論文 / 著書情報
Article / Book Information

題目(和文)	拡幅されたプレストレストコンクリート（PC）床版の破壊メカニズム
Title(English)	Failure Mechanisms of Widening Prestressed Concrete Deck Slabs with External Prestressing
著者(和文)	Fakhruddin
Author(English)	Fakhruddin
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第10480号, 授与年月日:2017年3月26日, 学位の種別:課程博士, 審査員:二羽 淳一郎,岩波 光保,竹村 次朗,千々和 伸浩,佐々木 栄一
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第10480号, Conferred date:2017/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Title :

Failure Mechanisms of Widening Prestressed Concrete Deck Slabs with External Prestressing

Thesis Outline:

The new prestressed concrete (PC) box girder widening technique has been developed by some researchers in Japan. In contrast to the conventional widening technique, the new technique has the potential to speed up the construction and reduce the cost. This is because the existing PC tendons need not be extended to the new deck slab and the precast members are used. Although this new technique has considerable merit, several investigations must be conducted for the proposal of the new widening technique. Therefore, two basic tests were carried out in this study, which consisted of the shear strength test of the interface between the old and new deck slabs, and the PC deck slab test subjected to a concentrated load. The thesis consists of 7 chapters. The contents of this thesis are organized as follows.

Chapter 1 introduces the background of the PC box girder widening technique. Subsequently, the aims and methodology of this study are shortly described. Some highway bridges worldwide become functionally obsolete due to inadequate width before they become structurally deficient. The existing width of the old bridge has been unable to meet the demand of increasing traffic flow. If the original old bridge is in service, widening may be an attractive option. The new PC box girder bridge widening technique has been developed by some researchers in Japan. This new technique can potentially reduce the cost and improve the speed of construction of bridges. However, for the proposal of the widening technique, several investigations must be conducted. Therefore, the major objective of this research is to perform the basic tests for the proposal of the new PC box girder bridge widening technique. Eventually, the results

obtained from this research will be considered for the proposal of the new widening technique and for the application in the real structure.

Chapter 2 reviews the existing literature concerning the failure behavior of concrete-to-concrete interface and the failure behavior of two-way deck slabs. The research works related to these two failure behaviors are also presented. Prediction equations for the shear carrying capacity of concrete-to-concrete interface are also listed in this chapter.

In **Chapter 3**, the experimental program of the shear behavior of the interface between the old and new deck slabs is described. The experiment of nine specimens belonging to four series was conducted under a direct shear test, to investigate the effects of the initial prestressing level, the connection between steel bars, the reinforcement ratio at the interface, and the surface roughness of the interface. The details of the specimens including the material properties, dimensions, and arrangement of steel bars are detailed. After that, the procedures of the fabrication, loading method, and instrumentation are explained. Finally, the experimental results of each series are presented. In order to clarify the effects of each parameter on the behavior of the interface, the crack pattern, the load-joint opening, the load-displacement, the strains increment in the prestressing rod, and the shear capacity of the interface are investigated. It is found that the shear behavior of the interface was greatly affected by the initial prestressing level, the reinforcement ratio at the interface and the surface roughness of the interface. In addition, by increasing the initial prestressing level, the shear capacity of the interface increased. However, the increasing ratio of the shear capacity was not proportional to the initial prestressing level. More positive influences of the prestressing level were obtained when the initial prestressing level enhanced from 0.5 to 1.0 MPa as compared to the increase in from 1.0 MPa to 2.0 MPa. In contrast to previous studies, the results in this study indicated that greater reinforcement ratio could decrease the shear capacity. This is caused by the decrease in the opening of the joint, which further reduced the contribution of the prestressing force acting perpendicularly to the interface. In addition,

the surface roughness of the interface has a remarkable influence on the behavior of the interface, where the shear capacity extremely decreased as the surface roughness of the interface changed from rough to smooth surface.

Based on the experimental results in Chapter 3, the failure mechanism of the interface between the old and new deck slabs is presented in **Chapter 4**. The factors affecting the failure mechanism of the interface are discussed based on the experimental outcomes. In addition, the calculation based on the equations in the recent design guidelines is also presented. The results indicated that the main contribution on the shear resistance of the interface comes from the interlocking force, frictional force and dowel action. For reinforced rough interface, the interlocking force and frictional force are the most important influencing factors on the shear resisting mechanism of the interface. On the other hand, the dowel action predominates in reinforced smooth interface. Moreover, by comparing the experimental shear capacity with the recent design guidelines, it can be stated that all the guidelines are conservative for all specimens in this study, except for the specimen with the reinforcement ratio of 1.01%. For the reinforcement ratio of 1.01%, the accuracy of the some guidelines increased.

Chapter 5 presents the details of the experiment of widening prestressed concrete deck slabs under concentrated load. The dimensions of all the specimens and the material properties are shown first together with the consideration for each series specimens. Next, the procedures of fabrication, instrumentations and test setup are explained as well. Finally, the experimental results of each series are presented in this chapter. By comparing the crack pattern, load-joint opening, load-displacement, strains of rebars, prestressing rods and concrete, and the ultimate capacity of test slabs in each series, the effects of each parameter on behavior of widening prestressed concrete deck slabs are investigated. It is found that the ultimate capacity increased with increasing the initial prestressing level and the concrete strength of the new deck slab. On contrary, the variation of surface roughness at the interface has no remarkable influence on the

ultimate capacity, as long as the prestressing force is sufficiently introduced to the interface.

Based on the experimental results in Chapter 5, the shear resisting mechanism of the widening prestressed concrete deck slabs under a concentrated load are presented in **Chapter 6**. The investigation on the failure mode is explained in this chapter based on the crack pattern and the measured strains in longitudinal and transverse rebars. In addition, the nonlinear FEM analysis was carried out to investigate the effects of each parameter in this study on the behavior of widening PC deck slabs such as the joint opening, the failure mode and the principal strain flow. The details of the material model and the interface model used in FEM analysis are also introduced in this chapter. Based on the experiment and FEM analysis, it has been confirmed that all the PC deck slabs in this study failed in a brittle manner when the shear cracks developed at the interface between the old and new deck slabs. Therefore, the experimental shear capacities were compared with predicted shear capacities obtained from the existing design guidelines. However, for the slabs subjected to a concentrated load, the shear capacity of the interface should not be calculated over the entire area of the interface (A_c) but over a certain effective area of the interface (A_{eff}). Therefore, the effective area of the interface was proposed in this study. Furthermore, by using the value of the effective area instead of the total area of the interface, it has been confirmed that predicted shear capacities obtained from the existing design guidelines provided a good lower limit for the experimental ultimate capacities.

Finally, the conclusions of the study and the recommendations for the future research are given in **Chapter 7**.