Concrete Construction and Structural Evaluation: A Symposium Honoring Dov Kaminetzky

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Determining Location of Reinforcement in Concrete

By Luke M. Snell

Synopsis: This paper is based on a presentation in honor of Dov Kaminetzky's long-term interest in how to use reinforcement location techniques in evaluating concrete structures. All methods of locating reinforcement are spot specific and can be used to determine the location of a particular reinforcement. In most cases, the engineer or contractor needs to confidently determine the location of the entire reinforcement system used in a member. This requires a detailed sampling plan to be developed and to use appropriate statistical methods. This paper describes four different reasons why reinforcement may need to be located within a structure and present a statistical method that is appropriate for each of these methods.

Keywords: Coring, Investigation, Reinforcement, Tolerance

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INTRODUCTION

Engineers and Contractors need to locate reinforcement in concrete primarily for four (4) different reasons. These are:

1. To locate safe areas where they can drill or core without hitting reinforcements (reinforcement avoidance).
2. To determine if the reinforcement had been installed.
3. To determine if the reinforcement had been installed in accordance with the contract drawing and industry accepted tolerances.
4. To determine the approximate location of the reinforcement when plans and specifications are not available.

Each of these types of investigations requires different procedures and will be discussed separately.

EQUIPMENT

The equipment used to locate reinforcement within concrete for each of the above methods is similar and generically called a cover meter. This equipment can vary from the very simple (basically, stud finders) costing less than $100USD to the very complex equipment, which provides an image of the reinforcement location and costs several thousand dollars (USD). Details on this equipment can be found by searching the internet for “Cover Meter” or “Reinforcement Locator.”

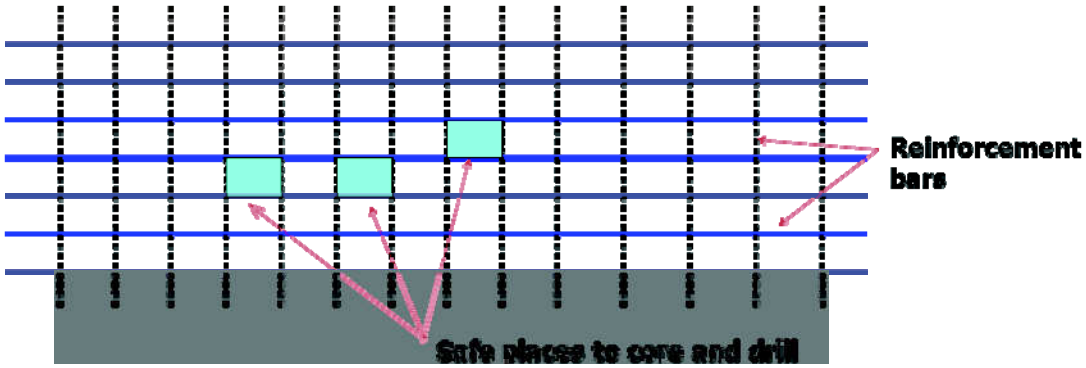
REINFORCEMENT AVOIDANCE

This method of finding a safe area to drill and/or core is relatively simple. However, a mistake resulting in hitting a prestress or post tensioned cable or reinforcement can be quite serious. If a person recognizes that reinforcement generally follows a pattern, this procedure becomes rather straightforward. The procedure requires scanning the concrete with the cover meter and marking on the concrete the location of the steel as indicated by the equipment. Use the same procedure to scan 90 degrees from the original scan. This method will locate the reinforcement in both directions. Several reinforcements should be located in order to estimate the spacing.[1]

Once the reinforcement in a particular area is determined, the location of a safe area to drill or core can be easily identified as the areas between the reinforcement. After the area to be cored or drilled has been identified, the selected area should be re-scanned to confirm that the area is without any reinforcement or steel.

