NUMERICAL ANALYSIS ON SEEPAGE AND STABILITY OF EARTHEN EMBANKMENT USING FINITE ELEMENT METHOD

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ABSTRACT: The paper presents seepage and stability analysis performed by using finite element method based software PLAXIS 2D. The Analysis conduct on seepage conditions: Steady state, rapid drawdown, slow draw down duration for high flood and full supply level of dam. The different combination of filter thickness and length is examined. The filter length consider as 20 m, 40m, 60m and thickness as 4m, 6m, 8m and also varying the cohesion and permeability of core section. The length of filter have increased from 20m to 40m with the thickness of 4m, the water at F.S.L then the F.O.S was increased upto 3.15% for steady state and for the rapid draw down conditions it was reduces upto 2.11%. For the slow draw down condition, the F.O.S was increase upto 1.17%. At H.F.L, the F.O.S decreased for the steady state 2.2% and for the rapid draw down condition, the F.O.S reduces upto 0.58%. For the slow draw down, condition the F.O.S increased upto 0.58%. In rapid draw down condition, the F.O.S values observed were reduced. Due to the sudden change of water level, this may cause due to development of excess pore water pressure.

Keywords: *Earth dam; Zoned core; Steady state; Transient analysis; Stability; Finite Element Method.*

1. **Introduction:** Dams are used especially for water storage, energy production and irrigation purpose. Dams mainly divided into four categories based on their types such as gravity dams, butter dams, arch dams, and embankment dams. Embankment type considered the best dam because it is conservative from the development perspective. The dam body was constructed from most impermeable materials for preventing flow into an earth fill dam. Due to rapid draw down of water at upstream side, the material becomes unstable. By this, while designing earth-fill dam there is an expectation of some seepage flow through the dam body. Development of water in soil frequently is a basic issue in an earth-fill dam. Seepage relies upon a few factors, the porousness of soil, also by pressure gradient, and the couple of forces acting on the water through gravity and some other factors. Due to forces or pressure behind the seeping of water, it could create enlarging of existing seepage path. The excessive pore water pressure or internal erosion causes strength loss of material. The seepage take as critical part in slope stability and distortion of Geotechnical structures. (Athani et al., 2015) the diminishing of crest displacement used to be performed by way of increasing young's modulus of shell and core. By interpretation in angle of internal friction fulfill the complete stability. (Andreea 2015)Carsel and Rawls define the core and filter has an unsaturated attribute. According to them exceptional permeability gives exclusive porosity and the distinction between stress head values of Carsel and Rawl. (Kanchana et al. 2015) The 25% of black clay soil was used in design mix that reduces the permeability this is an important property of core material. The form of material used offers safety for small or medium height of earthen dam. Mahmoud et al. (2014) the results derived from actual topographic observation the seepage rate was increased up to 23 percent. P. Gopal et al. (2014) the bishop method was used in each state and with the help of SLIDES, the minimal FOS was calculated.

2. PARAMETRIC STUDY OF EARTHEN DAM.

In this paper the results of seepage and stability was inspected the earth dam, the analysis on the basics of finite element modelling by using PLAXIS 2D. Full supply level and high flood level of dam was studied without filter and varying length and thickness of filter. Also studied about the effect of rapid drawdown conditions in the comparison of slow drawdown condition. The study enlighten the behaviour of stability by varying the cohesion and permeability of core section. These can be checked by following seepage conditions: Steady state, rapid drawdown, slow draw down duration. For high flood and full supply level of dam. By the application of three different lengths of filter and thickness of filter, the study was done. The length of filter was toward the axis of dam from downstream side and the thickness is varied in upward direction.

To find the stability of dam, the zoned type earthen dam was proposed for H= 35m height with h= 30 m sub-soil and a= 210m in length. A crest width of T =10m was gave in proposed design with side slopes of 1:2.5 both the upstream and downstream side. The boundary conditions were assigned to the base of the sub-soil. The freeboard was consider for the full supply level is FB = 5m and H.F.L was without freeboard. The length of filter is (x) and thickness of filter (y). "F" is shown as filter line diagram.

