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Use of control charts in the production of concrete

Utilisation des cartes de contrôle pour la production du béton

Anwendung von Qualitätsregelkarten bei der Herstellung von Beton

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Foreword

This document (CEN/TR 16369:2012) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, the secretariat of which is held by DIN.

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Introduction

It is safe to assume that ever since manufacturing commenced, attempts have been made to control the process in order to improve quality and drive down costs. The application of statistical techniques to manufacturing was first developed by physicist Walter A. Shewhart of the Bell Telephone Laboratories in 1924. Shewhart continued to develop the idea and in 1931 he published a book on statistical quality control [1].

Shewhart recognised that within a manufacturing process there were not only natural variations inherent in the process, which affected quality but there were also variations that could not be explained. Shewhart recognised that it is possible to set limits on the natural variation of any process so that fluctuations within these limits could be explained by chance causes, but any variation outside of these limits, special variations, would represent a change in the underlying process.

Shewhart's concept of natural and special variations is clearly relevant to the production of concrete at a ready-mixed plant or precast factory and the requirement to achieve a specified compressive strength. Natural variations exist in the process due to variation in the raw materials (aggregate grading, chemical composition, etc), batching accuracy, plant performance, sampling and testing, etc. Special causes of variation outside of the natural variations could be due to changed constituent materials being used, weigh-scales losing accuracy, a new batcher, problems with testing equipment, etc.

Control charts have found widespread use in the concrete industry in both ready-mixed concrete and precast concrete sectors as a tool for quality control. Control charts can be applied to monitor a range of product characteristics (e.g. cube/cylinder strength, consistence, w/c ratio), constituent materials (aggregate grading, cement strengths, etc.) or production (batching accuracy).

Their most common application of control charts is as a means of continuously assessing compressive strength results in order to:

- check whether target strengths are being achieved;
- measure the variations from target (all products vary);
- identify magnitude of any variation;
- objectively define action required (e.g. change w/c ratio) to get the process back on target;
- identify periods and concretes where the strength was less than specified so that investigations can be carried out and corrective action taken.

The use of control charts should not be treated in isolation from the rest of production control. For example routine checking and maintenance of weigh equipment will minimise the risk of a weigh-scale failure. Control charts provide information about the process, but the interpretation of the information is not a mechanical process. All the information available to the concrete producer should be used to interpret the information and make informed decisions. Did a change in quality occur when a new batch of constituent was first used? Is all the family showing the same trend? Are other plants using similar materials showing a similar trend? Such information leads to the cause of the change in quality being identified and appropriate action being taken. For example a loss of accuracy in the weigh-scales should lead to repair, maintenance and re-calibration and not a change in mix proportions. Where a change in mix proportions is required, the use of control charts can lead to objectively defined changes in proportions.

Effective control of concrete production is more easily achieved when there are good relationships with the constituent material suppliers, particularly the suppliers of cementitious materials. Early warning of a change in performance from the constituent material supplier should be part of the supply agreement, e.g. that stock clinker is being used during the maintenance period, and on the basis of this warning, the producer will decide the appropriate action.

Some producers use changes in cement chemistry to predict changes in concrete strength. Effective production control is about using all this information to produce concrete conforming to its specification. Effective production control, which includes the use of control charts, significantly reduces the risk of non-conformity benefiting both users and producers of concrete.

There are drawbacks to the existing method of assessment of conformity of mean strength adopted in EN 206-1 [3] including not following the CEN Guidance on the evaluation of conformity [2]. It is believed that control charts (already widely used as a quality assurance tool in factory production control) would provide an alternative and better means of ensuring the characteristic strength is achieved and it is a method that follows the CEN Guidance.

1 Scope

This Technical Report reviews various control systems that are currently used in the concrete industry and, by the use of examples, show how the principles are applied to control the production of concrete. This CEN/TR provides information and examples of the use of method C in Clause 8 of prEN 206:2012.

2 Symbols and abbreviations

AOQ	**Average outgoing quality**
AOQL	**Average outgoing quality limit**
C_{mra}	**Constant giving the cement content increase required to produce a 1N/mm^2 increase in strength**
dc	**Change in cement content**
Dl	**Decision interval**
G	**Gradient**
f_{ci}	**Individual test result for compressive strength of concrete**
f_{ck}	**Specified characteristic compressive strength**
f_{cm}	**Mean compressive strength of concrete**
k	**Statistical constant**
L_l	**Lower limit**
LCL	**Lower control limit**
LWL	**Lower warning limit**
n	**Number of samples**
q_n	**Statistical constant that depends upon *n* and the selected AOQL**
s	**Sample standard deviation**
UCL	**Upper control limit**
UWL	**Upper warning limit**
x_i	**Test result** **NOTE According to EN 206-1 [3], a test result may be the mean value of two or more specimens taken from one sample and tested at one age.**
$\bar{x}$	**Mean value of 'n' test results**
σ	**Estimate for the standard deviation of a population**