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A Review on Construction Method and Material of Embankments Dam: Future Trends and Research Directions

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Abstract

Embankment dams play a crucial role in water resource management and flood control. To guarantee the stability and durability of these dams, much attention must be taken in their design and construction. To avoid failures and guarantee the safety of the nearby communities, research on the materials and building techniques used in embankment dam construction is crucial. Inadequate construction methods are among the main reasons embankment dams fail. As a result, establishing quality assurance and control procedures during the building process is essential. It has been determined that roller compaction is essential to maintaining the structural integrity of embankment dams. Future research directions in roller compaction quality control and assurance should focus on addressing potential issues that may arise during construction. An infrastructure that is durable and sustainable is necessary to ensure the longevity of embankment dams. Researchers can enhance the design and construction of embankment dams to withstand a range of environmental circumstances by implementing improved pavement materials and engineering approaches. Another important part of making sure embankment dams are stable is to keep an eye on how they are deforming. Researchers can forecast possible collapses and take proactive steps to reduce hazards by regularly observing the deformation trends of embankment dams. In the future, research on embankment dam building should concentrate on enhancing quality control procedures, introducing novel materials and engineering methods, and putting cutting-edge monitoring systems into practice.

Keywords: Embankment Dam, Construction Materials, Construction Methods, Stability Analysis

1. Introduction

The development of reservoirs and water management systems requires the use of embankment dams. To guarantee their stability and lifespan, building techniques and materials must be carefully chosen. In order to maintain the structural integrity of the dam, general design and construction considerations stress the significance of choosing appropriate embankment dam materials early in the construction phase [1]. Concurrent construction procedures are necessary to achieve specified criteria for new dam projects, according to research on zoned dam construction methods [2]. The use of filters in embankment dams is essential for ensuring the stability of the structure. The study's main objective was to assess potential materials for use in new dam construction's filter design [3]. The choice of suitable materials is still crucial even though hydraulic fill procedures are becoming less frequent in contemporary dam building because of worries about cyclic deformation [2]. With a tendency towards creative filter design techniques to improve dam stability, geotextiles are becoming an increasingly important part of embankment dam construction [4].It is imperative to monitor dam deformation patterns in order to detect prospective failures based on construction materials and time, as highlighted by future research directions in the field of dam failure disaster study [5]. This emphasizes the necessity of continual research and development in building techniques and materials for embankment dams in order to guarantee their longevity and safety. It is crucial to apply the proper techniques for assessing the likelihood of liquefaction and calculating the deformations of embankments, including dams [6].

A Review on Roller Compaction Quality Control and Assurance conducted by, emphasizes the significance of addressing important possible research topics in this field [7]. The research has also concentrated on the quality control and assurance of roller compaction in dam construction. Future developments in embankments and other materials

and building methods for dams are also crucial factors for the sector to take into account. In general, more study into the material and construction technique of embankment dams is essential to guaranteeing the efficacy and safety of these constructions. In order to enhance the design and construction of embankment dams for upcoming projects, the industry can keep up with research and developments in important areas including quality control, material selection, and building processes [8].

The paper reviews the literatures and evaluates the research on the impact of embankment building materials and the most recent methods that are frequently applied to increase the stability of embankment dams. This paper is organized into three sections to accomplish this goal. Factors influencing embankment stability are covered in the first section. While the third section discusses future trends and research goals, the second section discusses the elements influencing embankment dam design methods. This technique is extensively utilized and has significant benefits in terms of sustainability, cost savings, and construction time. The primary findings and recommendations for the future will be discussed last.

1.1. Review of Literatures

General Overview of Embankment Dams: The development of reservoirs and water management systems requires the use of embankment dams. The longevity and stability of embankment dams are largely determined by the materials and construction techniques employed. Emphasis how crucial it is to look at seepage issues in earthen embankments utilizing resistivity methods [9]. This technique can help to guarantee the structural integrity of the dam and spot possible problems. In their analysis of patented formwork methods for construction, address the application of innovative principles [9]. This strategy may result in creative fixes and improvements to embankment dam construction techniques. Ensuring the safety and dependability of earth and embankment dams requires careful consideration during the design and construction phases [10]. The entire stability and functionality of the dam depend greatly on the materials used in the building of the embankment. It is imperative for contractors to meticulously choose materials that fulfill all relevant specifications and criteria [11]. Furthermore, the embankment dam's longevity and quality may be impacted by the compaction techniques employed during construction [7].

