

Guide to Consolidation of Concrete in Congested Areas (Reapproved 1997)

Reported by ACI Committee 309

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This guide is primarily directed toward architects/engineers and constructors. It describes various situations where design requirements result in highly congested forms that impede consolidation of concrete. Techniques to overcome these difficulties are presented. The guide also identifies for constructors various difficult placing and consolidation conditions and proposes solutions such as special procedures and mix proportions. In addition, the guide alerts constructors to review design drawings closely where congested areas are expected to insure that appropriate allowances have been included in their bids.

Keywords: admixtures; concrete construction; consolidation; embedment; formwork (construction); mix proportioning; parting agents; placing; pre-placed aggregate concrete; reinforced concrete; reinforcing steel; splicing; structural design; surface defects; tunnel linings.

CONTENTS

Chapter 1-Introduction, pg. 309.3R-1

Chapter 2-Criteria for designation as a congested area, pg. 309.3R-2

- 2.1-Reinforcing steel
- 2.2-Embedments and boxouts
- 2.3-Formwork
- 2.4-Definitions

Chapter 3-Factors contributing to congestion problems, pg. 309.3R-3

- 3.1-Reinforcing steel arrangement
- 3.2-Embedded parts/boxouts
- 3.3-Formwork

- 3.4-Mix proportioning
- 3.5-Concrete placing methods
- 3.6-Construction considerations
- 3.7-Tunnel linings

Chapter 4-Consequences of congested areas in concrete construction, pg. 309.3R-4

- 4.1-Honeycombed concrete
- 4.2-Reduced density
- 4.3-Increased cleaning costs
- 4.4-Increased formwork costs
- 4.5-Increased placing costs

Chapter 5-Recommended practices, pg. 309.3R-6

- 5.1 -Design considerations
- 5.2-Construction considerations
- 5.3-Summary

Chapter 6-References, pg. 309.3R-9

- 6.1 -Specified and/or recommended references
- 6.2-Cited reference

CHAPTER 1-INTRODUCTION

Many concrete structures such as those with seismic provisions, post-tensioning, and high-strength concrete are difficult to consolidate because of congested areas within the formwork. This congestion can result in

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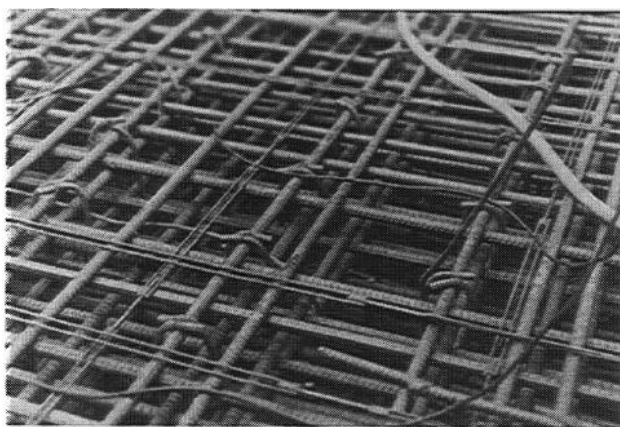


Fig. 1 -Dense reinforcing steel

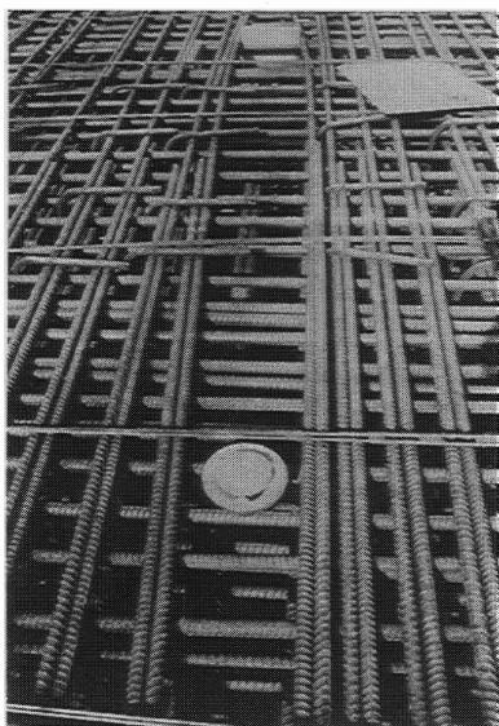


Fig. 2-Dense reinforcing steel

structural inadequacy and time-consuming and expensive remedial work.

