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Proceedings of the Workshop on Evaluation of Cement and Concrete Laboratory Performance

James H. Pielert, Editor

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Construction Materials Reference Laboratories
Building Materials Division
National Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

Hosted By:

Standards Institution of Israel
Tel Aviv, Israel
September 6–7, 1989

Sponsored By:

RILEM Technical Committee 91-CRL on Testing and
Control Procedures for Cement and Concrete Reference Laboratories

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PREFACE

A workshop sponsored by RILEM Technical Committee 91-CRL was held in Tel Aviv, Israel on September 6-7, 1989 to consider the evaluation of cement and concrete testing laboratory performance. The workshop attracted 30 participants from the United Kingdom, France, Israel, Sweden, United States, Austria, Switzerland, Germany F.R., Finland and Spain. Papers were presented on the following subjects: (1) quality assurance programs for testing laboratories, (2) assessment of the technical performance of laboratories, and (3) role of reference laboratories. The workshop resulted in an excellent exchange of information and showed a high degree of interest in the quality of testing of cement and concrete on the international level.

WORKSHOP ORGANIZING COMMITTEE

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Contents

1. Introduction

A Workshop on the Evaluation of Cement and Concrete Laboratory performance was hosted by the Standards Institution of Israel in Tel Aviv on September 6-7, 1989. The workshop was organized by the International Union of Testing and Research Laboratories for Materials and Structures (RILEM) Technical Committee 91-CRL on Testing and Control Procedures for Cement and Concrete Reference Laboratories. RILEM is concerned with research on civil engineering materials and structures, and applications of results in the field.

Sponsorship of the workshop in Israel was provided by:

Nesher Cement Works

The Readymixed Concrete Association

Akerstein Industries

2. Purpose and Organization of Workshop

In planning the workshop Technical Committee 91-CRL recognized that the performance of cement and concrete laboratory testing was taking on added importance as the construction industry is becoming more international in scope. Specific factors pointing to the need to study this subject are; (1) cement and concrete are among the most basic and widely used materials of construction, (2) the quality of testing may vary between reputable laboratories, (3) testing variations may lead to greater risks to the public, and (4) there is a need for international sharing of methods for maintaining the quality of testing.

The workshop was organized around three sessions on the following topics:

Session I - Quality Assurance Systems in Laboratories

Session II - Assessment of the Technical Performance of Laboratories

Session III - Role of Reference Laboratories

Section 3 of these proceedings contains the presented papers, section 4 the papers accepted but not presented, and section 5 the results of the workshop.

3.0 Workshop Papers

WELCOME ADDRESS

S. Avudi
Standards Institution of Israel

Ladies and Gentlemen,

On behalf of the Standards Institution of Israel and the National Delegates of the RILEM, I would like to welcome the members of the Workshop on the Evaluation of Cement and Concrete Laboratory Performance organized by the RILEM Technical Committee TC91-CRL.

Individuals engaged in the production of cement, and users of cement in the concrete industry, together with people whose concern is the assurance of the quality of the cement, concrete and concrete products are engaged in a constructive profession. The construction industry has through the ages been concerned with providing the habitat and environment for human activities, and for the improvement of the general welfare of the population.

The participation in this workshop of members of the industry, research institutions and laboratories from various countries in Europe and from the United States, who have agreed to meet, share, discuss and sum up their joint experience, points out the importance placed by the construction and testing community on the performance of testing laboratories.

In hosting this workshop, The Standards Institution of Israel believes in the importance of the theme of the workshop.

The convening of this workshop has been possible through the continuous efforts and guidance of Mr. James Pielert, chairman of TC91-CRL, who steered the Planning Committee of the workshop and was personally involved in the work of preparing an interesting program. The industrious work of the other members of the Planning Committee has also been extremely important.

I wish to express my thanks to Mr. Maurice Fickelson, Secretary General of RILEM, who honors us with his attendance and to the Nesher Cement Works, The Readymixed Concrete Association and the Akerstein Industries for sponsoring the workshop.

I wish you a very fruitful meeting and hope you shall have a pleasant stay in Israel.

WELCOME AND INTRODUCTION TO WORKSHOP

James H. Pielert
National Institute of Standards and Technology

On behalf of RILEM Technical Committee 91-CRL on Testing and Control Procedures for Cement and Concrete Reference Laboratories, I welcome you to this workshop on Evaluation of Cement and Concrete Testing Laboratories. Special thanks goes to the TC91-CRL Planning Committee who have worked hard over the last 2 years to make this workshop possible. These individuals are Dr. John Rogers of the United Kingdom, Dr. Herman Sommer of Austria, Mr. Franck Hawthorn of France, and Mr. S. Avudi of Israel. I also thank Mr. Thomas Tipler of the British Cement Association, a former member of the Planning Committee, who hosted the first planning meeting for this workshop. Appreciation is extended to Mr. Maurice Fickelson, Secretary General of RILEM, for his welcome on behalf of RILEM and for his constant encouragement of the work of the Technical Committee.

Special thanks are due Mr. S. Avudi of the Standards Institution of Israel (SII) for coordinating and hosting the workshop. SII staff have been extremely helpful in making the necessary arrangements to insure that the workshop is a success. The Nesher Cement Works, Ltd., The Readymixed Concrete Association, and Ackerstein Industries, Ltd. are to be commended for sponsoring this workshop.

How did we get to where we are now? It started with a request from the National Institute of Standards and Technology (NIST) of the United States to RILEM to form TC91-CRL. It was apparent to NIST that the evaluation of the performance of cement and concrete testing laboratories varied throughout the world and there were opportunities for us to learn from each other. You may ask why this subject should be of importance? Cement and concrete are among the most basic and widely used materials of construction. They are commodities which frequently cross national borders resulting in a concern about their quality which is directly related to the quality of testing. The quality of testing done on these materials may vary between reputable laboratories and cause perfectly acceptable material to be rejected or inferior material to be accepted for use. Testing variations may lead to greater risks to the public and to economic losses resulting from structural failures. There is a need for international sharing of knowledge and methods for maintaining the quality of testing. It is desirable to provide available information on national systems in a convenient form which can be adapted by other countries for their local use.

The objective of TC91-CRL work is to prepare guidelines for evaluating the performance of cement and concrete testing laboratories. There were four primary products envisioned when the Technical Committee was formed:

1. State-of-the-art report on evaluation of laboratories
2. Guideline or prestandardization document for a model evaluation program
3. Recommendations for international cooperation
4. List of technical needs and recommendations of future activities

The committee met for the first time in Paris in September 1987 and began the collection of information for meeting its objective and for planning a workshop. Workshop Planning Committee meetings were held in London in June 1988 and in Paris in February 1989, where the planning for this workshop was completed.

It was decided at the London meeting to collect information on existing systems which are operating to evaluate the performance of cement and concrete testing laboratories. A questionnaire was developed and broadly distributed throughout the world to identify existing systems. Twenty-one such systems located in 16 countries were identified. Those of you in the audience who have national programs which are not represented, should send information to me so that it can be included. [Note, the questionnaire and survey results to date are in Appendix A.]

Some of the observations possible from reviewing the survey results are:

- 15 countries have some type of program for evaluating laboratories,
- 15 systems provide formal recognition through certification or accreditation,
- 17 systems have some type of national government participation or support,
- 7 systems have reciprocal agreements with other nations,
- 8 systems base accreditation on individual tests, 3 on fields of test and 4 on various combinations,
- 17 systems require on-site assessment,
- 17 systems require that deficiencies be resolved before accreditation can be granted,
- 18 systems require an observation of testing being conducted in the laboratory,
- 11 systems require an evaluation of the quality assurance manual, and
- 17 systems require laboratories to participate in a proficiency sample program.

As a result of the survey and other information collected, the Planning Committee organized this workshop to cover three topics.

1. Quality assurance systems in laboratories
2. Assessment of technical performance of laboratories
3. Role of reference laboratories

The purpose of this workshop is to prepare a state-of-the-art report on evaluation of cement and concrete laboratories and to collect information for preparing the other TC91-CRL products. The workshop is structured to include a half-day to discuss each of the main topics and to reach conclusions which can be included in the proceedings. There will be a concluding session where the results of the workshop will be presented by the session chairmen. Active participation by the workshop attendees is encouraged so that the most can be gained from the time available. The workshop proceedings will be prepared by NIST and distributed to all participants.

Again, welcome to Israel for this important workshop; we encourage your active participation for a productive meeting.

[Note, the workshop program is Appendix B and the attendance list is Appendix C.]

CURRENT PRACTICE FOR ASSESSING QUALITY ASSURANCE SYSTEMS IN LABORATORIES

Dr J A Rogers

National Measurement Accreditation Service, NPL, UK

ABSTRACT

The use of national, independent third-party accreditation systems is growing as laboratory users seek more confidence in the quality of testing. An increasing number of countries are developing accreditation schemes which use internationally agreed requirements for assessing the technical completence of laboratories.

The mechanisms for assessing laboratories for compliance with such criteria vary from country to country but the basic principles are the same. In this paper the system used in the UK to assess, accredit and monitor testing laboratories is described with particular reference to cement and concrete laboratories.

INTRODUCTION

In 1973[1] a report by a committee set up to examine the need for a national authority for construction materials testing in the UK cited evidence of lack of control in testing and of significant errors in available test data. These findings were supported by evidence from a Concrete Society report[2] on a study of the performance of compression testing machines. This report concluded that errors in the values of the compressive strength of concrete cubes of + 12% to − 24% could arise from the machine alone. A similar study by BRMCA[3] revealed that in compression tests on concrete performed by 105 laboratories over a half of the results showed a variation in strength of 4% while in 12% of the laboratories the difference was greater than 10%.

On a wider front studies by the Transport and Road Research Laboratory[4][5] revealed similar problems in soils and aggregate testing indicating that the problem of variability in test data extended to all the main construction materials.

The need for better control of materials testing was therefore clear and the ready-mixed concrete industry decided to take immediate action. BRMCA instituted a Register for Test Houses performing compression tests on concrete cubes. Test Houses achieved admission to the Register by demonstrating that they satisfied criteria relating to staff, equipment, procedures, records and reports, the requirements of BS1881[6] (the testing standard for concrete) and certain additional requirements specified by BRMCA.

When the Register was launched some 142 laboratories were invited to participate, 82 agreed to be assessed and of these 56 met the requirements and were listed in the first published Register in 1975.

INFLUENCE OF BRMCA REGISTER ON LABORATORY STANDARDS

During the assessment of these laboratories BRMCA noted that over 50% were using machines that had not been checked for platen alignment[7] a known cause of variability in test data. By requiring the laboratories to introduce regular reverification of their testing machines for force, and for platen alignment, this problem was greatly reduced. However, because there was no requirement within the BRMCA Register to operate a quality management system in the laboratory inconsistency in test house performance could still occur.

The quality assurance division of the British Standards Institution (BSI) recognised this omission when they introduced their Registration Scheme for Test Houses of Assessed Capability in 1977. This scheme, which was open to all types of laboratory, required that the laboratory operate a quality management system. Unfortunately this scheme did not attract many laboratories and it was not until 1981 when the government launched the National Testing Laboratory Accreditation Scheme (NATLAS) that accreditation based on the use of a quality management system became available to all types of laboratory. In fact to help promote the NATLAS scheme both BRMCA and BSI encouraged their registered test houses to seek accreditation and within 2 years there were around 80 laboratories accredited by NATLAS for testing construction materials and products and some 63 of these engaged primarily in concrete cube testing.

Now some 8 years later the national scheme, renamed the National Measurement Accreditation Service (NAMAS) because it also incorporates calibration laboratories, has accredited 224 laboratories for testing construction materials and products generally, of which some 168 are accredited for concrete cube testing and some 16 accredited for chemical, mechanical and physical tests on cement. By the end of 1990 the number of accredited construction laboratories is likely to have increased to nearer 300.

REQUIREMENTS FOR ACCREDITATION

To obtain accreditation laboratories have to demonstrate that they meet the requirements of the NAMAS Accreditation Standard(8) and comply with the NAMAS Regulations(9). Accreditation is only granted for specific tests or types of test and each laboratory is issued with a schedule detailing the tests for which accreditation has been given.

The key requirements that laboratories have to satisfy are summarised in Table 1 and relate to the staffing, management, equipment, facilities, procedures and records that the laboratory employ.

ASSESSMENT OF THE LABORATORY

To provide confidence in the arrangements that the laboratory makes to control the quality of testing NAMAS conducts formal assessments at the laboratory using experts in quality assurance and the field of testing concerned. Each expert is trained by NAMAS before being contracted to visit laboratories.

Quality Management System

The first task for the leader of the team of experts (the team may be one person in a small laboratory) is to appraise the quality management system operated by the laboratory. This is done by first examining the quality documentation used by the laboratory for compliance with the NAMAS requirements and then by assessing the use and effectiveness of these arrangements in the laboratory.

All laboratories are expected to document their quality arrangements in a Quality Manual and to support this Manual with technical and other procedures as necessary. The Quality Manual must define the quality policy of the laboratory as percieved by top management and must clearly indicate who has responsibility for technical matters and for control of quality on a day-to-day basis. In assessing this aspect of the quality management system the assessor looks for a clear definition of duties and responsibilities backed up by an unambiguous organisational chart for the laboratory and, where necessary, for the associated organisation owning the laboratory. Care is taken to ensure that the quality of testing in the laboratory can not be adversely affected by the influence of commercial or production management whose objectives may conflict with acceptable practices as far as the quality of testing is concerned. In this connection the NAMAS assessor will be checking to see that the quality policy of the laboratory forbids the performance of tests to any other standard than that set by the NAMAS requirements for the tests for which they are accredited. The assessor will also check that the staff are not subjected to pressures or inducements that may affect the quality of their work.

Documentation Control

Having established that the laboratory has an acceptable management structure the assessor then checks to see that the necessary procedures and resources are available to carry out the testing for which accreditation is sought. He will first check to see that a system exists for the control of all documentation used by the laboratory so that it is always up-to-date, issued to all relevant staff and reflects current practices. He will check to see that all in-house procedures that may affect the quality of testing are documented.

Quality Audits

The team leader will then usually examine the laboratory's procedures for auditing the quality system ie checking that staff are following the procedures laid down in the Quality Manual and any associated documentation. In particular he will look for evidence of a regular programme of audits so designed that each area covered by Table 1 is examined at least once a year, or more frequently if the work-load requires. The Quality Officer or designated trained member of staff will be expected to perform these audits and all observations made whether negative or positive have to be recorded. Wherever possible, the assessor will expect the auditor to be someone independent of the testing under examination; staff are not permitted to audit their own activities.

The team leader will examine recent audit records in detail to check that any non-compliances with the laboratory's quality arrangements and with NAMAS requirements have been recorded and have been discharged within a reasonable timescale.

Quality System Review

The laboratory will need to review its overall quality arrangements from time to time in the light of the findings from audits, any complaints received from clients and any changes in organisation, staffing etc. The team leader will check that appropriate arrangements for periodic review of the quality system by top management are in place and being acted upon.

Quality System – General

The other main elements of the quality system that the lead assessor will scrutinise are the procedures for training staff, the arrangements for selection and calibration of all testing and measuring equipment, the procedures adopted for receipt, handling and disposal of test items, the preparation, checking and issue of test reports and certificates, any arrangements made for sub-contracting tests and the procedures adopted in the event of a complaint or dispute.

Some of these areas will also be covered by individual technical assessors but the team leader will be forming an overview of the effectiveness of the system across departments. For example, he will check that there is a sample handling procedure that ensures that all samples are individually and uniquely identified at all times especially when they move from one department to another and that there are clear rules for the storage, handling, bonding and disposal of all test samples.

Measurement and Calibration System

In the same way the team leader will look for centrally coordinated arrangements for the maintenance and calibration of all test and measuring equipment including ancilliary items. He will check that calibrations are performed at the appropriate intervals and over the range used for the accredited tests. He will ask to see the results of any calibrations performed in-house including evidence that the operator concerned has been trained, is following documented procedures, and is using reference standards that are calibrated and that the calibrations are traceable to national standards. Finally, he will check that the calibration uncertainty is appropriate to the test measurement to be made.

Test Reports

To check that all test data is correctly reported the team leader will randomly sample the central test reports file. Reports will be examined by comparison with original observations, checked for content as required by the test specification, and checked for accuracy and to ensure that they have been checked and signed by an authorised officer and that they contain no misleading statements.

Role of Technical Assessor

While the team leader is carrying out his assessment of the overall quality system the Technical Assessors will go to the testing areas and assess the technical competence of the staff, the suitability of the equipment and facilities, the availability and content of test and calibration procedures, the procedures for handling, storage and disposal of test items, the methods for recording and reporting results and any other aspect of the laboratory's activities that may affect the quality of testing.

In particular, the assessors will ask laboratory staff to demonstrate their competence in the tests for which accreditation is sought preferably by observing tests on real samples for clients. The assessors will first check that the testing staff understand what they are trying to do and have adequate documented instructions available for operating the equipment and for performing the test consistently. If the assessors have any doubts about the competence of any of the staff they will then ask the laboratory management to show them the list of staff authorised to perform specific tests and/or operate specific items of testing equipment. The assessors will also expect to be able to see the training records for such staff at some stage during the assessment.

Equipment

For each test the laboratory performs the assessor will take great care to check that the laboratory has all the equipment required for the test and that it all complies with the requirements of the test specification. The assessor will also check that the main items of test equipment and any ancillary items having a bearing on the quality of the test results are calibrated and the calibrations evidenced by current certificates showing traceability of the measurements to national standards.

In the UK the laboratory is normally expected to obtain such certificates from an accredited calibration laboratory. It is also expected to show through the records that it maintains for all calibrations that the uncertainty of measurement is appropriate to the uncertainty it claims for its testing and that calibrations are performed at intervals in keeping with these requirements and any requirements stated in the testing specification.

During the performance of the test the assessor will compare the procedure adopted by the testing staff with that stated in the published specification and/or in-house procedural document. Should the testing staff deviate from the stated procedure this fact will be recorded after discussing the deviation with the staff concerned. The assessor will take note of any observations made as part of the testing process and will point out any additional information or data that the testing staff should be recording to ensure that the test can be repeated at a later date, that the requirements of the testing specification have been met and that the sources of any errors can be identified. Checks will be made of worksheets and workbooks to establish that records are consistently made at all times and that any alterations to observed data or calculations have been made in such a way that all the original observations can still be identified.

Where the laboratory uses test methods that are not published or contain insufficient detail the assessor will expect to see a documented in-house procedure that contains all the elements necessary to perform the test with precision and consistency. This situation frequently occurs in chemical analysis and the assessor will expect to see instructions in the written method covering the whole testing process from the preparation of the sample to the estimation of precision of the test results. He will expect to see evidence of the regular use of certified reference materials to 'calibrate' the method. This is particularly important where the method uses instrumental techniques in which the operator is only provided with the final result.

Assessors will also ask to see evidence that checks have been made on testing equipment that employs software to verify that the output data is what it should be.

While the assessors are touring the laboratory facility they will check that adequate space and lighting is available and that the testing environment meets any requirements of the test specification. They will also check that arrangements exist to prevent unauthorised access to the laboratory and unauthorised use of equipment used for testing. Particular note will be taken of the arrangements made to ensure client's information, reports etc are held in confidence and securely stored.

While the team leader will concentrate on examining the system for identification, preparation, approval and issue of test reports and test certificates each individual assessor will be expected to check reports and certificates for accuracy, content, pagination and unique identification.

OUTCOME OF ASSESSMENT

After the assessment team has completed its tour of the laboratory and considered its findings in private the team leader prepares a summary report. This report contains the recommendation on accreditation and refers to any non-compliances with the NAMS requirements that have to be discharged before accreditation is granted. These non-compliances are detailed on standard forms and are based on observations agreed and witnessed by staff as the assessors toured the laboratory.

The summary report and non-compliance detail forms are passed over to the laboratory management who then indicate on the forms the actions they intend to take to discharge these non-compliances. At the end of this final meeting with laboratory management there is therefore a clear understanding of what has to be done to achieve accredited status within a given timescale.

MAINTENANCE OF ACCREDITATION

As soon as the laboratory has discharged all the actions and paid the necessary fees accreditation is granted and a schedule of accredited tests issued.

From this point onwards the laboratory has to maintain compliance with the NAMAS requirements at all times and there are three ways in which this is monitored. Firstly, the laboratory is expected to carry out its programme of audit and review and in doing so make sure that any non-compliances noted are discharged within the agreed timescales. Secondly, clients and other laboratories often act as 'policemen' to ensure standards are maintained. Finally, NAMAS conducts regular, and if necessary, unscheduled visits to monitor performance.

During these visits, which are conducted 6 months after accreditation and thereafter at 12 monthly intervals, the assessors sample the activities of the laboratory to check for continuing compliance with the laboratory's own quality manual and with NAMAS requirements. Any non-compliances found are reported as during assessment and the laboratory has to discharge them within one month to retain accreditation.

Once every 4 years the assessment team will carry out a complete examination of the laboratory's activities as in the initial assessment to ensure all requirements are still being met.

SUMMARY

The above description of the NAMAS process for assessing laboratories applies to all types of testing laboratory and all the cement and concrete testing laboratories in NAMAS have been assessed in this way. It is of interest to note that although some cement and concrete testing laboratories take longer than others to achieve accredited status they can all reach this status if they are prepared to make the effort to institute the necessary systems and make changes in their current practices where necessary. One of the biggest hurdles is convincing these laboratories of the need for a documented quality system to ensure consistency from day-to-day in their testing activities.

It is NAMAS experience that those laboratories that have shown no inclination to obtain accreditation generally operate without any form of documented quality system, do not carry out internal audits in a structured or regular manner and do not understand the need for a calibration management system and for measurements to be traceable to national standards.

One of the most common observations made by NAMAS assessors on their visits to cement and concrete laboratories is that laboratories claim to work to testing standards such as BS1881[6]. Assessment shows that this is often not so partly because staff have not been adequately trained in the use of the standard, they have misunderstood the requirements of the standard or they believe they can ignore certain features of the standard.

Findings from assessments of concrete laboratories show, for example, that most machines are calibrated for force but sometimes the calibration is not traceable to national standards and more importantly the requirements to check platen alignment and platen flatness have not been satisfied. It is also observed that when the laboratory has a high throughput of test samples some of the other requirements of BS1881 are not always satisfied. For example, curing tanks are sometimes overloaded preventing proper water circulation and the achievement of uniform conditions around the cubes. On occasions it is noticed that the water is not changed regularly in curing tanks as required by the standard and so the curing tank water becomes heavily contaminated. The requirement to control the temperature of the curing tank water between specified limits and to record the maximum and minimum temperatures experienced by cubes during curing is also not always complied with.

The other areas where non-compliances with the standard occur relate to the failure to measure cube dimensions before determining density on cubes which have dimensions outside the nominal tolerances allowed by the standard, the tendency to use higher rates of loading during the compression test than the standard specifies and failure to include all the required information in the test certificate.

None of the above are difficult to correct but some of these findings especially when taken together could cast serious doubts about the validity of test results generated by the laboratory.

CONCLUSIONS

The increasing tendency for users of testing laboratories to specify NAMAS accredited laboratories for cement and concrete testing in the UK is undoubtedly an indication that accreditation has given the user greater confidence in the quality of the work done by such laboratories.

Because these laboratories should be operating to properly documented procedures at all times the user should have confidence that the tests are being performed consistently from one day to another and in accordance with the prescribed methods.

If the accreditation service wants to generate even more confidence in the performance of the laboratory it can require the laboratory testing staff to participate in a proficiency testing scheme. Such schemes can generate valuable statistical information but this is most meaningful and useful if it has been obtained from laboratories that operate quality management systems and have been accredited.

TABLE 1

NAMAS ACCREDITATION CRITERIA

1 GENERAL REQUIREMENTS

2 ORGANISATION AND MANAGEMENT

3 QUALITY SYSTEM – QUALITY MANUAL, QUALITY POLICY AND DOCUMENTATION CONTROL

4 QUALITY AUDIT AND REVIEW

5 STAFF

6 EQUIPMENT

7 MEASUREMENT TRACEABILITY AND CALIBRATION

8 METHODS AND PROCEDURES FOR CALIBRATIONS AND TESTS

9 LABORATORY ACCOMMODATION AND ENVIRONMENT

10 HANDLING OF CALIBRATION AND TEST ITEMS

11 RECORDS

12 CALIBRATION CERTIFICATES, TESTS REPORTS AND TEST CERTIFICATES

13 HANDLING OF COMPLAINTS AND ANOMALIES

14 SUB-CONTRACTING OF CALIBRATIONS OR TESTS

15 OUTSIDE SUPPORT SERVICES AND SUPPLIES

REFERENCES

1. "The Case for a Construction Industry Testing Authority"
Report of the committee for establishing a National Testing Authority for the Construction Industry, London 1973.

2. "The Performance of Existing Test Machines"
Concrete Society Technical Paper PCS 62, London 1971.

3. "BRMCA figures show up Test House failings"
New Civil Engineer, London August 1972.

4. "Factors Affecting the Results of Polished Stone Value Tests"
TRRL Report LR 216, 1968.

5. "The Reproduceability of the Results of Soil Classification and Compaction Tests"
TRRL Report LR 339, 1970.

6. BS1881: 1983, Methods for Testing Concrete.

7. "A Proving Device for Concrete Cube Testing Machines"
P Foote, Cement and Concrete Association Report TRA 443: 1970.

8. M10: NAMAS Accreditation Standard: General Criteria of Competence for Calibration and Testing Laboratories.

9. M11: NAMAS Regulations: Regulations to be met by Calibration and Testing Laboratories.

R.N.E. - THE FRENCH ACCREDITATION SYSTEM FOR LABORATORIES

J.F. COSTE
Director of LCPC - France

Abstract

The French laboratory accreditation system monitored by the Reseau National d'Essais (R.N.E.) i.e. the National Testing Network is discussed. After a review of the objectives which led to the formation of the R.N.E. in 1979, the R.N.E. testing laboratory accreditation system is described and the technical requirements for accreditation are enumerated.

An analysis of the main phases of the accreditation procedure is provided. The cement and concrete accreditation programme includes the following components: the administrative investigation of the request, the technical assessment by the audit group, the accreditation delivered for specific tests by the Board of Directors on the recommendation of the Sectorial Committee, and periodic re-inspections with follow-up intercomparative tests.

In summary, accreditation is currently granted to 28 French cement and concrete laboratories belonging either to private firms or associated with the Ministry of Transportation. The test quality and performances of laboratories in the R.N.E. system are recognized by other countries. Bilateral agreements either exist with ECC countries (NAMAS-UK) or are under discussion. Motivation for such agreements is being provided by movement toward a unified European inner market by 1992.

<u>Key Words:</u> accreditation, recognition agreement, test quality, testing laboratory

1. Introduction: Quality of testing, a key factor for civil engineering

Reliable tests and measurement data are required from building and civil engineering laboratories. Such measurements concerning building materials refer mainly to conventional data scales and processes. Testing is performed by laboratories showing a wide range of proficiency, size and technical knowledge. This includes state laboratories, semi-private laboratories with government support, private laboratories, and laboratories belonging to universities. In-house testing by industrial firms is also growing.

Since 1979 accreditation of laboratories in France has provided a mechanism for assessing the reliability and quality of testing provided by laboratories which helps avoid discrepancies between results of different laboratories.

2. The Reseau National d'Essais

2.1 Organization

The Reseau National d'Essais (R.N.E.), a non-profit-making Association governed by the Law of 1st July 1901, was founded in 1979 at the initiative of the Public Authorities in order to organize the testing function in France. The Association is governed by a Board of Directors consisting of prominent representatives of the full range of parties involved in testing: public and private laboratories, Ministerial technical departments, professional organizations and test service users. The Government is represented on the Board by a Government Commissioner who has veto power.

The R.N.E. is further characterized by:

- the purely voluntary mode of participation of each member, the R.N.E. possesses no regulatory power;
- the accessibility of all laboratories to a method for proving their competence; and
- its multi-disciplinary approach which currently includes electrical tests, chemical tests and analysis (including petroleum products), building tests, civil engineering tests, physical and mechanical tests, and food products tests which were recently added.

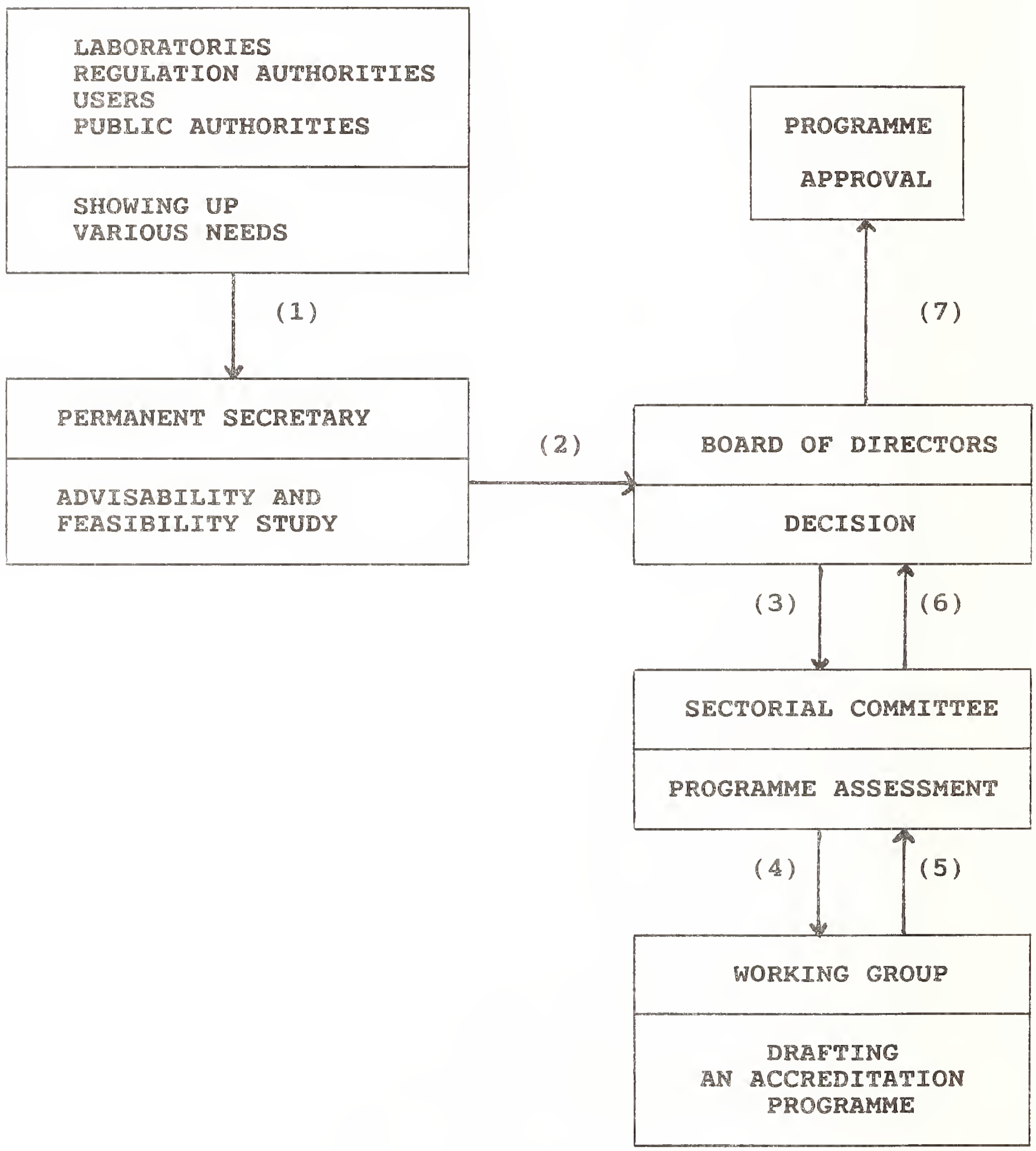
2.2 Users of R.N.E. Services

The R.N.E. programs are available to all economic groups including:

- public authorities, requiring testing in accordance with technical regulations or as purchasers of products, may seek assurances with regard to the technical competence of the laboratories with which they deal;
- certifying bodies for which tests are the basis for decisions on awarding qualification certificates;
- individual consumers, whose need for precise and authenticated technical information to guide their purchasing decisions is becoming more and more apparent, and consumer organizations which refer to laboratories for their comparative tests;
- product distributors and purchasing organizations who use test results to be sure of the properties and performance of the products they acquire and offer for sale;
- industrialists may also make use of the R.N.E.'s services such as testing when required to perfect new products, in assessing product's properties before entering into a contract, or to provide an independent testimony regarding the quality of the products they are offering for export;
- insurance companies rely on performance tests of security systems or of machines used by their clients as a means of assessing the risks involved; and finally
- laboratories themselves may wish the R.N.E. to become involved in a technical field where discrepancies have appeared.

THE ACCREDITATION PROCEDURE

DRAFTING AN ACCREDITATION PROGRAMME



2.3 Structures of R.N.E.

The Reseau National d'Essais relies on a Permanent Secretariat to carry out its functions, as well as Sectorial Committees headed by the following major laboratories:

- the C.S.T.B. (Centre Scientifique et Technique du Batiment), the L.C.I.E. (Laboratoire Central des Industries Electriques), the L.C.P.C. (Laboratoire Central des Ponts et Chaussees), and the L.N.E. (Laboratoire National d'Essais) are respectively in charge of tests on buildings and analyses, electrical and electronic tests, tests in the field of civil engineering, and physical and mechanical tests.
- In the chemical area, the Sectorial Committee is headed by three other laboratories:
  - o IFP (Petroleum Research-Institute),
  - o CERCHAR (Coal Research Institute),
  - o INRS (National Safety Research Institute).
- The Sectorial Committee for food products is headed jointly by the Department of Agriculture and the Department of Finance.

3. Accreditation Procedure

3.1 Definition

The R.N.E. accreditation procedure involves evaluating, certificating, and publicizing the value and technical quality of the testing performed by a laboratory.

3.2 Characteristics

a) <u>Scope of the Recognition Granted</u>

For obvious technical reasons, a laboratory may not be recognized for all the services it offers. Accreditation is granted to "technical units" for clearly defined tests (i.e. a set of technical and human resources).

b) <u>Reference to a Program</u>

The number of different tests carried out in France is considerable. The technical or economic value attached to the issuance of an accreditation varies from one industrial sector to another depending on the commercial rules that prevail.

