Evaluation of Strength Test Results of Concrete in Libya (Case Study)

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تقييـم نتائـج اختبـار مقاومـــة الخرسانـة في ليبيا
(دراســة حـالـــة)

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ملـخص

الخرسانة هي إحدى مواد البناء الرئيسية في صناعة البناء والتشييد في ليبيا، ربما تكون الخرسانة هي المادة الوحيدة المستخدمة في تشييد المباني ويتم إنتاجها من ثــلاث عناصر رئيسية؛ وهي الاسمنت والركام والماء. وعليه يجب أن يكون المنتج متوافقًا مع المواصفات القياسية في مراحل التصنيع لضمان الجودة المقبولة. حيث تتركز هذه الدراسة على إنشاء برنامج حاسوبي يسمى (Concrete Expert) بنـاءً على المعايير الأمريكية ACI214 والذي يعمل علي مراقبـة جودة الخرسانة بشكل مستمر طوال فترة التنفيذ ويسجل القراءات اليومية لاختبارات مقاومـة الخرسانــة وبناءً عليه تـم إنشاء مخططات التحكم لكل بيانات اختبارمقاومـة الخرسانـة. حيث تكمن أهمية مخططات التحكم للمتغيرات في التعبير عن حالة النظام (داخل أو خارج حدود التحكم). يسجل النظام البيانات ، ويحلل ، ثم يحدد اختبارات المقاومـة الفردية ، والمتوسط المتحرك ، ومدى الحركة ، ونسبة الحد الأدنى من المقاومة إلى مقاومــة التصميم ، ومدى كفاية التحكم في عمليات الخرسانة والاختبارات. يمكن الاستفادة من بيانات الاختبارات لهذه الأغراض: لمساعدة مصنع الخلطات في إنتاج خرسانة عالية الجودة للمشاريع ؛ لتحديد مدى كفاية إجراءات الاختبارات ، وإنشاء العلاقات الإحصائية وصقلها لمشاريع مماثلة في المستقبل. تم تطبيق البرنامج الحاسوبي لاختبـار كفاءة وأداء مشروعين ضخمين في ليبيا ، وكذلك مقارنـة وتقييم جـودة الخرسانة لعشرة مشاريـع من خــلال إدخـال بيانات مختلفة في فترات زمنية مختلفـة. حيث أظهـرت النتائـج أن مراقبـة الجـودة تـراوحت من ممتـاز إلى جيد حسب التصنيف (Overall Variation/General construction testing) وتـراوحت بين الجيد إلى ضعيف حسب التصنيف (Within-test variations/Field controlling testing) وفقًا لـ المواصفــة الأمريكيـة ACI214.

كلمات دالة: ضبط الجودة ، الخرسانة ، مخططات التحكم ، مقاومـة الضغط.

Evaluation of Strength Test Results of Concrete in Libya (Case Study)

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ABSTRACT

Concrete is one of the major construction materials in building construction industry. In Libya, concrete is probably the only materials used for building constructions and it is produced from three basic ingredients; namely, cement, aggregate and water. Accordingly, the product should be compatible with the standard specifications within manufacturing stages to ensure acceptable quality. This study focuses on creating system called (Concrete Expert) based on American Standards ACI214, that monitors concrete quality continuously throughout the implementation period and records daily readings of compressive strength tests and accordingly the control charts for each strength test data were established. The importance of control charts for the variables lies in the expression of the system status (inside or outside the control limits). The system records data, analyzes, and then determines the individual strength tests, moving average, moving range, ratio of minimum strength to design strength, and the adequacy of control over concrete and testing operations. The test data could be benefited for these purposes: to assist the batch plant in the production of high-quality concrete for projects; to determine the adequacy of testing procedures, and to establish and refine the statistical relationships for future similar projects. The system was applied to test the efficiency of the performance two huge projects in Libya, also comparison and assessment quality of concrete for ten projects by inserting different records in different intervals of time; results show that the quality control ranged from excellent to a good as per the classification (Overall Variation/General construction testing) and ranged from fair to poor as per the classification (Within-test variations/Field controlling testing) according to ACI214.