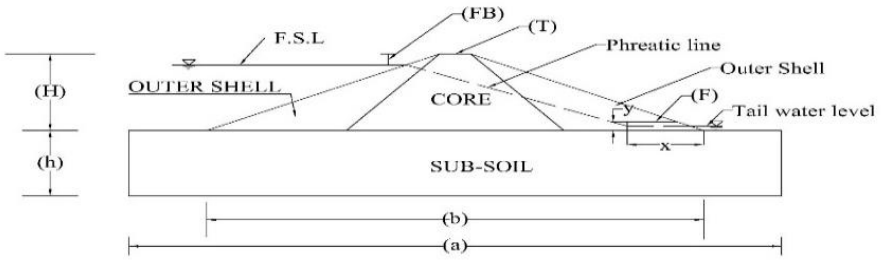


Fig 1: Line diagram

Table 1: Soil Properties

The study was carried out by varying the parameters:

Description	Units	Values of sub-soil	Values of Filter	Values of shell	Values of (C-1)	Values of (C-2)
TYPE	-	Drained	Drained	Drained	Undrained	Undrained
MODEL	-	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unsaturated soil (γ_{usat})	kN/m^3	17	18	16	16.09	15.08
Saturated soil (γ_{sat})	kN/m^3	22	21	20	19.20	18.20
Modulus of Elasticity (E)	kN/m^2	2.000E+08	4.000E+04	5.000E+07	2.500E+07	2.400E+07
Poisson ratio (ν), Cohesion (c)	-	0.25,1	0.200,0.5	0.330,5	0.300,113	0.300,40
Friction angle (φ), Dilatancy angle (ψ)	-	35°,0°	35°,3°	30°,1°	20°,0°	30°,0°
Coefficient of permeability (k)	m/day	0.200	1.4200	0.200	7.949E-0.3	9.504E-05

3. Results and Discussion

2.1 Following results shows the FOS value obtained from the without filter and material variation of core section material variation of core section material variation of core section

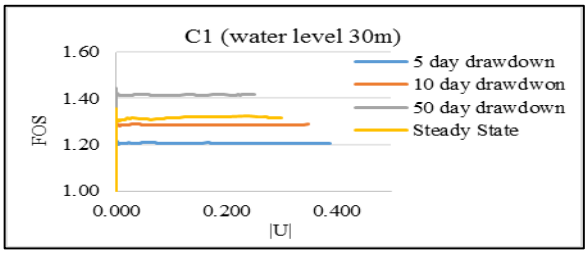
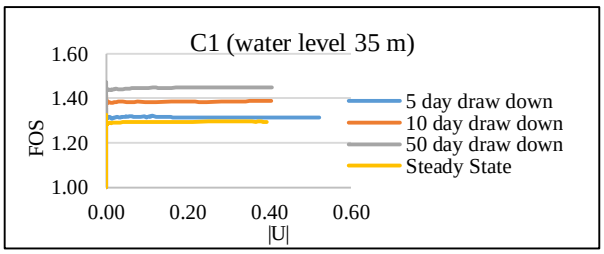


Fig 2: FOS vs Displacement (without filter)



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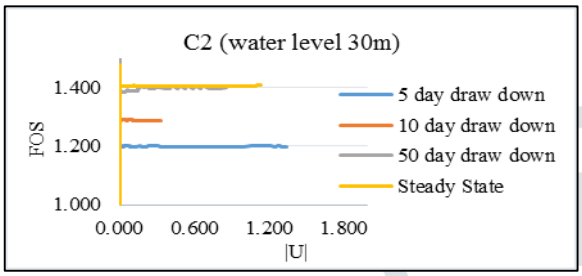


Fig 4: FOS vs Displacement (without filter)

