Conical and Hyperbolic Paraboloid Shell Foundation

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Abstract:-Shell foundations present an economical alternative solution to the conventional plane foundations in case of heavy loads to be transmitted to low-bearing capacity soil. There are various types of shells are used in foundations like hyperbolicparaboloidshell,conical shell, inverted dome, elliptic paraboloid, pyramidal shell, triangular shell, cylindrical shell etc.Two types of shells are used in this study, namely, hyperbolicparaboloid (HYPAR) and conical shells. The objective of this study is to promote shell footing as an economic alternative to conventional foundation and design study of conical and hyperbolic paraboloid foundation and comparison between them.

Keywords:- *Shell, Bearing capacity, Conventional footing, Hyperbolic paraboloid, Conical footing.*

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I. INTRODUCTION

Shell foundations are considered cost-effective when heavy loads are to be carried by weak foundation soils. Such situations require large sized foundation because of the low bearing capacity. If we use bending member such as slabs and beams, the bending moment and shears in them will be large and the sections required will also be large. Shell which act mostly in tension and compression will be more efficient and economical in such situations. Even in smaller foundation, the amount of materials that is necessary for a shell to carry a load will be considerably less than that required for bending member such as beams and slabs. However, the labor involved in shell construction will be more than that is necessary in conventional type of foundation. Thus, in special situation, onecan consider shell foundations.[1]

The first recognized use of shell foundations dates back to the early 1950's where Spanish architect, Felix Candela (1955) has undisputedly been regarded as conceptual pioneer and forefather of the shell footing foundations notion. Experimenting with shell shapes, Candela‟s concern for elegance and style were his underlying motivations in opting for a structural shell. This conviction led to an extensive exploration of shell structural forms many of which are still in existence today. The Hyperbolic paraboloid otherwise known as "Hypar" shell footings, for example, was one he envisioned and used repeatedly on Mexican soil. This geometric shell was implemented successfully in a vast majority of his works in light of other experimental work on barrels and funicular vaults he was using. These shapes were further developed to support column loads in many parts of the world (Sondhi and Patel, 1961). Soon later, the Hypar shell form was suitedfor high–rise buildings and outfitted for water tank structures founded on poor soil .[2]

Numerous different nations have used shells as footings for especially powerless soil conditions, typically frail dirts. Russia, India and the United States be that as it may, have been prevalent clients of the shell structure in such structures. Extraordinary accomplishment in quality was shockingly accomplished in light of style and capacity to build these structures financially. Since the amount of both cement and steel material in shell development is insignificant, their economy helps in diminishing costs identified with shaping as was found in dreary arrangements, for example, in raft–shell establishment plans .[3]

Over time, designers have seemingly benefited not only from shells strength but from substantial cost–savings. For example, in Havana, the New City Hall was a 24–storey building constructed on a bearing soil of 287.3 kPa [6000 psf] capacity. The two options available to designers were a flat slab with deep beams and a raft formed by folded plate slab. The folded plate slab was selected as the preferred solution due to cost effectiveness of that option. The net savings experienced was reported to be 30% on the construction of such foundations. [4]

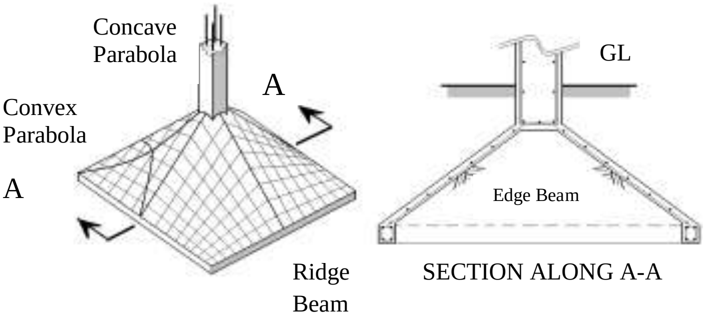
In the United States, the Summer High School in Washington, a classical example of a large stadium, was constructed of precast prestressed concrete units in attempt to seat some two thousand spectators. The site was reportedly a fill underlain by a deep deposit of soft mud. Thin reinforced concrete Hypar shell footings were adopted for this project to satisfy the established engineering requirements while maximizing space and optimize cost–savings from construction materials used. [5]

II. METHODOLOGY

The Bureau of Indian Standards has published IS 9456(1980) Code of Practice for the Design and

Construction of Conical and Hyperbolic Paraboloidal Type of Shell Foundations.

