Master's Thesis Engineering Technology

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Modelling of the anchorage zone of prestressed concrete elements

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1. INTRODUCTION

Prestressed concrete beams can be used as bridge as depicted in Figure 1. Due to the prestressing of the horizontal strands, it is possible to achieve longer spans or a higher bearing capacity by using the materials more efficiently. The prestress force needs to be transferred from the prestress strands to the concrete in the anchorage zone. As a result of this stress distribution, vertical tensile stresses are induced in the anchorage zone which may lead to horizontal cracks as displayed in Figure 3. In order to counteract this cracking, vertical reinforcement is placed in this specific zone. Due to a lack of knowledge and techniques to efficiently calculate this reinforcement, a larger amount of reinforcement is placed than necessary.

At the moment, vertical reinforcement is calculated by using a numerical model with some simplifications. A geometric optimisation of the strut-and-tie model will achieve better placement and a smaller amount of reinforcement. Moreover, this research includes the translation from theory to practice by implementing prestress losses in the numerical model to achieve a realistic and safe result. Finally, the problem is considered solved if a model is achieved in which the crack formation is limited and the calculated amount of reinforcement has a realistic and minimal value.

2. METHOD

The anchorage zone is a disturbed region due to the application of the prestress load and due to the support reaction loads. The traditional beam theory from Bernoulli is not applicable. Therefore the use of a strut-and-tie model (STM) is required. To obtain a STM it is necessary to determine the complex flow of forces through a non-linear finite element analysis. This analysis shows the flow of forces based on vector plots as depicted in Figure 2. This vector plot gives a good approximation for the directions of the struts and ties. The locations of the nodes are dependent on the locations of the applied loads and boundaries. The vertical location of the nodes depend on the linear stress state at the transmission length. As can be seen in Figure 2, two struts depart from each node due the spreading of the prestress load. The horizontal locations of the nodes are determined by the transmission length.

Next, in a numerical model the forces in the struts and ties are determined based on the stiffness, the displacements and the imposed forces. The ties will represent the reinforcement, which will distribute the tensile stresses. The struts will represent the concrete, these will distribute the compressive stresses.

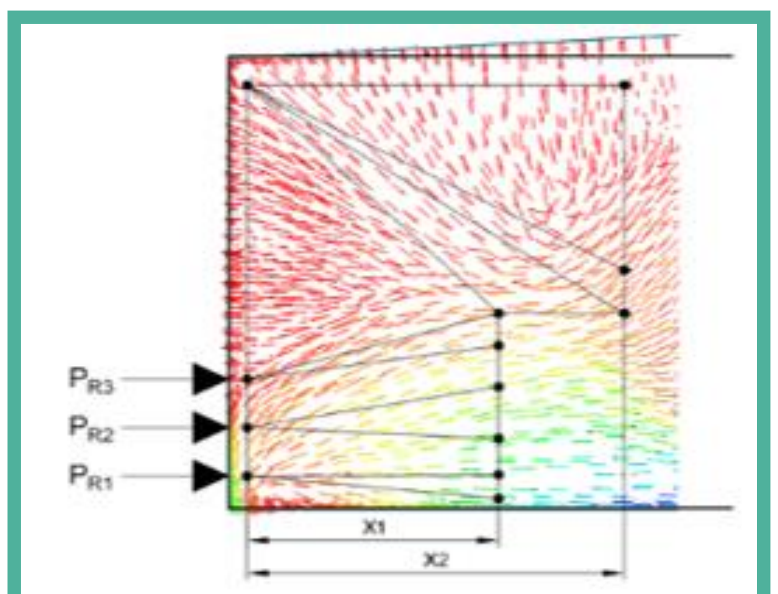

Figure 2: STM based on vector plot


Figure 1: Prestressed I-girder [1]


Figure 3: cracks at anchorage zone [2]