Keywords: Quality control ,concrete, control charts, compressive strength.

INTRODUCTION

In recent years, suffered many of the concrete structures collapsed have caused in many deaths and damage the buildings, which mainly due to the poor concrete quality and control. Moreover, the ingredients of concrete should be of good quality that satisfies the requirements set in standards. which in order to get quality concrete product, which satisfies the strength and durability requirement. In addition, to follow the concrete production process, quality control and corrective procedures to obtain the desired quality concrete. Therefore, A good and a bad concrete may be made of exactly the same ingredients if there is a difference on the quality control of the production. (Abebe et al. 2005).

Previous study by Chen, Sung, and Shih (2004) found that the usual primary requirement of good concrete in its hardened state is a satisfactory compressive strength, but there are properties must be ensured such as density, tensile strength, impermeability, resistance to abrasion. To guarantee good citation.

Concrete in reinforced concrete structure (RC) is generally under significant compressive stress load. As reported by American Concrete Institute code (ACI318-95) to guarantee required quality and ductility, various tests have to be conducted to measure the concrete's compressive strength. The ductility of the RC structure is mostly influenced by the compressive strength of its concrete. Then, the fit compressive strength of concrete can be determined based on the ductile ratio. It takes daily concrete samples for strength tests and evaluation of the average compressive strength of concrete. If the compressive strength of concrete greatly exceeds the specified strength, it will seriously affect the ductile ratio of the structure. On the other hand, if the deviation of compressive strength of concrete is over the limit, it causes imbalance to the ductile ratio of structure, and adversely influence the seismic capability of the structure (Chen, Sung, and Shih 2004).

Statistical process control (SPC) is a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability (Montgomery 2009). Thus, (SPC) is one of the greatest technological developments of the twentieth century because it is based on sound underlying principles, is easy to use, has significant impact, and can be applied to any process (Montgomery 2009). As reported by Evaluation of Strength Test Results of Concrete ACI Committee 214R-02. Statistical procedures provide tools of considerable value when evaluating the results of strength tests. (Kane 1986) So statistical methods are used to evaluate the manufacturing capacity and quality control of manufacturers. First, the standard deviation is decided by at least thirty successive sets of test results of dispensed concrete prescriptions, and then the average compressive strength requirement of concrete is imposed to identify the quality control capability of a manufacturer. In the process of construction, although the dispensed prescriptions of concrete are the same, some uncertain factors may cause imbalance to the deviation of compressive strength of concrete and affect the engineering quality and the required compressive intensity and ductility of the structure. It may even cause an unexpected structure collapse. paragraph Standard-paragraph.

THE OBJECTIVES

The purpose of this research is to develop a quality control system of concrete to undertake qualitative and quantitative assessment on the quality of concrete in the building construction industry of Libya using computer program (Concrete Expert). It works to monitor concrete quality continuously throughout the implementation period, which is aiming to achieve the following objectives: -

- Assess the control level of concrete and to apply the criteria of the required average strength based on (ACI 214R-02).
- To objectively evaluate the fitness and stability degree of compressive strength of concrete. To evaluate the level of quality control of concrete.
- To draw control charts for variables (Average, X), (Range, R) for any period of time required.
- To display the results of all tests at any time and obtain respective reports.

METHODOLOGY

- General information about production stages, and sequence of operation, were gathered.
- Historical data of previous concrete production, and covers all the relevant material to evaluate of quality control of concrete compressive strength.
- Study ACI approach and the set of criteria to evaluate the concrete quality and control according (ACI 214R-02).

Computer program (Concrete Expert) created by using (C Sharp) Language will be used to evaluate and analyze the quality of concrete.

INTRODUCTION TO QUALITY CONTROL

Quality Control (QC) is all the measures that are taken during material selection, concrete production processes and on finished concrete products to ensure the compliance of works with the specification. Hence, concrete quality affects the overall quality of buildings to a higher extent. Moreover, to get quality concrete products, proper care and control has to be done during ingredient selection and production processes. It should also be reminded that all professionals and firms involved in the construction industry have to give special emphasis to quality control (Abebe et al. 2005).

