Comprehensive Review of Retaining Wall Structures: Innovations, Stability, and Economic Efficiency

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Abstract: This paper presents a comprehensive review of recent advancements in retaining wall technologies, focusing on structural integrity, durability, and efficiency. The review covers various innovative approaches, including the development of closed-form equations for determining natural frequencies and deformation modes, and the incorporation of torsional and translational springs in soil modeling. Additionally, the effectiveness of interlocking gabion designs in flood-prone areas and the cost-efficiency of recycled steel pipelines in slurry-type retaining walls are highlighted. The study further explores the reduction of lateral earth pressure through compressible layers and geogrid reinforcements, showcasing significant decreases in active and quiescent earth pressures. Advanced imaging technologies, such as Structure from Motion Photogrammetry and Structured-light Scanning, are discussed for their potential in providing accurate deformation assessments of retaining walls. Seismic performance is a critical focus, with experiments demonstrating the impact of soil liquefaction and backfill properties on retaining wall stability. The use of geofoam to reduce ground pressure and the development of balanced weight retaining walls are also examined, offering optimal configurations and scientific foundations for design improvements.

Key Words: *Retaining wall, stability*

1. INTRODUCTION:

Retaining structures play a crucial role in various sectors of infrastructure, including ports, transportation networks, lifelines, and other constructed facilities. Therefore, the examination of these structures has been deemed essential by geotechnical engineers for several decades, especially in areas that are susceptible to frequent seismic activity. The acceleration of a seismic event causes the retaining structure and the soil it supports to move, leading to the application of corresponding inertial forces. The holding structure experiences increased tension when the combined forces of external forces and gravitational forces act upon it. The importance of highlighting the transient nature of seismic inertial forces, along with their periodic fluctuations in magnitude and direction, should be underscored. These characteristics serve to differentiate them from gravitational forces. These disparities have a significant impact on the preservation of structural seismic design parameters.

2. LITERATURE REVIEW

Mohammad et. al. [1] This study presents three closed-form equations that can be used to determine the first three natural frequencies of a retaining wall. The formulations presented here are based on a unique analytical model. The initial stage of the study focuses on the analysis of retaining walls as a solid body. It presents two mathematical expressions that provide accurate solutions for calculating the natural frequencies of the rigid mode of deformation. As a result, a novel mathematical expression is formulated that utilizes the energy approach to accurately calculate the natural frequency of the flexural deformation mode. The foundation soil modeling in this study incorporates torsional and translational springs, which is a unique characteristic. The analysis of the retaining wall's motion can be enabled by considering both swaying and sliding modes. In addition, weightless translational springs are installed along the wall to reduce the effects of soil contact caused by backfill. The utilization of ANSYS software for numerical analysis and the subsequent comparison of the results with the provided formulas led to the attainment of a satisfactory agreement.

Ramli et. al. [2] The integrity of earth-retaining structures in flood-prone areas has emerged as a significant concern in many countries. Flooding-related collapses are primarily caused by the erosion and abrasion of the foundation of the superstructure. Scour-arresting measures, such as gabions, are commonly installed on various structures, including bridges, in order to mitigate erosion on the piers and abutments caused by flooding. A study was conducted to enhance the resistance of gabions against lateral displacement by implementing an interlocking configuration, as opposed to the conventional stack-and-pair technique. The construction of two retaining wall systems with equivalent dimensions involved the use of rectangular and hexagonal gabion types. This was done to simulate lateral thrusts. The interlocking design of the wall demonstrates enhanced structural integrity by effectively resisting lateral movement, as compared to the traditional box gabion-based wall. The presence of this phenomenon can be clearly observed in the evolution of deformation. The use of interlocking design is recommended as an effective method to prevent scour in earth-retaining structures.

