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Impact of Compaction Methods on Strength Properties of Roller-Compacted Concrete

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Abstract: This research explores the influence of different compaction methods on the strength characteristics of roller-compacted concrete (RCC) with plain cement at a 15% cement content and a predetermined Optimum Moisture Content (OMC) of 7%. The study focuses on both compressive and flexural strengths, examining three compaction methods: Vibratory Compaction, Standard Proctor Compaction, and Marshall Compaction. The study finally recommended Marshall compaction for roller compacted concrete due to higher flexural and compressive strengths

Keywords: roller-compacted concrete, compaction types, strength.

I. BACKGROUND AND MOTIVATION

Roller-compacted concrete (RCC) has emerged as a versatile and economical construction material, finding applications in various infrastructure projects. Its unique properties make it suitable for dams, pavements, and other structures. The success of RCC relies heavily on the compaction process, which directly influences its strength characteristics. Understanding the impact of different compaction methods becomes imperative for optimizing RCC's performance and ensuring its successful application in diverse engineering projects.The compaction process plays a pivotal role in determining the final properties of concrete. In the context of RCC, where traditional methods may not be directly applicable, specialized compaction methods come into focus. Each compaction approach brings unique advantages and challenges, influencing the structural integrity and durability of the resulting concrete. This study aims to shed light on the specific contributions of Vibratory Compaction, Standard Proctor Compaction, and Marshall Compaction to the strength properties of plain cement RCC.

Despite the growing popularity of RCC, there is a gap in the understanding of how different compaction methods impact its strength properties. This research aims to address this gap by systematically investigating the compressive and flexural strengths of RCC compacted using Vibratory, Standard Proctor, and Marshall methods. The primary objectives are to quantify the strengths achieved by each method, identify their relative effectiveness, and provide insights that can guide engineers in selecting the most suitable compaction approach for specific applications.

II. LITERATURE REVIEW

Ribeiro and Almeida (1999) investigated a concrete blend merging roller compacted concrete features with high-performance concrete. Their study assessed properties such as compressive strength, tensile strength, abrasion resistance, and modulus of elasticity. Notably, the results showed exceptional compressive strength and superior abrasion resistance compared to typical concrete, with the modulus of elasticity exhibiting a proportional relationship to compressive strength. Li et al. (2002) explored the behavior of roller compacted concrete (RCC) cores under uniaxial tension. The study included properties like tensile strength, modulus of elasticity, fracture energy, and stress-crack width for both the RCC matrix and interface. Findings highlighted the relationship between uniaxial tensile strength and compressive strength, as well as the influence of aggregate size and specimen dimensions on properties like modulus of elasticity and fracture energy. In 2005, Kimitaka investigated the construction of Roller Compacted Concrete (RCC) Dams, emphasizing the importance of fly ash in RCC Dams, commonly substituting 20 to 30% of cement. Challenges were noted in ensuring the availability of fly ash with suitable qualities. The study outlined specific properties of RCC Dams in Japan, providing a comparative analysis with practices in other countries. Park et al. (2007) explored the mechanical and durability performance of roller-compacted concrete (RCC) incorporating fly ash for dam applications. Laboratory tests assessed properties in both fresh and hardened RCC with varied fly ash replacement ratios. The results highlighted the most favorable replacement ratio as 30% fly ash, indicating exceptional mechanical and durability properties in the RCC mixture.Karimpour (2010) focused on properties crucial for dam construction, revealing that in conventional concrete, extended delays in compacting led to substantial property deterioration. Interestingly, when ground granulated blast furnace slag (GGBFS) was included, prolonged delays did not lead to property loss. Instead, enhancements in compressive strength, permeability, absorption, and adsorption were noted. The study suggested potential advantages of using GGBFS in RCC mixtures, especially in scenarios with unavoidable delays during the compacting phase. Further Damrongwiriyanupap et al. (2012) studied the feasibility of roller compacted concrete for roadways in Colorado state in USA. Whereas, Abdo. (2008), Su and Wei. (2013) and Bass. (2003) reviewed the mechanical behavior of RCC for dams and further explored design and construction of dams with RCC.

