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Assessment of Circular Cavity in Concrete Gravity Retaining Wall

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Abstract— Design of Gravity retaining wall cross-section is a trial and error process and it is determined using prescribed conditions of stability. The stresses developed along the cross section of wall are very low and hence material strength of cross-section remains unutilized. The gravity retaining wall cross-section can be effectively utilized and also structural performance of the cross section can be enriched by introducing cavity in the section. An attempt is made by introducing circular cavity in the cross-section of gravity retaining wall and stresses developed along the cross-section are calculated. The stresses induced in the cross section with and without cavity are compared in this study. The effect of circular cavities at two different locations on stresses distribution along the cross section is worked out.

Keywords— Circular Cavity, FEA, Gravity retaining wall, Stress distribution, FEA programming

I. INTRODUCTION

Gravity retaining walls are mostly constructed in infrastructural projects like, railways highways, bridges, canals and gravity walls are used in many other engineering works. The design of gravity wall is trial and error process and the cross section so proportioned that it should satisfy stability conditions i.e. sliding, overturning and excessive settlement. And also, development of tensile stresses along the cross section should be eliminated. In the analysis of retaining wall it is observed that the factor of safety against overturning increases beyond the safe limit while factor of safety against sliding is just reaches to its safe limit. It means that requirements of stability criteria of sliding is satisfied but, ample stability is available against overturning criteria. The design of gravity retaining wall is restricted by said criteria, which leads to redundant provision of material. Due to availability of material as per requirement of stability, the stresses developed in the wall cross-section are very low as compared to limiting value of stresses. And hence from material strength point of view the cross-section remains unutilized. This concern can be addressed by introducing circular cavities in gravity retaining wall.. In this paper an attempt is made to work out the stress distribution in the gravity retaining wall cross-section and also study the effect of circular cavities at two locations on stresses distribution along the cross section and also results are compared with wall without cavity. The present study is aimed to optimize concrete gravity retaining wall cross-section by introducing circular cavity in the cross section

II. PROBLEM FORMULATION

The cross-section of concrete gravity retaining wall under consideration is subjected to self-weight and soil pressure which produce combined effect of direct and bending stresses. These stresses increase with the distance of horizontal section from top of the wall.

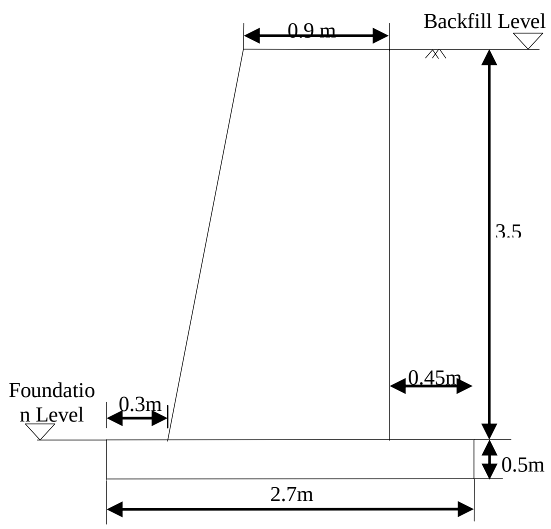


Fig 1 Retaining Wall of Cross-Section

A gravity retaining wall with vertical face backfill face retaining horizontal backfill is considered as problem in this study. Backfill soil having density of 18kN/m^3, angle of friction of 30^0 and cohesion =16kN/m^2 is considered along with M20 grade of concrete for gravity retaining wall for analysis. The cross-section of gravity retaining wall under consideration is shown in Fig 1.

The stresses developed in gravity wall cross-section are found using FEA. A computer code is developed for using FEA procedure. In the pre-processing a separate function is written for mesh generation using wall geometry. 4 noded isoperimetric elements and constant strain triangle elements are used for analysis. The mesh is generated in such way that aspect ratio of the elements in any portion of the wall remains close to one. Support conditions and prescribed loads are incorporated as per requirement

During the analysis by FEA of retaining wall it is assumed as plane strain problem. The dataset prepared by the pre-processor is used as input. FEA code, constructs and solves a system of linear algebraic equations, namely K_{ij} u_j = f_i where u and f are the displacements and externally applied forces at the nodal points respectively. The stiffness matrix is generated according to the selected elements (Robert D. Cook 1989).

