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Review on Design and Sustainability of Retaining Wall Structures

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Abstract- This review paper provides a comprehensive exploration of the multifaceted world of retaining walls in civil engineering and landscaping. Retaining walls are pivotal structures, integral to preventing soil erosion, creating terraced landscapes, and ensuring stability in diverse terrains. Through an extensive examination of various retaining wall types, including gravity walls, cantilever walls, and innovative solutions, this review underscores the significance of thoughtful design and construction methodologies. Critical factors such as soil characteristics, drainage considerations, and structural stability are highlighted, emphasizing the importance of a holistic approach in retaining wall projects. As the field continues to advance, embracing technological innovations and sustainable practices, the review identifies ongoing challenges and highlights the need for interdisciplinary collaboration. The dynamic nature of retaining wall research and development is emphasized, acknowledging its role in addressing contemporary issues such as climate change and urbanization. This abstract provides a snapshot of the diverse aspects covered in the review, offering insights into the current state and future prospects of retaining wall technology within the broader context of resilient and sustainable infrastructure.

Index Terms- Weld Joint, Fatigue Life, Safety Factor, ANSYS

I. INTRODUCTION

A retaining wall is a structure designed to restrain soil and other materials from moving downhill or erosion. It is commonly used in landscaping and civil engineering projects to create a difference in elevation between two areas. Retaining walls are essential in situations where there is a slope, and the lateral pressure of the soil needs to be counteracted to prevent erosion and maintain stability. Retaining walls serve to hold back or retain soil, preventing it from sliding or eroding due to gravity or other external forces. Retaining walls can be constructed using various materials, such as concrete, stone, brick, wood, or reinforced soil. The choice of material depends on factors such as the wall's height, the type of soil, and the aesthetic preferences of the designer. The design of a retaining wall considers factors like the type of soil, the slope of the terrain, the height of the wall, and the drainage conditions. Engineers use principles of geotechnical engineering to ensure the stability and effectiveness of the retaining wall. Retaining walls are used for various purposes, such as preventing soil erosion, creating terraced landscapes, supporting roads and structures, and improving the aesthetics of a property.

II. LITERATURE REVIEW

Donkada et. al. [1] found that at developing an understanding of optimal design solutions for three types of reinforced concrete retaining walls, namely, cantilever retaining walls, counterfort retaining walls and retaining walls with relieving platforms. Using genetic algorithms, parametric studies were carried out to establish heuristic rules for proportioning the wall dimensions corresponding to the minimum cost points. Optimal cost estimates of the retaining walls types were compared to establish the best design alternative for a given height. Also, the advantages of retaining walls with relieving platforms, which are relatively new in India, are discussed.

Patil et. al. [2], found that a retaining wall is one of the most important types of retaining structures. It is extensively used in variety of situations such as highway engineering, railways engineering, bridge engineering and irrigation engineering. Reinforced concrete retaining walls have a vertical or inclined stem cast with base slab. These are considered suitable up to a height of 6m. it resist lateral earth pressure by cantilever action of stem, toe slab and heel slab. The tendency of wall to slide forward due to lateral earth pressure should be investigated and the factor of safety of 1.5 shall be provided against sliding. Cantilever retaining walls are found best up to a height of 6m. for greater heights earth pressure due to retained fill will be higher due to lever arm effect, higher moments are produced at base, which leads to higher section for stability design as well as structural design. This proves to be an uneconomical design. As an alternative to this, one may go for counter for retaining wall, which demands greater base area as well as steel. As a solution to this difficulty, a new approach that is to minimize effect of foeces coming from retained fill, short reinforced concerete balance the locally appearing forces and will result into lesser moment and shear forces along the stem. Also it will reduce the bending action that is pressure below the base.

