

DETERMINATION OF FORMWORK STRIPPING TIME FOR REINFORCED CEMENT CONCRETE MEMBERS AT VARIOUS TEMPERATURES

ABSTRACT

One of the most accepted composite structural construction materials used globally to build infrastructure and shelters is reinforced cement concrete (RCC). Formwork is essential to RCC construction, ensuring concrete structures are cast precisely and accurately. Determining the duration necessary for removing formwork is a significant concern in reinforced concrete construction, as safety and cost-effectiveness rely on it. The removal of formwork should be delayed until the hardened concrete has attained adequate strength to withstand all applied stresses. The duration of removing the formwork is mostly based on the types of cement and concrete grade, as well as the ambient temperature and relative humidity. There is a scarcity of scholarly articles and other sources specifically addressing the duration required for removing formwork from RCC constructions. Furthermore, there is a dearth of studies, which investigates the impact of temperature on the duration required for formwork stripping. Hence, the author employed an experimental methodology to ascertain the duration required for removing the formwork from RCC structures under varying ambient environmental temperatures.

The study initially entailed thoroughly examining the provisions in the codes of India, Britain, the United States, Japan, Germany, and Uganda concerning the duration required for formwork to be removed. It has been observed that there is a lack of consistency among countries regarding formwork stripping time. Certain codes depend on attaining a minimum level of strength, while others rely on establishing the minimum duration for stripping, and some codes describe both criteria. The results of my study indicate that most codal provisions do not provide specific guidelines about stripping time when the temperature is below 15°C.

Certain codes recommend field testing and non-destructive tests (NDTs) to ascertain the duration required for stripping, especially when there are deviations from the parameters indicated in the standards. Typically, for structural elements that bend, it is advisable to remove the bottom formwork once the freshly poured concrete reaches a compressive strength that is 70% or greater than the intended strength. The duration for removing the formwork of various concrete components, as outlined in the codes of practice adhered to in different nations, ranges

from twelve hours to twenty-eight days. Nevertheless, certain regulations have specified the duration for removing formwork based on the compressive strength of the concrete in place, ranging from 3.5 MPa to 14 MPa (N/mm²).

Based on the experiments conducted by the author, removing the formwork for vertical concrete structures within a time frame ranging from 6 hours to 5.5 days is necessary. The specific duration depends on the type of cement used and the temperature range, which can vary from 0°C to 45°C. The duration for removing horizontal formwork varies from 2.6 to 124.4 days, depending on the cement grade and the ambient temperature range of 45°C to 0°C. It is important to use caution when removing the formwork to avoid excessive stress and potential damage to the concrete, particularly when the surrounding temperature is below 15°C. This is due to the lack of guidance in many standard codes of practice regarding the appropriate period for stripping when the temperature is below 15°C. Based on the laboratory findings from this study conducted at IIT Delhi, it is recommended that nominal mix cement concrete should possess a compressive strength exceeding 3.50 MPa to safely remove the vertical formwork in concrete made with ordinary Portland cement (OPC). For concrete made using Portland Pozzolana Cement (PPC), the compressive strength should be at least 3.25 MPa.

Nevertheless, variations in material properties, environmental circumstances, and construction techniques might influence the time of the stripping process. This study investigates non-destructive testing techniques to ascertain the optimal timing for removing formwork without causing harm to the concrete structure. This research utilizes rebound hammer and ultrasonic pulse velocity (UPV) measurements technique. In the case of flexural members, the bottom formwork should not be removed until the hardened concrete reaches a compressive strength of at least 70 percent. A minimum strength of 3.5 MPa is required for vertical concrete elements to prevent spalling of concrete. Based on these criteria, this study suggests that the formwork should be removed when the rebound number (RN) exceeds 3.0 units and the ultrasonic pulse velocity (UPV) is greater than 2.6 km/s for vertical components. For flexural concrete elements, it is advised that the RN and UPV values exceed 15.0 units and 3.0 km/s, respectively. The proposed technique offers a more reliable and accurate way of evaluating the time at which formwork can be removed, considering different atmospheric conditions and variable compositions of concrete.

The optimal efficiency in RCC construction is attained by removing the formwork as soon as feasible while ensuring that there is no damage caused to the concrete. This study aims to assess

the efficacy of superplasticizers and nanomaterials in the fresh concrete mixture for decreasing the time required to remove the formwork from reinforced concrete structures in cold ambient temperatures (below 15°C). According to the experimental investigation, 0.5% superplasticizers combined with 1% Nano-colloidal silica (NCS) can effectively reduce the time required for stripping, resulting in lower formwork expenses. This effect remains even when the ambient temperature falls below 15°C. Vertical formwork significantly reduces the time needed for formwork stripping, decreasing it from 4.5 days to just one day within the 0-5°C temperature range. However, the time required to remove the slab formwork is reduced from 54 to 37 days at 0°C. The cost analysis demonstrates that by incorporating 0.5% superplasticizers and 1% NCS into the concrete, the total cost of RCC can be decreased due to the reduction of formwork expenses. This study presents the initial results of experiments carried out in a concrete laboratory to ascertain the compressive strength and extraction time for formwork removal from vertical and horizontal concrete elements using Destructive and Non-Destructive Tests.

The research determines the formwork stripping time for members made of reinforced cement concrete at different temperatures. This information can be used by practitioners in the RCC works carried out at different temperatures, more so when the temperature is below 15°C.

Keywords: Admixtures, Ambient temperature, Cement, Concrete, Cost analysis, Destructive tests (DT), Horizontal and vertical formwork, Maturity of concrete, Nanomaterials, Non-destructive tests (NDT), Rebound hammer (RH), Stripping period, Superplasticizers, Ultrasonic pulse velocity (UPV).