According to the Evaluation of Strength Test Results of Concrete ACI Committee 214R-02, strength test results vary. Variations in measured strength may originate from any of the following sources:

- Batch-to-batch variations of the proportions and characteristics of the constituent materials in the concrete, the production, delivery, and handling process, and climatic conditions; and
- Variations in the sampling, specimen preparation, curing, and testing procedures (within-test).

Control Charts

Quality-control charts have been used by manufacturing industries for many years as aids in reducing variability, increasing production efficiency, and identifying trends as early as practicable. It is an essential tool of continuous quality control; monitor processes to show how performing and how capabilities are affected by changing in processes.

Control charts determine if a process is under control or out of control, also monitor the variance of output of a process over different intervals of times, by comparing this variance against upper and lower limits to see if it fits within the expected, specific, predictable and normal variation levels.

If so, the process is considered in control and the variance between measurements is considered normal random variation that is inherent in the process. If, however, the variance falls outside the limits, or has a run of non-natural points, the process is considered out of control (Elshiekh and khayal 2018).

When the variation between the points is large enough for the process to be out of control, the variation is determined to be due to non-natural or assignable (special) causes.

Average Charts (X-bar Chart) Average chart in (Figure.1). Shows the results of all strength tests plotted in succession based on casting date. Chart often includes the specified strength and may include the acceptance criteria for individual tests. This chart is useful because it shows all of the available data but it can be difficult to detect meaningful shifts in a timely fashion (ACI214R-02).

$$\bar{X}=\frac{\sum_{i=1}^{n} Xi}{n} \qquad (1)$$

$$UCL = f'_{cr} + A2\bar{R}$$

$$LCL = f'_{cr} - A2\bar{R}$$

Range Charts (R-Chart) The lower chart in (Figure.1). Shows the moving average of the range, the maximum difference between companion cylinders comprising a single strength test, which is used to monitor the repeatability of testing.

The laboratory has the responsibility of making accurate tests, and concrete will be penalized unnecessarily if tests show greater variations or lower average strength levels than actually exist. Because the range in strength between companion specimens from the same sample can be assumed to be the responsibility of 41 the laboratory, a control chart for ranges should be maintained by the laboratory as a check on the uniformity of its operations.

These changes will not reveal day-to-day differences in testing, curing, capping, and testing procedures or testing procedures that affect measured strength levels over long periods (ACI214R-02).

