Influence of Different Shank Distribution on Slip in Composite Beams

Bin DUAN¹, Dong Hua ZHOU² Yong LUO²
¹ Faculty of Architectural Engineering, Kunming University of Science and Technology, Kunming, Yunnan 65000, China
² Faculty of Architectural Engineering, Kunming University of Science and Technology, Kunming, Yunnan 65000, China
Email: 1176780666@qq.com

Abstract: The beam model is modeled by simple beam analysis model. The finite element software ANSYS was used to analyze the model, and the two sets of models were not considered, and the shear deformation of the concrete and the steel was not taken into account. The model-one composite beam connection was adopted in the uniform arrangement of the model. The method of arrangement, comparing the results of the two groups, the value of the interface slip can be seen in the model two, due to the uniform arrangement of the way, the interface slip value is significantly reduced.

1. Introduction
In general, the shear connections at the interface of the composite beam are elastic shear connections, i.e., there are slippage on the interface or large or small, the absolute rigid shear connection (slip 0) or no shear connection (free slip) does not exist in actual engineering. [1] The steel-concrete composite beams combine the concrete slabs and the steel beams together by means of the shear link to bear the load and deformation. Since the shear connections can only provide limited rigidity, the interface between the concrete slab and the steel beam cannot be completely eliminated slip, therefore, in the actual engineering, most of the composite beams are elastic shear connection, that is part of the shear connection. Because the existence of slip will reduce the stiffness and the combined effect of the composite beam and increase the deflection, it is insecure to consider the effect of considering the slip of the interface slip beam without considering the slip. [3]

The force performance of the pegs is directly related to whether the two materials can work together. At present, the problems in the design of the composite frame are mainly concerned with the...
connection and construction of the floor and the steel beam. In particular, when the overall structure of the steel-concrete composite frame is analyzed, the actual shear stiffness of the stud is neglected. When the model is connected with the steel beam by the common joint, the actual shear stiffness. The lack of practical thinking on the impact of structural performance. Based on the ANSYS finite element simulation software, the mechanical behavior of the composite frame considering the actual shear stiffness of the peg is analyzed. Taking the force performance of the peg as the starting point, the single peg is modeled numerically, and the spring element. The force of the stud is studied by using the studs under the uniform load. [2] With respect to the connection key evenly arranged, the loose ends of the connecting keys are arranged so that the deflection of the composite beam and the relative slip of the interface increase, and the ends are closely arranged to reduce the deflection of the composite beam and the relative slip. [3]

![Fig.2 The stud uniform layout diagram](image)

2. Composite Beam Model under Different Arrangement

2.1 Composite beam modeling

At present, most of the composite beams are arranged along the beam evenly arranged shear joints, mainly because the uniform layout to a certain extent, can reduce the interface slip, but also makes the construction convenient. But it also caused the shear connector in some parts of the beam distribution and some parts of the distribution of too much, the formation of waste of resources, shear connectors cannot be fully utilized. How to use a limited number of shear connections to effectively reduce the interface slip becomes more practical engineering significance. At present, there are few reports in this field, and are analytical methods, very inconvenient to practical applications in the project.

![Fig.3 Simple Supported Beam with Uniform Load and Its Cross Section Size](image)

Before starting the test, it can be seen from the text [4] that the maximum slip is at the free cross section of the beam, where the longitudinal shear force is the largest, so the beam of the end of the arrangement of more than some of the connector, so the second set of bolt spacing narrow, see whether the finite element analysis slip value decreases.

In the experiment, the two simple support beams were modeled by ANSYS software, and the deflection value, the interface slip value and the pegging force at each node were calculated. Model
one, the pegs evenly arranged, spacing \( e = 25 \text{cm} \), take half of the beam \( L = 5 \text{m} \) modeling analysis. In model two, the pegs are evenly arranged, the spacing \( e_1 = 16.67 \text{cm}, e_2 = 50 \text{cm} \), take half of the beam \( L = 5 \text{m} \) modeling analysis. Finite element modeling analysis, concrete using solid45 unit, steel beam with plane42 unit, bolt with combine39 unit to simulate, through the finite element analysis and calculation results are as follows.

