

DESIGN OF COMPOSITE BEAMS USING LIGHT STEEL CONSTRUCTIONS

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Abstract: Composite light steel beams use back to back double C sections rather than hot rolled steel I beams, but the general form of construction is similar to conventional composite construction. Importantly, welded shear connectors cannot be used for the relatively thin steel used in light steel construction, and therefore it has been necessary to develop alternative forms of shear connectors using powder actuated, or pneumatically driven pins. These shear connectors use profiled strip steel elements which are fixed by pins. To know the resistance and behavior of these innovative shear connectors some tests have been carried out determine the design resistance of these connectors. The aim of this project is to provide guidance on the design of composite beams using light steel sections, a carefully study has been carried out getting eventually design examples which illustrate the calculus method and can be adapted in a easy way to a design particular characteristic, and design tables to aid rapid selection of light steel sections, depending on the span, the loading and the steel grade used.

Key words: Bucket, Composite, light steel, composite beams, connectors, resistance.

1. Introduction

Composite construction achieves important benefits by making steel and concrete work together, but these advantages can be improved if light cold formed steel sections instead of hot rolled sections are used. In modern composite construction, the steel framing elements are erected first and provide a stable structure that is capable of supporting construction loads. The composite action that developed later with the concrete or other material serves to provide resistance to imposed loads, and importantly, to improve the stiffness of the construction. Often serviceability criteria dominate in modern design and therefore control of deflections and vibration response are as important as load resistance. After several years of experience on composite construction as a construction method, light sections have been introduced in this type of construction. The general principles of composite design using light steel sections are the following:

- During construction light steel beams are designed ELASTICALLY to support the construction loads.
- Once the steel and concrete are acting compositely, composite light steel beams are design PLASTICALLY to support the loads acting at the ultimate limit state.

A minimum degree of shear connection is required. Light steel sections introduce some particularities in composite construction. Composite light steel beams use double C sections rather than hot rolled and profiled strip steel connectors fixed by powder actuated pins instead of welded shear connectors.

2. Types of composite slabs

The classification of slabs depends basically on their geometry properties and the construction stage conditions. The common span of composite slabs is between 3m and 4 m, but these values are considering unprompted construction stage. If temporary propping is used it is possible to used longer spans. Considering a shallow decking, slab thicknesses are in the range 100 mm to 200 mm, and for deep decking between 280 mm and 320 mm. The most common composite slabs consist on the combination of steel decking and in-situ concrete placed onto the steel decking. When the concrete has gained strength, it acts as a composite slab with the tensile strength of the decking. There are different types of in-situ composite slabs considering their dimensions and also the steel decking used. In the actual building construction pre-cast concrete floors are widely used. There is an increase of composite frames and slim floors construction where the pre-cast slabs are design to interact structurally with the steel frame. In the same way as in-situ composite slabs, the composite action can be developed by welded shear connectors attached to the steel beams and by transverse reinforcement. The most common types of pre-cast slabs are:

- Hollow core units, with continuous circular or elongated openings along their length. The depth is between 150 mm and 260 mm (Figure 1).

- Solid planks, which are designed to use with an in-situ concrete topping. The depth of the solid planks is between 75 mm and 100 mm, but without considering the concrete topping (Figure 2). There is a wide variety of composite slabs considering all the combinations of composite slabs with in-situ concrete and the wide range of pre-cast slab products available from various manufacturers. There is a different type of composite slab construction called slim floor. The main difference of this construction is that the supporting beams are contained within the depth of the concrete slab. Other forms of slim floor construction, using precast concrete plans to form the slab, are less effective in several aspects, such as ease of service integration (Figure 3).

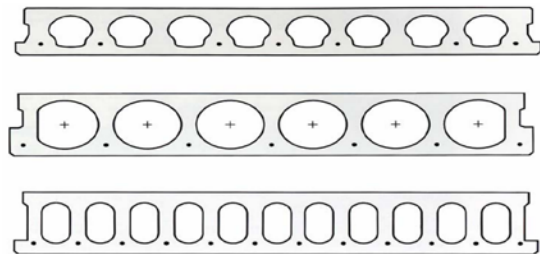


Figure 1 Examples of hollow core slabs

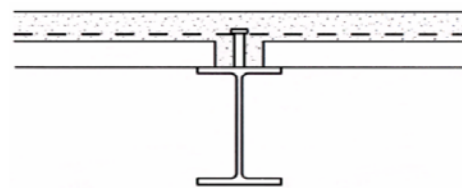


Figure 2 Example of solid planks slabs

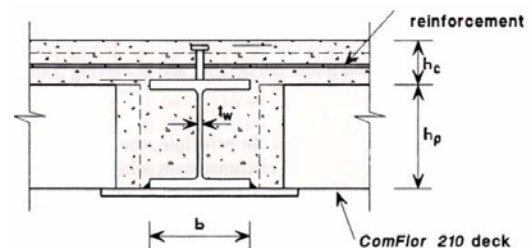


Figure 3 Basic components "Slumlord"

3. Types of composite beams

Composite beams typically consist of steel "I" sections acting structurally with a concrete slab by means of shear connectors attached to the top flange of the steel section. The beams are generally designed to be simply supported, and an

effective part of the slab is taken as acting as a part of the composite section on either side of the centerline of the section. It is possible a significant saving in steel weight and/or structural floor depth due to the composite action of the steel beam and the concrete slab which increases the stiffness of the beam and the load capacity. The size of the steel section used is often chosen by limitations on serviceability considerations. Composite beams tend to be used for long span applications, (in excess 9 m), which means that deflection and dynamic criteria may be critical. Primary beams have decking spanning in a direction parallel to them, so the decking do not provide laterally restrain. Secondary beams are perpendicular to the decking spanning direction and the top flange of the steel beam is restrained laterally due to the decking and fixings. This is very important to consider at the design stage to choose the proper steel "I" section.

