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New shear connector for Open Web Steel Joist with metal deck and concrete slab floor system

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HIGHLIGHTS

- Composite floor system of Open-Web Steel Joists and concrete slab is discussed.
- The composite action using shear stud connectors is reviewed and summarized.
- Puddle welds and Hilti-screw pins shear connectors are proposed and investigated.
- Two full-scale OWSJ composite deck slabs were constructed and tested.
- Puddle-welds shear connectors provided significant levels of composite action.

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ABSTRACT

The composite floor system, consists of a concrete slab poured on steel sheets, supported over Open Web Steel Joists (OWSJ); is widely used in commercial and industrial buildings. To achieve the desirable strength, shear connector (studs) have to be welded on the OWSJ to ensure composite action of the three components. Extending the application of this composite floor system to residential buildings, alternative shear connectors such as puddle-welds and Hilti-screws would greatly reduce the expense and accelerate the construction. Yet the current design codes consider these alternates structurally inadequate due to lack of research. The objective of this research is to investigate the ability of puddle-welds and Hilti-screws to develop composite action for building applications. The experimental program consists of testing two full scale composite decks, each consisted of two OWSJs supporting a 2.4 m wide concrete slab over 6.7 m span. Puddle welds and Hilti screws were used as main and only shear connector. Both test prototypes were tested until failure under different combinations of static and fatigue load cycles. Test results showed that significant composite action is developed using puddle-weld shear connectors and their behaviour meets the serviceability and ultimate strength requirements for residential applications.

1. Introduction

Over the last few decades, steel and concrete structures have been a very popular selection in construction; particularly composite floor systems consisting of a concrete deck poured on top of corrugated steel sheets, supported by Open-Web Steel Joists (OWSJ). Open Web Steel Joists (OWSJ) are steel trusses of relatively low mass with parallel or slightly pitched chords and triangulated web systems proportioned to span between walls, structural supporting members, or both, and to provide direct support for floor or roof deck [1]. OWSJs offer enlarged effective depths with minimal increases in material as oppose to W-shape beams of similar depths. Therefore, OWSJs are attractive structural elements for increased strength and stiffness while offering sufficient opening for air ducts and other services. The corrugated steel sheets act as permanent in-place formwork and a thin layer of tensile reinforcement for the concrete slab. Most corrugated steel decking used in composite flooring systems contain embossments within the profile of the deck to maintain a superior bond to the concrete slab cast on top. The concrete slab is designed to resist compressive stresses with only light, top reinforcement (welded wire mesh) to eliminate/control shrinkage cracks. The purpose of this construction practice is to build upon the strengths of each material and to compensate for the weakness of each other simultaneously. Composite construction is typically used in repeated floor

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buildings because the floor system can be replicated efficiently floor after floor. Composite elements also have a larger moment capacity, which allows for smaller section size and depth; which reduce the floor height over the course of a soaring structure. Therefore, composite elements are lighter, slenderer, stiffer and more economical while resisting identical loads compared to non-composite ones.

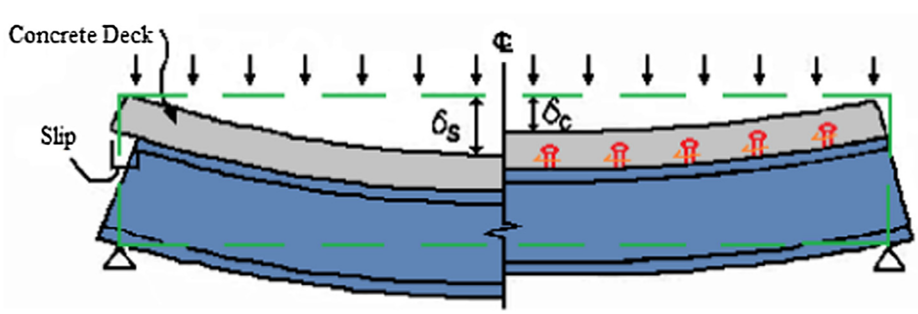
Composite action is the term used to describe the behaviour of a composite structure and has a great effect on the stress and strain of beam and floor composite systems. To ensure full strain compatibility at the interface between steel and concrete elements in composite section (composite action), stiff and rigid shear connectors, commonly called shear studs, are used [1]. (Fig. 1) illustrates the behaviour and strain profile of a composite to a non-composite section [2]. The composite section undergoes less deflection and no slip due to the addition of the shear studs. Shear studs are shear resisting dowels welded to the top flange of the steel sections and encased in concrete in order to transfer the longitudinal shear forces between the deck and the supporting beam. The shear studs are the primary horizontal shear resistance component in the composite element and are the only code-approved method for achieving sufficient composite action [1]. However, shear studs impose construction constraints such as extra cost, time, licensed professionals and trip hazards.

