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Comparison of Conventional and Ferrocement soil Retaining Structure

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***Abstract* - Due to rapid development of Construction industry in the world. Concrete and reinforcements are popular construction materials used to get creation of conceptualization due to mouldability. Sometimes Heavy self-weight is disadvantage. Prestressed and Ferrocement are the alternatives having advantages. Ferrocement can be replace all conventional construction materials like RCC, bricks, timber, steel etc. and construction become eco-friendly. In this research work retaining wall study is carried out by comparing ferrocement retaining wall with RCC conventional retaining wall with analytical exercise with variation of thickness and geometry has been discussed in detail. Analytical exercise done with the help of FEM based ANSYS.17.0 software. Results of the analytical study shows use of ferrocement with minimum thickness can sustain stresses with permissible deflection.**

***Index Terms* - Direct stress, Geometry, Ferrocement, Retaining wall.**

I.INTRODUCTION

Walls built for backing granular solid materials like soil, earth, loose stone, sand coarse aggregate, coal, grains etc. are called Retaining walls. Loads of these materials when piled together will not remain in a vertical face. They have tendency to slide down and repose themselves to a particular inclination. Soils in cutting or embankment have got the same tendency of sliding down. When such embankments and cutting or loads of granular materials are to be kept in vertical position, there should be supporting structure to keep the material from falling into an inclined repose formation. The conventional type of retaining walls is made of brick, stone masonry and RCC cantilever and counterfort retaining walls are constructed depending upon vertical heights of retaining material to be supported. These retaining wall having heavy, bulky foundation, also required more time for construction. Therefore, alternative material as ferrocement is came as good alternative in which time for construction, weight of the structure and cost can be reduced as compared to RCC cantilever and counterfort retaining wall. Ferrocement is basically composed of reinforcement and mortar, one is naturally desirous to compare it with reinforced concrete. RCC is a heterogeneous composite. After first crack, steel and concrete share the load separately and the design is based on concrete taking compression and steel taking tension. In ferrocement due to strong bond between wire meshes and mortar, even after the first crack steel and mortar act together as homogeneous material. Up to the yield of steel wires, strains in steel and mortars are same.

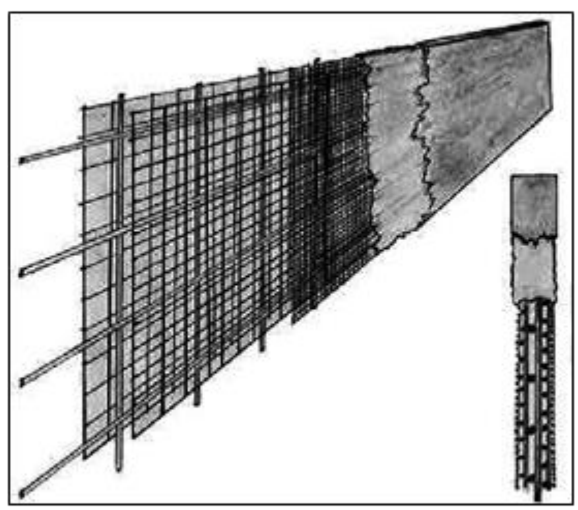


Fig.1: Ferrocement Wall

Ferrocement can replace all types of construction material. It is thin walled and continuity and placement of equal mesh reinforcement in both directions make it possible to achieve high equal strength in both the direction. It can be molded in any shape and size. Its strength to weight ratio in tension and compression is very low. There is various advantage of this material which make it best alternative of RCC. In this project work comparison of conventional RCC retaining wall is done with ferrocement retaining wall, for comparing some common data is adopted like height of wall is considered as 5m, soil retained by wall having density18kN/m3back fill supported by the wall is on counterfort side depth of surcharge is considered equal to height of stem and backfill is assumed to be horizontal. By considering all this data for various geometrical configuration, optimal geometrical configuration needs to be found out and after that parametric study on optimal section is done.

II. OBJECTIVE OF STUDY

Conventional and Ferrocement Soil Retaining Structure Comparison Using Various Geometrical Configuration.

