Study on the influence of step changed spacing of shear stud connector on the behavior of continuous composite beams

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Abstract: In practice, in the steel-concrete composite continuous beam, the shear stud connectors with step changed spacing are often used: How are the slip, deflection and the shear stud connector forces influenced by the step changed spacing of studs connectors? For this question, it will be discussed in the text.

1. Introduction
In order to analyze the influence of spacing step changed studs connector on the behavior of continuous composite beams, two kind of shear stud connector spacing are assumed, which can be seen in the Fig.2. For example, in areas near the end support of the beam it adopts a e1 spacing, while in the area near the central support the e2(=2e1) spacing. At the same time, it has three conditions, under each there is a different stud connector stiffness, and the conditions will be separated by numbers from 1 to 3. To analyze the structure models by ANSYS, the element solid65 is used to simulate the concrete, combin39 to simulate studs and plane 42 to simulate the steel beam, meanwhile, it is assumed that the analysis is linear. At last, the result under the third condition will be compared with the result of the uniform spacing of stud connectors.

2. Study on the shear stud connectors with step changed spacing
In Fig.1 there are parameters for cross section, elasticity modulus, Poisson’s ration of the beam. In Fig.2, there are structure model, graphs of the results. The step changed spacing means that there are two kind of stud connector spacing in the beam. One is e1(100mm) which refers to the spacing in both side area and the central area of the beam, another is e2(200mm) in the left area. Both span of the beam are the same. The number of the curves in the graphs means that their shear stud connectors have different stiffness. For instance, K1 means that the curve is under the condition of stud connector stiffness K1(1.5x10⁵N/mm). So it is the same to K2(=3K1) and K3(=9K1).
Fig. 1 parameters of cross section and materials

- Stud connector force [KN]
- Slip [mm]
- Deflection [mm]
- X [m]
- Y [m]
- Z [m]

Fig. 2 slip, stud connector shear forces and deflection graphs of the step changed spacing

- $E_c = 3.0 \times 10^5$ N/mm$^2$
- $E_s = 2.1 \times 10^5$ N/mm$^2$
- Poisson ratio of concrete = 0.2
- Poisson ratio of steel = 0.3
The results in Fig. 2 show that a sudden change in the stud connector shear forces occurs at the transition points of the stud connector spacing, especially when the stiffness of the stud connector is high. But the extent of the sudden change is different. In the area near the middle support, it falls much more strongly than in the area near the end support, for the slip there is also correspondingly larger. Although the stud connectors at the transition points of the stud connector spacing are fundamentally more heavily stressed, the transition points around the middle support according to the present example are more critical. This should also be taken into account in the practical design. In contrast to the stud connector shear forces, the sudden change of the slip at the transition points is relatively small. In addition, it also indicates that the maximum of the slip and stud connector shear forces happen in one fixed point near the transition points around the central support. The slip curves and stud connector shear forces curves under different stud connector stiffness all intersect in one point in the c2 spacing areas. It is obvious that the higher the stiffness of the stud connectors, the less of the deflection value.

3. **Compare between the step changed spacing and the uniform spacing of shear stud connector**

In order to compare the influence of the spacing step changed stud connectors with the equidistant spacing of stud connector which have a stud connector spacing of 400/3mm, the stud connector shear forces, the slip and the deflection for the two cases are compared with the stud connector stiffness K3(9*1.5x105N/mm) in Figure.3. The K3 refers to the condition that the stud connector stiffness is K3.
Fig. 3 shows that in the areas that have a $e_1$ spacing of stud connector the slip and stud connector shear forces value in the case of the step changed spacing of the stud connector are smaller than that in the case of the uniform spacing of stud connector. However, in the areas which have a spacing of $e_2$, the former has a larger value than the later. We can also find that the amount of the part which the former exceeds the later is almost equal to the amount of the part which the former is less than the later. This also means that the sum of the stud connector shear forces and slip in the composite joint remains nearly the same for both cases, and only the distribution of the stud connector shear forces and slip is different. In terms of the deflection, the step changed spacing of stud connector has little difference from the uniform spacing of stud connector.

4. Conclusions
Through the analysis of step changed spacing of stud connector in the steel-concrete composite continuous beam and the compare with the uniform spacing of stud connector it can be seen that:

[1] A sudden change in the stud connector forces occurs at the transition points of the spacing of the stud connectors, especially when the stiffness of the stud connectors is high, and the change at the transition points near the center support is more intense than that near the end support, while the change for the slip is rather small.

[2] Under different stud connector stiffness, in the step changed spacing of stud connectors the maximum of the slip and stud connector shear forces happen in one fixed point near the transition points which is closer to the central support, and both the slip curves and the stud connector shear forces curves intersect in one point in the areas which have a $e_2$ spacing.

[3] The sum of the stud connector shear forces and slip in the composite joint remains nearly the same for both the step changed spacing of stud connectors and the uniform spacing of stud connectors, and only the distribution of the stud connector shear forces and slip is different.

[4] In terms of the deflection, the step changed spacing of stud connectors has little difference from the uniform spacing of stud connectors.

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