ISSN 2229-5518

COFFERDAMS- FORCES ANALYSIS AND DESIGN CRITERIA

Rameez Gahlot[1], Prof. Roshni John[2], Roshan Zemse[3]

[1]Department of civil engineering, scoe, rameezgahlot@gmail.com

[2]Department of civil engineering, scoe, roshnijjohn@gmail.com

[3]Department of civil engineering, scoe, roshanpzemase@gmail.com

ABSTRACT: This paper presents the forces on cofferdam and stability criteria of various types of cofferdams. Various researchers has studied the stability of cofferdam by using finite elements software and the results are quite comprehensive. These papers give the conventional method of stability of cofferdams, According to Indian code.
Keywords: cofferdams, stability, cell shear, sliding, bursting.

INTRODUCTION

This chapter presents a review of relevant literature to bring out the background of the study undertaken in this special topic. The research contributions which have a direct relevance are treated in greater detail. Some of the historical works which have contributed greatly to the understanding of the stability of the structures are also described. First, a brief review of the historical background is presented. The concepts of structural stability, strengthening the structure, live loads acting, and failure of structures, related to work carried out in this thesis, are then discussed. The amount of the literature on the subject has increased rapidly in recent years; particularly on deformation/stability of Structures.

Bahaa El Sharnouby, Amr Adel Kamel, Hamdy Mohamed El Kamhawy et.al (2010)[1], Enhance the performance of harbor cellular walls. When the live load of the Cellular quay walls is expected to increase due to change in serviceability conditions, analysis is required to ensure adequate safety of the structural elements against overstressing .In most cases, a retrofitting of the cellular quay wall is required for the structure to withstand the newly imposed changes. four methods for retrofitting the cellular quay walls to increase its carrying capacity and decrease the stresses in its skin assuming that the overall stability of the wall is not compromised. The analysis is conducted using 3D model to illustrate the effect of different methods to enhance the capacity of a cellular quay wall .The ANSYS finite element package is used throughout the analysis. Results are analyzed and effects of each method on stress reduction as regards to Von Mises are studied. All values are farther compared to evaluate the effect of each retrofitting method on Von Mises stress reduction. The parametric analysis shows that a decrease up to 25% of the stresses acting on the circular cell could be achieved using additional inner smaller cell. Installing sheet pile at the connection line of the cell and arc provides good improvement too, particularly for stresses acting on the arc. Although a raw of short separated piles

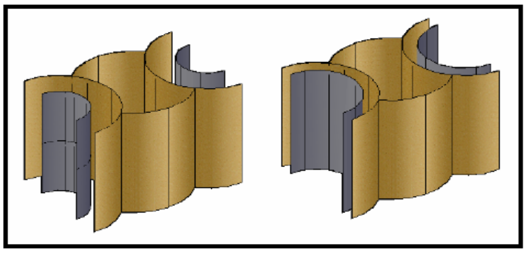


Fig 1 installing internal cell

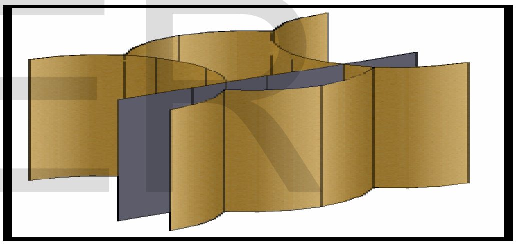


Fig 2 sheet pile segment

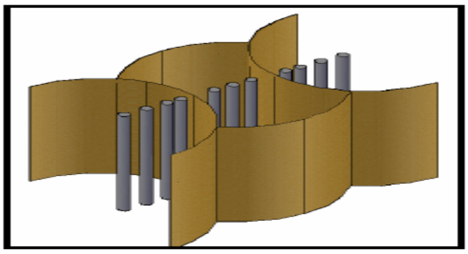


Fig 3 installing internal short pile

Rossow M et.al(1984)[3], presented a method for calculating the interlock tension in the sheet pile walls of a circular cellular cofferdam. A horizontal strip of unit width of wall is considered and the governing equation are derived from equilibrium and compatibility requirements for the strip. The pressure of the cell fill against the sheet pile wall is assumed Bulging of cell walls and rotation of the legs of the connecting "Y" are also found. The theoretical justification for use of an equation for estimating the force in common wall and lead to a generalization of that equation.