III. MATERIALS AND METHODS

3.1 Description of Materials: For this study, the materials include ordinary Portland cement, aggregates, and water. The cement-to-aggregate ratio is maintained at a predetermined 15% for consistency. The aggregates conform to ASTM C33 specifications. The mixing process ensures homogeneity of the mix, and the predetermined Optimum Moisture Content (OMC) is set at 7% for the roller-compacted concrete (RCC).

3.2 Mixing Proportions for Plain Cement RCC: The mix proportions are determined based on ASTM C192 and ASTM C1602 standards. The mix design includes the selection of water-cement ratio, aggregate grading, and other parameters. The objective is to achieve a workable and durable RCC mix.

3.3 Compaction Methods: Three compaction methods are investigated:

- **Vibratory Compaction:** Conforming to ASTM D4253, a vibrating roller compactor is used to achieve densification.
- **Standard Proctor Compaction:** Following ASTM D698, the Standard Proctor compaction method is employed using a specified energy input.
- **Marshall Compaction:** Adhering to ASTM D1559, a Marshall compaction hammer is used to compact cylindrical RCC specimens.

3.4 Compressive Strength Testing: Compressive strength tests are conducted on 100 mm cubes following ASTM C39. Specimens are cured for 7, 14, and 28 days, and the loading rate is set at 0.25 MPa/s. The maximum load at failure is recorded, and compressive strength is calculated.

3.5 Flexural Strength Testing: Flexural strength tests are performed on RCC beams following ASTM C78. The beams, with specified dimensions, are tested after curing for 7, 14, and 28 days. The loading setup complies with ASTM C293, and the average flexural strength is determined.

IV. RESULTS AND DISCUSSIONS

4.1 Compressive Strength: The compressive strength results have been examined to unravel the influence of distinct compaction methods on the 28-days strength of roller-compacted concrete (RCC). Figure 1 has summarized the average compressive strengths for Vibratory Compaction, Standard Proctor Compaction, and Marshall Compaction, standing at 29.2 MPa, 27.6 MPa, and 32.0 MPa, respectively.

A detailed analysis reveals that Vibratory Compaction has demonstrated a commendable 28-days compressive strength of 29.2 MPa. Renowned for its efficiency in achieving high compaction density, this method has significantly contributed to the overall strength of RCC. The consistency across trials reinforces the reliability of this compaction method.

Standard Proctor Compaction, with an average strength of 27.6 MPa, has proven to be a competitive performer. While not surpassing Vibratory Compaction, it has established itself as a viable method for RCC. The consistent results suggest a reliable and predictable strength outcome.

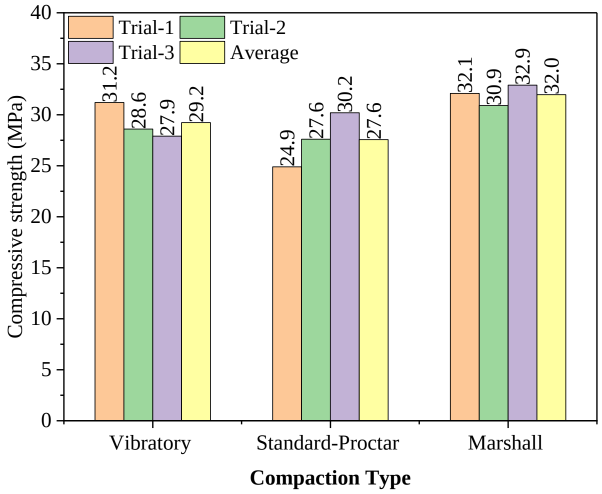

Figure 1. Effect of compaction type on compressive strength of roller compacted concrete

Marshall Compaction emerges as the most effective method in terms of 28-days compressive strength, recording an average strength of 32.0 MPa. Despite being less conventional for concrete compaction, this method showcases its potential applicability in achieving superior strength characteristics for RCC. Shifting the focus from individual method strengths, the discussion now explores the broader implications of compaction types on RCC compressive strength.In examining the effect of compaction types without specific headings, it is evident that the choice of compaction method significantly influences the overall compressive strength of RCC. Vibratory Compaction, while providing a balanced performance, may be preferred in scenarios where both compressive and flexural strengths are critical. Standard Proctor Compaction, though not excelling in achieving the highest strengths, maintains a consistent and reliable outcome. Marshall Compaction, with its superior compressive strength, stands out as a noteworthy method, especially when high strength is a priority in the project requirements. The data prompts a nuanced consideration of compaction methods, emphasizing that the selection should align with the specific structural demands and objectives of the project. It is not merely about achieving the highest strength but also about striking a balance between various strength aspects and practical applicability. The discussion underscores the importance of these findings in guiding practitioners and engineers toward informed choices in compaction methods for roller-compacted concrete, taking into account both compressive and flexural strength requirements.