Valeriy et. al. [3] This article presents an architectural and technological methodology for constructing slurry-type retaining walls. The main difference lies in the use of recycled steel pipelines with interposed timber plates, instead of the bore supports that were used in the authors' construction. The critical attribute of the retaining wall is its resistance to the lateral pressure exerted by ground coverings, foundation excavations, and adjacent buildings and structures. Ensuring the long-term durability of such a facility is not a challenging task. The implementation of this retaining wall design in industrial civil and hydraulic engineering structures has been highly efficient due to several factors. Firstly, the use of inexpensive recycled pipes, which were purchased at a scrap metal price, has contributed to cost savings. Secondly, the design is user-friendly, making it easy to understand and implement. Thirdly, the design has proven to be technologically effective, meeting the required standards and specifications. Additionally, the availability of widely-used and relatively affordable construction machinery has facilitated the construction process. Lastly, the retaining wall design has a significant load-bearing capacity, ensuring its stability and durability. The proposed wall design meets the specifications of the hydraulic structure. However, this system operates in multiple ways that are not directly tied to technology. The incorporation of measures to reduce excavation effort can contribute to environmental considerations, resulting in a decreased reliance on landfills. In addition, the use of recycled steel pipelines and other processed materials can be considered as an alternative.

Yoshimichi et. al. [4] The focus of the study is on enhancing the structural integrity of retaining wall systems by incorporating a compressible layer, specifically expanded polystyrene blocks, behind a rigid retaining wall. This is done in combination with submerged geogrid layers within a thick granular backfill. The lateral earth pressure during wall movement is assessed by applying different surcharge pressures to mobile model retaining walls in close proximity to reinforced model specimens. The test results provide accurate determination of the coefficients of active and quiescent earth pressure. Three test series are performed to evaluate different methods of reinforcement for retaining walls. The first series focuses on installing expanded polystyrene blocks behind the wall. In the second series, expanded polystyrene blocks are installed behind the wall and geogrid layers are embedded within the model specimens. The third and final series involves installing expanded polystyrene blocks behind the wall and placing geogrid layers between two adjacent expanded polystyrene blocks and inside the model specimens. The following text discusses the interpretation of several factors related to a specific topic. These factors include the controlled yielding of compressible expanded polystyrene blocks, the induced tensile strains along geogrid layers, the connection between expanded polystyrene blocks and geogrid layers, and the presence of a facing unit composed of expanded polystyrene blocks. The examination of these factors is conducted in relation to the reduction in earth pressure at rest and active earth pressure that can potentially occur due to different reinforcement patterns.

Maxwell et. al. [5] This publication addresses the problem of identifying and quantifying deformations in swaying and protruding masonry retaining walls. Currently, these deformations are assessed using subjective visual inspections. The main objective of this project is to assess the capabilities of Structure from Motion Photogrammetry (SfM) as a data-driven, objective, and accurate alternative to eye examinations for the detection and tracking of these anomalies. The objective of this research was to conduct a comparative analysis between the utilization of Structure-from-Motion (SfM) inspections and a baseline three-dimensional (3D) imaging technique called Structured-light Scanning (SLS) for the assessment of retaining wall-like constructions. Consequently, controlled laboratory studies were conducted. The assessment involved evaluating different wall layouts and camera types. The software tool CloudCompare was utilized to perform an analysis on the 3D image data obtained during the trials by conducting comparisons of field point clouds. A comparison was made between the baselines and test models. The findings suggest that both Structure-from-Motion (SfM) and Structure Light Scanning (SLS) methodologies have the ability to produce accurate three-dimensional models of retaining wall systems. However, Structure-from-Motion (SfM) seems to be a more cost-effective solution for conducting comprehensive quantitative evaluations of retaining walls. The selection of a 3D imaging technology should be based on the level of precision required for the project and the specific site conditions. These factors should guide the decision-making process. This study highlights the significance of considering the "banana effect" and other distortions caused by Structure-from-Motion (SfM) when utilizing this technology for uniform flat surfaces, such as specific linear retaining walls.

Xiaoyu Guan [6] The previous seismic events have caused significant damage to retaining walls and other structures located along the littoral due to soil liquefaction. The LEAP project performed experiments on cantilever retaining walls with porous, saturated backfill at multiple centrifuge facilities. The retaining wall's toe penetrated the fine sand stratum beneath it for a distance of approximately 0.5 meters. The study involved conducting experiments on retaining walls with different ratios of the penetration depth (d) to the maintained height (h). The relationship between the dimensions of a wall and its deformation during liquefaction was examined through additional experimentation conducted by Cambridge University as part of the LEAP project. The purpose of this study is to demonstrate the relationship between the size of a wall and the amount of rotation and displacement experienced at its summit, specifically when considering a specific height-to-depth (h/d) ratio. The accuracy of constitutive models in capturing the reduction in soil dilatancy at high confining pressures can have a significant impact on the numerical simulations.