### 2.2 Composite beams - evenly arranged throughout the section

![Fig.4](image1)

Table 1 Comparison of beam end slip under uniform load

| Uniform load \([q=50\text{KN/m}]\) | Beam end slip value \([\text{cm}]\) |
|-----------------------------------|----------------------------------|
| \( \omega l = 10 \)               | 0.03230                          |
| \( \omega l = 20 \)               | 0.00792                          |
| \( \omega l = 40 \)               | 0.00179                          |

It can be seen from Table 1 that under the uniformly distributed load, the interface slip of the composite beam is reduced with the increase of the rigidity of the single bolt.

![Fig.5](image2)

Table 2 Comparison of Maximum Deflection of Composite Beams under Uniform Load

| Uniform load \([q=50\text{KN/m}]\) | Deflection maximum \([\text{cm}]\) |
|-----------------------------------|----------------------------------|
| \( \omega l = 10 \)               | -3.1882                          |
| \( \omega l = 20 \)               | -3.0276                          |
| \( \omega l = 40 \)               | -2.9859                          |

It can be seen from Fig. 5 and Table 2 that when the stiffness of the individual pegs changes even when the pegs are evenly arranged, the maximum value of the deflections is basically in the position...
of the beam and the joints are connected with different stiffness. The mid-span deflection does not change much.

![Graph of force of the studs](image)

**Fig.6 The whole period of evenly distributed force stud**

**Table 3** The whole period of evenly distributed force stud maximum

| Uniform load [q=50KN/m] | Deflection maximum [cm] |
|--------------------------|-------------------------|
| $\omega l = 10$          | -3.1882                 |
| $\omega l = 20$          | -3.0276                 |
| $\omega l = 40$          | -2.9859                 |

Since the end slip of the composite beam is generally much larger than that of the mid-span slip, it is necessary to prevent the occurrence of large slip at the cross section near the end of the composite beam. The most direct and effective method is to Cross sections are arranged with more shear connections. [4]That is to say, to increase the shear connection stiffness of the interface of the composite beam. There are usually two ways, one is to increase the number of connectors, the use of full beam spacing evenly arranged; Second, the number of connections remain unchanged, the use of sub-uniform layout. The principle is that the number of shear connections is set according to the distribution of longitudinal horizontal shear flow at the interface of the composite beam, and the composite beams are divided into sections. The number of shear connections can be adjusted in each section to approximate the longitudinal horizontal shear Flow distribution such that the rectangular area of the bearing capacity of the shear link in each section is greater than or equal to the principle of the trapezoidal area of the load shear flow to set the shear link, which is more efficient to utilize and play the stiffness and strength of the connector. [4]

2.3 Composite beam - segmented evenly arranged

In the second stage, the spacing between the pegs is $e_2 = 50$cm, and the other test conditions are the same as those of the simulation. The results are as follows.

![Graph of slip values](image)

**Fig.7 Segmented evenly arranged deflection diagram**
Table 4 Comparison of beam end slip under uniform load

| Uniform load [q=50KN/m] | Overall uniform Beam end slip value [cm] | Segmented evenly arranged Beam end slip value [cm] | Reduce the ratio |
|------------------------|-----------------------------------------|-----------------------------------------------|-----------------|
| $\omega l = 10$        | 0.03230                                 | 0.020000                                      | 38.1%           |
| $\omega l = 20$        | 0.00792                                 | 0.004680                                      | 40.9%           |
| $\omega l = 40$        | 0.00179                                 | 0.000973                                      | 45.6%           |

The calculated data from Table 4 and Figure 7 show that the maximum slip of the end of the composite beam can be reduced by about 38.1% to 45.6% under the uniform load when the joints are evenly arranged. It can be seen that the arrangement of the connecting parts is an extremely important factor affecting the interface slip of the composite beam. In the case of no increase in the number of connections, the use of sub-arrangement method can effectively reduce the joint beam interface slip, thereby enhancing the stiffness of composite beams. In addition, because the shear connector is evenly arranged when the construction is more convenient, therefore, in the actual project worthy of popularization and application.