Highlight the importance of using conventional methods of construction while building dams as well as the continuous research and development of new and improved materials for embankment dams [1]. Research in this area is essential for identifying future trends and research directions in the construction of embankment dams [12]. Research on dam construction is likely to focus on breaching, stability, and the use of cutting-edge building supplies and techniques in the future. In conclusion, the technique of construction and the choice of materials used in embankment dam construction are important aspects that affect the longevity, stability, and safety of these buildings. Through the integration of cutting-edge technologies and materials, scholars and engineers can persistently enhance the construction techniques and materials employed in embankment dam initiatives. To maintain the long-term performance and safety of embankment dams, future research initiatives are probably going to concentrate on improving the design, construction, and monitoring of these structures.

Review on Material of Embankment: Embankment material is a crucial component in civil engineering projects, playing a vital role in the construction of roads, railways, and levees. These materials are used to create stable foundations and support structures, providing stability and durability to infrastructure projects. From natural materials like soil and rock to engineered materials like concrete and asphalt, embankment materials come in a variety of forms to suit different project requirements.

The selection of embankment material is a critical decision that engineers must make when designing and constructing infrastructure projects. Factors such as the site characteristics, traffic loads, and environmental considerations all play a role in determining the most suitable material for the job. With advances in technology and materials science, engineers have more options than ever before when it comes to choosing the right embankment material for their projects, leading to more efficient and sustainable construction practices.

An inorganic clay (CL) material was utilized as embankment material in the world's longest embankment in Korea. The clayey soil had optimum moisture content (OMC) of 14.5% and a maximum dry unit weight of 17.75 kN/m3. A series of box model tests were conducted to ensure the suitability of the proposed material. Materials such as crushed gravel and composite geotextiles were used as reinforcements for the soft clay. The study concluded that the use of clayey soil in combination with crushed gravel and composite geotextiles as embankment material was suitable in terms of bearing capacity [13]. However, when considering sustainability and cost, this particular investigation may not be as convenient, as the expenses of geotextiles and gravel were not taken into account.

1.2. Embankment Dam Failure and Stability Analysis

The main reason embankment dams in the US fail are highlighted in the General Design and Construction Considerations for Earth Engineering paper. To increase the safety and dependability of embankment dams, it is imperative to comprehend these failure spots in order to improve future construction techniques and materials. Making the right material selection is essential when building embankment dams. Ethiopia's Ribb River's Morph Dynamic Trends examines the utilization of particular materials for embankment construction prior to building a dam. To ensure the stability and lifespan of the dam, appropriate materials that can withstand the forces pressing on it must be used. The Filters for Embankment Dams FEMA document emphasizes the critical function filters play in the construction of embankment dams. In order to ensure that filters effectively prevent seepage and erosion in the dam

structure, proper construction and compaction procedures are required. Improving the safety and effectiveness of these structures will require new trends and research directions in the material and construction techniques of embankment dams. Projects that study the stability and breaching of embankment dams are important, according to the National Dam Safety Program statement. More durable embankment dams that can tolerate a range of environmental conditions can be produced by improvements in building methods and materials.

To sum up, embankment dam lifetime and safety are greatly dependent on the type of material used during construction as well as other aspects. Future embankment dams in water management systems can be made more resilient and dependable by employing appropriate building techniques, choosing appropriate materials, and adding improved monitoring mechanisms. Important structures like embankment dams are susceptible to failure for a number of reasons, such as the materials and techniques used during construction. The rate at which water is released from a reservoir can be greatly impacted by the occurrence and formation of a dam embankment breach brought on by flood overtopping (Hanson *et al*). Embankment dam failures are thought to be primarily caused by the use of geotechnical unstable materials and inappropriate building techniques [14]. Abutment slopes and cross-valley arching are two examples of elements that might affect the settlement behavior of embankment dams, such as concrete faced rock-fill dams [15]. The form of the impervious clay core can also influence stability of embankment dams; in some circumstances, inclined core shapes are preferable to reduce settlements during the building of the dam [16]. Using characteristics like the elasticity modulus of filter and transition zones as well as core geometry, finite element analysis has been performed to examine the deformation and arching inside the core of embankment dams during construction [17].