The performance of certain tests sometimes requires observing special precautions which has led the R.N.E. to draw up "Accreditation Programmes." Today about 60 such programmes have been established for the fields involved in the R.N.E. network, including about 10 programmes concerned with Civil Engineering. A programme is a document which contains a list of tests for which R.N.E.'s recognition may be obtained. It specifies the requirements of the tests in question for the applicant laboratory along with other conditions (number of examiners, comparison tests, etc.) that must be met by applicants. For example, Accreditation programme No. 3 deals with concrete tests and tests of its components (cement, aggregates, water and additives). There are 21 tests assigned to cement.

Tests refer generally to French standards (AFNOR) or international standards such as ISO, and to specific requirements related to the field involved. For example, specific requirements concerning cement tests are given for the humidity and temperature levels of the testing room where samples are stored.

c) Requirements

The technical criteria used to evaluate a laboratory's competence is assessed under Rules of Procedure established by R.N.E. Prior to 1988, the criteria were based on provisions of the ISO-CEI GUIDE No. 25: "General Requirements for the Technical Competence of Test Laboratories", which were compatible with those adopted by major laboratory accreditation systems existing abroad. They have been recently modified to abide by the "European norme" EN 45001.

Requirements specific to a particular type of test may also be provided by the accreditation programme. These requirements are expressed in terms of objectives to be reached. It is up to each laboratory, depending on its size, its field of operations, its internal structure, etc. .. to determine for itself the means for meeting these requirements.

d) Assessment Operations

Accreditation is not easily obtained, but results from a formal and rigorous assessment and inspection of operations aimed at demonstrating objectively that the requesting laboratory meets the requirements laid down by the R.N.E.

4. Procedure for Accreditation of Testing Laboratories

The procedure for laboratory accreditation is set in motion once a feasibility study has shown the need for qualification of testing within a well-specified technical field. These may be technical needs in areas where discrepancies in the results of several laboratories have appeared, commercial needs in areas where R.N.E. backing may help promote quality products in domestic or international markets, or needs expressed by the end users of test results. Public authorities or certifying bodies often wish to obtain assurances about the qualify of the services of the laboratories on which they rely. There are three phases in this procedure:

4.1 Drafting an Accreditation Programme (see flow chart)

This programme specifies the list of tests (with reference to documents defining testing methods/categories of products) for which accreditation may be awarded. Once definitive approval of the programme has been decreed by the R.N.E.'s Board of Directors, a laboratory may apply for accreditation for all or part of the tests in the programme.

4.2 Laboratory Accreditation

Accreditation is awarded on completion of a rigorous evaluation designed to ensure that applicant laboratories actually comply with the requirements. The procedure for investigating accreditation requests from testing laboratories relies on three phases: administrative investigation of requests, technical investigation, and the decision making phase.

a) <u>Administrative Investigation of Requests</u>

On receipt of a letter of intent from a testing laboratory interested in the R.N.E. accreditation system, the Permanent Secretariat sends the applicant:

- a set of documents giving procedural details,
- a form that then enables the laboratory to confirm its request officially and to specify its scope,
- an estimate of the expenses relating to the assessment operation that the laboratory will have to pay, and
- an offer to visit the laboratory to describe the procedures, to review the responsibilities and financial obligations attached to belonging to the R.N.E., and to list the technical requirements to which its aptitude for accreditation will be assessed

The accreditation request must clearly specify the technical unit(s) of the laboratory seeking accreditation and the tests covered by the application. In addition, a laboratory may, under certain conditions, ask for accreditation for tests which differ somewhat from those explicitly described in the programme.

On receipt of an official application, the assessors responsible for conducting the assessment of the applicant laboratory are appointed. These assessors may be refused by the applicant and others will be appointed.

Obviously, all information gathered by the R.N.E. or its representatives, along with the very existence of an application are considered to be confidential.

<u>b) Technical Assessment</u>

The technical assessment is carried out by the Audit Group, appointed by the R.N.E., that consists generally of two experts: one trained in laboratory assessment methods and having a good comprehension of quality management and assurances techniques, and the other a technical expert who has broad experience with the tests being assessed.

Assessment consists of obtaining, as objectively as possible, an overall view of the situation in the laboratory being assessed in terms of the rules of proper professional practice laid down by the R.N.E. It is not up to the audit group to make any judgement as to the applicant's aptitude to be accredited.

The objective of the procedure is to ensure, by means of interviews, review of documents, visit to the premises and, where applicable, examining the results of interlaboratory tests, that the applicant laboratory is operating in accordance with R.N.E.'s requirements. The Audit Group conducts its visit as described in the paper by Mr. Treps, "Experience in Obtaining R.N.E. Accreditation" included in these workshop proceedings.

c) <u>Decision-Making Phase</u>

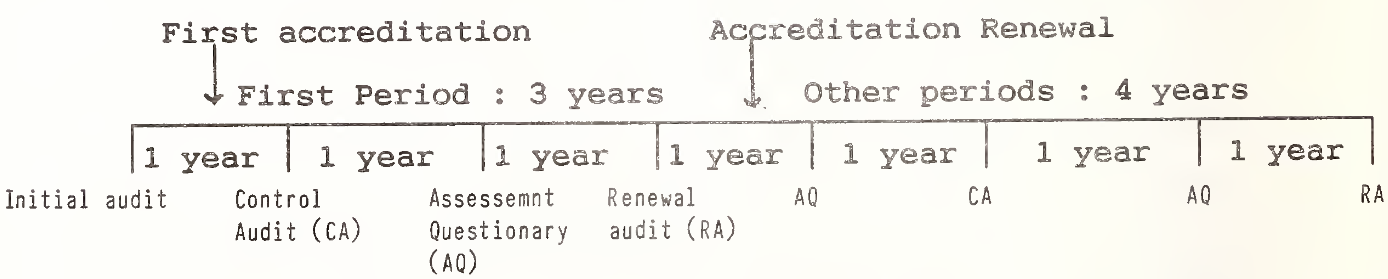
The decision-making phase begins with the examination of the assessment file by an Ad-hoc Sectorial Committee. This committee consists of representatives from the sector of industry involved including testing laboratories. It may (or may not) propose, with or without reservations, that the R.N.E.'s Board of Directors grant a certificate of accreditation to the applicant laboratory. This proposal is sent to the applicant for comment before being forwarded to the Board.

The Board of Directors of the R.N.E. makes its decision based on the proposals of the Sectorial Committee and the comments of the applicant laboratory. If approved, an official accreditation certificate is issued to the laboratory.

4.3 Follow-up of Accredited Laboratories

An accreditation certificate is issued for a duration of three years to laboratories that have met the requirements. However, accreditation may at any time be suspended or withdrawn, totally or partially, if it turns out that the laboratory no longer complies with the R.N.E. requirements or is failing to meet its obligations.

In order to ensure continuity of their competence over time, accredited laboratories are subjected to periodic checks. This includes a visit to the laboratory every two years, and the laboratory is asked to complete an assessment questionnaire for monitoring and checking the activities the other year.



The technical units accredited by the R.N.E. may, when they provide the testing services specified in their certificate, advertise in their documents that they belong to the Reseau National d'Essais and use the R.N.E. logo.

5. Status of the R.N.E.

5.1 Accredited Laboratories in France

As of January 1989, 97 laboratories have been accredited by the R.N.E. for about 60 accreditation programmes. These accreditations concern 182 technical units with some laboratories involving one or several units located elsewhere in France. There are 28 cement and concrete laboratories in France accredited with the following breakdown:

Status	State Labs	Government Supported Labs	Private Labs	In-house Labs	Total
Number	18	3	3	4	28

5.2 International Links

The R.N.E. is closely following the work of the International Laboratory Accreditation Conference (ILAC). ILAC periodically holds meetings of representatives of countries and international organizations seeking to inform each other of the various technical, legal and administrative problems related to mutual recognition of test results.

On October 13, 1986, the R.N.E. signed a mutual recognition agreement with the National Physical Laboratory (NPL/NAMAS) in the U.K. This agreement gives mutual guarantees for the test results of accredited laboratories in both countries. Other agreements are under discussion with similar laboratory accreditation organizations of the European Economic Community (E.E.C.) in order to avoid duplication of testing.

6. Conclusions

The Reseau National d'Essais seeks to recognize the technical competency of testing laboratories in a timely and efficient manner. It is hoped that the quality and reliability of its work will bring about recognition of the credibility and technical competency of participating laboratories. Documents issued by its member laboratories will then have proper recognition by all parties, both nationally and internationally. This especially applies to the European Economic Community.

References

Articles of Reseau National d'Essais, R.N.E., May 1989 (French)

Rules of Procedure, R.N.E., May 1989 (French)

Training of Assessors at the R.N.E., Dublin, 1987 (English)

Programme No. 3 - Tests for Concrete and Its Components, R.N.E. (French)

Treps, J., Experience in Obtaining R.N.E. Accreditation, Proceedings of the Workshop on Evaluation of Cement and Concrete Laboratory Performance, NIST Special Publication, Gaithersburg, MD (in-press).

ISO Guide No. 25 "General Requirements for the Technical Competence of Testing Laboratories"

European Standard EN 45001

EXPERIENCE IN OBTAINING R.N.E. ACCREDITATION

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Quality Department, CIMENTS FRANCAIS

Abstract

Even though the laboratory of CIMENTS FRANCAIS had a good reputation in France it was decided to seek accreditation by the Reseau National d'Essais (R.N.E.). It was the first private laboratory to be accredited by the R.N.E. for physical and chemical tests on cement and concrete.

A great deal of work was necessary to obtain accreditation even though the laboratory was performing well. Special efforts were required in the areas of organization, documentation, training, operational procedures, and calibrations. Significant investments were made in purchasing calibration equipment and for obtaining calibration of equipment by accredited national laboratories according to national standards. A section on metrology was added to the organization. Participation of all the executive staff of the plant was important in achieving accreditation.

The advice of the R.N.E. was very helpful during the accreditation process. The quality audit evaluating the laboratory's organization and technical competency was very thorough. All this work and money spent obtaining accreditation resulted in higher quality of testing, fewer number of tests requiring re-running, new customers being obtained by the laboratory, and other benefits which go with recognition as a qualified laboratory.

1. Introduction

The Accreditation by the Reseau National d'Essais (R.N.E.) in France provided many benefits to our laboratory but it required a great deal of work and an organized approach to accomplish. The cost in time and money was significant. It is necessary to obtain the support of all the staff in obtaining accreditation and their involvement from the beginning was important. I will present our experience in obtaining R.N.E. accreditation.

2. Situation Prior to Accreditation

The central laboratory of CIMENTS FRANCAIS was already well known in France. It was chosen as a reference laboratory by CERILH for its cement proficiency sample program, and it is evaluated by organizations like SNCF (the French railway).

The three laboratories of CIMENTS FRANCAIS are an analytical chemical laboratory, a cement laboratory doing physical and mechanical testing, and a concrete laboratory. The two first laboratories are being monitored by the laboratory of the City of Paris which is an officially recognized testing laboratory accredited by the R.N.E. Since 1979 the main work of these laboratories is to conduct tests in accordance with French standards. The aim of these standards is to ensure the quality of cement and concrete testing and to minimize variability in testing. The laboratories of CIMENTS FRANCAIS conduct about 40 different tests on 6000 to 8000 samples a year.

The need for accreditation became apparent to CIMENTS FRANCAIS in 1985 when society became more international in scope and transnational recognition of test results became important. It was decided to seek accreditation by the R.N.E. to increase the reputation of CIMENTS FRANCAIS laboratories both nationally and internationally. Accreditation required a great deal of work and costs even though the laboratory already had a good organization, quality system and necessary equipment.

3. Preparations for the Accreditation

3.1 Organization

Special efforts were made in motivating and training staff, and in proving that we were able to execute the tests in conformity with the standards. The R.N.E. requires the presence of a quality supervisor independent of the laboratory management who reports to the director. His job is to establish the quality assurance organization and to monitor its effectiveness by communicating with the engineers in charge of the laboratory. It was also necessary to show we have taken the proper steps in assuring our customers that information will not be divulged to a third person.

3.2 Equipment

The R.N.E. requires calibration of equipment in accordance with national standards. Substantial investments were made for calibration equipment and for calibrations provided by national laboratories. We estimate the cost of calibration which must be done every four years at $7000 (45,000FF) per year . Often the cost of calibration is equivalent to the cost of the equipment.

The R.N.E. sometimes specifies more strict requirements when the standard is felt to be deficient.

<u>Example</u> Rate of increase of load of the cement compression machine

French standard $1/N/mm^2/s$ to $2N/mm^2/s$
RNE requirement $1.4/N/mm^2/s$ to $1.6N/mm^2/s$

It was difficult to explain to the staff that the certificate on equipment provided by the supplier has no value, even if it is a foreign one. The amount of defective equipment delivered has decreased since manufacturers realize that we are more careful in the preparation of specifications, and in the inspection of equipment when received. We believe suppliers are more careful with the equipment before delivery since they know it will be inspected closely in regard to conformance to standards. That actually results in a real savings in time and money to the supplier and the purchasing laboratory.

3.3 Staff

Our experience shows that the most difficult task is gaining the support of staff in implementing new laboratory procedures. They are set in their ways and do not like to change. We now get them involved early in the accreditation process which helps to motivate them.

We try to impress on staff the importance of quality. The value of a quality organization is emphasized instead of changes in work procedures. For example, when a technician was given the responsibility of checking thermometers delivered by a supplier, he encountered two which did not conform to the standard procedures. This made him a vital part of the quality system.

3.4 Documents

Some new documents had to be introduced by the laboratory including the following:

- Quality Manual and Quality Plan. We encountered some difficulty at the beginning in determining what should be in each book. We received assistance from the R.N.E. which saved a lot of time.

- Anomalies Book and Claims Book. Since these records were not in our organization before accreditation, it was necessary to explain their importance to the staff. We had to explain how we can use these records to prevent future problems or to explain the purpose of new equipment.

- Methods and Procedures. We initially encountered some difficulty in documenting test methods and procedures. The technicians who did the most complicated tests did not want to write the explanations of the standard test procedures since it seemed to be a waste of time.

3.5 Receipt of Specimen Preparation and Testing

Since we routinely conducted tests on 6000 to 8000 cement samples a year, we already had a good system in place for sample storage, preparation and testing. We had only to prove to the R.N.E. that the system was operating effectively.

3.6 The Test and Its Control

We had only to verify that a system of traceability existed. We were required to maintain data sheets for each sample since all intermediate results were sometimes not kept. Here again it was necessary to show the staff the value of this new task.

3.7 Transmission of Test Results

A data base existed before accreditation which did not include all the data concerning the customer and his order. We were required to create another computer file for these data. Test reports had to be printed on special paper and since we had only one output printer, we had to change the paper for each kind of test report. Each laboratory has since obtained its own output printer. The special colored paper on which these reports are printed is another additional cost related to the accreditation.

3.8 Preventative and Corrective Action

Our quality policy was changed to include an internal quality audit once a year as required by the R.N.E. The audit is now well accepted by the staff because they recognize its benefit. Responsible laboratory staff find the audit helpful in explaining and justifying the increased investment of time and money.

4. Quality Audit by the R.N.E.

4.1 Frequency

The frequency of the R.N.E. audit is once a year for the two first years and once every two years thereafter. Between each audit we have to complete two questionnaires. The first one asks for action taken on the preceding audit including new equipment and procedures. The second one a year later asks for the result of the internal quality audit and the results of interlaboratory testing.

4.2 Preparation

A month before the audit, the laboratory sends the R.N.E. auditor its quality manual to review, and the R.N.E. provides the laboratory responses to the questionnaires.

4.3 The Audit

After a meeting with management staff, the auditor reviews the laboratory organization by use of a check list. This takes the whole morning with the afternoon used for the technical aspect of the audit.

With the technical questionnaire the auditor checks the three laboratories of CIMENTS FRANCAIS with particular attention to:

- calibration
- procedures
- traceability of the tests and equipment
- laboratory (documentation, anomalies, claims, etc.)

Laboratory staff participate in this part of the audit, which provides them with a better understanding of accreditation procedures. Normally, the audit is conducted by a senior auditor; however, because of the size of our laboratories, all the audits were done by junior auditors. At the end of the day, the auditor reviews with laboratory management the results of the audit and interlaboratory testing conducted in common with other laboratories using the French standards.

After the audit, the quality supervisor in the laboratory organizes a meeting with the engineers responsible for each unit to review the points listed by the auditor. A schedule is prepared to correct all non-conformities and to prepare a response for the auditor.

A report is received from the auditor within a month. The quality supervisor prepares a response including the schedule of required actions which is sent to the auditor and to laboratory staff management.

4.4 Decision After the Audit

The report of the auditor and the laboratory response are studied by a commission of experts which proposes a decision on accreditation to the bureau of the R.N.E.

5. Benefits of R.N.E. Accreditation

The work required to obtain R.N.E. accreditation is costly and time consuming. An example is the investment in calibration equipment and calibrations by national authorities which amounted to around $20,000 for CIMENT FRANCAIS. In spite of these costs, there are significant benefits to our organization.

- Calibration equipment and equipment which is calibrated is used in all 12 of our plants.
- Accreditation can be advertised to solicit customers for our laboratory.
- Fewer numbers of tests have to be repeated with a greater reliability of results. Good traceability permits us to identify errors and to pinpoint their source.
- Accreditation has increased our testing business. This has required us to decentralize a part of the autocontrol of our plant laboratories because existing staff were not able to handle all the added testing. The resulting reorganization allows us to make more tests with the number of reports tripling in three years.
- Recognition of our laboratory provided by the R.N.E. accreditation is apparent.
- Laboratories other than those of the producer who conduct tests for standardization (autocontrol) of cement and concrete may, through the R.N.E. accreditation, be used with confidence.
- R.N.E. accreditation puts our laboratory in a better position when we have a dispute with a supplier. We see a decrease of non-conformity of materials from suppliers even if the specifications are more strict. Suppliers are more careful with their deliveries since they know that we are in a better position to make claims against them.
- A R.N.E. accredited laboratory operates with more confidence because of a highly motivated staff.

6. Future of the R.N.E.

We think that the internationalization of the R.N.E. through mutual recognition with the other national systems is a good thing, especially with the trade frontiers falling in Europe resulting in an increase in the exchange of test results. It is a guaranty of quality when only methods which are standardized are accepted.

While the R.N.E. requirements seem difficult, they have many benefits. A laboratory which has decided to not seek accreditation has come to us to do their testing. They do not think the cost of accreditation is worth it because of the small amount of testing they conduct.

7. Conclusion

R.N.E. Accreditation cannot be achieved without the strong endorsement of laboratory management staff. They must participate in the accreditation process since it properly informs them of the nature of the tasks and motivates them toward the attainment of the goal.

LINK BETWEEN TEST RECORDS ON CONCRETE AND ITS INGREDIENTS OBTAINED FROM DIFFERENT LABORATORIES

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Abstract

Control tests of ingredients and then of concrete are conducted on different levels during production, acceptance and in service. The tests are carried out by producers, users or their representatives, and independent bodies. In the traditional quality control of concrete structures, the link between the test records from different laboratories involved in the specific construction process is weak or negligible. Efforts are currently being made in quality assurance systems to correlate and analyze the test results from different levels for their use in production control.

This paper presents the results of an investigation of the construction of a hydroelectric power plant, by means of serial correlation, segmentation technique and moving average. An algorithm relating concrete, cement and aggregate data bases has been developed. Instead of a global approach, the effect of time dependent parameters on quality are obtained.

1. Introduction

Control tests of ingredients and then of concrete are conducted on different levels during production, acceptance and during service as shown in Fig. 1. In the traditional quality control of concrete structures the link between the test records from different laboratories involved in the specific construction process is weak or negligible. Control tests of concrete ingredients are conducted every day in the manufacturer's laboratory for use in production control. This is the case for cement, aggregate fractions and admixtures. The independent institution takes samples for testing from production at random depending on the output, but on an average of about once per month. The national standards organization issues a certificate valid for the next six months after the test results are statistically evaluated. The statistical treatment assumes that the data are normally distributed, i.e. time independent and internally not correlated.

Records of quality tests of ingredients are not used in concrete mix design and quality control of concrete, with only the existence or not of a certificate considered. Results of concrete control tests from central batching plants for ready mixed concrete are formally segmented into records of a duration not longer than three months. Again, they are considered as normally distributed. The test results from the site laboratory are evaluated every month, but records shall not be longer than 30 data points. Normally, the link between these data sources will be investigated only if test results fail to meet the design requirement.

Recently, Rackwitz (1977), and Taerwe (1987, 1988) have shown that cement or concrete strength values and aggregate characteristics have significant serial correlation which influences the distribution of usual sample statistics. The origin of serial correlation in records may be related to the nature of the production process, and more particularly to the characteristics of the input variables. The records may be split into segments with variable length by means of appropriate statistical methods.

This paper presents the results of an investigation of the construction of a hydroelectric power plant.

2. Theoretical Background for Data Analyses

An attempt was made to show time dependent properties and their correlations by applying the statistical techniques of autocorrelation, segmentation and moving average.

Serial Correlation

There will be dependencies of one kind or another between successive terms for series which are random. One very useful measure of this effect is the correlation coefficient between pairs of strength values, where the components of each pair are k units apart in the sequential sampling process. Given n values $X_1, \ldots X_n$ the so-called serial correlation of lag k (k < n) is defined by Kendall (1983) as:

$$r_k = \frac{\frac{1}{(n-k)} \sum_{i=1}^{n-k} (X_i - \bar{X}_n)(X_{i+k} - \bar{X}_n)}{\frac{1}{n} \sum_{i=1}^{n} (X_i - \bar{X}_n)^2}$$

where :
- n : the total number of observations
- k : lag; "distance" between pair observations (expressed as a number)
- x_i : i-th observation in a serias or sample
- x_n : mean of a sample or series

The graphical representation of Vu as a function of k is called a correlogram.

Segmentation Technique

Taerwe (1986) has used a segmentation technique which makes it possible to subdivide records of properties of concrete and its ingredients over time. A minimum segment length of $T_0 = 4$ observations is assumed. Values s, q, and r are calculated for each observation:

$$s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2$$

$$r = \frac{q^2}{s^2}$$

$$q^2 = \frac{1}{2 (n-1)} \sum_{i=1}^{n-1} (X_{i+1} - X_i)^2$$

It is checked whether $r < r_{0.05}$ for T_0 observations, if $r < r_{0.05}$ T_0 is taken as estimate of the length of the first segment, if not the next value is added to the segment.

$$r_{0.05} = 1 + \frac{u_{0.05}}{\sqrt{n+1}}$$

– where 0.05 fractile in the standardized normal distribution

<u>The Moving Average</u>

The enormous number of data with a large range of results suggested the analysis of moving average. This procedure was used in an attempt to eliminate the random errors of data and to diminish the influence of different factors.

3. Results

The investigation was conducted for the data obtained from the construction of a hydroelectric power plant which required the production of special cement. Also, the particular screening plant was preparing aggregate fractions for the batching plant. Cement was tested according to the previously described procedure. Aggregate was tested only in the site laboratory as was the concrete. All data are stored in the personal computer, which enables data processing by means of dBASE III PLUS and STATGRAPHIC software packages. The statistics are listed in Table 1.

The figures show results of statistical methods: Fig. 2. Summary Statistics for Concrete Data; Fig. 3. Cement Correlogram; Fig. 4. Segments of Concrete for the First 100 Data Points; and Fig. 5. Moving Average (3-20 data points) for Cement Strength, Aggregates Fineness Modulus, and Concrete Strength. The moving averages were calculated for three to twenty samples. Increasing autocorrelation can be seen in Fig. 6 Concrete Correlogram before and after moving average for three samples.

4. Conclusions

The analyses presented in this paper show that successive values of cement strength, fineness modulus of aggregate, and concrete strength are dependent on time. Certain auto correlation exists in properties of concrete and its ingredients.

The origin of serial correlation in records may be related to the nature of the production process. Connecting the data bases by statistical methods is promising a better understanding of variations in quality of concrete and its ingredients. A tool is provided for their time dependent correlation.

References

Kendall, M., Stuart, A and Ord, J. (1983) The Advanced Theory of Statistic, Vol 3, (ed. Griffin) London, pp. 422-656.

Rackwitz, R. (1977) A Simple Stochastic Model for In-Situ Concrete Strength, in Miscellaneous Papers in Civil Engineering, Dialogue, (ed. Denmarks Ingenirakadem, Bygningsafdelingen, Lyngby 19), pp. 117-133.

Taerwe, L.R. (1987) Detection of Inherent Heterogeneities in Cement Strength Records by Means of Segmentation, in Uniformity of Cement Strength (ed. E. Farkas and P. Klieger, STP-961), ASTM Philadelphia, pp 42-65.

Taerwe, L.R. (1988) Serial Correlation in Concrete Strength Records, in L. H. Tuthill International Symposium on Concrete and Concrete Construction (ed. Grant T. Halvorsen SP-104), pp. 223-240.

Table 1. Results of Statistical Methods

PROPERTIES	CEMENT STRENGTH (28 DAYS)	AGGREGATE FINENESS MODULUS	CONCRETE STRENGTH (28 DAYS)
S U M M A R Y S T A T S T I C S			
DATA FROM- TO	13.01.86 29.12.88	07.01.87 27.12.87	11.12.86 17.12.87
NUMBER OF TESTS	597	167	582
MEAN VALUE	30.01 (MPa)	2.61	31.72 (MPa)
STANDARD DEVIATION	2.00 (MPa)	0.198	6.64 (MPa)
COEFFICIENT OF VARIATION (%)	6.66	7.56	20.91
A U T O C O R R E L A T I O N			
r_1	0.57994	0.36542	0.22833
r_2	0.50117	0.26682	0.17816
r_3	0.39872	0.18772	0.12044
r_4	0.40138	0.11426	0.16005
r_5	0.33328	0.20638	0.10924
S E G M E N T A T I O N			
NUMBER OF SEGMENTS	93	18	49
MEAN VALUE OF SEGMENT'S LENGTH	6.39	9.17	11.88
LENGTH OF SEGMENTS MIN	4	4	4
LENGTH OF SEGMENTS MAX	29	57	59
M O V I N G A V E R A G E (M. A.)			
NUMBER OF TESTS WHEN M.A. IS CONST.	6	6	6
M.A. 0-SAMPLES MAX RANGE = = X s	14.7 (MPa) =7.4 s	1.1 =5.6 s	45.4 (MPa) =6.8 s
M.A.20-SAMPLES MIN RANGE = =X s	5.52 (MPa) =2.8 s	0.35 =1.8 s	13 =2.0 s