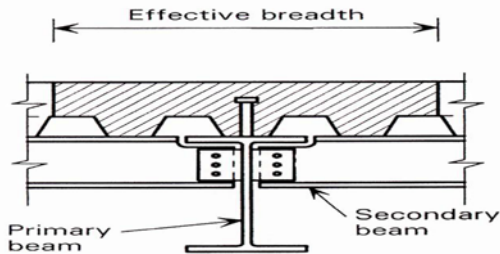


Figure 4 Primary and secondary beams

4. Types of shear connectors

There are quite different types of shear connectors, some welded and other nailed connectors. Welded connectors were commonly used in composite construction, but with the development of the use of thinner steel sheets, it has been necessary the use of nailed instead of welded. The choice of a specific type of connector is based on its ultimate resistance which depends not only on its own properties, also on the concrete grade used.

4.1 Headed studs

The standard dimensions of headed studs are $\varnothing 19$ mm and a length of 125 mm. The behavior of the headed studs does not vary a lot when concrete properties are changed. Their load capacity is much lower than that of perfobondstrip and T-shape connectors, and it is always around the same value although fiber concrete, light weight concrete or higher strength concrete is used. Headed studs characteristic resistance is lower than that of perfobondstrip and T-shape connectors, and it depends on the number of studs used (Figure 5)

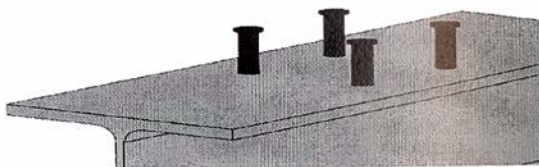


Figure 5 Headed studs

4.2 Oscillating perfobondstrip

Oscillating perfobondstrip with a height of 100 mm, a thickness of 8 mm, 5 holes $\varnothing 50$ mm and bend in 1.5 wave with an amplitude of 110 mm. But this behavior disappears if light weight concrete (LC30/37), concrete with fibers or a high strength (C70/85) is used. Oscillating perfobondstrip connectors have also a higher characteristic resistance than others connectors as headed studs and T-shape connectors, and should be taken into account that the failure modes are different for lower and higher concrete strength (Figure 6).

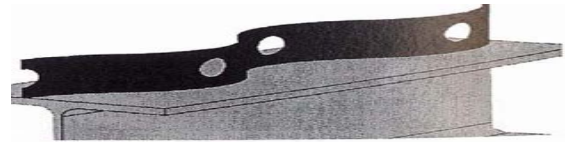


Figure 6 Oscillating perfobondstrip

4.3 Continuous perfobondstrip

Continuous perfobondstrip with a height of 100 mm, a thickness of 12 mm and 5 holes $\varnothing 50$ mm. The evolution in the behavior of the continuous perfobondstrip, according to the change in concrete properties, is similar to oscillating perfobondstrip, but always archiving lower load capacity and characteristic resistance (Figure 7).

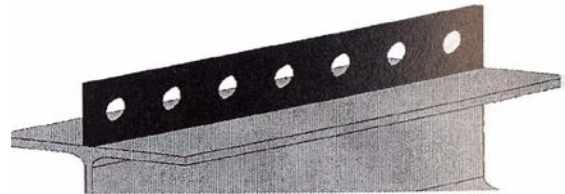


Figure 7 Continuous perfobondstrip

4.4 Waveform strip

Waveform strip with a width of 50 mm, a thickness of 6 mm and bend in 2 waves with amplitude 110 mm. Welded with prop-welds $\varnothing 25$ mm. It had a very disappointing behavior in tests. Due to that its use is not recommended (Figure 8).

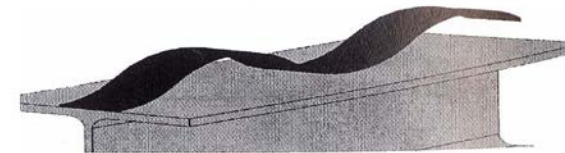


Figure 8 Waveform strip

4.5 T-shape connectors

A section with a length of 300 mm of a standard T-shape 120 welded to the beam. T-shape connectors performed very well to headed studs. T-shape connectors achieve the same load capacity as oscillating perfobondstrip. The T-shape connectors have the highest characteristic resistance and the mode of failure changes for different concrete strengths (Figure 9).



Figure 9 T - shape connector

4.6 Hilti HVB shear connectors

Hilti HVB shear connectors can be found between the nailed shear connectors which are presented as an alternative to welded headed studs connectors for composite beams. Hilti HVB shear connectors are cold formed angle shear connectors, fixed by two powder-actuated fasteners driven with a powder-actuated tool. It is possible to use one, two or three connectors in each steel decking rib, depending on the requirements (Figure 10).



Figure 10 Hilti HVB shear connector

5. Conclusions

A wide range of possibilities of cold formed sections and light steel framing has been developed in recent years. It is appreciated that the design of these sections may appear to be more complicated than that of hot rolled sections. It is therefore important to understand the design principles and also the practical considerations of the structural use of these sections. Composite construction is widespread in building practice and the development of light steel composite structures has a great demand because the clear benefits that they incorporate. Using light cold formed sections of 1.2 to 3.0 mm thickness as composite beams, means an economic benefit due to the reduction of material involved. Light steel sections are slender and the possibility of local buckling has to be checked. As light steel sections have so thin steel elements, has been necessary to design innovative shear connectors and to carry out several tests with the purpose of improve their performance and determine their design resistance. Knowing light steel sections special properties, secondary beams of a composite slab have been designed to study the performance of these thin sections working compositely with in situ concrete. Design tables, which are very useful in the design stage, have been computed.

Literature:

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