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HOGGING MOMENT OF STEEL-CONCRETE COMPOSITE CONSIDERING DEFORMABLE SHEAR CONNECTION

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Abstract: The present study investigated the effects of shear slip on the deformation of steel–concrete composite beams. Limited experimental results have been reported in the literature on the fatigue and ultimate static loading behavior of composite beams subjected to negative bending moment. This paper examines experimentally the behavior of composite steel-concrete beams. The behavior of steel-concrete composite beams is strongly influenced by the type of shear connection between the steel beam and the concrete slab. For accurate analytical predictions, the structural model must account for the interlayer slip between these two components.

Keywords: Steel-concrete Composite; Shear Connection; Hogging Moment

1. Introduction

Taking advantage of the high tensile strength of steel materials and high compressive strength of concrete materials.Much existing research has been carried out to determine the positive moment capacity of the composite beams.The behavior of composite beams,made of two components connected through shear connectors to form an interacting unit,is significantly influenced by the type of connection between the steel beam and the concrete slab.

Over the past several decades,the composite action between steel and concrete depends on the performance of shear connectors at their interface.The number of connectors which assures no loss of ultimate flexural strength can be evaluated on the basis of the ultimate limit state.

Compared to common monolithic beams, composite beams with deformable shear connection present additional difficulties. Even in very simple structural systems (e.g., simply supported beams), complex distributions of the interface slip and force can develop; furthermore, these distributions of the interface slip and force can develop; furthermore, these distribution can be very sensitive to the shear connection properties. Different finite elements representing composite beams with deformable shear connection have been proposed in the literature. Despite the difficulties encountered in the nonlinear range of structural behavior, locking-free displacement-based elements (such as the one used in this study) produce accurate global and local results provied that the structure is properly discretized. Locking-free displacement-based elements were used successful for accurate analysis of steel-concrete composite beam structures even in the case of very high gradients of the interface slip due,for example,to horizontal concentrated forces produced by external by external prestressing cables.

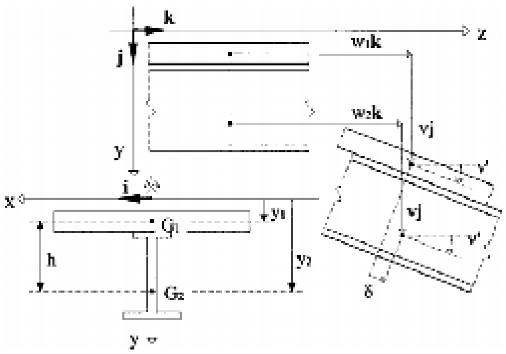

Figure 1. Kinematics of two-dimensional composite beam model

2. Strain of Shear Connectors

Although some of the studies discussed previously have provided preliminary information on the static and fatigue behavior of composite structures, most of them were generated and analyzed from the push-out tests. The specimens were small and had a lim-ited number of shear connectors, and the tests were essentially pure shear tests (Yen et al. 1997). In real-life structures, the composite beams also are subjected to bending moments and transverse shear forces, and the specimens contain a much greater number of shear connectors. The stress field in the concrete slab and the interaction between the shear studs and the concrete slab are quite different. For these reasons, further studies are needed on the problems involving shear studs–concrete interaction and formation, as well as propagation of the cracks and the fatigue phenomenon of concrete slabs, particularly the experimental results of full-scale or semi-full-scale flexural members.

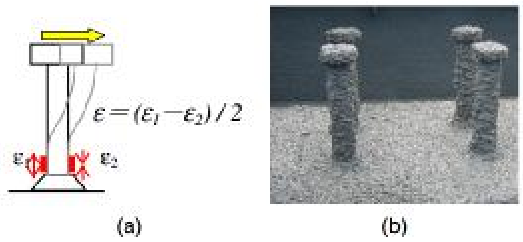

Figure 2. Rubber-latex mortar sprayed on the shear stud:(a)strain of stud; (b)rubber-latex mortar on stud

3. Effect of Shear Connectors

The results in this paper indicate that PBL specimens have relative large beam stiffness and ultimate load-carrying capacity, but a rel-atively small amount of slip on the steel-concrete interface. As a concrete slab cracks, the composite neutral axis moves away from the PBL plates, resulting in PBL plates being more effective at maintaining beam rigidity and loading capacity than stud shear connectors. The interaction among the PBL connectors, the reinforcing bars (transverse bars go through the holes of the PBL), and the concrete restricts interface slip. In addition, the results indicate that the stud specimens exhibit better mechanical behavior than PBLs with regard to the initial cracking of the concrete slab. But all in all, both PBLs and stud connectors are effective shear connective devices for composite beams subjected to a negative bending moment.

4. Conclusion

This paper focuses on materially nonlinearlly-only analytical response sensitivity analsis, using displacement-based finite elements in conjunction with the direct differentiation method,of composite beams with deformable shear connection under quasi-static monotonic and cyclic loading conditions. Realistic uniaxial constitutive models are used for the steel and concrete materials as well as for the shear connection. The concrete and shear connection material models as well as the static condensation procedure at the element level are extended for response sensitivity computations using the direct differentiation method. Two benchmark problem that have been the object of experimental texting are used to illustrate the proposed methodlogy for response sensitivity analysis. The first benchmark problem consists of a two-span asymmetric continous beam subjected to mononic loading with a concentrated force. The second benchmark problem consists of a frame subassemblage subjected to qusi-static cyclic loading. The response sensitivity analysis results obtained according to the direct differentition method are validated by means of forward finite difference analysis. Selected results of response sensitivity analysis are presented in an effort to quantify the effect and relative importance of various material constitutive model parameters in regards to the nonlinear quasi-static monotonic and cyclic response of a tested steel-concrete composite beam. Using the benchmark problem considered,it isalso shown that use of an inadequate convergence tolerance in the nonlinear finite element response calculation may introduce numerical errors in response sensitivity analysis results obtained using both the direct differentition method and forward finite difference analysis.

Eight steel-concrete composite beams were tested to study the mechanical behavior under a negative bending moment. The ex-perimental program was developed to study various aspects of composite beams, including SFRC, shear connectors, rubber-latex mortar coating, fatigue, and static loading tests. Deflections, load-ing capacity, crack width, and slip between the concrete slab and steel beam due to the applied loads were measured during the tests, and the effects of SFRC, shear connectors, and rubber-latex mortar on the mechanical behavior of composite beams subjected to a hogging moment were investigated. Based on the fatigue test results, it seems when the repeated load is smaller than the initial cracking load of the composite beams, no special consideration is necessary. But if the repeated load is equivalent to the stabilized cracking load, the fatigue load-ing may affect the behavior of the shear connectors significantly. The bond on the steel-slab interface will be broken, and the beam rigidity and the load-carrying capacity of the composite beam were about 5% smaller than those of the specimen without fatigue loading.

Based on the static test results, the experimental ultimate load-ing capacity of test specimens was 20–30% larger than flexural action capacity calculated via a conventional plastic moment, as shown in Table3. The current AASHTO LRFD criterion provides typically conservative values in calculating loading capacity for composite beams subjected to a hogging moment. The present experimental results suggested that PBL connectors could increase the beam rigidity and the ultimate loading capacity, while composite beams with studs as shear connectors have relatively high initial cracking loads, and no other obvious differences were observed. Also, the crack control effects of SFRC on slab and adhesion bonding effects of rubber latex on steel-slab interface were confirmed in the test. In addition, the effects of SFRC on the ultimate loading capacity of the composite beam were depen-dent shear connectors, and the application of SFRC would enhance the loading capacity of stud specimens, but no obvious effects can be observed for PBL specimens.

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