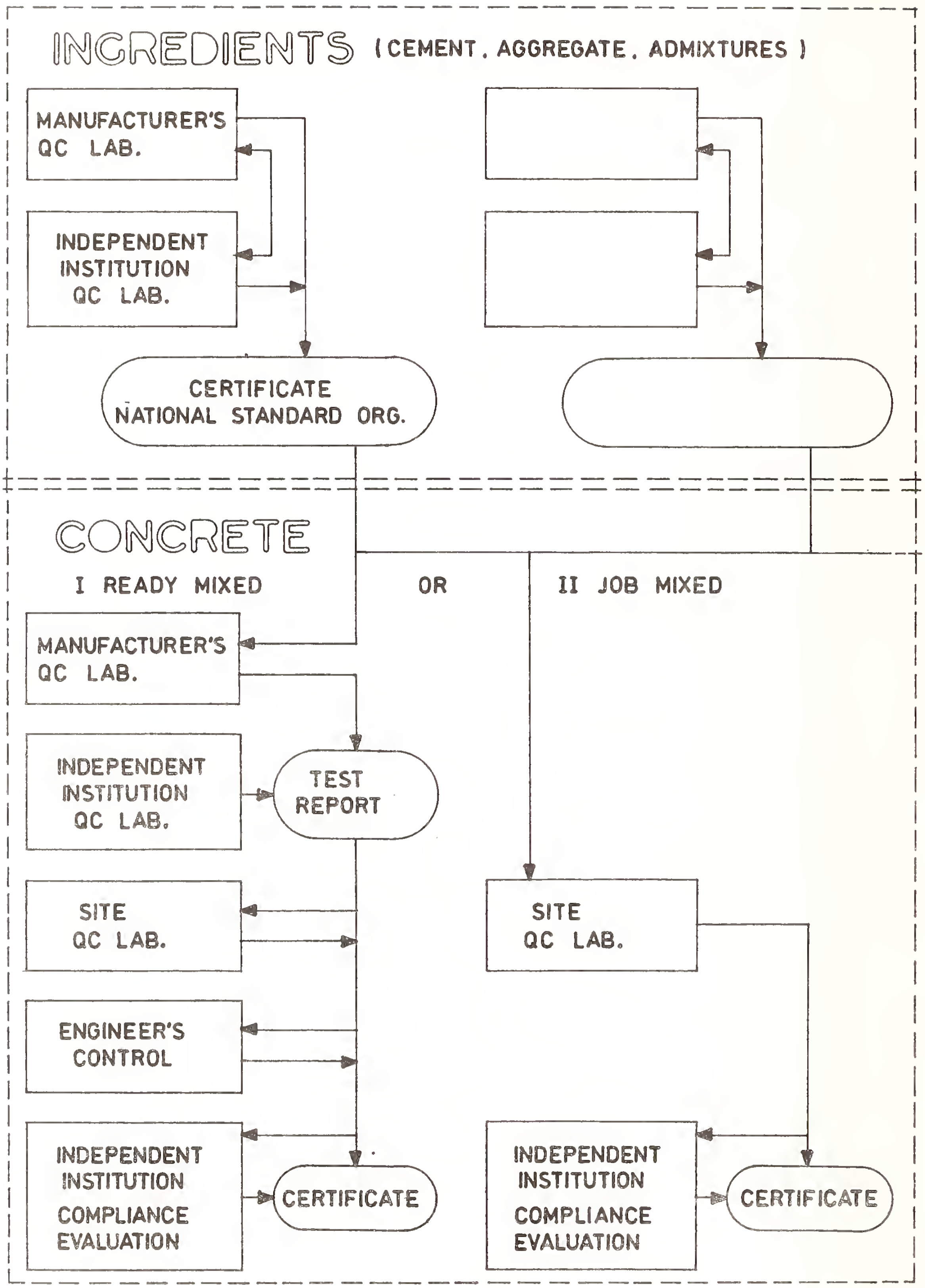

Fig. 1. Flow of data on quality control of ingredients and concrete.

```
ENTER THE NAME OF THE VARIABLE CONTAINING YOUR DATA:  tlc28
NUMBER OF OBSERVATIONS = 582  (0 MISSING VALUES EXCLUDED)
SAMPLE AVERAGE = 31.7201
SAMPLE VARIANCE = 44.0325
SAMPLE STANDARD DEVIATION = 6.6357

MINIMUM VALUE = 13.9   MAXIMUM = 59.3   RANGE = 45.4
LOWER AND UPPER QUARTILES = 27.3 35.9
INTERQUARTILE RANGE = 8.6
MEDIAN = 31.5

COEFF. OF SKEWNESS = 0.281766   STANDARDIZED VALUE = 2.77507
COEFF. OF KURTOSIS = 3.5588   STANDARDIZED VALUE = 2.75179
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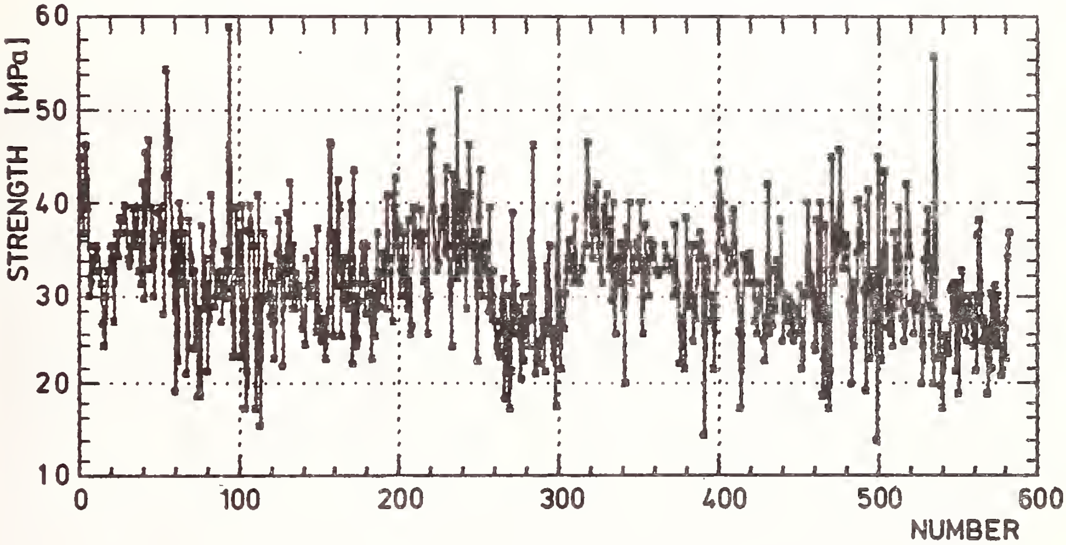

Fig. 2. Summary statistic for concrete data

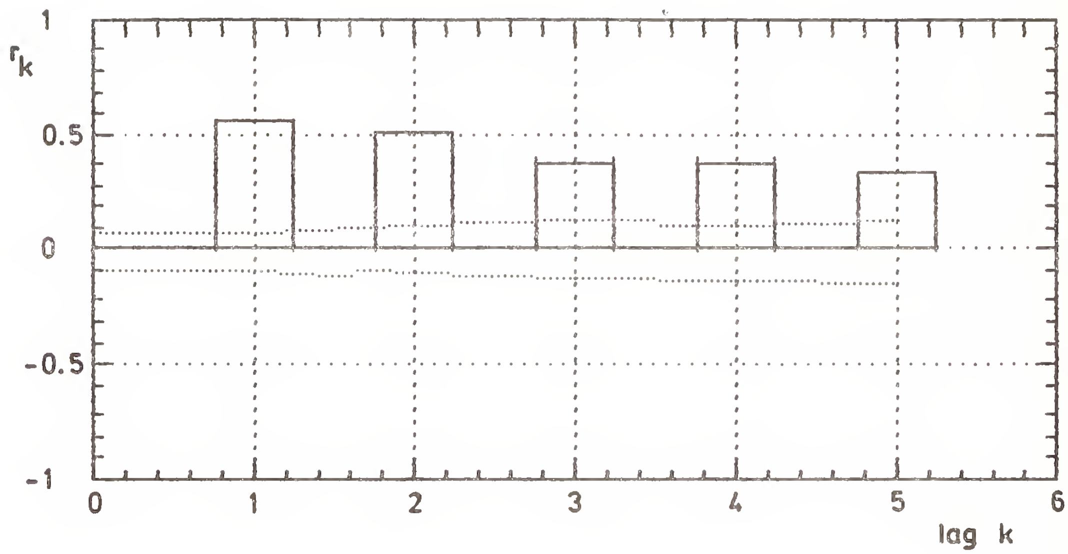

Fig. 3. Cement correlogram

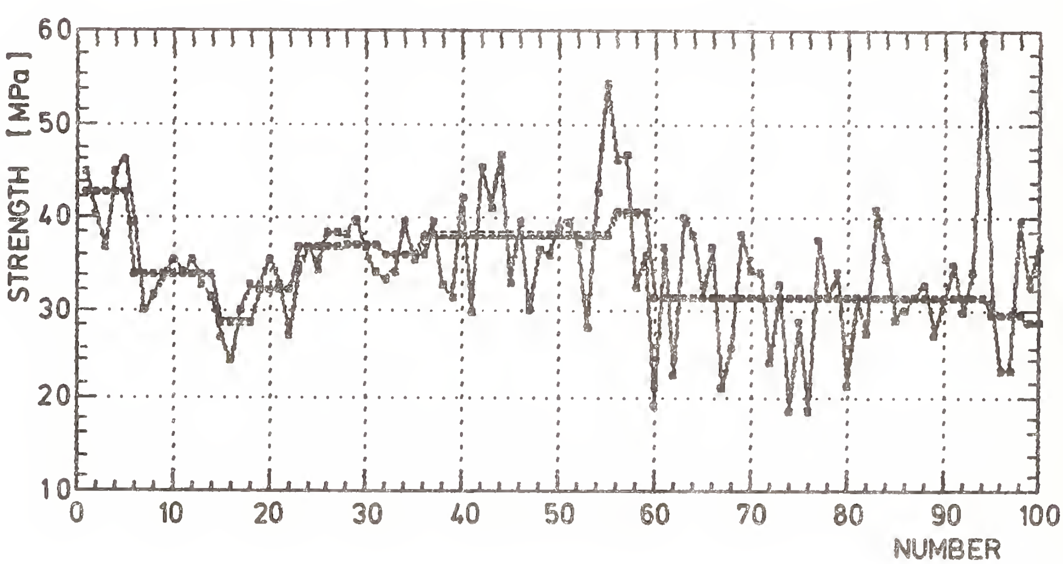

Fig. 4. Segments of Concrete for the first 100 data

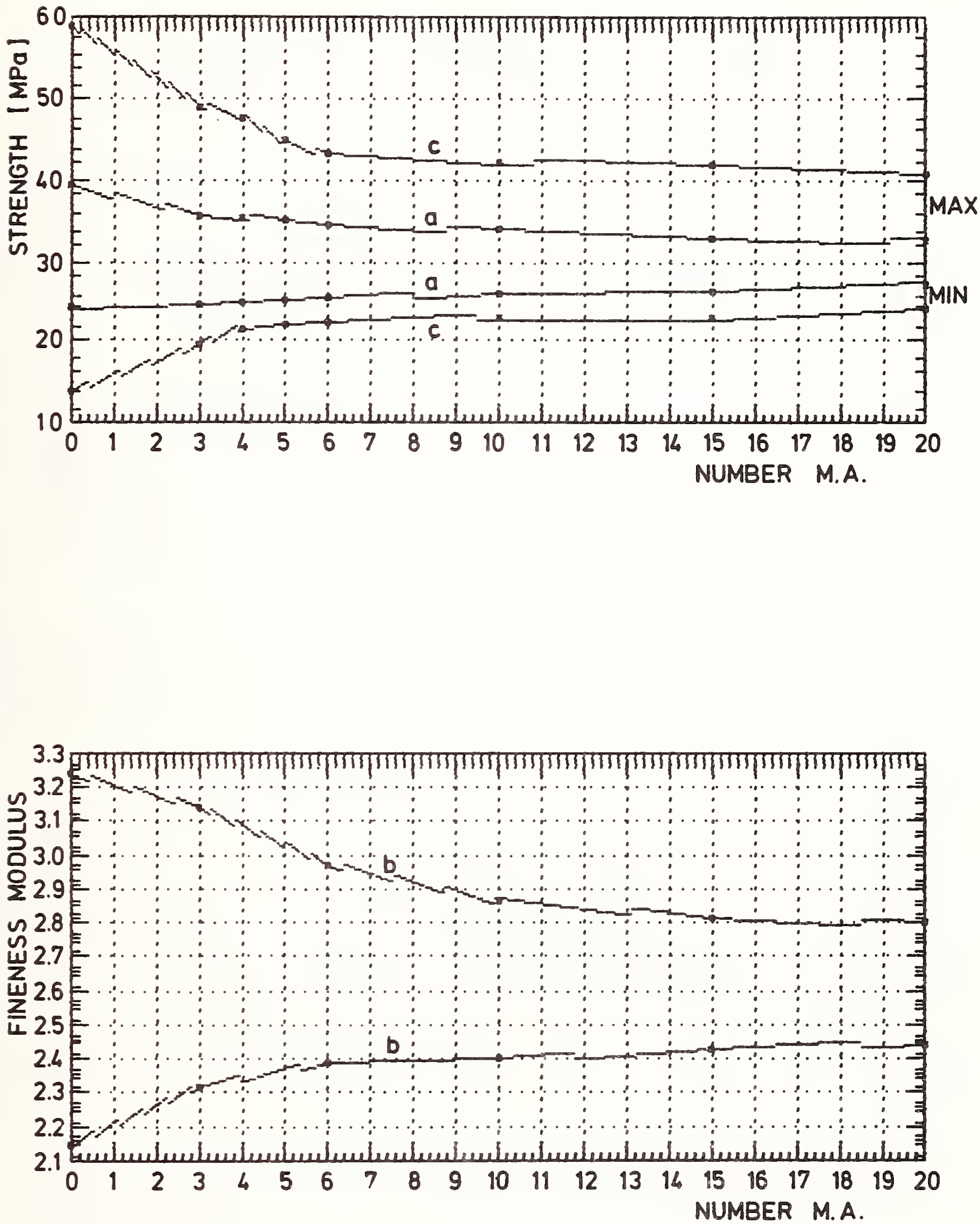

Fig. 5. Moving average (3 - 20 data) for
a) cement - strength
b) aggregate - fineness modulus
c) concrete - strength

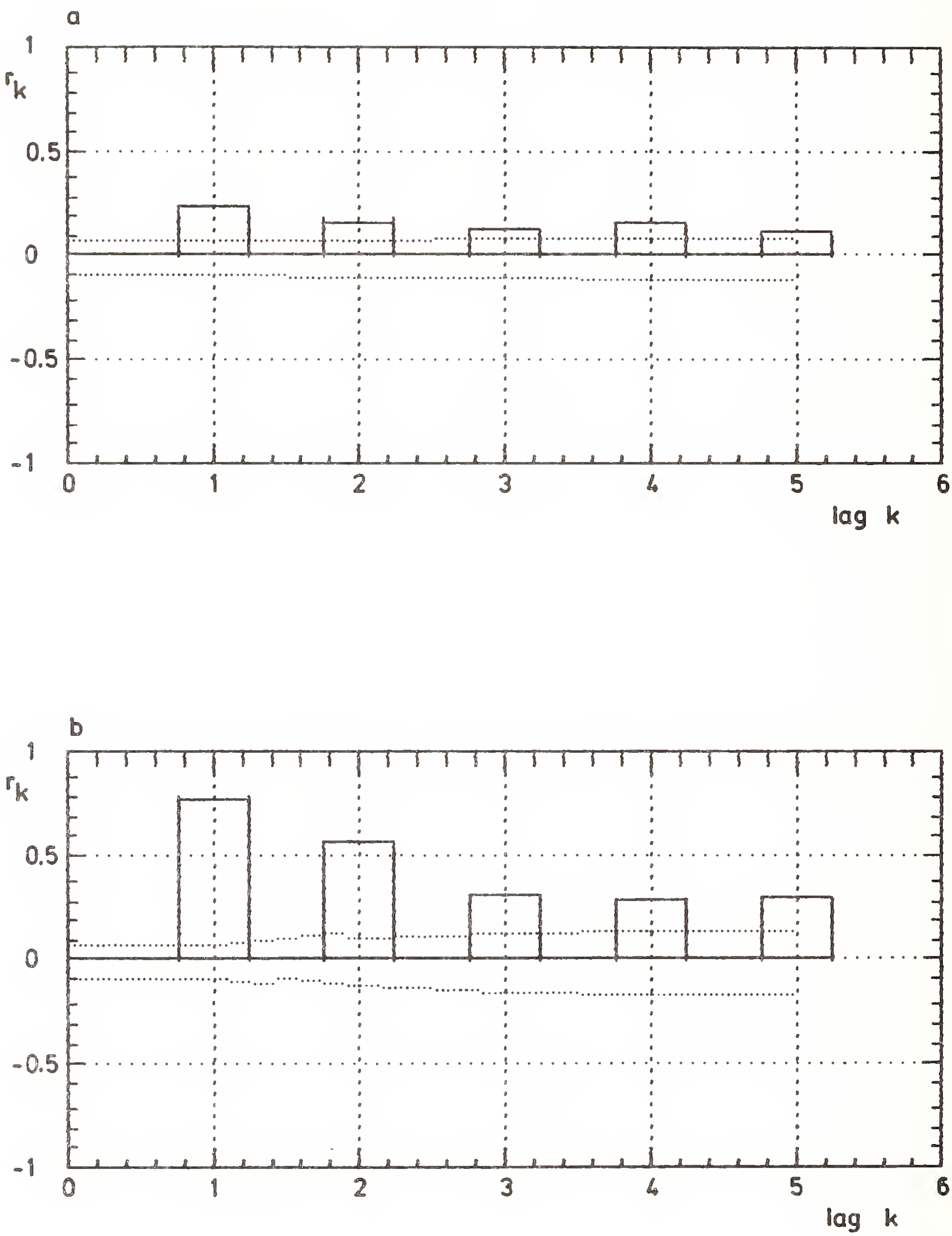

Fig. 6. Concrete correlogram for
a) single data
b) moving average (3 data)

TEST FREQUENCY AND PRECISION OF RESULTS

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Abstract

Quality assurance manuals are a pre-requisite for, but not a proof of proper work. Comparative tests between different laboratories are indispensable, but unless they can be organized very frequently they can provide only a snap-shot. That snap-shot, however, is likely to be representative, if test frequency is high at a laboratory and internal statistical evaluation indicates that repeatability is at a constant and satisfactory level.

Laboratories should advise their accrediting bodies of their test frequencies for the different methods of test. For the more complicated tests the number of determinations should be such as to allow a statistical evaluation to be made each year or, preferably, to keep an operator occupied for most of his working time.

1. Introduction

In the future, quality assurance manuals - a term borrowed from production control and not very fortunate for describing the way a testing laboratory should be organized - must be comparable on an international level and should, therefore, conform to the relevant international standards and guidelines.

The importance of these manuals may be overestimated when the costs of drafting and application are considered. However, they are only a prerequisite for and not a proof of proper work; and in many respects they can offer only generalities.

Since laboratories from many countries are possibly involved, methods for evaluating the accuracy and precision of the test results are more important than ever. Therefore, comparative tests between laboratories are indispensable, but unless they can be organized more frequently than is often practical, they can provide only a snap-shot.

That snap-shot is more likely to be representative, however, if test frequency is high at a laboratory and internal statistical evaluation indicates that repeatability is at a constant and satisfactory level.

2. Examples for the Importance of Test Frenquency

Fig. 1 shows how repeatability for standard strength of cement developed since the CEN-method (EN 196, part 1) was introduced as an additional method in the Viennese Cement Research Institute (CRI).

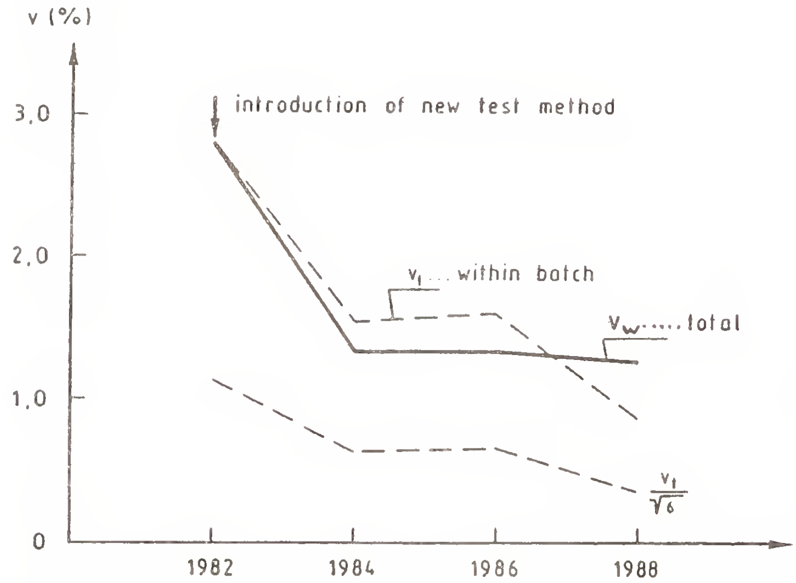

Fig. 1. Testing cement for standard strength - coefficients of variation for test repetitions, influence of test frenquency

The same cement was tested twice by five operators. In 1982 the relative standard deviation (RSD) was 2.8%, but in 1984 and the following years it was less than 1.5%.

The operators were, of course, well experienced with the Austrian method of test (which is still the standard) which does not differ greatly from the CEN method (w/c 0.50 instead of 0.60, compaction by machine instead of by hand). Fig. 1 demonstrates the importance of test frequency, even when the method of test is changed only in detail.

In Fig. 1 the variation V_t between the six compressive strengths found on the specimens of the same batch are also plotted. The variation within batch developed in a similar way as the total variation.

Though V_t (because of $S_w^2 = S_b^2 + S_t^2/6$) adds only little to the variation between different batches, it appears to be a good indicator for repeatability and operator performance.

Fig. 2 shows the relative standard deviation (RSD) V_t within batch calculated from the results (6 single values each) of some hundreds of standard strength determinations according to the Austrian standard. For operator 1 V_t is smaller and scatters less than for operator 2, who had joined the laboratory only recently. Statistical evaluations like fig. 2 are a valuable means for checking operator performance and the training of new staff.

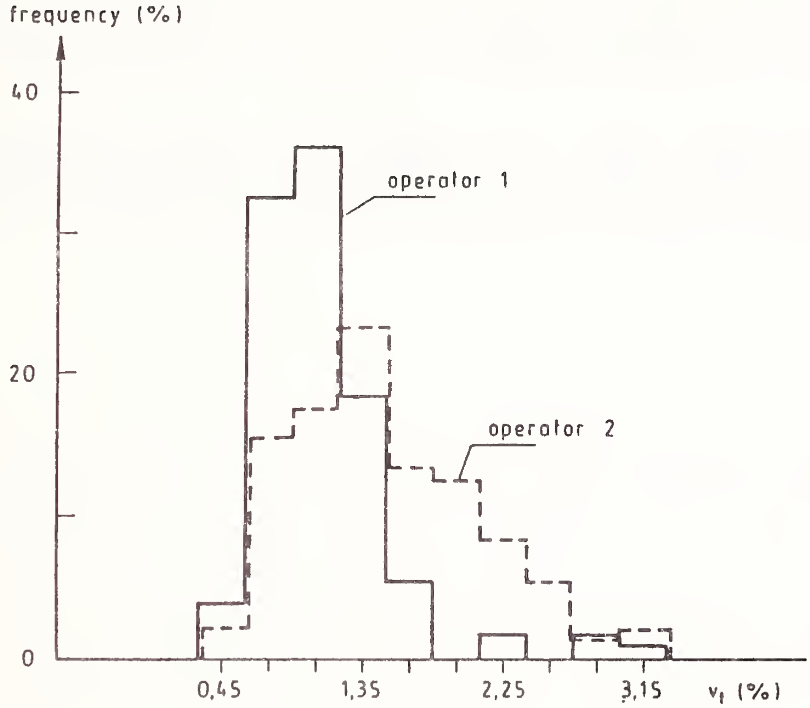

Fig. 2: Testing cement for standard strength-coefficients of variation within batch for different operators

3. Desirable Minimum Test Frequency

A modest test frequency will be sufficient, if the test method is simple and a calibration material available, e.g. for the Blaine test; or where it is easy to make a check on repeatability, as is the case with the microscopical determination of the air-void characteristics on hardened concrete using the Rosiwal-method, where the measurements can always be repeated along a few lines (provided the concrete surfaces are well prepared and the lines of measurements well marked).

Higher test frequencies are often necessary. For example, it is known to be important for the determination of the standard strength of cement, where many parameters are of influence. The number of determinations should at least allow a statistical evaluation of operator performance to be made each year, or preferably to keep an operator occupied (and experienced) for most of his working time. This would mean a minimum of something between perhaps 60 (if the RSD v_t is the same for the types of cement tested) and 200 cement samples per year.

4. Summary

Adequate exercise is a pre-requisite for satisfactory results. Laboratories should advise their accrediting bodies of their test frequencies for each method of test.

For third-party testing laboratories and the more complicated tests like that for standard strength of cement, the number of determinations should at least allow a statistical evaluation to be made each year; preferably it should be such as to occupy at least one operator for a considerable part of his working time.

Experience With Proficiency Testing and Round Robin Testing in the United States

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Abstract

Interlaboratory studies such as proficiency testing and round robin testing are conducted to determine if a test method is reliable and to obtain information from which statements of precision may be prepared. The American Society for Testing and Materials (ASTM) has prepared a family of standards which address the issues related to interlaboratory testing. Standard practices are available for conducting ruggedness analysis to determine if an interlaboratory program is appropriate, for conducting interlaboratory test programs, and for preparing statements of test precision. Proficiency and round robin programs for cement and concrete materials in the United States are discussed, as are application of these programs in preparing estimates of test precision.

Key Words: cement, concrete, laboratory, precision, proficiency, testing

1. INTRODUCTION

Proficiency testing and round robin testing are used to determine if a test method is reliable, to obtain information for the preparation of statements of precision, and to evaluate the performance of testing laboratories. Round robin testing is often used to evaluate a test method by a small number of laboratories, while the purpose of proficiency testing is to provide a measure of the performance of individual laboratories in comparison with the average of a large group using the same test methods. This paper discusses available standards for interlaboratory testing, proficiency testing programs conducted by laboratory evaluation and accrediting organizations, and provides examples of applications of proficiency and round-robin testing by standards committees.

2. STANDARDS FOR INTERLABORATORY TESTING

The American Society for Testing and Materials (ASTM) has taken a lead role in integrating statistical principles into the standards development process [Ullman, 1985; ASTM, 1963]. All ASTM test methods must include statements on precision and bias, and the statements must, when possible, be developed through an interlaboratory test program [ASTM, 1986]. ASTM defines precision as "the closeness of agreement between selected individual measurements or test results," and bias as "a systematic error that contributes to the difference between a population mean of the measurements or test results and an accepted reference or true value." If a standard test method is to be considered reliable, then each committee must demonstrate the quality of the results the method will provide. The data obtained in the interlaboratory study and the detailed analyses of the data shall be on file at ASTM headquarters. ASTM procedures recognize situations exist where it is not possible to provide definitive precision and bias statements, such as when interlaboratory data are not available. However, standards committees are expected to work toward obtaining such data.

ASTM has prepared the following standards related to interlaboratory testing [ASTM, 1989].

E177 Practice for Use of the Terms Precision and Bias in ASTM Methods

E456 Terminology for Statistical Methods

C1067 Standard Practice for Conducting a Ruggedness or Screening Program for Test Methods for Construction Materials

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

C802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

C670 Practice for Preparing Precision Statements for Test Methods for Construction Materials

It is important that test methods be well developed before being subjected to interlaboratory testing. ASTM Standard C1067 provides procedures for detecting and reducing sources of variation in test methods for construction materials early in their development and prior to an interlaboratory study. The standard requires a study to be conducted with a small number of laboratories to determine if the test method is well written and good enough to justify a larger interlaboratory study. ASTM Standard C1067 outlines the theory of ruggedness or screening analysis and an example of its application to an asphalt material. Ruggedness is defined as "the characteristic of a test method that produces test results that are not influenced by small differences in the testing procedure or environment." Screening is defined as "the detection of significant sources of variation as compared to chance variation."

ASTM Standard E691 describes general techniques for planning, conducting, analyzing, and interpreting results of an interlaboratory study conducted to evaluate a test method. ASTM Standard C802 provides specifics needed on conducting interlaboratory tests on construction materials. A requirement for using this standard is the existence of a valid and well-written test method, developed in competent laboratories, including the provisions for a ruggedness or screening procedure. ASTM Standard C670 offers guidance in preparing precision and bias statements for ASTM methods pertaining to certain construction materials.

3. PROFICIENCY TESTING USED BY LABORATORY EVALUATION AND ACCREDITATION PROGRAMS

Proficiency testing is a procedure used to compare test results within or among laboratories for the purpose of examining and comparing laboratory performance. Laboratory evaluation and accreditation programs operating in the United States use proficiency testing as a method of evaluating laboratory performance. An additional benefit of these programs is the availability of data which can be used in the preparation of estimates of precision for incorporation in test method standards.

3.1 Construction Materials Reference Laboratories

The Construction Materials Reference Laboratories (CMRL) located at the National Institute of Standards and Technology (NIST) (formerly the National Bureau of Standards) has the goal of improving the quality of testing of construction materials. The CMRL consists of the Cement and Concrete Reference Laboratory (CCRL) and the AASHTO Materials Reference Laboratory (AMRL). These NIST Research Associate Programs are sponsored by the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO), respectively. The major functions of the CMRL are the inspection of testing laboratories and the distribution of proficiency test samples [Dise, 1979; Steele, 1981]. Figure 1 shows the scope of current programs which are utilized by almost 1000 laboratories located in Australia, Canada, Denmark, France, Greece, Mexico, Norway, South Africa, Spain, Sweden, United Kingdom and the United States. The levels of laboratory participation in the proficiency sample programs are shown in figures 2 and 3, and the laboratory inspection programs in figure 4.

Laboratory participation in the CMRL programs is voluntary, and is initiated by requests from interested organizations willing to pay established fees. Laboratories are not rated, certified or accredited; however, existing laboratory accreditation programs do use certain CMRL programs in the evaluation of laboratory performance as will be discussed later.

CMRL proficiency sample programs provide comparisons of results of standard tests within or among laboratories for the purpose of aiding in the recognition of, and correction of, deficiencies. These programs involve preparing and shipping a pair of samples of a given material type to each participating laboratory. The samples in the pair are similar, but not identical. The laboratories run the appropriate tests on the samples and return the data to the CMRL which prepares statistical analyses.

All proficiency sample programs are operated in a similar way. At intervals of either 6 or 12 months, quantities of two slightly different lots of a given material are procured, carefully homogenized, and divided into two groups of individual test samples. Each participating laboratory receives a pair of

Laboratory Inspection	Proficiency Sample
CCRL	CCRL
o cements	o portland cement
o concrete	o blended cement
o aggregates	o masonry cement
o reinforcing steel	o portland cement concrete
o pozzolans	o fly ash
AMRL	AMRL
o soils	o soils
o aggregates	o fine aggregates
o asphalt cement	o coarse aggregates
o bituminous concrete	o asphalt cement
o plastic pipe	o cut-back asphalt
	o bituminous concrete
	o emulsified asphalt
	o paint

Figure 1. CMRL Laboratory Inspection and Proficiency Sample Programs.

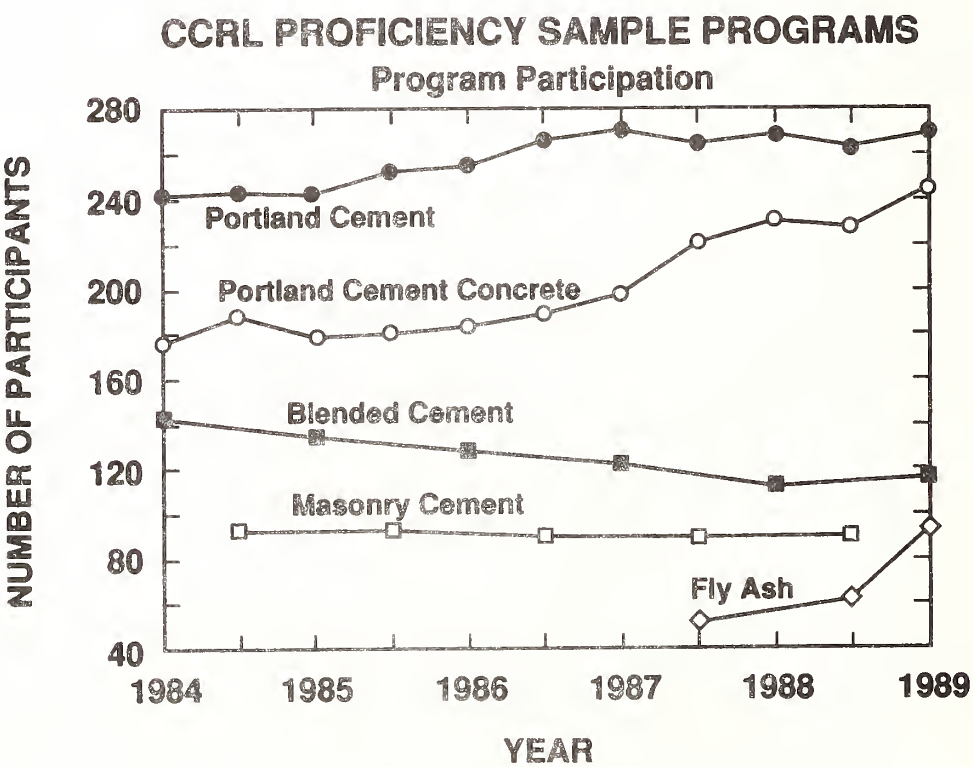

Figure 2. Participation levels in the CCRL Proficiency Sample Programs.

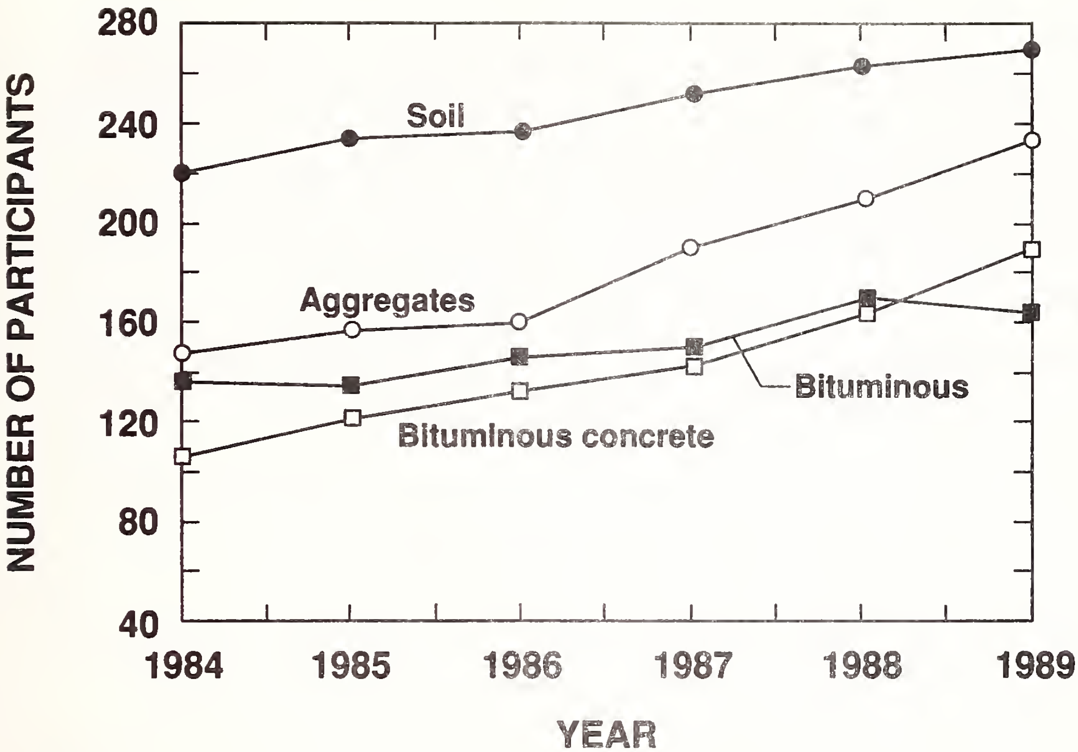

Figure 3. Participation Levels in the AMRL Proficiency Sample Programs.

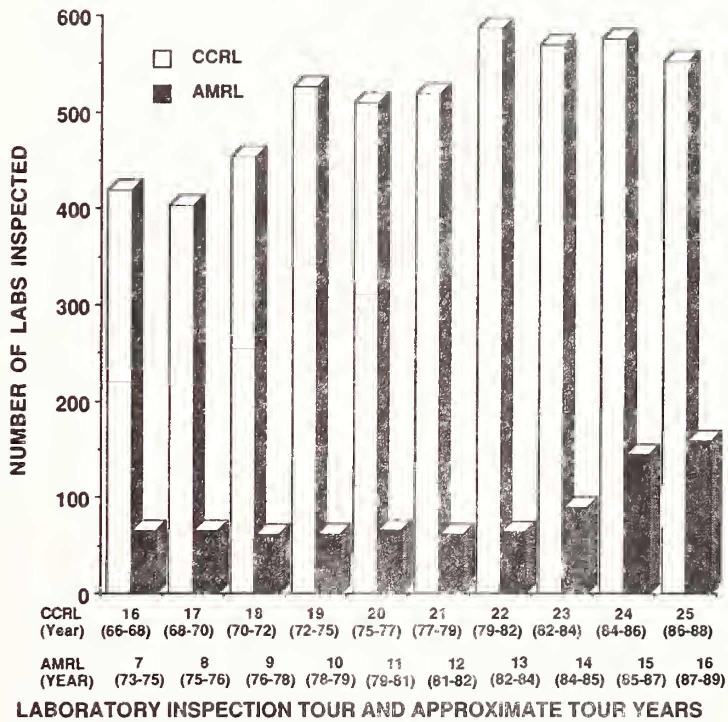

Figure 4. Participation Levels in the CMRL Laboratory Inspection Programs.

samples (one from each group), performs the specified tests on each and returns the results to the CMRL. Within approximately 2 months after sample distribution, a final report is distributed to all participants. The report contains average values, standard deviations, scatter diagrams and other statistical information obtained using the procedures set forth in papers by Youden [1959], and by Crandall and Blaine [1959]. Figure 5 shows a typical statistical presentation of results. Each laboratory is given a code number so that it may distinguish its test results, but not the results of other laboratories. Summaries of the results obtained by a particular laboratory for specific proficiency testing programs are issued periodically in the form of performance charts to provide a clear picture of the laboratory's overall performance for the past ten pairs of samples (fig. 6).

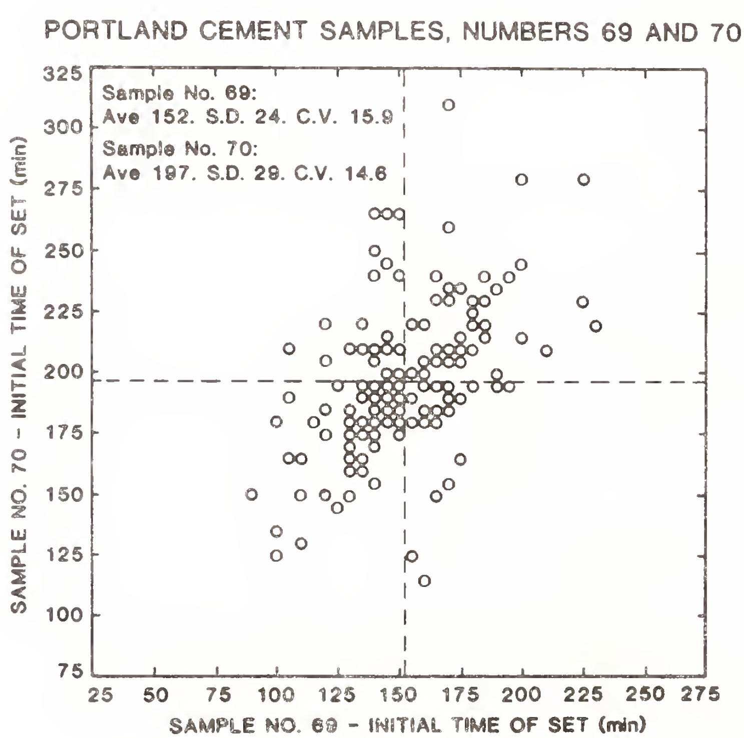

Figure 5. Youden Scatter Diagram for Initial Time of Set - Gillmore Needles.

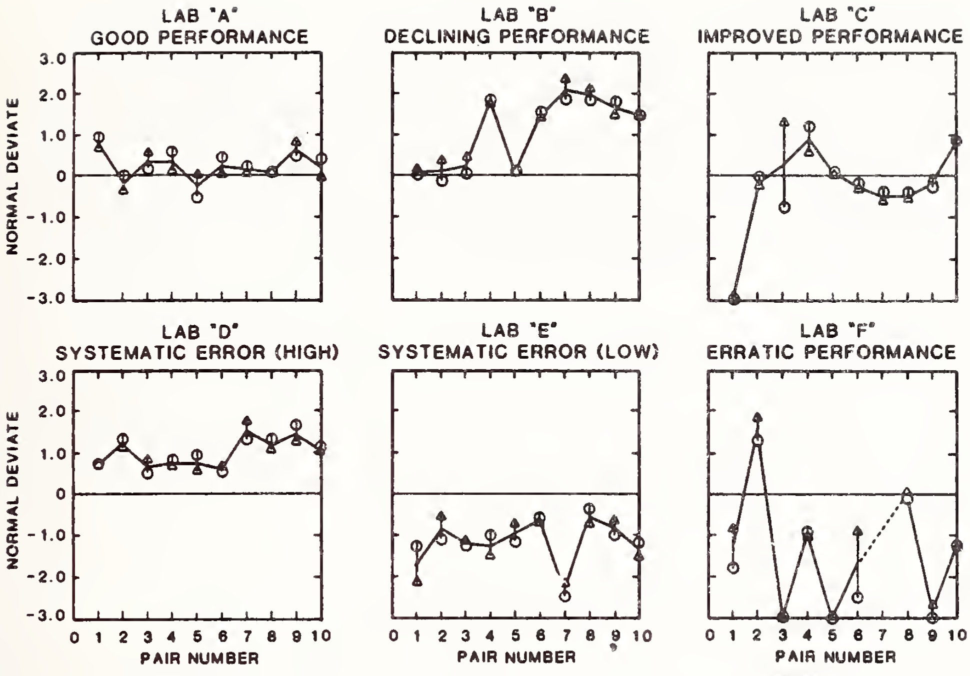

Figure 6. Performance Charts Showing Various Levels of Laboratory Performance Over Time.

Data from CCRL programs may also be used by standards committees in assessing the adequacy of current test methods or determining the impact of revisions to standards. Final reports from the various proficiency sample programs are routinely distributed to the chairpersons of appropriate ASTM committees. Committee C1 on Cement and C9 on Concrete and Concrete Aggregates have found proficiency sample data from the CCRL programs very useful in assessing the adequacy of existing test methods, determining the impact on revisions to standards, and in the development of precision statements. ASTM Standard C670 provides a method for using CCRL proficiency sample results for formulation of precision statements. Estimates of precision for selected ASTM cement test methods have been prepared for consideration by Committee C1 [Pielert, Haverfield, and Spellerberg, 1985]. Other applications of CCRL data in the development of standards are discussed in a paper by Pielert and Spring [1987].

3.2 AASHTO Accreditation Program

AASHTO started the AASHTO Accreditation Program (AAP) in 1988 for materials testing laboratories [AASHTO, 1989]. AAP will certify the competency of testing laboratories in carrying out specific tests on soils, asphalt cements, cut-back asphalts, emulsified asphalts, bituminous mixtures, bituminous concrete aggregates, and portland cement concrete and aggregates. The laboratory inspection and proficiency sample programs of CCRL and AMRL are used to evaluate the performance of laboratory testing.

3.3 National Voluntary Laboratory Accreditation Program

The U.S. National Voluntary Laboratory Accreditation Program (NVLAP) is administered by NIST. NVLAP's function is to accredit public and private testing laboratories based on evaluation of their technical qualifications and competence for conducting specific test methods in specific fields of testing. NVLAP accreditation in the construction testing services is available for methods of test for concrete, aggregates, cement, admixtures, geotextiles, soil and rock, and bituminous materials [Gladhill, 1989].

Proficiency testing is an integral part of the NVLAP accreditation process. Participation in the CCRL proficiency sample programs for cements and concrete is required for laboratories seeking accreditation in these fields of test. A within-laboratory proficiency program for concrete cylinder load testing is also required by NVLAP. One-week and five-week patterns in the within-laboratory variation of cylinder results may reveal long-term effects such as equipment being out of calibration or technician problems.

3.4 American Association of Laboratory Accreditation

The American Association of Laboratory Accreditation (A2LA) was formed in 1978 as a nonprofit, scientific, membership organization dedicated to the formal recognition of testing organizations which have been shown to be competent. A2LA has granted accreditation in the following fields of testing: biology, chemistry, construction materials, geotechnical, electrical, mechanical, nondestructive testing, and thermal. Most construction materials are included in the construction materials field of testing. A2LA requires its participating laboratories to participate in the applicable proficiency sample programs of CCRL and AMRL. A paper on A2LA programs is included in the proceedings of this workshop [Locke, 1989].

4.0 CASE STUDY

Many ASTM committees developing standards for cement and concrete have used proficiency and round robin testing as a basis for preparing statements of precision and bias.

ASTM Standard C670 contains special guidance on use of CCRL and AMRL proficiency sample results for preparing precision statements in accordance with ASTM Standard C802. Many ASTM standards recognize the contributions of CCRL and AMRL in the preparation of precision statements. For example, ASTM Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory (C192) recognizes the contribution of CCRL by stating "data to establish precision statements for various testing required by this standard were obtained in the Concrete Proficiency Sample Program of the Cement and Concrete Reference Laboratory."

An example of a round robin program being conducted to prepare precision statements is that being carried out by Subcommittee C09.03.01 of ASTM Committee

C9. Because ASTM C42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, does not currently have a precision statement for compression testing of cores, a round robin testing program was conducted to obtain the necessary data. Seventeen laboratories representing the commercial testing industry, state and Federal testing agencies, the ready-mixed concrete industry, and the cement industry participated in the program. Slabs were cast by a participating laboratory, cores were removed according to C42 procedures, and sent to participating laboratories for testing. The data from the 17 laboratories were analyzed and used to draft precision statements based on ASTM Standard C670. These precision statements are being balloted in subcommittee for inclusion in C42.

5.0 CONCLUSION

Proficiency testing and round robin testing programs provide important data in determining the reliability of test methods and in evaluating the performance of testing laboratories. ASTM has prepared a family of standards stating how these programs should be operated and the resulting data evaluated and used for preparation of precision statements. Many ASTM committees are involved with round robin testing to obtain the necessary data. Committees C1 and C9 are fortunate to have the programs of CCRL and AMRL which routinely produce large quantities of data which are extremely useful in standards development.

REFERENCES

Ullman, N. R., (1985) The Use of Statistics in Standards Development, ASTM Standardization News, July 1985, pp32-36.

ASTM, (1963) Manual for Conducting an Interlaboratory Study of a Test Method, Philadelphia, PA.

ASTM, (1986) Form and Style for ASTM Standards, Philadelphia, PA.

ASTM, (1989) Annual Book of ASTM Standards, Philadelphia, PA.

Dise, J. R., (1979) Fiftieth Anniversary of the Cement and Concrete Reference Laboratory, Concrete International: Design and Construction, Vol VI, No. 10, pp. 100-105.

Steele, G. W., (1981) Quality Assurance for Our Highways - The AASHTO Materials Reference Laboratory, AASHTO Quarterly, Vol. 60, No. 1, p.35.

Youden, W. J., (1959) Statistical Aspects of the Cement Testing Program, Proceedings, American Society for Testing and Materials, Vol. 59, p. 1120.

Crandall, J. R. and Blaine, R. L., (1959) Statistical Evaluation of Interlaboratory Cement Tests, Proceedings, American Society for Testing and Materials, Vol. 59, p. 1129.

Pielert, J. H., Haverfield, J. W. and Spellerberg, P. A., (1985) Application of CCRL Data in the Formulation of Precision Statements for Selected Cement Standards, Cement, Concrete and Aggregates, ASTM, Vol. 7, No. 1, pp. 37-42.

Pielert, J. and Spring, C., (1987) Application of CCRL Data in the Development of Cement Standards, ASTM STP 961, E. Farkas and P. Klieger, Ed., ASTM, Philadelphia, PA.

AASHTO, (1988) Procedures Manual - AASHTO Accreditation Program, Washington, DC.

Gladhill, R. L., (1989) Program Handbook-Construction Testing Services, NISTIR 89-4039, National Institute of Standards and Technology, Gaithersburg, MD.

Locke, J. W. (1989) Quality Assurance in the Construction Materials Laboratory, Proceedings of the Workshop on the Evaluation of Cement and Concrete Laboratory Performance, Tel Aviv, Israel, June 1989 (In Press).

EVALUATION OF CEMENT STRENGTH TESTING BY FOUR LABORATORIES

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Abstract

Samples of cement are divided and tested for strength according to Israeli Standard No. 1 (Portland Cement) in four laboratories. Strength result graphs depict the differences obtained; one laboratory always shows the lowest strengths, the other three laboratories show higher strengths, variably parallel. Can such testing serve as a means for estimating the "real" cement strength? How often should samples be taken and tested?

A revision of Israeli Standard No. 1 is underway and it is possible that prescribed tests may be modified and altered, and laboratory practices and operations be streamlined.

Testing as Practiced

Samples of cement, taken by technicians of the Standards Institution, or the National Building Research Institute (Institute of Technology), are divided into five portions and tested for strength according to Israel Standard No. 1 (Portland Cement) in four laboratories. The fifth portion is held for reference.

The laboratories participating in the study are:

1. Laboratory of the cement works producing the cement sampled (Haifa, Ramla and Hartuv);
2. Central Laboratory of the Nesher Israel Cement Enterprises Ltd.;
3. Laboratory of the Building Department of the Standards Institution (Ramla and Hartuv Works) or the Laboratory of the National Building Research Institute (Haifa Works); and
4. Laboratories of the Readymix Industries (Israel) Ltd. - Ramat-Gan (Ramla and Hartuv Works), Haifa (Haifa Works).

Comparative Data Control