Various techniques have been employed to alleviate this type of problem. This document presents an overview of the factors contributing to the problem, the consequences of inappropriate concrete procedures in these areas, and recommended practices to minimize the problem.

As a prerequisite to successful concreting in congested areas or difficult placing conditions, it is important that architects/engineers become more aware of how their designs will be constructed, and that constructors become more aware of special procedures and necessary precautions. Most importantly, communication between the architect/engineer and constructor is essential to insure that the design details, construction materials, and procedures are compatible.

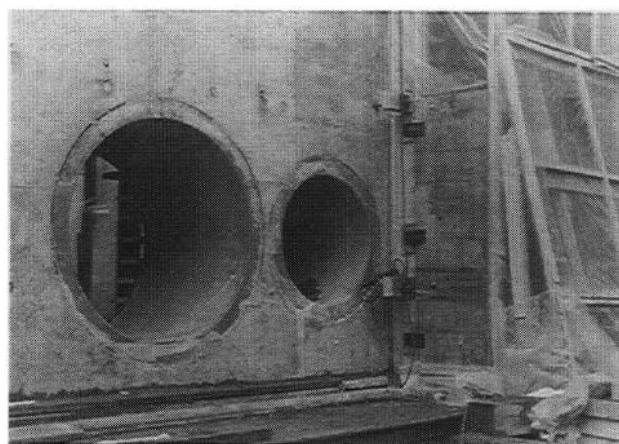


Fig. 3-Closely spaced embedments

CHAPTER 2-CRITERIA FOR DESIGNATION AS A CONGESTED AREA

Congested areas are those in which the reinforcing steel, embedments, boxouts, prestress ducts and anchorages, or configurations and form shape make concrete placement and consolidation difficult to achieve. To obtain the desired placement results and degree of consolidation, access for inspection and consolidation, special concrete mixtures, special formwork, additional consolidation effort, and specific placing methods are frequently used.

2.1-Reinforcing steel

Congestion causes problems when the clear spacing between reinforcing bars or between a bar and the form is less than $1\frac{1}{2}$ times the maximum size of coarse aggregate used in the concrete mixture. This condition is more likely to occur at splices and bends in reinforcement and at beam-column connections. Sometimes, congestion is caused by multiple layers of reinforcement in which the bars in the lower layers are not directly below those in the upper layers, as shown in Fig. 1 and 2. See ACI 117 for tolerances for concrete construction and materials.

2.2-Embedments and boxouts

Embedments consist of items such as plumbing, prestress hardware, ducts, connection inserts, and anchorages for handling devices that are cast into the concrete (see Fig. 3). Boxouts are used to form openings, keyways, or pockets in the concrete. When these items restrict the placement and consolidation of the concrete, they cause congestion. The spacing between embedments, boxouts, and the form must be at least $1\frac{1}{2}$ times the nominal maximum size of the coarse aggregate to avoid this problem. Frequently, these items cause congestion because the concrete cannot be placed and consolidated easily underneath them (see Fig. 4). The architect/engineer must be alert to such conditions, and construction procedures must provide for proper placement and consolidation of concrete on the undersides of these embedments.

2.2.1 Embedments may be anchors, weld plates, me-

chanical and electrical boxes, threaded inserts, or other devices used to attach or incorporate items after formwork is removed.

2.2.2 Sleeves are openings that generally go all the way through a wall or slab to allow piping or other penetrations to pass. Formwork for these openings is often completely removed prior to piping placement.

2.2.3 Boxouts are either removable or stay-in-place. Removable boxouts are similar to sleeves but generally are much larger, as in door and window boxouts or hatch boxouts in slabs. Most removable boxout forms can be adapted readily for placement and vibration tubes, as described in [Section 5.1.2](#). If these removable forms are not provided, the constructor must move the concrete horizontally under the formed boxout, which usually results in segregation of the concrete, adds additional stress to the boxout form, allows the buildup of frictional resistance along the formwork, and slows down the entire placement. Without placement and vibration tubes, the degree of consolidation is generally reduced under a boxout. Boxouts often are designed with open bottoms.