Parametric Study of Ferrocement Soil Retaining Structure.
Objectives:
To determine and compare the Deflection and Stress behavior in compression and shear of conventional and ferrocement structure in various members of retaining wall.
To determine geometrical configuration to useful material strength and full section strength.
To determine which structure is economical.
To analyze behavior of ferrocement soil retaining structure in variation with different parameter like height, arch rise and volume reinforcement.

III. PROBLEM STATEMENT

The conventional RCC soil retaining structure has got its certain drawbacks of being too heavy and costly. For solution over drawback ferrocement is chosen as an alternative to conventional RCC soil retaining structure. There are various structures like water tanks, dams, pipe, domes, roof slabs, shells, etc. where ferrocement is used widely. Ferrocement structures can be shaped in such a way that the full section of the member and the full strength of material can be utilized, so its stem is shaped as an arch to use higher compressive strength of mortar and full cross section of arch sharing the load, due to reduced thickness requires material will be less. Therefore, taking this advantage of ferrocementitius application for soil retaining structure needs to be checked. To achieve the same, analyze behavior of ferrocement soil retaining structure in variation with different parameter like height, arch rise and volume reinforcement.

IV. METHODOLOGY

This project work includes comparison of conventional Reinforced Cement Concrete retaining structure and Ferrocement soil retaining structure. Also, parametric study on arch shaped stem and base ferrocement soil retaining structure. For comparing Reinforced Cement Concrete structure with Ferrocement structure, retaining wall of 5mheight with soil density of 18 kN/m3 is considered. For Reinforced Cement Concrete retaining wall other dimensions of structure is calculated by manual analysis.
Manual calculation for RCC structure is given below:
GIVEN DATA: Height of retaining wall=5m, Soil bearing capacity =180kN/m2, Unit weight of soil=18 kN/m2, Angle of internal friction=300, Coefficient of friction between concrete and soil=0.5Gradeof concrete=M20, Grade of steel = Fe415.

SOLUTION:
Coefficient of active pressure Ka = 1-sin30/1+sin30=1/3, Coefficient of passive pressure=Kp=3
1.Dimensions of various parts:

- Base width= 0.5Hto0.6H =0.55*5=2.75m
- Length of toe=¼Bto1/3 B
- Length of toe slab=α*base width==0.8m
- Length of heel slab=2m
- Clear spacing between counterfort=2m
- Assuming thickness of stem =200mm
- Assuming thickness of heel and toe =300mm

Sr.No.	Designation	Force(kN)	L.A.(m)	Moment about Toe (kN-m)
1	W1	0.2*4.7*1*25=23.5	0.9	21.15
2	W2	0.3*2.75*1*25=20.625	1.375	27.878
3	W3	1.75*4.7*1*18=148.05	1.875	277.59

1. Moment about toe = weight of stem per meter length W2=weight of base slab, W3=weight of soil on heel slab

∑W=192.175kN, Mo=123. 998kN.m,
MR=326. 61kN.m, Mo =123.99
Net moment =∑M
=MR-M0=326.61 -123.99 =202.62 kN.m

Against overturning
= 326.61/123.99 =2.634 >2 Hence, safe.
F.S. against sliding =μ$\sum w/ Ph$
= (0.5∗192.175)/74.25=1.29

Horizontal earth pressure
Ph=ka*γ*H2/2= 0.33*0.5*18*52= 74.25kN @1.67m.
X =$\sum M$/∑W =202.62/192.175=1.054
and, Eccentricity, e =(b/2)- x=0.32m
Pressure under toe=P1=$\sum W$ (1+6e/b)
= 192.75*(1+(6*0.32)/2.75)
=118.67 kN/m2 < 180 kN/m2
Pressure under heel=P2= $\sum W$ (1-6e/b)
= 192.75*(1-(6*0.32)/2.75) = 21.09 kN/m2

Analysis of heel slab:
Clear spacing of counterforts = 2m c/c
Pressure under heel=P2=21.09 kN/m2
Downward load due to weight of earth
= 4.7*18=84.6kN/m2,
Self-weight of heel slab=0.3*25=7.5kN/m2
Total downward intensity
=p=84.6+7.5-21.09=71.010kN/m2