Composite flooring with shear studs is typically used in industrial buildings, i.e. large spans and heavy live loads. In case of lighter live loads and shorter spans, designers often opt for non-composite options but have to use deeper cross sections for girders. Currently, during construction, arc-spot weld (puddle welds) or screw pins (Hilti-screws) are used in order to temporarily fasten the metal deck sheets in place on top of the supporting members. (Fig. 2) displays two alternate fasteners. To date, all design codes do not account for puddle welds [3] or screws [4] in the load resistance, i.e. no composite action is exploited in a puddle weld or Hilti-screw connector design. This is mostly due to the lack of research allotted to this topic. If these two simple fasteners can develop and maintain composite action, significant economic benefits can be achieved. Easy and faster construction as well added safety to the workers and construction site through eliminating the trip and injury hazards from using projected shear studs are just prime examples. Moreover, the anticipated construction cost (include labour, tools and material) puddle-welds and Hilti-screws is less than 50 and 20% of shear studs, respectively. Furthermore. the extra strength from considering a composite action will be beneficial to reduce the depth of the section and/or allow covering longer spans. These advantages will promote the composite floor system to residential building and make it more efficient in industrial application.

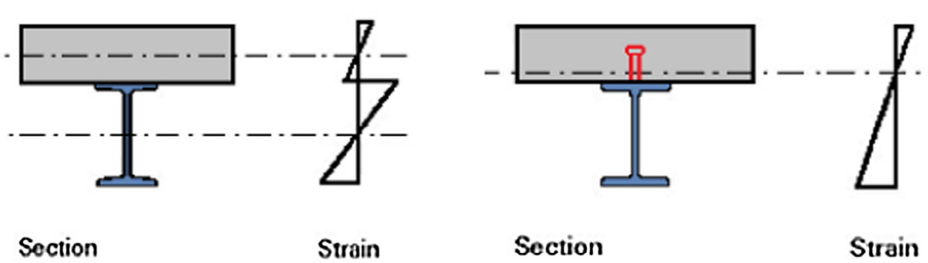
The objective of this research is to determine if composite action can be achieved without the use of shear stud and if partial or full-composite action can be achieved when puddle welds and Hilti-screw are used as an alternate shear connector for shear studs.

2. Background

Robinson and Fahmy (1978) presented the experimental results and analysis of a number of composite open-web joists with metal deck. Test results showed that composite open-web joists with ribbed metal floors have greater stiffness, strength and ductility than non- composite open-web joists [5]. Kennedy and Brattland, (1992) studied the effect of concrete shrinkage on the behaviour of composite steel joists and recommended the use of light top reinforcement mesh [6]. Wang et al. (2010) conducted twelve push-out test specimens of stud shear connectors with large diameter and high strength. It was found that overall capacity increased with the use large diameter and high strength studs [7]. Hedaoo (2012) studied the structural behaviour of composite concrete slabs with profiled steel decking with different shear span lengths, under static and cyclic loadings over simply supported conditions. Steel sheets with embossments were used to increase the composite interaction between the concrete and to improve their bond



(a) Composite beam with shear connectors (right) vs. non-composite beam (left)



(b) Dis-continuous strain profile (non/partial-composite section)

(c) Continuous strain profile (fully composite section)

Fig. 1. Composite vs. non-composite structures [2].