Anurag et. al. [7] Significant deformations or even collapse have been observed in numerous cantilevered retaining structures constructed to protect coastal regions during previous medium-sized earthquakes. The caisson-style quay walls demonstrated effective functionality despite the severe Kobe earthquake of 1995, distinguishing them from other types of quay walls. A recent study in the sector has shown that the saturated backfill next to retaining structures may not fully liquefy and is highly prone to shear-induced dilation mechanics caused by the significant static stress. Nevertheless, when the backfill does not completely liquefy and there are negative excess pore pressures, cantilevered retaining walls may undergo significant deformations. The purpose of this investigation was to utilize a geotechnical centrifuge experiment in order to propose a deformation mechanism for a submerged backfill consisting of Ottawa F-65 sand. This backfill is supported by an embedded cantilever retaining wall. An evaluation of the dynamic response of the soil-structure system was conducted using measurements, and an analysis of the mechanics of each cycle was performed. The duration of the earthquake was 20 seconds, and it can be categorized into three separate segments. During the first six seconds of phase I, the retaining wall experienced deformations that can be described as "sliding". This sliding was caused by the wall's inertia and the small amount of strain applied to the sediment in the backfill. The retaining wall experienced movement towards the backfill due to the repetitive seismic pulses in phase II, leading to significant decreases in suction. The hydrostatic value was exceeded by the negative surplus pore pressure. The soil underwent a notable softening after reaching the phase-transformation threshold. This softening was caused by a temporary decrease in suction as the wall distorted towards the shore. The backfill experienced significant plasticization, leading to the deformation of the wall at its base through a process called "rotation". The increase in the phase transition of excess pore pressures played a role in the observed increase in cumulative soil straining along the backfill. This relationship was demonstrated through intra-cyclic measurements. As a consequence, the wall underwent increasingly larger rotations until the passive resistance in front of the wall was fully mobilized. This occurred due to the execution of additional cycles in phase II, with a duration of up to 14 seconds. The prevention of the wall's sudden and disastrous collapse was achieved through the implementation of the re-dilation process. This process facilitated the generation of negative excess pore pressures as the soil underwent a phase transition. The wall continued to move closer to the shore, resulting in another occurrence of this phase transition. The retaining wall successfully achieved stability, as it prevented any additional deformations. The observed outcome can be attributed to the displacement of the effective stress path from its initial position and the reduction in mobilized passive stress as the amplitude of the applied cycles decreased towards the end of the motion (phase III). The proposed deformation process demonstrates that significant distortions of an immersed cantilever retaining wall can occur even without complete liquefaction. The text highlights the significance of understanding vacuum mechanics in scenarios where there is an accumulation of excess pore pressure.

Yeonwook et. al. [8] This study investigates the effectiveness and suitability of using geofoam to reduce the ground pressure on retaining walls. An evaluation of the geometric properties of the geofoam was conducted using finite element (FE) analysis in order to identify the most optimal configuration. The optimal configuration for retaining walls has been determined to be a triangle constructed using geofoam material. In addition, the purpose of this investigation was to provide a clear understanding of the use of geo foam to reduce ground stresses on the retaining wall. The soil pressure on the retaining wall was calculated by considering factors such as the geofoam area, backfill slope, and appropriate ties. The validity of the finite element (FE) analysis was verified through a comparison of its conclusions with experimental data obtained from retaining walls that were similar in nature. An investigation was conducted to explore the concept of minimizing the soil pressure exerted on a retaining wall that is reinforced with geofoam. In addition, the analysis considered the variability in soil pressure along the wall. The results indicate that the use of geofoam to reinforce the base of the retaining wall consistently reduced the soil pressure, irrespective of the wall's shape.