$$R=\frac{\sum_{i=1}^{n} R_i}{n} \qquad (2)$$

$$UCL = D4\bar{R}$$

$$LCL = D3\bar{R}$$

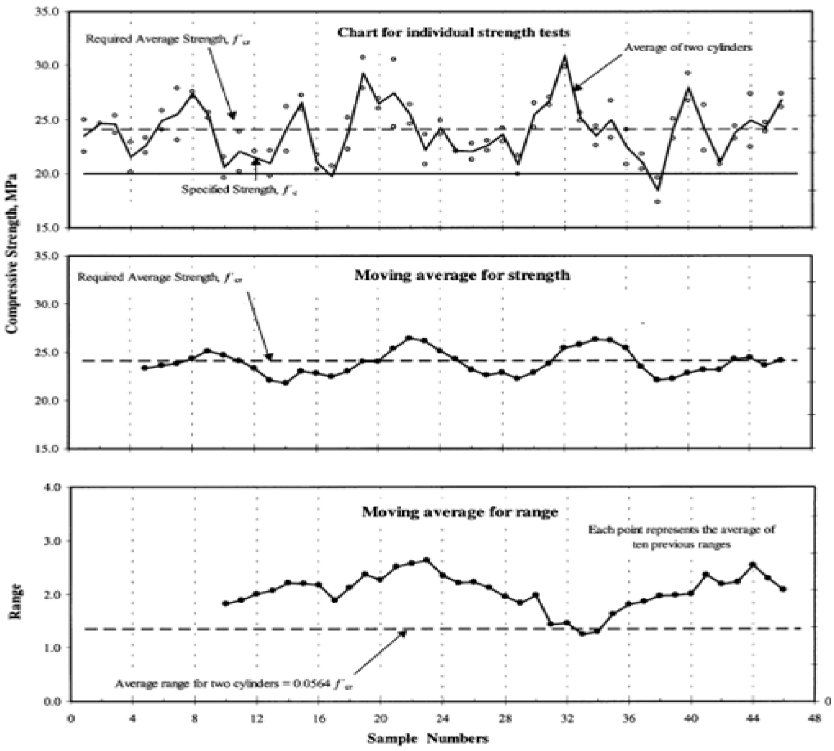


Figure.1. Three Simplified Quality Control Charts: Individual Strength Tests, Moving Average for Strength and Moving Average for Range

SOFTWARE CONCRETE EXPRET

Introduction

Concrete Expert is the module of the concrete quality package. It is created to improve quality control process, mix design and raw materials management. The compressive strength test results of concrete were evaluated according to ACI 214R-02 (Standard for guidance in planning, designing, executing, and inspecting construction). Moreover, the Concrete Expert was determined as follows:

Inputs The software inputs include:

1. Details of projects information such as owner, location, contractor.
2. Physical tests types of raw materials (aggregates, cements, water).
3. Equipment calibration and verification.
4. Batch plant: actual and intended batch quantities (every truck), customer details.
5. Fresh concrete tests, and in situ temperature records.
6. Hardened concrete test result.

Processing

1. Calculate the average results for strength and range for every test in any period of time.
2. Calculate the upper and lower control limit for any experiment at any period of time.
3. Criteria for strength requirement-determine the minimum required average strength concrete performance.
4. Compare the status that the pattern will be out of control, with samples distribution in the chart for any period of time.

Outputs

1. Establish multiple functions at the database such as adding or deleting records.
2. Viewing the contents of the database Statistics table for any period of time include Standard Deviation, adjusted standard deviation, Coefficient of Variation, Within-Test Standard Deviation, Within-Test Coefficient of Variation.
3. Construct quality control charts for (Individual test, moving average for strength of three, and Moving average for range of ten) at any period of time required, and express the suitable treatment if it needs.
4. Printing all outputs as reported.

Robust pro-active Scheduling The software was written in C-Sharp, which is a programming language, and development environment created by Microsoft that runs on the .NET Framework.

In addition, it is based on C++ and contains features similar to those of Java. It is a simple, modern, and object-oriented language that provides modern day developers flexibility and features to build software that will not only work today but will be applicable for years in the future.

User interface the software contains three forms which could be explained as follows:

The Main Form

When starting the program, this form will display first. The title of this form is Projects; (Figure.2). The anymore forms will carry out from the main form as Add Project, Materials, Batches, Concrete QA/QC.

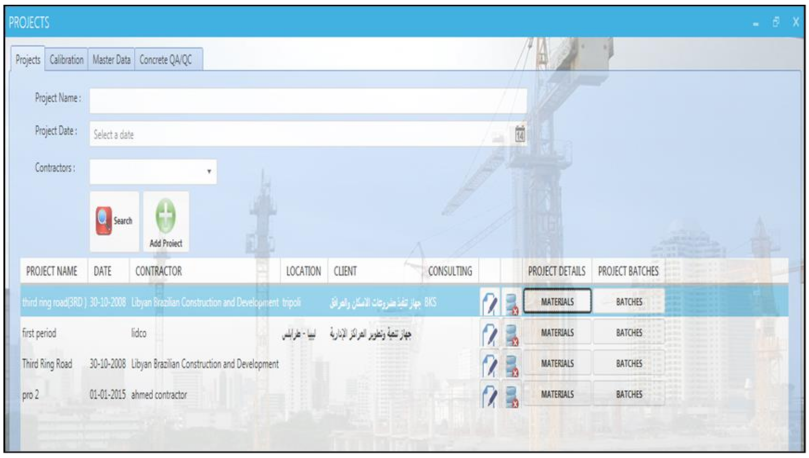


Figure 2: Main Form

The Processing Screen

This screen named Project Batches, which includes two tabs: The first tab (Figure.3) called Batch add/ edit which display add and save the daily batch quantities, fresh concrete testing data. The second tab in (Figure.4) called Specimen Tests which enter the hardened concrete tests (Test Results). In these screens there are about four commands help users in displaying, adding, saving, deleting, reporting and canceling as shown.