Furthermore, reliability evaluation techniques that take base and filter variability into account have been developed to assess the likelihood of meeting empirical filter design criteria in embankment dams [18]. Additionally, studies on the application of piles and reinforcement in embankment construction have been conducted to examine the mechanisms of failure and the distribution of stress in multi-layered soil [19]. To comprehend the failure mechanisms of earth dams, such as hydraulic failure, seepage failure, piping through the dam body, and structural failure owing to earthquakes, seepage and stability calculations utilizing finite element methods have been carried out [20]. Generally, maintaining the stability and safety of these vital structures requires an understanding of how building materials behave in embankment dams. To guarantee the structure's lifetime and safety, stability must be carefully considered throughout the construction of embankment dams. To improve embankment dam stability for various reasons, numerous techniques have been investigated. The use of fly ash in the construction of embankment dams, especially in the repair of already-existing earth dams, was examined by [21]. To improve the dam's homogeneity, stability, and impermeability, the study concentrated on combining fly ash with a particular sealing clay. Improving the overall stability of the dam was successfully accomplished with this strategy.

In their study, employed the finite element method to compare several models for stress and deformation analysis of the Roodbal embankment dam during construction [22]. The study concentrated on the importance of stress and deformation analysis as design and stability factors for embankment dams. Studied the safety factor of high embankment dam slopes during earthquake conditions [23]. In addition to calculating the stability and safety factors of dam slopes based on various elements, the study sought to improve the design requirements for high embankment dams. The results shed light on high embankment dam stability and safety considerations in a range of scenarios. The results provide light on the safety and stability characteristics of high embankment dams in various scenarios. Overall, the literature review emphasizes how crucial it is to use a variety of construction techniques to improve embankment dam stability for a range of applications, including seepage and stability analyses, repairs, reliability assessment, stress and deformation analysis, and safety factor evaluation in seismic conditions.

These studies provide important new understandings into how to guarantee the stability and safety of embankment dams both during construction and throughout the course of their lifetime. The materials used during construction significantly influence the total stability and performance of embankment dams. Numerous studies have emphasized how crucial it is to choose the right materials and comprehend their stress-strain properties when building. According to, the rise in effective stresses that occurs during the construction of earth material layers has an impact on embankment dam deformation. To guarantee the dam's structural integrity, this stress-strain study is crucial [24]. Concentrated on creating a material model that was more straightforward to understand in order to examine how asphalt cores behave in embankment dams under various loading scenarios [25].

For finite element assessments of the interaction between the asphalt core and surrounding dam zones, this model can be useful. Using a finite element study, investigated at the arching activity that occurs inside embankment dam cores during construction [17]. The study emphasized how crucial it is to take into account the stiffness of various materials in the dam body in order to comprehend load transfer mechanisms. In the impermeable core of embankment dams, addressed the application of lime stabilization for highly flexible clayey soil [26]. By strengthening the core material's strength and impermeability, this technique can improve the dam's overall stability. Overall, the lifetime and structural performance of these hydraulic structures are greatly influenced by the qualities and choice of building materials used to build embankment dams. Enhancing embankment dam building safety and efficiency requires more investigation and developments in material science.

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Important structures like embankment dams must be built carefully to avoid failure in terms of construction methods. The form of the impervious clay core, geotechnical features, and the usage of unstable materials during construction are some of the variables that might impact an embankment dam's stability. In order to reduce settlements during construction, emphasized the preference for an inclined core form and emphasized the significance of the core shape in the stability of embankment dams [16]. In addition to seepage problems and geotechnical instability, found that one of the main reasons embankment dams fail is poor building techniques [14].