Chuanxiang et. al. [9] The balanced weight retaining wall is classified as a gravity retaining wall. However, there exist only a limited number of hypothetical scenarios that are relevant to earth pressure. The examination of backfill soil failure modes using finite element limit analysis considered various parameters, such as the width-to-depth ratio of the fill soil and the angle of rock inclination. The formula for calculating the active earth pressure of a balancing weight retaining wall in translational displacement mode was derived using the wedge limit equilibrium approach and differential element methods. The parameter investigation reveals a direct relationship between the increase in interface friction resistance and the increase in boundary friction angle. The magnitude of the active earth pressure exerted on the retaining wall is directly proportional to the ratio of the width to depth of the filling, and inversely proportional to the friction angle of the filling. The research findings provide a scientific basis and technical recommendations that can be beneficial for the design and construction of the counterweight retaining wall. The failure mode of the counterweighted retaining wall under translational displacement is significantly influenced by several factors including the width-to-depth ratio of the filling, the internal friction angle of the filling, the slope of the rock layer, and the interface friction angle. The increase in the interface friction angle will impact the failure mode of the fill soil, thus preventing the formation of "reflective" sliding surfaces. The identification of seven frequent failure scenarios of the soil infill behind the wall is made possible by the findings from finite element modeling. The soil modularization technique is utilized to compute the active earth pressure exerted on the wall. This technique considers the stress deflection effect at different infill positions.

Jin et. al. [10] The evaluation of safety in existing retaining walls is a topic of current research in the field of built environment development. Unfortunately, the majority of current assessment results are generated using a single evaluation method that is neither practical nor well-suited. This investigation proposes a comprehensive safety assessment methodology for the current subgrade retaining walls. The quantitative and qualitative indicators were weighted using the Interval Analytic Hierarchy Process (IAHP), the Entropy Weight Method (EWM), and the Improved Radial Movement Optimization (IRMO) algorithm, in accordance with a systematic summary. The TOPSIS approach can be utilized to evaluate the weighted indices by comparing safety to an ideal solution. The prescribed methodology was implemented in five instances. The data presented in this study clearly indicate that the technique employed in this research significantly improves the objectivity and rationality of judgment. This is achieved by minimizing the reliance on subjective and arbitrary weighting computations. The proposed model aims to improve the evaluation of safety for existing retaining walls by enhancing both accuracy and applicability.

Liua et. al. [11] An experiment was conducted to assess the seismic performance of a model retaining wall constructed using soilbags. The soilbag retaining wall models were subjected to a series of small-scale trembling table experiments using sinusoidal waves of varying amplitudes. In addition, the Wenchuan earthquake wave was used as an input for a large-scale trembling table test conducted in a specially designed laminar shear box. In addition, small-scale tremor table testing was conducted to implement models of horizontally reinforced retaining walls. An analysis was conducted on the Fourier spectra, dynamic earth pressure, horizontal acceleration responses, and lateral displacements of the soilbag retaining wall models through shake table tests. The results indicate that the seismic behavior of the soilbag retaining wall is similar to or slightly better than that of the horizontally reinforced retaining wall. The soilbag retaining wall exhibits fundamental frequency and Fourier spectral features that are similar to those observed in backfill sediments. The dynamic earth pressure of the wall model undergoes simultaneous changes with the input Wenchuan wave, and the seismic loading does not result in any residual earth pressure. The soilbag retaining wall exhibits a resilient seismic performance, with minimal lateral displacements caused by repetitive swaying.

Susumu et. al. [12] A series of experiments using a 1 g trembling table model is conducted to showcase the seismic behavior of a retaining wall. The focus is on highlighting the impact of backfill cohesiveness. The presence of cohesive backfill soil improves the integrity of retaining walls, as indicated by the results of the model test. Based on a comprehensive analysis of the seismic activity that impacted the retaining wall, the behavior of the cohesive backfill soil was observed and the following findings were made: The initial variables include the activation of cohesiveness along the failure plane of the backfill soil, an increase in shear stress at the boundary between the wall and the backfill soil, and the existence of a stable zone in the upper part of the backfill soil. When a stable zone is present, both the propelling force and the overturning moment experience a decrease. However, the stable zone experiences a decrease in size when there is a significant seismic burden. The resistance moment of the wall increases proportionally to the shear tension applied to its rear face, effectively preventing it from collapsing. The activation of this resistance remains consistent even in the presence of high levels of seismic activity. The activation of the cohesiveness along the failure plane of the soil wedge leads to a reduction in seismic active earth pressure. In addition, the system retains its mobility even when subjected to significant seismic strain caused by a powerful earthquake. The aforementioned observations indicate the need for further research to confirm the effectiveness of the retaining wall at the prototype scale and to determine the specific conditions for seismic design. However, a logical approach to evaluate the seismic performance of the retaining wall involves considering the cohesion of the backfill during the calculation of the seismic active earth pressure.

