AMERICAN SOCIETY OF CONCRETE CONTRACTORS

TECHNICAL BULLETIN
STRAIGHT TALK ON TECHNICAL TOPICS AFFECTING CONCRETE CONSTRUCTION

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Free Fall of Concrete

Concrete placing operations often are planned to allow for the free fall of concrete. This planning also must consider any segregation that might occur when the concrete free falls into place. Techniques such as placing concrete through windows in wall forms or equipment such as collecting hoppers, trunks, or drop chutes can minimize the effects of concrete free fall. However, using these measures unnecessarily can increase concreting costs without benefiting the in-place quality of the concrete.

Specification Requirements

Sometimes specifiers and inspectors dictate the maximum free fall distance of concrete because they believe limiting free fall is necessary to minimize concrete segregation. Usually they limit the free-fall distance to 3 to 4 feet, but occasionally the limit is as little as 2 feet.

However, neither ACI 301-99, “Specifications for Structural Concrete,” nor ACI 318-99 “Building Code Requirements for Structural Concrete,” limits the maximum distance concrete can free fall.

ACI 304-99, “Guide for Measuring, Mixing, Transporting, and Placing Concrete,” says that if forms are sufficiently open and clear so that concrete is not disturbed in a vertical fall into place, direct discharge without the use of hoppers, trunks, or chutes is usually desirable.

ACI 301, 318, and 304, however, all require placing concrete in its final position to avoid segregation.

DOES FREE FALL CAUSE SEGREGATION?

Does Free Fall Cause Segregation?

At least four field studies have shown that free fall from great distances doesn't reduce concrete quality. Although all the field studies have been for caissons, the results should also apply to walls, columns, and mat foundations. In the Chicago area, contractors routinely construct concrete caissons by allowing the concrete to free fall to depths of up to 150 feet. Full-length cores taken from more than 100 of these caissons over a 30-year period do not show segregation or weakened concrete. In 1999, FHWA (Ref. 1) eliminated its 25-foot free-fall limitation and now allows unlimited free fall of concrete.

Baker and Gnaedinger report. In a 1960 investigation (Ref. 2) concrete was dropped into a 3-foot-diameter, 80-foot-deep caisson without striking the sides. After 2 weeks, cores were removed and visually examined. A 50-foot-deep observation excavation was made along the shaft, and the strength of the concrete was tested with a rebound hammer. The investigators found no concrete segregation or reduction in compressive strength.

DuPont tests. Turner (Ref. 3) describes field tests in which concrete was dropped vertically 50 feet into caissons of various diameters. Technicians removed samples of fresh concrete from three caissons ranging in diameter from 3 to 8 feet. The unconfined, free-fall concrete samples were analyzed for changes in aggregate gradation. The analysis showed that the gradation of aggregate in the concrete that had been dropped was essentially the same as that in the concrete sampled directly from the ready-mix truck. No segregation of the concrete was detected.

FHWA tests. In 1994, STS Consultants conducted an extensive study of the effects of free fall on concrete (Ref. 4). They placed concrete in four 60-foot-long, 3-foot-diameter drilled shafts. To assess concrete quality, they took standard 6x12-inch cylinders for each lift placed and compared them in lab tests to 4-inch-diameter cores taken after the concrete was adequately cured. None of the lifts placed exhibited any signs of segregation. The design strengths of concrete dropped directly into the center of the caissons ranged from 13% lower to 20% higher than the reference cylinder strengths. The measured core strengths varied from 5510 to 7060 psi, all well above the 4000-psi design strength. Several other interesting discoveries were made during this study:

CONCRETE HITTING REBAR

- **Concrete hitting rebar.** The placing chute was positioned so that concrete would directly strike the rebar. The investigators noted that this placement technique resulted in a considerable amount of ricocheting of aggregate, movement of the rebar cage, and complete coating of the rebar with cement paste. In seven out of eight comparisons, the core strengths of concrete hitting the rebar were higher than those of concrete not striking the rebar. No segregation of the concrete was observed. The investigators noted that "the general expectation that striking of the rebar cage will cause segregation or weakened concrete is invalid."

EFFECT OF SLUMP

- **Effect of slump.** Concrete mixes with slumps of 4 to 5 inches and 7 to 8 inches were used. A high-range water reducer (superplasticizer) was added to the high-slump mixes. The investigators found no segregation or strength differences between the low- and high-slump concrete mixes.

MIXING SOIL WITH CONCRETE

- **Mixing soil with concrete.** When concrete was directed into the caisson's soil sides and rebar cage, it did cause a problem. The movement of the rebar against the soil sides and the action of the concrete hitting the soil caused the soil to slough off and mix with the concrete. Because of the concern of soil-contaminated concrete, the investigators did not recommend allowing the concrete to strike the rebar cage or caisson sides.

WHAT FIELD STUDIES AND PRACTICE PROVE

What field studies and practice prove.
Free fall of concrete from heights of up to 150 feet, directly over rebar or at high slumps, DOES NOT:

- Cause segregation, or
- Reduce strength

Restricting free-fall heights DOES decrease concrete production, increasing owners' costs without increasing concrete quality.

REFERENCES

References

1. FHWA, Drilled Shafts: Construction Procedures and Design Methods, Vol. 1, FHWA-IF-99-025, August 1999.
2. C.N. Baker Jr. and J.P. Gnaedinger, "Investigation of the Free-Fall Method of Placing High Strength Concrete in Deep Caisson Foundations," 1960.
3. C.D. Turner, "Unconfined Free-Fall of Concrete," Journal of the American Concrete Institute, ACI, Farmington Hills, Mich., December 1979, pp. 975-976.
4. STS Consultants Ltd., The Effects of Free Fall on Concrete in Drilled Shafts, Report to the Federal Highway Administration, 1994.

Note: References 1, 2, and 4 are available from The International Association of Foundation Drilling, Dallas Texas; phone (214) 343-2091.

The information contained in this bulletin originally appeared as an internal Baker Concrete Construction article authored by Dr. Bruce Suprenant in February, 2001.