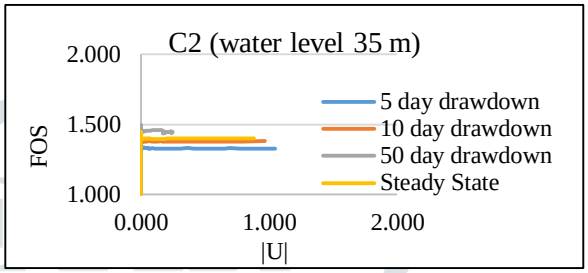


Fig 5: FOS vs Displacement (without filter)

2.2 Following results were obtained from combination various size of filter and material variation of core section

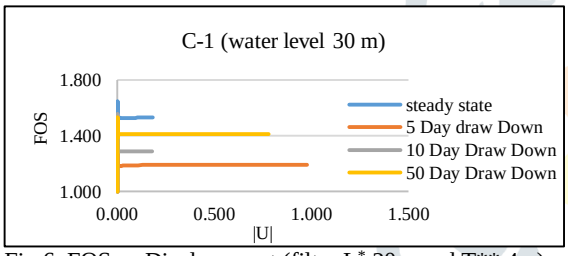


Fig 6: FOS vs Displacement (filter L* 20m and T** 4m)

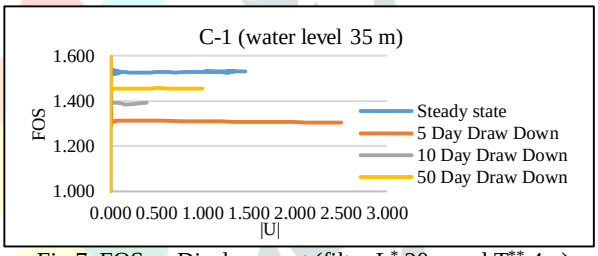


Fig 7: FOS vs Displacement (filter L* 20m and T** 4m)

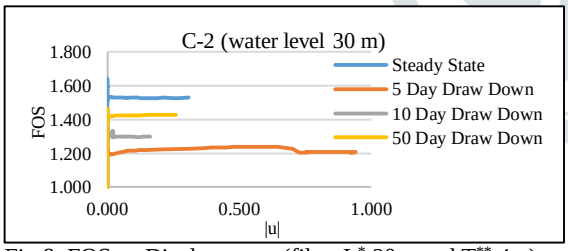


Fig 8: FOS vs Displacement (filter L* 20m and T** 4m)

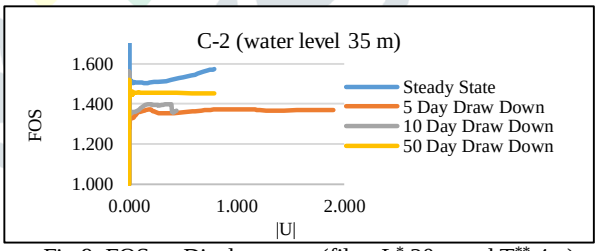


Fig 9: FOS vs Displacement (filter L* 20m and T** 4m)

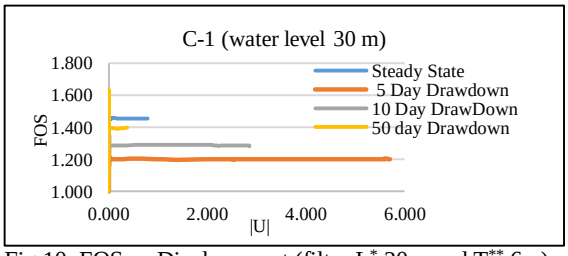
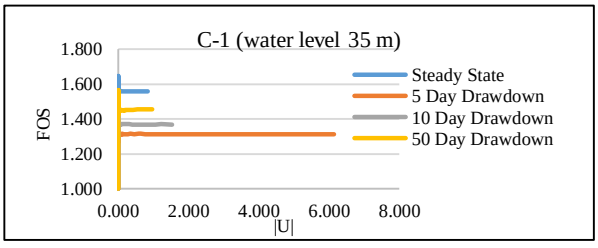