EXAMPLE 1

- **Determination of safe coring and drilling area:**
  - . Scanning the surface. Marking: Chalk marks
  - . Connecting marks: straight lines
- **The safe Place to core and drill: Scan the selected area one more time for certainty**



SAMPLING PLAN

Each of the next procedures requires the development of a generalized statement about the location of the reinforcement. These types of investigations require that a random sampling plan with adequate number of readings be obtained. To obtain an adequate random sampling, you must show that every area that is being investigated has an equal chance of being selected. Typically, using a random numbers generator and selecting one corner of the project as a reference point will accomplish this. An example of this method would be to select the North East corner as a reference point and use a random number generator to get two random numbers of 37,77. The area to be investigated would be 37% of the distance South and 77% of the distance West of the reference point.[2,3] This procedure would be used to develop each area to be tested until the desired number of samples is obtained. The number of samples should be predetermined prior to the testing and should not be altered by the test results. To develop a good statistical program the investigated areas should be 30 or more samples.

DETERMINE IF REINFORCEMENT WAS INSTALLED

This type of investigation might occur when inspections are not completed during construction or the contractor needs to verify that reinforcement was installed. This method involves using the Fraction Defective method for analysis of the data. If at least 95% of the reinforcement had been installed at the designed locations with a probability of error of 5% or less, the following evaluation can be used:

1. Determine the number of samples that you want to test; ideally 30 or more samples should be selected
2. Use random numbers to locate the areas to be investigated
3. Record the number of places where reinforcement was not found in your predetermined sample size
4. Use the following table.

Sample size versus critical value:

Sample size	Critical value *
29-40	5
41-53	6
54-67	7
68-81	8
82-95	9

*** If the number of locations where reinforcement was not located equals or exceeds the critical value, then the reinforcement would be considered not successfully installed.**

5. Determine if the area being tested meets the accepted criteria as defined by the sample size versus critical value table given above.[2,3]

EXAMPLE 2

A contractor needs to verify that reinforcement was installed in a masonry wall. Thirty (30) random areas were selected by using the random number generator for study. Since the reinforcement was to be placed on 2 foot spacing – the area investigated was ±1 foot of the area selected to be tested. The investigator found that in the 30 test areas only one location did not have reinforcements. Since the critical number for this investigation was 5, the conclusion is that the contractor did install the reinforcement.

REINFORCEMENTS INSTALLED TO SPECIFICATIONS

The procedures to investigate if reinforcement was installed to the contract document and to industry accepted tolerances are similar to ones used to determine if reinforcement had been installed that was discussed above. The major difference is that the investigator must determine what tolerances are appropriate. ACI 117 "Specifications for Tolerances for Concrete Construction and Materials and Commentary"[4] is usually incorporated in the project specifications and are specific for each structural member. There are different limits for conventional reinforcement and welded wire reinforcement (WWR). Each of these will be discussed separately to illustrate how this method can be used.

CONVENTIONAL REINFORCEMENT

One example of tolerances would be from ACI 117.2.2.3, which states, "the vertical deviation for slab-on-ground (SOG) reinforcement is ± ¾ inch (19mm)." This would mean that reinforcements which were specified to be placed with a 3 inch (75mm) cover in a SOG would be considered to be successfully placed if it were located between 2¼ - 3¾ inches (57- 95mm).

EXAMPLE 3

A SOG was to be investigated to determine if the reinforcement cover was within the specified tolerance. The SOG was 8 inches (200mm) with the reinforcement cover specified to be 4 inches (100mm). ACI 117 was included in the specification.

All parties to the investigation agreed to use the Fraction Defective method for analysis of the data. The cover of the reinforcement would be considered acceptable if at least 95% of the reinforcement covers were located at 4 inches, the specified tolerances with a probability of error of 5% or less. Sixty (60) areas to be tested were randomly selected.

