Understanding the impact of degradation of concrete structures

Rene VEERMAN
PhD Student
Delft, University of Technology
Delft, Netherlands
r.p.veerman@tudelft.nl

Eddie KOENDERS
Associate professor
Delft University of Technology
Visiting professor
COPPE-UFRJ, Rio de Janeiro, Brazil
e.a.b.koenders@tudelft.nl

Summary

During the service-life, concrete infrastructures are loaded by traffic and environmental actions which affect the structural and material induced degradation mechanisms. In the last fifty years, the traffic intensity has increased significantly, and also increasing the number of local damage to many infrastructures. In addition, damage caused by material degradation mechanisms has increased as well. In order to assess the effect of structural and material degradation on the performance of infrastructure a simple supported beam has been developed with the aim to include most dominant material and structural related degradation phenomena. In this first order approach, the effect of the on-going hydration of compression strength, creep and the effect of stochastic traffic loads on bridge structures have been taken into account while the degradation mechanisms such as ASR and chloride ingress have not been explicitly modelled yet.

Keywords: Concrete structures, aging, cracks, degradation, creep, vibrations.

1. Introduction

In the last decades, assessing the service-life of concrete structures is a theme that has gained enormous interest. The complex interactions between various actions and the response of the infrastructural elements are the main topics to be dealt with in order to assess the actual condition of our national stock of infrastructural assets. In this respect, a structural analysis including both traffic induced loading and material degradation and the interaction between both is the major issue to be solved. In this paper, the first preliminary ideas of a simplified model are being presented, representing a very basic blueprint of the final numerical model. Emphasis will be on the inclusion of the dominant structural and material damage models.

2. Simplified model

The simplified model being considered is a simply supported beam on two hinge supports. The cross-section is a rectangular concrete section with a single layer of reinforcement bars. For several calculations, a range of different parameters is used.

3. Material properties

As reinforced concrete is an inherent heterogeneous and brittle material, its mechanical performance shows highly nonlinear and a scattered behaviour. Sima [1] has published a bi-linear formula to calculate the concrete stress-strain relationship. This stress-strain relation has been linearized by a tetra-linear stress-strain relation. The same principle has been employed for the stress-strain relation of the reinforcement steel. Bond failure is not taken into account in the model.

https://doi.org/10.2749/222137813806735507

In general, the basis for designing concrete structures is the 28 day strength of the concrete. However, since after 28 days, the properties will further develop with time. Ghali [2] has described the on-going hardening process through a set of formulas formulas.

4. Loads

The girder can be loaded by an axial load and/or a distributed load perpendicular to the girder's axis. The permanent axial load could be a prestressing load. Quasi-permanent loads, like traffic jams have also a small contribution to the total permanent load and are included in the creep calculation.

Permanent loaded concrete structures will deform in time according to creep. Due to this, the concrete strain increases, while the concrete stresses decrease, the steel stress increases and the internal level arm decreases. Creep has a negative influence on the failure load. Many failure load calculations have been made and many parameters are used. The failure load reduction due to creep is several percentages.

A bridge girder will be mainly loaded by traffic loads. Concentrated loads, representing vehicles, may pass the girder at various speeds and at a different timescales, i.e. different vehicles with different masses, causing so-called traffic induced vibrations to the girder. Galenkamp [3] has derived a formula to calculate the traffic induced vibrations to concrete girders for crossing loads.

5. Mechanical degradation

For a structure loaded in bending, the actual compressive stress level depends on the location considered. The outer "fibre" of the cross-section experiences the highest stress level. When this stress level has reached the ultimate stress, some capacity is left in other fibres and failure has not yet occurred. Failure occurs if the strain in the outer fibre reaches the ultimate strain. In the tension stage, concrete will crack when the ultimate stress is reached. The tension force will be fully taken over by reinforcing steel. Since the cross sectional area of concrete is far larger than the cross sectional area of steel, a new equilibrium stage will coincide with large strains.

6. Conclusion

Based on a simple model of a simply supported beam, the influence of strength hardening, creep, and traffic has been analysed. The strength of concrete will continue to increase with time. This hardening process increases the failure capacity with time. Creep disturbs the equilibrium between the internal stresses and has a negative influence on the load carrying capacity. The model presented in this paper will be further developed. Validation of the model will be done using real time monitoring data from the Hollandse Bridge monitoring system. The data analysis will be conducted by the LIACS centre in Leiden which is a cooperating partner in this project.

The authors like to thank STW and the companies involved in the InfraWatch project for their financial support.

7. References

[1] SIMA, J. F., ROCA, P., and MOLINS, C. "Cyclic Constitutive Model for Concrete." *Engineering Structures* 30, no. 3 (2008): 695-706.

[2] GHALI, A., FAVRE, R., and ELBADRY, M. *Concrete Structures*. Stresses and Deformations: Analysis Design for Serviceability. Spon Press, 2012.

[3] GALENKAMP, H. F. "The Influence of Traffic Vibrations on the Hydration Process of Early-Age Concrete." Delft University of Technology, 2009.