Chen et. al. [13] The use of narrow cohesive backfill is commonly utilized in the construction of retaining walls, making traditional theories outdated. The objective of this study is to present analytical solutions for the active earth pressure exerted by a narrow cohesive backfill against a rigid retaining wall that undergoes rotation around its base. Additionally, the text incorporates the rotational impact of primary stress that is caused by contact friction. The multi-segmented failure surface is quantitatively calculated through the utilization of a conventional Finite Element Method (FEM) analysis and an analytical derivation. The object consists of a logarithmic spiral curve in the lower half and a tangent line in the upper section. The narrow cohesive backfill is commonly acknowledged to exhibit three primary failure models, along with three distinct categories of differential components that are determined by the aspect ratio of the narrow backfill. The determination of the distribution, consequences, and application point of the active earth pressure can be easily achieved by implementing computer programming to automatically identify these three failure situations. The level of agreement between the recommended analytical solutions and the Finite Element Method (FEM) results is determined through a comprehensive two-step process of comparison. Upon conducting a more comprehensive analysis, it becomes apparent that the active earth pressure exhibits an inverse relationship with soil cohesiveness and interface friction. Conversely, it demonstrates a direct correlation with the slope inclination angle and aspect ratio.

Peng et. al. [14] This article presents a research study that utilizes numerical modeling to analyze the bearing capacity of two-tiered reinforced soil retaining walls. The finite element limit analysis (FELA) method is utilized for performing numerical simulations. The efficacy of the system is verified through a comparison of its results with those obtained from model testing and other numerical simulation studies. A parametric study is being conducted to investigate the influence of foundation width and location, upper wall setback, and reinforcing parameters on the bearing capacity of two-tiered reinforced soil retaining walls. The load-bearing capability of the substructure may be influenced by the ratio of tensile strength values of the reinforcement used in the two tiers of the wall, especially when it is located in close proximity to the confronting wall. The bearing capacity of the footing exhibits a humped shape when it is accurately positioned directly above the reinforced zone. The bearing capacity of a structure is minimally affected by the upper wall setback and reinforcement length when the height of the upper wall is increased. The discussion of these findings is presented in relation to the slip plane geometries that are depicted in the numerical models.

Mingxing et. al. [15] This paper outlines the methodology for predicting the horizontal earth pressures on rigid retaining walls using geofoam inserts. The solution was obtained by utilizing the iterative method to extend the previous analysis of the lateral stress-strain relationship of the backfill. The recommended procedure can be performed without any requirement for prior knowledge of the compressive value of the geofoam inserts. Furthermore, a series of model experiments were conducted to examine the lateral earth pressures exerted on nonyielding retaining walls made of expanded polystyrene (EPS) geofoams. The recommended solution underwent verification by comparing it to test data that was acquired without any surface impact. The recommended technique is supported by numerical simulations conducted for field-scale applications, which involved a vehicle load, as well as an earlier examination of laboratory-scale model testing with surface loading.

Hany et. al. [16] The cantilever retaining wall is a specialized form of retaining wall that incorporates pressure-relieving platforms. The total earth pressure exerted on a retaining wall can be reduced by incorporating pressure relief platforms on the backfill side. The outcome of this is a design for a cantilever wall that is more cost-effective and an overall wall that is thinner. The available literature provides a limited number of measurements and solutions for this specific type of wall. The earth pressure distributions measured in each investigation displayed distinct morphologies due to the different model scales employed in the research. For instance, in some measurements, the wall was allowed to move, while in others it was not. The Finite Element analysis of the specific wall type was performed using PLAXIS2D-AE.01. The act of replenishing the shelving leads to a decrease in the overall active earth pressure. The influence of the platforms on the distribution of earth pressure was determined to be significant.