The application of geotextile reinforcement and the evaluation of filter design parameters, in addition to building methods, are important factors in preventing embankment dam failure. Basal geotextile reinforcement has been shown by to be beneficial in preventing subsoil failure during embankment building [27]. A novel approach to evaluating the likelihood of meeting empirical filter design criteria that takes base and presented filter heterogeneity into consideration [18]. To further forecast, peak discharge after dam failure, the assessment of embankment dam breach parameters is essential. Stressed the significance of dam-break analysis in guaranteeing dam safety and suggested the usage of artificial neural networks for precise calculation of dam breach parameters [28].

In general, the literature highlights how crucial it is to build embankment dams correctly, considering geotechnical factors, and utilizing innovative methods like geotextile reinforcement. By taking care of these issues, the likelihood of embankment dam failure can be decreased, improving the stability and safety of these vital infrastructures.

1.3. Constructions Method of Embankment Dams

In the field of hydraulic engineering, embankment dam construction techniques have long been of interest. The stability, settling, and seismic retrofit of embankment dams have all been examined in a number of researches. A technique utilized in the building of embankment dams is called Roller Compacted Dam Concrete (RCD) Technology, as explained [29]. In order to evaluate the stability of the Thika Dam during construction, carried out a finite element analysis [30]. Insights into the geological and geotechnical features of construction were provided by, who concentrated on the monitoring and analysis of settlement and stability of an embankment dam built progressive on soft ground [31]. Examined several dam types and settling factors while analyzing the post-construction settlement of rock fill dams [32].

He examined a variety of rock fill dam designs, such as dumped membrane faced, compacted membrane faced, sloping core, and central core dams. According to, there are a number of unknowns in embankment dam engineering [33]. These include the difficulties in precisely forecasting the performance of the dam because of variables like soil composition and weather. In order to provide technical basis for the redesign of the dam) carried out a geophysical examination of the Success Dam foundation to determine depth to bedrock and identify deep faults [34]. Excavating and building a buttressing embankment downstream, covered deformation analysis for the seismic retrofit of an embankment dam, which involves [35]. Concentrated on ground improvement techniques to reduce seismic risk to already-existing embankment dams, while studied the behavior of Zipingpu Dam under different conditions of loading by using an advanced plasticity model in static and seismic assessments [36,37].

The Buckeye Lake Dam rehabilitation was covered by, who emphasized the use of deep soil mixing techniques for the construction of seepage barriers and composite gravity dam structures [38]. Overall, these studies offer insightful information about the techniques used in embankment dam construction, stability analysis, settlement monitoring, and seismic retrofitting. They also emphasize the significance of cutting-edge technologies and procedures in guaranteeing the dependability and safety of these vital infrastructure projects. A variety of techniques have been developed and applied for embankment dam stability analysis, each with pros and cons. carried out a stability analysis for embankments built on alluvial marine clay using the effective stress method; the study compared measured and predicted excess pore water pressure, emphasizing the significance of considering anisotropy and strain rate in the analysis [39].

Reanalyzed embankment failures using the simplified Bishop method for total and effective stress analyses; the comparison of observed and calculated slip surfaces highlighted the need for accurate stability analysis techniques to prevent [40]. In order to determine the safety factor of stability against sliding for slope and dam foundation concerns, invented the Vector Sum Method (VSM) [41]. The limits of conventional stability analysis techniques based on the strength reduction concept were covered in the article. Underlined the need of seepage study for embankment dams since issues endangering the integrity of the dam could result from ignoring seepage [39]. The study used the finite element approach to quantitatively model the seepage of the body of the Zonouz embankment dam. Used Duncan's nonlinear strength criterion with Bishop's simplified method to provide a reliability-based method for assessing the stability of high rock fill dams [42]. The methodology was used to investigate the rock fill embankment dam at Shuang Jiang Kou's stability.

