Research on seismic performance of composite concrete slab with no-protruding rebar shear wall joints

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Abstract. Precast concrete composite slab is one of the most widely used precast elements in civil engineering, which is suitable for all kinds of prefabricated concrete structure. The longitudinal bars at the bottom of precast slab extend beyond the ends of it, which brings a lot of inconveniences in fabrication, transportation and installation. In order to avoid those disadvantages of traditional precast concrete composite slab, a new no-protruding rebar concrete slab shear wall joint is developed in this paper. And five concrete slab-shear wall joint specimens were fabricated to research the joint structure of composite slab with no-protruding rebar but including additional rebar. In order to verify the seismic performance of the new concrete slab-shear wall joint, Pseudo-static testing of those specimens were carried out and the bearing capacity, stiffness, ductility and energy-dissipating capacity of different specimens were compared. The experiment results show that the additional rebar is necessary to the joints of composite slab with no-protruding rebar shear wall to ensure the seismic reliability of the joint connection; the bearing capacity and ultimate deformation of the new no-protruding rebar concrete slab-shear wall joint increase with the increasing of the lapped length of additional rebar.

1. Introduction

The precast slab can be used as a formwork for the upper cast-in-place layer during the construction phase; composite slab can also be a whole with the cast-in-place layer during the service stage. Owing to those advantages, the precast concrete composite slab is one of the most widely used precast elements in civil engineering. However, the longitudinal bars at the bottom of traditional precast slab extend beyond the ends of it \cite{1, 2}. Hence, the side die need to be reserved hole according to the position of the rebar in the precast production stage, which lead to the increase of mold type, and the number of times of the mold is reduced. In addition, the protruding rebar are easy to bend and collide, which makes installation of precast elements difficult. In order to avoid those disadvantages of traditional precast concrete composite slab, a new no-protruding concrete slab-shear wall joint \cite{3} is developed in this paper. However, the effective height of the section is directly reduced without the rebar at the bottom of slab, and it will lead to significantly reduce of the flexural bearing capacity of the slab \cite{4}. Ye Xianguo \textit{et al.} \cite{5} studied the details and transmission properties of joints between superposed slabs based on experiments, and the partial loss of flexural capacity can be compensated by adding reinforcement. Therefore, the performance of joint can be improved by adding reinforcement. In recent years, the good seismic performance of composite concrete slab with protruding rebar-shear wall joints has been proved based on experiments \cite{6-8}, while the in-depth study of composite concrete slab with no-protruding rebar shear wall joints weren’t carried out. Hence,
this paper conducts an experimental study on the seismic behavior of composite concrete slab with no-protruding rebar-shear wall joints to prove it good seismic performance.

2. Specimens design
In order to research the influence on seismic performance of composite concrete slab with no-protruding rebar shear wall joint, five concrete slab-shear wall joint specimens were designed. The comparison of those specimens is shown in Table 1. In addition, except for the comparison variables, the remaining conditions of the five test specimens are the same, and the detailed processing of the test specimens is shown in Figure 1, respectively.

| Specimen Identifier | Slab Type                     | Length of Additional Rebar (mm) | The Way of Assembly                  |
|----------------------|-------------------------------|---------------------------------|-------------------------------------|
| JDB1-1               | Slab with protruding rebar     | 0                               | Joints cast in situ                 |
| JDB2-1               |                               | 0                               | Longitudinal bar splicing           |
| JDB2-2               | Slab with no-protruding rebar  | 240 (110+130)                   | in shearing wall are                |
| JDB2-3               |                               | 400 (110+290)                   | connected by rebar                 |
| JDB2-4               |                               | 460 (170+290)                   | connection sleeve                  |

Figure 1. Drawing of specimens processing.

3. Specimens loading and measure scheme
The test loading device is shown in Figure 2. The shear wall only bears the in-plane load and exerts the vertical force through the axial compression jack, and the upper and lower sections are fixed. During the test, the floor cantilever is loaded; the steel beam is loaded; the end of the laminated plate is clamped and connected with the jack. Assuming that the balance position of the specimen is the section at the joint of the wall slab, considering the bending moment at the end of the floor caused by uniformly distributed load and dead weight, 1.29kN vertical force is applied to the cantilever end before repeated loading to ensure that the specimen is in the balance position at the beginning of loading.
According to the technical standard, the loading is a force-displacement hybrid control system. Firstly, force control loading is used, and the increment of each stage was determined to be 0.9kN by calculating the cracking load. When the skeleton curve shows obvious nonlinearity, the corresponding displacement is considered as the yield displacement, and the displacement control is used. After that, the loading is carried out at equal amplitude according to the multiple of yield displacement. The loading process is shown in Figure 3. The loading is stopped when the bearing capacity drops to 85% of the peak value or the crack width generated by the test piece is greater than 3 mm. It is a positive load when the load head is up and a negative load when it is down. In addition, the strain gauges were placed along the additional rebar, in order to study the additional rebar stress change and actual anchoring requirements, and the strain gauges were arranged as shown in Figure 4.

![Figure 2. Specimens loading device.](image)

![Figure 3. Loading process.](image)

4. Testing phenomenon and results analysis
First, the initial cracks of all the test specimens were caused by the bending of the upper and lower vertical slab surface cracks. After that, the cracks gradually extend to the middle of the slab section until the upper and lower cracks meet and the concrete was crushed and destroyed. The brittle failure occurs to the JDB2-1 because of insufficient reinforcement, plastic hinges were formed on the outer
slab of the joint area, which was ductile damage. And JDB2-2, a small amount of parallel slab cracks along the prefabricated layer and the cast-in-place layer appeared in the plastic hinge position, and there were no parallel slab surface cracks in other test specimens. The steel bar strain of each specimen is shown in Figure 5. Those phenomena are indicated that the prefabricated layer and the cast-in-place layer of the concrete composite slab are well combined. In addition, the hysteresis curve was drawing, respectively, as shown in Figure 6.

From the test result curve, the JDB2-1 specimen with no-protruding rebar and no additional rebar have significantly lower bearing capacity and energy consumption than other specimens, and brittle failure occurs at lower load levels due to crack penetration. Compared with the JDB1-1, JDB2-2, JDB2-3 and JDB2-4 with no-protruding rebar have large gaps between the positive and negative indicators. And as the lapped length of the additional rebar increases, the gap is significantly reduced. Figure 7 is a comparison of the JDB2-2, JDB2-3, and JDB2-4 skeleton curves. The three skeleton curves are basically the same before the yielding of the rebar, and the JDB2-4 with the longest additional rebar is the best in bearing capacity, ultimate deformation capacity and ductility among the three specimens, and the JDB2-2 with the shortest length of additional rebar is the earliest yielding during forward loading, which indicates that the bearing capacity of the joint can be improve by the length of the additional rebar. In addition, the ultimate deformation capability of the joint can be improved by increasing the anchorage length of the additional rebar into the support.

Figure 4. Arrangement of strain gauge.
Figure 5. Steel bar strain of specimens.

Figure 6. Hysteretic curves of specimens
5. Conclusions
In this paper, the influence on seismic performance of composite concrete slab with no-protruding rebar shear wall joint was studied based on experimental test. And seismic performance indexes of the specimens such as bearing capacity, stiffness and ductility were compared. According to the experimental phenomena, the conclusions can be drawn as follows: (1) the additional rebar is necessary to the joints of composite slab with no-protruding rebar shear wall to ensure the seismic reliability of the joint connection and avoid brittle failure. (2) The bearing capacity and ultimate deformation of the new no-protruding rebar concrete slab-shear wall joint increase with the increasing of the lapped length of the additional rebar.

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