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Basic applicability of an insulated gang form for concrete building construction in cold weather

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HIGHLIGHTS

- The rigid urethane board was integrated into external side of gang form.
- The temperature history and strength development of concrete were examined.
- The applicability of developed gang form was verified through field test.

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ABSTRACT

In cold weather, construction sites typically find it difficult to achieve quality results when preparing concrete structures. In such construction projects, improper selection of the formwork for concrete placement can delay the project schedule and result inconsiderable expense. In this study, rigid urethane board was bonded to the exterior surface of a conventional gang form to ensure sufficient compressive strength of the concrete structures in cold weather. To verify the applicability of the insulated gang form, the temperature history, maturity, and characteristics of strength development of the concrete were examined and compared with the conventional type after the concrete had been placed.

1. Introduction

The proper selection of formwork is an important factor in the successful completion of construction projects of high-rise buildings that involve reinforced concrete structures [1]. Initially, steel was used for reinforcement in the early stage of construction of such tall buildings to shorten construction time. Recent improvements in construction materials and methods have made it possible to shorten the period needed for the construction of reinforced concrete structures [2]. With the growing migration of workers to urban areas, the demand for high-rise residential buildings has rapidly increased, and construction companies are making an effort to comply by augmenting productivity [3].

Compared with the conventional formwork currently used at most sites where high-rise structures are being created in Korea, the gang form offers many advantages [4]. Quality control has been emphasized in the construction of these modern buildings, as has the need to follow and satisfy project schedules [5]. To remain synchronous with the prosperous business cycle in the construction industry, it is important to avoid delays irrespective of the season.

In cold weather, the two most important factors in high-rise building construction are (1) to prevent damage to freshly poured concrete caused by freezing temperatures and (2) to ensure the initial compressive strength of the concrete so it will be sufficiently strong when it hardens [6–9]. Freezing can degrade the compressive strength of concrete depending on diverse factors; however, if the compressive strength is comparatively well developed before the concrete is initially exposed to frost, the structure can resist the damage related to freezing temperatures [10–12].

Today, lots of chemical admixtures are employed in construction site to prevent fresh concrete from freezing damages [13].

Several measures can be taken to prevent fresh concrete from such damage, including curing by means of spatial heat or covering with a blanket (or tent), or strength adjustment through the use of chemical admixtures [6–8]. Methods such as heating the mixture of water and aggregate to increase the temperature of the concrete mixture itself or applying chemicals or antifreeze solutions to

Abbreviation: RC, reinforced concrete.

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lower the freezing point of the concrete are also typically employed at construction sites during the winter [14]. The latter applications have been the focus of numerous studies. Among them is a representative study conducted by Mustafa Culluand and Metin Arslan who explored the physical and mechanical properties of concrete treated with anti-freezing agents in cold weather [15]. In addition, Jae-Suk Ryou and Yong-Soo Lee explored the application of an accelerator to attain sufficient strength of concrete in an attempt to prevent the freezing of fresh concrete [9].

In Korea, however, chemical admixtures are seldom used owing to the issues of mixing control, degradation of the concrete's initial strength, and chlorides (inducing corrosion of reinforcement); instead, curing through spatial heating, which allows direct control of the curing temperature, is employed [16]. But this method has certain disadvantages, such as the high cost of fuel, the need to install temporary equipment, a reduction in efficiency, and environmental contamination from the associated air pollution [14,17]. Therefore, studies are now under way to explore different approaches that can compensate for the disadvantages of curing by means of spatial heating. One basic study involves insulating formwork for concrete structures in cold weather, as carried out by Kyoung-Min Kim, and Sang-Jin Jung has examined the characteristics of concrete relative to its temperature history, along with the application of gang forms coated with polyurethane foam for use during cold weather [17,18].

In this study, instead of applying chemical admixtures to lower the freezing point of concrete, we examined the use of insulated gang forms that would prevent the fresh concrete from being exposed to cold outside air and that would exploit the concrete temperature to avoid early damage from freezing and thus achieve the necessary initial compressive strength of the concrete.

2. Experimental conditions

2.1. Experimental plan

For our experiment, we prepared the insulated gang form by integrating the rigid urethane board by bonding it to the exterior of a conventional gang form. The test was designed to examine and compare the temperature distribution in fresh concrete and the characteristics of compressive strength development of the concrete placed inside both the prepared (insulated) gang form and a general gang form. To conduct the test under the conditions of a cold environment, we used a refrigerated container. Fig. 1 shows a cross-section of the prepared insulated gang form integrated with the bonded rigid urethane board on the outside.