Table 1: Summary of Literature review

Author Name	Work Done	Findings of the Research
Mohammad et al. [1]	Developed closed-form equations for determining the first three natural frequencies of retaining walls using a unique analytical model.	Presented mathematical expressions for calculating natural frequencies in rigid and flexural deformation modes. Introduced foundation soil modeling with torsional and translational springs, allowing analysis of swaying and sliding modes. Utilized ANSYS software for numerical analysis, achieving satisfactory agreement with the proposed formulas.
Ramli et al. [2]	Enhanced resistance of gabions against lateral displacement by implementing an interlocking configuration instead of the conventional stack-and-pair technique.	Constructed two retaining wall systems with rectangular and hexagonal gabion types. The interlocking design demonstrated enhanced structural integrity by effectively resisting lateral movement compared to the traditional box gabion-based wall. Recommended the use of interlocking design as an effective method to prevent scour in earth-retaining structures.
Valeriy et al. [3]	Presented an architectural and technological methodology for constructing slurry-type retaining walls using recycled steel pipelines with interposed timber plates.	The design was cost-effective, user-friendly, and technologically efficient, meeting required standards. The retaining wall showed significant load-bearing capacity, ensuring stability and durability. The design contributed to environmental considerations by reducing excavation effort and using recycled materials.
Yoshimichi et al. [4]	Investigated the enhancement of structural integrity in retaining walls by incorporating a compressible layer (expanded polystyrene blocks) and submerged geogrid layers within a thick granular backfill.	The study evaluated different methods of reinforcement, finding that the combination of expanded polystyrene blocks and geogrid layers effectively reduced earth pressure at rest and active earth pressure. The controlled yielding of the compressible layer and induced tensile strains along

		geogrid layers were key factors in reducing lateral earth pressure.
Maxwell et al. [5]	Assessed the capabilities of Structure from Motion Photogrammetry (SfM) as an alternative to visual inspections for identifying and quantifying deformations in swaying and protruding masonry retaining walls.	Both SfM and Structured-light Scanning (SLS) produced accurate 3D models of retaining wall systems. SfM was found to be a cost-effective solution for comprehensive quantitative evaluations of retaining walls. The study highlighted the importance of considering distortions caused by SfM when using this technology for uniform flat surfaces.
Xiaoyu Guan [6]	Conducted experiments on cantilever retaining walls with porous, saturated backfill at multiple centrifuge facilities to study the relationship between wall size and deformation during liquefaction.	The study demonstrated the relationship between wall dimensions and the amount of rotation and displacement experienced at the wall's summit. It emphasized the importance of constitutive models in capturing the reduction in soil dilatancy at high confining pressures for accurate numerical simulations.
Anurag et al. [7]	Investigated the deformation mechanism of submerged backfill supported by an embedded cantilever retaining wall during seismic events using geotechnical centrifuge experiments.	The study proposed a deformation process where significant distortions of an immersed cantilever retaining wall can occur without complete liquefaction. The observed outcome was influenced by the vacuum mechanics in scenarios with an accumulation of excess pore pressure.
Yeonwook et al. [8]	Investigated the effectiveness of using geofoam to reduce ground pressure on retaining walls through finite element (FE) analysis.	The study determined that a triangular geofoam configuration is optimal for reducing ground stresses on retaining walls. The analysis showed that geofoam consistently reduced soil pressure irrespective of the wall's shape.
Chuanxiang et al. [9]	Analyzed the active earth pressure on balancing weight retaining walls using finite element limit analysis considering various parameters.	The findings revealed a direct relationship between interface friction resistance and boundary friction angle. The magnitude of active earth pressure was directly proportional to the ratio of width to depth

		of the filling and inversely proportional to the friction angle of the filling.
Jin et al. [10]	Proposed a comprehensive safety assessment methodology for existing retaining walls using Interval Analytic Hierarchy Process (IAHP), Entropy Weight Method (EWM), and Improved Radial Movement Optimization (IRMO) algorithm.	The study improved the objectivity and rationality of judgment by minimizing reliance on subjective computations. The proposed model aimed to enhance the accuracy and applicability of safety assessments for retaining walls.
Liua et al. [11]	Conducted experiments to assess the seismic performance of a soilbag retaining wall model using shaking table tests.	The soilbag retaining wall exhibited resilient seismic performance, with minimal lateral displacements. The study found similarities in the dynamic behavior of the soilbag retaining wall and horizontally reinforced retaining wall models.
Susumu et al. [12]	Conducted a 1 g trembling table model experiment to highlight the impact of backfill cohesiveness on retaining wall integrity during seismic events.	The study found that cohesive backfill soil improved retaining wall integrity by reducing seismic active earth pressure. The findings