Stay-in-place boxout forms, such as hollow metal door and window frames, often require bracing and do not allow placement and vibration tubes to be cut through them. This increases the chances of voids or incomplete consolidation.

2.2.4 Formwork accessories, architectural items such as cast-in numbers and letters, form liners, rustication, chamfers, and keyways can cause simple to complex consolidation problems in one manner or another. This is especially true of horizontal rustication or keyways in a wall.

2.3- Formwork

The surface texture, shape, type, and orientation of the formwork may restrict concrete placement. Consideration needs to be given to form release agents that are compatible with form texture, particularly if intricate shapes are to be cast into the concrete at the formed surface. These release agents may also serve to somewhat reduce the frictional resistance between the plastic concrete and the form, thereby improving the ease of removing entrapped air. The forms must also be designed for easy removal.

Used or poorly oiled wood forms are more likely to hinder consolidation than steel or plastic-lined forms. The frictional resistance of a wood form impedes the flow of concrete and can create difficulty when used in conjunction with congested embedments.

2.4-Definitions

2.4.1 External form tie rods-External form tie rods are installed on the outside of narrow wall forms in the longitudinal direction. The tie rods are attached to the bulkhead walers at the ends of the wall.

2.4.2 Lie-flat hose-Lie-flat hose is a very pliable polyvinyl chloride reinforced discharge hose, typically

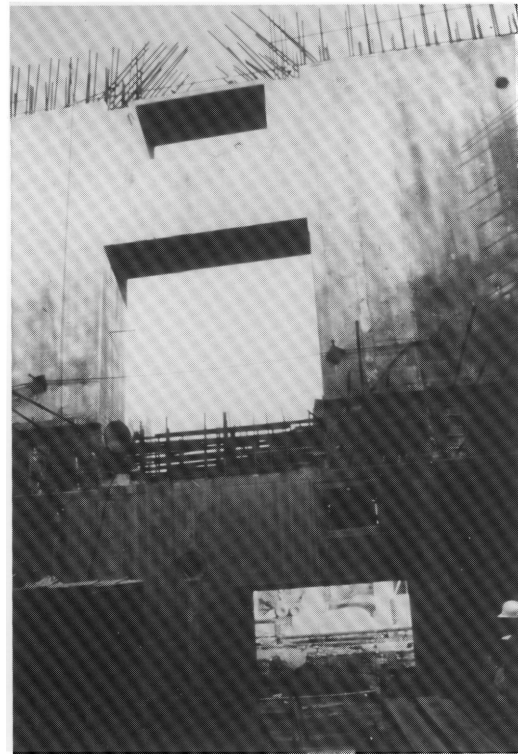


Fig.4--Stacked boxouts

purchased in 4- or 5-m. (100- or 125-mm) diameter by 300-ft (92-m) long rolls.

2.4.3 Side ports-Side ports are temporary openings in the form on one side of narrow walls. The purpose of the side ports is to allow insertion and extraction of vibrators and to observe consolidation of the concrete.

2.4.4 Slide valve-A slide valve is a short piece of steel pipe with a slide plate mounted in it. The pipe is the same diameter as the concrete discharge hose and the other end is bolted to the form. The purpose is to allow pumping of concrete through the open slide valve to completely fill a form to the underside of a horizontal structural steel beam. When the form is full, the slide plate is closed, preventing the concrete from seeping back through the valve.

2.4.5 Steel reinforced hose-Steel reinforced hose is a rubber concrete-discharge hose reinforced with strands of steel wire between the tube and outer cover.

CHAPTER 3-FACTORS CONTRIBUTING TO CONGESTION PROBLEMS

3.1 -Reinforcing steel arrangement

The reinforcing steel arrangement must take into account the factors that contribute to congestion. Seismic and strength design requirements often result in a reinforcing steel layout that inhibits access for preplacement cleanup and concrete placement and consolidation. Recommended practices are described in Chapter 5.

3.1.1 Splices-The density of reinforcing steel resulting from current design procedures often makes it difficult to provide continuity of reinforcing bars by the traditional method of lap splices. The various methods