Fig 10: FOS vs Displacement (filter L* 20m and T** 6m)



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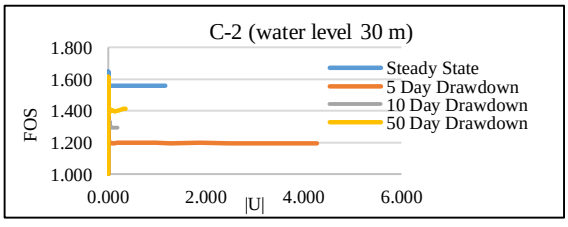


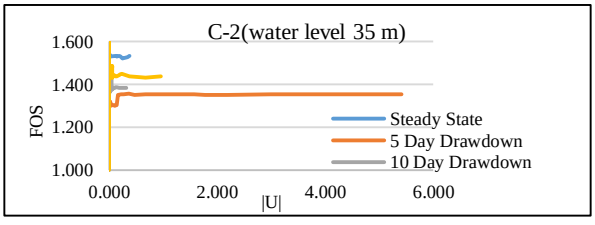


Fig 12: FOS vs Displacement (filter L* 20m and T** 6m)

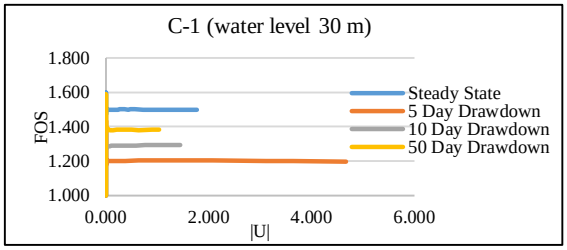
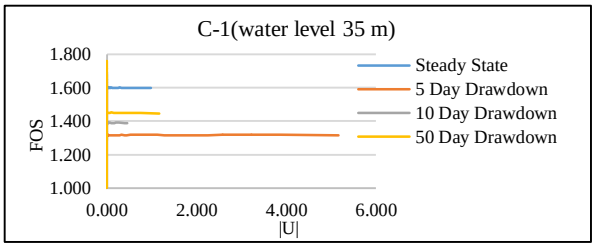


Fig 13: FOS vs Displacement (filter L* 20m and T** 6m)



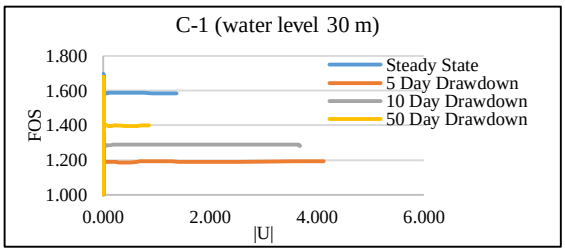
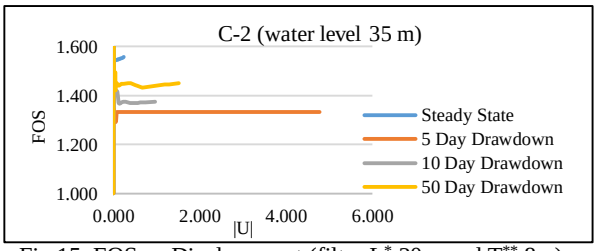


Fig 14: FOS vs Displacement (filter L* 20m and T** 8m)



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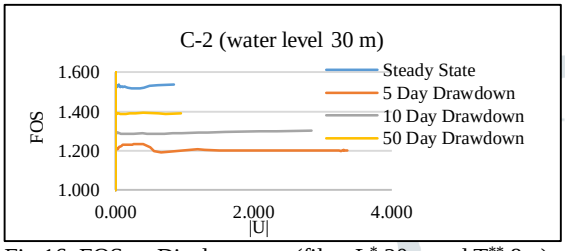