![Segmented evenly arranged deflection diagram](image)

Fig. 8 Segmented evenly arranged deflection diagram

Table 5 The composite beam section is evenly arranged with the maximum deflection value

| Uniform load [q=50KN/m] | Deflection maximum [cm] | The whole section is evenly distributed maximum [cm] | Reduce the ratio |
|------------------------|--------------------------|---------------------------------------------------|-----------------|
| $\omega l = 10$        | -2.4832                  | -3.1882                                           | 22.1%           |
| $\omega l = 20$        | -2.3482                  | -3.0276                                           | 22.4%           |
| $\omega l = 40$        | -2.3577                  | -2.9859                                           | 21.0%           |

Compared with the uniform distribution and uneven distribution, we can see that the maximum deflection of the composite beam is reduced by about 22%, which can improve the stiffness of the composite beam and increase the combined effect, so that the shear connector to play a full role. The reduction of this deflection fully proves that the uniform arrangement of the segment can play a role in adjusting the stiffness of the beam.

The influence of the connection key arrangement on the deflection of the composite beam is relatively large. With the increase of the connection key stiffness, the influence of the connection key arrangement on the deflection of the deflection beam is gradually reduced.
Fig. 9 Piecewise uniform distribution of the stud

Table 6 Compare different layouts of the stud force

| Uniform load [q=50KN/m] | Overall uniform The maximum stud force [KN] | Segmented evenly The maximum stud force [KN] | Reduce the ratio |
|-------------------------|-----------------------------------------------|-----------------------------------------------|-----------------|
| l = 10                  | 58.074                                         | 37.258                                         | 35.8%           |
| l = 20                  | 63.62                                          | 41.41                                          | 34.9%           |
| l = 40                  | 68.479                                         | 45.487                                         | 33.6%           |

The force of a single peg is also changed, showing a decreasing trend, evenly arranged after the end of the pin closer to the end of the larger force, the analysis of this part of the force, from the maximum change can be obtained at the end of the The bolt is reduced.

3. Conclusions
(1) When the whole beam is evenly arranged, the interfacial slip value of the end is the largest. With the increase of the stiffness of the shear connector, the anti-slip ability of the end is increased and the slip value decreases.

(2) In the case of evenly arranged in the case of pegs, the slip values are evenly distributed with the whole arrangement, and the slippage can be reduced by the uniform arrangement, which will improve the overall stiffness of the composite beams.

(3) The composite beam can be used to reduce the interfacial slip by using the method of evenly arranging the pegs. However, it is necessary to set up the model and calculate the analysis to determine the spacing between the sections.

Acknowledgments
This work was financially supported by the National Natural Science Foundation (51668027 and 51468026).

References
[1] Zhou Donghua, Sun Lili, Fan Jiang, et al. Effective stiffness method for calculation of deflection of composite beams[J]. Journal of Southwest Jiaotong University, 2011, 46 (4): 541-546
[2] Zeng Xinggui, Jiang Shaofei, Zhou Donghua. Optimum Arrangement of Shear Connection of Composite Beam Based on Finite Element Method[J].Journal of Applied Basic and Engineering Sciences,2014,22 (3): 512-523
[3] Zhang Zhengyang, Xiang Tianyu, Xu Tengfei, et al. Study on Optimum Arrangement of Connection Key of Steel - concrete Composite Beams[J]. Journal of Shandong Jiaotong
[4] Wang Peng, Zhou Donghua, Wang Yonghui, et al. Calculation on slip of composite beams with stepwise uniform distribution of shear connectors[J]. Building Structure, 2011, 41(8) : 96-101