Guide for Shoring/Reshoring of Concrete Multistory Buildings

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This guide presents information and design criteria for shoring/reshoring operations during the construction of reinforced and post-tensioned multistory buildings. It provides methods for developing safe construction schedules and provides design examples. It is written for the use of formwork engineer/contractors and engineer/architects.

Keywords: construction loads; falsework; form removal, formwork; post-tensioning; reshoring; shoring.

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CHAPTER 1—INTRODUCTION

In multistory cast-in-place concrete building construction, freshly cast floors are placed on formwork that is temporarily supported by a system of shores and reshores until the concrete has the ability to be self-supporting. Construction loads, imposed by the shoring system on the slabs below, may be significantly larger than the design loads of those floors. Furthermore, the concrete of slabs below may not have attained sufficient strength before the construction loads are applied. As a result, it is critical to determine the early-age load strength of the floor slabs, including punching shear strength, to avoid the possibility of partial or total failure of the structural system due to construction overload. To reduce and distribute the large construction load on the floor immediately below, to several lower floors, it is important to add reshores on lower levels. Therefore, an engineering analysis that considers both the construction load distribution and the early-age load-carrying capacity of the concrete slabs should be performed before shoring/reshoring operations begin.

Formwork failures and failures caused by improper reshoring or premature removal of supports and inadequate lateral bracing, have periodically occurred throughout the history of concrete construction. Premature removal of shores and reshores can contribute to construction failures or defects such as permanent excessive deflections (sagging) or cracking in the completed structure. Also, if over-loaded prematurely, time-dependent deflections under load (creep) will be larger, and sagging is more likely to be both noticeable and objectionable.

Decisions regarding the removal of forms and relocation of the shores are too often made without the benefit of a proper analysis of the structural effects, or in many cases, without any analysis at all. Still, there is no commonly accepted method considered as the proper analysis in the construction industry.

To ensure satisfactory performance and structural safety during construction, a thorough understanding of construction loads applied to the slabs at early ages is necessary. Equally important is knowledge of the behavior and the strength of early-age concrete members that support their own weight and construction loads.

The formwork engineer/contractor is usually guided in formwork operations by the following codes, standards, or guides:

- ACI 347, "Guide to Formwork for Concrete"
- ACI 318, "Building Code Requirements for Structural Concrete"
- ACI 301, "Specifications for Structural Concrete"
- ANSI A10.9, "American National Standard for Construction and Demolition Operations—Concrete and Masonry Work—Safety Requirements"
- OSHA 29 CFR, "Construction Safety and Health Regulations for Construction"
- SEI/ASCE 37, "Design Loads on Structures During Construction"

Other documents that can provide formwork design requirements or guidelines include state and local building codes, and guidelines prepared by contractors, formwork manufacturers, and certain construction agencies.

The above referenced documents provide basic guidelines for general formwork operations. At the present time, however, there are no codes or standards that provide detailed design and construction requirements specifically for shoring/reshoring operations for multistory reinforced and post-tensioned concrete construction. Investigation for usable procedures to establish safe and cost-effective shoring/reshoring operations has been ongoing for several decades. The effort has focused on two major areas: determining the distribution of loads carried by the concrete structure during construction, and estimating the strength of the concrete members to resist the construction loads.

This report outlines the importance of proper formwork design for multistory structures and provides basic requirements for safe construction. ACI SP-4, *Formwork for Concrete*, serves as an expanded commentary to ACI 347, "Guide to Formwork for Concrete," and provides detailed information relative to formwork practices, including a discussion of and procedures for shoring/reshoring analysis. ACI 318, "Building Code Requirements for Structural Concrete," requires contractors to furnish the building official, upon request, with the structural calculations and concrete strength data used in planning and implementing shoring/reshoring operations. Such data and information should be furnished to the engineer/architect who should evaluate the effects of construction loads to immediate and long-term deflections. This code requirement obliges contractors and formwork designers to acquire an understanding of the construction loads and the structural behavior of the buildings during construction. This understanding enables them to develop a rational shoring/reshoring system design that is as economical as possible without compromising safety, quality, and serviceability.

The objective of this document is to present practical guidelines for the design of shoring/reshoring operations. This document provides formwork design tools to evaluate the safety of construction schedules for multistory reinforced concrete and post-tensioned concrete structures.

CHAPTER 2—SHORING/RESHORING CONSTRUCTION NEEDS

2.1—Definitions

The following terms will be used in this guide. All these terms may also be found in ACI 347.

backshores—shores placed snugly under a concrete slab or structural member after the original formwork and shores have been removed from a small area at a time, without allowing the slab or member to deflect; thus, the slab or other member does not yet support its own weight or existing construction loads from above.

centering—specialized temporary support used in the construction of arches, shells, and space structures where the entire temporary support is lowered (struck or decentered) as a unit to avoid introduction of injurious stresses in any part of the structure.

engineer/architect—the engineer, architect, engineering firm, architectural firm, or other agency issuing project plans