Engineering Structures 176 (2018) 681–696

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

# Efficacy of roof-to-beam mechanical connections on the diaphragm behaviour of precast decks with spaced roof elements

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ARTICLE INFO

*Keywords:*
Precast concrete
Seismic performance
Roof-to-beam connections
Diaphragm action
Pseudo-dynamic testing
Non-linear analysis
Seismic design

ABSTRACT

The diaphragm action of slab/roof decks ensures the collaboration of different parts of the lateral load resisting system of a building. In reinforced concrete precast buildings for industrial/commercial halls, not seldom the deck is not provided with a cast-in-situ topping: this results into diaphragm action to rely upon the floor mechanical connections alone. In this study, the efficacy of three different typical floor-beam connections, namely hot-rolled angle brackets, cold-formed angle brackets and dowel bars, on the diaphragm action of the deck has been investigated. To this purpose, simplified macroscopic "behaviour models" have been proposed, based on the results of monotonic and cyclic tests carried out within the framework of the research project Safecast (FP7-SME-2007-2; GA 218417/2009). A numerical model of a dry-assembled precast structure with mechanical floor-to-beam connections has been checked against the results of cyclic and pseudo-dynamic tests carried out on a full-scale prototype within the framework of the Precast Structures EC8 project (GA G6RD-CT-2002-70002). Non-linear dynamic analyses have then been performed to investigate the diaphragm action effectiveness of the three different technological solutions to connect slab and beams considering a seismic action orthogonal to the roof elements. Different stiffness distributions of the lateral load resisting system have been considered, investigating the possible bracing effect induced by an integrated connection system of the external cladding panels. A simplified "design-wise" analytical interpretation of the phenomenon is also formulated and checked against the numerical results.

## 1. Introduction

The seismic behaviour of precast frame buildings is affected by the diaphragm effectiveness of the floor/roof decks [1–6]. In partially-precast concrete buildings, for which in-situ concrete casting is required for completion after assemblage, a structural concrete topping is often present. The deck provided with structural topping, if the latter is correctly reinforced and detailed, features a large diaphragm stiffness, and can be assumed as rigid, following the rules of the main structural codes [7,8]. The seismic behaviour of the decks in partially-precast structures was investigated in [9–13], mainly with reference to typical multi-storey parking facilities built in the USA. A design framework for partially precast structures was set in [14–18]. Tailored tests on topping connections were performed by [19,20] and full-scale prototype testing was performed by [21].

As a matter of fact, in several European countries, dry-assembled precast structures, which are assembled without any in-situ concrete casting following the concept of the maximum industrialisation of the construction process, are much more common.

In this type of structures, the diaphragm effectiveness has to rely upon the mechanical connections of the floor/roof decks only. Not seldom the roof decks are made with spaced elements, to allow zenith lighting of the buildings (Fig. 1), which, by preventing mutual floor-floor connections to be installed, may also result in jeopardised effectiveness of the diaphragm action.

The seismic behaviour of the decks of dry-assembled precast structures lacks an in-depth investigation. Preliminary studies on the subject are available in [22–25]. The most typical floor-beam connections consist of angle brackets for TT elements and dowels for other types of elements, such as the wing-shaped ones [26,27]. Tests on typical and tailored floor-beam mechanical connections have been reported in [28] and [29], respectively. Tests on dowel connections are reported in [30–35]. Design rules for these connections were proposed in [36]. The results of cyclic and pseudo-dynamic tests on full-scale prototypes of precast structures with dry-assembled diaphragms are reported in [37–44].

Three typical mechanical roof-to-beam connections have been considered in the present work. They are: (i) hot-rolled angle brackets

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https://doi.org/10.1016/j.engstruct.2018.09.027
Received 10 October 2017; Received in revised form 11 September 2018; Accepted 12 September 2018

**Fig. 1.** Roof of precast dry-assembled industrial building made with spaced wing-shaped elements with zenith light openings.

