3. Limits for under-reinforced flexural sections and reinforcement ratios in columns
4. Immediate and long-term service load deflections
5. Lateral load drift
6. Vibration effect
7. Satisfaction of static equilibrium
8. Column slenderness
9. Deep beam behavior
10. Diaphragm proportions
11. Resistance to effects of lateral loads
12. Ductility

## DRAWINGS

Engineering and detail drawings show in a condensed form the final results of the planning and design stages. Drawings, along with other documents, serve as instructions to the contractor as to how to build the structure, and form part of the basic contract. The drawings should be complete and in sufficient detail so that no misinterpretation can be made, and from which only one structure can be built.

Standard accepted drafting principles should be used in the general layout and presentation scheme of drawings.

The engineer should not abbreviate the preparation of drawings by substitution with general notes and typical schedules. While general notes and typical schedules have their place and are essential, the reliance on them can lead the contractor into building a structurally unsafe structure.

To avoid errors in drawings, it is essential that they be carefully checked. Once construction has started errors are either built in and hidden by the concrete or cause delays if discovered.

Foundation plans, in particular, need careful dimensioning, and elevations have to be clearly indicated on the drawings. Foundation drawings and specifications should adequately outline backfilling operations, particularly in cases where backfill requires the structural support of foundation walls.

Schedules form a necessary part of reinforced concrete drawings, but should be presented in such a way that they are not subject to misinterpretation. Cutoff points for bars should be shown on drawings or diagrams and cross-referenced to the schedule.

Congested beam-column intersections should be carefully laid out and checked, and if necessary, shown as a separate sketch on the schedule or detailed on the detail design drawing.

If engineering drawings do not show the details of the entire project, they will be supplemented by shop drawings prepared by others. The engineering drawings must be sufficiently complete and accurate to show exactly how the items are to be detailed.

Shop drawings should be checked and approved for the intent of the design, and the responsibility for shop drawings clearly specified.

## SUMMARY

With the increase in scope and complexity of many present day structures, it becomes important that sufficient time is spent on thinking through and checking in the concept, planning, design and detailing stages, to avoid gross errors and subsequent failures of structures.

A design is not really finished until the completed structure has stood the test of time. The design engineer should therefore become familiar with the structure during construction and should maintain a continuing interest in its performance.

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# Field Corrections to Partially Embedded Reinforcing Bars

By WILLIAM C. BLACK*

**Discusses field correction of reinforcing bars. Results of bend tests on two grades of bar are presented. It is concluded that bars can be successfully reworked in the field.**

**Keywords:** bars; bend tests; bending (reinforcing steels); concrete construction; reinforced concrete; reinforcing steels.

One frequently encountered problem in the field is correcting rebars partially embedded in concrete. This may be due to incorrect fabrication, incorrect placing, accidental misalignment after concreting or even a design change. ACI 318-71 Section 7.1.4 Bending, states that "All bars shall be bent cold, unless otherwise permitted by the Engineer. No bar partially embedded in concrete shall be field bent except as shown on the plans

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## TABLE 1—TENSION TEST RESULTS

| Size | Original yield strength, psi | Original tensile strength, psi | Final yield strength, psi | Final tensile strength, psi |
|---|---|---|---|---|
| #11 | 66,000 | 103,200 | 61,500 | 99,200 |
| # 8 | 71,300 | 110,100 | 73,500 | 114,000 |

or permitted by the Engineer." The Commentary to the Code elaborates on this section as follows:

"This section requires that all bends be made cold unless otherwise permitted by the Engineer. In this sense the Engineer is the engineer or architect employed by the owner to perform inspection. For unusual bends exceeding ASTM bend test requirements special fabrication may be required. It may be necessary to bend bars that have been embedded in concrete, and it usually is not possible to provide a pin of the minimum diameter specified in the Code at the point of bend. Such bending cannot be done without authorization of the inspecting engineer. If he so authorizes he will determine whether or not the bars can be bent cold without damage or if heating is necessary. If heating is permitted it must be controlled to avoid splitting of the concrete or damage to the bars. When bars are not embedded in thin sections, temperatures ranging from 600 to 800 F are usually satisfactory to permit bending without damage to the bars or the concrete."

We have had occasion to investigate the feasibility of field bending rebars partially embedded in concrete and would like to share this information with Journal readers.

