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A new shallow precast/prestressed concrete floor system for multi-story buildings in low seismic zones

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ABSTRACT

A key economic value for multi-story office buildings, hotels, and similar structures is to have a shallow floor system that reduces the total building height and, consequently, reduces overall building cost. Additionally, minimizing the need for shear walls results in additional economy and flexibility in re-modelling. This paper presents the development of a new precast prestressed concrete framing system that achieves both goals for buildings up to six-story tall built in areas of low seismicity. The proposed system consists of precast hollow core slabs, shallow inverted tee beams, multi-story columns, and cast-in-place topping, which are the common components in conventional precast construction. The proposed system eliminates the need for permanent concrete column corbels, and achieves continuity in the inverted tee beam through column block-outs to improve the system's resistance to lateral and gravity loads. Hollow-core slabs are also made continuous to minimize the need for shear walls in the hollow core direction. An experimental investigation was carried out to verify the theoretical capacities of the system components and to ensure that demand was met for the conditions being considered. Testing was performed using a full-scale specimen representing the area around an interior column. Test results indicated that the system is simple to construct and connection capacities can be adequately predicted using strain compatibility and shear friction theories. The design and construction of an office building in Lincoln, NE was presented as a successful implementation of the new system.

1. Introduction

A conventional precast concrete floor system consists of hollow-core (HC) slabs supported by inverted-tee (IT) beams, which are supported on column corbels or wall ledges. This floor system allows rapid construction of multi-story buildings that are economical, durable, fire-resistant, and that have excellent deflection and vibration characteristics. The top surface of the HC floor system can either be a thin non-structural cementitious topping or cast-in-place (CIP) concrete composite topping that also provides a continuous leveled surface. Despite the advantages of conventional precast HC floor systems, they have two main limitations: (a) relatively large floor-to-floor height due to the depth of standard IT beams and the use of relatively large column corbels, and (b) uncoupling of the gravity load resisting system from the lateral load resisting system and, thus the need for a significant amount of shear walls.

Typically a 30 ft span would require a 28 in. deep IT plus a 2 in. topping resulting in a total floor depth of 30 in. and a span-to-depth ratio of 12; in addition to a 14 in. deep column corbel [11]. On the other hand, a cast-in-place post-tensioned concrete floor can have a structural floor depth of 8 in. resulting in a span-to-depth ratio of 45 and without corbels [10]. However, cast-in-place post-tensioned concrete floors are time consuming and relatively uneconomical due to the labor intensive operations of shoring and forming concrete. A shallow depth precast concrete floor could be very favorable due to its rapid construction and high quality control. Reducing the depth of structural floor and eliminating column corbels also result in a reduced floor height and saves on the cost of architectural, mechanical and electrical systems, allowing construction of additional floors for the same building height. Shear walls are typically used in conventional precast concrete floor systems to resist lateral loads. However, owners and developers would prefer the architectural flexibility of beam/column frames compared to using structural walls which increase

