \times 120}$ = 0.14%

Some recommend 0.5% as minimum steel to reduce crack width in the slab.)
(This steel is more than the minimum 0.12% for shrinkage)

(Maximum spacing is less than 2xthickness)

Provide this steel parallel to the sides of the shell.

Provide 8 mm Ø at 150 mm c/c

Ast prov = 152.38mm^2

Step 4: Check for compression:

Compression stress, τ_c = 2.30N/mm^2

Which is much less than 0.4 fck = 0.4×20 = 8 N/mm^2

Step 5: Tension in edge beam:

Max tension (each shell) = Shear x Length

L = $\sqrt{s^2 + h^2}$

= $\sqrt{0.9^2 + 0.101252^2}$ = 0.91m

Shear x Length = 60.75 × 0.91 = 55.10kN

Area = $\frac{55.10 \times 1000}{0.87 \times 415}$ = 152.38 mm^2

Provide 10mm Ø at 250mm c/c

Provided area , Ast prov = 314.16 mm^2

No. of bars, n = 2

Assume width = $\frac{size\ of\ column}{2}$ = $\frac{400}{2}$ = 200 mm

Assume depth = 300 mm

pt = $\frac{314.16\times100}{300\times200}$ = 0.5236%

Good percentage for a beam. Not more than 5%. Also provide nominal ties of 6 or 8 mm @ 200 mm spacing.

Step 6: Ridge beam:

Length of ridge beam = $\sqrt{0.101252^2 + 0.20252^2}$ = 0.23m

Compression on both sides = shear × length (both sides)

= 2× 0.23 × 6.075 = 27.945 kN

Compare the above compression as calculated from the column load.

Check for compression load = $\frac{P\ l}{4h}$ = $\frac{1500\times0.232}{4\times0.475}$ = 851.85kN

Assume size of beam = 300mm ×100 mm

Total beam area = (300×100) + (0.5×300×100) = 45000mm^2

(As the compression member is attached with the shell, we need not check L/d ratio.)

Compression, C = 0.4fckAc + 0.67fyAs

Here, As = $\frac{(851.851\times1000) - (0.4\times20\times45\times1000)}{0.67\times415}$

= 1768.93mm^2

pt = $\frac{1768.93\times100}{300\times100}$ = 5.89%

Provide 20mm Ø at 170mm c/c

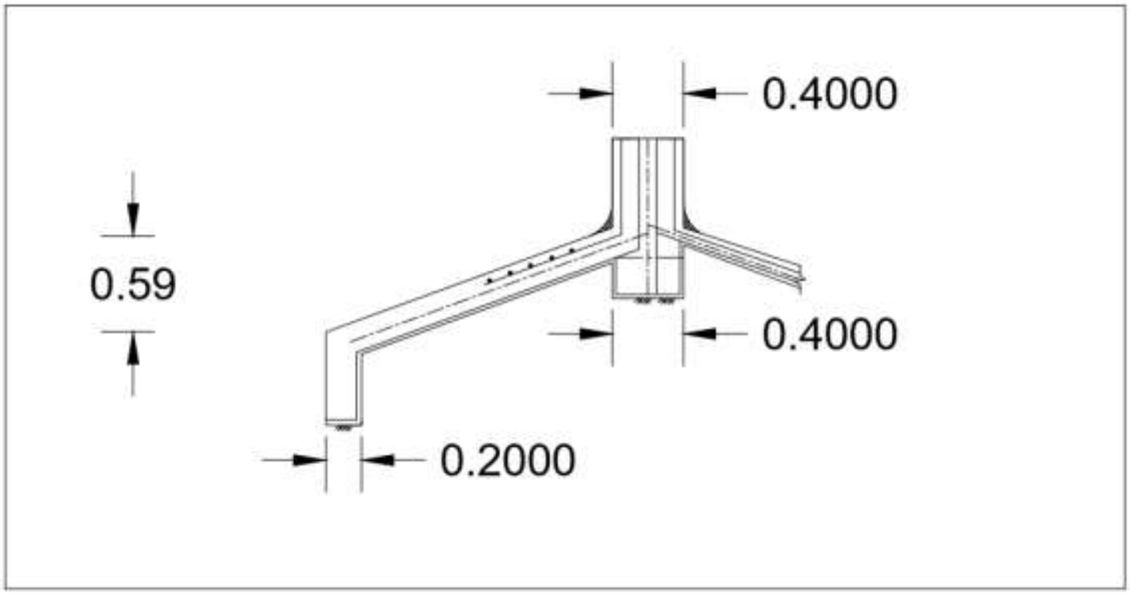
Ast prov = 1847.99mm^2

No. of bars = 6

Provide nominal ties of 8mmØ at 200mm c/c

It is better to over-design this ridge member so that its vertical component can support the column load with ample safety margin.

Step 7: Reinforcement details:



4. CONCLUSIONS

Hyperbolic shell footings are the most suitable type of footings for weaker soils. They are able to transmit negligible eccentric loads safely into the soil. Hypar shells are suited for supporting single-column loads, because of their single point of discontinuity These footings are safer and cost effective up to 30%than conventional type of footings in case of large scale constructions with unsafe soil. It can also be used for structures with heavy columns loads and soil having low bearing capacity making the structure economical.

5. REFERENCES

[1].Analysis and Design of Shell Foundation -Shaikh Mohd Ahmed, Shilpa Kewate
[2].Conical and Hyperbolic Paraboloid Shell Foundation -Mahesh Salunkhe, Manoj Yadav, Sanjeet Pal, Shubham Patil, Miss.Vaibhvai Mhatre
[3].Behavior of hyperbolic paraboloid shell footings under point loading -Syed jalaludeen shah, Thahzin sageer, Anu sidharthan
[4].Limit state design of reinforced concrete by P.C. Varghese
[5]. Structural engineering handbook (Third edition) by Edwin H. Gaylord, JR. Charles N. Gaylord
[6]. IS 9456 (1980): Code of practice for design and construction of conical and hyperbolic paraboloid types of shell foundations