Maximum negative bending moment in heel slab.
M1 = Pl2 /2 = (71.02^2)/12 =23.67 kN.m
Mu1=1.5*23.67=35.50 kN.m

Depth Calculation-Applying moment equilibrium equation,
23.67*106=0.138*20*1000*d2
d =113.45mm D=113.45+50=163.45
Provided D=300mm
Shear force-
M1 = Pl /2 = (71.02^2)/2 =71.02 kN
Vu=1.5*71.01=106.5kN

Maximum positive bending moment in heel slab.
M1 = Pl2 /2 = (71.02^2)/16 =17.75 kN.m
For fixed beam or slab carrying U.D.L the point of contraflexure is situated at a distance of 0.211L
=0.211*2=0.42m
Shear force=V = P(l/2-0.63)
=71.01(1.37-0.42) = 67.8kN

Analysis of toe slab:
Pressure under toe=118.67kN/m2
Self-weight of toe slab=0.3*25=7.5kN/m2
Total downward intensity
=p=118.677.5=111.27kN/m2Maximumnegative bending moment in toe slab
M1 = Pl2 /12 = (111.27^2)/12 =37.09 kN.m
Mu1=1.5*37.09=55.635 kN.m

Depth calculation;
By moment equilibrium
55.635*106=0.138*20*1000*d2
d=141.97, D=141.97+50=191.97mm
provided d=300mm… hence safe
Shear force V= Pl /2=111.27∗2/2=111.27kN
Vu=1.5*111.27=166.90kN

Maximum positive bending moment=
M1 = Pl2 /2 = (111.27^4)/16 =27.81 kN.m
For fixed beam or slab carrying U.D.L the point of contraflexure is situated at a distance of 0.211L
=0.211*2=0.42m
Shear force=V=P(l/2-0.42)
=111.27(1.375-0.42) =106.26kN

Analysis of stem:
Clear spacing between counterforts=2m
Intensity of earth pressure=h= ka*γ*H =0.33*18*4.7
=27.92kN/m2
Self-weight of stem=0.2*25=5kN/m2
Maximum negative bending moment in heel slab
M1 = Pl2 /2 = (27.92^2)/12 =9.30 kN.m
Mu1=1.5*9.3=13.95 kN.m

Depth calculation;
By moment equilibrium
13.95*106=0.138*20*1000*d2
d=81.27, D=81.27+50=131.27mm
D= 200 mm hence safe
Shear force V= Pl /2=27.92∗2/2=27.92kN
Vu=1.5*27.92=41.88 kN

Maximum positive bending moment=
M1 = Pl2 /2 = (27.92^4)/16 =6.98 kN.m
For fixed beam or slab carrying U.D.L the point of contraflexure is situated at a distance of 0.211L
Shear force=V=P(l/2-0.42)

=111.27(1.375-0.42) =39.98kN

Height of retaining wall =5m

Thickness of stem=200mm

Thickness of counterforts=200mm

Thickness of heel and toe=300mm

Counterfort spacing =2000mm Depth undersoil =1000mm

By this calculation dimensions of structure are fixed. Value of young's modulus of elasticity is taken as 22360.67 N/mm2 for grade of concrete M20 and density of RCC taken as 25000N/mm2. from this data model of rectangular RCC structure is modelled in ANSYS workbench 17.0.

After this ferrocement model of same dimensions as calculated for RCC with grade of concrete M20 and considering properties of welded square mesh as a reinforcement having yielding stress 450 N/mm2. Taking modulus of elasticity as 30000N/mm2i.e. for minimum value of ferrocement. Same dimension model is modelled with properties of ferrocement and results are analyzed. Then keeping material properties same of ferrocement rectangular retaining wall, again retaining wall of only 50 mm thickness is modelled and results are analyzed. Ferrocement wall thickness hardly exceeds 50mm.it is the material consist of sprayed mesh layers throughout the section which helps in increase in flexural strength and reduced thickness. After this to confirm the best.