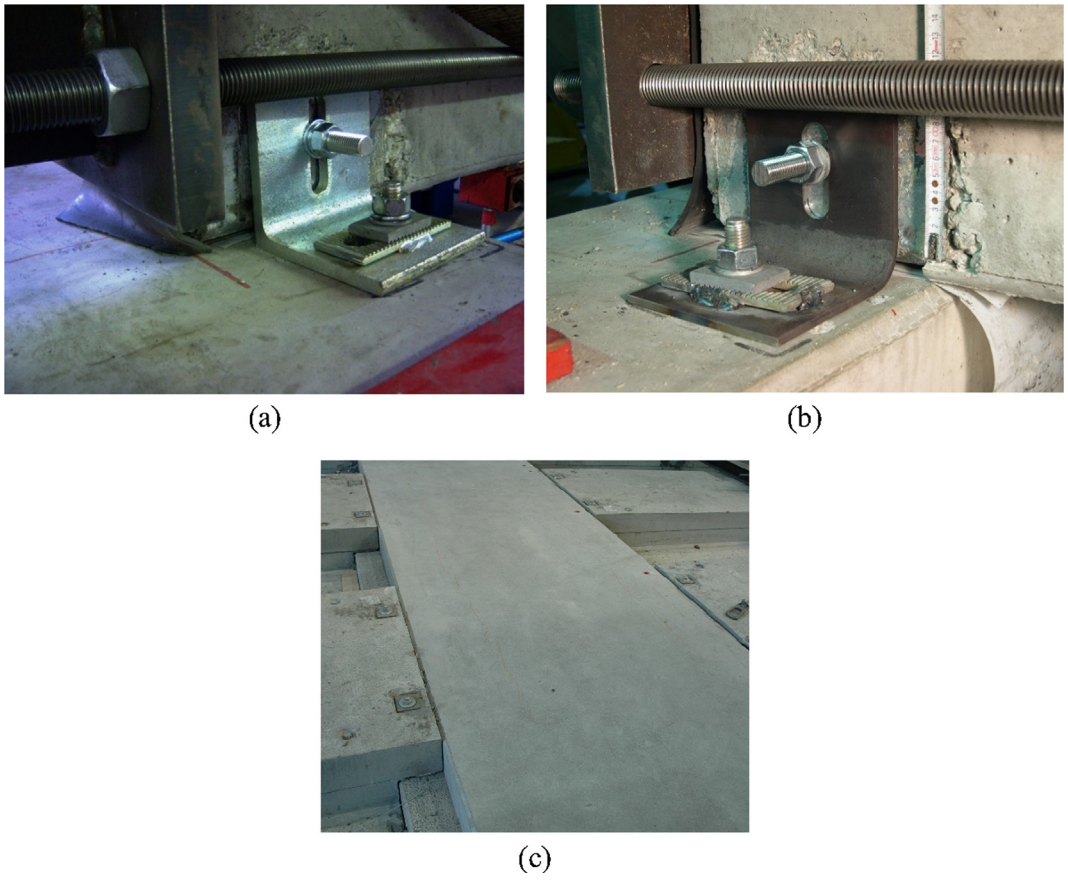


**Fig. 2.** Typical roof-to-beam connections: (a) hot-rolled angles, (b) cold-formed angles, (c) dowels.

(Fig. 2a), made by cutting thick hot-rolled steel profiles and connected by post-inserted anchors to the beam and by a threaded bar to the roof element; (ii) cold-formed angle brackets (Fig. 2b), made by bending steel plates at right angle and connected by post-inserted anchors to the beam and by a threaded bar to the roof element; (iii) dowels (Fig. 2c), vertically protruding from the beam and inserted into a pocket left into the roof element, generally completed with cast-in-situ mortar.

In this study, the effectiveness on the diaphragm action with each of the three different typical floor-beam connections has been investigated. To this purpose simplified macroscopic "behaviour models" have been proposed, based on the results of tests carried out within the framework of the research project Safecast (FP7-SME-2007-2; GA 218417/2009) [28]. A numerical model of a dry-assembled precast structure with mechanical floor-to-beam connections has been checked against the results of cyclic and pseudo-dynamic tests carried out on a full-scale prototype within the framework of the Precast Structures EC8 project (GA G6RD-CT-2002-70002). Non-linear dynamic analyses have then been performed to investigate the diaphragm action