DIANA Users Association - Lecture Meeting 13 March 2025

Location: Office Witteveen+Bos, Hoogoorddreef 15, 1101 BE Amsterdam

Register before 6 March 2025 by an email: info@dianausers.nl

19.00 Thermal shrinkage cracking in steel fibre reinforced underwater concrete floors; A probabilistic finite element approach

Dennis Slockers, Witteveen+Bos, Master Thesis TU Delft/ABT

An underwater concrete (UWC) floor is a common construction type in the Netherlands that is often applied to create building pits under the groundwater table. Usually, these (generally unreinforced) UWC floors only function as a watertight bottom layer of the building pit with only a temporary sealing function. Water tightness and crack prevention are very important aspects of this type of construction. A permanent reinforced structural top floor is frequently used on top of the temporary UWC floor to make a completely watertight construction, which is not the most sustainable and cost-efficient solution. Advances in concrete technology such as fibre-reinforced concrete have made it possible to integrate both the UWC and structural top floor or even use the UWC floor as the permanent structural floor. In these cases, the UWC floor should already function as a watertight barrier and controlling leakage by limiting the crack width becomes even more important. The addition of fibres to concrete may prevent through crack formation in the UWC slab and the possible consequent leakage. An important cause of cracking in UWC floors is thermal shrinkage during the cooling phase of the hardening reaction shortly after casting the UWC floor.

Currently, there are no guidelines for the construction of fibre-reinforced concrete (FRC) floors and the prevention or limitation of thermal shrinkage cracking. A CROW-committee ”Steel fibre reinforced underwater concrete (SFRUWC) floor as permanent structural floor” has been formed. This committee aims to set up a design recommendation and part of that is addressing the thermal shrinkage cracking problem. There is a lot of uncertainty in geometry, material properties and boundary conditions associated with SFRUWC floor design and construction. Because of this, there is a need for a probabilistic approach to investigate the influence of these uncertainties and tolerances on crack formation in SFRUWC floors during the hardening phase. This research aims to determine a suitable probabilistic method to investigate the failure probability of SFRUWC floors and the parameters that influence this.

In order to achieve this, a finite element model was developed that determines the shrinkage cracking behaviour in a part of a UWC floor in a building pit. Before this model could be developed, all the necessary input parameters and design equations were collected from literature and existing guidelines. To set up a model, first the behaviour of UWC floors was studied, followed by the development of a finite element model that includes the hardening behaviour and strength development of young concrete. An important aspect of this finite element model is the use of random fields to introduce spatial variation in the strength properties of the SFRUWC floor, which is a first step to include stochastic variation in the model for the probabilistic analysis. A probabilistic sensitivity study was performed with the finite element model by calculating multiple samples for each set of input parameters. Separate input parameters were varied and the influence on the results was investigated. The parameters that were considered, include the random field properties, material properties and thermal properties. Finally, a full Monte Carlo analysis was performed to give a proof of concept on how to calculate the failure probability regarding thermal shrinkage cracking in SFRUWC floors.

In order to prevent leaking cracks and satisfy the crack width criterion, the tension-hardening behaviour of FRC has to be utilised. Tension hardening behaviour will lead to a distributed cracking pattern, consisting of multiple small cracks which can satisfy the crack width criterion as opposed to a single large separation crack which does not satisfy the maximum allowable crack width criterion. It was found that the tensile behaviour of FRC and the use of random fields to model this tensile behaviour were major parameters that influenced the crack width and the occurrence of a distributed crack pattern. An important parameter is the standard deviation of the random field, which influences the difference between the maximum and minimum tensile strength in different locations in the slab. Looking at material behaviour, the main conclusion was that the introduction of a small hardening branch in the tensile material model was the governing influence factor. Both the standard deviation of the random field and the introduction of a hardening branch in the tensile behaviour affect the ratio between the tensile strength of the ordinary concrete and the residual tensile strength of the fibre-reinforced concrete. These two factors in combination with the model that was used, turned out to be dominating the results in such a way that the other input parameters only had a relatively small influence on the crack widths.

