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Guarantee of concrete quality

Ken Day

Around the world there are various approaches for ensuring that the purchaser of concrete gets a material of the desired quality. The old-fashioned way of doing this was for the purchaser to specify in detail what materials and proportions were to be used and then to test the materials being delivered to ensure that they are of the intended quality. This method had the unfortunate by-product that it provided no incentive for the concrete producer to know or care anything about concrete technology or to have advanced plant and machinery and employ competent personnel. Under competitive tendering, the work tended to go to those who spent least on these items and were therefore least competent. For major projects, where concrete quality was critical, it was also necessary for the purchaser to employ inspectors to check on the quality of concrete as well as the condition of the plant and the procedures in use. This approach was obviously impractical for the general purchaser.

In some countries, the better concrete producers sought a means of eliminating unfair competition from sub-standard producers and formed associations to set standards for membership. In other countries, government departments set standards. I understand that in India, ready-mixed concrete business has been established in many urban centres during past few years and is growing rapidly. I also understand that the need for suitable quality control norms is being felt in the country. Although a late starter in the use of RMC, India would certainly be in an advantageous position, in that the country can learn from the experience of others and hopefully try to avoid their mistakes.

A key feature of the economical production of high quality concrete is the diminution in variability. It is not really possible to ensure low variability by inspecting plant, facilities and materials. Rather, it must be done by testing the resulting product. This raises the question of the reliability of testing and the assessment of test data. It is apparent that a compression test result is not necessarily accurate, and that in any case, a substantial number of tests are necessary in order to assess variability. Virtually all other tests on concrete are even less reliable and repeatable. This certainly does not mean that they are not useful and desirable, only that they are less suitable as a basis for the routine control of quality.

Assuming that standard mixes are being provided to a number of purchasers, it is obvious that it is more effective and economical to base control on production at the plant than on deliveries to individual projects. This can be organised through an independent laboratory and consultant (who may or may not be part of the same organisation) or by a consultant receiving results from a number of laboratories. The former, followed by the latter, was the role played by the author in Australia in the late 1960s. Where producers are prepared to establish high standard laboratories that are independently certified, this is an even more effective solution.

An interesting question is whether, given a flow of trusted data establishing that the concrete being produced is of low variability and satisfactory quality, it is still necessary to have independent regulation and inspection of the plant and equipment in use. An intermediate solution may require the producer to maintain records of plant performance and maintenance that are open to inspection at any time, but are normally only consulted by purchasers' representatives when a problem arises.

There is now a general recognition, in virtually all industries and most countries, of the need for and value of quality control. This has led to the establishment by the International

Standards Organization of a routine (ISO 9001) for establishing and certifying quality control systems. The routine is quite detailed and onerous. It requires producers to have a quality manual setting out their QC routine and procedures for dealing with all problems and eventualities. ISO is not specific to the concrete industry, so their requirements involve procedures and responsibilities, rather than aspects of concrete technology. In effect, it is possible to achieve certification of adherence to a documented routine, without that routine necessarily being optimum. A particular aspect of this is that the detection and resolution of problems may be effective but without reference to a time frame or establishment of the cause. For example, it may be based entirely on 28-day results, rather than early age results and it may not provide for advanced methods such as the author's multi-grade, multi-variable, cusum analysis, which can drastically reduce the time taken to detect any downturn and establish its cause.

So there are a number of aspects and alternatives in achieving a satisfactory guarantee of concrete quality. These can be summarised as:

(i) independent physical inspection and certification of production facilities and procedures,

(ii) independent inspection and certification of concrete testing laboratories and field testing,

(ii) specification of concrete in such a manner as to permit the establishment of a range of mixes common to many purchasers and their control on the basis of the quality of concrete being produced (including accurate assessment of variability) rather than the quality of concrete being delivered to a particular project,

(iv) the adoption of advanced methods of storing, analysing and presenting data,

(v) independent certification of a comprehensively documented procedure covering all aspects of production and control.