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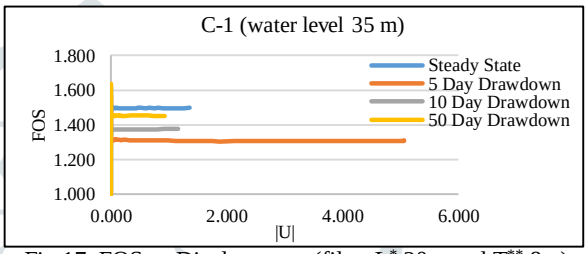


Fig 17: FOS vs Displacement (filter L* 20m and T** 8m)

*Length of filter
** Thickness of filter

Fig 18: FOS vs Displacement (filter L* 40m and T** 4m)

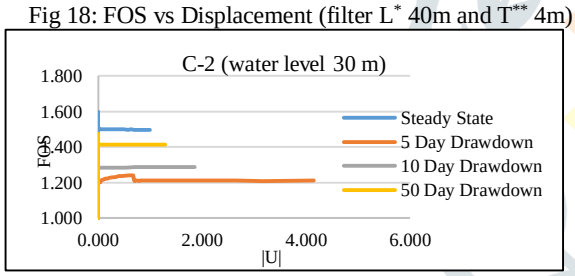


Fig 19: FOS vs Displacement (filter L* 40m and T** 4m)

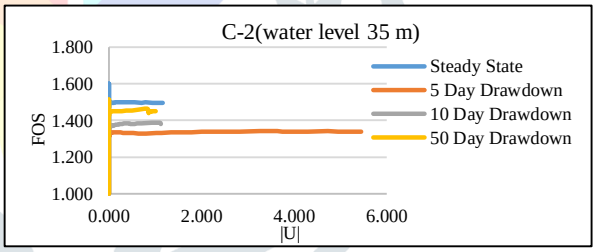


Fig 20: FOS vs Displacement (filter L* 40m and T** 4m)

Fig 21: FOS vs Displacement (filter L* 40m and T** 4m)

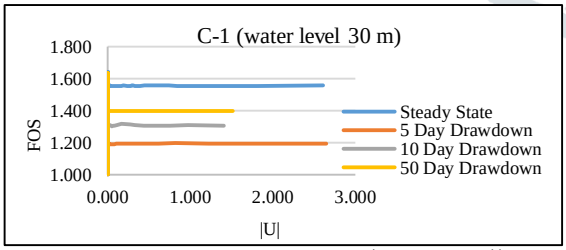
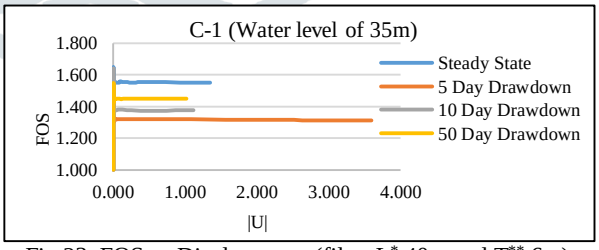


Fig 22: FOS vs Displacement (filter L* 40m and T** 6m)



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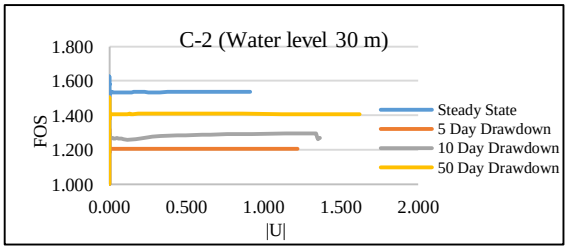


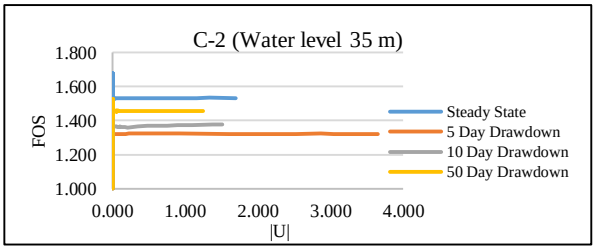
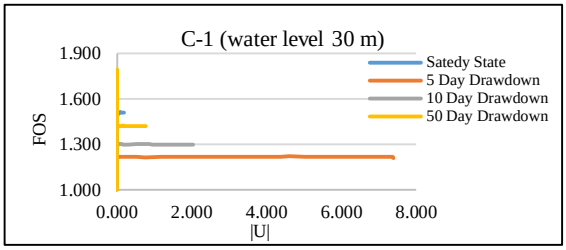