This attempt to reach comparative data control by testing the same cement in four laboratories is a result of "agreeing to disagree" by the manufacturers and the users of cement. It is an effort to come to a consensus as to the strength of the cement sampled and tested; thus acting in the spirit of the ASTM definition - "a standard represents a common viewpoint of the parties concerned with its provision, namely: producers, users and general interest groups."

Local Conditions

1. Cement is produced in Israel in three works, all owned and operated by Nesher Israel Cement Enterprises Ltd.
2. Israeli Standard No. 1 (I.S. No. 1) - Portland Cement, is an "official standard" which contrary to the ASTM definition makes I.S. No. 1 mandatory, not voluntary. Production, sale and use of cement that fails to comply with all the specifications of the standard are contrary to law.
3. Results of tests of building materials, including cement, are recognized in the Law Courts only if certified by either the laboratories of the Standards Institution or the National Building Research Institute. This is according to the Law of Standards.
4. All concrete cast in structures designated as "Air Raid Shelters" is by law specified to be no less than 33 megapascal at twenty eight days, and certified as such by one of the "authorized" laboratories.

Thus it became necessary to design a testing procedure that includes a specified sampling procedure and simultaneous testing in the four laboratories. There is a risk of overlooking some of the specifications of I.S. NO. 1.

Accelerated Testing

I.S. No. 1 provides cement strength data at three days which is used to estimate 28 day strength. The need for earlier information eleven years ago prompted the readymix concrete industries to develop an accelerated test method that made it possible to estimate the 28 days strength after eight and one half hours. The decision to develop the accelerated test method was triggered by the challenge voiced by the president of "Nesher". He asked, "Do you test cement? No, you test concrete! Do we sell you concrete? No, we sell cement!" Our accelerated test uses a cement and water paste (no sand or gravel), and the results reflect the strength of the cement only.

Correlation Between Standard and Accelerated Tests

Prediction of the 28 day strength using the accelerated test was made possible after extensive experiments with cement from each of the three works. Separate predictive formulas were developed for each. However, the basic parameters lost their constant values when qualitative changes in production were introduced (i.e. a new limestone quarry, inclusion of pulverized fly ash, and new grinding systems installed to increase capacity while the old equipment continued in operation). Additional variability is added to the system since grinding is sometimes done in closed circuit, and sometimes in open circuit. Such changes manifested themselves directly in a disorder in our correlation figures. Relationship between the accelerated test results and the standard test results became haphazard and, therefore, unreliable. We still carry on, but only with the aim of getting, at least, some indication of what may happen in 28 days, and to help avoid serious failures.

I.S. NO. 1 Norms - I.S. NO. 118 (Concrete Strengths) Norms

The norms underlining the figures expressing the relationship between the strength of the standard concrete mix used in cement testing at three days and twenty eight days were good years ago. However, as all parameters affecting the rate at which concrete hardens have undergone substantial changes, those norms must be revised. Early knowledge of strength is vital for the users of cement since no readymixed concrete plant has storage capacity enabling it to hold its cement twenty eight days. Therefore, the possibility of predicting 28 days strength from the three days results, a prediction justified only when certain norms are conserved, is vital.

Let us see whether a reliable system can be deducted from a study of such results by looking at Figures 1,2,3 and 4. These graphs should not be allowed to mislead. They represent results of testing one sample of twenty kilograms a day (from the particular works) taken from one thirty ton container as it is being loaded for shipment. This sample is then divided into five portions and tested with the hope of arriving at results indicative of the cement marketed by that works on that day - a total of some two thousand tons. As shown by the figures, the differences between the results of the four laboratories make any agreed and acceptable result questionable. It appears, however, that there is a certain consistency in the results where the laboratory of the Standard Institution shows almost consistently lower results than the rest. The fact that this is the "authorized" laboratory complicates the matter.

On the other hand, from the results of concrete strength at seven days and twenty eight days, one can easily see the difficulty of assessing and predicting the 28 days strength of concrete from the seven days results of the same concrete when the cement contains pulverized fly ash (PFA). The norms in the relevant standard (No. 1 and 118) were formulated when PFA was not in use. Today, the early strength may be considerably lower, while the full 28 days strength will reach the figures required in the standards. This may quite frequently lead to misleading deductions and disrupt normal activities on the building site.

Test Results Values - Assessment

The claim of the "authorized" laboratories that only testing done by them is recognized in the standards procedure, tends to minimize the value of the comparative data arrived at by simultaneous testing in four laboratories which is described. No acceptable formula for the assessment of the results has been found. At the same time, proving exact and direct linkage between cement strength tested as described, and strength results of concrete manufactured in a readymixed concrete plant, is rather difficult and quite impractical. This is due to the structure of the plants, their procedures and the demands of their customers - the final users of the cement. They are the real victims if and when problems of strength of concrete arise. They, in turn, rely on the readymixed suppliers who are bound by contract to supply concrete of specified strength. Thus we return to the need to reach consensus as to the strength of the cement which it is often convenient to point to as the main culprit in a failure. Comparative data control is a means to that end.

INTER LABORATORIES RESULTS

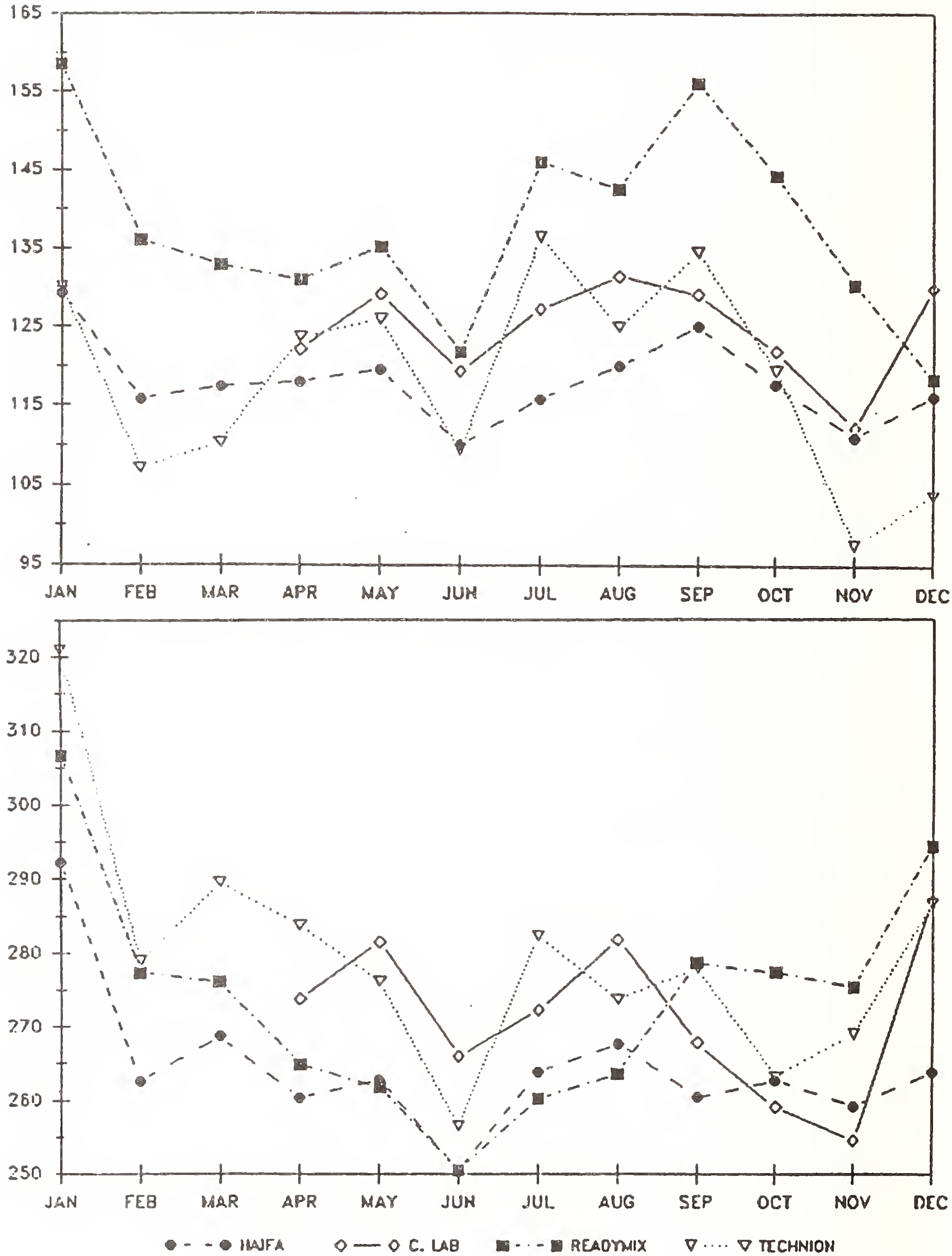

Fig. 1: 3 and 28 days Compressive Strength (Kg/cm²). Monthly average (n=184). C.P. 250 - Haïfa plant (Jan. to Dec. 1988.)

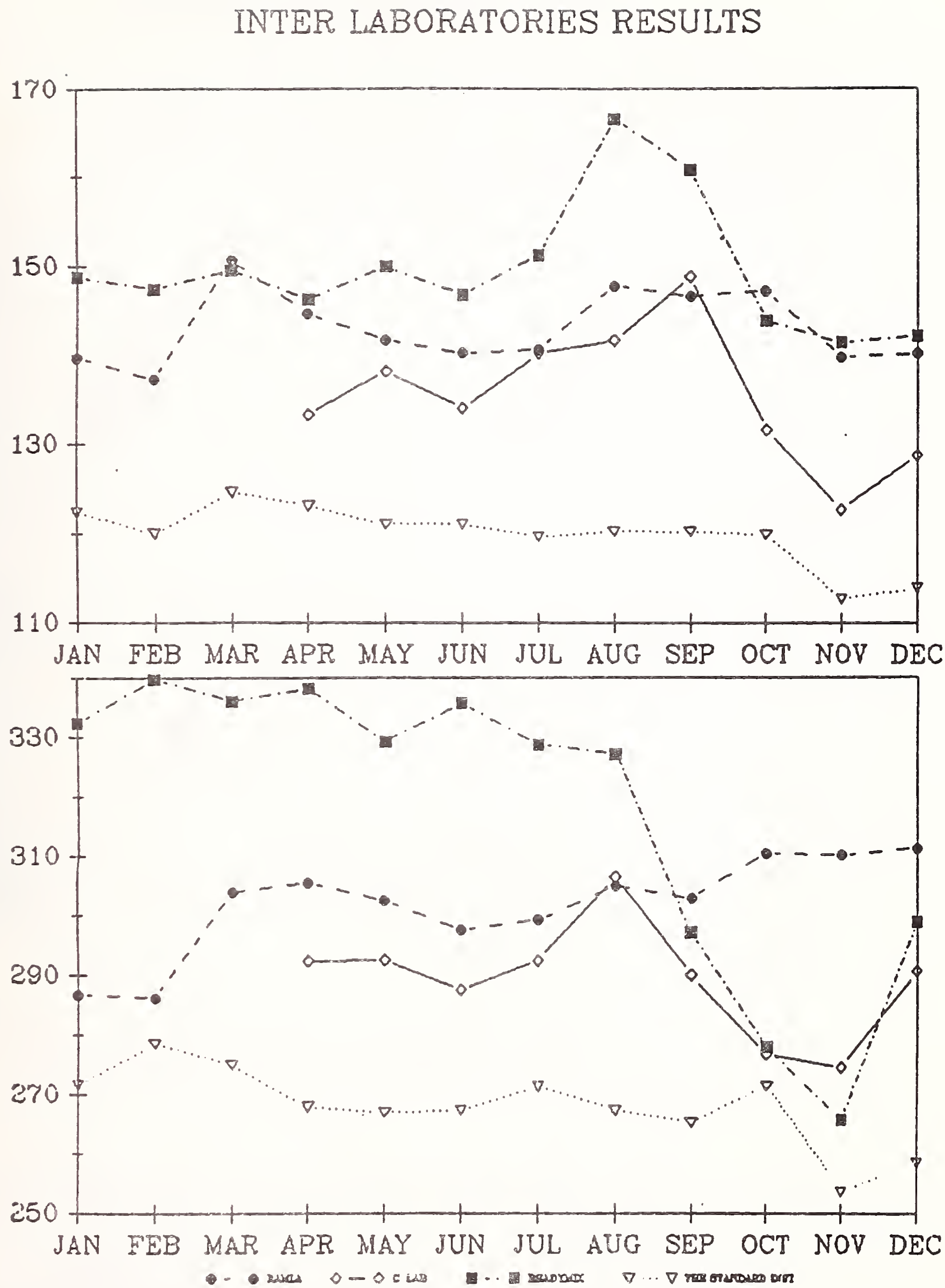

Fig. 2: 3 and 28 days Compressive Strength (Kg/cm²). Monthly average (n=149). C.P. 250 - Ramla plant (Jan. to Dec. 1988.)

INTER LABORATORIES RESULTS

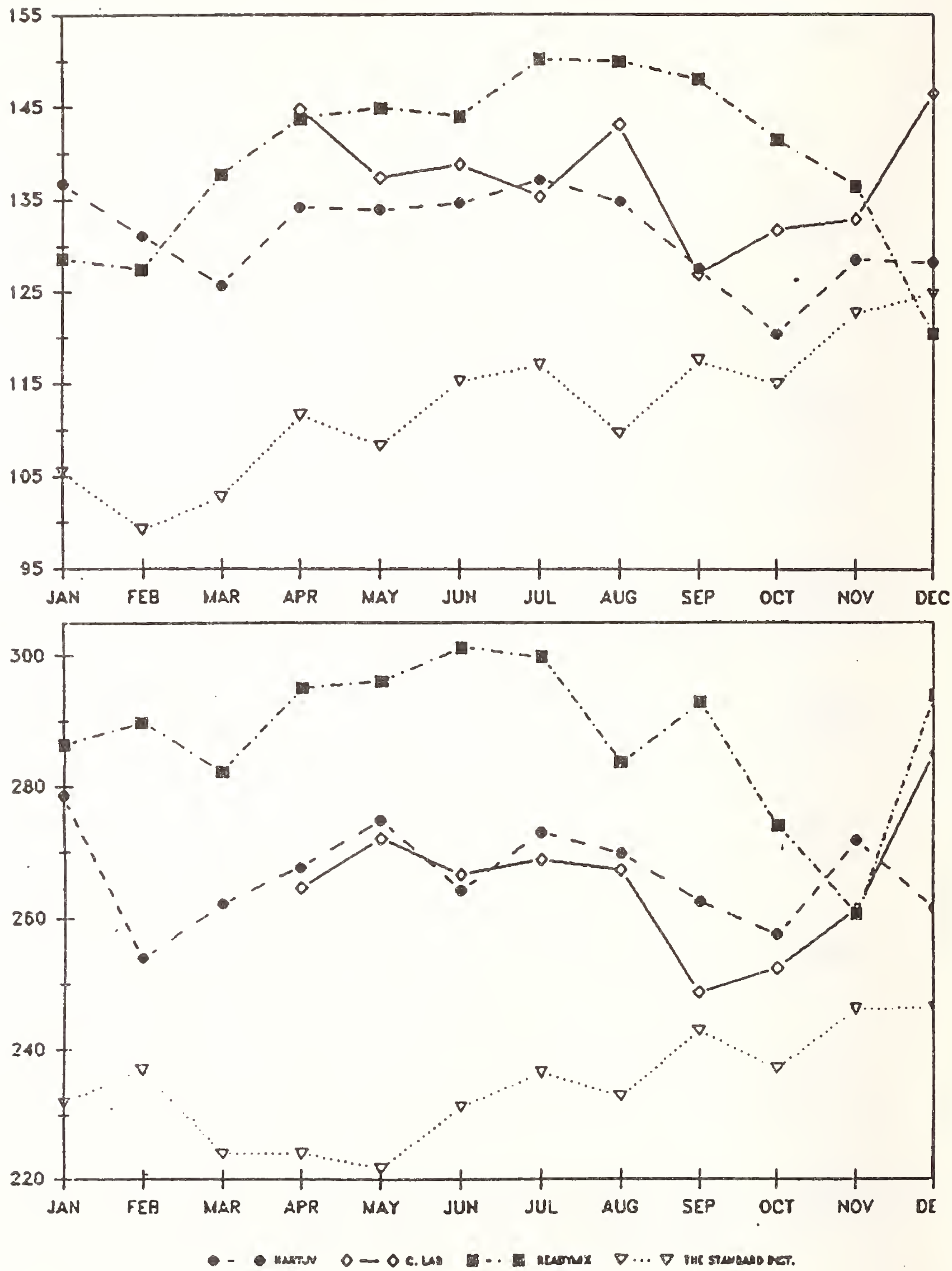

Fig. 3: 3 and 28 days Compressive Strength (Kg/cm²). Monthly average (n=153). C.P. 250 - Hartuv plant (Jan. to Dec. 1988.)

COMPARATIVE DATA CONTROL

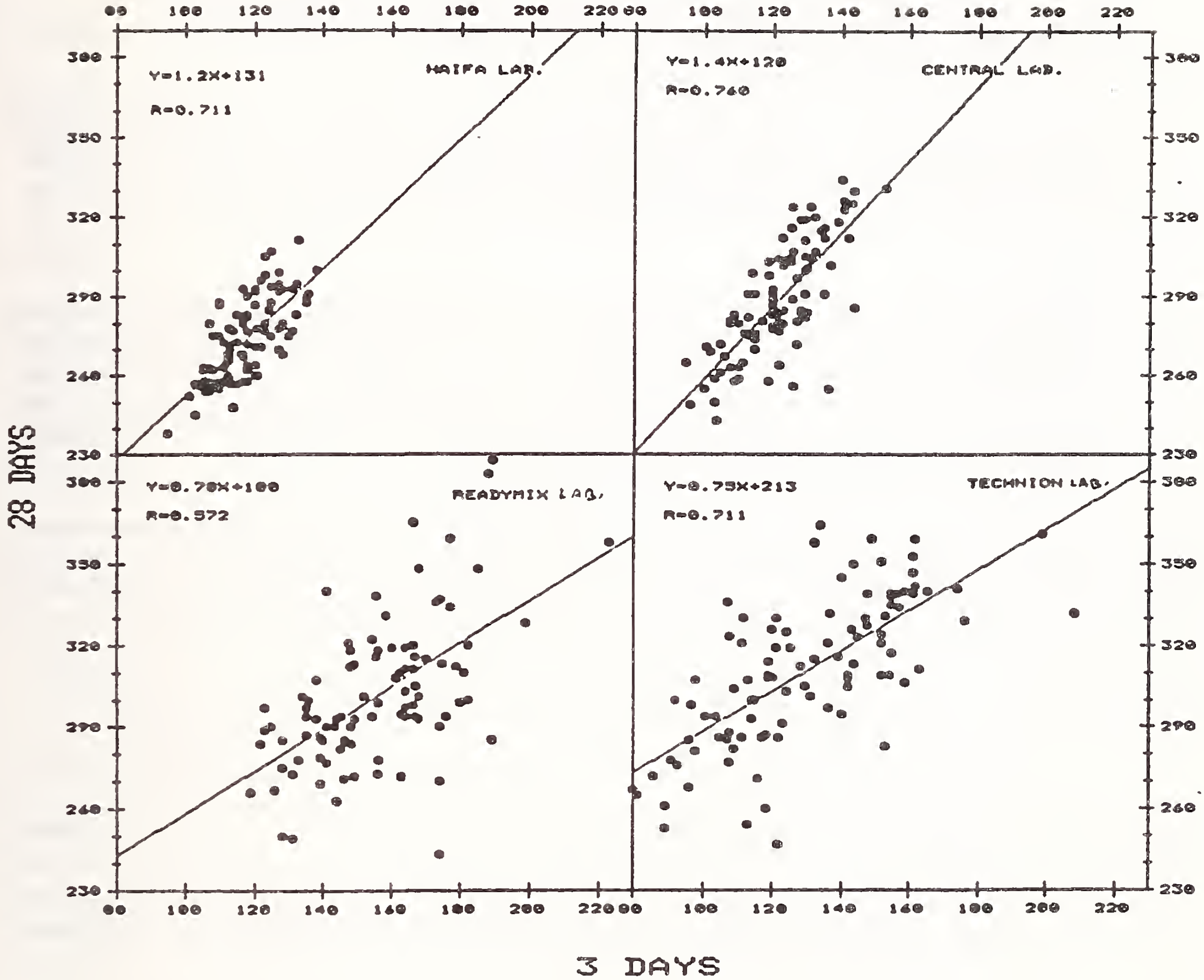

Fig. 4: 3 vs 28 days Compressive Strength (Kg/cm²)
Haifa plant – C.P. 250-samples (Jan. to Jun. 1989).

Purpose of Testing

What is then the purpose of the cement testing described? What can be derived from the comparative data collected? What do "producers, users and general interest groups" want? If we can give answers to those questions, we can determine how it can be done.

It is not too difficult to answer the question about the interest of the three main groups listed in the ASTM definition.

> The producers desire is to produce good cement, and to achieve maximum credibility as to the quality of their product as listed on the shipment vouchers, or printed on the bags.
>
> The users interest is in the knowledge that the cement they buy is always of the quality that allows them to produce quality concrete with a minimum of cement. Mixes are required that will not be too costly while providing the specified strength and reducing the risk of cracking due to heat of hydration.
>
> Other general users groups seek the same confidence in the cement - be it the structural engineers, the precast concrete industry, local government supervisors certifying the concrete in buildings, or "authorized laboratories". They all want to be assured that fluctuations in the quality of cement remain within reasonable limits, and that strength deviations are within acceptable tolerances.

The purpose of testing cement is to satisfy the interest of the groups recognized in the ASTM definition and to provide the assurances they seek. In no way can the testing be an end in itself - it is a way to answer the needs of the "interest groups", and should therefore be designed with this in view.

The same principle must therefore be borne in mind when the I.S. No. 1 is revised (its revision is mandatory now). The subjects under discussion include:

1. Allowing introduction of blast furnace slag as an admixture to the clinker.
2. Introduction of mechanical mixers in laboratories to minimize human errors.
3. Introduction of a specially designed standard mix with aggregates from one source worked to fit exactly defined gradation limits for a tight, dense concrete.
4. Definition of strength requirements at an early date, and at 28 days as a result of tests made on mixes with current cement types.
5. Specifying cement strength requirements to be within certain boundaries, allowing for deviations that can be reasonably deduced from statistical data. Day-to-day follow up will show the trend of strength development, and the works will keep the users posted as to these developments.

Conclusion

Steps as described, accompanied by further systematic testing by the four laboratories, will, we hope, bring us closer to a possible new evaluation of cement using the comparative data control system. This will provide a means of reaching the consensus which has proven to be illusive up to now.

The comparable data bank of accumulated test results will serve as a reliable source for statistical information on the behavior of the different types of cement manufactured and used.

EXPERIENCE WITH INTERLABORATORY TESTING IN FRANCE

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Abstract

More than 29 years experience in interlaboratory testing provides a good indication of the level of expertise of various French laboratories. This experience has been very useful in improving the quality of testing of the laboratories of cement producers, as well as State owned and private testing laboratories. A general consensus in the way cements have to be tested has been achieved.

French cement industry laboratories are now performing to a very high level of quality and consistency in support of the certification scheme of cements (NF VP mark). With the participation of more than fifty laboratories from countries around the world, useful comparisons with other standards have been established.

1. Introduction

My purpose is to present the French cement interlaboratory testing program which is now organized by the Association Technique de l'Industrie des Liants Hydrauliques (ATILH), the technical association of the French cements producers. ATILH is a small organization with a staff of twenty, mostly from French cement companies. It was started two years ago after CERILH closed to continue the interlaboratory testing program of cements started by CERILH.

I will briefly describe the history and scope of the interlaboratory testing program and then try to answer the following questions:

1. What has been the value of past interlaboratory testing?

2. What is the current interest in interlaboratory testing in the French framework?

3. How can interlaboratory testing be improved within the European framework?

I am in a position to give my opinion as a user since I was involved in the quality assurance aspects of testing in the laboratories of Ciments Francais works for seventeen years prior to joining ATILH. I want to present my experience to you because I think it has been of great importance in achieving certification of cement in France.

2. History

Initially, interlaboratory testing was organized by CERILH in 1960 and only French laboratories were allowed to participate. Figure 1 shows the growth in the number of participants since 1960. Participation reached 100 laboratories in 1967 and stabilized at around 120 in 1972 after the program was opened to foreign laboratories. The 40 percent decrease in the number of works in France after the economic crisis in 1974, and the withdrawal of the laboratories of a major cement producer were almost offset by increases in foreign laboratory participation.

Participation of foreign laboratories has permitted some comparisons between French standards and foreign standards such as those prepared by BSI and DIN. Cement strength is an area where this is possible. But, in my opinion, this has not been done in a satisfactory manner and more work is needed.

Unfortunately, a procedure for comparing the results of tests done according to an AFNOR standard to results given by ASTM, BSI, DIN, Belgium or Italian standards is not available. However, in a way the most important parameters for the measurement of cement strengths have been identified, including sand type, mixing procedures, and compacting equipment. I believe this has been useful in establishing European Standard EN 196 (Methods of Testing Cement).

It has been possible to compare the results of what we call, the French "pilot laboratories", with laboratories of cement works, laboratories of users including state laboratories, and foreign laboratories. All of them used, more or less, AFNOR standards with their own sand or with French sand. Useful comparisons have been established for absolute measurements such as chemical analysis.

3. Existing Procedure

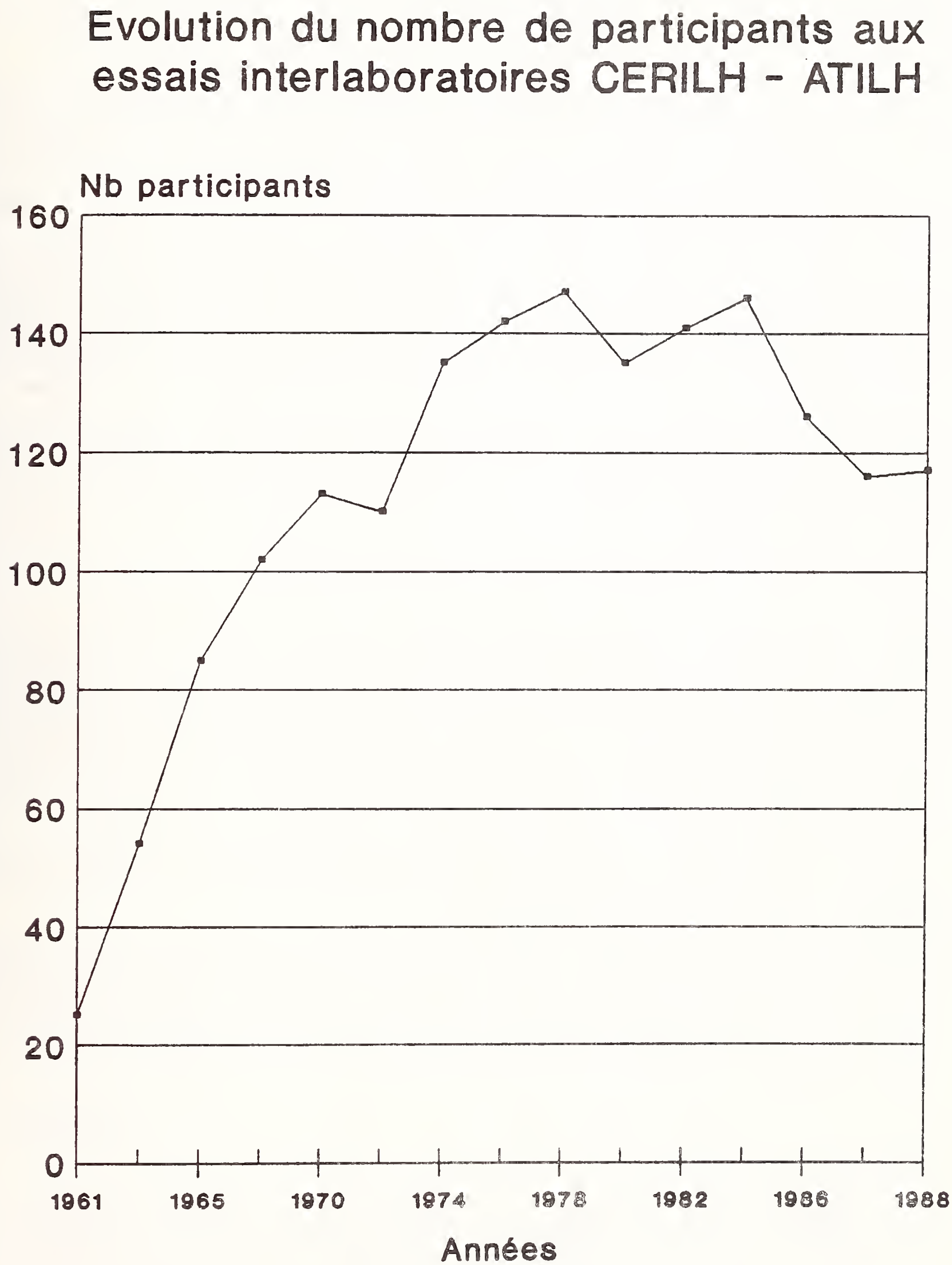
Near the end of each year every laboratory participating in the interlaboratory testing program receives 5 kg of cement, and the foreign laboratories are also sent a certain quantity of French AFNOR sand. They are asked to run tests on the samples consistent with the scope of their testing capabilities. Additional cement may be provided to the laboratory if necessary.

Results are tabulated on preprinted sheets and returned to ATILH. The use of telefax for receiving results from overseas laboratories has saved a lot of time. Most of the results this year were received by the end of May which is quite unusual.

A portion of a technician's time is devoted to data processing. We hope that with the microcomputers we have now, we will soon be able to obtain the results more quickly and improve their presentation. Comparisons between the different types of laboratories can also be done more easily.

The test values are entered into the computer and they are selected according to three criterion; test, method and type of laboratory. Means and standard deviations are calculated, aberrant values are eliminated, and corrected means and standard deviations are re-calculated.

FIGURE 1



Evolution du nombre de participants aux essais interlaboratoires CERILH - ATILH
Nb participants
160
140
120
100
80
60
40
20
0
1961
1965
1970
1974
1978
1982
1986
1988
Années

Tables are presented where every participating laboratory is able to find its own results through a code number, compare them with the mean value and with the results of the "pilot laboratories."

A graphical presentation is prepared for every test in the form of a histogram based on the type of laboratory or the test method used. Additionally, tables are provided which compare the results of the different types of methods as far as it is possible. In some cases, it is not always clear from the information provided by the participating laboratories which method was actually used.

Finally, general comments are given on the accuracy of the different methods and, when possible, on the evolution of the test methods. For example, the 1970's have seen a nearly complete disappearance of the use of wet methods for chemical analysis of cements. These have been replaced by physical methods, mainly x-ray fluorescence. Chemical procedures are still used for those which are standardized: sulphate content, loss on ignition and insoluble residue.

It would be interesting to examine in detail the evolution of the different test methods through the 28 years of the interlaboratory testing program. But, I am not sure it would be of any use. I prefer now to try to give an answer to the first question posed earlier:

4. What has been useful in the past interlaboratory test program?

I would say that every participating laboratory has been able to compare its own results with those of other laboratories. This has been very useful, because in many cases, the results of these interlaboratory tests were the annual opportunity for estimating the level of quality of a particular works laboratory. In many cases, procedures in the laboratories have been improved after a poor result indicated a problem. Interlaboratory tests are also used to estimate the accuracy of the non-cement industry laboratories.

In other cases, laboratory equipment has been brought up to date, and inaccurate and out-of-date methods have been deleted and replaced by methods which are more accurate, reproducible, and automated.

In one case I know well, all works laboratories in 1970 operated their chemical analysis with wet chemistry. The accuracy of the results was rather poor. X-ray fluorescence was systemically introduced in 1974 in all the works and the results of "chemical analysis" are now as good and sometimes better for the cement works laboratories when compared to the results of the "pilot laboratories".

The results of pilot laboratories are compared to the following French "reference" laboratories:

1. Laboratorie de la Ville de Paris which is the third party testing laboratory in the French certification scheme.

2. Central laboratories of the major French cement companies.

This is very important in our certification scheme, because once a year all the laboratories test cement samples from the same source. Tests are repeated many times with many operators, with the results enabling us to estimate the repeatability and the reproducibility of the methods. The analysis of the results of the various types of laboratories gives an indication of what is possible in a well run laboratory. It is remarkable that results of laboratories in French cement works are not more dispersed than the results of the "pilot laboratories".

This means that in complying with the AFNOR P 15301 cement standard since 1978 which is required by certification, French cement works laboratories have improved their testing quality considerably.

I pointed out in the introduction that some cement works laboratories no longer participate in the interlaboratory test program. Does this mean that the interlaboratory tests are of no use? Quite the opposite is true. Some companies have realized the value of interlaboratory testing, and have organized their own, within company, interlaboratory program. This is possible to do when you have 20 participating laboratories, or more if overseas works are included. In this case, instead of testing just once a year, testing two or three times a year is possible. Since it is not necessary to homogenize a large amount of cement, more cement can be sent to each laboratory which is then available as a reference sample in every works laboratory. It can be used for calibrating individual laboratories each time it becomes apparent that something is wrong.

Staffing in works laboratories in France has been reduced to the lowest possible level, requiring that non-productive testing be eliminated. Some companies have decided to run their own interlaboratory testing programs and to stop participating in ATILH's program. However, for calibrating their results with other French laboratories the central laboratory participates in the ATILH program. In the French cement certification scheme, results of every laboratory are compared monthly with results obtained by the Ville de Paris laboratory. Results of all the cement laboratories are interconnected through "Ville de Paris". Interlaboratory testing has been a very good way for comparing results of the French cement industry laboratories.

It has been shown that for obtaining good results, even on tests as simple as strengths or setting time, laboratory technicians <u>must</u> also be experienced. This means that for producing good results on cements this type of testing must be done every day. This can be a problem for non- cement industry laboratories, which carry out some kinds of tests on cement only from time to time.

5. What is now the interest of interlaboratory testing within the French framework?

The interest of French cement works laboratories in interlaboratory testing is now rather low because most of them have reached a high level of competence, and their results are interconnected through the cement certification scheme AFNOR, NF-VP. This is true for all the works since cements produced according to NF P 15301 are certified through this scheme.

Individual customers laboratories are primarily interested in comparing their results with those of the "pilot laboratories", remote laboratories, or other

European laboratories interested in testing results according to the French standards.

Two years ago, we asked the laboratories to use the European EN 196 standard as an alternative method. Even though wet chemistry methods are of little interest, they can provide relative information with other methods which can be of value. This is very useful when the value measured is arbitrary, depending only on the testing method, such as for strength measurements. So we now have a good comparison between French standards and CEN standards.

In coming years, when Europe will be considering certification schemes, and methods of mutual recognition of such schemes, it will be absolutely necessary to have at our disposal a well experienced interlaboratory test program for comparing the laboratories of the third party certification bodies. I believe this is the main reason of the existence of the ATILH interlaboratory testing program. If the interlaboratory test programs must continue in the European framework, they will have to adapt.

6. How to improve the interlaboratory testing in the European framework?

First of all, ATILH has to make sure that the best and most well known European laboratories participate in its interlaboratory testing program. A procedure will have to be clearly defined in order to be sure that this chosen laboratory can be called a European "pilot laboratory." A start has been made this year, too late for obtaining complete results, but it is a beginning.

For the next year, we will organize a meeting between the laboratories to establish a clear procedure for becoming a "pilot laboratory". A uniform testing procedure has to be followed in these laboratories in order to obtain comparable results which have broad value.

I know this could be done in the framework of CEN but I fear that it will take a great deal of time to get a written agreement. It is preferable to use our existing ATILH scheme and to improve it. The guarantee of using a small organization is that testing will be done only when needed and not only for pleasure.

It will be possible to define a procedure for updating cement testing repeatability and reproducibility values on a yearly basis through testing by competent laboratories. Through this procedure, it will be possible to compare the results obtained using the EN 196 standard with those from testing to national standards. On another hand, this scheme will make it possible to test new procedures before presenting them for European standardization as part of the EN 196 review process.

7. Conclusion

The 28 years of experience of interlaboratory testing allows comparison of results between French laboratories. Through the French certification scheme and the ATILH interlaboratory testing program we have reached a very good national agreement on the quality of test results in France. Since we have to do the same for Europe, the French experience can be of great value.

COMPARATIVE TESTS BETWEEN 20 ACCREDITED LABORATORIES

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Forschungsinstituts der Zementindustrie

To minimize the risk of a collapse, all structural building materials used in Germany have to be supervised and certified by accredited testing laboratories and certification bodies. Based on a specific law, private or state-owned organizations or laboratories may be accredited by the authorities provided they meet detailed requirements. The Verein Deutscher Zementwerke (VDZ), the Technical Association of the German Cement Works, is an accredited certification body for cement established in 1877. It has operated its own accredited testing laboratory, Forschungsisnstitut der Zementindustrie (FIZ), since 1902. At present there are some 20 (mainly state-owned) national or foreign testing laboratories which are accredited for supervising and/or certifying cement. More than 95% of the cement consumed in the Federal Republic of Germany is supervised by FIZ and certified by VDZ. This amounts to nearly 25 million tons per year spread over approximately 400 different cements produced by 71 plants.