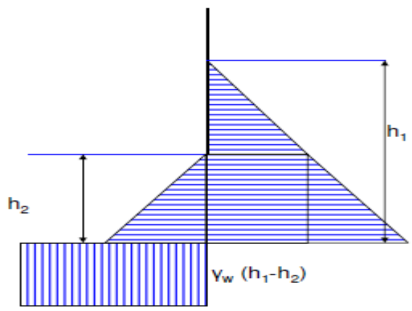
AL – Kelabbee et.al(2010)[5], studied nonlinear finite element analysis has been used to predict the load deflection behaviour of circular cell cofferdam under lateral load by using ANSYS (Analysis System) (version 5.4) computer program. Three different sections of dam with (diameter/depth (D/H) =1, 0.85, 0.75) have been analyzed in example one and their results are compared with experimental data and found to give good agreement. In addition to that, studied there are three case studies (cofferdam with arcs once and with arcs and backfilling another, cofferdam has filling material differ from the base of the dam, and cofferdam have filling soil layered) and there is isolated cell cofferdam in example two and last example was field study. Among the conclusions obtained, the stability of dam increases with diameter (base) to height ratio of dam decrease . In case studies (cofferdam supplied by arcs and backfilling , differ between filling soil inside and outside the dam and, dam with layered filling soil) there is reduction in displacement of cofferdam by about (82.58%, 89.24%, 5.1%, 40.91%) respectively.

Al- Rmmahi et.al (2009)[6], studied the design and construction of cellular cofferdams through test models to observe their stability. Series of laboratory tests had been carried out on two diaphragm cells of different width to depth ratios (0.75, 0.85, and 1). The tests include the following factors. These factors are effect of width, height, properties of soil and embedment depth to height ratios (0.15, 0.3, and 0.45). Four type of soil are used. These types are sub base, sand passing sieve No.4, sand river and clay soil. Then analysis of cellular cofferdam by software which is known PLAXIS is used to compute deformations, stresses, and strain in the body of cofferdam and foundation. And comparison the results between laboratory tests and the software PLAXIS.

Reliability of results that obtained from experimental tests by statistical analysis to formulation these results by four functions are created to computes the deformations. The functions represent the relation between deformations and embedment depths that occurred after applied loads. Many conclusions had been drawn from this study. Among these are the embedment depth is greatly affected the stability of cells.

Forces on cofferdams and their load combination.

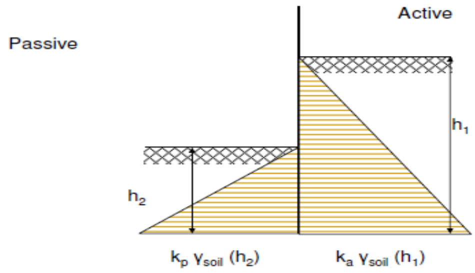
- **Hydrostatic pressure**:



The maximum probable height outside the cofferdam during construction and the water height inside the cofferdam during various stages of construction need to be considered. These result in the net design pressure.

- **Forces due to Soil Loads**:

The soils impose forces, both locally on the wall of the cofferdam and globally upon the structure as a whole. These forces are additive to the hydrostatic forces. Local forces are a major component of the lateral force on sheet-pile walls, causing bending in the sheets, bending in the wales, and axial compression in the struts



- **Current Forces on Structure**:

With a typical cofferdam, the current force consists not only the force acting on the normal projection of the cofferdam but also on the drag force acting along the sides. With flat sheet piles, the latter may be relatively small, whereas with z-piles it may be substantial, since the current will be forming eddies behind each indentation of profile.

- **Wave forces**:

Waves acting on a cofferdam are usually the result of local winds acting over a restricted fetch and hence are of short wavelength and limited to height. However, in some cases the cofferdam should have at least three feet of freeboard or higher above the design high water elevation than the maximum expected wave height. Wave forces will be significant factor in large bays and lakes where the fetch is several miles. Passing boats and ships, especially in a restricted waterway, can also produce waves. The force generated by waves is asymmetrical and must be carried to the ground through the sheet piling in shear and bending. The waler system must be designed to transmit the wave forces to the sheet piles.

