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Experimental study on shear strength of beam-and-block floors

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ABSTRACT

To better understand the response of beam-and-block floors in front of shear forces, 24 beam specimens that simulate a composite rib of a beam-and-block floor were tested. Beam specimens were primarily designed to evaluate the influence of the thickness of the compression slab on the shear strength. Other design variables were the type of joist, inverted T-beams or self-bearing I beams, and the amount of prestressed reinforcement. The details of the beam specimens, material properties, instrumentation and the testing procedure used are carefully described in this paper. They will be useful for researchers to compare and analyse other design approaches. The test results are presented, discussed and compared with different shear design approaches. It is concluded that the compression slab increases the shear strength of beam-and-block floors and that none of the studied models correctly predict the shear strength of these elements.

1. Introduction

Eugène Freyssinet took out the first patent on prestressed concrete in 1928. This was a process of applying compression by "pretension and bonded wires", which facilitated the manufacture of precast elements [1]. In 1935, Rutten patented in United States a non-prestressed beam-and-block floor system [2]. It is the combination of these two technologies what created the prestressed beam-and-block floor systems, and these relatively small prestressed beams were, in fact, one of the first and most popular applications of prestressed concrete. Despite the years, this technology has not fallen into disuse. Far from it, the beam-and-block floors are still used around the world. Fig. 1 shows the countries in which this research has been able to document the manufacture of prestressed beams for beam-and-block floors, which stretches across the five continents.

Although the machinery and facilities for the production of these prestressed beams, also called prestressed joists, is very similar to that necessary for the manufacture of hollow-core slabs, precast elements that allow longer floor spans, machinery for transporting and erecting is of lower cost for the prestressed joists. However, beam-and-block floors require more manpower for placement. In any case, in Spain and in many other countries, the beam-and-block floors are an efficient and economical alternative for the construction of suspended ground, or first floor, slabs in building structures, even though the rest of the floors of the building are designed using another structural type.

While the mechanisms of the flexural strength of prestressed beam-and-block floors are perfectly known, even the aspects related to its bending cracking behaviour [3] and its dynamic performance [4], this type of slab has a number of features that make it a complex element when referring to shear strength (Fig. 2):

- There are two different concrete types in the cross-section, even in the same horizontal fibre.
- The floor is built in successive phases.
- The cross-section has a precast prestressed concrete part, and another part of in situ reinforced concrete.
- The cross-section is T-shaped, with a variable width along the depth.
- In the case of precast concrete blocks, the consideration, or not, of the wall of the blocks as a shear resisting element.

All these features have probably produced that the research on the mechanisms of the shear strength of these elements is not as developed as for other structural elements, as for example for one-way concrete slabs [5], hollow-core slabs [6,7] or prestressed beams [8,9]. The result is that there are not many models or Code formulations that address the specific characteristics needed to evaluate the shear strength of this type of slabs, and the number of scientific and technical publications is also very low.

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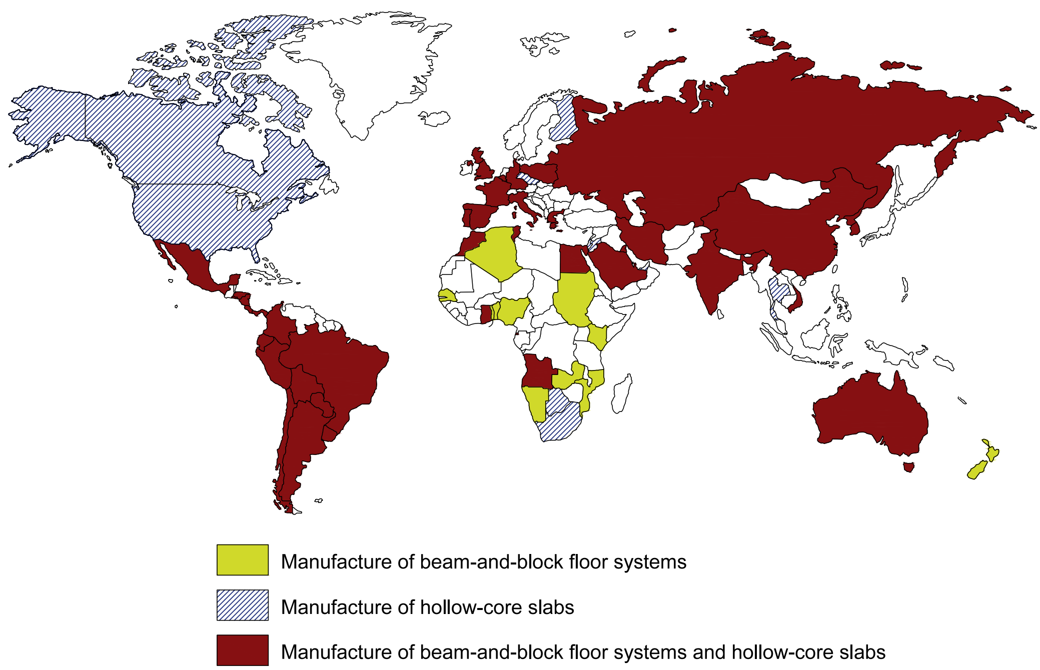