V. RESULTS AND DISCUSSION

After analysis results are considered in the form of deflection, shear stress and direct stress and all the comparison is done by considering these parameters only at various positions of stem base and counterfort. Following are figures shown of various retaining walls:

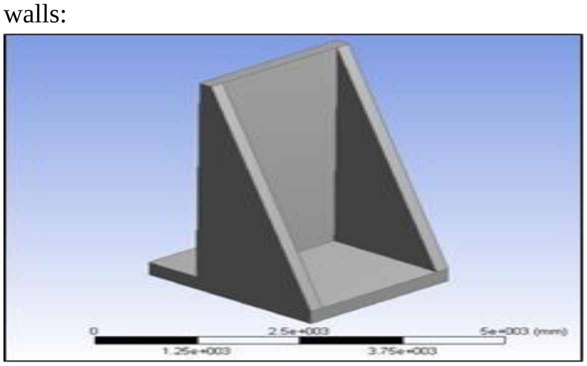


Fig.1: RCC Rectangular Retaining Wall

Height of retaining wall =5m

Thickness of stem=200mm

Thickness of counterforts=200mm

Thickness of heel and toe=300mm

Counterfort spacing =2000mm

Depth under soil =1000mm

Length of heel=1750mm

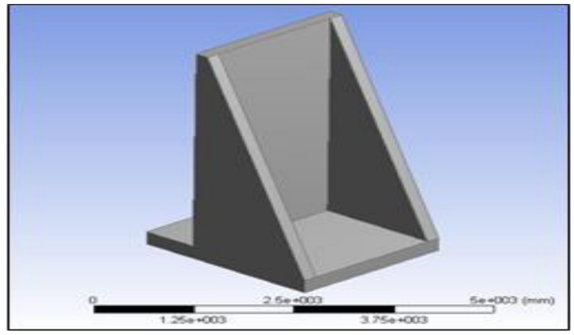
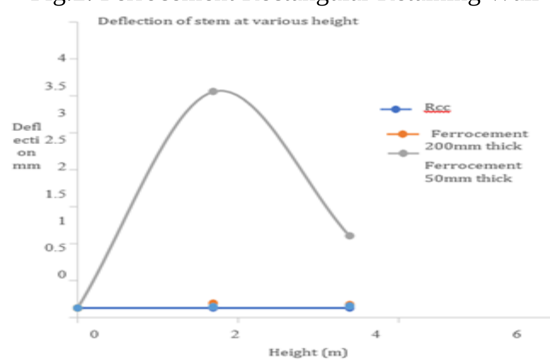


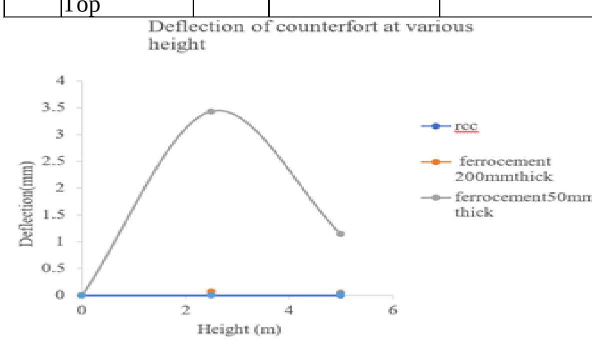
Fig.2: Ferrocement Rectangular Retaining Wall



Graph 1: Deflection of stem at various height

Table 2: Deflection within RCC and ferrocement structures at various position of counterfort

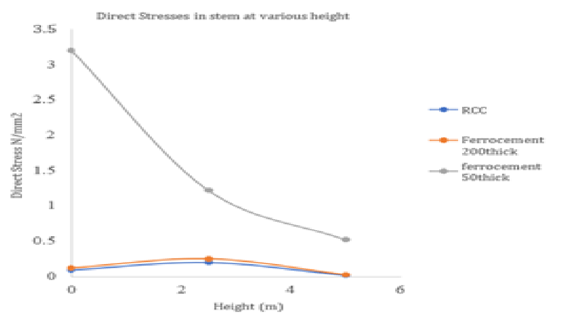
Sr. No.	Height (m)	RCC	Ferrocement of same dimensions	Ferrocement with 50mm thickness
1	0 Bottom	0	0	0
2	2.5 Middle	0	0.068	3.43
3	5 Top	0	0.042	0.76