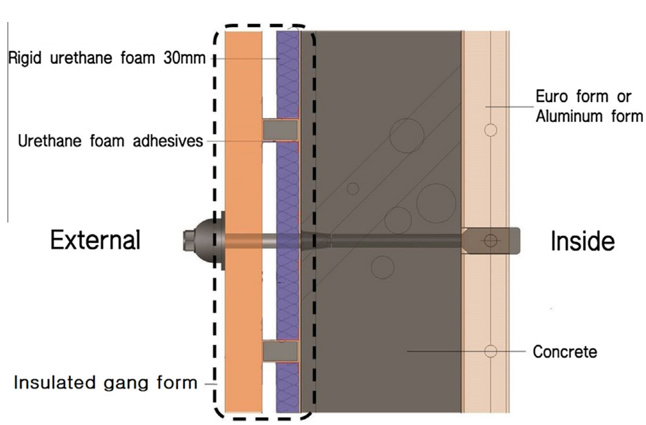

Fig. 1. Configuration section of insulated gang form.

The gang form integrated with the rigid urethane board facilitates installation and obviates additional preparations at the construction site, in contrast to previous reports that involved insulated formwork [17]. Moreover, our insulated gang form would not only require less manpower but also realize greater economic efficiency, as compared with conventional curing and other methods for protecting fresh concrete structures against winter temperatures. Figs. 2 and 3 show the configuration and methods of curing and protecting both the conventional gang form and the insulated gang form.

The desired compressive strength of the concrete was set at 24 MPa. To mimic the conditions for curing concrete in cold weather, we set the outer-air temperature to be between 5 °C and −15 °C to correspond to the typical range of outdoor temperatures during the winter season. The period required for obtaining measurements of the compressive strength, concrete temperature, and the maturity of the concrete was set at 28 days. Tables 1–3 summarize the details of the experimental design, the curing plan, and the concrete mixture.

2.2. Materials

2.2.1. Cement

We used ordinary Portland cement of ASTM C150 for the test. Table 4 lists the physicochemical properties of the cement.

2.2.2. Aggregate

According to the ASTM C33, coarse aggregate with a maximal grain size of 25 mm was used with a fine aggregate of washed sand. Table 5 lists the physical properties of the aggregate.

2.2.3. Chemical admixture

An air-entraining and water-reducing agent of the naphthalene family was chosen as the chemical admixture for the test. Table 6 lists the physical properties of the chemical admixture.

2.2.4. Insulated gang form

The insulated gang form was fabricated by using a steel plate (3.0 mm thick),with squared steel pipes (50 × 30 × 2.3 mm) employed for the horizontal and vertical members. The insulation of the rigid urethane board to be bonded onto the gang form was 30 mm thick. Table 7 lists the physical properties of the insulating materials.

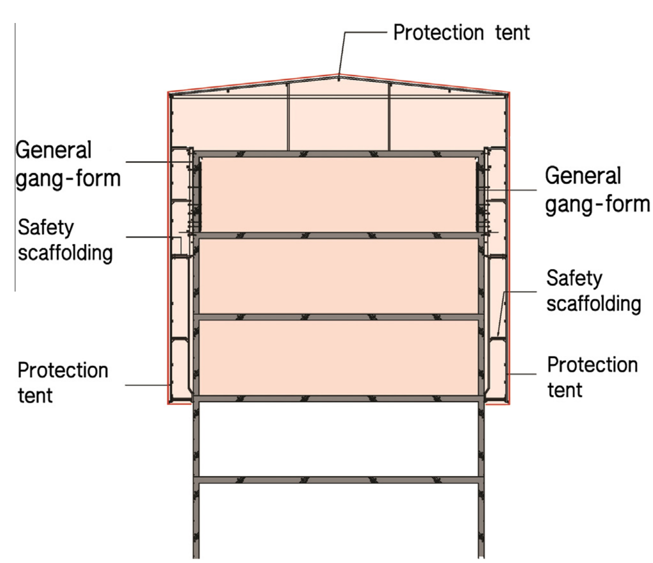

Fig. 2. General gang form.