Use of Slab composite with galvanized steel deck in reinforced concrete frame

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Abstract. Slabs composite with galvanized steel deck and in-situ concrete are commonly used in steel framed structures. This approach proven to reduce structural weight and increase the efficiency of structural design. Furthermore, the steel deck acts as permanent formwork and also as positive reinforcement after concrete hardening. The study reported in this paper concentrates on the use of composite slab with galvanized steel deck in reinforced concrete (RC) framed buildings. This requires the assessment of the system under flexural loads and slip forces that develops between the RC beam and the composite slab in shear transferring zone. Four-point static and push-off tests were used to find the flexural capacity of system and the amount of slip between the beam and the slabs. Results of the numerous experimental tests and analytical studies demonstrate that the composite slab can be implemented in RC frames since both composite beam flanges and RC beam flanges conducted by the same beam stem manifested almost the same flexural behavior and had roughly similar load-carrying capacity in static test. Moreover, no slip was developed between the RC beam and the composite slab in all four test cases with different reinforcement set up. This can be considered as an important advantage of this system.

1. Introduction

Over the last few decades’ composite slab application has been frequent and mostly accounted for the supremacy of steel frames in multi-story buildings. The interpretation of composite slab, which is formed by using in-situ concrete with galvanized steel deck, is acceptable when the deck develops a satisfactory shear bond with the concrete. In such situations the deck is not only used as a permanent formwork but it also sustains the construction loads during the execution, including the fresh concrete during casting process and acts as tension reinforcement for the composite slab. The slab weight dominates the overall weight of the building. The composite slab with a thin galvanized deck and approximately 25 percent less concrete than other types of reinforced concrete slabs, is lighter and it can develop the same stiffness. As a result, the structural members become smaller in cross section and lighter too and hence the loads that are transferred to the foundations are reduced leading to smaller size foundations. The light weight galvanized sheets reduce the transportation time and the time in which crane spends to transfer the material. Moreover, the application of the composite slab is quite simple when compared to other slabs since it often only needs shrinkage and temperature reinforcement after placing the sheets on beams. Reduced workmanship and material consumptions make composite slab a favorite alternative in steel building industry. The purpose of this paper is to investigate the possibility of providing these advantages to the reinforced concrete buildings through investigating the flexural capacity of the RC beam flange with composite slab. For this purpose, four
points load static test was used, the results were compare with the traditional reinforced concrete solid slab and the slip that usually occurs between the composite slab and the steel beam (in this paper between the composite slab and RC beam) in the shear transferring zone was measured using push-off test as per the requirements of Euro-code. Literature review did not reveal any evidence of investigation into this kind of composite slab with galvanized deck being used with RC beams in RC buildings. Hence, there is a need to understand such slabs individual behavior and also behavior as part of an RC frame. To do that one needs to review the understanding of such slab behavior within a steel framed building and hence try to understand how it would behave as part of a RC framed building. Nie and Wang [1] and Nie and Cai [2] both claimed almost the same results when they investigated composite slab with steel beam under four points static test and they concluded that including the slip impact has remarkably enhanced the deflection prediction. The slip effect developed an additional flexural moment which caused a depletion in the elastic flexural capacity. In addition to that composite beam failure mode relies on the shear connectivity degree. In fact, the main concern in composite structure is the slip between the concrete and the steel which requires shear connector to transfer the shear loads between the two materials. The literature is rich of such manuscripts that discusses this topic. Zona and Ranzi [3] has done a parametric study on slip demand in composite slab and they concluded that, for a given shear connection degree, the design parameters that influence shear connection demand are construction succession (propped construction shows slip demand always larger than unpropped construction), the length of the span (longer spans are the most censorious in terms of slip demand), and the shape of the steel section (sections with equal flanges are less censorious). They also found out that the shear connection distribution has a crucial effect as the non-uniform shear connection distributions with more connectors near the supports are more effective in limiting the slip demand, mostly for the full shear connection designs. Furthermore, the thickness of the slab, dead load to live load ratio, and concrete compressive strength, can have indispensable influence on the slip demand even though their overall importance is limited. The slip capacity test in this paper has been done in accordance to EN 1994-1-1 2004 [4] Annex B.2. and all specimens in both tests has been prepared in accordance to Euro code design requirements.

2. Material properties, sample preparation and load set-up

C25 concrete was used in static test and low strength concrete C5 were used in push-of test. S420 rebar were used for the RC slab and beams and Almetsan ALDECK 70/915, with S300 yield strength, a deck depth of 60 mm, thickness of 1 mm with an embossment distributed on the web of the sheet, were used. A total of sixteen specimens were tested in two different test set-up as follows:

- Four-point load static test were carried out to assess the behavior of the new system under flexural load. Then the behavior of new system was compared to the traditional reinforced concrete solid slab system to assess the efficiency of the new system.
- Push-of tests are standard for finding out slip between steel beams and composite slab with steel deck. Hence, twelve push-of test specimens were used to investigate if slip occurs between the composite slabs and the reinforced concrete beam of the new system.