As the part of post-processing desired outputs like displacements and stresses at different nodes are calculated. After calculating nodal stresses, global stress smoothening is carried (E. Hinton and J.S. Campbell 1974). The principal stresses are calculated and a stress contours representing stress levels are drawn along the wall profile.

Stress distribution along cross-section of retaining wall without cavity is as shown in Fig 2. From the stress distribution pattern it is observed that compressive stresses are concentrated near stem-toe junction and on the contrary negligible tensile stresses are developed at the stem-heel junction. It is also noted that very negligible stresses are developed near the top corner on free side up to mid height of wall on batter side. The stresses developed are very low as compared to permissible stresses for compression and tension according to clause no 6.1 and 6.2.2 of IS456:2000

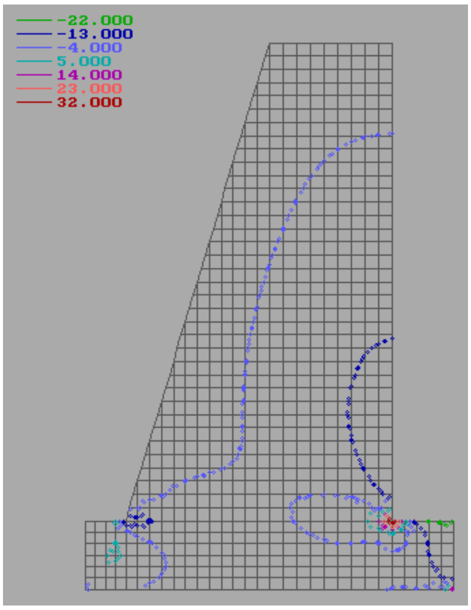


Figure 2 Stress distribution along Cross-Section of Retaining Wall

A. Introduction of Cavity

The study is made to optimize the cross-section of gravity retaining wall by removing material from in the form a circular cavity. Various positions of circular cavity are tried along with variation in its diameters. Effect of such variations on the largest tensile and compressive stress magnitude, its location, stress distribution along the cross-section and deformed shape of wall cross-section with cavity is studied. During the analysis it is noticed that the stability criteria of sliding is not satisfied .therefore a shear key is provided.

B .Assessment of Circular Cavity in Retaining Wall

A number of trials are taken by incorporating circular cavity with change in ratio λ_b and diameter of circular cavity. λ_b is defined as ratio of diameter of cavity to that of the width of stem at stem-base junction. Further the position of cavity is also changed using the parameters λ_h and $\lambda_{w.}$ λ_h is defined as the percentage of the height of base of cavity from top of wall to the height of stem and λ_w is defined as the ratio of horizontal distance of vertical face of cavity near the stem to the width of stem at stem-base junction. The position of cavity is bounded in area marked by edge distance of 0.27m from all the boundaries of retaining wall to avoid slender wall-like element being developed by the side of the cavity in the portion of the wall.

Extracts of computer code for above parameters are observed. Two representative cases are listed to study actual variation and trends. In cases considered value of λ_w is varied as 0.1385 (Case-I) and 0.2305 (Case-II). The effect of variation of λ_w on the stresses along the cross-section of the wall is studied for different value of λ_b i.e. (0.2307, 02769, 03230, 0.3692, 0.5076). For this purpose, stress ratios ψ_1 and ψ_2 are used. ψ_1 is defined as ratio of the maximum tensile stress developed to the permissible stress and ψ_2 is defined as maximum compressive stress developed to the permissible stress.

The variation of ψ_1 is plotted in graph G_1 and G_2 by changing λ_h for Case-I and Case-II respectively. Similarly, variation of ψ_2 is also plotted in graph G_3 and G_4 for Case I and II respectively.

