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Effect of wall friction on variation of formwork pressure over time in self-consolidating concrete

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ABSTRACT

In order to accurately predict the varying of formwork pressure over time, it is necessary to consider various factors influencing the development of formwork pressure. A prediction model has been previously proposed, but that model has some limitations in that only intrinsic material characteristics are taken into account. Extrinsic effects such as wall friction, formwork flexibility, and external temperature are excluded in the model. This study focuses on the wall friction effect as one of the extrinsic factors. First, by incorporating the intrinsic model and friction stress acting on the interface, a method of calculating formwork pressure considering the wall friction effect is suggested. To find out how much friction stress is acting on the interface and how it varies over time, formwork pressure tests were performed with circular column formworks having three different diameters. In these columns, the vertical pressure at the bottom and the lateral pressures were measured. To calibrate parameters of the intrinsic model for the same material as that used in the formwork pressure tests, additional tests were conducted with a specially designed apparatus that can exclude effects of extrinsic factors. From tests and analysis results, it was found that wall friction greatly affects the variation of formwork pressure over time. The newly suggested calculation method can give a good prediction of real formwork pressure.

1. Introduction

Self-consolidating concrete (SCC) was first developed in Japan and has become popular in construction all over the world because it offers a lot of advantages. SCC can flow easily into complex shapes; it improves strength and durability; it reduces labor; and it shortens the placing and finishing time. However, the formwork pressure of SCC is higher than that of normal concrete [1–3] mainly due to SCC's rheological feature, that is, lower yield stress [4–6]. Therefore, it is necessary to build more expensive and stronger formworks. In addition, the cancellation time of formwork pressure may be longer than that of ordinary concrete, which results in delay of the removal time of the formwork. In order to reduce the maximum lateral pressure and the cancellation time, it is necessary first to understand and predict the variation of formwork pressure over time.

There was pioneering research to find out the mechanism for SCC formwork pressure, where thixotropic behavior (or structural buildup at rest) was turned out to be the origin of the variation or decrease of the pressure during and after casting [6–8]. This current study focuses on suggesting a methodology to quantitatively predict the formwork pressure, rather than investigating the mechanisms related to the variation of formwork pressure.

Formwork pressure is influenced by many factors such as mix proportions, placing temperature, admixture, external temperature, casting rate, and friction at the interface between the concrete and the formwork. These factors can be classified into two categories, intrinsic and extrinsic factors. The intrinsic factors are related only to the material itself, while the extrinsic factors are related to the external environment and the formwork conditions. Most of the existing prediction models do not separately consider the intrinsic and extrinsic factors. Some empirical models [9–14] are primarily used to estimate the peak pressure, and do not provide information on the formwork pressure's varying over time. Another prediction model [15] was developed based on the rheological properties such as viscosity, yield stress, and thixotropy of the material. A model describing the intrinsic pressure response was previously developed by the authors [16]. This model only considers the intrinsic characteristics of materials. The applicability of the proposed model to cement-based materials for the prediction of formwork pressure, excluding extrinsic factors, was verified. Nevertheless, in order to

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