INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 04, Issue 11, November 2024, pp : 1503-1506
www.ijprems.com
editor@ijprems.com
e-ISSN : 2583-1062
Impact Factor : 7.001

CALCULATE CRACKING BEHAVIOR AND ITS SUBSEQUENT IMPACT ON SLAB DURABILITY

Shashi Kant Yadav[1], Sapana Madan[2]

[1]M.Tech. Scholar, School of Civil Engineering, Faculty of Engineering and Technology Madhyanchal Professional University Bhopal, M.P

[2]Associate Professor, School of Civil Engineering, Faculty of Engineering and Technology Madhyanchal Professional University Bhopal, M.P

ABSTRACT

The publication presents a study aimed at bridging the gap between research findings and established design codes for evaluating crack width in one-way reinforced concrete slabs. The primary concern addressed is the cracking behavior and its subsequent impact on slab durability, particularly the corrosion of reinforcement caused by such cracks. The research emphasizes the critical issue practitioner's face in managing and designing structures to control crack-induced damage. By developing a method to estimate the maximum fracture width, the study provides a formula based on the variation in steel reinforcement areas. Specifically, the study tests slabs reinforced with steel areas of maintaining a uniform slab length of 2 meters and a width of 0.6 meters. Key findings reveal that traditional research codes and prediction formulas suggest the maximum crack width is not heavily dependent on the steel area (As). However, the study's experimental data indicate that increasing the steel area effectively reduces the maximum crack width. The study concludes with the development of an approximation formula tailored for one-way slabs, offering a practical tool for engineers to manage crack widths effectively in slab construction, thus enhancing structural durability.

Keywords: Crack width, Slabs reinforced, Enhancing structural durability, Structural durability, Maximum crack width

1. INTRODUCTION

Cracking in concrete is indeed a significant concern as it affects the overall performance and durability of reinforced concrete (RC) structures. The tensile stresses that develop and exceed the tensile strength of concrete often lead to the formation of cracks. As you mentioned, these cracks have multiple negative consequences, including compromised durability, diminished aesthetic appeal, and reduced liquid or gas tightness. Repairing cracks can be costly and time-consuming, so it is generally preferable to limit crack formation at the design stage.

However, [3] noted, not all cracks can be controlled during structural design. Cracks are broadly categorized into controllable and non-controllable types. Controllable cracks typically arise from service loads and can be managed through careful structural design and reinforcement detailing. Non-controllable cracks, on the other hand, occur due to phenomena such as plastic shrinkage, alkali-silica reaction, or environmental effects like freeze-thaw cycles, which are difficult to mitigate fully during design.

To minimize service load-induced cracks, one strategy is to limit the tensile stress on the reinforcement. The Japanese code provides a guideline that if tensile stress in deformed bars from permanent loads is limited to 120 N/mm², checking for crack width can be omitted [4]. However, achieving this stress limitation often requires significant amounts of reinforcement, which can increase construction costs and make the structure more difficult to build. Therefore, rather than eliminating all cracks, designers often focus on controlling crack widths to acceptable levels to maintain structural integrity and functionality. This approach balances the need for durability and cost-effectiveness in construction.

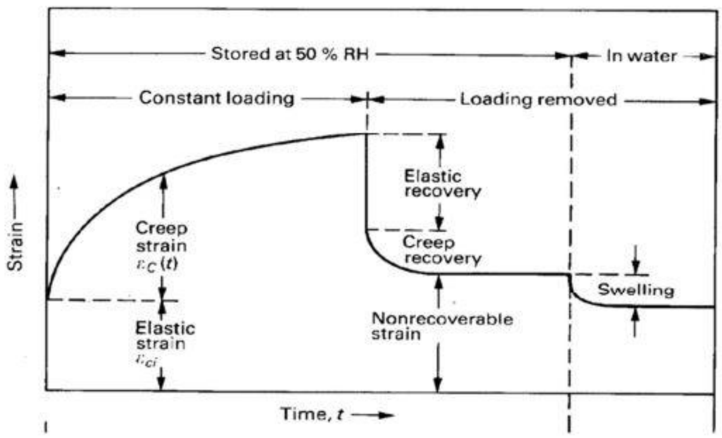

Figure 1 Crack propagation in structure

INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)
(Int Peer Reviewed Journal)
Vol. 04, Issue 11, November 2024, pp : 1503-1506
www.ijprems.com
editor@ijprems.com
e-ISSN : 2583-1062
Impact Factor : 7.001