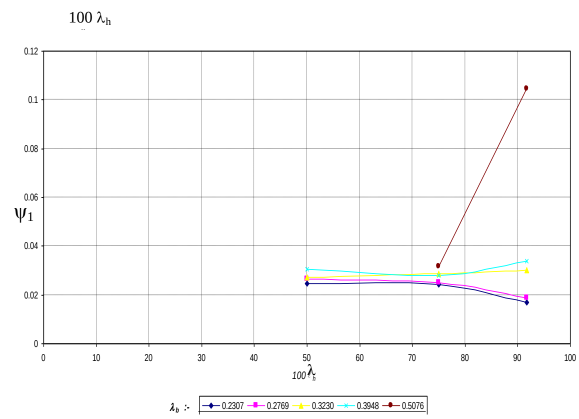
III. RESULTS AND DBSERVATIONS

A VARIATION OF TENSILE STRESS RATIO (□□□)

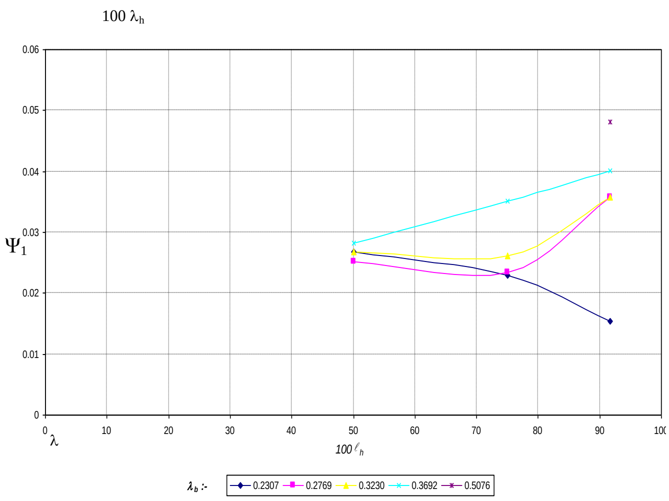
From Graph G_1 and G_2 it is observed that stress ratio ψ_1 decreases as λ_h for λ_b less than 0.2769 for Case-I and for Case-II ψ_1 decreases for λ_b less than0.2307. It is also noted that ψ_1 increases for λ_b greater than 0.2769 and 0.2307 λ_h increases for case I and II respectively.

It seen from the graph that as λ_b increases stress ratio increases and it is also observed that for same value λ_b stress ratio ψ_1 is changing as λ_h increase. The variation of for ψ_1 for small size circular cavity is practically negligible. For larger size cavity variation ψ_1 is observed but for any case value ψ_1 exceeds 0.12 0.05 for Case I and II respectively

For value of λ_h less than 75% the stress ratio ψ_1 remains practically close for λ_b less than 0.3948 for case I. The values of ψ_1 are found to increase with λ_h in Case-II .For cavity with λ_b=0.3230 for λ_h=0.7305 (in Case-II) the lowest ψ_1 is recorded.



