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Parametrical static analysis on group studs with typical push-out tests

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ABSTRACT

Group studs are known as shear connectors in steel and concrete composite structures. By now, many composite bridges have been characterized by long lateral cantilevers. The shear studs are actually under biaxial action consisting of shear force and action in light of lateral bending moment on concrete slab induced by long cantilever and passing by moving loads. Moreover, lateral bending moment may even lead to the initiation of bending-induced concrete cracks. These two situations can both affect mechanical performance of group studs. Thus, a parametrical FEM analysis was carried out, in which damage plasticity was introduced to simulate material nonlinear behavior. In the analysis, lateral bending moments respectively inducing maximum concrete crack widths of 0.1 mm and 0.2 mm, shank diameters of 13 mm, 16 mm, 19 mm and 22 mm and stud heights including 80 mm and 100 mm were parameters. It was found that mechanical behavior of group studs with large shank diameter would be less affected by biaxial action and initial bending-induced concrete cracks seemed unfavorable to stud shear stiffness. On the other hand, typical push-out tests were executed to investigate reductions of shear stiffness and shear capacity of group studs. The reliability of FEM analysis was also verified based on the tests. In addition, stud shear capacity evaluations according to several design specifications were presented. It indicated shear capacity evaluation of Eurocode 4 got a relatively large safety factor. Moreover, the applicability of these specifications for group studs on shear capacity evaluation was also discussed.

1. Introduction

In recent decades, steel and concrete composite girders have been widely constructed in many structures. Shear stud has been used as shear connector of steel and concrete in composite girders for over 50 years for its economical advantage. Since a growing application of prestress technique has been found in composite girders while arranging shear studs along the entire steel flanges, which can be referred as normally arranged studs, seemed unfavorable to it, arranging shear studs in groups, referred as group studs, was proposed. It makes prefabrication of prestressed concrete slab feasible. On the other hand, interlayer splitting phenomenon and reductions of shear stiffness and strength are the typical drawbacks of group studs.

By now, literatures [1–9] on the mechanical behavior of shear stud can be categorized into fatigue and static aspects in general, which reveals that parameters such as stud dimensional and material properties, reinforcement ratio, concrete compressive strength, loading history, etc are decisive factors. As to static behavior, D.J. Oehelers derived the static load–slip curve by executing push-out tests comprising of 53 push-out specimens with 13 mm, 19 mm and 22 mm shank diameter studs and found that studs embedded in strong concrete were stiffer than those in weaker concrete, etc [1]. Moreover, 25 push-out specimens were also tested to reflect that stud shear strength can be affected by the stiffness of transverse reinforcement in presence of longitudinally cracked concrete slabs [2]. C.S. Shim executed an experiment focusing on mechanical behavior of large stud and showed its shear stiffness was larger than that derived from empirical equations for normal studs [6–7]. J. Okada exhibited a parametrical study on shear strength in which stud arrangement and concrete strength were mainly concerned, and provided a strength evaluation equation for group studs [8]. Regarding fatigue behavior, D.J. Oehlers parametrically studied shear strength reduction of studs because of a cyclic loading [1]. R.P. Johnson statistically analyzed the existed research and experimental data and accordingly provided a recommendation on the exponent m in the usual expression for the fatigue endurance [3]. G. Hanswille also executed an analogous parametrical study [4–5]. R. Seracino carried out a bi-directional cyclic test on shear studs [9].

Nowadays, many composite bridges are characterized by long lateral cantilevers. The lateral bending moment on concrete slab caused by dead loads of cantilevers and passing by vehicle loads may become influential to mechanical status of group studs. Combined with longitudinal interlayer shear forces, the load action imposed on group studs becomes biaxial action. Moreover, initial bending-induced concrete cracks resulted by lateral bending moment may also affect the mechanical performance of group studs. Luis Pallares compared provisions concerning combination effects of shear and tension in different specifications and handbooks

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