Fig. 1. World map with the countries where it has been found that beams for beam-and-block floor systems, hollow-core slabs, or both, are manufactured.

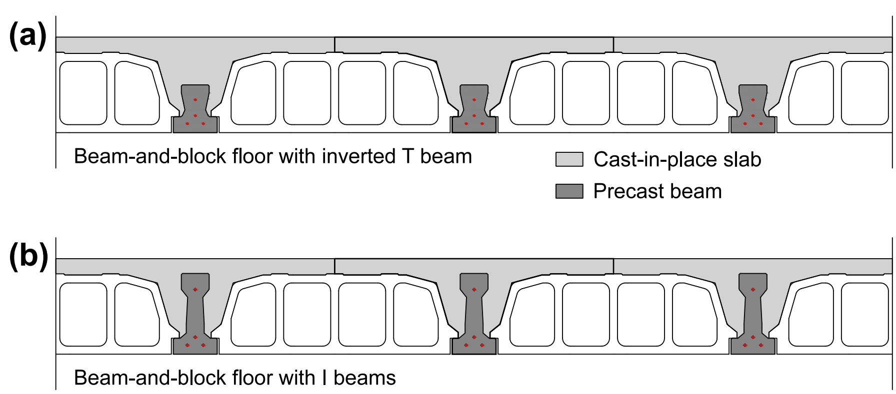

Fig. 2. Cross-section of beam-and-block floors. (A) Floor with inverted T beams and (B) Floor with I beams.

Regan [10] studied the effects on the shear strength of the precast blocks in beam-and-block floors. For floors composed of in situ topping and ribs, cast between precast blocks, the question arises as to whether the blocks can be taken to contribute to the shear resistance of the system. Once flexural cracking occurs at the section of the joints between adjacent blocks, it seems unlikely that there can be significant shear stresses between the smooth block faces. In that case, the active web breadth at these sections is probably only that of the in situ concrete. However, provided the blocks remain bonded, they should contribute to the tension resistance along the lengths of diagonal cracks. To evaluate it, Regan tested 10 T-beams cast in one piece, and six beams that had precast concrete plates positioned in the formwork to simulate parts of blocks. Regan obtained that the blocks of beam-and-block floors had a large effect on shear strength, and the shear resistance of the beam is more a function of the resistance to tension of the diagonal surfaces at which cracks form, and this includes the resistances of the precast components, at least for the widths of precast concrete considered in his tests [10].

Ribas and Cladera [11] studied the effects of differential shrinkage and creep in the shear strength of beam and block floors by means of FEM analysis. They concluded that these effects produced a decrease on the shear strength of less than 5% and, therefore, and due to the complexity of taking into account his phenomena, they recommended not to consider them.

Sagaseta and Vollum [12] compared the predictions of EC2 [13] and the shear strengths of beams with shear reinforcement and with rectangular, T- and I-shaped cross-sections tested by them and by other authors. The increased shear strength of the T and I beams, relative to the rectangular beams, was attributed to the contribution of the compression flange, and depending of its geometry, the flange increased the shear strength of the I and T beams by between 10% and 20%. This is a similar result that the presented in the ASCE-ACI Committee 426 in 1973 [14], based on the experimental tests carried out by Placas and Regan [15], in which beams with wide flanges had about 20% greater ultimate shear strength than equivalent rectangular beams. Giaccio et al. [16] reported increases on the concrete contribution to the shear strength up to 200% for beams with significant flanges respect of that of similar rectangular beams.

The authors have not been able to find any reference in the scientific literature on the influence of the flanges on the beam-and-block floor shear strength. In fact, the authors have not find any paper with a documented experimental campaign studying