G-1 Variation of ψ_1 Vs λ_h for Case-I



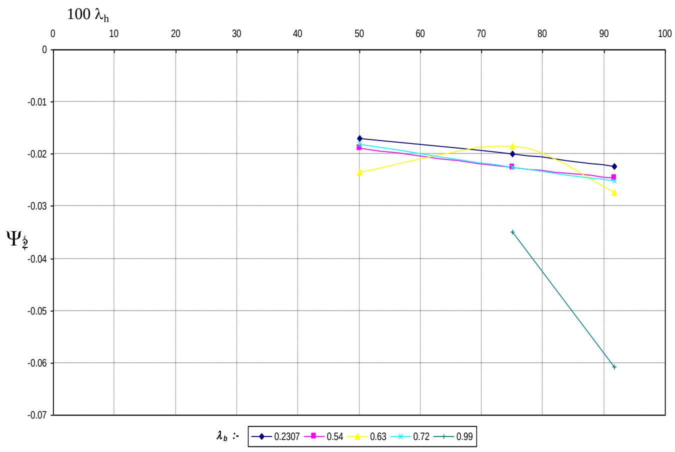
G-2 Variation of ψ_1 Vs λ_h for Case-II

B *Variation of Compressive Stress Ratio (ψ_2)*

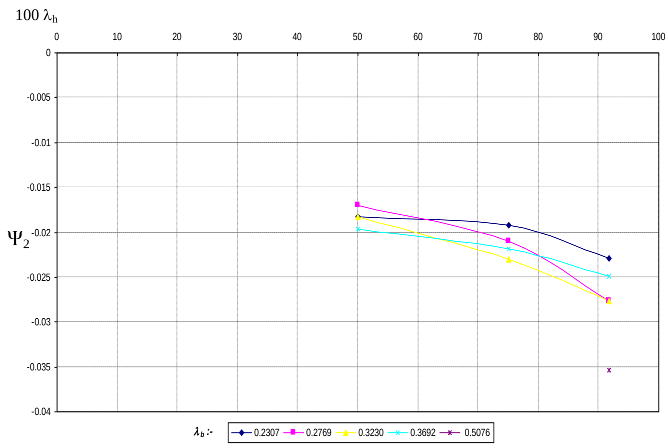
Graph G_3 and G_4 shows variation ψ_2 against λ_h. The value of ψ_2 increases with rise in with λ_h for all λ_b. For λ_b =0.3230 decrease in value of ψ_2 is observed. The above mentioned values indicate smallest compressive stress

Similar variation is noted for every λ_b value less than 0.3230 for Case-II. The maximum compression induced in section by providing circular cavity is not exceeds 0.06 and 0.04 for Case–I and Case-II respectively. From the observations it is highlighted that structural efficiency of circular cavity suggesting that still larger size of cavity may be proposed. But on account of minimum edge distance the largest cavity that cannot be provided. By using single cavity yet largest tension developed will be just around 11 percent of the permissible value.

As due to edge distance considered the no trials of large diameter cavity is restricted though there is even lager reserve strength is availed in the material. But considering exploiting material properties and underutilize capacities, it is ineffective i.e. material capacity remains unutilized to greater extent.



G-3 Variation of ψ_2 Vs λ_h for Case-I



G-4 Variation of ψ_2 Vs λ_h for Case-II

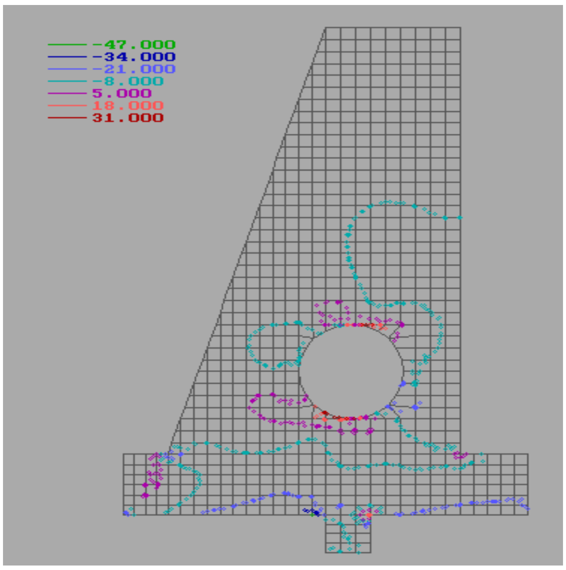


Figure 3 Stress distribution along Cross-Section of Retaining Wall with circular cavity (Case-II λ_b =0.3692)

From stress distribution pattern of Gravity wall with cavity as shown in Fig 3 it is observed that the stress locations of maximum stresses are shifted from its original position as shown in Fig 2. The stress are concentrated near top and bottom portion of the cavity and as mentioned stresses induced in the sections are increased.

Advantages of the invention:

1. The construction of circular cavity in the gravity retaining wall is easily adaptable.
2. The gravity retaining wall with circular cavity can be used for different purposes like accommodating water mains, telephone lines, electrical cables, sewage pipes, etc.
3. The stress in the cross section of gravity retaining wall without cavity is liked to be increased due to reduction in the material this increased in the stress is really utilizing the strength of material which is remain unutilized in the earlier form.
4. The gravity retaining wall with cavity along length helps to reduce water load in case of backfill with water table as the excess water can be removed through cavity in longitudinal direction. This is an added advantage of cavity to reduce the forces on gravity retaining wall in specific case of earth pressure with water table.

IV Conclusion

According to the results obtained and observations interpreted some following conclusions are drawn.

1. Gravity wall cross-section can be optimize by introducing circular cavity in the section.
2. Circular cavity in the Gravity wall cross-section utilizes material capacity in better fashion as it is a structurally efficient form.
3. Position of cavity influence stresses induced along the wall.
4. The location of maximum compressive stress is found to shift to backfill side lower bottom of cavity. Compressive stresses are also developed at batter side upper side portion of cavity.
5. The location of maximum tensile stress is found to shift to center height of cavity. Tensile stresses are also developed on top side of retaining wall above cavity.

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