A laboratory investigation on bonding properties of dowels in concrete roads

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ABSTRACT

Inclined dowel bars and unmovable bars may cause pavement cracking in the vicinity to the bar ends. The aim of the investigation is to study if there are any differences in bonding properties due to dowel material, coating or diameter of the dowel. Steel dowels with different coatings and dowels made of composite material are tested. The maximum draw-out force for a draw-out travel of 1.5 mm is measured. The test is repeated four times and ends with a final cycle to establish the constant force needed for a draw-out travel of 5 mm. Steel dowels with bituminous coating show the lowest initial draw-out force. The draw-out force increased 2 to 3 times with a diameter increase of 50% for steel dowels with plastic coatings. For composite dowels the comparing result showed an increase of draw-out force 2 to 5 times with an increase in diameter with one third. The results from the repeating test for several cycles showed that the draw-out and push-back force were almost the same for all dowels. However, for the dowels with bituminous coating a higher push-back force was needed compared to the draw-out force. It should be noted that the testing speed could affect the results, especially for dowels with bitumen.

RÉSUMÉ

Des goujons d'assemblage inclinés ou inamovibles peuvent engendrer des fissures au voisinage de leur extrémité. L'objectif de cette étude est de déterminer si les propriétés d'adhésion dépendent du matériau utilisé pour le goujon, de son revêtement ou de son diamètre. Des goujons en acier avec différents revêtements ainsi que des goujons en matériau composite sont testés. La force maximale correspondant à une extraction de 1,5 mm est mesurée. Le test est répété quatre fois et est suivi d'un cycle final pour déterminer la force constante nécessaire à une extraction de 5 mm. La plus petite force initiale d'extraction est obtenue pour les goujons en acier avec un revêtement bitumineux. Pour les goujons en acier avec revêtement plastique, la force d'extraction augmente de deux à trois fois lorsque le diamètre augmente de 50%. Pour les goujons en composite, la force d'extraction augmente de deux à cinq fois lorsque le diamètre augmente d'un tiers. Les tests comportant plusieurs cycles ont montré que les forces d'extraction et de rétraction étaient pratiquement similaires pour tous les goujons. Cependant, pour les goujons avec revêtement bitumineux, la force de rétraction était supérieure à celle d'extraction. Il doit être noté que la vitesse avec laquelle les essais étaient réalisés pouvait affecter les résultats, particulièrement pour les goujons avec revêtement bitumineux.

1. INTRODUCTION

The plain jointed concrete pavement (PJCP) is the most common type of concrete road pavement in Sweden. In order to reduce tensile stresses, limit cracking and limit joint movements the pavement is jointed every 5 meter [1-3].

Traffic loads cause stresses in the slabs and for un-dowelled slabs the stresses are approximately twice as great at the slab edges as in the middle of the slab [3]. With dowels the edge stress is distributed between two adjacent slabs and the principal function of the dowels is to transfer the load from one slab to the other. Omitting dowels in joints will reduce the load bearing capacity and if water is penetrated into the joint a pumping action can occur between the concrete pavement and the sub-grade [1-3]. The results could be step formation between the slabs and/or cracks in the concrete slabs. Using dowels leads to a more durable pavement system and a reduction of the overall pavement deflection [4].

The dowels often consist of smooth steel bars with a length of 600 mm. Dowels used for roads usually have a

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diameter around 25 mm, but there exist smaller ones too, with a diameter of around 17 mm. The diameter of the dowel is selected with regard to the slab thickness, [2]. The dowels are placed at mid-thickness in the slab, spaced about 300 mm apart, and at right angle to each joint. The dowels can be placed in the concrete by insertion and vibration in the fresh concrete or above the sub-base in advance. Fig. 1 shows a principle figure of the dowel placement in the slabs.

To prevent bonding between the dowel and concrete and to protect the dowel against corrosion, a coating is used on the dowel [1]. It is important that the coating lasts on the dowel. If the coating is not working properly the dowel will get stuck in the concrete resulting in cracks in the middle of the slab or at the cross section where the dowel ends [1].

Steel dowels with coatings of epoxy, plastic (polyethene) or bitumen are the most common type of dowels used for road constructions. Today there also exist dowels made of composite materials. However, as far as the author knows, composite dowels have not been used in concrete roads, at least not in Sweden. One advantage with them is that they are solid, i.e., they have no coating that could fall off.

Eisenmann et al. [5] describe an investigation with the purpose of determining the draw-out forces for a draw-out travel of 0.5 mm. The draw-out test was repeated several times showing that some of the draw-out resistances varied widely with time. The coating must stay on the dowel in order to allow the dowel to be drawn out and pushed back several times without changing the resistance. According to [6], the test speed was 1 mm/minute (maximum displacement 5 mm). After draw-out, the dowels were pushed back with the same speed to its initial position and then the test was repeated. The aim of the joint is mainly to allow longitudinal translations due to shrinkage and thermal movements. The translation of concrete pavements is usually uni-directional both on an annual basis and a daily basis. During its service life, e.g. 40 years, the concrete pavement may be exposed to more than ten thousand 24-hour thermal cycles. Hence, the demand of the dowel is high. Eisenmann’s test included steel dowels with coatings of bituminous and plastic films and with variation in dowel diameter. In the study it was stated: “an ideal coating should have the lowest possible initial draw-out resistance and this value should not increase in further draw-out tests”. Fig. 2 shows the results from Eisenmann’s test.

The effect of sloping or misfit of dowels has been studied in [4, 7]. In [7], steel dowels of length 500 mm and diameter 26 mm were tested with a slope variation from 0 to 40 mm. The dowels were coated with bitumen and RILSAN, with coating thickness 0.06 mm and 0.30 mm, respectively. The results show that plastic coated dowels can be installed at greater angles than those with bitumen. For plastic dowels, the maximum slope can be up to 20 mm and for bitumen, 10 mm, referred to a dowel length of 500 mm. Eom et al. [4] confirm that the misfit of dowels can affect the performance of the dowels in the concrete slabs negatively.

Several finite element studies of the load transfer of dowels in concrete pavements have been performed, see for example [4, 8, 9].

A literature review shows that dowels have been used for load transfer since the beginning of 1900. A thorough overview of the most relevant work regarding dowels in concrete slabs is presented in [9].

A laboratory investigation has been performed at the Swedish Cement and Concrete Research Institute (CBI) in Stockholm regarding bonding properties of dowels. The background to the study is experiences of two 70-year-old concrete road pavements in Sweden. These roads were repaired a couple of years ago and between old slabs and new...