It is now time to consider what selection of the above items has been, and is now, implemented by various countries. The author does not claim to be anywhere near a comprehensive answer to this question, but has extensive experience of operating concrete quality control in several countries over a period of many years.

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In Europe, the big news is that a new specification, EN 206, has been agreed upon between 19 countries. However, this specification is not a control system but an agreed set of criteria for what constitutes satisfactory concrete. The specification does envisage control by the producer using a multi-grading system (that is, combining the results of several grades of concrete into a single analysis for more rapid reaction and more economical control). However, the actual implementation of control is left to the individual countries. In the UK, this falls upon QSRMC (the Quality Scheme for Ready Mixed Concrete). This organisation, initiated by a group of the major producers some decades ago, administers a very comprehensive set of regulations and includes inspectors to visit all members on a regular basis. It includes inspection of plant and a test result analysis system using cusum analysis. The writer has criticised some details of the analysis system as reacting too slowly and failing to assist in the detection of causes of problems but it has been world-leading, and probably still is to some extent. The UK also has a laboratory accreditation system that was the first to develop effective tests of compression testing machines, leading to today's more compact and rigid machines, eliminating the old long travel ram and screw adjustment of top platens.

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Australia was the first country to develop a laboratory accreditation system (NATA, the National Association of Testing Authorities, commencing in the 1940s) that has been the model from which similar organisations have developed in many other countries. The author was for several years an honorary assessor in this scheme.

In the late 1960s the author, as an independent consultant acting for consulting engineers, developed a system of quality control software that was adopted by several major producers in the 1970s. This was partly responsible for Australian standards permitting individual producers to control their own concrete, issuing monthly reports to purchasers. Having the means to control variability, and having the incentive of being able to benefit fully from reduced variability by reducing the necessary margin between mean and specified strength, Australian producers generally achieved lower variability than in other countries.

ISO 9001 certification has generally been sought in the UK and Australia but, in the writer's opinion, this has been to a considerable extent been done with a view to increasing prestige from the sales promotion viewpoint, rather than leading to any substantial improvements in practice.

USA has been the country (in addition to Germany) where leading batching systems have been developed. However, specifications in USA have continued to be generally prescriptive in nature, providing no financial benefit to the producer from achieving improved control. As a result, US producers have been less receptive to improved control systems. Although this is now changing, general practice in USA is not yet an example of good QC. The leading producers there tend to be largely subsidiaries of Australian or European producers.

The writer admits to substantial bias and should not be taken as offering an unbiased academic view based on a detailed study of the world situation. His view is based on personally operating QC systems on substantial projects in a number of countries where effective systems were not previously in place. Often, a laboratory has been established for a particular project, but not under the personal day-to-day control of the author. So, whether or not in nominal control of the laboratory, he has been in charge of analysing test data produced by others. Examples of lack of competence, malpractice, and even dishonesty have been encountered and been very instructive. It is clear that it is not possible to produce dishonest test results over a period that are not distinguishable as such when closely examined. An artificial or adjusted array of results will not withstand expert examination by limited comparison testing, 28-day pair difference, 7 to 28-day gain, normal distribution diagram, and comparison with densities, temperatures and slumps. Of course, detecting that there is a lack of competence does not solve the problem and it is a substantial advantage to have a laboratory accreditation system in effective operation. Similarly, identifying that there is high variability, and even tracking down its cause, does not necessarily solve problems with batching plants or variable materials.

The question is what should India choose to do? The writer has visited a very few Indian producers but is not by any means fully aware of the current situation there. Therefore it is quite possible that some of his recommendations are already in place.