To determine maximum crack widths in SFRUWC floor it is essential to consider multiple samples with different random fields to find out if only a distributed crack pattern is possible or whether also single localised cracks can occur. The possibility of both these results being able to occur, leads to a large possible error in the maximum crack width. The results of this thesis have shown that the random field parameters remain uncertain and experimental research is needed to determine these correctly. Until then, it is important to investigate how significantly these parameters influence the results. It is recommended to extend this research by improving the model by making it more realistic and finding out if these two factors are still the dominating input parameters.

19.25 Discussion

19.30 Cloud-based DIANA simulations

Davide Moretti, TNO, Delft

19.55 Discussion

20.00 Quay Wall simulations, from 2D monotonic to 3D dynamic moving load

Francesco Messali, Department of Materials, Mechanics, Management & Design, Section of Applied Mechanics, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft

Historic masonry quay walls on timber pile foundations, originally designed as gravity retaining structures, now face increased stresses due to modern traffic loading. To assess their structural performance, a tiered finite element modelling approach is proposed, reducing computational demands while accurately simulating their structural response.

In Tier 1, the model computes how vehicular loads propagate through the soil to the structural system (wall and foundation). This output is then used in Tier 2, where a nonlinear 3D model of the masonry wall and the timber foundation is developed. The model incorporates boundary elements to efficiently account for soil-structure interaction.

This framework was applied to a case study of an existing Amsterdam quay wall, modelled in Diana (versions 10.5 to 10.9), evaluating structural safety, crack patterns, and failure modes under varying foundation degradation scenarios.

Additionally, four analysis procedures are proposed, ranging from 2D monotonic to 3D dynamic moving load simulations, to quantify the effects of 3D structural configuration and dynamic interactions on quay wall performance. The method captures load redistribution mechanisms, preventing overly conservative assessments that could lead to unnecessary interventions, and highlights the relevance of the foundation degradation on the ultimate capacity of quay walls.

20.25 Discussion

20.30 Recent DIANA implementations, Rocscience & future DIANA developments

Maziar Partovi, Laan van Waalhaven 462, 2497 GR The Hague, A Rocscience Company

20.55 Discussion

21.00 Closing, Refreshments

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DIANA
Users Association

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Vanaf NS-station Amsterdam Centraal of NS-station Duivendrecht neemt u de metro richting Gein. U stapt uit bij halte/station Bijlmer-Arena. U verlaat het station onderaan de trappen links en loopt direct linksaf langs het busstation richting de verkeerslichten. Steek vervolgens over bij de verkeerlichten en ga daarna rechtsaf. De eerste zijstraat (na P9/voor Adidas/Reebok-gebouw) gaat u links en loopt vervolgens met de weg mee naar rechts richting het Amerika-gebouw. U kunt zich melden bij de receptie van Witteveen+Bos op de tweede verdieping.