Fig 24: FOS vs Displacement (filter L* 40m and T** 6m)



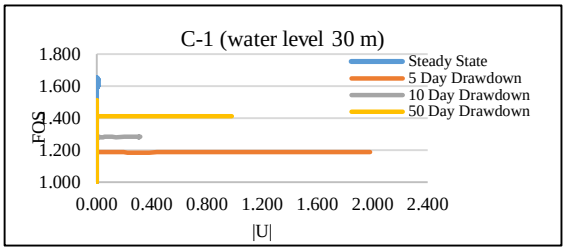


Fig 25: FOS vs Displacement (filter L* 40m and T** 6m)

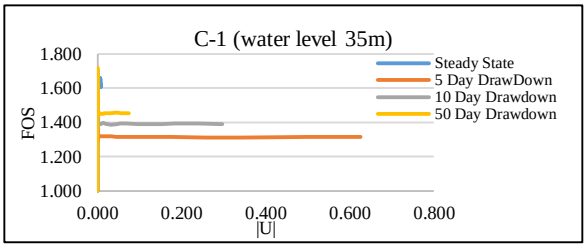
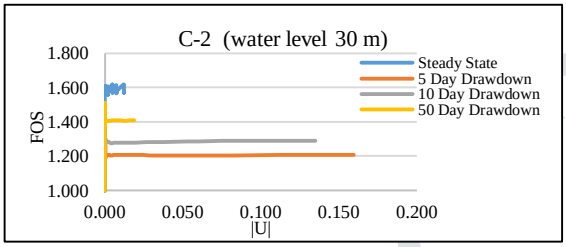


Fig 26: FOS vs Displacement (filter L* 40m and T** 8m)



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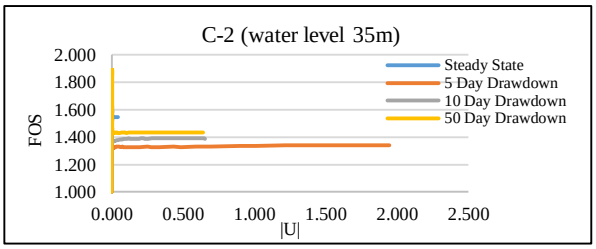


Fig 28: FOS vs Displacement (filter L* 40m and T** 8m)

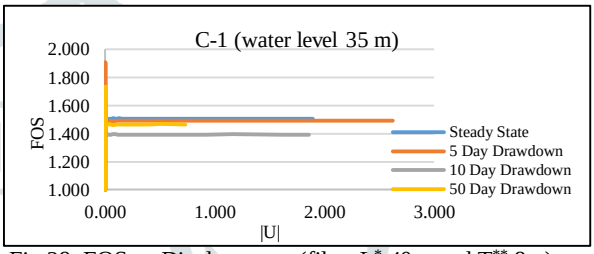


Fig 29: FOS vs Displacement (filter L* 40m and T** 8m)

*Length of filter
** Thickness of filter

Fig 30: FOS vs Displacement (filter L* 60m and T** 4m)

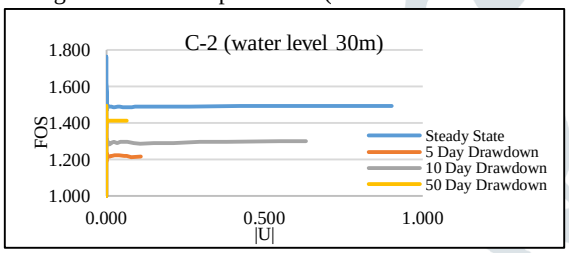


Fig 31: FOS vs Displacement (filter L* 60m and T** 4m)