Since 1971, all accredited testing laboratories for cement have to take part in comparative testing program twice a year. In this field the FIZ is, so to speak, acting as a reference laboratory, i.e. it homogenizes and dispatches the cement samples to the laboratories and evaluates the results by statistical methods. But all decisions concerning the accreditation are within the competence of the authorities. Since the FIZ has by far the most experience in testing cement, it offers its assistance by checking the equipment and training the technicians to those laboratories which have significant higher deviations in their results than the average. Due to these measures, in most cases the standard deviations of the results of the primary cement properties could be reduced remarkably. But it is still necessary to improve the testing of those cement properties which are not so common.

Figure 1 summarizes the results of comparative tests run in 1988 in which 22 laboratories took part. Figure 2 summarizes the standard deviations obtained in 35 comparative test programs organized by FIZ since 1972. Several measures taken since 1981 have improved reproducibility values from a range of 1.8 to 3.2 N/mn^2 to a range of 1.1 to 2.0 N/mn^2. Exceptions were high strength cements (PZ55) where stiff and flexible testing machines performed differently.

Figure 1

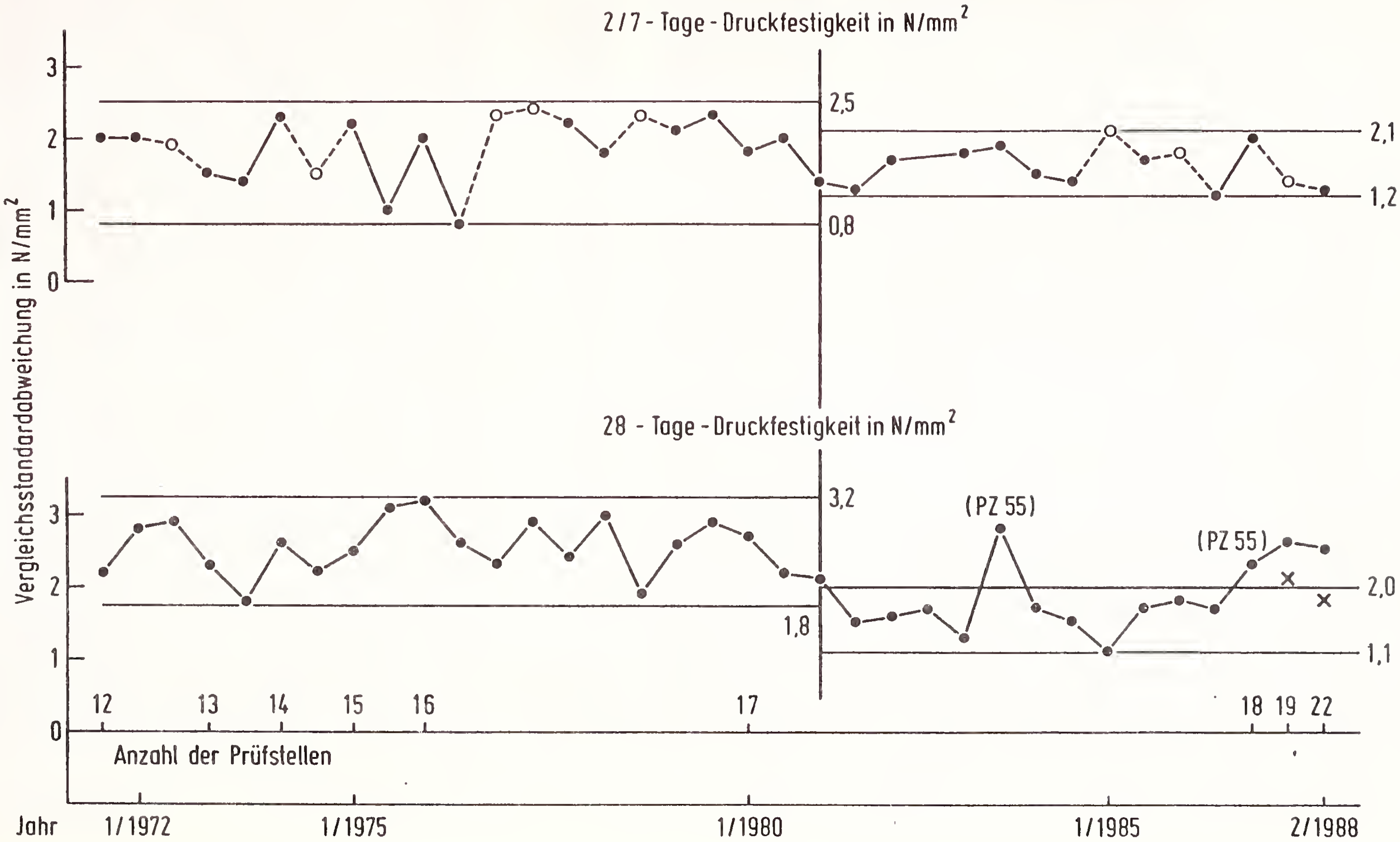
Vergleichsprüfung 1988
der nach DIN 1164 Teil 2, Abschnitt 4.1
bauaufsichtlich anerkannten Prüfstellen

(Eisenportlandzement Z 35 F - DIN 1164)

Anzahl der Prüfstellen	Prüfwert	Chemischer Befund					Mahlfeinheit			Erstarren		Festigkeiten in N/mm^2				Hüttensandgehalt
		Glühv.	CO_2	Unl.R	Cl	SO_3	R 0,2	Ospez.	H_2O	Beginn	Ende	Biegezug		Druck		
		G.-%	G.-%	G.-%	G.-%	G.-%	G.-%	cm^2/g	G.-%	min	min	2 T.	28 T.	2 T.	28 T.	G.-%.
22	n	22	21 1)	21 1)	22	18 2)	22	21 1)	21 1)	22	22	22	21 3)	22	22	21 3)
	x_M	1,97	0,95	1,50	0,017	3,41	0,07	2912	29,5	182	237	3,6	7,9	16	45	32
	x_{max}	2,52	1,15	1,81	0,100	3,53	0,50	3070	30,5	220	285	4,3	8,6	19	49	40
	x_{min}	1,18	0,60	1,13	0,001	3,29	0	2730	29,0	140	180	3,1	7,2	14	38	22
	s	0,39	0,14	0,20	0,020	0,07	0,13	98	0,5	23	24	0,3	0,4	1,3	2,5	4,2
	V	19,79	15,09	13,06	114,4	2,19	180,8	3,35	1,6	12,6	10,0	8,2	4,8	8,0	5,6	13,2

1) 1 Prüfwert als statistisch gesicherter Ausreißer (S = 95 %) nicht berücksichtigt.
2) 4 Prüfwerte als statistisch gesicherte Ausreißer (S = 95 %) nicht berücksichtigt.
3) nur 21 Werte eingegangen

Figure 2


2/7 - Tage - Druckfestigkeit in N/mm²
28 - Tage - Druckfestigkeit in N/mm²
Vergleichsstandardabweichung in N/mm²
3
2
1
0
2,5
0,8
2,1
1,2
3,2
1,8
2,0
1,1
(PZ 55)
(PZ 55)
12
13
14
15
16
17
18
19
22
Anzahl der Prüfstellen
Jahr
1/1972
1/1975
1/1980
1/1985
2/1988

BRITISH COMPARATIVE CUBE TESTING PROGRAMME

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Abstract

The purpose of this paper is to present the British Comparative Cube Testing Programme. The British Cement Association (BCA) introduced the comparative cube test 18 years ago. Large discrepancies had been discovered between the values obtained from machines which complied with BS 1610 load verification measurements. The comparative cube test allowed a machine user to check alignment of platens and ball seating together with other aspects of machine performance. In 1981 BCA gained approval from the National Measurement Accreditation Service (NAMAS) for the comparative cube test which is shortly to be covered by a new British Standard. Over 200 tests are carried out each year with BCA analysing the results. The test is also a valuable aid to monitoring the performance of testing in cement and concrete testing laboratories.

1. INTRODUCTION

Within the UK the concrete cube test is required by government clients, engineers and quality schemes for concrete, as a compliance test for design mixes. Incorrect cube results can lead to catastrophic failure of structures and to disputes causing unnecessary expenditure of both time and money for the parties involved. Mix proportions may be changed unnecessarily and in extreme cases quite acceptable concrete may be removed and replaced.

It is important, therefore, that all tests are performed to the correct procedure, by trained technicians using equipment that is fit for the purpose.

This paper outlines the development of the comparative cube test, what it is, why it was set up and its value to the construction sector, ending with a detailed look at the new British Standard.

2. BACKGROUND TO THE COMPARATIVE CUBE TESTING SERVICE.

As long as 43 years ago, on a large airport contract, it was observed that when notionally identical cubes were crushed on two different machines quite different values for strength were obtained, even though satisfactory load scale calibrations had been carried out on both machines. It was not until 1966, however, following a Cement and Concrete Symposium in London that the findings of Sigvaldson(1) and Cole(2) led to the then, Cement and Concrete Association (C&CA), the forerunner to BCA, being asked to look at the feasibility of providing a reference testing service for cube testing machines. The C&CA introduced their comparative cube testing service in 1970.

In 1981, in order to provide national recognition, C&CA sought approval from the British Calibration Service(3), now part of NAMAS, for the reference test.

3. THE COMPARATIVE CUBE TEST

Batches of cubes are made under carefully controlled conditions at BCA which acts essentially as a reference laboratory. The strengths and sizes of the cubes are selected so that on crushing they will highlight common machine faults. From one batch of cubes, sets of cubes are selected and sent to clients with detailed instructions for their handling and testing. One set is retained by BCA for testing on the reference machine. All sets of cubes are crushed by the clients and the reference laboratory at the same time. Results are entered on a proforma which the client returns to BCA, who perform all the calculations. Statistical analysis of the results is carried out and compliance assessed against prescribed criteria. A certificate of compliance, or non-compliance, is then issued to the client. In the event of failure of one or more of the sets to comply BCA provide a suggested check list to enable clients to identify problem areas. A copy of the certificate is to be found in APPENDIX 1, and a copy of the check list in APPENDIX II.

4. THE NEED FOR THE COMPARATIVE CUBE TEST.

The accuracy of load indication is only one parameter in assessing the suitability of a compression testing machine for concrete. Foote(4) identified the factors which would be most likely to affect machine performance as:

(i) platen cube interface conditions

(ii) errors in indication of the load not identified by BS 1610(5) calibration

(iii) failure to maintain loading rate - particularly immediately prior to failure

(iv) platen stability not shown by strain cylinder measurement

(v) operator errors

The strain cylinder(6) developed by C&CA is one means of assessing machine performance under static load. This provides limited information on the state of the machine and assists the manufacturer with his design. It quantifies the freedom of a testing machine platen to align on the specimen, the axiality of the load application and the restraint to tilting of the platens when the reaction is displaced from the testing machine axis. However, the comparative cube test involves crushing the cube to failure; the testing machine is therefore being assessed while in its routine mode of operation and machine performance will be assessed up to the point of failure of the cube.

5. VALUE OF THE COMPARATIVE CUBE TEST TO THE CONSTRUCTION INDUSTRY.

Statistics were gathered on machine compliance from the introduction of the reference testing service. Early figures, shown in the left hand diagram in Figure 1 revealed an alarming state of affairs; less than one in three machines were found to be satisfactory. After the introduction of the strain cylinder, assisting manufacturers in their design of machines, the scene improved as depicted in the central diagram. Nearly two out of every three machines then complied and this improvement continued with the compliance currently being around three out of four machines.

Machines that have been serviced, calibrated and checked with the strain cylinder may still fail the comparative cube test. Sometimes this is due to operator error, but quite often a machine fault is identified which had not been detected during routine service. Many NAMAS laboratories therefore regard this test as being the most effective method available for ensuring that cube testing is performed satisfactorily, and add it to the annual checks for load verification and strain cylinder checks.

6. BRITISH STANDARD FOR COMPARATIVE CUBE TESTING

6.1 Background.

In 1986 the British Standard(6) for concrete cube testing machines was amended to allow the use of the BCA comparative cube test as an alternative to the strain cylinder test for checking the performance of the testing machine. Following this development it was decided that a British Standard was needed to provide a method for verifying the performance of compression testing machines used for concrete cube testing. Work on the Standard has been completed and it is expected that the Standard will be published by the end of 1989.

6.2 Contents of Standard

6.2.1 The reference laboratory and reference machine.

In the Standard, definitions cover the reference laboratory, which must hold NAMAS accreditation for the comparative cube test, and the reference machine for comparative cube testing, which may be used for reference purposes only. The reference machine must be subject to close control if the comparative cube test is not to be invalidated. The Standard requires that the machine shall comply in full with BS 1881 Part 115 and further requirements listed in the equipment section of the Standard. The reference machine must be checked in accordance with Part 115 prior to use, in every week in which it is to be used. This comprises a check on the self alignment of the upper machine platen and the alignment of the component parts of the machine, together with a check on the restraint on tilt of the upper platen.

In addition to annual verification by the National Physical Laboratory, or an organisation accredited by NAMAS, the reference laboratory is required to monitor the reference machine at three monthly intervals using force measuring devices meeting Grade 1.0 requirements of BS 1610. Any drift or change of the indicated force in excess of 0.5% requires reference testing to be stopped and reverification to take place.

6.2.2 Cube production and storage.

For cube production, the moulds used have to meet the requirements of BS 1881: Part 108(7) with the addition of a plastic-coated strawboard gasket to minimise leakage. This addition to Part 108 is used to minimise variation between cubes from one batch .

Three sets of six cubes have to be made for the reference machine and each machine to be verified. The sets comprise:

(i) 150 mm cubes, 70 to 85 N/mm2 mean strength

(ii) 100 mm cubes, 70 to 85 N/mm2 mean strength

(iii) 150 mm cubes, 14 to 19 N/mm2 mean strength

The cubes have to be compacted using a vibrating table, hand compaction is not allowed, and the Standard requires the same operator to trowel all of the cubes from one batch.

The cubes, in their moulds, must then be cured in a relative humidity of not less than 90% for at least 16 hours.

After demoulding the cubes must be weighed in air and water and the density calculated.

If the mean density of a set of cubes differs from the overall mean density by more than 5 kgm^{-3} then the Standard requires the set be discarded. Furthermore, if the standard deviation of density of all the cubes of one size from the same batch exceeds 6.0 kgm^{-3}, then the cubes must not be used. The cubes must be stored for at least 40 days, and while the actual temperature variation is not important, it is essential that all cubes are subject to the same conditions of curing. Again the emphasis is on producing cubes with a very low variation in properties.

6.2.3 Packing and transporting.

Detailed instructions are given for removing the cubes from the curing tanks, wrapping and transporting them, with appropriate documentation.

6.2.4 Testing of cubes.

The cubes must be tested by both the clients and the reference laboratory on the same day. The testing must be to BS 1881: Part 116(8) with the addition that the position of the trowelled face relative to the front of the machine face is recorded. The results of the tests must be inserted on the forms supplied by the reference laboratory, and copies are included in the Standard.

6.2.5 Calculations

The Standard requires the reference laboratory to perform all the calculations. The mean strength obtained from a set of cubes crushed on the reference machine, and the mean strength obtained for the corresponding set of cubes crushed on the machine being verified, together with the corresponding standard deviations are calculated. The differences in the strengths expressed as a percentage of the mean strength obtained on the reference machine and the 95% confidence interval is calculated. This is then expressed as a percentage of the mean strength obtained on the reference machine using the Student's 't' distribution. The machine being verified is deemed to comply if the values of the differences between the means, and the standard deviations are within prescribed values.

6 2.6 Certification.

The Standard requires the reference laboratory to issue a certificate, including a statement of compliance. In the event of non-compliance, there is a requirement for the certificate to be overprinted in bold text that the machine did not comply.

7. CONCLUSION

The comparative cube testing service has been seen as a valuable aid for several years for many concrete testing laboratories in the UK. When the new Standard for comparative cube testing becomes available the number of laboratories using this service may well increase and this may lead to further improvements in machine performance.

REFERENCES.

(1) Sigvaldason, O.T. The influence of the testing machine on the compressive strength of concrete.
Proceedings of a symposium, London, Cement and Concrete Association, pp 162-171, 1966.

(2) Cole, D.G. The relationship between the apparent variation is compressive strength of concrete cubes and the inaccuracies found in the calibration of compression testing machines. Reference(1) pp155-161.

(3) Supplementary criteria for laboratory approval for comparative concrete cube testing, British Calibration Service document 0407, 1981

(4) Foote, P. Comparative cube testing - a review. Concrete, 1983.

(5) BS 1610 Materials testing machines and force verification equipment. Part 2(1986) Specification for the grading of equipment used for the verification of the forces applied by materials testing machines.

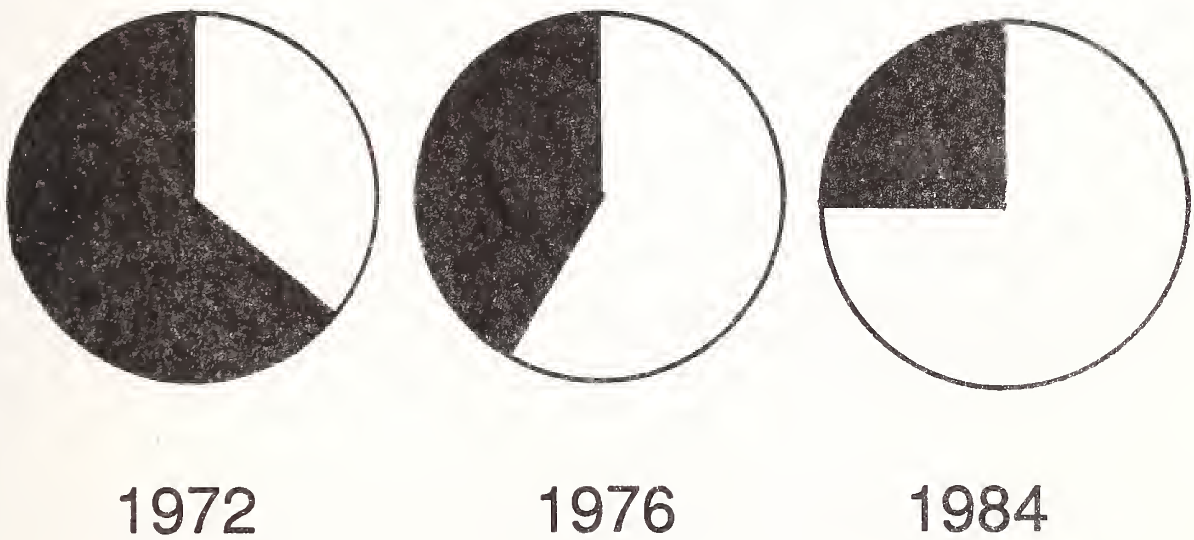
(6) BS 1881 Part 115: Specification for compression testing machines for concrete. Appendix A, 1986.

(7) BS 1881 Part 108: Method of making test cubes from fresh concrete, 1983.

(8) BS 1881 Part 116: Method for determination of compressive strength of concrete cubes, 1983.

FIGURE 1

COMPARATIVE CUBE TESTING
1972 - 1984



~~APPENDIX I~~

CERTIFICATE OF CALIBRATION

ISSUED BY C&CA Services

DATE OF ISSUE SERIAL NUMBER

NAMAS

CALIBRATION No. 0101

C&CA services

Quality Centre Laboratories
British Cement Association
Wexham Springs
SLOUGH,
SL3 6PL

Telephone: (0753) 662727
Fax: (0753) 660399

PAGE 1 OF 2 PAGES

APPROVED SIGNATORY

T. J. Tipler
J. E. Dilly

C&CA Services is a Division of the British Cement Association

For :

Description : kN Compression testing machine

Made by :

Identification :

Date of verification :

Basis of test : BCS Publication 0407

The results of the comparative cube test done on the above date using C&CA Services reference machine complied/did not comply with the criteria given below the Summary of results on page 2.

The uncertainties are for a confidence probability of not less than 95% Signed ....

CERTIFICATE OF CALIBRATION

NAMAS ACCREDITED CALIBRATION LABORATORY No 0101

C&CA services

SERIAL NUMBER

SUMMARY OF RESULTS

Cube size mm	Batch No.	C&CA Services Reference Machine				Estimate of difference %	Confidence limits %
		Mean strength MN/m²	S.D. MN/m²	Mean strength MN/m²	S.D MN/m²		
The confidence limits are for 95% probability. That is, there is only one in twenty chance that the true difference between machines lies outside the limits quoted.							

CRITERIA

a) The estimate of the difference of the means for any one or more of the three batches of cubes crushed, shall not exceed 4 per cent at a probability level greater than 95 per cent.

b) If the standard deviation of the machine under test exceeds 3.0 MN/m² for either of the 70 MN/m² concrete batches it shall not exceed 3.3 times that of the reference machine for that batch.

c) If the standard deviation of the machine under test exceeds 1.0 MN/m² for the 14 MN/m² concrete batch it shall not exceed 3.3 times that of the reference machine.

The uncertainties are for a confidence probability of not less than 95%

APPENDIX II

C&CA services

Wexham Springs, Slough SL3 6PL
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SUGGESTED CHECKS IN THE EVENT OF NON-COMPLIANCE WITH BCS CRITERIA FOR COMPARATIVE CUBE TEST RESULTS

1. **If results on one or more batches are high, i.e. estimate of difference is positive and exceeds 4%**
   Were the cubes allowed to dry before testing? (Cubes must be tested wet.)
   Did the operator load the cubes too fast? (See BS 1881)
   Was the pacer rate or loading rate correctly set?
   Is the pacer or load rate indicator accurate? (Check with stopwatch)
   Are the machine platens flat or have they worn concave?
   Are the machine platens backed by a flat surface? (Look for dirt under platen)
   Are the platens rusty, or badly pitted and scratched?
   Was the slave pointer or other peak holding device operating correctly?
   Is load indication accurate?*
2. **If results on low strength 100 mm cubes are high, also check:-**
   Were the cubes tested with trowelled face in contact with platen by mistake?
3. **If results on one or more batches are low, i.e. estimate of difference is negative and exceeds 4%**
   Did the operator make every effort to maintain rate near the failure point?
   Was the pacer or loading rate correctly set?
   Is the pacer or load rate indicator accurate? (Check with stopwatch)
   Were the cubes correctly centred on the lower platen?
   Were the cube faces in contact with the machine platens first wiped clean?
   Were the platens cleaned free of concrete before each cube was tested?
   Were the platens oily or greasy? (Oily platens should be cleaned with solvent)
   Are the auxiliary platens flat or have they worn convex?
   Are there oil leaks in the hydraulic system?
   Is the pump working properly?* (If belt driven, check belt tension)
   Is the automatic loading control working properly? (Automatic machines only)*
   Was the slave pointer or other peak holding device operating correctly?
   Is the load scale indication accurate?*
4. **If results on either high strength batch are low, also check:-**
   Are the column nuts tight? (Certain machines only)
   Are the platens properly supported? (Look for dirt under the platen or between packing pieces)
   Were the cubes tested with trowelled face in contact with the platen by mistake?
   Do the platens tilt during loading? (Are strain cylinder readings satisfactory)*
5. **If results on either 100 mm cube batch are low, also check:-**
   Does the upper platen align correctly on specimen at start of the test?
   (Are strain cylinder results satisfactory?)*
6. **If the standard deviation of a batch is too high (see criteria on certificate)**
   Were all cubes centred correctly? (Particularly applicable for high strength 100 mm batch)
   Were the platens degreased before testing the first cube?
   Was the machine "warmed up" before testing?
   Were some cubes tested with the trowelled face in contact with the platen?
   Does the upper platen align correctly on the specimen at start of each test?

Further information relating to specific test results and further information on simple methods of checking for certain faults available to the machine user may be obtained by telephoning Tom Tipler at C&CA Services : (0753) 662727

* Most machine users will not be able to make this check themselves but the supplier of the machine should be able to do so.

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COMPARATIVE INVESTIGATION OF COMPRESSION TESTING MACHINES FOR CONCRETE CUBES

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Technion - Israel Institute of Technology

Abstract

The measured compressive strength of hardened concrete specimens in the form of cubes depends not only on the inherent properties of the concrete, but also on the technical properties of the testing machine by which the compression test is performed.

It is true that the most important factor of accuracy in strength testing machines is the monitoring system. When tensile strength is considered, this is actually the only factor which is investigated.

During the compression testing of concrete cubes, additional non-axial forces are created in the testing frame. For that reason the observed strength depends on the nature and structure of the testing machine.

The paper reports a system of assessment of the compression strength obtained by use of testing machines of various types operated at the National Building Research Institute Testing Division. Calibration data of the machines and comparison cube compression test data are included. The differences observed between the compressive strengths depend on the nature of the various testing machines which has to be considered when compressive testing machines are selected.

1. Introduction

Calibration of materials testing machines is a routine procedure in every testing laboratory. The calibration is performed as a part of the testing quality assurance measures of the laboratory. This includes both a predetermined calibration programme and one performed at the end of any maintenance or repair operation of a testing machine. The importance of the calibration of testing machines is obvious and there is no need to justify the procedure.

The scope of this paper is to describe a series of calibration experiments performed on compression testing machines used for the determination of compressive strength of concrete at the testing department of the National Building Research Institute of the Technion, Haifa.

The paper outlines the mechanics of the compression strength experiment, describes the ways the characteristics of a testing machine may affect the testing results, and presents data on calibration experiments performed on five compression testing machines. The subject of nominating a reference testing machine is discussed and demonstrated.

2. Compression Tests of Concrete

The compression testing of concrete cubes is a complex process involving secondary forces acting on the tested specimen in addition to the axial compressive load imposed by the testing machine.

Concrete is a composite material comprising a cement stone matrix and inert aggregate particles. It has a high compressive strength but a very low tensile strength. This property is a result of (1) the brittle nature of both the cement stone and the aggregates, which cannot allow for any plastic deformation, and (2) a very high density of initial internal defects, which contribute to the fast development of catastrophic cracks at relatively low tensile stresses.

The state of the stress fields inside a cube shaped testing specimen is presented in figure 1. When the compression plates of the testing machine move towards each other, the testing specimen set inside the machine resists the free movement of the plates and axial compressive stresses are developed inside the specimen. As a result of the axial decrease of length due to the compressive stresses, the concrete tends to increase its length in the lateral directions. The free lateral movement of the specimen is disturbed by friction forces between the compressed concrete and the machine compression plates. The friction forces induce shear stresses inside the concrete cube specimen. However, these stresses are limited to the small volume of the concrete in the top and bottom layers of the cubes which are immediately adjacent to the compression plates.

The result of this state of stresses is a lateral movement of the peripheral parts at the middle of the height of the specimen. This process results in the formation of a large number of cracks inside the specimen. A picture of a concrete cube specimen after a properly conducted compression test is shown in figure 2.

The compressive strength of the concrete is obtained by dividing the ultimate compression force developed by the testing machine by the cross sectioned area of the specimen. If the conditions inside the compression frame of the testing machine do not permit an ideal distribution of stresses inside the concrete cube being tested, an inferior compressive load is required to fail the cube. The result is an apparent inferior compressive strength of the concrete.

3. Characteristics of a Properly Built Compression Testing Machine

In order to conduct a proper compression test, one has to assure the following conditions exist:

3.1 An even distribution of axial compressive strength must exist inside the specimen. Testing machines generally have one fixed compression plate and one adjustable plate. The adjustment of the plate to fit the surface of the specimen is accomplished by a spherical support (figure 3).