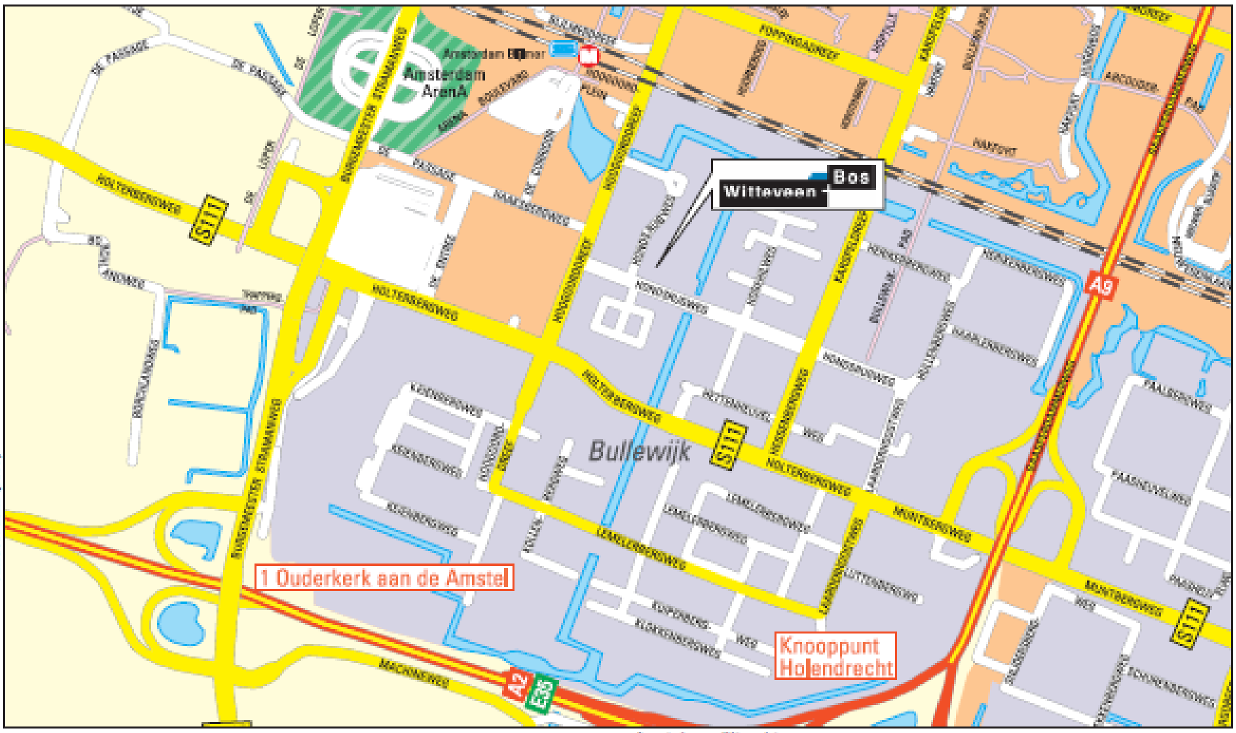
Vanaf NS-station Schiphol
Vanaf NS-station Schiphol neemt u de intercity richting Heerlen of Nijmegen. Zie verder 'Vanaf NS-station Amsterdam Centraal of NS-station Duivendrecht' vanaf 'U stapt uit bij halte/station Bijlmer-Arena'.

Vanuit de richting A2 (vanuit Utrecht/Amstelveen/Schiphol)
Vanaf de A2 neemt u de afslag naar de A9 richting Amersfoort en daarna meteen de eerste afslag S111 richting Amsterdam Zuidoost. Ga onderaan de afslag rechtsaf en rijdt rechtdoor richting Duivendrecht. Bij de vierde verkeerslichten slaat u rechtsaf. Bij de volgende verkeerslichten gaat u rechtdoor, vervolgens neemt u de eerste afslag rechts richting de parkeergarage Antartica (P9). De ingang van de parkeergarage Antartica (P9) bevindt zich aan uw linkerhand. Witteveen+Bos is gevestigd in het Amerika-gebouw. U kunt zich melden bij de receptie op de tweede verdieping.

Vanuit de richting A1 (vanuit Amersfoort/Almere)
Vanaf de A1 neemt u de afslag naar de A9 richting Amsterdam Zuidoost, Haarlem en Schiphol. Vanaf de A9 neemt u afslag S111 richting Amsterdam Zuidoost. Ga onderaan de afslag rechtsaf. U rijdt vervolgens rechtdoor richting Duivendrecht en gaat bij de derde verkeerslichten rechtsaf. Bij de volgende verkeerslichten gaat u rechtdoor, vervolgens neemt u de eerste afslag rechts richting de parkeergarage Antartica (P9). De ingang van de parkeergarage Antartica (P9) bevindt zich aan uw linkerhand. Witteveen+Bos is gevestigd in het Amerika-gebouw. U kunt zich melden bij de receptie op de tweede verdieping.

Fietsen
Fietsen kunnen achter het Amerika-gebouw in de daarvoor bestemde rekken worden gestald. U kunt via de achteringang het pand betreden.

Amersfoort/Almere



Amsterdam (A10)

Amstelveen/Utrecht