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4.2 Flexural Strength: Table 2 outlines the flexural strength results for roller-compacted concrete (RCC) subjected to different compaction methods. The average flexural strengths for Vibratory Compaction, Standard Proctor Compaction, and Marshall Compaction have been observed at 3.77 MPa, 3.38 MPa, and 3.64 MPa, respectively. In examining the individual performance of each compaction method, Vibratory Compaction has demonstrated a satisfactory 28-days flexural strength of 3.77 MPa. While not recording the highest strength among the methods, it showcases a balanced performance, making it suitable for applications where both compressive and flexural strengths are crucial. Standard Proctor Compaction, with an average flexural strength of 3.38 MPa, exhibits a consistent and competitive performance. The results suggest that while this method may not excel in compressive strength, it maintains a reasonable level of flexural strength, contributing to the overall structural integrity of RCC. Marshall Compaction, despite excelling in compressive strength, displays a slightly lower average flexural strength of 3.64 MPa. This variation emphasizes the importance of considering multiple strength aspects when selecting a compaction method for RCC. Transitioning from individual method strengths, the discussion now delves into the broader implications of compaction types on RCC flexural strength without explicit headings.

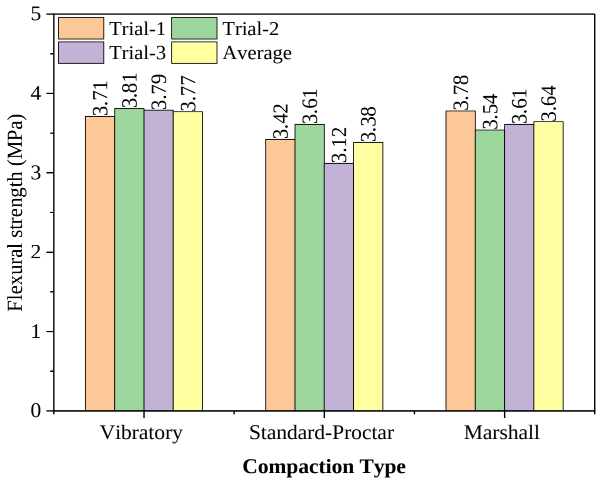

Figure 2. Effect of compaction type on flexural strength of roller compacted concrete

Analyzing the effect of compaction types on RCC flexural strength, it becomes evident that the choice of compaction method has a considerable influence. Vibratory Compaction, while not recording the highest flexural strength, offers a balanced performance, indicating its versatility for applications requiring a combination of strengths. Standard Proctor Compaction, with its consistent flexural strength, becomes a viable option in scenarios where a reliable and predictable outcome is prioritized. Marshall Compaction, despite its slightly lower flexural strength compared to compressive strength, remains noteworthy for projects where both aspects are critical.

This integrated discussion underscores the importance of considering flexural strength alongside compressive strength when evaluating the performance of different compaction methods. The selection of a compaction method should align with the specific structural demands and objectives of the project, emphasizing a holistic approach to strength characteristics.

V. SUMMARY

The study has investigated the impact of different compaction types, namely Vibratory Compaction, Standard Proctor Compaction, and Marshall Compaction, on the 28-days compressive and flexural strengths of roller-compacted concrete (RCC) with plain cement concrete at a 15% cement content and predetermined Optimum Moisture Content (OMC) of 7%. Utilizing standard protocols outlined by ASTM, the methodology involved conducting compression and flexural tests, with results presented in tables. In terms of compressive strength, Marshall Compaction exhibited the highest average strength at 32.0 MPa, making it a preferred choice for projects emphasizing high compressive strength. However, for a more balanced and versatile performance in both compressive and flexural strengths, Vibratory Compaction and Standard Proctor Compaction are recommended. The study provides valuable insights for practitioners in making informed decisions based on specific project requirements, acknowledging the nuanced strengths offered by different compaction methods.

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