3.2 The center of the sphere must coincide with the compression plane of the compression plate. Any defect in the spherical surface due to inaccuracy in production or pitting caused by intensive stresses or corrosion, may affect the free adjustment of the plate to the cube surface and result in uneven stress distribution.

3.3 The compression frame of the testing machine must be sufficiently rigid to prevent a mutual lateral displacement of the compression plate. This may induce additional shear load on the tested specimen and fail the specimen at a lower compressive load with all the consequences involved.

The two last phenomena may result in an eccentric compression load, which in extreme cases may even induce tensile stresses in one side of the specimen (figure 4). A picture of a cube failed in eccentric load is shown in figure 5.

4. Load Monitoring in Testing Machines

The testing of concrete in compression is performed by hydraulic testing machines capable of loading the tested specimen at a constant rate of stress increase. The monitoring of the load produced by the machine pump may be achieved by various mechanical or electrical installations such as:

4.1 Additional ram acting against a calibrated spring or a calibrated mechanical pendulum. The monitored load is linearly related to the respective extension of the spring or the angular movement of the pendulum.

4.2 A direct measurement of the load by simple manometer consisting of a hollowed metal arch connected to the hydraulic system. Any change in the hydraulic pressure will result in a displacement of the arch end which is mechanically transformed to a rotating dial.

4.3 New sophisticated testing machines are equipped with electronic systems capable of monitoring the hydraulic pressure or directly determining the load in the machine frame.

It should be mentioned that when the load is determined through measurement of the hydraulic pressure inside the loaded system, the testing machine displays the product of measured hydraulic pressure times the cross sectional area of the main ram of the testing machine.

Load measuring errors result from this indirect monitoring of load. For example, friction inside the main ram may result in a negative deviation of the actual load from that displayed on the machine monitor. Some hydraulic fittings may cause a delay of the response of the monitor to the pressure buildup on the main ram; this results in a positive deviation of the actual load against the displayed load. Some of these phenomena may be built in during the manufacturing of a testing machine which justifies the calibration of any new testing machine before it goes into operation. Other defects in testing machines may be caused by prolonged regular operation, or by incidental overloading or mishandling of the machine.

5. Calibration of Compression Testing Machines

In calibrating a tension testing machine, it is usually sufficient to verify the accuracy of the measured load by one of the available calibration devices. However, when a compression testing machine is calibrated it is not sufficient to determine accuracy of the load monitoring system, as it is done for a tension testing. In addition to the regular calibration process, it is necessary to determine the effect of the testing machine on the specimen, i.e. to investigate the testing performance of the compression testing machine. This investigation is performed by simultaneous comparative testing of batches of standard specimens in the machine undergoing calibration and in a reference compression testing machine.

It is first required to nominate such a "reference" machine. From the analysis of the possible effects of testing machine characteristics (excluding the load monitoring system) on the compressive strengths of the specimens tested, it is possible to conclude that any malfunction of the testing machine will adversely affect test results. Thus it is logical to nominate as a "reference" machine, a testing machine which yields the highest compressive strength. Another approach is to nominate as a reference machine the machine from which compressive strength results have the minimal deviation from the average result of a group of testing machines under investigation.

The compressive strengths of a population of concrete specimens made of the same concrete batch obey the normal distribution law, and can be represented by the average strength and standard deviation. When the total population of concrete specimens is randomly split into small subgroups, each of the subgroups has an average compressive strength and standard deviation. If all the subgroups are tested in the same testing machine, one can expect to obtain similar average compressive strengths and similar standard deviations for all the subgroups. If the testing of each of the subgroups is performed in a different testing machine, the average strength of each subgroup may be affected by the performance of the particular machines. However, the relative standard deviation should be maintained unchanged, provided other variables like testing age and curing conditions are the same for all the subgroups.

It is not uncommon that when a large number of specimens is prepared from a single batch, a small number of the prepared specimens may have particularly high deviation of the tested strength. As we look on the groups of cubes as a "calibration tool", it is possible to smooth the deviations by automatically rejecting the two extreme results (the lowest and the highest) of each group, and obtaining a more gentle tool free of incidental deviations.

It is desirable to perform the calibration tests at various working ranges of the testing machine. Careful analysis of the performance at each one of the working ranges may be used to analyze the causes for the poor performance of a testing machine.

A special device nominated "equivalent cube" was developed by the Cement and Concrete Association in Britain to simulate the behavior of a cube under test. The device is intended for direct assessment of the performance of compression testing machines. However, the device is extremely expensive and it is not yet in common use by testing laboratories around the world.

6. The Calibration Experiment

Comparative calibration studies of compression testing machines were performed at the National Building Research Institute during the period from December 1985 to January 1986. The testing machines used in the studies were two heavy duty testing machines (RIHLE 80t and RIHLE 150t) and three portable testing machines (FORNEY 120t). Characteristics of the testing machines are presented in table 1.

The calibration studies were performed in two stages: (1) calibration of the load monitoring system; and (2) comparative compression testing performance.

6.1 Calibrations of the load monitoring systems were carried out using two calibration aids: (1) a volume displacement mercury AMSLER 200t dynamometer; and (2) a 100t electric strainguage resistance dynamometer made by TEDEA. The testing machines were operated with a dynamometer set in the compression frame. Loads monitored by the compression machines were compared with the loads displayed by the dynamometers. The calibration process of each one of the testing machines consisted of three loading cycles with each one of the dynamometers. A summary of the calibration data is presented in table 2.

6.2 Three grades of concrete (B-200, B-300, B-400) were used for the compression testing performance studies. The details of the concrete mixes, used for production of 0.06 cubic meter concrete batches are shown in table 3. The concrete batches were mechanically mixed, according to the mixing schedule described in the Israeli Standard IS896 for the preparation of comparative concrete mixes. The content of each batch was evenly distributed between the large number of molds (50 to 55). The specimens were 100 mm cubes. Measures were taken to avoid segregation of the concrete and to ensure uniform and complete compaction of the specimen. The cubes were continuously cured by submersion in lime saturated water at 21° C until the compression test at age of about 28 days.

Each lot of cubes was randomly divided into five subgroups for the compression testing in each one of the testing machines. The compression tests were performed simultaneously in all five testing machines. Compression test data are shown in table 4.

7. Test Results

7.1 The deviation between the testing machines readings and the dynamometer displays are shown in table 2. The highest average deviation was observed in machine 1 (-0.70%). The lowest average deviations were observed in machines 4 and 5 (-0.25%). Relating the deviations to either machine 1 or machine 2 as possible reference machines, the highest deviation was observed between machine 4 and machine 1 and machine 2 (+0.47%). The average deviations between the two heavy duty machines (1 and 2) were only 0.04%.

7.2 The compressive strengths of the three concrete grades tested in all the testing machines are given in table 4. Results are provided for the total populations of the tested subgroups of specimens and for the populations after deleting the two extreme results of each subgroup. Very small differences are observed between the average strengths of the total populations and of the reduced populations. However, as expected, the standard deviation and the coefficients of variations of the reduced populations are substantially smaller than those of the whole population. The comparison between the results yielded by the various machines is based on the reduced population data.

7.3 The difference between the compressive strengths attained from the various machines are shown in table 5. The highest average compressive strengths were obtained from the subgroups tested by machine 1. The compressive strengths of the subgroups tested by machine 2 were in the best agreement with the average results obtained from all the machines.

8. Discussion and Conclusions

The calibration of the compression testing machines using two types of dynamometers yielded very similar results of relatively small negative readings of the testing machine against the dynamometer readings. The difference between the display of different testing machines was even smaller (less than 0.5 percent).

The compression testing performances of the different testing machines exhibited much higher deviations between the machines. The performances of the testing machines could not be predicted from the calibration stage of the study, and was revealed only from the results of the compression strength of concrete stage of the study. The deviation observed in this stage was higher by one order of magnitude (up to 5.0 percent) from the deviation in the first stage.

Regarding the nomination of a "reference" testing machine, two possibilities were considered: nominate the "closest to the average performance" testing machine (machine 2), or to nominate the "best performance" testing machine (machine 1). Referring to the previous discussion concerning possible variations in the compressive strengths yielded by different machines, it was decided to nominate machine 1 as the "reference" testing machine, assuming that this machine has the smallest number of possible defects.

The study demonstrated the importance of the indirect study of the performance of the compression testing machines in addition to the regular calibration process.

The analysis of the results will allow a determination of the reasons for the inferior performance of the compression testing machines, and will assist in the modification process of the machine hardware required for upgrading of the machine's performances.

Future calibration of all the laboratory compression testing machines will include the two stages, and necessary measures will be taken to upgrade the performance of a machine if it is found unsatisfactory.

TABLE 1 : TESTING MACHINES DETAILS

TESTING MACHINE	MAKER AND MODEL	MAXIMUM CAPACITY (10^3Kg)	SPHERICAL BEARING DIAMETER (mm)	LOCATION OF SPHERE CENTER ABOVE TO PRESSURE SURFACE (mm)
1	RIHLE	80	135	14
2	RIHLE	150	135	14
3	FORNEY	120	133	10
4	FORNEY	120	133	10
5	FORNEY	120	133	10

TABLE 2 : DEVIATIONS BETWEEN TESTING MACHINE MONITOR AND DYNAMOMETER AVERAGE READING

TESTING MACHINE	STRAIN GAUGE ELECTRICAL DYNAMOMETER			VOLUME DYNAMOMETER (AMSLER 200T)			AVERAGE DEVIATION		DIFFERENCE of [III] BETWEEN TESTING MACHINE AND REFERENCE MACHINE	
	I	II	III	I	II	III	II	III	MACHINE 2	MACHINE 1
1	0-75.0	-0.67	-0.58	0-75.0	-0.80	-0.75	-0.74	-0.67	-0.02	-
2	0-105.0	-0.72	-0.63	0-100.0	-0.62	-0.83	-0.67	-0.65	-	+0.02
3	0-95.0	-0.47	-0.24	0-100.0	-0.55	-0.29	-0.38	-0.31	+0.34	+0.36
4	0-95.0	-0.04	-0.07	0-100.0	-0.57	-0.42	-0.31	-0.19	+0.46	+0.48
5	0-95.0	-0.37	-0.39	0-100.0	-0.09	-0.13	-0.24	-0.27	+0.38	+0.40

I - Full range of calibration ($Kg*10^3$)

II - Average deviation for full calibration range (percent)

III- Average deviation for experiment working range :$20.0 \div 50.0*10^3$(percent)

TABLE 3 : CONCRETE MIXES DATA

*MIX INGREDIANTS	MIX PROPORTION (KG PER M^3)		
	B-200	B-300	B-400
12-19 MM CRUSHED BENJAMINA DOLOMITE	1021	1024	974
2-5 MM CRUSHED BENJAMINA DOLOMITE	266	266	254
0.1-0.6 MM NATURAL BEER SHEBA QUARTZ SAND	662	606	555
P.C -NESHER HAIFA PORTLAND CENTER	268	343	454
MIXING WATER	189	191	200
TOTAL	2406	2430	2437
SLUMP (MM)	120	125	140

* THE AGGREGATES USED FOR THE CONCRETE MIXES WERE FROM THE SAME SOURCES AS THE STANDARD AGGREGATES EMPLOYED FOR COMPRESSIVE STRENGTH OF CEMENT TESTING ACCORDING TO I.S-1.

TABLE 4 : COMPRESSIVE STRENGTH DATA

TESTING MACHINE			1			2			3			4			5		
CONCRETE GRADE			B-200	B-300	B-400	B-200	B-300	B-400	B-200	B-300	B-400	B-200	B-300	B-400	B-200	B-300	B-400
	SPECIMEN COMPRESSIVE STRENGTH (MPa)	1	25.3	36.0	(51.1)	(25.4)	34.3	45.1	(21.5)	(36.7)	(43.7)	(25.2)	(31.2)	47.0	26.6	35.4	47.1
		2	26.2	37.4	46.3	24.3	(33.9)	46.1	24.1	35.1	45.2	(21.6)	33.6	45.2	25.9	34.6	44.1
		3	25.0	37.3	47.7	24.1	35.1	(47.1)	24.0	(33.0)	44.7	22.3	32.2	45.2	25.2	36.5	45.1
		4	24.8	36.9	45.0	24.9	36.9	45.8	24.7	35.7	46.6	24.0	34.3	45.6	25.8	(33.1)	47.1
		5	25.2	37.8	47.3	(22.9)	35.2	(44.7)	24.5	36.6	44.4	23.3	35.1	47.1	25.9	(37.3)	45.4
		6	25.3	36.8	46.7	25.3	35.4	46.4	24.3	36.3	45.9	23.1	(35.6)	45.1	(23.5)	36.4	(48.8)
		7	24.4	37.1	(44.7)	23.8	35.1	46.1	24.4	36.0	44.2	23.5	34.7	(38.8)	25.6	36.6	44.3
		8	24.8	(35.5)	(44.7)	24.6	35.1	44.9	24.0	36.4	(48.4)	23.8	34.9	45.2	24.4	35.9	48.4
		9	(23.2)	(38.4)	45.0	24.5	35.3	44.9	23.9	35.4	45.6	23.7	34.1	(47.5)	(26.7)	35.7	44.5
		10	25.0	36.5	46.1	24.3	(37.7)	46.3	(25.9)	35.1	44.6	24.3	35.3	47.1	25.7	36.1	47.4
		11	(26.8)	---	---	---	---	---	---	---	---	---	---	---	25.8	---	44.2
1WHOLE	AVERAGE (MPa)		25.1	37.0	46.5	24.3	35.4	45.7	24.1	35.6	45.3	23.5	34.1	45.5	25.6	35.8	46.0
	STANDAED DEVIATION (MPa)		0.92	0.84	1.96	0.72	1.12	0.80	1.14	1.10	1.38	1.01	1.42	2.51	0.92	1.19	1.76
POPULATION	COEF. OF VARIATION . (PERCENT)		3.7	2.3	4.2	3.0	3.2	1.75	4.8	3.1	3.1	4.3	4.2	5.5	3.6	3.3	3.8
TRIMMED	AVERAGE (MPa)		25.1	37.0	46.1	24.5	35.3	45.7	24.2	35.8	45.2	23.5	34.3	46.1	25.6	35.9	45.9
	STANDARD DEVIATION (MPa)		0.50	0.56	1.12	0.47	0.73	0.63	0.29	0.59	0.83	0.62	1.01	0.88	0.64	0.67	1.60
POPULATION	COEF. OF VARIATION (PERCENT)		2.00	1.50	2.40	1.90	2.10	1.40	1.20	1.60	1.80	2.60	2.90	1.90	2.50	1.90	3.40

* TRIMMED EXTREMELY DEVIATION VALUES

TABLE 5 : INTER TESTING MACHINES COMPRESSIVE STRENGTH VARIATIONS

TESTING	B-200				B-300				B-400				AVERAGE DEVIATIONS		
MACHINE	I	II	III	IV	I	II	III	IV	I	II	III	IV	II	III	IV
1	25.1	+2.1	+2.4	---	37.0	+4.0	+4.8	---	46.5	+1.3	+1.7	---	+2.5	3.0	---
2	24.5	-0.3	---	-2.4	35.3	-0.8	---	-4.8	45.7	-0.4	---	-1.7	-0.5	---	-3.0
3	24.2	-1.5	-1.2	-3.6	35.8	+0.6	+1.4	-3.4	45.2	-1.5	-1.1	-2.8	-0.8	-3.0	-3.3
4	23.5	-4.4	-4.1	-6.5	34.1	-4.2	-3.4	-8.2	46.1	+0.4	+0.9	-0.8	-2.7	-2.2	-5.2
5	25.6	+4.1	+4.5	+2.1	35.8	+0.6	+1.4	-3.4	46.0	+0.2	+0.7	-1.0	+1.6	+2.23	-0.8
AVERAGE	24.6	0.	+0.4	-2.6	35.6	0.	+1.1	-5.0	45.9	0.	+0.6	-1.6	0.	+0.8	-3.1

I - COMPRESSIVE STRENGTH (MPa)
II - DEVIATION FROM REFERENCE (PERCENT) (AVERAGE STRENGTH = 100%)
III - DEVIATION FROM REFERENCE (PERCENT) (MACHINE NO. 2 = 100%)
IV - DEVIATION FROM REFERENCE (PERCENT) (MACHINE NO. 1 = 100%)

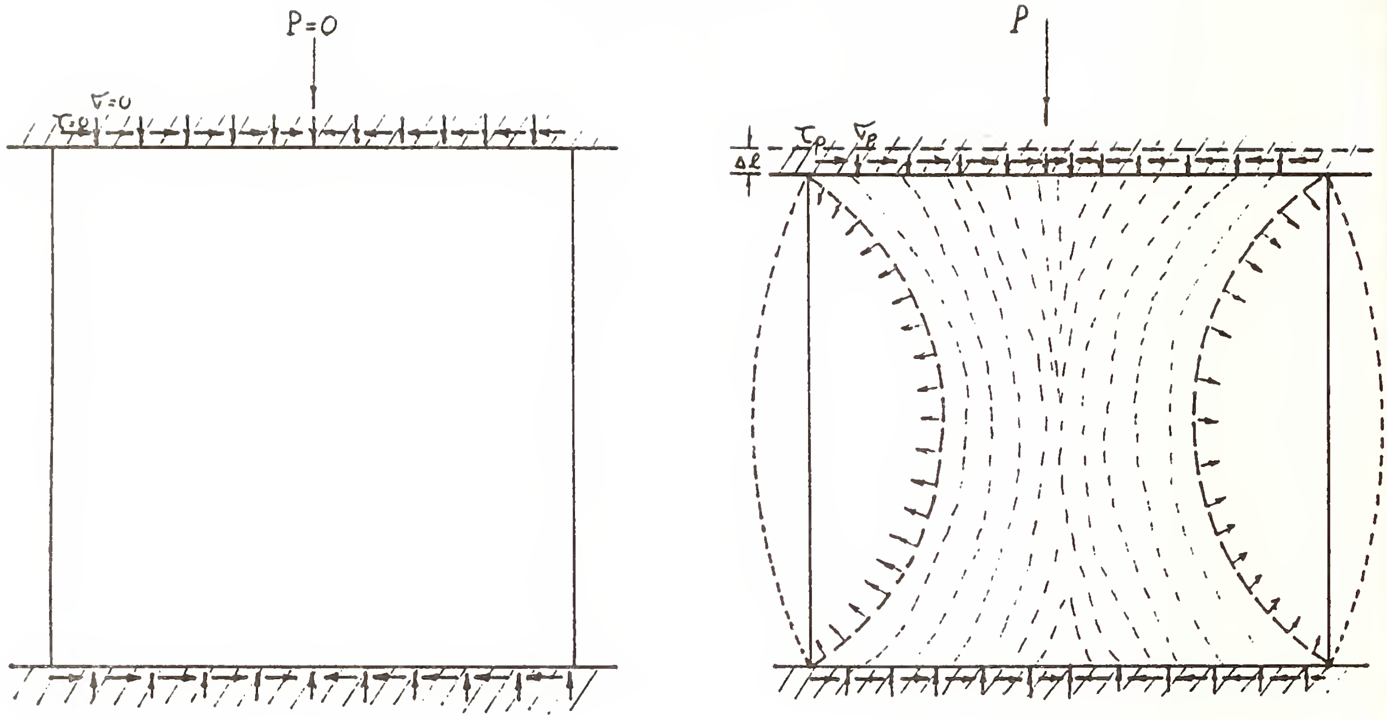

Fig 1 - Stress fields inside a compession cube

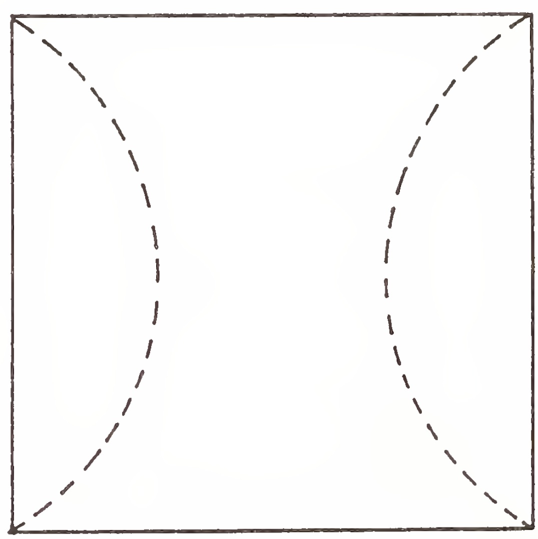

Fig 2 - Ideal failure of a compressive concrete cube specimen.

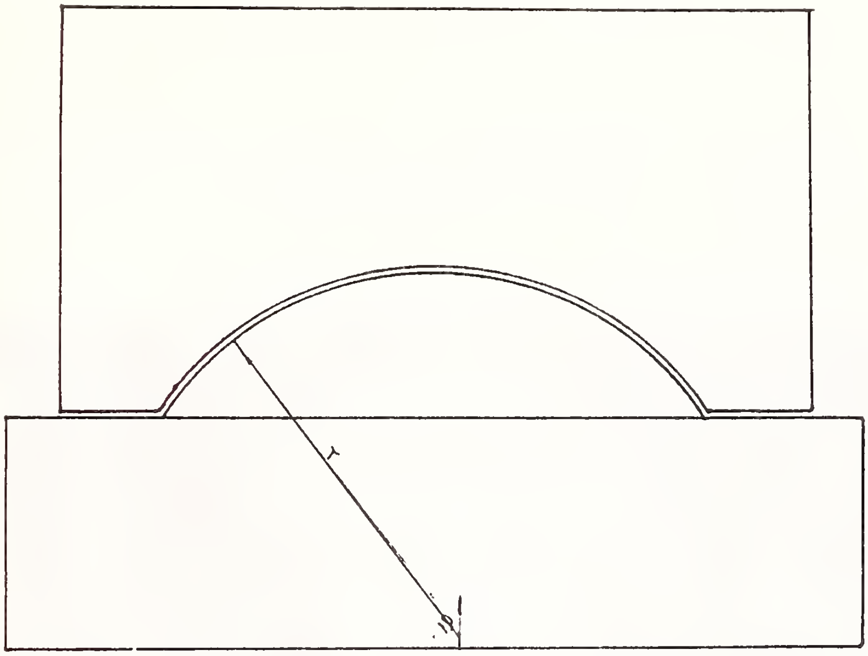

Fig 3 - spherical support of a compression plate.

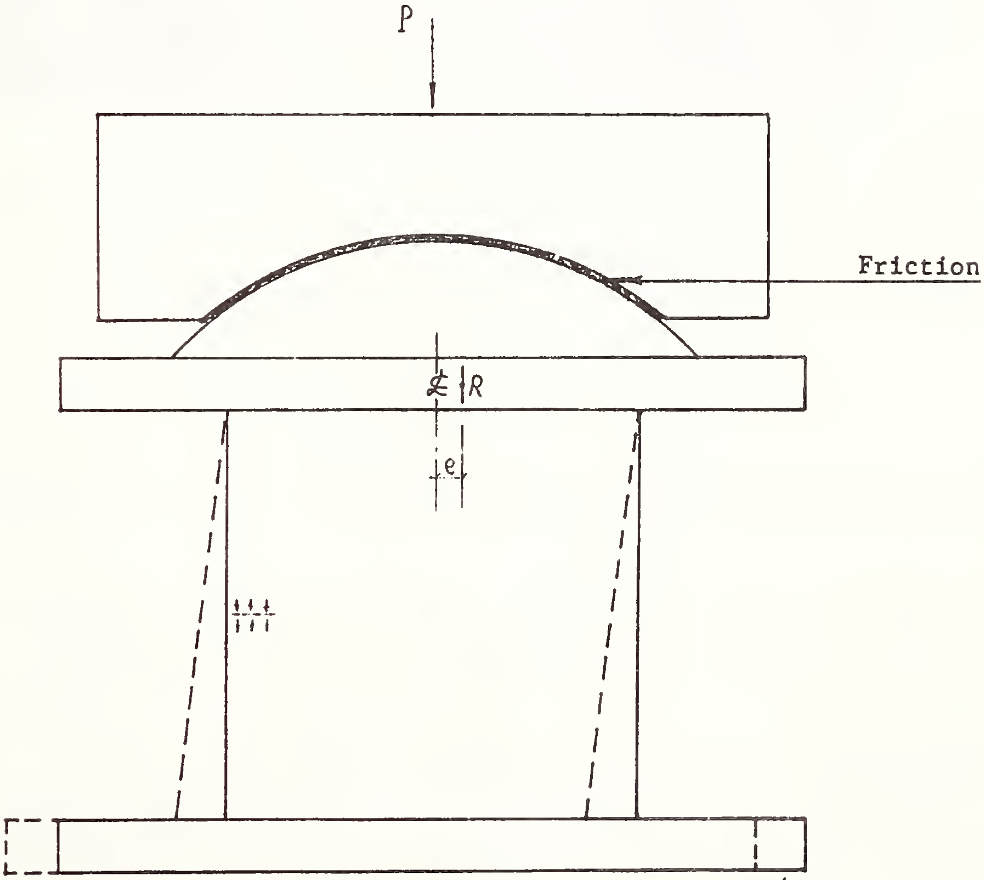

Fig 4 - Resultant excentric load on a
a compressed cube.

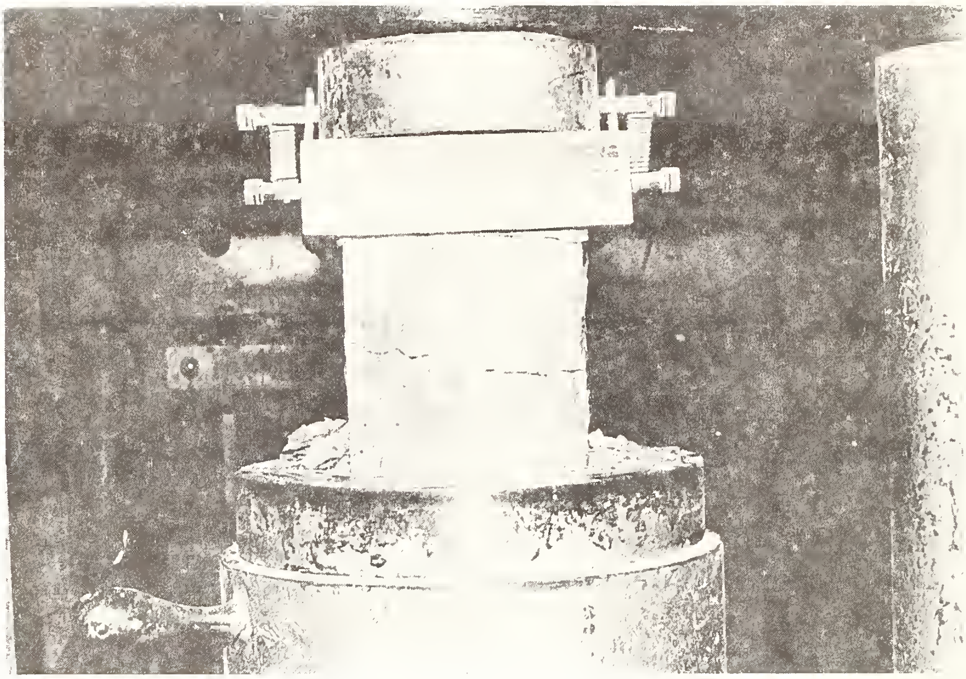

Fig 5 - Cube failed in excentric load.

EXPERIENCE WITH A CEMENT REFERENCE LABORATORY IN AUSTRIA

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Abstract

The Austrian Cement Research Institute in Vienna does the third party testing for all the cements produced in Austria. That also includes controlling the test results obtained by the local laboratories at the cement plants and requires that each sample taken and tested by the institute be also tested by the local laboratory. These frequent comparative tests assure good agreement between the laboratories concerned and between the results of autocontrol and third party tests. This system of combining laboratory evaluation and product quality control is thought to be both very effective and economical.

1. Status of the Reference Laboratory

The Research Institute of the Austrian cement industry is accredited by the federal government as a cement and concrete testing laboratory. Ever since its re-opening after the war in 1951 it has done the third party testing for all the cements produced in Austria.

The basis for that work is an agreement with the cement companies. That agreement obliges the Cement Research Institute (CRI) to inform the certification body of any case of non-conformity and requires, among other things (frequency of testing for auto control and third party, control and statistical evaluation of autocontrol by third part, etc.) that for each sample taken by CRI at the cement plant a split sample be also tested by the plant laboratory and the results communicated to CRI for comparison.

2. Method of Testing Cement for Strength

Though each cement sample has to be treated for a number of physical and chemical properties, strength, of course, is the property of the greatest interest to the cement user.

According to the Austrian cement standard 40 x 40 x 160 mm prisms are made from a mortar with a water cement ratio of 0.60 using a well defined standard sand and tested in flexure and compression at various ages. The compressive strength at 28 days is called standard strength.

Unfortunately for cement strength there is nothing like the calibration material in use for many other test methods. The method of determining strength is only an indirect method of testing the cement and many parameters exert influence. Therefore, determination of strength requires great care and a high frequency of testing.

3. Examples for Comparisons Between Reference Laboratory and Plant Laboratories

Fig. 1 gives an example for a disagreement: plant laboratory B is obtaining exceptionally low strengths.

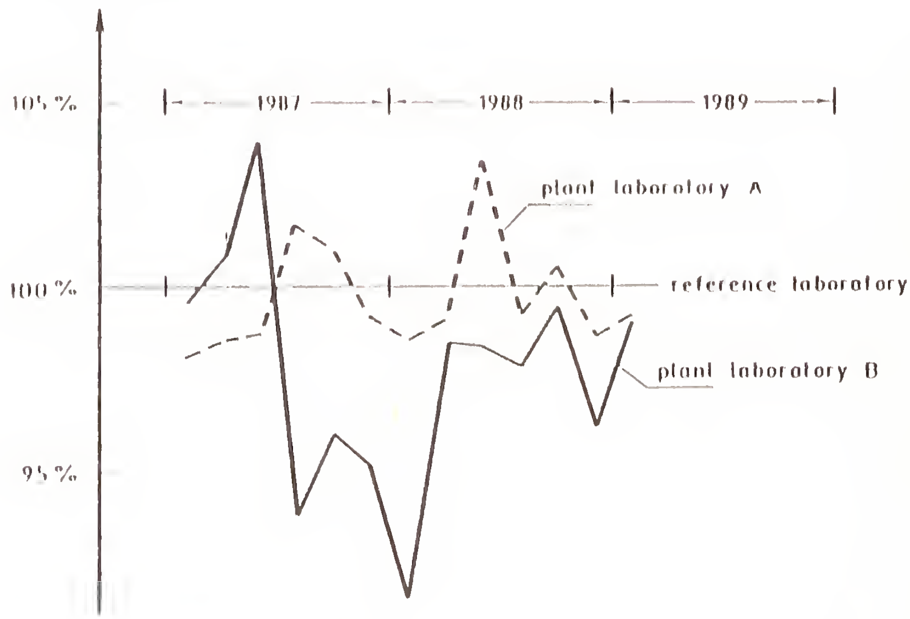

Fig. 1: Standard strengths found by reference laboratory and 2 plant laboratories

Inspection of the plant laboratory revealed that the temperature in the moist cabinets (used for curing the prisms during the first 24 hours), though still within the specified range, was somewhat lower than usual. The adjoining room had not been heated in winter and this had influenced the moist cabinets attached to a separating wall.

In Fig. 2 the deviations for strength between the reference laboratory and 15 plant laboratories are plotted. The graph for January-February shows that plant laboratory B is a singular case. It also shows that a majority of laboratories are below the reference institute in winter (obviously curing temperatures are more critical in winter), while overall agreement is quite good in July-August. Another parameter recently found to be of influence was the time taken to conduct the test; here also the range should be more narrow than permitted by standard.

4. Improving the Test Methods

While cases of bigger differences are settled between the reference laboratory and the plant laboratory concerned, general improvements are a matter of teamwork. The head engineers of all the plant laboratories meet regularly at CRI to discuss problems.

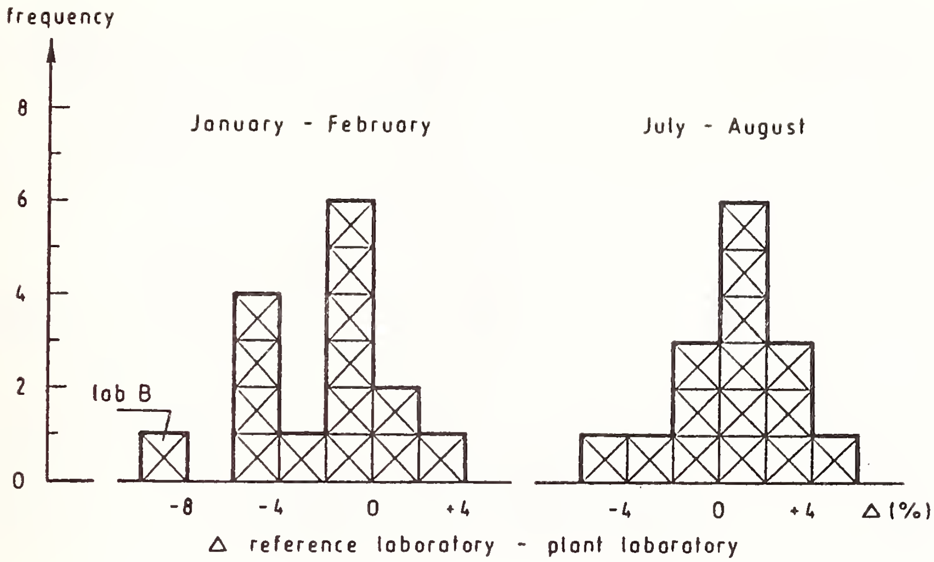

Fig. 2: Difference between standard strengths found by reference laboratory and 15 plant laboratories

Unsatisfactory standard deviations often are caused by inadequate description of the test method. Improvements of the test methods and the effect of modifications are evaluated by means of comparative tests. Of course, not only is strength covered but the other physical and chemical properties as well, which are also tested both by CRI and the plant laboratories.

5. Success and Conclusion

CRI organizes a comparative test at regular intervals: samples of the same cement are sent to all laboratories accredited by the federal government for testing cement and to 14 plant laboratories in order to be tested for mechanical and physical properties.

The results for standard strength are shown in Fig. 3. The accredited laboratories show a wider scatter than those of plant laboratories. Of course, the plant laboratories annually test cement samples by the hundreds, while most of the accredited laboratories test only dozens a year.

This proves that official recognition, a good quality assurance manual, a high quality testing machine, and careful work alone do not guarantee optimum results. A high frequency of testing, and continuous comparisons and optimization of the test methods are necessary. Elements which are brought together by a system combining laboratory evaluation and product quality control are very effective and economical.

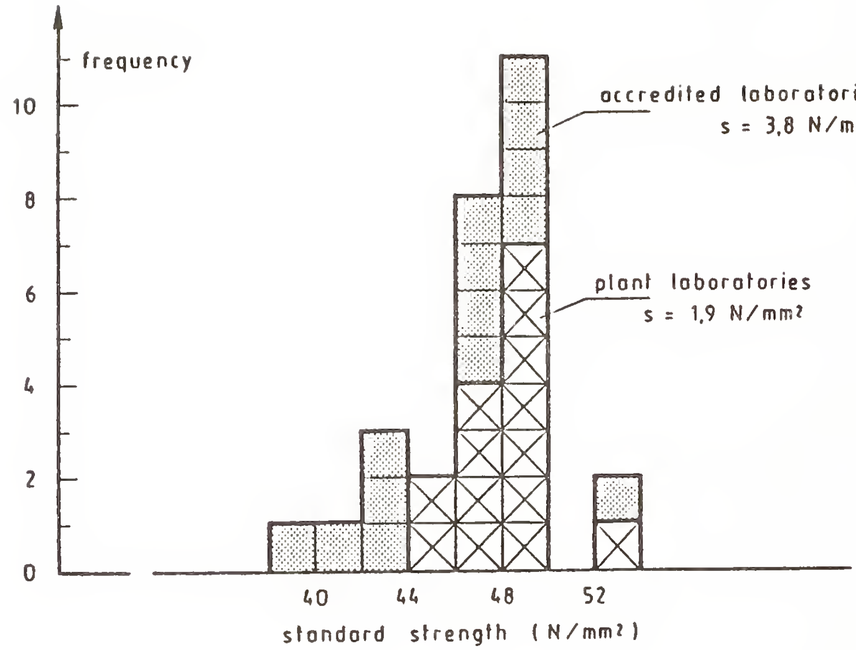

Fig. 3: Results of a comparative test (samples of same cement sent to 14 plant laboratories and 14 accredited laboratories).

COOPERATION BETWEEN A CENTRAL CEMENT LABORATORY AND 60 PLANT LABORATORIES

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In the Federal Republic of Germany the accordance of cement with the standardized requirements is certified by accredited bodies. The certification is based on five different measures of control, inspection and testing, namely

1. Third-party inspection of the manufacturing equipment of the plant
2. Third-party inspection of the laboratory equipment of the plant
3. Auto-control of the product by the producer
4. Third-party inspection of the auto-control
5. Third-party testing of random samples of the product.

The Verein Deutscher Zementwerke (VDZ), Technical Association of the German Cement Works, and its Forschungsisnstitut der Zementindustrie (FIZ), Research Institute of the Cement Industry, are accredited by the authorities as certification body and testing laboratory for cement. The scientific staff of the FIZ includes about 30 engineers, chemists, physicists etc., some of whom are experts in the field of cement manufacturing processes and testing of cement and concrete. VDZ and FIZ supervise and certify about 400 different cements produced in 62 national and 9 foreign plants.

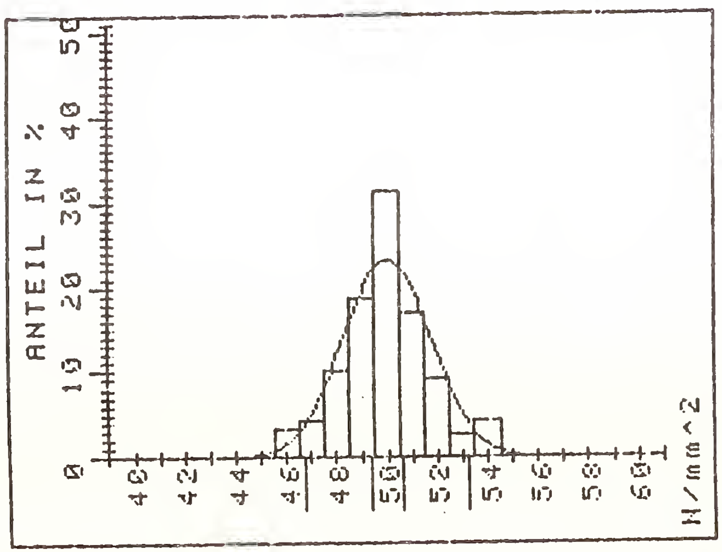
Within the task of certification, FIZ is acting as a reference laboratory for more than 60 plant laboratories. At least once a year the equipment of the plant laboratory and its regular calibration is inspected by experienced testing engineers of FIZ. At least six times a year random samples of cement are taken without previous notice by an independent organization, authorized for taking samples.

One half of each sample is tested at the plant laboratory, the other half at FIZ (corresponding to No. 5 above). The plant has to send the testing result to FIZ, which compares and evaluates both the results of the plant laboratory and FIZ under two aspects. Concerning certification, they have to meet the requirements of the standard and have to be within the total population of the results of the much more frequently achieved results of the auto-control. Examples of the data are given in Figures 1 and 2. Secondly, the difference between the results of the same sample tested at the plant laboratory and at FIZ should not exceed a comparatively normal amount. Otherwise FIZ is acting as a reference laboratory, i.e. checking the equipment in the plant, its calibration, the procedure of the test and, if necessary, training of the technicians.

Figure 1

ANZAHL n	119
MITTELWERT $\bar{x}$:	50
Xmax :	54
Xmin :	46
ANZAHL>DINmax :	0
ANZAHL<DINmin :	0
VARIANZ s^2 :	2.96
ST.-ABWEICHUNG s:	1.72
VAR.-COEFFIZIENT V:	3.45
FAKTOR FOR K:	1.90
FRAKTILE 95%:	53.22
FRAKTILE 5%:	46.68
R/s BEOBACHTET:	4.65
UNTERER GRENZWERT:	4.43
OBERER GRENZWERT :	6.02

BEOBACHTETE VERTEILUNG DER EINZELWERTE			NORMALVERTEILUNG		
N(<= 40):	0 =	0.0%	N(<= 40):	.0=	.0%
N(= 41):	0 =	0.0%	N(= 41):	.0=	.0%
N(= 42):	0 =	0.0%	N(= 42):	.0=	.0%
N(= 43):	0 =	0.0%	N(= 43):	.0=	.0%
N(= 44):	0 =	0.0%	N(= 44):	.1=	.1%
N(= 45):	0 =	0.0%	N(= 45):	.4=	.3%
N(= 46):	4 =	3.4%	N(= 46):	1.9=	1.6%
N(= 47):	5 =	4.2%	N(= 47):	6.0=	5.1%
N(= 48):	12 =	10.1%	N(= 48):	14.0=	11.8%
N(= 49):	22 =	18.5%	N(= 49):	23.3=	19.6%
N(= 50):	37 =	31.1%	N(= 50):	27.6=	23.2%
N(= 51):	20 =	16.8%	N(= 51):	23.3=	19.6%
N(= 52):	11 =	9.2%	N(= 52):	14.0=	11.8%
N(= 53):	3 =	2.5%	N(= 53):	6.0=	5.1%
N(= 54):	5 =	4.2%	N(= 54):	1.9=	1.6%
N(= 55):	0 =	0.0%	N(= 55):	.4=	.3%
N(= 56):	0 =	0.0%	N(= 56):	.1=	.1%
N(= 57):	0 =	0.0%	N(= 57):	.0=	.0%
N(= 58):	0 =	0.0%	N(= 58):	.0=	.0%
N(= 59):	0 =	0.0%	N(= 59):	.0=	.0%
