Research on Transverse Cracks in Continuously Reinforced Concrete Pavements Using Fiber Reinforced Polymer Bars

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***Abstract*—In order to further understand those transverse cracks in continuously reinforced concrete pavements(CRCP) using fiber reinforced polymer bars, the CRCP transverse crack spacing and width is investigated, to explore the influence of the transverse crack spacing and the width of the transverse crack on the pavement and the impacts of the tensile strength of concrete, dry shrinkage, temperature shrinkage and FRP reinforcement on the transverse cracks. The transverse crack of continuous reinforced concrete pavement is analyzed by simulation calculation model, optimization design of CRCP reinforcement to control the spacing and width of the transverse crack. Research shows that the concrete and the performance of FRP reinforcement has a certain influence on transverse cracks, the appropriate reinforcement ratio is helpful to control CRCP transverse cracks.**

Keywords-FRP bars; CRCP; transverse cracks; crack spacing; crack width

I. INTRODUCTION

The steel bar of Continuously Reinforced Concrete Pavement(CRCP) is set in the vertical. However CRCP using fiber reinforced polymer bars adopts polymeric fiber to replace common steel bars. CRCP using FRP improves the performance of the road, ensure the driving safety and prolongs the service life of pavement without transverse expansion crack and shrinkage crack. Roger H.L. Chen and JeongHoon Choi [1] have proposed that GFRP could reduce the inner temperature of concrete pavement and slow down corrosion of steel bars. The common failure modes of Continuously Reinforced Concrete pavement are transverse cracks and thrust damage, etc. Jian-ping Wei et al. [2] have analyzed the disease of Leiyang-yizhang highway and Changsha-changde highway's Continuously Reinforced Concrete Pavement and proposed that the main crack diseases of Continuously Reinforced Concrete Pavement are transverse cracks and longitudinal cracks.

II. EFFECT OF TRANSVERSE CRACKS ON THE PERFORMANCE OF CRCP

A. Transverse Crack Spacing

Transverse crack spacing is the one of important indexes which effect the performance of CRCP and failure of many pavements are related with crack spacing closely. Xiao-feng Jia [3] proposed that the study of crack distribution of CRCP can't simple evaluated by average crack and narrow spacing and wide crack should be taken seriously.

When transverse crack spacing of CRCP is relatively large, because of the effect of base friction, the CRCP plate can produce very big tensile stress and pass to the steel bars in the plate. As a result, steel bars in the cracks bear very big tensile stress and it also accelerates the cracking of concrete at the crack. When transverse crack spacing of CRCP is relatively small, CRCP in the cracks is prone to occur the thrust failure of road panel. Appropriate horizontal crack spacing can reduce friction and transverse crack width. So the distance between the horizontal cracks has significant impact on stress of steel bar and width of crack.

Xiao Zhang and Sheng Hu et al. [4] have study the characteristic of transverse crack of CRCP. He described 6 kinds of forms of transverse crack and point out that there is no significant difference in the crack spacing of CRCP with the same ratio of steel bars and different thickness of plate.

B. Width of Transverse Crack

When the width of transverse crack is relatively large, the lost of the pavement load leads to low load capacity. Vehicle load can increase the transverse stress of concrete plate. Repeated axle load increases the fatigue of concrete plate. After accumulation of repeated fatigue exceeds fatigue strength, the concrete in cracks can peel off and CRCP can crack longitudinally. The width of the transverse crack is mainly influenced by the crack spacing, it increases with increasing of the transverse crack. To common CRCP, because of the large transverse crack, wide transverse cracks lead to the corrosion of ordinary steel. However, CRCP using FRP bars can avoid corrosion of steel bar effectively.

Yun-he Chen and Xue-jun Deng et al. [5] have deeply analyzed early cracking process of CRCP, established a simple calculation model and match theoretical analysis and engineering measurement. They proposed that steel bar ratio is the main factor which affects the width of the crack, and the thickness of pavement don't have obvious impact on the width of the crack.

III. TRANSVERSE FRACTURE ANALYSIS OF CRCP

The shrinkage deformation of concrete was constrained by reinforcement. So the crack dispersed in more parts. Usually, there is a tiny crack in every 1.5-4.0m of CRCP. However, due to the role of reinforcement, it remains in close contact. The tiny cracks will not undermine the overall continuity of the road and driving stability. The rain also not easy to enter and the effect of using continuous reinforced concrete pavement is ideal.