2.1 HYPAR FOOTING



1. Find shell dimensions.
   Area of footing=load / SBC
2. Depth of footing(f) .
   The ratio of rise to base(f/a)= 0.5 to 1
   Where,
   f= depth of footing.
   a= half of base.
3. Calculate membrane shear on factored load.
   $N_{xy} = P_v/2k$
   Where,
   N_{xy}= membrane shear.
   P_v=factored pressure =1.5×load/area provided
   k= wrap of shell = f/a^2
   Assume shell thickness(t)
   Shear stress(τ)=N_{xy}/t
4. Design the steel in shell. (*Find area of steel for tension due to shear).*
   $Ast_{req}=(N_{xy}\times 1000) / (0.87\times f_y)$
   Check % steel
   If %steel>0.5 hence ok
   If %steel <0.5 then provide 0.5%
5. Check compression in concrete in the shell.
   Compression stress = tensile shear < 0.4 f_{ck}
   Hence ok
   If >0.4 f_{ck}
   Compression steel is required in shell structure.
6. Design of edge beam.
   Max tension(T)=t×a
   $Ast=T/(0.87\times f_y)$
7. Design of ridge beam.
   Compression(C)= $2t\,(a^2+f^2)^{1/2}$
   Width of beam=column width
   $C=0.4f_{ck}\,A_c + 0.67f_y\,A_s$

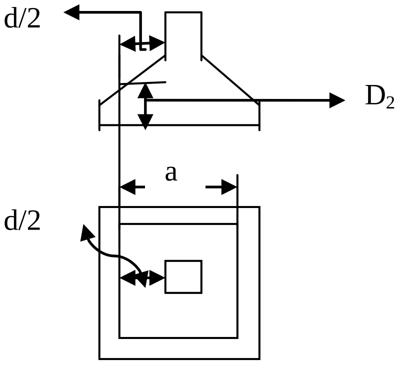
2.2 DESIGN STEPS OF CONICAL FOOTING

1. Find base diameter.
   Area of footing= load/SBC
2. Depth of footing(f).
   The ratio of rise to base radius(f/r)= 0.5 to 1
3. Find shell parameters (*S_1, S_2, α)*.
   S_1= Distance from apex to the column.
   S_2 = Distance from apex to the end of the shell.
   α= half central angle.
4. Find vertical pressure(q_v).
   q_v=1.5 ×(load/area)
5. Maximum compression per meter is at base of the column at the top of cone.
   $N_c=(q_v/2S_1)\tan\alpha\,(S_2^2-S_1^2)$
6. Design for compression.
   Assume min thickness(t) of footing 15cm.
   Total compression in concrete (T_c) = $N_c\times\pi\times d$
   $Ast/m=(T_c-SV_c)/(0.67\times f_y)$
   Where,
   d = diameter of column.
   safe value of compression in concrete (SV_c)= $0.4\times f_{ck}\times(\pi\times d)\times t$
7. Design for maximum hoop stress@ s_1.
   $N_t= q_u\times S_1\times\tan\alpha$
   $Ast/m = N_t/(0.87\times f_y)$
8. Design for maximum hoop stress @s_2..
   $N_t=q_u\times S_2\times\tan\alpha$
   $Ast/m =N_t/(0.87\times f_y)$

2.3 DESIGN STEPS FOR CONVENTIONAL FOOTING

1. Find area and size of footing.
   Area of footing= load/SBC
2. Calculate upward soil pressure on footing.
   w_u=load/area provided
3. Find out bending moment.
   $M=(w_u\times L\times a^2/2)$
   Where,
   a=(L-l)/2
   L= length of footing.
   l= length of column.
4. Calculate the depth of footing by using ultimate bending moment.
   $M_u=M$
   $M=R_{u\,max}\times f_{ck}\times b\times d^2$
   Where,
   b= width of column.
   d= depth of footing.
5. Find area of steel.
   $Ast=((0.5\times f_{ck}\times b\times d)/f_y)\times(1-(1-((4.6\times M_u)/(f_{ck}\times b\times^2))^{1/2})$
   Spacing=(area of one bar/Ast)×1000
6. Check for one-way shear.
   Critical section act at a distance d from the face of column.
   a. If critical section occur outside from the footing then it is safe in shear.
   b. If critical section lies in the footing, then check weather $\tau_c>\tau_v$or not.

7. Check for two-way shear.
   Critical section act a distance d/2 from the face of column.
   a. At the critical section, the shear resistance is obtained as per cl.31.6..3.1of IS 456 which gives τ_c..
      $V_{ur}=\tau_c \times A_1$
      Where,
      $A_1=P \times D_2$
      Perimeter(P)=4×a



b. Actual shear force is determined on the basis of average soil pressure at the centre line of the cross section.
   $V_{u=} w_u \times$Area.
   Where, Area=a^2
   Check, $V_{ur}>V_u$ or Not

III. RESULTTABLE

After designing the shells and conventional type footing for the same load (1000 Kn) and bearing capacity of soil(50 Kn/m^2) following result is obtain.

Grade of Concrete: M20
Grade of Steel: Fe415

Material	Hypar	Conical	Conventional
Steel (tonne)	0.63	0.440	0.72
Concrete (m^3)	5.7	0.55	13

IV. CONCLUSION

From the above result table we can conclude that shell foundations are economical and effective in low bearing soil compare to conventional type foundation. It can also be used for structures with heavy columns loads and soil having low bearing capacity making the structure economical.

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