In order to guarantee the safety and stability of embankment dams, the literature review emphasizes the significance of applying sophisticated stability analysis techniques, such as the effective stress method and reliability-based approaches. The examined papers show that seepage analysis, stress distribution evaluation, and coupled effects consideration are important components of embankment dam stability study.

1.4. Future Perspective and Research Directions

Because of the possible dangers of failure, embankment dam stability is a crucial problem in geotechnical engineering. As pointed out, it is essential to comprehend how fine-grained

soil particle mobility impacts fluid flow within the dam core [43]. This may compromise the structural integrity of the embankment. Precise numerical solutions depend on the efficient characterization of hydraulic and electrical properties. A computational method for simulating head cut migration and suggested breaching in cohesive and zonal embankments [19]. They emphasized the significance of adequate input assignment for precise predictions. The study demonstrated that erosion and force/moment equilibrium govern breach processes in various dam types.

A method for conducting a comprehensive risk analysis of embankment dams under seismic conditions was presented by [44]. The authors employed various techniques to evaluate the seismic hazard and risk ratings of the structures. This research aids in predicting the stability of dams in the event of future earthquakes. Examined the effect of horizontal drain size on embankment dam stability under both steady and transient seepage situations [45]. One popular way to improve stability is to use horizontal drains to release pore water pressure. Concentrated on embankment dam deformation-based limit state analysis, taking into account a number of variables that affect the performance limit states and deformation response [46]. The analysis in the study was carried out using finite-element analysis, and the outcomes were integrated into probabilistic calculations [47]. Recommended these techniques for future settlement forecasts in an effort to forecast settlement in central core rock fill dams utilizing intelligent algorithms.

Examined the difficulties in maintaining road embankments on soft ground and suggested areas for future study pertaining to artificial intelligence-based stability factor prediction [48]. The literature assessment as a whole shows that there is increasing interest in risk analysis, sophisticated numerical approaches, and intelligent prediction tools for comprehending and improving the stability of embankment dams. To fill in the gaps in the available data and enhance our comprehension of embankment dam failures, more research is required. To improve dam safety and avert repeat mishaps, research into the factors underlying dam failure and risk assessment is crucial.

According to the literature reviewed, future studies on embankment dam materials and construction techniques should concentrate on strengthening erosion processes understanding, developing sustainable ecological design techniques, developing monitoring technologies, and optimizing remediation methods for the safety and performance of dams. Prospective avenues for research could center on integrating novel technology and methodologies to enhance the evaluation of embankment dam stability. Future studies on the stability of embankment dams should concentrate on geotechnical investigations, core design, monitoring techniques, and the effects of climatic variables such temperature changes and floods. Researchers can improve the longevity and safety of embankment dam systems by focusing on these important areas.

2. Conclusion

The primary objective of the current inquiry was to review the difficulties encountered during the construction of embankment dams and propose a course for further advancement. In order to guarantee the stability and safety of civil works projects, embankment dams are essential. The longevity and efficacy of the dams are largely dependent on the construction process and materials chosen. Analyses of breach parameter prediction techniques, stability considerations, and case studies of dam failures have been the main topics of previous study. In order to increase the durability of existing dams, new designs must also adhere to stricter safety regulations. The Stability and Breaching of Embankments Dams project, which intends to address important challenges linked to roller compaction quality control and assurance in dam building, is one of the future research paths in the field of embankment dams. Important factors that must be taken into account to prevent failures include the evaluation of existing dams and the construction procedure for new dams. Moreover, developments in engineering and pavement materials may have an impact on embankment dam construction and upkeep. It is critical to stay up to date on new trends and avenues for research as the area of dam construction develops. Research patterns in tailings dam failure disaster research can be identified with the use of Scientometric analysis, which can yield important information for enhancing dam safety protocols. A study of flood management trends also emphasizes how crucial it is to update flood control plans on a regular basis in order to reduce risks and improve resilience. To sum up, in order to guarantee the stability and safety of civil works projects, research and innovation on the building technique and materials of embankment dams are essential. With the potential for higher safety standards and increased resilience, the future of embankment dam building appears bright when new research areas and trends are investigated.

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