Asvitha Valli S et al (2023) cracking in concrete structures is indeed a major area of concern as it directly affects the structural integrity and durability of buildings. The formation of cracks and cavities not only compromises the load-bearing capacity but also poses significant risks to the waterproofing and overall tightness of the structure, potentially leading to long-term failures if left untreated. Mechanisms behind Concrete Cracking Understanding the mechanics of concrete cracking is essential for developing effective prevention methods. Here's a deeper look into the phenomena. The field continues to evolve, with cutting-edge studies exploring new materials and technologies to enhance the performance and longevity of concrete structures. These advancements reflect a concerted effort to address the vulnerabilities associated with cracking, ultimately leading to safer and more durable infrastructure.

Seyed Vahid Razavi Tosee et al (2022) this research investigates the use of a hybrid Grey Wolf Optimizer (GWO) Neural Network Model to predict the crack width in reinforced concrete (RC) slabs strengthened with carbon fiber-reinforced polymers (CFRP). The study focuses on RC one-way slabs of dimensions 1800 × 400 × 120 mm, strengthened with CFRP sheets of varying lengths (1800 mm, 1100 mm, and 700 mm), which were subjected to four-point bending tests. The goal was to compare the crack behavior of CFRP-strengthened slabs with conventional RC slabs.

2. METHODOLOGY

The phenomenon of restraint forces induced by out-of-phase volume changes in slab frame bridges is crucial to consider in bridge design. These forces arise from differential temperature variations affecting the bridge components differently over time.

Explanation of the Phenomenon:

Temperature Differentials: The bridge deck, exposed directly to the atmosphere, experiences significant temperature fluctuations, changing with diurnal and seasonal variations. On the other hand, the rigidly connected walls, which are insulated by backfill and soil, maintain a relatively constant temperature closer to the thermal properties of the surrounding ground.

Out-of-Phase Volume Changes: These temperature differences lead to out-of-phase volume changes between the bridge deck and the walls. The deck expands and contracts more significantly than the walls, resulting in induced restraint forces. Since the deck is restrained by the connected walls, it cannot freely expand or contract, causing stress and strain within the structure.

Impact on Structural Integrity: These induced forces can create internal stresses, potentially leading to cracking, fatigue, or other forms of structural damage over the bridge's design life. Over time, the cumulative effect of these stresses can impact the bridge's durability and performance.

Design Considerations:

Thermal Analysis: Engineers must account for thermal gradients and perform a detailed thermal analysis to predict the extent of volume changes and resulting forces.

Joint and Bearing Design: To mitigate the impact of these forces, proper design of expansion joints and bearings may be necessary to allow for relative movement between different parts of the structure.

Material Selection: Using materials with appropriate thermal properties and adequate reinforcement to withstand stress variations can also improve the structure's resilience. Designing slab frame bridges to accommodate these thermal effects is essential for ensuring long-term structural performance and safety.

3. RESULT AND DISCUSSIONS

The results of the parametric study highlight the complexity and unpredictable nature of crack behavior under restraint forces, especially in terms of allocation and crack widths. The analysis showed that in many cases, intuitive or expected causal relationships were not clearly established. However, a consistent observation across all simulations was the inverse relationship between crack width and the number of cracks: as the number of cracks increased, the width of individual cracks decreased. This behavior suggests that the strain energy generated by thermally induced restraint forces was distributed across more cracks, reducing the width of each crack.

Interestingly, the expected impact of different bond quality levels on maximum crack widths did not emerge from the simulations. Despite initial expectations, no significant correlation was observed. A possible explanation is that the thermal interval applied during the study may have been insufficient to generate the necessary tensile stresses in the reinforcement to demonstrate this effect. Further research with a broader range of thermal intervals may be needed to better understand these relationships.

Numerical modeling of cracking behavior was challenging due to variability in concrete properties and the need for simplifying assumptions.

Challenges in Numerical Simulations: The concrete strength, surface roughness, and material properties had significant variation, making it difficult to simulate accurately. Experimental setups often lack sufficient details, forcing reliance on assumptions that can introduce errors.

Concrete Hardening and Early-Age Effects: The lack of time-dependent effects in the model limited its ability to replicate the early-age behavior of concrete, which can impact cracking and stress distribution.