- **Seismic Loads**:

These have not been normally considered in design of temporary structures in the past. For very large, important, and deep cofferdams in highly seismically active areas, seismic evaluation should be performed.

- **Accidental loads**:

These are the loads usually caused by construction equipment working alongside the cofferdam and impacting on it under the action of waves.

- **Scour**:

Scour of the river bottom or seafloor along the cofferdam may take place owing to river currents, tidal currents, or wave-induced currents. Some of the most serious and disastrous cases have occurred when these currents have acted concurrently. A very practical method of preventing scour is to deposit a blanket of crushed rock or heavy gravel around the cofferdam, either before or immediately after the cofferdam sheet piles are set. A more sophisticated method is to lay a mattress of filter fabric, covering it with rock to hold it in place.

- **Load Combination**:

ISSN 2229-5518

Design of coffer dam shall be based on the most adverse combination of the probable load conditions which are most likely to occur .Combination of transient load which have little or no probability of occurrence are not generally considered in the design of cofferdams.
The combination of load for high flood level(HFL) is
-WP+EP
The combination of load for low flood level(LFL) is
-WP+EP
-WP+EP+WL
The cofferdams design shall be based on loading condition by using the factor of safety should not be less than 3.0

DESIGN CRITERIA FOR DIFFERENT OF COFFERDAMS

ROCK FILL COFFERDAMS

STABILITY REQUIREMENT: the stability requirement shall be check for sliding.
SLIDING: - Rock fill coffer dam with an impervious central core/upstream face would have a relatively high factor of safety against sliding because of the large mass involved. Adequacy of the foundation
shall also be checked. However, the factor of safety against sliding between the rockfill material and the impervious core/membrane shall invariably be checked, as this is very important.

MASSONARY COFFERDAM

STABILITY REQUIREMENT: the stability requirement shall be check for sliding, overturning.
SLIDING:
Many of the loads on the coffer dam are horizontal or have horizontal components which are resisted by frictional or shearing resistance along the horizontal or nearly horizontal planes in the body of the cofferdam and on the foundation. The stability of a coffer dam against sliding is evaluated by comparing the minimum total available resistance along the critical plane of sliding to the total magnitude of the forces tending to induce sliding.
The factor of safety against sliding may be computed by the following equation :

$$F = (W-U) \tan \emptyset + CA/P$$

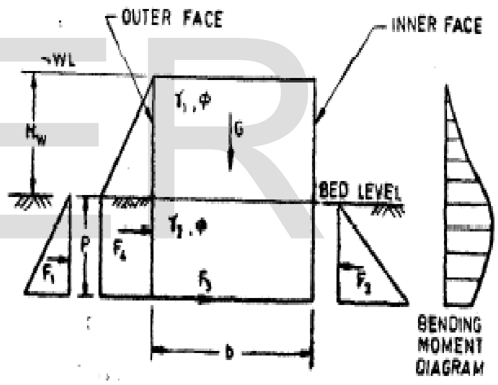
where
F =factor of safety;
W= total weight of the dam;
U = total uplift force;
Tan ∅=coefficient of internal friction of the material;
C = cohesion of the material at the plane considered, if existing
A =area under compression; and
P = total horizontal force, including earthquake forces, considered, if any.
The values of cohesion and internal friction of the materials along the plane considered for analysis may be assumed, based on the available data on similar or comparable materials. The factor of safety shall not be less than 3.0

OVERTURNING:
Before the coffer dam overturns bodily, other types of failures may occur, such as cracking of the upstream material due to tension, crushing of toe material and sliding. A gravity coffer dam is, therefore, considered safe against overturning if the following criteria are satisfied.

a) The resultant of all forces shall normally fall within the middle third of the base.
b) The maximum compressive stresses at any point within the cofferdam and in the foundation below for the worst combination of loading shall be within the permissible values for the dam and foundation materials respectively.

DOUBLE WALL STEEL SHEET PILE COFFERDAM

STABILITY REQUIREMENT: The stability requirement such type of cofferdam shall satisfy following condition of equilibrium.
a) ∑ horizontal forces =0
b) ∑ moments 0
c) $(F_4+F_1-F_2) < G\tan\emptyset\ (F_3)$
Further, the resultant of all forces shall lie within the middle third of the base, since earth cannot take any tensile force. The compressive stresses developed at the foot of the sheet pile shall be within the bearing capacity of the foundation soil.



