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New concepts in the design and construction of concrete-steel composite beams

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Oral presenter

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Project aims and objectives

Many researchers presented composite beams (C.B.s) where the connection is achieved by encasing part of the web directly into the slab, saving the top flange area and the welded shear connector which are regarded as prerequisite in traditional C.B.s (Jurkiewiez & Hottier, 2005; Zanon & Hechler, 2012; Remennikov & Roche, 2014). See **Fig 1 (a,b,c)**.

However, eliminating the top flange normally causes a noticeable reduction in moment resistance especially in hogging regions as the slab cracked concrete provides a negligible contribution to the moment resistance. Furthermore, to the authors' knowledge, detailed studies to highlight the effect of encasement depth on both sagging and hogging moments are not available; design rules to efficiently fabricate continuous beams according to the bending moment diagram (B.M.D) are also not available.

The aim of this research is to construct competitive C.B.s according to the B.M.D by employing the beams own resources to achieve the required bond. The top flange area is re-distributed to ensure a higher moment resistance and achieving the bond by the encasement of the upper part of steel beam.

To acquire the composite action, the reinforcement perpendicular to the girder is arranged in a developed layout which passes through a novel pattern of perforations at web upper part, and works synergically with the concrete forming the reinforced concrete dowels to resist the separation between the slab and the beam. Thus, the competitiveness of this beam, compared to other methods of connection, might be regarded in the light of its efficient use of materials as no shear connectors or extra reinforcement are needed.

To achieve these goals, a comprehensive literature review followed by analytical and experimental programme are conducted.

Description of methods and results

Analytical studies analysed the effect of redistributing the top flange area and its penetration into the slab on the overall moment resistance while the experimental campaign investigate connection behaviour, including encasement depth, perforations geometry and rebars presence.

Analytical investigations

Two traditional C.B.s, (where the slab is attached to a symmetrical I-steel girder, subjected to hogging and sagging moments) were selected. Several re-designs for the upper flange and the web of these beams were parametrically investigated. The unsymmetrical I shaped beams have the same area of steel and are attached to the same concrete slabs thus maintaining the same overall height of the C.B.s. This has allowed a direct comparison between the results of this parametric study and the original designs.

Using the plastic analysis of the C.B.s, this part of the study highlighted the relationship between the bending moments, the depth of the girder encasement and the position of the plastic neutral axis position.

The results demonstrate an increase in both sagging and hogging moment capacity, despite a portion of the web being encased (**Fig 2**). This increase is correlated with the penetration depth.

Experimental investigation

New push-out test (POT) method

Based on an extensive review for (POT) methods used by other researchers, a new one-sided POT (OSPOT) method was devised and adopted for the experimental campaign. The OSPOT shear-studs' results were compared against current codes of practice predictions and those POTs published by other researchers, showing consistently an excellent agreement. Hence, the new OSPOT allows obtaining two results per specimen (ono for each side), is smaller in size, requires the application of less shearing load, and simplified the samples fabrication.

Sensitivity study

Since the behaviour of the perfobond shear connectors in C.B.s depends on various parameters, a sensitivity analysis was conducted to identify the most influential parameters, which are found to be diameter of the holes and rebars. The study results implemented in the design of the experimental programme, allowing to efficiently manage the research resources, focusing on those parameters.

POTs campaign

As part of the experimental campaign, 41 POTs (9 headed-studs, 14 perfobonds and 18 developed perforations) were executed. The results were evaluated, analysed and compared against each other, and with reference to published results. The new type of perforations has shown a better performance in term of the ductility and the overall capacity when compared to standard connectors.

Potential for application of results

Continuous C.B.s are widely used in the construction industry owing to several advantages such as reduced deflections and higher span/depth ratio compared to simply supported C.B. Due to the cracked concrete at the internal supports need special considerations as the beams generally require a full-composite action between concrete and steel. One of the solutions is to encase the

beam at the internal support within the concrete. However, this structural form might be economically non-competitive.

The analytical and experimental finding can be used as an innovative and efficient method for fabricating full-composite continuous beams. The steel beam profile could be constructed according to the moment distribution and magnitude of the (B.M.D). See **Fig 1(d)**.

Moreover, the C.B.s can be fabricated as precast segment(s) (sagging and hogging segments), with the length of the segments determined by the distance between points of contra-flexure points or the supports, where the bending moment is zero. These segments could then be assembled together on site, reducing the overall construction time and cost, increasing the quality and reducing the weather impact.

References

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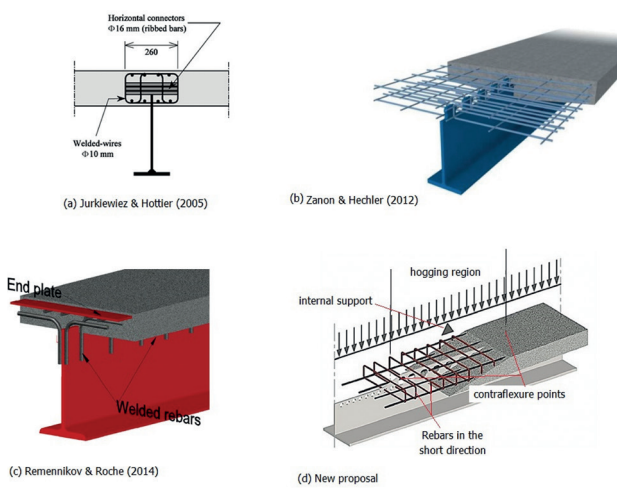


Fig 1 *Comparison between different kinds of connection methods which employ the web for connection*

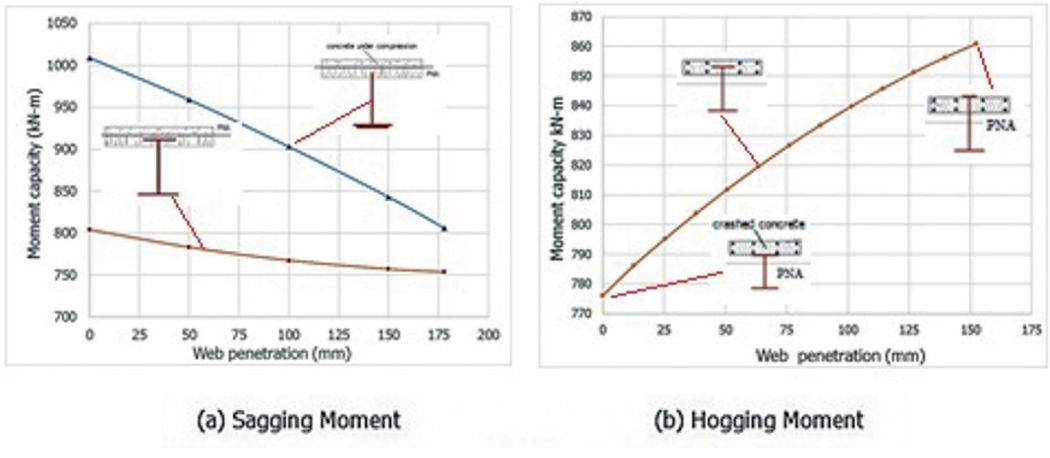


Fig 2 *The effect of beam penetration on the overall moment resistance of the composite beam*