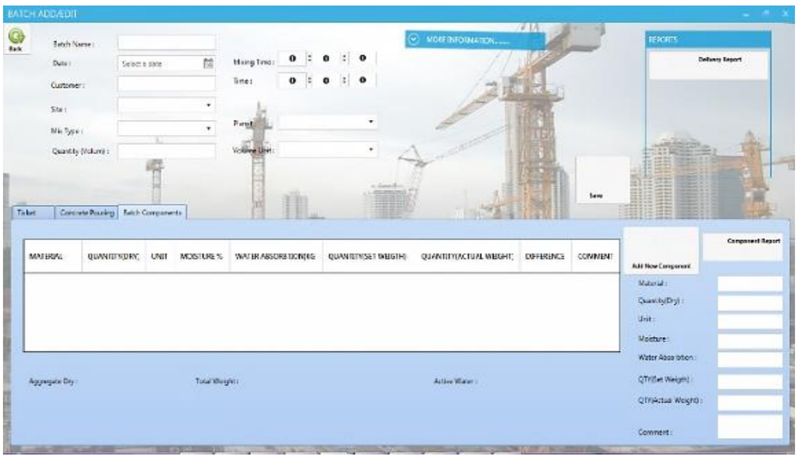


Figure 3: Project Batch Information

Figure 4: Specimen Tests Information

Constructing Chart and Analysis Screen

This screen named Concrete QC, which includes four tabs:
The first tab in (Figure.5) called Static Table which display data for any certain period of project, where you can select a starting date and ending date for your analysis.

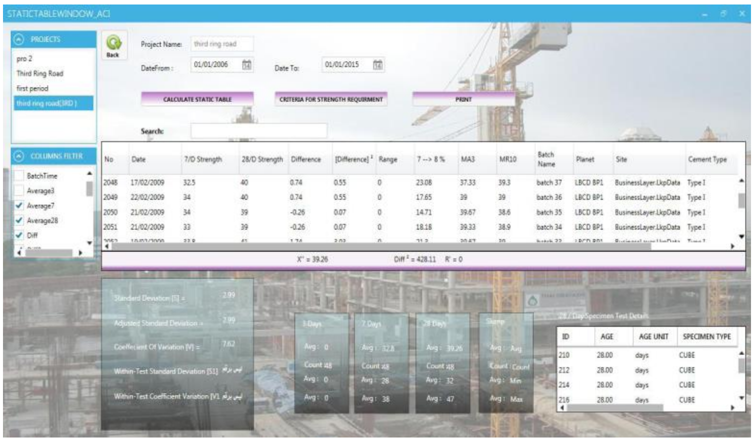


Figure 5: Data in Periods

The second tab called Analysis ACI214R (Figure.6), this tab display data for determined Criteria for Strength Requirement fcr', and the main function of this tab to display the four simplified Quality Control Charts.