CELLULAR STEEL SHEET PILE COFFERDAM

STABILITY REQUIREMENT: The stability of the cellular steel sheet pile cofferdam shall be checked for cell shear, sliding, tilting, and bursting of cell.

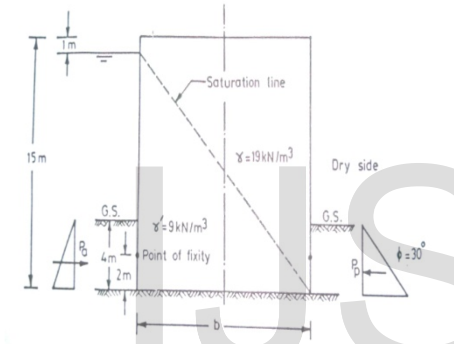
Cell Shear - The safety against vertical shear failure at midsection of cell shall be examined as follows:
Vertical shear force (V) = 1.5 M/B-
Soil shear strength (S) = 0.5* γ KH^2 (tan ∅ + f)
Factor of safety against cell shear failure (S/V)should not be less than l-25.
NOTE - Contribution of interlock friction should not be taken more than that
due to fill (f< tan+).
SLIDING- The safety against failure due to sliding of cell shall be examined as for a gravity structure shall not be less than 1.25.The factor of safety against sliding.
TILTING- The safety against failure due to overturning of the cell shall be examined according to Gumming's method outlined in Appendix The factor of safety against tilting shall not be less than 1.2.
BURSTING of CELL - The safety against failure of interlocking joints due to hoop tension developed due to

active pressure of fill shall be examined at a critical height equal to 0.75 I-I. The hoop tension developed shall not be greater than the allowable interlock tension, which can be considered as 150 t/m.

PARAMETRIC STUDY

A circular cellular steel sheet pile of height 15m is design and considering following properties of soil and design it under high flood level, the properties are:

a) Take allowable interlock tension of 1500KN/m (as per IS : 9527 PART 4 1980),
b) Angle of internal friction of fill and soil $\emptyset = 30°$,
c) Interlock friction f= 0.3, angle of friction between the fill and the pile $\delta = 25°$,
d) K= krynine constant $= \frac{\cos 2_{\emptyset}}{2-\cos 2_{\emptyset}}$ = 0.6,
e) $\gamma w = 10$ KN/m*2,
f) Unit wt. Of fill above saturation line γ = 19 KN/m*3,
g) Submerged unit wt. Of fill below saturation line γ' = 9 KN/m*3.



Preliminary section:

D = 1.2H = 1.2 * 15 =18 m (where D= diameter of main cell)

D1 = 0.6D = 0.6 * 18 =10.8 m (where D1 = diameter of connecting cell)

B = 0.875D = 0.875 * 18 =15.75 m. let us take B= 16m. (where B = Average width)

By considering the above stability requirements it is seen that the cofferdam fulfil the stability criteria.

CONCLUSION : It is seen from conventional method the result obtain is within the limit as mentioned in above design criteria. In a parametric study a circular cellular sheet pile cofferdam is choosen because of following condition, it can be used singularly in a group, it will not collapse in the event of failure of adjoining cells, each cell acts independently of other, less number of sheet pile require. Both conventional method and finite element method gives better results, with small error.

REFERENCES:

1) Bahaa El-sharnouby, Amr Adel kamel, Hamdy Mohamed EL kamhawy **"**Enhancing the performance of harbour cellular Walls" (2010) **26th** International Conference for Seaports Maritime Transport" Integration For a Better Future "
2) Rossow, M. (1984)."Sheetpile Interlock Tension in Cellular Cofferdams." J. Geotech. Engrg., 110(10), 1446–1458.
3) Al –Kelabbee ,Z.D.(2010) "Finite element analysis of cellular circle bulkheads" M. Sc. thesis, College of Engineering, University of Babylon
4) Al-Rmmahi, S.H. (2009):"Effect of Width to Depth Ratioon Stability of Cellular Cofferdams". M. Sc. thesis, College of Engineering, University of Babylon