Crack Pattern Analysis: Despite challenges, the numerical models produced crack patterns that were qualitatively similar to experimental results. However, they tended to overestimate crack widths, particularly near bottom corners, suggesting areas where modeling could be improved.

Impact of Base Restraint: A 100% base restraint led to unrealistic stress concentrations and larger crack widths near corners. Introducing interface elements and shear dowels allowed for some uplift and slip, which better represented real-world behavior and improved the accuracy of the simulations.

Role of Shear Dowels: Implementing shear dowels helped mimic the combined effects of shear action from reinforcement and the roughness at concrete interfaces.

This addition allowed for stress redistribution and more realistic crack development, demonstrating the importance of accounting for interface behaviors.

4. CONCLUSION

The discussion surrounding the L/H-ratio (length-to-height ratio) in concrete members highlights its significant influence on cracking behavior caused by restraint forces. Key observations include:

Crack Width and L/H-Ratio Relationship: When analyzing the maximum crack widths under increasing L/H-ratio conditions, it is noted that for lower ratios, the maximum crack widths tend to increase. However, as the L/H-ratio grows larger, these widths converge to a stationary or limiting value.

Overly Conservative Estimates: The use of normal forces derived from linear finite element analysis (FEA) simulations as input for crack estimation expressions outlined in tends to produce results that are excessively conservative.

This suggests the need for careful interpretation and possibly less conservative approaches to better predict cracking due to restraint forces.

Impact of Thermal Gradients: When a thermal gradient is applied to structural members in contact with backfilling material, the resulting maximum crack widths decrease compared to those obtained using a uniform temperature distribution. This effect becomes evident in scenarios where temperature differences are modeled as described.

Beneficial Effect of Permanent Loads: In nonlinear simulations of thermal load responses, such as in a concrete slab frame bridge, the inclusion of permanent external loads—like the dead weight of the structure and earth pressure—before applying temperature loads leads to a more uniform distribution of vertical cracks.

This effect, which reduces the concentration of cracks, is particularly beneficial during warmer seasonal load conditions. These findings underscore the complex interactions between thermal and mechanical loads on concrete members and the importance of considering various factors, such as L/H-ratio, thermal gradients, and pre-existing loads, when predicting and managing crack behavior in structural elements.

5. REFERENCES

[1] Asvitha Valli S [a], Ravi Kumar M S “Review on the mechanism and mitigation of cracks in concrete” Applications in Engineering Science Volume 16, December 2023, 100154 https://doi.org/10.1016/j.apples.2023.100154

[2] David Z. Yankelevsky * , Yuri S. Karinski and Vladimir R. Feldgun “Analytical Modeling of Crack Widths and Cracking Loads in Structural RC Members” Infrastructures 2022, 7, 40. https://doi.org/10.3390/infrastructures7030040 https://www.mdpi.com/journal/infrastructure.

[3] Alfredsson, H. and Spåls, J. (2008). Cracking Behaviour of Concrete Subjected to Restraint Forces. Master’s Thesis, Chalmers University of Technology, Civil and Environmental Engineering. Gothenburg, Sweden.

[4] Ansell, A., Hallgren, M., Holmgren, J., Lagerblad, B., and Westerberg, B. (2013). Concrete structures EDITION 2013. Royal Institute of Technology, Civil and Architectural Engineering.

[5] TRITA-BKN 143, Stockholm. Bažant, Z. P. and Oh, B. H. (1983). Crack band theory for fracture of concrete. Materials and Structures, Vol. 16, pp. 155-177. RILEM.

[6] Björnström, J., Ekström, T., and Hassanzadeh, M. (2006). Spruckna betongdammar - Översikt och beräkningsmetoder. Report 06:29, Elforsk..

[7] Rodriguez G, Casas JR and Villalba S. Assessing cracking characteristics of concrete structures by Distributed Optical Fiber and Non-Linear Finite Element Modelling. EWSHM-7th European Workshop on Structural Health Monitoring, Nantes France, July 2014.

[8] D.J Haavik. Evaluating concrete cracking by measuring crack width. Publication #C900553. The Aberdeen Group. 1990.

[9] Nazmul I and Matsumoto T. High Resolution COD image analysis for health monitoring of reinforced concrete structures through inverse analysis. International Journal Solids Structures. 45 pp159-174, 2008.

[10] Jahanshani MR, Masri SF and Sukhatme S. Multi-image stitching and scene reconstruction for evaluating defect evolution in structures. Structural Health Monitoring International journal, 10 pp 643-57, 2011