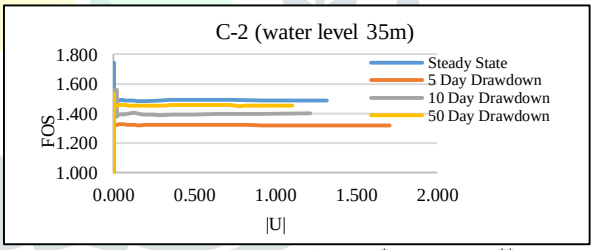
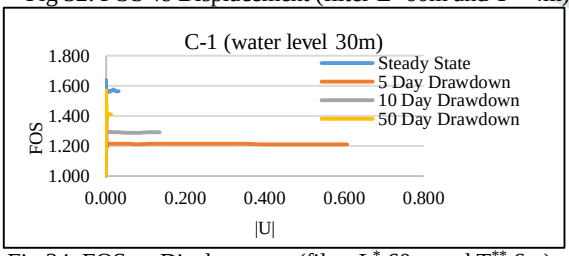


Fig 32: FOS vs Displacement (filter L* 60m and T** 4m)

Fig 33: FOS vs Displacement (filter L* 60m and T** 4m)



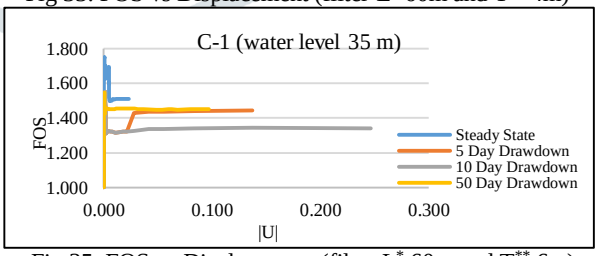
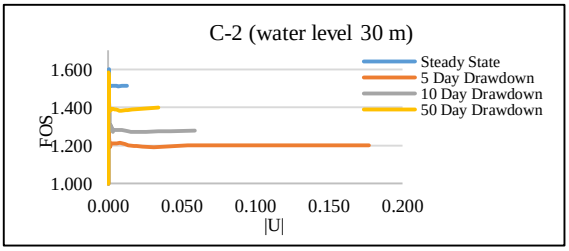


Fig 34: FOS vs Displacement (filter L* 60m and T** 6m)

Fig 35: FOS vs Displacement (filter L* 60m and T** 6m)



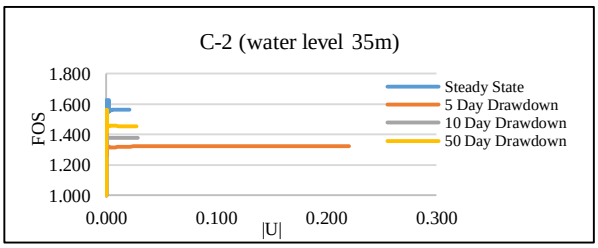


Fig 36: FOS vs Displacement (filter L* 60m and T** 6m)

Fig 37: FOS vs Displacement (filter L* 60m and T** 6m)

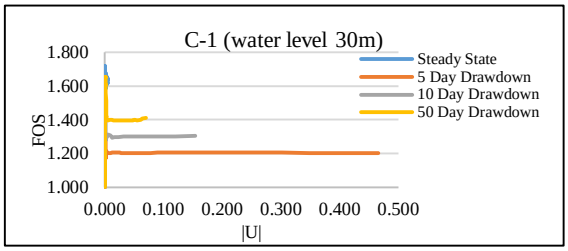


Fig 38: FOS vs Displacement (filter L* 60m and T**8m)

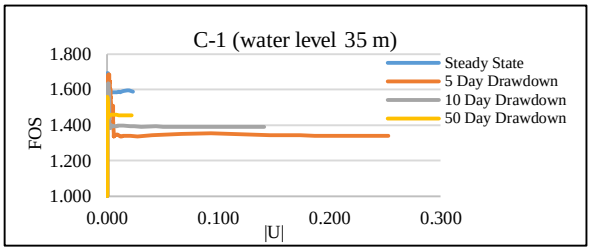


Fig 39: FOS vs Displacement (filter L* 60m and T** 8m)