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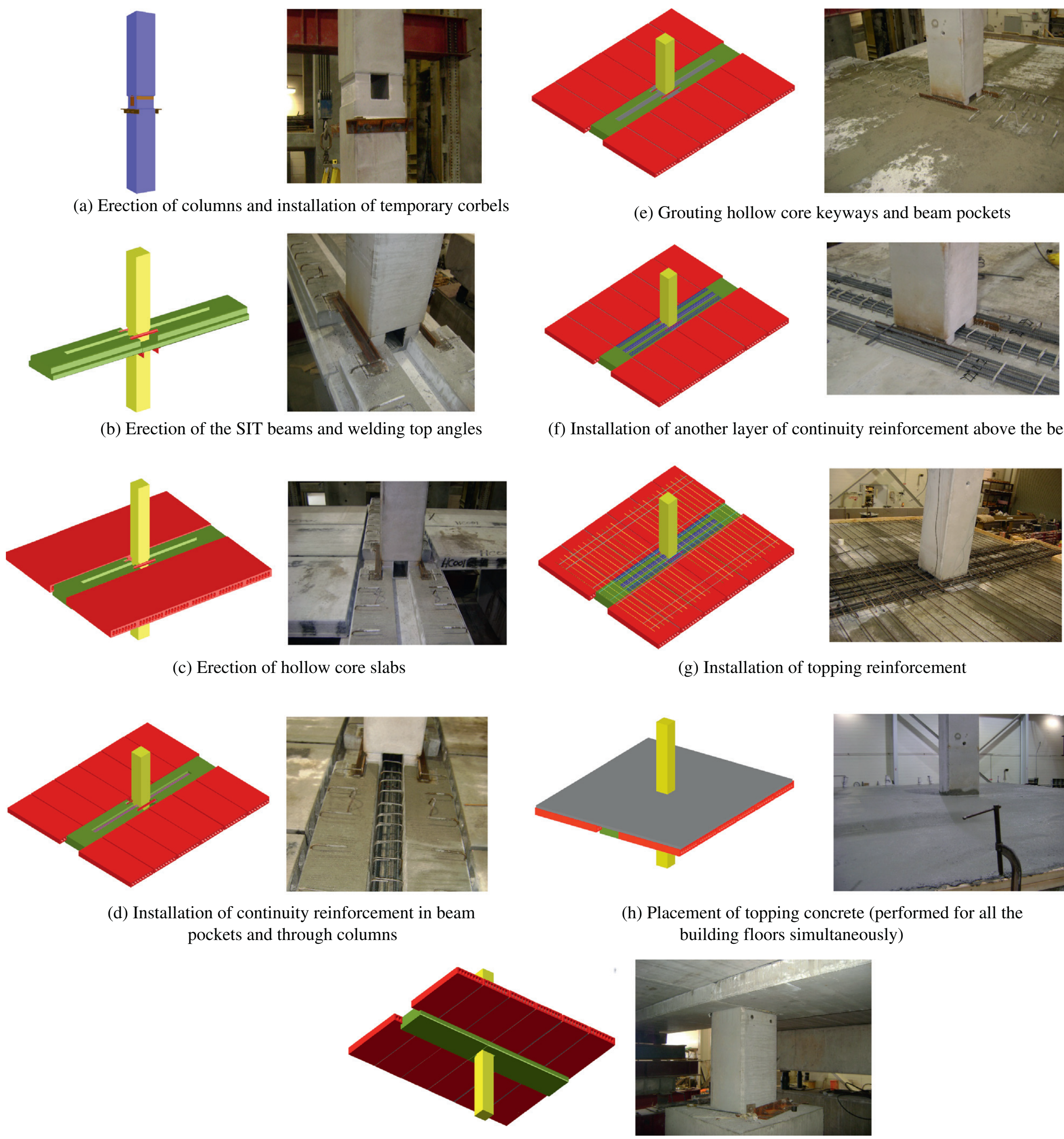
construction cost and time, and limit remodeling options. Precast concrete floor systems could gain significant advantages over cast-in-place floor systems, if they could be designed as continuous floor systems that minimize the need for shear walls limiting their construction to around stair wells and elevator shafts.

Innovative precast floor systems have been developed over the last few decades by researchers and industry experts. Examples are the shallow floor system with single-story precast columns developed by Low et al. [7], Low et al. [8]; the floor system of inverted tees and double tees with openings in their stems to pass utility ducts developed by Thompson and Pessiki [14]; and the total precast floor system with integrated column capital for multi-story buildings developed by Hanlon et al. [5]. Although these systems are shallow precast floor systems, their use have been limited due to the need for special forms to fabricate and/or special equipment to erect these systems.

The main objective of this paper is to present the development of a shallow precast concrete floor system for multi-story residential and commercial buildings that eliminates the limitations of existing systems with regard to clear floor height and continuity, while maintaining speed of construction, simplicity of fabrication and economy. To achieve this general objective, the following specific objectives were identified for the proposed system:

- A span-to-depth ratio that reaches 24 under normal loading conditions (up to 100 psf).



(a) Erection of columns and installation of temporary corbels

(e) Grouting hollow core keyways and beam pockets

(b) Erection of the SIT beams and welding top angles

(f) Installation of another layer of continuity reinforcement above the beams

(c) Erection of hollow core slabs

(g) Installation of topping reinforcement

(d) Installation of continuity reinforcement in beam pockets and through columns

(h) Placement of topping concrete (performed for all the building floors simultaneously)

(i) Removing temporary corbels

Fig. 1. Construction sequence of the proposed framing system.