Patil et. al. [3] have found that a retaining wall is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil. The most important consideration in proper design and installation of retaining walls is to recognize and counteract the tendency of the retained material to move down slope due to gravity. This creates lateral earth pressure behind the wall which depends on the angle of internal friction (ø) and the cohesive strength (c) of the retained material, as well as the direction and magnitude of movement the retaining structure undergoes. In many cases we have to come across the retaining wall of 7m, 8m, 9m height. So we will consider these heights for noncohesive soil conditions for different spacing of counter-forts. We studied, by changing the spacing of counter-forts what will be the change in thickness of stem as well as heel slab, what is the optimum spacing of the counter-forts, what is the effect of changing spacing of counter-forts on bending moments, and plotted a graph of optimum spacing of counter-forts vs height of wall. The data presented here in following sections clearly indicates that changing spacing of counter-forts for retaining wall results in, reduction of spacing of counter forts will result in reduction in bending moments in heel slab and stem wall, reduction of spacing of counter forts will result in reduction in thickness of heel slab and stem wall. It is also observed that for 1m, 1.5m, 2m, 3m, 3.5m, 4m spacing of counter-forts the concrete and steel quantities per meter length of retaining wall is more than at 2.5m spacing. So optimum spacing of counter-forts for 7m, 8m, 9m height retaining wall is observed to be 2.5m.

Tamad her Aboodet. Al. [4], has found that retaining structures hold back soil or other loose material where an abrupt change in ground elevation occurs. The retained material or backfill exerts a push on the structure and thus tends to overturn or slide it, or both. The cantilever is the most common type of retaining wall and is used for walls in the range of 3to 6m in height. This study presents analyses and design of cantilever retaining wall which is made from an internal stem of steel-reinforced, cast-in-place concrete (often in the shape of an inverted T). In this work a detailed analyses and design for this type of walls which include estimation of primary dimensions of the wall, then these dimensions were checked. The factor of safety against sliding, overturning and bearing were calculated.

Inder Kumar et al. [5], found that the analysis for the behaviour & optimal design of counter fort retaining wall and gravity wall in concrete dam. Cost analysis against each design of wall is evaluated by using volume of concrete and amount of steel. A comparative study is carried out & alternative with the least cost estimate is chosen as the best design solution.

Prof. Sarita Singla et al. [6], has discovered that during development of land, one often comes across with the challenge of creating a difference in terrain elevation over an arbitrary horizontal distance. This can often be done by creating slopes or by constructing retaining walls. Retaining walls are structures that are constructed to retail soil or any such materials which are unable to stand vertically by themselves. In this paper the study of the behavior and optimal design of three types of reinforced concrete walls of varying heights namely cantilever retaining wall, counterfort retaining wall and retaining wall with relieving platforms is done. Cost against each optimal design of wall for particular height is calculated by using the volume of concrete and the amount of steel. Amidst the cost estimates of all the three optimal designs for particular height, a comparative study is carried out and the alternative with the least cost estimate is chosen as the best design solution.

Yash Chaliawala et al. [7], has found that the behavior and optimal design of two types of reinforced concrete walls of varying heights namely cantilever retaining wall, counter fort retaining wall. Cost against each optimal design of wall foe particular height is calculated using the volume of concrete and the amount of steel. Amidst the cost estimate is chosen as the best design solution [8].

Cherubini [9] used a probabilistic approach to examine the design of anchored sheet pile walls.

Yang and Ching [10] used a novel simplified geotechnical reliability analysis technique. In this research, they used the first and second-order reliability methods (FORM and SORM) and simulation-based techniques such as MCS to find the reliability index.

Menon et al. [11] used the FORM, SORM and MCS reliability methods to evaluate the probability of failure linked to the sliding failure of a cantilever retaining wall.

Wang et al. [12] used the central point method to analyze the reliability analysis of a gravity retaining wall under a mount torrent load, and the performance functions of the anti-slip stability and overturning stability were obtained.

Xiao et al. [13] used FOSM to set up a fuzzy random reliability analysis. Dao-bing et al. [14] performed a reliability analysis of retaining walls with multiple failure modes. In this research, they used the upper-boundary theory of limit analysis to analyze two dissimilar types of retaining wall failures, namely anti-slipping and anti-overturning.