N(>= 60):	0 =	0.0%	N(>= 60):	.0=	.0%



CHI^2-TEST

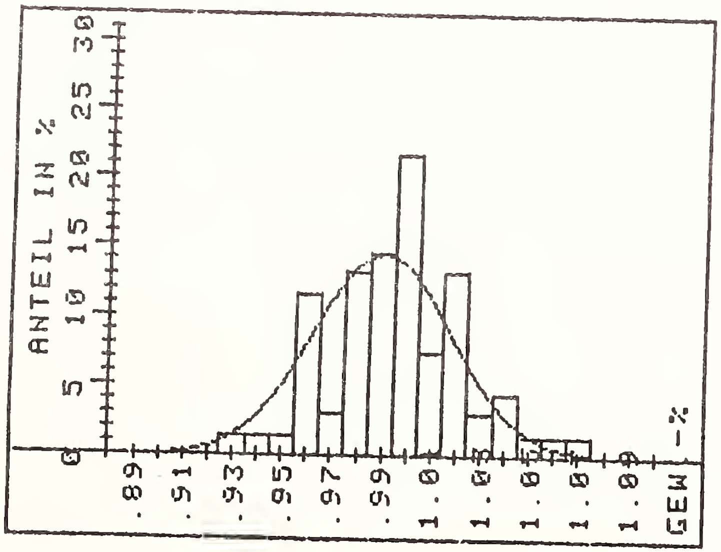
CHI^2 errechnet:	4.78
FREIHEITSGRADE:	4
CHI^2 tabelliert(S=95%):	9.94
CHI^2 tabelliert(S=99%):	13.28

WERTE MIT S=95%
ANGENAHERT NORMAL VERTEILT

Figure 2

ANZAHL n:	69
MITTELWERT x̄:	1.00
Xmax :	1.07
Xmin :	.93
ANZAHL>DINmax :	0
VARIANZ s^2 :	.00
ST.-ABWEICHUNG s:	.03
VAR.-COEFFIZIENT V:	2.75
FAKTOR FOR K:	1.99
FRAKTILE 95%:	1.05
FRAKTILE 5%:	.94
R/s BEOBACHTET:	5.11
UNTERER GRENZWERT:	4.05
OBERER GRENZWERT :	5.62

BEOBACHTETE VERTEILUNG DER EINZELWERTE			NORMALVERTEILUNG		
N(<= .89):	0 =	0.0%	N(<= .89):	.6=	.0%
N(= .90):	0 =	0.0%	N(= .90):	.0=	.1%
N(= .91):	0 =	0.0%	N(= .91):	.1=	.2%
N(= .92):	0 =	0.0%	N(= .92):	.4=	.6%
N(= .93):	1 =	1.4%	N(= .93):	.9=	1.3%
N(= .94):	1 =	1.4%	N(= .94):	1.9=	2.8%
N(= .95):	1 =	1.4%	N(= .95):	3.5=	5.0%
N(= .96):	8 =	11.6%	N(= .96):	5.5=	8.0%
N(= .97):	2 =	2.9%	N(= .97):	7.7=	11.2%
N(= .98):	9 =	13.0%	N(= .98):	9.4=	13.6%
N(= .99):	10 =	14.5%	N(= .99):	10.1=	14.6%
N(= 1.00):	15 =	21.7%	N(= 1.00):	9.4=	13.6%
N(= 1.01):	5 =	7.2%	N(= 1.01):	7.7=	11.2%
N(= 1.02):	9 =	13.0%	N(= 1.02):	5.5=	8.0%
N(= 1.03):	2 =	2.9%	N(= 1.03):	3.5=	5.0%
N(= 1.04):	3 =	4.3%	N(= 1.04):	1.9=	2.8%
N(= 1.05):	1 =	1.4%	N(= 1.05):	.9=	1.3%
N(= 1.06):	1 =	1.4%	N(= 1.06):	.4=	.6%
N(= 1.07):	1 =	1.4%	N(= 1.07):	.1=	.2%
N(= 1.08):	0 =	0.0%	N(= 1.08):	.0=	.1%
N(>= 1.09):	0 =	0.0%	N(>= 1.09):	.6=	.0%



CHI^2-TEST

CHI^2 errechnet:	14.19
FREIHEITSGRADE:	6
CHI^2 tabelliert(S=95%):	12.59
CHI^2 tabelliert(S=99%):	16.81

WERTE MIT S=95%

NICHT ANGENAHERT NORMAL VERTEILT

4.0 Papers Not Presented at Workshop

QUALITY ASSURANCE IN THE CONSTRUCTION MATERIALS LABORATORY

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Abstract
Laboratory accreditation is all about quality in the testing laboratory. How things are to be done is specified, checked, and documentation of actual performance required. A2LA has had a very active construction materials program for over 10 years, and its accreditations are based on laboratory quality documentation and on-site demonstration. The quality manual is the key to establishing quality in the laboratory. Current guidelines are based on ISO Guides 25 and 38, but in the future, the subjects to be covered in demonstrating laboratory quality will be influenced by the more comprehensive quality guidance given in the ISO 9000 series of standards.
Key words: Laboratory accreditation, quality system, quality manual.

1. Laboratory Accreditation Is Quality System Evaluation.

The key to competent testing is a laboratory's use of an effective, comprehensive laboratory quality system involving both quality control and quality assurance activities. There is no rigid format for such a system; it must be tailored to the unique characteristics and capabilities of each laboratory.

Managing a laboratory effectively cannot be achieved unless all staff members understand the laboratory's quality policies and operating procedures and the extent of their own duties and responsibilities. For this to be achieved and maintained, it is essential that the laboratory's policies, procedures, and practices be documented in a quality manual. This manual forms the framework of the quality system -- it describes how you will operate your laboratory. Assessors will use it as a base reference to your laboratory operations. Three principles will be employed:

Have you described what you want done in a written form -- a manual?

Do you operate the way your manual says you operate?

Have you documented that you are operating the way you say you are?

The first requirement is to write down how you and your laboratory operate. Everyone should know their role. Your commitment to quality should be described and reenforced by the procedures you use. The second requirement is to have everyone perform the way you have stated they should perform. When you deviate from what is written, rewrite that portion of the manual, if it is all right with you. The third principle, particularly important in cases involving litigation, is to be able to demonstrate that you actually operated the way you wanted to.

2. A2LA Basis for Establishing Quality

The American Association for Laboratory Accreditation (A2LA) is often asked to provide advice on the development of a quality system and the preparation of a quality manual. The A2LA program for accrediting construction materials laboratories was first implemented in 1980, based on a criteria document developed by a Construction Materials Advisory Committee. The program was revised to accommodate the ISO Guide 25 Criteria for accrediting laboratories.

Other accreditation systems have been implemented in the United States. One is offered by the National Voluntary Laboratory Accreditation Program (NVLAP) at the National Institute for Standards and Technology (NIST) and another offered by the American Association of State Highway and Transportation Officials (AASHTO) also operating from NIST, but neither offers the flexibility to serve the entire needs of the construction materials laboratory community the way the A2LA system does.

A2LA does not specify a particular format for a quality manual since the document must reflect operational practice in the laboratory, but does provide some guidelines. The guidelines are based on national and international guidance documents including those provided by the American Council of Independent Laboratories (ACIL) and the International Standards Organization (ISO).

3. The Quality Manual

A quality manual is simply a document or set of documents stating the quality policy, quality system, and quality practices of an organization (ISO definition). A quality manual may relate to the totality of an organization's activities or only part of it. The title and scope of the manual reflects the field of application. A quality manual will normally contain or refer to at least:

1) quality policy;

2) the responsibilities, authorities, and interrelationships of personnel who manage, perform, verify, or review work affecting quality;

3) the quality system procedures and instructions; and

4) a statement for reviewing, updating and controlling the manual.

3.1 Why is a Quality Manual Necessary?

A quality manual serves as the basic reference to a laboratory's quality system. Most accrediting agencies and government regulatory policies require a written manual of some sort.

Of course, the written manual will also have internal benefits for the laboratory. It should serve as the central repository of knowledge, skills and experience of the laboratory. A written manual will minimize misconceptions and misunderstandings among laboratory personnel and will help to prevent unintended changes in the quality system.

A manual is fundamental for a training program of new staff. It should serve as an orientation guide or textbook to laboratory operations affecting quality.

A written manual promotes the recognition of quality throughout the laboratory. It demonstrates to outsiders plans for its operational procedures to ensure the quality and reliability of its work.

The main purpose is not the production of a manual per se, but rather the implementation of an effective system of operations. The manual should reflect as closely as possible the actual quality system in use. A "paper program" which expresses management's wishes, but does not correspond to reality will soon be perceived for what it is, and the laboratory's credibility will suffer. No quality manual, regardless of how well prepared, can serve a useful purpose unless measures which it describes or refers to are actually followed on a day-to-day basis by the testing laboratory. It is not the existence of a manual that is of utmost importance, but rather the implementation of an effective quality system. The quality manual simply describes the elements of the system and documents how they are implemented in the laboratory. Generally, it is better to have a system not completely documented than to have complete documentation of a system that is not carried out or impossible to adhere to.

The manual should simply describe the elements of the system and document how these elements are implemented in the laboratory.

3.2 Prerequisites for Writing a Quality Manual
The need for a quality system documented in a quality manual must be recognized by all concerned. Top management must accept and endorse it. The quality policy (or policies) must be formulated as a basis for the manual. The quality policy must make it clear to staff that quality involves them all. The momentum of producing, amending and updating it must be maintained. Regular revision will be necessary. Revisions (by page, section, chapter, or the whole document) should be dated and recorded. A computer/word processing system with disk storage is the ideal medium for the manual, because it can readily be revised. Because a relatively small number of copies will be needed, commercial printing can be avoided. Simply photocopying page changes will keep costs low. Measures to achieve a desired level of quality might be quite different among laboratories.

3.2 Development of a Quality Manual
Development of a quality manual requires extensive thinking about the objectives of the quality system and the means of attaining them. When initiating the development of the manual, you should:

1) Involve all levels of laboratory personnel.

2) Top management should identify a quality manager, either full-time in a large laboratory, or as part of the responsibilities of the top technical manager.

3) Identify the needs of your customers (how accurate do test results have to be; what standards need to be followed). Identify the goals and

objectives to be accomplished. Examine internal policies and understand those external quality policies with which there is interaction, such as from customer requirements or government regulations. If the laboratory is part of a larger organization whose policies must be followed, the laboratory's quality policies must at least co-exist and certainly not conflict with those of the larger organization. They should be reinforcing.

One of the first steps in developing a manual is to identify and document the quality procedures already implemented and then, identify and clearly define quality responsibilities for all personnel. List all existing documentation, identify any gaps and ask staff most intimately involved to write up a standard operating procedure (SOP).

When writing a quality manual the following considerations should be kept in mind. The quality manual should be:

- o clearly written
- o comprehensive but concise
- o descriptive but brief
- o well organized and indexed
- o accessible to pertinent staff and
- o user friendly.

3.4 Typical Contents of a Quality Manual

The actual contents of the manual will vary with many factors: the size of the laboratory, the testing technologies involved, the specific work done, and the organization of the work to name a few. The format, or order of presentation of topics may be left to the discretion of laboratory management. Some of the topics may be combined. It may not be necessary to include all of the topics listed below, but comparison with this list may indicate topics which have been overlooked. The topics will lead to a fairly voluminous manual for a large laboratory. Lists of equipment and instrumentation, text of standard operating procedures will all add to the bulk of material. In addition, if the laboratory is in a stage of rapid growth, frequent revision of these lists and documents may be necessary. In a sizable, diversified laboratory, it is certainly wise to have more than one manual, with the different manuals corresponding to different areas of the laboratory, testing technologies, fields of testing or type of samples; for example, manuals for analytical techniques, or by type of sample. This would be especially advantageous if the actual quality program is different for the different analytical areas. A common and recommended practice is to keep lists of equipment, personnel, and test protocols separate from the manual and simply refer to these lists in the manual proper. The lists can be separately maintained and revised, and made available as supplements to the manual for readers who need them. Typical topics include:

1) Table of contents
2) Quality policy

3) Description of the manual
4) Description of the laboratory
5) Staff
6) Equipment
7) Environment/facilities
8) Test methods and procedures
9) Updating and control of documents affecting quality
10) Handling of specimens or samples
11) Verification of results
12) Test reports
13) Diagnostic and corrective actions
14) Records
15) Subcontracting

Again these topics do not have to be in this order. We merely suggest that they should be considered and appropriately addressed.

Each page should be uniquely identified, dated, and should be initialed by the person responsible for quality in the laboratory and by top management.

4. Quality Trends

Laboratory accreditation and quality guidelines have been based on the work of the International Laboratory Accreditation Conference (ILAC) and ISO Council Committee on Conformity Assessment (CASCO) which has published many of the recommendations of ILAC. But there is a new force influencing quality policy. It comes from ISO Technical Committee 176 (TC 176) which has produced a series of ISO standards commonly referred to as the ISO 9000 Series on Quality Management. These standards will require some additional considerations to be added to the quality manual. These may include:

1) Quality in marketing -- what do we sell and how do we sell it?
2) Quality in specification and design -- which test methods should be used in which situations?
3) Quality in procurement -- supplies, equipment, subcontractors
4) Product verification -- product quality auditing and acceptance testing
5) Post production functions -- after sales servicing, market reporting and product supervision

ISO CASCO is currently considering revision to the ISO Guides 25 and 38. Hopefully these will take into account the ISO 9000 Series so that we do not have two quite separate laboratory accreditation criteria in the market place.

A2LA continues to participate in the deliberations of both of these ISO groups with the goal of bringing together the laboratory quality requirements in a straightforward and unambiguous way.

References

"Guidelines for development of a Quality Manual for a testing laboratory," ISO Guide 49-1986.

Quality Assurance, A Laboratory Management Practice Manual, American Council of Independent Laboratories, May 1986.

"Quality Management and Quality Assurance Standards - Guidelines for Selection and Use", ANSI/ASQC Q90-1987 (equivalent to ISO 9000)

"Quality Systems - Model for Quality Assurance in Design/Development, Production, Installation, and Servicing", ANSI/ASQC Q91-1987 (ISO 9001)

"Quality Systems - Model for Quality Assurance in Production and Installation", ANSI/ASQC Q92-1987 (ISO 9002)

"Quality Systems - Model for Quality Assurance in Final Inspection and Test", ANSI/ASQC Q93-1987 (ISO 9003)

"Quality Systems - Quality Management and Quality System Elements - Guidelines", ANSI/ASQC Q94-1987 (ISO 9004)

"A2LA Guide for Laboratory Quality Manual Preparation", A2LA G0703889

COMPARATIVE COMPRESSION CUBE TESTS BETWEEN APPROVED TESTING LABORATORIES IN FINLAND

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Technical Research Centre of Finland
Concrete and Silicate Laboratory

ABSTRACT

Currently there are 10 officially approved testing laboratories for concrete in Finland. Approvals are given by the Ministry of Environment. The Technical Research Centre of Finland (VTT) is by law the principal approved laboratory acting as technical advisor to the Ministry, which makes once-yearly inspection visits to the other laboratories. The results of the visits are reported to the Ministry. Also, once a year VTT arranges comparative cube tests between all approved laboratories as required in their approval certificates. This paper describes some results of these tests.

INTRODUCTION

The Technical Research Centre of Finland (VTT) has systematically arranged comparative cube tests between officially approved testing laboratories for the last 15 years. During this time the number of participating laboratories has risen from six to ten. The majority have two compressive machines, a primary one and an additional or so-called vice-machine. Every machine is calibrated once a year by VTT, which calibrates it's own load cells in the Finnish national measuring centre of force situated in VTT's Metals Laboratory.

CONCRETE MIXES AND TEST SPECIMENS

Concrete mixes are selected from a number of VTT's standard mixes. The strength of the concrete varies from year to year from 15 MN/m^2 to 70 MN/m^2. Comparative cube tests are performed using 150 mm cubes prepared from the same carefully mixed batch. After demolding, the specimens are cured in VTT's curing room at $20\pm2^{\circ}C$ and relative humidity greater than 95%.

TRANSPORTATION AND TESTING

Before distribution to the participating laboratories the specimens are randomly separated into groups of six. After carefully packaging, one group is sent to each testing machine with an accompanying letter describing the testing procedure. All packages are opened at the same time and the specimens placed in curing rooms. All tests are performed according to the Finnish standard on the same day and at the same time in every laboratory. The compressive strength and density are calculated for every specimen.

TEST RESULTS

The test results are sent to VTT's research scientists who compile them for statistical calculation. The final results are sent to each participating laboratory.

Table 1 shows the results from one year in the early 1980's. The mean values and standard deviations of the primary testing machines for each laboratory are shown in MN/m^2. The mean values are also shown in percentages with 100% being the mean value of all the results of primary testing machines in each laboratory. This is chosen because the technical quality of primary testing machines is roughly the same. The staff is also equally trained in every laboratory.

Table 2 shows the same data from additional testing machines. 100% is as in table 1 because several additional testing machines are fairly old and their quality more variable than with primary machines.

Figures 1 and 2 depict the mean percentage values of Tables 1 and 2. Figure 3 shows the variations in primary testing machines over a period of 4 years. The results are shown as deviations from the mean of 100%. Figure 4 shows the variations in additional testing machines in the same laboratories as in Figure 3 during the same period.

CONCLUSIONS

The comparative cube tests carried out in Finland between approved testing laboratories compare the mean of six results from each compressive machine with the mean of all results from the primary testing machines of participating laboratories. If the compressive machine of VTT, for example, is considered to be a reference machine in Finland, the results of the tests would be very similar to those described above. This is because the mean value of the VTT testing machine has been very close to 100% or consistently very near to the mean value of all results from primary machines every year.

TABLE 1

	lab1	lab2	lab3	lab4	lab5	lab6	lab7	lab8	MEAN
mean	42.7	44.2	43.5	44.1	43.0	42.4	42.8	43.0	43.2
SD	0.8	0.8	0.6	0.6	0.5	0.8	0.3	1.7	1.0
mean, %	98.8	102.3	100.6	101.9	99.5	98.2	99.1	99.5	100.0

Table 1. The mean values and standard deviations of six results of primary testing machines for each laboratory in MN/m2. The mean values are also in percentages when 100% is a mean value of all results of all primary machines.

TABLE 2

	lab1	lab2	lab4	lab5	lab6	lab7	lab8	MEAN
mean	42.1	44.3	42.5	42.0	43.3	42.5	44.0	43.0
SD	1.1	0.6	0.8	1.0	0.6	0.5	1.1	1.2
mean, %	97.5	102.5	98.4	97.2	100.2	98.3	101.9	99.5

Table 2. The mean values and standard deviations of six results of additional testing machines in MN/m2. The mean values are compared in percentage to same value as in Table 1.
There is no additional machine in lab3.
MEAN is the mean value of all additional testing machines.

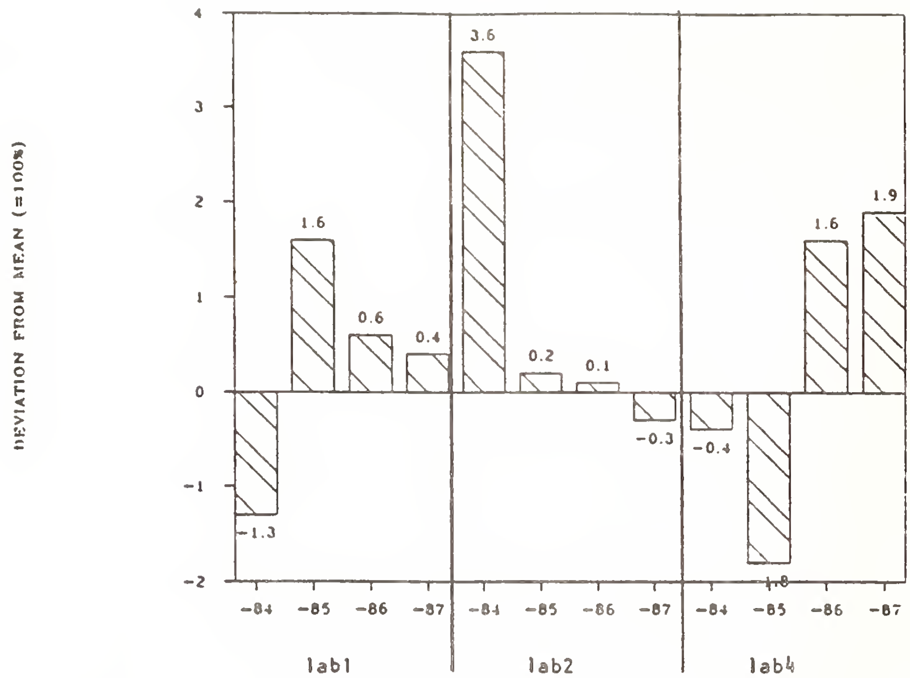

Figure 3. Deviations of the mean values of primary machines in percentage units from the mean value of all primary testing machines in three laboratories during years 1984 - 1987.

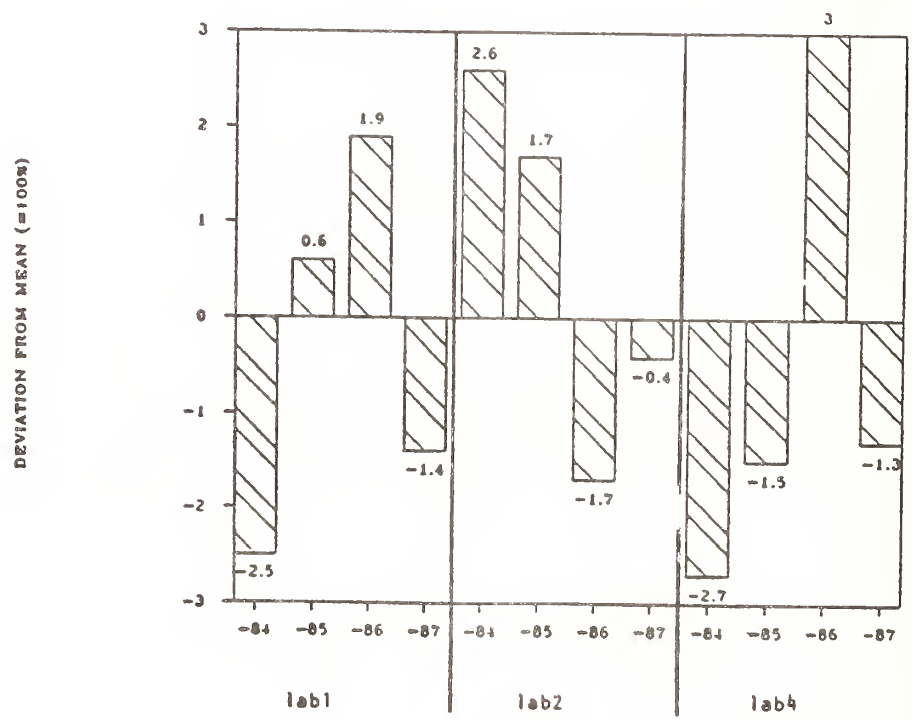

Figure 4. Deviations of the mean values of the additional testing machines in percentage units from the mean value of all primary testing machines in three laboratories during years 1984 - 1987.

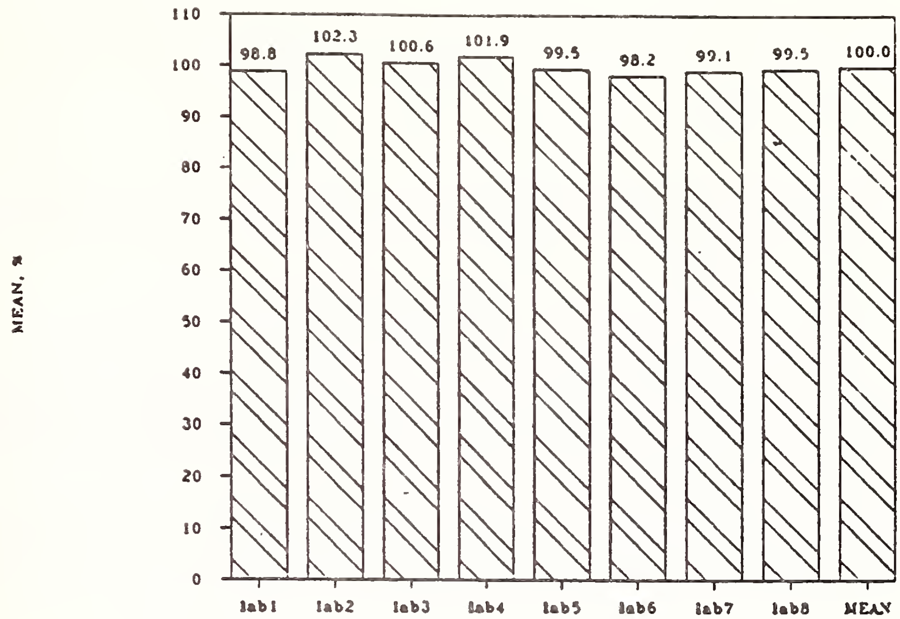

Figure 1. The mean percentage values of the primary testing machines for each laboratory. 100% is same as in Table 1.

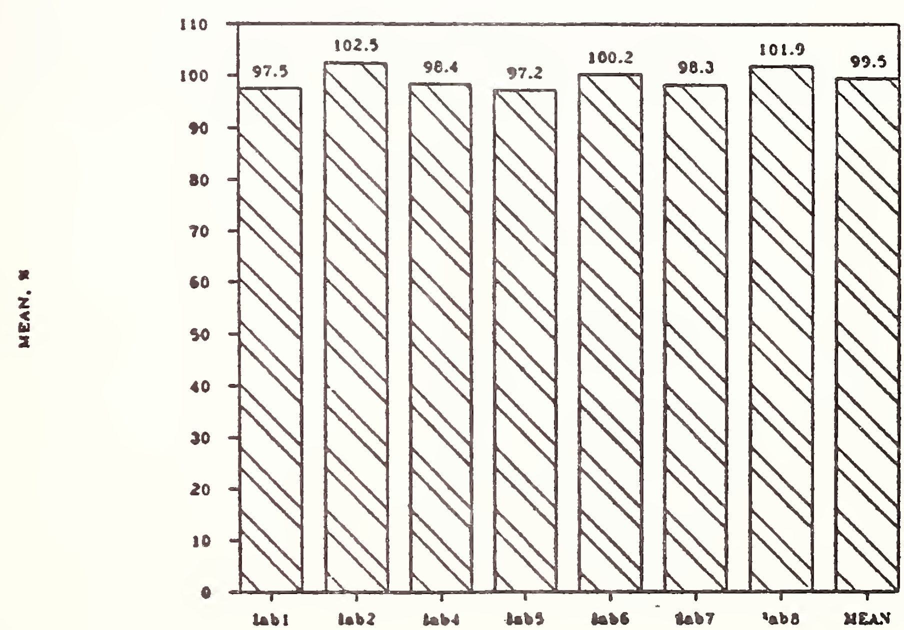

Figure 2. The mean percentage values of additional testing machines. 100% is same as in Table 1.

5.0 Session Results

Summary of Session I
Quality Assurance System in Cement and Concrete Testing Laboratories

F. Hawthorn

The session included talks on two national quality assurance systems: NAMAS in the United Kingdom and R.N.E. in France. Laboratories in these countries who have been accredited related their experience in obtaining the recognition.

It is apparent that it is not easy to obtain accreditation of a laboratory, and it is expensive and time consuming. However, a laboratory has much to gain because it provides the opportunity to check apparatus, calibrations and testing procedures.

Not only are laboratories expected to provide reliable testing, a number of plant laboratories of large companies assess the conformity of a product to a standard. Products are checked in the field for a certification mark by a certification body. This RILEM TC91-CRL workshop has provided a good opportunity to examine these types of laboratories.

The following factors should be taken into consideration in defining "good" laboratories and "reference" laboratories:

- tests are conducted every day
- laboratories have the best equipment
- laboratories have motivated and well trained staff
- laboratories are able to check the validity of test results and reproduce results when in doubt

Summary of Session II
Assessment of Technical Performance of Laboratories

H. Sommer

Assessing the technical performance of laboratories may be accomplished by organizing interlaboratory comparative tests. These tests not only provide an assessment, but if organized regularly they will also improve agreement between laboratories.

However, test results and precision may be very sensitive to even minor changes in the method of test. Therefore, the method of test needs to be well defined in every detail.

Comparative tests have been organized for many years in a number of countries. It is recommended that RILEM TC91-CRL compare the procedures in detail and report the findings.

It is also recommended that available information on precision data for the various methods of test be collected. It should be born in mind, however, that precision is not a constant for a specific method of test. The importance of test frequency is generally recognized; for the CEN-method of testing cement for strength the relative standard deviation for repeat tests within a reference laboratory will be between 1.2 and 2%, for comparative tests between laboratories with a high frequency of testing 4% or less, and for laboratories which are well equipped and organized, but have only a low test frequency, it will be 6% and more.

Even with the same level of frequency of testing, factors such as weather, staff competency and condition of equipment will effect precision. Regular repeat and comparative tests are necessary between the primary (reference) national laboratories. For the future it will be necessary to organize international comparative tests between the primary (reference) national laboratories.

Summary of Session III
Role of Reference Laboratories

J. Rogers

The third session of the workshop was devoted to papers relating to reference testing programs and the role of reference testing laboratories in organizing such programs.

We learned from the first speaker, Mrs. Atkinson of NAMAS, of the emergence of a new part to BS 1881, the standard for testing concrete. This new standard sets down the requirements for the operation of a cube testing service where the results from a "reference" laboratory are statistically compared by that laboratory with those of a commercial test house using carefully prepared cubes from a single batch.

In this approach the reference laboratory maintains a machine for reference testing only and the performance of the machine is frequently checked for load measurement and alignment. Calibration of the machine is performed by the National Physical Laboratory (National Standards Laboratory) using the most accurate proving devices available and the machine is considered to be significantly more accurate than those used by commercial test houses.

The aim of the comparative cube testing service is to establish confidence in machine and operation performance and to assist test houses in identifying machine faults or operator errors. In discussion, Mr. Tipler of BCA reported that in 1988 some 200 machine tests involving 600 sets of cubes had been carried out and that most of the failures observed related to low strength cubes where lower than expected compression strengths were reported probably as a result of not maintaining the required loading rate at failure.

