How good is your QC?

Part I of Concrete Quality Control Series

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Quality Control (QC), also called Process Control, is defined as those actions and considerations necessary to control the level of quality being produced in the end product. Regularly measuring aggregate moistures and correcting batch water is one such action; regularly verifying accuracy of measuring devices is another. A large number of ready mixed concrete companies are making significant efforts in QC. However, with Quality Control there is always room for improvement. Most companies probably feel that they have a good QC program. But how does a company know for certain? For example, to evaluate a company's operational efficiencies there are several benchmarks such as yards/hour, delivery costs for fleets, safety statistics that a company can measure and compare to industry averages. There are similar financial benchmarks developed by the NRMCA Business Administration Committee. Are there benchmarks specific to quality of ready mixed concrete? A start can be made by the company by annually monitoring its cost that can be attributed to poor quality. For some companies this may be a paradigm shift because they currently think in terms of the cost of their QC program. The cost due to poor quality may be measured by monitoring the following:

- Amount of rejected concrete (as a percent of the concrete produced) for non-compliance with project specifications such as slump, air content, etc.
- Cost to repair, replace or mitigate hardened concrete issues (cores etc.) because concrete did not meet purchaser's or specification requirements, expectation, etc.
- Variability in compressive strength as measured by standard deviation of the 5 top selling mixtures
- Perception of company's quality by customer through an annual customer survey – Excellent, Very Good, Good, Fair, Poor

The NRMCA Research Engineering and Standards Committee has developed the NRMCA Quality Measurement and Benchmarking survey to develop QC metrics or benchmarks for the industry. This survey will be initiated in 2010 and it includes the above questions as part of the survey. Any company or division can participate in this survey and compare its QC metrics to industry averages. As with all NRMCA surveys, confidentiality of individual company information will be maintained.

The first two of the above questions are fairly obvious. Rejected concrete even if it is beneficially reused is still money lost in terms of truck time and man hours. Cost to repair hardened concrete can involve core tests, evaluating cracking etc. and can become very expensive, even if it does not go to litigation. It is realized that concrete could be rejected or the producer could be asked to provide costs to address a hardened concrete issue for reasons that are not within the control of the concrete producer, such as delays in pour at the jobsite and jobsite mixture adjustments. However for the same contractor quality level a better quality producer is still likely to have a lower amount of rejected concrete and lower costs to deal with hardened concrete issues on an annual basis.

The third question is also very important and should be carefully monitored by every company for at least its 5 largest volume mixtures. Variability in compressive strength as measured by standard deviation (s) is an excellent measure of a company's QC. Table 1, which is a reproduction of Table 3.2 from ACI 214R-02[1], shows that the standards of concrete control based on general construction testing can vary from Excellent ($s < 400$ psi) to Poor ($s > 700$ psi). This applies to typical concrete strengths in the range of 3000 to 5000 psi.

A low s is desirable because it will result in a lower required average strength (f'_{cr}) that a producer needs in a mix submittal for a specified strength (f'_c). A lower required average strength will reduce the material costs for each class of concrete. ACI 318-08[2] requires that the required average strength (for f'_c<5000 psi) should be the higher of the following two equations:

$$f'_{cr} = f'_c + (1.34 \times s)$$

$$f'_{cr} = f'_c + (2.33 \times s) - 500$$

These equations are based on a one in 100 chance of the strength results falling below the two ACI 318 standard acceptance requirements.

Table 2 shows the target average strength calculated for $f'_c = 4000$ psi for different levels of QC. Assuming that for each 200 psi increase in f'_{cr} results in an increase in concrete materials cost of $1/yd^3, the cost savings due to the lower f'_{cr} can be estimated. It is instructive to note that improving QC, i.e. reducing "s" from 750 psi to 350 psi can result in a saving of $3.9/yd^3 in concrete materials cost due to a reduction in f'_{cr} from 5250 psi to 4470 psi! Another way to look at this is with poor QC ("s" of 750 psi as compared to 350 psi) one may have to add more cement at a cost of $3.9/yd^3 to avoid low strength test results. But unfortunately that will result in highly un-optimized mixtures and therefore is not a cost effective practice. Poor testing quality can also increase the "s". There are ways to help improve testing quality and that will be a subject of a different article. However, for the same level of testing quality the producer with better QC will still have a lower "s" and is therefore still in a better position.

The final question, which is the perception of a company's quality in the eyes of the customer, is also very important and should be monitored annually by concrete producers. A customer's perception of a company's quality is formed by a number of factors such as personnel, facilities etc. If the customer believes he will get a better product he will pay more for it. When the inevitable problems do occur the customer is more willing to look at himself, the lab or other factors beyond the concrete producer. The owner, engineer and architect are more willing to trust and even take the advice of the concrete producer when problems do occur. They may even consult and seek the help of the concrete producer on matters of specification and desired concrete performance. The bottom line is a happier, satisfied customer which will inevitably lead to more business and a higher profit.

Is it worthwhile not to invest in improved QC under certain circumstances?

Let us say a company primarily supplies to applications where there are no jobsite testing and acceptance requirements. Then the amount of rejected concrete related to testing will be negligible. Even though there will be no strength results to deal with the cost to repair will be slightly higher for the producer at a lower level of quality as he will incur greater call back costs due to aesthetics such as cracking etc. Compressive strength is not even measured so there is no advantage in reducing standard deviations. Finally, companies with an excellent quality perception are likely to command a better profit. So if the company primarily supplies to applications where there are no jobsite testing and acceptance requirements then the value of improved QC may not be so obvious. But if that company starts supplying to projects involving jobsite testing and acceptance requirements then they are likely to start seeing significant costs resulting from their lower level of QC. ■

References

1. *ACI Committee 214, "Evaluation of Strength Test Results of Concrete (ACI 214R-02)," American Concrete Institute, Farmington Hills, MI, 2005, 20 pp.*
2. *ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, 471 pp.*

Table 1. Standards of Concrete Control (adapted from ACI 214R-02 Table 3.2)

Overall Variation					
Class of Operation	Standard Deviation for Different Control Standards, psi				
	Excellent	Very Good	Good	Fair	Poor
General Construction Testing	< 400	400 to 500	500 to 600	500 to 700	> 400

Table 2. Cost Savings Due to Improved QC for f'_c = 4000 psi

QC Standards (ACI 214)	Excellent	Very Good	Good	Fair	Poor
s, psi	350	450	550	650	750
f'_{cr}, psi	4470	4600	4780	5020	5250
Cost Savings, $/yd^3	3.9	3.2	2.3	1.2	0.0

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