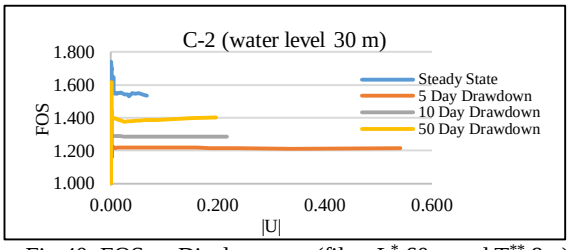


Fig 40: FOS vs Displacement (filter L* 60m and T** 8m)

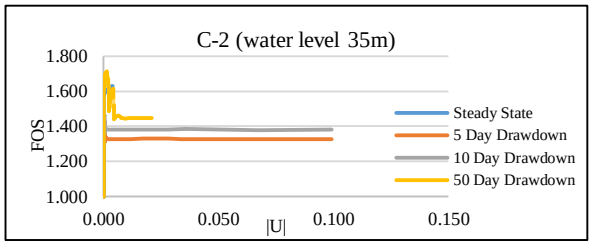


Fig 41: FOS vs Displacement (filter L* 60m and T** 8m)

*Length of filter
** Thickness of filter

As observed from above graphs, the F.O.S of dam in all conditions of steady state and 50-day draw down remained almost similar. However, F.O.S for the draw down condition of 5 day and 10 day decreased due to sudden draw down of water pressure. Further observations were carried out for different combination of filter and without filter cases. For steady state, the F.O.S varied from 1.290 to 1.620 and for 5 day draw down cases the F.O.S varied from 1.191 to 1.492 and for 10 day draw down cases the F.O.S varied from 1.267 to 1.394 and then for the 50 day draw down (slow draw down) cases the F.O.S varied from the 1.382 to 1.465. From above results, it was observed that if filter of 20m length from downstream to the axis of dam was provided, the phreatic line lies near to the toe of dam. When the filter of 40m length was provided, the phreatic line gets into intermediate position. Finally, the 60m length of filter resulted in phreatic line to be inside the core section, which was not suitable from safety point of view because it may erode the core material and cause larger seepage paths.

4. Conclusion

1. The length of filter have increased from 20m to 40m with the thickness of 4m, the water at F.S.L then the F.O.S was increased upto 3.15% for steady state and for the rapid draw down conditions it was reduces upto 2.11%. For the slow draw down condition, the F.O.S was increase upto 1.17%. At H.F.L, the F.O.S decreased for the steady state 2.2% and for the rapid draw down condition, the F.O.S reduces upto 0.58%. For the slow draw down, condition the F.O.S increased upto 0.58%. In rapid draw down condition, the F.O.S values observed were reduced. Due to the sudden change of water level, this may cause due to development of excess pore water pressure.
2. When the filter thickness kept upto 6m and the length of filter increased from 20 to 40m and the water level at F.S.L the F.O.S for steady state was increased upto 3.69%, for the rapid draw down conditions it decreased upto 0.075%, and for the slow draw down condition the F.O.S reduced till 0.31%. When water

was at H.F.L the F.O.S. reduced for steady, rapid and slow draw down conditions. The reduction of F.O.S for all cases was may be due to the increment of thickness.

3. Now, the thickness is increased upto 8m and the length of filter increased from 20m to 40m the water was at F.S.L then the F.O.S for steady state was increased upto 0.21% and for the rapid draw down conditions the F.O.S decreased upto 0.12%, and for the slow draw down condition the F.O.S reduced upto 0.26%. When water level was at H.F.L then F.O.S. was seen reduced for all cases.
4. The filter length is kept at the edge of the core section because if not so then, filter length reached at the axis of dam into the core section which may lead the erosion of core material that cause the instability of dam.

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