One small test* involved bending sample ASTM A 615 Grade 60 #8 and #11 bars, one bent cold and the other preheated. The #8 bar was cold bent to an approximate 75 deg angle around a 7½ in. pin and cold straightened. The #11 bar was cold bent similarly around a 9½ in. pin and heated to approximately 1100 F and straightened. The bars were then dye checked for cracking with negative results and tension tests were then made with the results shown in Table 1.

For the #8 bar it is apparent from the test results that the break occurred away from the cold worked area.

Subsequently, a small series of pilot tests was run on ASTM A 615 Grade 40, #10 and #11 bars. The test results are given in Table 2.

We recently completed a similar series of tests on ASTM A 615 Grade 60 bars. Those results are given in Table 3.

As can be seen from the foregoing limited data, reinforcing bars can be successfully reworked in the field, both cold and with preheat but there are dangers. First, considerable field experience indicates that cold bending or rebending of partially embedded bars is hazardous at best. The statistical chances are that the bar may break, especially if ambient temperatures are low. Judicious application of heat prior to bending should increase the chances of a successful reworking. Even though the Commentary speaks of 600 to 800 F as the optimum temperature, our metallurgists feel that this is too low and may do more harm than good. They suggest temperatures of 1100 - 1200 F, and would even recommend higher temperatures to insure more "bendability" but realize that the yield and tensile strengths could be adversely affected if the temperatures exceeded this range, so the suggested temperature range is a practical compromise.

## TABLE 2—TEST RESULTS ON GRADE 40 BARS

| Bar size | Condition* | Yield point, psi | Tensile strength, psi | Elongation 8 in., percent |
|---|---|---|---|---|
| #10 | A | 41,300 | 74,500 | 22.5 |
| | B | 40,800 | 73,700 | 21.0 |
| | C | 39,100 | 72,600 | 19 |
| #10 | A | 44,100 | 77,400 | 24 |
| | B | 46,500 | 77,200 | 24 |
| | C | 44,100 | 75,600 | 20 |
| #11 | A | 44,900 | 78,500 | 19.5 |
| | B | 44,200 | 76,800 | 18.5 |
| #11 | A | 45,600 | 75,300 | 23 |
| | C | 44,500 | 74,600 | 21 |
| #11 | A | 49,600 | 86,300 | 19 |
| | B | 50,000 | 85,900 | 17 |
| | D | 49,400 | 86,500 | 16 |

*A = as rolled
B = as rolled, bar heated to 1100 F and air cooled
C = as rolled, bar heated to 1100 F, free bend to 45 deg, straightened and air cooled
D = as rolled, bar bent (cold) to 45 deg around 6d pin, heated to 1100 F, straightened, and air cooled

## TABLE 3—TEST RESULTS ON GRADE 60 BARS

| Bar size | Condition* | Yield strength, psi | Tensile strength, psi | Elongation, percent |
|---|---|---|---|---|
| #11 | A | 69,900 | 107,100 | 14.0 |
| | B | 66,700 | 104,500 | 16.0 |
| | C† | 67,100 | 102,600 | 7.5 |
| #11 | A | 73,200 | 111,500 | 15.0 |
| | B | 67,900 | 107,300 | 15.5 |
| | C | Bar broke in straightening | | |
| #10 | A | 70,600 | 105,800 | 15.0 |
| | B | 65,000 | 103,900 | 11.0 |
| | C | 64,900 | 88,200 | 3.0 |
| #10 | A | 78,000 | 115,700 | 10.5 |
| | B | 72,100 | 111,000 | 12.0 |
| | C | Bar broke in straightening | | |

*A = as rolled
B = as rolled, bar heated to 1100 F and air cooled
C = as rolled, bar heated to 1100 F, free bend to 45 deg, straightened and air cooled
D = as rolled, bar bent (cold) to 45 deg around a 6d pin, heated to 1100 F, straightened, and air cooled
†Bar broke in bend area

It is our belief then that partially embedded reinforcing bars can be successfully rebent (or bent for the first time, which should be less critical) if they are first preheated to 1100 - 1200 F, and then bent as gently and in as gradual an arc as possible. If there is no failure at the bend area, the reworked bars should be able to perform as originally intended. Heating must be performed in such a manner that there is no damage to the concrete and if the bend area is within 6 in. or so of the concrete some protective insulation may have to be applied.

### METRIC CONVERSION FACTORS

1 in. = 2.54 cm

1 psi = 0.07031 kgf/cm²

$t_C = (t_F - 32)/1.8$

*All tests reported herein were made on reinforcing bar specimens only, not on bar specimens embedded in concrete.