2.1. Static test

The tests were done by using a simply supported reinforced concrete (RC) beam carrying a continuous RC slab to primarily investigate the flexural behavior of both of them under four-point load (two loads applied on the slab and two reactions from the supports). The overall length of the specimens was 3700 mm with a pure bending (pure bending is the distance between the two line loads) of 250 mm. 150 mm thickness was used for both solid slab and composite slab. Both slabs were carried by a 25/45 cm reinforced concrete beam. The reinforcement in solid slab was Ø8/17 in the short direction and Ø8/25 in the long direction with Ø8/25 at the negative moment zone to make it similar to the composite slab, since steel mesh were used. On the other hand, the composite slab had only a mesh reinforcement with Ø8/25 in both directions to prevent concrete shrinkage cracking. Finally, the RC
beam has 3Ø12 rebar at top and bottom for flexure and Ø8/20, as shear reinforcement. Figure 1 displays one of the specimens before loading. The load has been applied gradually so that the failure load can be achieved within an hour. Low Voltage Displacement Transducers (LVDTs) were placed in the mid-span of the beam and the two slabs to monitor the deflection throughout the test period.

![Figure 1. Static test load set-up and specimen dimensions](image)

2.2. **Push-off tests**

The push test is required for the composite beam to investigate the effectiveness of the new type of shear connector to guarantee the composite action between the concrete and the steel component. In this new system the test was carried out to analyze the developed stresses and internal forces between the reinforced in-situ concrete beam and the composite slab with galvanized deck. Push test was carried out by using four different test cases in conformity with Euro code 4, Annex B.2. Figure 2 shows specimen dimensions and load set-up. In Case1 (SC-FR) the beam, and slab had reinforcement and there was a proposed connector. In Case2 (SC-SR) beam and slab had reinforcement but without connectors. In Case3 (SC) beam had reinforcement but slab had no reinforcement and connector. In Case4 (SC-Con) beam had reinforcement with connector and slab had no reinforcement. Thus the tests were carried out in order to investigate which component will influence the slip capacity and the failure mode.
Figure 2. Specimen dimensions and load set-up for push-off test.

The load has been applied in a way that the failure would not occur in less than 15 minutes with LVDTs were replaced at the bottom of the beam and in the mid-span of the beam where the connectors were embedded.

3. Results and discussions

3.1. Static test
Composite and solid slab supported by RC beam behaved in a similar manner, with small differences, such as the initial elastic stiffness of the solid slab was higher than the composite one; the elastic load was about 10% higher with elastic mid-span deflection being around 30% lower. On the other hand, although the failure load was almost the same, the total mid-span deflection corresponding to failure load was 25% more for the composite slab whereas the average crack width was considerably lower for composite slab. The solid slab specimen attained less total mid-span deflection than the composite one. This could be due to composite slab having galvanized flexible steel sheet that made the overall slab to have more flexible behavior. Figure 3 compares the mid-span deflections of the composite slab specimen and solid slab one.
3.2. Push-off test

Euro code 4 requires 6 mm slip for ductile behavior, all cases had brittle behavior. Ductile failure does not exist in this system as the connector does not play any role in either load carrying capacity or total slip. This behavior has been predicted with an understanding of the nature of reinforced concrete structures. This can be an advantage of the new system since slip capacity is one of the major concerns in designing composite beam with slab composite with galvanized steel deck.

Despite the fact that proposed connectors had slightly increased the load carrying capacity of the specimen. However, more investigations should be done in future with different connectors and different types of concrete to try to understand the behavior and level of ductility of such systems. Figure 4 shows load versus longitudinal slip for a specimen from each series.
4. Conclusion

The conclusion drawn from the work done can be summarized as follows.

- Composite slab and reinforced concrete solid slab carried by the same RC beam showed the same flexural behavior and had almost identical load carrying capacity in static test. Yet composite slab showed more total deflection than solid slab but with less crack width.

- The four cases used for push-off tests indicated that no slip occurred between the slabs and the beam since all of them has been casted together so the shear forces would be transferred by the concrete itself. Thus usage of this system may provide some advantages since no slip was developed. However, all test cases showed brittle behavior in accordance to Euro code 4 evaluation. It should be mentioned that although slab reinforcement is only for shrinkage and temperature it played an important role in increasing the system load carrying capacity and causing the specimen to have a ductile failure mode.

- In summary the composite slab which consist of galvanized steel deck and in-situ concrete can be applied easily on reinforced concrete beam under gravity loads.

References

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