Graph 2: Deflection of counterfort at various height

Sr. No.	Height (m)	RCC	Ferrocement of same dimensions	Ferrocement with 50mm thickness
1	0 Bottom	0.08	0.115	3.2
2	2.5 Middle	0.196	0.248	1.22
3	5 Top	0.010	0.0201	0.52

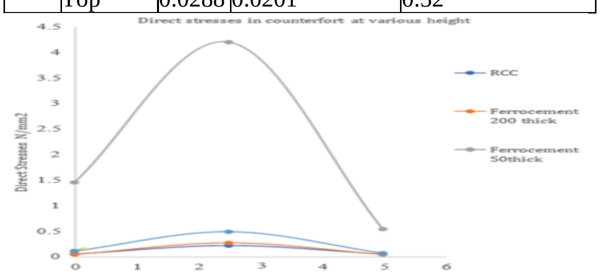
Table 3: Direct stresses in stem within RCC and ferrocement structures at various position of stem.



Graph 3: Direct stresses in stem within RCC and ferrocement structures at various position of stem.

Table 4: Direct stresses in counterfort within RCC and ferrocement structures at various position of counterfort.

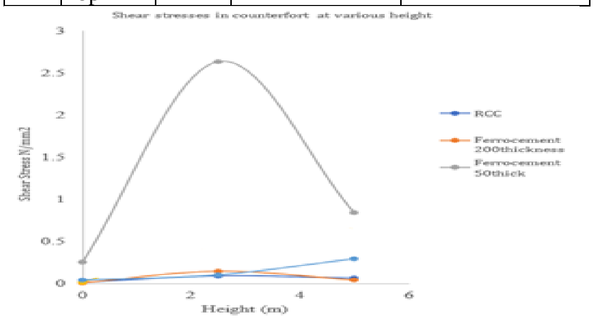
Sr. No.	Height (m)	RCC	Ferrocement of same dimensions	Ferrocement with 50mmthickness
1	0 Bottom	0.0288	0.0201	1.44
2	2.5 Middle	0.196	0.248	4.2
3	5 Top	0.0288	0.0201	0.52



Graph 4: Showing direct stresses in counterfort within RCC and ferrocement structures at various position of counterfort.

Table 5: Shear stresses in counterfort within RCC and ferrocement structures at various position of counterfort.

Sr. No.	Height (m)	RCC	Ferrocement of same dimensions	Ferrocement with 50mm thickness
1	0 bottom	0.008	0.0037	0.25
2	2.5 middle	0.086	0.141	2.637
3	5 Top	0.06	0.038	0.84



Graph 5: Showing Shear stresses in counterfort within RCC and ferrocement structures at various position of counterfort.

VI. CONCLUSIONS

Steel meshes used as reinforcing material is dispersed throughout the structure due to strong bond between wire meshes and mortar even after first crack steel and mortar act together as a homogeneous material. This shows ductile properties of material. The deflection limit under limit state of collapse is considered which allows 20mm deflection and as we are using grade of mortar M20 its permissible limit of direct stress is 5MPa from IS456-2000.From Table 1 -5 and graph 1-5 following conclusions are observed.

1. In rectangular shape counterfort retaining wall maximum deflection is observed at h/3distance on stem. while in arch shape counterfort retaining wall, maximum deflection is observed at top surface of stem.
2. Direct stresses are maximum at middle height of counterfort from inside in all the types of retaining wall.
3. Shear stresses are maximum at middle height of counterfort from outside in all the types of retaining wall.
4. Values of deflection and stresses of ferrocement rectangular retaining wall with same dimensions as RCC is more than conventional RCC retaining wall.
5. Very large deflections and maximum direct stress values are observed in rectangular shaped ferrocement counterfort retaining wall with50mm thickness, hence application of rectangular shaped

ferrocement retaining wall with less thickness is unsafe.

6. Direct stress values in stem at various heights of ferrocement arch stem and base retaining wall is 3.5% more in comparison with conventional RCC retaining wall and values are within permissible limits.
7. Deflection at base in all the types of retaining wall is found to be zero.

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