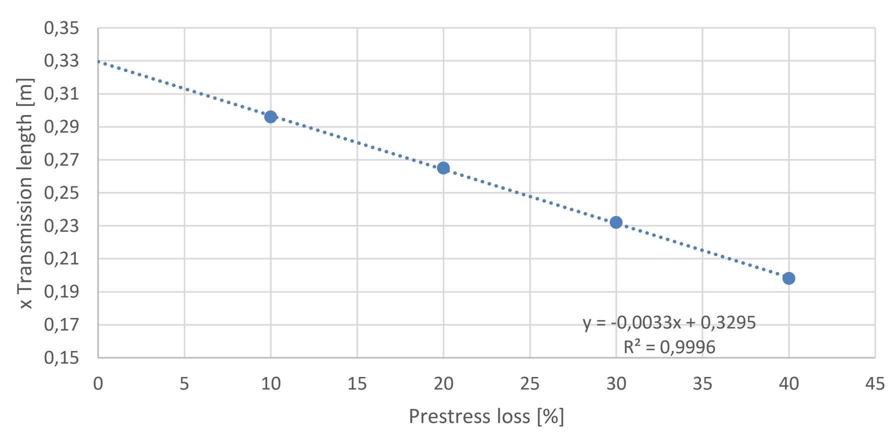

Figure 4: Correlation between the percentage prestress loss and the lever arm

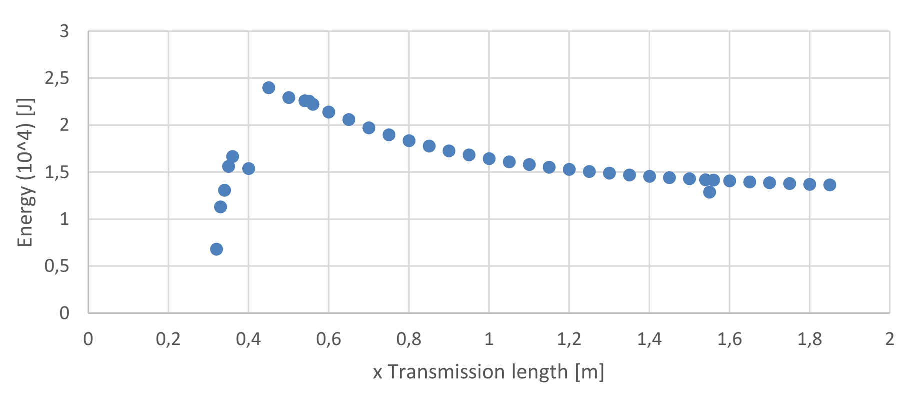

Figure 5: Energy of the STM in function of the transmission length with varying stiffness

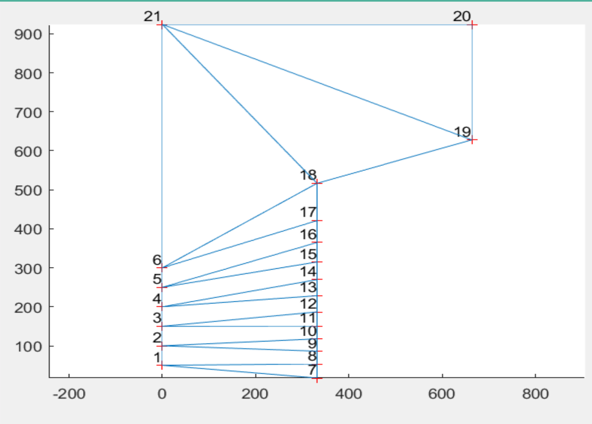
Figure 6: Proposal STM in this research

3. RESULTS

At first, all the different prestress losses relevant to this research are determined. The most important losses are the immediate losses that will occur right after the prestressing. This will be the elastic shortening of the concrete and the anchorage slip. In total an average prestress loss of 25% is achieved over time. The safety factor for prestressing which is unfavourable is 1,3 and is highly recommended.

Next, a correlation between the percentage prestress loss and the lever arm is found, as depicted in Figure 4. Now the same reinforcement can be calculated as before the prestress losses were taken into account, this will serve as a safety.

Another part of this research is the optimisation of the strut-and-tie model provided by R. Steensels. A first approach was to find an optimal value of the lever arm by measuring the total amount of energy of the model. The relation between the lever arm and the energy is depicted in Figure 5. An optimal lever arm of 0,32 times the transmission length has been found. Another approach was to redesign the geometry of the STM. The best proposal designed in this research is depicted in Figure 6. Unfortunately, a fully optimised model is not found.

Supervisors / Cosupervisors: ing. Rik Steensels

[1] Rafie, „What are the advantages of prestressed concrete over R.C.C?," Civil Engineer, 27 July 2017. [Online]. Available: https://th3civilengineer.blogspot.com/2017/07/what-are-advantages-of-prestressed.html. [Geopend May 2018].

[2] P. Okumus, „Sources of Crack Growth in Pretensioned Concrete-Bridge Girder Anchorage Zones after Detensioning," ASCE Library, 3 May 2016. [Online]. Available: https://ascelibrary.org/doi/full/10.1061/(ASCE)BE.1943-5592.0000928. [Geopend May 2018].

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