Transverse cracks mainly appeared in early. For early transverse cracks of continuously reinforced concrete pavement, the non-load stress is the main factors. Such as temperature stress and shrinkage stress [6]. The tensile stress caused by temperature changes and shrinkage will be released due to the formation of transverse cracks. If the crack spacing is not appropriate will affect the performance of pavement. Most diseases caused by irregular crack and crack spacing are too short or too long.

A. The Influence of Concrete Properties on the Transverse Cracks

1) Tensile strength of concrete: Concrete material is a brittle material, its tensile strength is much lower than the compressive strength, ultimate tensile deformation is much lower than the ultimate compressive deformation [7]. Concrete material has a high compressive strength of the concrete. The tensile strength of concrete is low, so in the construction and operation period cracks of CRCP will be generated easily under the role of external force and temperature variations.

2) Drying shrinkage of concrete: Dry shrinkage can lead to the development of cracks and the decrease of the load carrying capacity. In the process of concrete drying, the dry shrinkage of the concrete will increase with time. And if it is wet, the dry shrinkage of the concrete will be reduced, but the shrinkage of the dry period can’t be reduced. The relative humidity of the surrounding environment is the main factor that undermine dry shrinkage of partial pavement. The size of dry shrinkage is related to many factors, including the volume of water, the type and content of the aggregate, the type of cement, the relative humidity and temperature of the environment.

3) Temperature shrinkage of concrete: For concrete structure, the volume of concrete will change with the change of environment temperature, so the temperature shrinkage caused by the outside temperature is also the main reason for the transverse cracking of concrete pavement. The aggregate has a great influence on the temperature shrinkage coefficient of concrete, especially the effect of silicon content in aggregate significantly. After the concrete is poured, under the influence of the external environment condition and the various factors of itself, the panel produces a large temperature shrink stress. In the early time, the tensile strength of concrete is low. When the external concrete’s tensile stress exceeds the tensile strength of concrete at that time, the concrete pavement will produce transverse cracks. Any difference of decreased temperature can be divided into uniform temperature drop and non-uniform temperature difference. The former is mainly caused by the cracks in the pavement. The latter is mainly caused by the surface cracks.

B. The Influence of Performance of FRP Bars on Transverse Crack

The tensile strength of FRP bars is 2-10 times as large as regular reinforcement, but weight is only about a quarter of reinforced. Using FRP reinforcement in concrete pavement can reduce the weight of CRCP and improve the efficiency of construction, so reduce the inherent load of the subgrade from the road surface and improve the bearing capacity of the pavement on the extent. The stress-strain relationship in the process of tensile FRP bars is growth in linear elastic. The strain is very small in the FRP bar when it reach the ultimate strength and the stress-strain relationship curve without apparent yield platform. With increasing temperature of concrete slab, FRP fiber can generate the additional stress of the crack, reduce the width of expansion joint and construction joint and improve pavement quality.

IV. ANALYZING THE CALCULATION MODEL OF CRCP

Yi-ming Tang [8] research the basic theory and design method of CRCP and discuss the standard of controlling crack spacing and width. Using three dimensional finite element analysis method to study the stress of CRCP and establishing a crack spring model to simulate the load transfer function of the longitudinal reinforcement in the crack position.

According to the stress-strain relationship of bond slip between materials, Chang-shun Hu et al. [9] from Chang’an University in China obtain the calculation model of CRCP and the stress equilibrium differential equation, establishing expressions of displacement and stress of concrete and steel bars under the condition of warping deformation, temperature drop and dry shrinkage of CRCP.

V. THE DESIGN AND RESEARCH OF FRP-CRCP

Jianhe Zhu and qiang Chen [10] analyze the reinforcement of the continuously reinforced concrete pavements using basalt fiber reinforced polymer bars, to investigate the influence of different reinforcement ratio and diameter on the crack width and the stress of CRCP, the design idea of “small diameter reinforced material and small space setting” is put forward.

With the increase of reinforcement ratio, the crack width decreases, the concrete stress increases and the stress decreases. Under the same condition, the stress and displacement of CRCP are also affected by different reinforcement modes, which makes the reinforcement have a larger holding area because of the small diameter and small spacing.

VI. CONCLUSION

FRP reinforced concrete pavement will generate random transverse cracks under the action of cooling and drying. Some FRP bars and concrete have good performance of the bond stress. The performance of concrete and FRP bars has a certain effect on the transverse crack. The design method of “small diameter reinforced material, small spacing setting” is used, the ratio of reinforcement is increasing, the width of the crack is reduced. Therefore, it is also need to speed up the pace of research, improve the design and construction theory and methods, and thus effectively control the transverse cracks.

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