Babu and Basha [15] used target reliability practice to scrutinize sheet pile walls. To examine the anchored cantilever sheet pile wall, the inverse first-order reliability technique was used.

Low [16] studied the reliability-based design applied to retaining walls. In this research, the author explains practical reliability-based design measures for retaining walls based on the Hasofer–Lind index and first-order reliability method (FORM).

Sun and Yuefei [17] used the particle discrete element method (PDEM) to model the simultaneous effects of particle size and porosity in simulating geo-materials. The main idea behind this research was to enable the development of more realistic discrete elements and to help simulate the more complex rock and soil materials.

Sun [18] analyzed the hard particle static force in a soft rock fracture. He analyzed the mechanics of particles in rock fissures, especially under the compression of rock from both sides.

Wang [19] used a machine learning algorithm (genetic algorithm) to improve the prediction of earthquake-induced soil liquefaction.

Harandizadeh et al. [20] analyzed the application of improved ANFIS approaches to compute the bearing capacity of piles.

Zhang and Goh [21] analyzed a geotechnical engineering system by using multivariate adaptive regression splines (MARS).

Mishra et al. [22] designed a retaining wall using a machine learning approach. In their study, they used numerous machine learning models such as emotional neural network (EmNN), multivariate adaptive regression spline (MARS) and symbiotic organisms search-least square support vector machine (SOS-LSSVM) to predict the factor of safety against sliding.

Zhang et al. [23] analyzed the inverse analysis of soil and wall properties in braced excavation by using the machine learning algorithm MARS.

Xiang et al. [24] used AI algorithm MARS model for the estimation of maximum wall deflections induced by braced excavation in clays.

Zhang et al. [25] estimated lateral wall deflection profiles caused by braced excavations in clays using the MARS approach.

Mishra and Samui [26] performed a reliability analysis of retaining walls by using an artificial neural network (ANN) and adaptive neuro fuzzy inference system (ANFIS).

Ghani et al. [27] analyzed liquefaction analysis on fine-grained soil by using principal component analysis (PCA)-based hybrid soft computing models.

Zhang and Goh [28] used multivariate adaptive regression splines (MARS) and neural network (NN) models for the prediction of pile drivability.

Wang et al. [29] used the MARS model for the stability analysis of earth dam slope under transient seepage.

Zhang et al. [30] used a soft computing approach for the prediction of surface settlement induced by earth pressure balance shield tunneling.

Wang et al. [31] used the extreme gradient boosting method for the efficient reliability analysis of earth dam slope stability.

Wu et al. [32] predicted wall deflection by braced excavation in spatially variable soil using a convolutional neural network.

Yong et al. [33] used the finite element method (FEM) and artificial neural network (ANN) optimized by the metaheuristic algorithm for the analysis and prediction of diaphragm wall deflection induced by deep braced excavations.

III. CONCLUSION

In conclusion, retaining walls play a crucial role in civil engineering and landscaping, serving as vital structures to control soil erosion, create terraced landscapes, and provide stability to uneven terrains.

The diverse types of retaining walls, ranging from gravity walls to cantilever walls and beyond, offer engineers and designers versatile solutions for varying terrains and project requirements. As evidenced by the extensive literature and case studies reviewed, the design and construction of retaining walls require careful consideration of factors such as soil characteristics, drainage, and structural stability.

Advances in materials and construction techniques continue to contribute to the evolution of retaining wall technology, enhancing their durability and efficiency. While retaining walls address immediate engineering needs, ongoing research and innovation are essential to refining design methodologies, enhancing construction practices, and adapting to emerging challenges, such as climate change and urbanization.

The interdisciplinary nature of retaining wall design underscores the importance of collaboration among geotechnical engineers, architects, and environmental experts to create resilient and aesthetically pleasing solutions. As we navigate the complexities of modern development, the study of retaining walls continues to be a dynamic field, driving advancements that contribute not only to the structural integrity of landscapes but also to the sustainable and harmonious coexistence of human development and the environment.

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