The most basic requirement is to have access to reliable test data on concrete. I understand that India has a limited number of of high-standard laboratories (mainly in urban centres, incidentally where ready-mixed concrete is trying to establish its roots) and also a laboratory accreditation scheme. But it seems that the concept of accreditation has not caught on as only a few concrete laboratories can presently boast of having an accreditation certificate. Therefore, accreditation of concrete laboratories should be an urgent priority. It is not sufficient for them to be government or privately-owned public laboratories. Any major concrete producer should have his or her own accredited laboratory. I understand that many RMC producers in India have established their own laboratories and this augers well from a quality perspective. However, these laboratories need to have proper accreditation. Further, an accredited laboratory will only be financially justified for the producer if specifications allow financial benefit from reduced variability and permit a degree of mix standardisation. It is not a difficult matter to establish confidence in results from a producer's laboratory where this is merited. Certainly, having duplicate teams taking samples from different trucks of nominally the same mix is likely to be both expensive and not very conclusive. However, having one team casting a few double sets of cubes or cylinders to be tested at two laboratories will quickly establish whether or not there are any problems. It may also be necessary to have a clerk of works or other person ensure that the trucks to be sampled are randomly selected.

Accreditation of concrete laboratories should be an urgent priority in India.

Once reliable test results are being entered in high-standard control software it will quickly be obvious whether a satisfactory standard of control is being exercised. Where this is not the case, it may be necessary to insist on an established batching system able to export detailed results to the control system being used. This will show whether the mechanics of the batching system require attention.

Given satisfactory batching, remaining variability may be caused by variation in the quality of input materials. These should also be tested and the results entered in the control system software.

So the absence of ISO certified producers and the equivalent of the UK QSRMC is no problem to the author when requiring well-controlled concrete for a major project in another country. However, this does not mean that some such form of certification would not be of substantial benefit to small and medium sized projects. To a large extent it does not matter where the initiative for certification comes from. It could be initiated by a group of concrete producers, testing laboratories, any group of professionals, government authorities, or even a single widely respected independent concrete technologist.

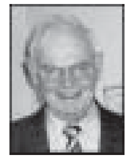
The first step would be to call for the submission of test data by ready mix producers interested in being certified. It is possible that they do not receive much of the test data being obtained by others on the concrete being produced. If so, this must be rectified and arrangements made to make data available. The better ready mix producers should welcome such a move from any direction, since it would obviously strengthen their market position.

As noted above, once data is obtained and entered in an analysis system, it would rapidly become apparent whether there are problems in the industry and whether some producers are already doing a satisfactory job. If the latter is the case, competition can be expected to cause a rapid improvement in general standards. If the data shows that standards in the industry are generally unsatisfactory, the next step would depend on available information as to which of the aspects of input material quality, batching accuracy, testing, mix adjustment or data analysis were causing problems.

Another approach would be for some governmental or other authority to lay down standards for materials testing, batching accuracy, testing frequency and result analysis and dissemination.

In the writer's opinion, the best outcome will be if there are one or more producers of a reasonable standard to initiate competition based on quality and a mechanism is devised to recognise and publicise their attainment.

There is substantial concern, especially in USA, that compressive strength is an inadequate criterion of quality. This is certainly true but does not necessarily invalidate the above. The Australian Code requires a certain minimum strengths for nominated aggressive conditions, for example 32 MPa is the minimum strength that may be specified for any external reinforced concrete, but this is still just a strength specification. In addition a minimum percentage of fly ash or silica fume can be specified without losing the incentive of a strength specification. It is quite common in Australia to also specify a maximum shrinkage which, in some areas, would limit the choice of coarse aggregate or require a particular admixture. Batch records can be checked to ensure that such provisions are adhered to but the primary requirement of ensuring low variability concrete of consistent quality is ensured by strength testing.



Mr Ken Day is an honorary member of the Concrete Institute of Australia and a fellow of ACI, the UK ICT, and IE(Aust). After periods of R&D in industry and as a lecturer at the University of NSW, he operated his own consultancy, Concrete Advice Pty. Ltd for 28 years, producing the 'Conad' MixDesign and QC software and undertaking QC on many significant buildings. He is the author of more than 100 papers and the textbook "Concrete Mix Design, quality control and Specification". Ken Day has recently joined with Contek and Shilstone to develop a new level of software and technical assistance to the readymix industry, details are available on his website www.kenday.id.au.

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