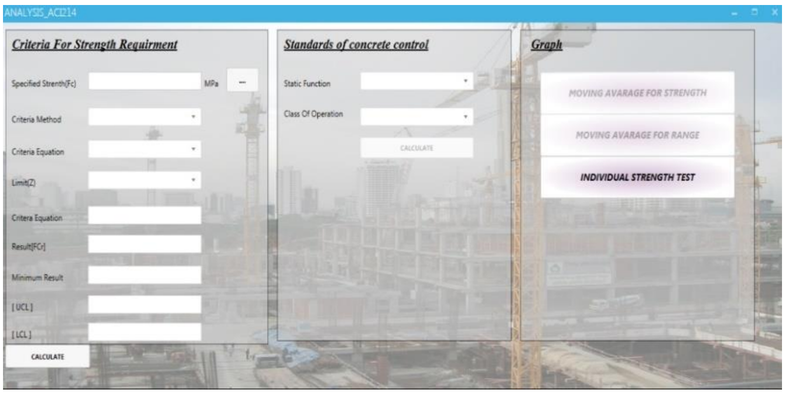
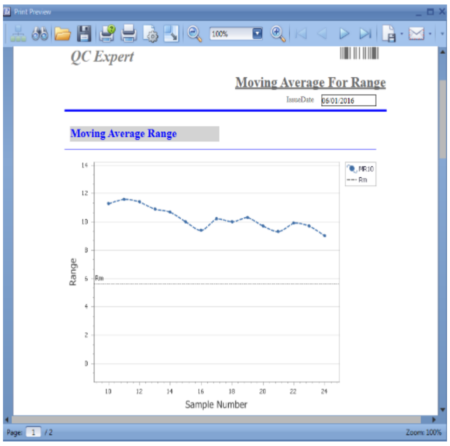
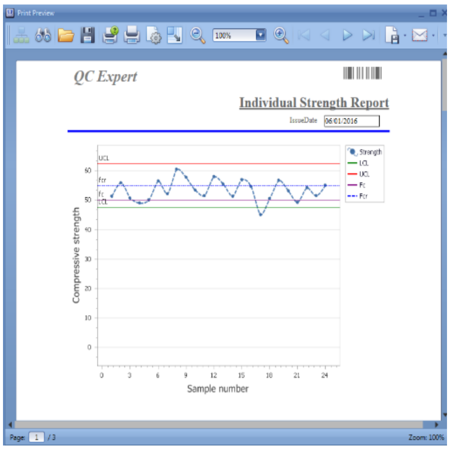


Figure 6: Analysis ACI214R

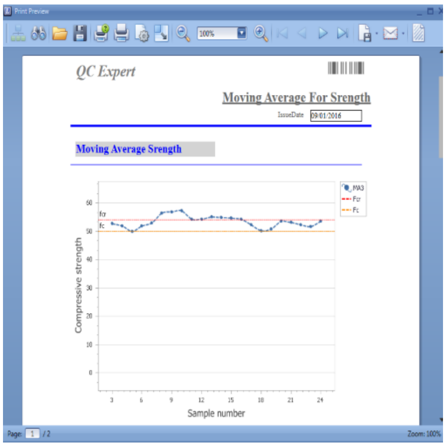
The last tab called Graph in (Figure.7). The main function of this tab to display data as quality control charts.



Moving average of the range of ten



Individual test with UCL, LCL



Moving average of three

Figure 7: Chart Presentation

CONCLUSIONS

This study investigated the quality of raw materials and the fitness and stability degrees of concrete quality affect tremendously the stability of concrete structures. Based on the results of this study, the following conclusion can be drawn:

1. A new software was created to evaluate the level of quality control of concrete by using ACI214R which prescribes a statistical approach.
2. Statistical analysis made on compressive strength test results of two huge projects in Libya the outcomes of the result indicated that the quality control ranged from excellent to a good. As per the classification: (Overall Variation) of ACI 214R-02. Control over testing: The within test coefficient of variation (V1) indicates that the control over testing changed from “fair to poor” this corresponds to within-test range equation (R) which is (max strength – min strength) and confirms the believe that fluctuations in the range value are not due to variations in the manufacturing process but rather to variation in testing procedures.
3. To put the process of testing back to control, the quality control laboratory should find out what has caused the change in the inherent variation and make corrections accordingly. Normally, when the out-off control situation is due to inadequate testing, the probable causes may include a momentary lack of attention the, fatigue, a change in testing method, or errors in measurements and arithmetic.
4. The causes for poor quality can be summarized as ignorance, poor materials, poor design, poor detailing, and poor workmanship, improper quantity of cement, improper concrete mix, excess water, inadequate compaction, substandard forms, inadequate curing, inadequate cover and above all the lack of technical knowledge.
5. There is a need for further researches to improve the quality of workmanship involved in the building construction industry of Libya and its impact on concrete quality, and developing a new version of a Software by addition of different data of performance improvements and new features.

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