		indicated the need for further research to confirm the effectiveness of the retaining wall at the prototype scale.
Chen et al. [13]	Presented analytical solutions for the active earth pressure exerted by narrow cohesive backfill against a rigid retaining wall undergoing rotation around its base.	The study identified three primary failure models and distinct categories of differential components based on the aspect ratio of the narrow backfill. The active earth pressure exhibited an inverse relationship with soil cohesiveness and interface friction and a direct correlation with slope inclination angle and aspect ratio.
Peng et al. [14]	Used numerical modeling to analyze the bearing capacity of two-tiered reinforced soil retaining walls using finite element limit analysis (FELA).	The study found that the load-bearing capability of the substructure could be influenced by the ratio of tensile strength values of the reinforcement used in the two tiers. The bearing capacity of the footing exhibited a humped shape when positioned

		above the reinforced zone.
Mingxing et al. [15]	Predicted horizontal earth pressures on rigid retaining walls using geofoam inserts and conducted model experiments to examine lateral earth pressures.	The study found that the use of geofoam inserts effectively reduced lateral earth pressures on retaining walls. The findings were verified through numerical simulations and model experiments.
Hany et al. [16]	Investigated the effect of pressure relief platforms on the total earth pressure exerted on cantilever retaining walls.	The study found that pressure relief platforms reduced the total active earth pressure on retaining walls, resulting in a more cost-effective and thinner wall design. The influence of platforms on earth pressure distribution was significant.

RESEARCH GAP:- Addressing these gaps will contribute to a more nuanced understanding of how different materials and design configurations can enhance the structural integrity and efficiency of retaining walls, thus informing better engineering practices and design strategies.

3. CONCLUSION

The comprehensive review of recent studies on retaining wall technologies has highlighted several innovative approaches and methodologies aimed at enhancing the structural integrity, durability, and efficiency of retaining walls under various conditions. Analytical models and closed-form equations have been developed to accurately determine natural frequencies and deformation modes of retaining walls, incorporating unique characteristics such as torsional and translational springs in soil modeling. Advances in flood-prone area applications have shown the effectiveness of interlocking gabion designs in resisting lateral movements, while recycled steel pipelines in slurry-type retaining walls offer cost-effective and environmentally friendly solutions. Research has also emphasized the importance of reducing lateral earth pressure through the use of compressible layers and geogrid reinforcements, demonstrating significant reductions in active and quiescent earth pressures. The utilization of advanced imaging technologies, such as Structure from Motion Photogrammetry and Structured-light Scanning, provides objective and accurate assessments of deformations in retaining walls, enhancing the evaluation process. Seismic performance studies have underscored the critical role of soil liquefaction and backfill properties, with experiments highlighting deformation mechanisms and the impact of shear-induced dilation mechanics. Further, the implementation of geofoam to reduce ground pressure and the development of balanced weight retaining walls have been explored, presenting optimal configurations and scientific bases for design improvements. Comprehensive safety assessment methodologies incorporating quantitative and qualitative indicators have been proposed, enhancing the objectivity and rationality of safety evaluations for existing retaining walls. The seismic behavior of soilbag retaining walls and the impact of cohesive backfill on retaining wall stability during seismic activity have been rigorously analyzed, providing insights into the effectiveness of these systems under dynamic loads. Overall, the findings from these diverse studies provide valuable contributions to the design, construction, and maintenance of retaining walls, addressing both static and dynamic challenges and promoting the adoption of innovative materials and techniques in civil engineering applications. Despite the significant body of work exploring various aspects of retaining walls, there is a notable lack of studies that focus on the comparative analysis of different backfill materials' impact on the structural performance of retaining walls. Furthermore, the influence of shelf placement and configuration on the earth pressure distribution and overall wall stability remains underexplored. Although finite element analysis (FEA) has been employed in various studies to analyze retaining walls, the application of response surface optimization techniques to optimize design parameters and assess their effects on output variables is relatively unexplored.

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