Mr. Tipler also stressed the importance when operating a comparative cube testing service of ensuring that not only was the machine in first-class condition but that great care was taken to ensure that cubes were prepared under carefully controlled and, reproducible conditions.

In the second paper of the session Dr. Korin of the Israeli National Building Station described the results of an investigation into the performance of five different testing machines when used to perform compression tests on concrete cubes prepared under carefully controlled conditions. It was observed that while there was little difference in the calibration results for the machines there were significant differences in the compressive strengths obtained when testing cubes from a single batch and three different grades of concrete. The authors of the paper concluded that the performance of a testing machine could not be predicted from calibration data and was only revealed during compression testing where deviations between test results were an order of magnitude higher than deviations between calibration data.

It was suggested that machine performance would be improved by using comparative testing programs, identifying the faults and modifying the machines. It was then proposed that the machine achieving "best performance" i.e. exhibiting the smallest defects would be used as the reference machine for future comparative studies.

In the third paper of the session Dr. Sommer of the Austria Cement Research Institute (CRI) described his laboratory's role as the "reference" laboratory for the Austrian Cement Industry. The CRI perform tests on split samples taken from 15 cement plants and compare their results with those of the cement plants for the other portion of the sample.

Tests are performed in accordance with the Austrian standard on mortar prisms using a well-defined standard sand. Dr. Sommer showed examples of how plant laboratory test data deviated from that of his "reference" laboratory and described the steps taken to identify the causes of the differences. He observed that the coefficient of variation in the reference Laboratory was below 1% within a batch in comparison with 3% for the plant laboratories.

The extent and nature of the deviations from the results of the reference laboratory depended upon climatic conditions, testing rate and the test method documentation used in the plant laboratory.

In addition to their work with plant laboratories the CRI organize interlaboratory comparison programs with 14 plant laboratories and 14 government accredited laboratories. The results of these exercises show a much wider variation in the strengths obtained by accredited laboratories than by plant laboratories and this is attributed to the fact that accredited laboratories only test samples infrequently and lack the expertise and experience of the plant laboratories. Dr. Sommer suggested therefore that a high frequency of testing, with constant comparisons with a reference laboratory and the development of the test method were more valuable than accreditation.

In the final paper of this session Professor Wischers of the Research Institute of the German Cement Industry (FIZ) outlined how his laboratory fulfilled a similar role to that described by Dr. Sommer from CRI.

FIZ acts as the "reference laboratory" for some 62 national and nine foreign plants producing 400 different cements and involving some 60 plant laboratories. FIZ apply a similar approach to CRI but in addition to arranging comparative tests they also send trained engineers to the plant laboratories annually to check equipment and its calibration regardless of the results achieved.

Professor Wischers showed the results of statistical analyses from tests on random samples taken six times a year without prior notice by an independent organization. Laboratories are warned when they fall outside the prescribed limits (i.e. if standard deviation exceeds 3) and FIZ staff will investigate the cause of the departure.

GENERAL DISCUSSION

Two topics emerged in the general discussion of these papers. The first was the need to be careful when talking about "accredited" laboratories since the term as used in Austria and Germany clearly did not necessarily mean the same as in the UK and France. In some cases laboratories could achieve accredited status without demonstrating to a team of experts from a third-party organization that their quality management system and testing complied with the requirements of published criteria such as EN 45001 and ISO Guide 25. It was suggested that if the cement laboratories operating in Austria and Germany employed simple quality systems the work of the Cement Research Institutes would be made easier because some of the causes for inconsistent performance would disappear in plant laboratories.

The second topic that generated wide-ranging discussion was the need for a definition of a "reference laboratory". It was agreed that a laboratory should only be designated as a "reference laboratory" if it has a high testing throughput and,

(a) a testing machine that is frequently calibrated and reserved for reference testing work only,
(b) a testing machine that is more accurate than that of a commercial laboratory and has been checked for stiffness and alignment,
(c) well documented and established test procedures,
(d) thoroughly trained staff and tight control over sample preparation, storage, handling and testing.

Finally, it was suggested that the performance of reference laboratories should be monitored by encouraging more intercomparisons between the reference laboratories in different countries using a common test method.

CONCLUDING REMARKS
by
James H. Pielert

I am very happy that we have had this excellent exchange of information on systems for evaluating cement and concrete testing laboratories. Special thanks go to the session chairmen, the speakers and the participants who traveled to Israel to support this workshop.

I would again like to thank Mrs. Miller and Mr. Avudi of the Standards Institution of Israel for hosting this workshop and making these excellent facilities available. I would also like to give a special thanks to Nesher Cement Works, Ltd, The Readymixed Concrete Association and Ackerstein Industries Ltd. for sponsoring this workshop in Israel.

Workshop proceedings will be developed as soon as possible and distributed to all attendees and to other interested parties throughout the world. The Planning Committee of RILEM TC91-CRL met this week and decided that a TC91-CRL meeting will be held in the spring in Vienna. Its purpose will be to review the progress made to date and to continue the preparation of procedures for the technical assessment of cement and concrete laboratories.

This concludes the workshop. Thanks again for coming and have a safe trip home.

APPENDIX A

QUESTIONNAIRE AND SUMMARY OF SURVEY RESULTS

Summary of Results of Questionnaire

RILEM TC91-CRL
QUESTIONNAIRE

Assessing and Monitoring the Competence and Performance of Cement and Concrete Laboratories

I. Programs for Cement and Concrete Laboratories

1. Are there programs in your country for assessing and monitoring the competence and performance of laboratories that test cement and concrete?

Yes 15
No 1 (Proceed to Section II)

2. Please give the name, address, contact person and telephone number of the organization responsible for the program.
(See Table)

3. Does the program provide formal recognition of the laboratory through accreditation or certification?

Yes 15
No 5
No Entry 1

4. Is there national government participation in the program?

(4)
No 3
Yes 17
No Entry 1

(4a) Type of Participation

3 Sponsorship
4 Operation
1 Technical Support
-- Administrative Support
2 Others (specify)
6 Combination
4 No Entry

5. Does the national government or certain government departments require cement and concrete laboratories to be evaluated by the program before they may operate?

No 8
Yes 11
No Entry 2

For what purpose?

6. Does the program or the scheme of which the program is part have reciprocal recognition agreements with other nations?

No ___13___
Yes___7___ Which countries?________________
No Entry___1___

Are these agreements between private sector bodies or public sector bodies?

7. Has the program published specific criteria for assessing and monitoring the competence of testing laboratories?

No ___4___
Yes___16___ (Attach a copy if available)
No Entry___1___

Are these based on published national or ISO standards?

8. What is the nature of the financial support of the program?

___2___ 100% Government Funding
___-___ Sponsoring Organization Funding
___8___ Fee Charged for Services
___1___ Partial Government Support
___-___ Tariffs on the Products
___7___ Combination
___2___ No Entry

9. If fees are charged for services of the program, how are they based?

___-___ Flat periodic rate
___-___ Per method of test
___8___ Charge made when on-site assessment and proficiency sample services are employed
___6___ Combination of above
___-___ Other
___5___ No Entry

Attach fee schedule if available. Yes_______ No_______

10. What organization(s) produce test methods and standards used in the program? (See Table)

Are there any limitations to the test methods that can be used?

11. Is the recognition provided by the program based on individual test methods or on a specific field of testing?

- 4 Combination
- 3 Field of Testing
- 8 Individual
- 6 No Entry

12. Does the program operate with a core of required test methods or provide recognition on test method by test method basis?

- 5 Core of Required Method
- 8 By Test Method
- 1 Combination
- 7 No Entry

13. What type of documentation is provided by the program?

- \- Requirements to be satisfied by testing laboratory
- 1 Schedule of tests for which accreditation/ certification has been awarded
- 2 Certificate of Accreditation/Certification
- 1 Report Documenting Results of On-Site Assessment and Proficiency Sample Testing
- 1 Other (please specify)
- 15 Combination
- 1 No Entry

14. Does the certificate of accreditation/certification list:

- 9 Schedule of tests for which accreditation/ certification has been awarded
- 5 Field of testing without specific methods listed
- \- Other (please specify)
- 4 Combination
- 3 No Entry

15. Does the program require the laboratory to maintain a quality control/quality assurance manual?

Yes 13
No 6
No Entry 2

16. Which of the following elements of a quality system are required by the program?

a. 19 Description of laboratory operations
b. 11 Training requirements
c. 17 Qualification of laboratory staff
d. 14 Description of job functions
e. 13 Check of personnel competency
f. 9 Problem resolution procedures
g. 17 Sample handling procedures
h. 16 Records and documentation handling procedures
i. 19 Equipment calibration procedures
j. 13 Periodic audit and review of the quality arrangements
k. 16 Documented test procedures
l. 3 Others (please specify)

17. Are on-site assessments of laboratories required by the program?

Yes 17 How Often______________
No 3 (Go to Question 21)
No Entry 1

18. Does the program require that all departures from the requirements of the program resulting from the on-site assessment and proficiency sample testing be corrected by the laboratory?

Yes 17 What type of evidence is required?
No 1
No Entry 2
N/A 1

Do these have to be rectified before accreditation/certification is awarded?

Do these have to be rectified after monitoring visits to retain accreditation?

How long is allowed for rectification?

19. Does the on-site assessor check the following?
Equipment and Apparatus

a. Suitability Yes 18 No - No Entry 2 N/A 1
b. Calibration Yes 18 No - No Entry 2 N/A 1
c. Maintenance Yes 16 No 2 No Entry 2 N/A 1
d. Observe test procedures Yes 18 No 1 No Entry 2 N/A 1
e. Quality system and Quality Manual Yes 11 No 3 No Entry 5 N/A 1
f. Test certificates/reports Yes 17 No 1 No Entry 2 N/A 1
g. Internal audit and review records Yes 14 No 3 No Entry 2 N/A 2
h. Others (please specify)

20. Are the personnel used by the program to conduct on-site assessments:

a. __3__ Combination
__7__ Full time employees of the program organization
__8__ Outside assessors used as needed
__-__ Others (please specify)
__3__ No Entry

b. Are they trained in assessment techniques? Yes_16_ No_1_
No Entry_2_ N/A_1_

c. Are they experts in cement and concrete technology? Yes_14_
No_2_ No Entry_4_ N/A_1_

21. Does the program require a laboratory to test proficiency samples?

Yes ___17_
No ___3_
No Entry _1_

22. What specific materials are included in the proficiency sample program?

cement	2	cement and concrete	2
concrete	-	concrete & aggregates	1
aggregates	-	cement, concrete & aggregates	5
others	1	cement, concrete & rebars	2
no entry	3	N/A	4

How often are these tested by laboratory?

23. What type of statistical analyses are made with the proficiency sample results? (See Table)

24. What is the criteria for evaluating proficiency sample results? (See Table)

25. Is accreditation/certification refused/suspended/terminated based on poor proficiency sample test results?

Yes___8_ Is this after only one poor result? Yes___No___
No ___4_
N/A___7_
No Entry_2_

26. What are the fees for participation in the proficiency sample program?

27. How many laboratories participate in the proficiency sample program? (See Table)

28. If available, please attach documents which describe the program for assessing and monitoring the competence and performance of laboratories (criteria, fees, organization, etc.)

Are documents attached? Yes______
No ______

II. Program Needs

Please provide information on inadequacies you see in the existing system in your country, or if no system currently exists, indicate the needs as you see them.

Name and Address of Individual Completing Questionnaire

____

____

____

____

Please return by April 1, 1988 to:
Mr. James H. Pielert, Group Leader
Construction Materials Reference Laboratories
National Bureau of Standards
Building 226, Room A365
Gaithersburg, MD 20899

RILEM TC91-CRL

Summary of Questionnaire Responses

Assessing and Monitoring the Competence and Performance of Cement and Concrete Laboratories

Question

Country	Respondent(s)	1	3	4	4a	5	6	7	8	9	10	11	12	13	14
Australia (NATA)	D. Cook	Y	Y	Y	Sponsor	N	Y	Y	Fee charged and sponsor	Combination	Standards Assoc. of Australia			Accredit. Certif.	Schedule of Tests
Austria	H. Sommer	Y	Y	Y	Operation	Y	N	Y	Partial Govt.	Charge when services provided	ISO, EC Drafts, Austrian Standards Institute	Field of Testing	Core of Req'd Methods	Accredit. Certif.	Field of Testing w/o Methods
Belgium	H. Lambotte	Y	Y	Y	Operation	Y	N	Y	100% Govt.	NA		Field Test, Individ Methods		Schedule of Tests	Schedule of Tests
Cameroon	V. Kamguea	Y	N	Y	Sponsor & Administ. Support	Y	N	Y	Fee chgd., partial govt.	Per method when services provided		Field Test, Individ Methods	Core of Req'd Methods	Requir-ments to be satis. & reports	Field of Testing w/o Methods
Finland	A. Sarja	Y	Y	Y	Operation, Technical Support, Admin. Support	Y	N	Y	Fee Charged	Charge when service provided	Concrete Assoc. of Finland, National Cement Commmittee	Field of Testing	Core of Req'd Methods	Require-ments, schedule of tests, cert., report	Schedule Tests, Field of Tests
France	F. Hawthorne (ATILH)	Y	Y	Y	Sponsor	N	Y	Y	Fee chgd., partial govt.			Indiv-idual Methods	Indivi-dual Tests	Require-ments, schedule, certific. report	Schedule of Tests
France	RNE	Y	Y	Y	Technical Support	Y	Y	N	Fee chgd., partial govt.	Combination	RNE, AFNOR	Indiv-idual Methods	Core of Req'd Methods	Require-ment, Schedule, Cerficate Report	Schedule of Tests
Luxembourg	G. Scharfe	Y	N	Y	Technical and Admin. Support	Y	N	N	100% Govt.	NA	Permanent Comm. of Mat'ls of Construct, German Stds, CEN	Field Test, Individ Methods	By Test Method	Require-ments and Report	Field of Testing w/o Methods
Nigeria	D. Adepegba	N													
Switzerland (Monitoring Program for Cement and Lime)	T. Erismann	Y	N	N	Private Program, EMPA Gov't Lab Partic.	Y	N	N			SIA, later CEN			Other	
Switzerland Gov't. Accred. Program)	T. Erismann	Y	Y	Y	Operation		N	Y	Fee partial govt.	Charge chgd., service provided	when			Require-ments, Schedule of Tests, Cert., Report	Schedule Tests, Field of Tests

Country	Respondent(s)	15	16	17	18	19a	19b	19c	19d	19e	19f	19g	20a	20b	20c	21	22	23	24	25	27	28
Australia (NATA)	D. Cook	N	a,b,c,h, i,k	Y	Y	Y	Y	Y	Y		Y		Outside Volunteers	Y	Y	N	NA	NA	NA	NA	NA	Y
Austria	H. Sommer	N	a,c,e,g, h,i,k	Y	Y	Y	Y	Y	Y	N*	Y	Y	Full Time, Outside	Y	Y	Y	Cement Concrete	Compar. Tests	Inter-Lab. Stand. Dev.	Y	28 Cem. 20 Con.	N
Belgium	H. Lambotte	N	a,c,i,j	Y	Y	Y	Y	Y	Y		Y	Y	Full Time Employ.	Y	Y	N	NA	NA	NA	NA	NA	Y
Cameroon	V. Kamguea	Y	a,c,d,f, g,i,k	N	Y	Y	Y	Y	Y		Y	Y	Full Time Employ.	Y		Y	Cement Concrete Aggregates			Y		N
Finland	A. Sarja	N	a,c,e,g, h,i,j,k	Y	Y	Y	Y	N	Y	N	Y	Y	Full Time Employ.	Y	Y	Y	Cement Concrete Aggregates Admixtures Rebars	t-test, means, std. dev., varian.	Conc.-allow statist differ. Cement SFS	Y	9 Con. 6 Cem.	N
France	F. Hawthorne (ATILH)	Y	a,c,d,g, h,i,j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Asses-sors	Y	N	Y	Cement				150	Y
France	RNE	Y	a,b,c,d, e,f,g,h, i,j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Asses-sors	Y	N	Y	Cement Concrete Aggregates Metals			NA	20-100	Y
Luxembourg	G. Scharfe	Y	a,d,e,g, i	N												Y	Cement Concrete Aggregates			Y	8-10	N
Nigeria	D. Adepegba																					
Switzerland (Monitoring Program for Cement and Lime)	T. Erismann			N	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	Cement Lime Gypsum	Stand. Proced.	Stand. SIA 25	N	15	N
Switzerland Gov't. Accred. Program)	T. Erismann	Y	a,b,c,d, e,g,h,i, j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Asses-sors	Y		Y				Y		N

RILEM TC91-CRL

Summary of Questionnaire Responses

Assessing and Monitoring the Competence and Performance of Cement and Concrete Laboratories

Question

Country	Respondent(s)	1	3	4	4a	5	6	7	8	9	10	11	12	13	14
Turkey	H. Ismailoglu (Turkish Stds. Institute)	Y	Y	Y	Others(?)	N	N	N	Fee charged for serv.	Combination	Turkish Stds. and Others	Both		Requirements, Certif.	Schedule of Tests
United Kingdom (NAMAS)	J. Rogers T. Tipler	Y	Y	Y	Operation	N	Y	Y	Fee chgd., partial govt.	Based on Assessment Effort Required	BSI, BRE, BCA, ASTM, etc.	Individual Methods	Classes of Test or Individual Tests	Requirements, Schedule of Tests, and Certif.	Schedule of Tests and Certif.
United States (NVLAP)	J. Donaldson	Y	Y	Y	Administrative, Sponsor, Technical Support	Y	Y	Y	Fee charged for serv.	Combination	ASTM U.S. Corps of Eng.	Individual Methods	By Test Method	Requirements, Schedule, Certif., Report	Schedule of Tests
United States (A2LA)	J. Locke	Y	Y	N	NA	N	N	Y	Fee charged for serv.	Combination	ASTM	Individual Methods	By Test Method	Requirements, Schedule, Certif., Report	Schedule of Tests
United States (AASHTO Accreditation Program)	J. Pielert	Y	Y	N	NA	Y	N	Y	Fee charged for serv.	Charge When Services Provided	ASTM AASHTO	Individual Methods	By Test Method	Requirements, Schedule, Certif., Report	Schedule of Tests
United States (Cem. and Concrete Reference Laboratory)	J. Pielert	Y	N	Y	Administrative and Technical Support	N	N	Y	Fee charged for serv.	Charge When Services Provided	ASTM	Individual Methods	By Test Method	Reports	NA
Canada	M. Archambault	Y	Y	Y	Indirect	N	N	Y	90% Govt. Fee charged	Periodic Rate	CSA ASTM In-house	Individual Methods	By Test Method	Requirements, Certif., Report, Directory	Fields Testing w/Test Methods
New Zealand (Telarc)	A. Thakardas	Y	Y	Y	Act of Parliament	Y	Y	Y	Fee charged for serv.	Combination	SANZ ASTM BSI	Field Test, Individ Methods	By Test Method	Requirements, Schedule, Certif., Report	Schedule of Tests
Norway	O. Karlsen J. Karlsen	Y	Y	Y	Administrative	N	N	Y	Fee charged for serv.	Yearly Flat Fee	Norw. Stds. Organ.	Field of Testing	Core of Req'd Methods	Requirements, Certif., Report	Field of Testing
Sweden	P. Peterson	Y	N	Y	Administrative	Y	Y	Y	Fee charged for serv.	Yearly Fee	Swedish Gov't, ASTM			Requirements	No Certificate

Country	Respondent(s)	15	16	17	18	19a	19b	19c	19d	19e	19f	19g	20a	20b	20c	21	22	23	24	25	27	28
Turkey	H. Ismailoglu (Turkish Stds. Institute)	N	a,c,d,e, g,h,i,k	Y	Y	Y	Y	Y	Y	N	Y	N	Outside Assessors	N	Y	Y				Y		N
United Kingdom (NAMAS)	J. Rogers T. Tipler	Y	a,b,c,d, e,f,g,h, i,j,k,l	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Assessors	Y	Y	N	Planning to Introduce, BCA has Tstg. Machine Program	NA	NA	NA	NA	Y
United States (NVLAP)	J. Donaldson	Y	a,b,c,d, e,f,g,h, i,j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Assessors	Y	Y	Y	Cement Concrete Aggregates Others	Mean, Stand. Dev.		Y		Y
United States (A2LA)	J. Locke	Y	a,b,c,d, e,f,g,h, i,j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Outside Assessors	Y	Y	Y	Cement Concrete Aggregates			N		Y
United States (AASHTO Accreditation Program)	J. Pielert	Y	a,b,c,d, e,f,g,h, i,j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Full Time Employ.	Y	Y	Y	Concrete Aggregates	Youden Analy.	Within 2 Std. Dev.	N	300	Y
United States (Cem. and Concrete Reference Laboratory)	J. Pielert	Y	a,b,c,d, e,f,g,h, i	Y	N	Y	Y	N	Y	Y	N	N	Full Time Employ.	Y	Y	Y	Cement Concrete	Youden Analy.	None	NA	300	Y
Canada	M. Archambault	Y	a,b,c,d, e,f,g,h, i,j,k,l, (others)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Full Time Outside	Y	Y	N	NA	NA	NA	NA	NA	Y
New Zealand (Telarc)	A. Thakardas	Y	a,b,c,d, e,f,g,h, i,j,k,l	Y	Y	Y	Y	Y	Y	Y	Y	Y	Full time, volunt.	Y	Y	N	Cement, Concrete, Aggregates		Outlier test, ISO 5725	Y	23	Y
Norway	O. Karlsen J. Karlsen	Y	a,b,c,d, e,g,h,i j,k	Y	Y	Y	Y	Y	Y	Y	Y	Y	Full Time	Y	Y	N	NA	NA	NA	NA	NA	Y
Sweden	P. Peterson	N	a,g,h,i k	Y	Y	Y	Y	Y	Y	N	Y	N	Full Time	N	Y	Y	Cement	Mean, Std. Dev.	Dev. Between Mean Values	N	6	Y

APPENDIX B

WORKSHOP PROGRAM

WORKSHOP PROGRAM

September 6, 1989

8:00 - 9:00	Registration		
9:00 - 9:30	Welcome by: S. Avudi, Standard Institution of Israel M. Fickelson, Secretary General, RILEM		
9:30 - 10:00	Welcome and Introduction to Workshop - J. Pielert, Chairman TC91-CRL		
10:00 - 10:30	Coffee Break		
10:30 - 2:00	Session I: Quality Assurance Systems in Cement and Concrete Testing Laboratories, F. Hawthorn, Chairman		
		10:30 - 10:50	Current Practice for Assessing Quality Assurance Systems in Laboratories - Dr. J. Rogers, NAMAS, U.K.
		10:50 - 11:10	RNE - The French Accreditation System for Laboratories - J. F. Coste, Laboratoire Central des Ponts et Chaussees
		11:10 - 11:30	Experience in Obtaining RNE Accreditation - J. Treps, Direction Technique et Scientifique, Ciments Francaise
		11:30 - 11:50	Link Between Test Records on Concrete and Its Ingredients Obtained from Different Laboratories - V. Ukrainchik, Gradjevinsky Institut, Zagreb
		11:50 - 12:10	Test Frequency and Precision of Results - Prof. P. Schutz, TVFA der Stradt, Vienna
		12:10 - 1:00	Discussion
		1:00 - 2:30	Lunch
2:30 - 4:45	Session II: Assessment of Technical Performance of Laboratories Dr. H. Sommer, Chairman		
		2:30 - 2:50	Experience with Proficiency and Round Robin Testing in the U.S.A. - J. Pielert, National Institute of Standards and Technology
		2:50 - 3:10	Evaluation of Cement Strength Testing by Four Laboratories - J. Even and G. Koster, Readymixed Concrete Association, and Nesher Cement Works, Israel

3:10 - 3:30		Experience with Interlaboratory Testing in France - F. Hawthorn, Association Technique de Lindustrie des Liants Hydrauliques, France
	3:30 - 3:50	Coffee Break
	3:50 - 4:10	Comparative Tests Between 19 Accredited Cement Laboratories - Prof. G. Wischers, Forschungsinstituts der Zementindustrie, Dusseldorf
	4:10 - 5:00	Discussion

September 7, 1989

9:00 - 11:50	Session III: Role of Reference Laboratories Dr. J. Rogers, Chairman	
	9:00 - 9:20	British Comparative Cube Testing Program - C. Atkinson, NAMAS, National Physical Laboratory, U.K.
	9:20 - 9:40	Comparative Investigation of Compression Testing Machine for Concrete Cubes - Dr. U. Korin, Dr. M. Ben-Bassat and J. Sikuler, National Research Institute, Technion, Israel
	9:40 - 10:10	Coffee Break
	10:10 - 10:30	Experience with a Cement Reference Laboratory in Austria-Dr. H. Sommer, Forschungsinstitut, Vienna
	10:30 - 10:50	Cooperation Between a Central Cement Laboratory and 60 Plant Laboratories - Prof. G. Wischers, Forschungsinstituts der Zementindustrie, Dusseldorf
	10:50 - 11:50	Discussion
11:50 - 1:00	Closing Session - J. Pielert, Chairman	
	Reports by Session Chairmen:	
	Session I	F. Hawthorn
	Session II	Dr. H. Sommer
	Session III	Dr. J. Rogers
1:00	Lunch	

APPENDIX C

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10. SUPPLEMENTARY NOTES

J. H. Pielert paper "Experience with Proficiency and Round Robin Testing in the United States" has been approved by WERB. Non-NIST papers have been approved by the organizations of the authors.

☐ DOCUMENT DESCRIBES A COMPUTER PROGRAM; SF-185, FIPS SOFTWARE SUMMARY, IS ATTACHED.

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

A workshop sponsored by RILEM Technical Committee 91-CRL was held in Tel Aviv, Israel on September 6-7, 1989 to consider the evaluation of cement and concrete testing laboratory performance. The workshop attracted 30 participants from the United Kingdom, France, Israel, Sweden, United States, Austria, Switzerlanc, Germany F.R., Finland and Spain. Papers were presented on the following subjects: (1) quality assurance programs for testing laboratories, (2) assessment of the technical performance of laboratories, and (3) role of reference laboratories. The workshop resulted in an excellent exchange of information and showed a high degree of interest in the quality of testing of cement and concrete on the international level.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

accreditation; cement; concrete; laboratory; quality assurance; testing

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