The reinforcement in this example would be considered successfully placed if the appropriate number of reinforcement covers were between 3¼ - 4¾ inches (83 to 121mm). During the investigation the testing laboratory found:

a). 53 locations had the reinforcements between 3¼ - 4¾ inches (83 to 121mm).

b). 7 locations had the reinforcements either placed higher or lower than the specified limits of 3¼ - 4¾ inches (83 to 121mm).

Since the critical number for this study was 7, the conclusion is that the reinforcement was **not** placed in accordance to the specifications.

The writer would recommend in the above example that the reinforcement cover for each location tested be plotted on the SOG drawing. The reinforcement covers that are not in compliance with the specification may be isolated to one area of the structure. If this is found to be true, a separate investigation may be warranted so that the areas of the noncompliance covers can be determined.

WELDED WIRE REINFORCEMENT (WWR)

ACI 117 states in R2.2.1, R2.2.2, and R2.2.3 "Tolerances for fabrication, placement, and lap splices for welded wire reinforcement are not covered by ACI 117 and, if required, should be specified by the specifier."[4]

In a previous research by the writer, several structural engineers who designed slabs-on- ground were asked what tolerance they would think appropriate when they use WWR. After receiving several opinions, the writer re-surveyed them with the most common opinion which was that the WWR should be located between 1/3 - ½ of the slab-on ground thickness (as measured from the top of the slab).[5,6]

Obviously, the tolerance of WWR is the structural engineers' decision and they should establish "reasonable limits" in their specifications. Some state Departments of Transportation include in their specification books exact tolerances for WWR, i.e. ±1 inch (25mm) of the designated location.

EXAMPLE 4

A 6 inch (150mm) slab-on-ground (SOG) was designed to have WWR at the neutral axis 3 inches (75mm) cover. After construction, the location of the reinforcement was questioned and an investigation was authorized. At the project meeting, it was agreed to use the Fraction Defective method for the analysis of the data. The WWR placement would be considered acceptable if at least 95% of the reinforcement was located between 1/3 - ½ the depth of the SOG thickness and there was a probability of error of 5% or less. It was also agreed to test thirty randomly selected areas. A cover meter measured the WWR location and the following results were obtained:

a). 26 measurements were between the 1/3 - ½ the SOG thickness (2-3 inches or 50-75mm)

b). 4 measurements were above or below the 1/3 - ½ the SOG thickness (2-3 inches or 50-75mm)

Since the critical number is 5, the WWR placement would be considered acceptable.

LOCATION OF REINFORCEMENT WHEN PLANS ARE UNAVAILABLE

When investigating structures that do not have plans and specifications, one of the first steps in the analysis of these structures is to determine the location of the reinforcement. To determine an estimate of the locations of the reinforcement, the engineer can use standard statistical procedures. For cover determination, this would involve

determining the average and standard deviation of the measured reinforcement covers for multiple randomly selected areas.

An estimate of the reinforcement covers for 95% of the reinforcement, use the formula of:

$$\bar{x} \pm 1.96\ S$$

Where: $\bar{x}$ is the average of all readings, **S** is the standard deviation.

EXAMPLE 5

An estimate of the cover of the reinforcement for a warehouse loading dock was to be determined. The engineer stated that a 95% confidence level would be acceptable for the investigation.

Fifty (50) random locations were examined and the following information was obtained:

$\bar{x}$ was calculated to be 3.22 inches (82 mm)

S was calculated to be 0.42 inches (11 mm)

Thus 95% of the reinforcement is estimated to be 3.22 ±1.96 (0.42) or 3.22 ±0.83 inches.

Thus 95% of reinforcement cover will be estimated to be between 2.40 - 4.04 inches (61mm to 103mm).[6]

CONCLUSIONS

It is important to realize that it is impossible to absolutely locate all reinforcements or to be able to make a statement that all reinforcements are per the contract documents. Every investigation of reinforcement location will have some uncertainty involved with it. By using a random sampling technique and applying the standard statistical procedures, the engineer can make a rational decision on the location of the reinforcement and it acceptable.

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