CONCRETE QUALITY CONTROL IN ROAD CONSTRUCTIONS

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MASTER IN CIVIL ENGINEER — SPECIALIZATION IN CONSTRUCTIONS

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To my parents, sister and Barbora

To be great is to be misunderstood

Ralph Waldo Emerson

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Finally to my family. The most important thing I have in life. To my sister that who cannot show it openly, I know that she always concerned about me. For the short but important conversations we had making me feel happy to have her. To my father for the talks about football that glad me so much because is something that I missed a lot. To my mother for putting me always aware of what was going on in Portugal, with the rest of the family and friends. To the three for the great support they gave me. Not in these 5 months, but in all my life. Were, are, and will always be my support, my safe haven. Without them I would not be here today, certainly. Without the love, affection and understanding of them I would never have gotten where I am now. To them I owe everything that I am.

To all my sincere thanks.

ABSTRACT

The title of the thesis presented herein, refers the primary objectives that underpin the research work.

Quality Control for Roads in the Concrete Constructions aims to carry out quality control for concrete, a stage prior to being placed in work to ensure the quality parameters required for road works, which typically have a very important dimension. For the approach to this issue, is preliminarily made a contextualization of all work, which begins by noting the types of existing concrete applied in the situation under study.

Since the thesis was performed in cooperation with a Slovak company, is also presented to the reality of this company regarding to national and European level, and made a short background of the current situation within the buildings in general.

For a better understanding of the importance of quality control addresses the issue in general, is defined the meaning of quality control and also made a comparison between the same control and quality assurance, two concepts often wrongly confused, but being both important in this work.

Once the concrete is an important aspect of this thesis is given a theoretical explanation of their technical specifications in general, since its production, materials, transportation and application on the construction. It is an extremely important material in any road work, which is why the element has been chosen to carry out its quality control.

Chapter four discusses in detail the importance of testing in the fresh concrete and also the hardened concrete. After an explanation of each are presented checklists created and applied work.

At the end are presented the results of the implementation of the respective check-lists showing the feedback from several elements present in the work, that later can be done a improvement and permanent use in the future. It has also presented a brief report graph, the results on the key aspects to consider in each of the tests observed, to give a better idea of the impact that had the check-lists in the course of the work.

KEYWORDS: Quality Control, Concrete, Roads Constructions, Fresh Concrete Tests, Check-Lists.

GENERAL INDEX

INDEX OF FIGURES

INDEX OF TABLES

SYMBOLS AND ABREVIATTIONS

NaCl - Sodium chloride

Fck – Resistance Characteristic of Concrete

SK - Slovakia

ISO - International Organization for Standardization

BS – British Standards

QA – Quality Assurance

QC – Quality Control

TS – Technical Specifications

STS – Special Technical Specifications

STN – Standard

EN – European Norm

e.g. – for example

i.e. – that is

CTS – Control and Test Schedule

1

INTRODUCTION

1.1. INITIAL CONSIDERATIONS

Following recent developments at the level of degrees awarded in all higher education, mainly caused by the Bologna Process, the establishment of the Master in Civil Engineering should be considered as an opportunity to deepen some technological knowledge in various areas of expertise. In this context, and for the development of this thesis, was given the chance to the author to do it abroad, in partnership with a company, working there for five months, having access to more diverse kinds of information such as literature, direct contact with workers, suppliers, engineers, free Internet access, among others, which allowed him an enormous enrichment, both personally and professionally.

1.2. PURPOSE AND SCOPE OF RESEARCH

As the concrete is one of the main components of any road work, it seemed correct to apply the quality control of that component. When speaking of any work of this kind, means find concreting work of various kinds.

One of the simplest and most basic is the concrete used for paving the way, in this case, and of course is always referring the country in question, is used a very coarse asphaltic concrete - modified with 60 mm of thickness, being the sixth layer of eight to apply in the pavement.

All other concrete applied in this type of construction is reduced to works of art existing in the section of road, such as bridges, tunnels, retaining walls, etc.

In this study, and since the author had access to only one part of the road, it was only possible follow the construction of a civil engineering work, in this case a bridge as well as retaining walls, some of the many existing throughout layout.

In the bridge studied, referred as M – 09, there are several types of concrete to be applied, starting with Blinding Concrete is the sort C8/10 specifications XC1 (SK) 25 Cl 0.20 Dmax, which is used to protect all the artwork's own ground running as the name indicates like a shield of the artwork to external factors, in this case the foundation soil.

The following is the Foundation Concrete, is a concrete type C25/30 specifications XC2, XA1 (SK) 25 Cl 0.20 Dmax, which is used for the concrete foundations of the artwork.

Then there is the concreting of the pillar where the type of concrete used is of type C30/37 specifications XD1, XF2 (SK) 25 Cl 0.20 Dmax, a stronger concrete because it is used for most important areas of all the artwork.

For the concrete used in the Seat of the bridge, is the same used in the concrete columns and with the same kind of specifications.

Then, and for the profile of the bridge itself, is used a concrete type C35/45 specifications XD1, XF2 (SK) 25 Cl 0.20 Dmax, the more resistant concrete used throughout the artwork.

This type of concrete is also used in the implementation of Bearing Blocks but with specifications for XC3, XF2 (SK) 25 Cl 0.20 Dmax, and also in achieving the Cornice with specifications XD3, XF4 (SK) Cl 0.20 Dmax 25.

The goal held up well with the screening of the concreting activity resulting in a work station, from the simplest (asphaltic concrete) to the more complicated as the concreting done in the great works of art created in the project.

For that reason and because the records of quality control existing in Slovakia, and more specifically in the company (VÁHOSTAV - SK) did not seem satisfactory, all the work throughout the semester had to do with the creation or improvement of those check lists for quality control of concrete and concreting work R3 Expressway Trstena - bypass one of the major works taking place in the north of Slovakia.

1.3. STRUCTURE OF WORK

The work consists in five chapters, subchapters due to various issues, there is always the care of each chapter has a brief introduction to the subject here treated as a conclusion to it.

Chapter 1, entitled "Introduction," makes a brief background of why the completion of the thesis in a foreign country, as well as a brief presentation of its objectives, through a brief description of various types of concrete that will be controlled and a sample of how it will be structured around the work presented later. It also provides a general overview of the company in which was conducted this whole thesis in order to be able to put in a perfunctory manner the recent and current reality of the company, and referred to the main aspects of it as a general profile, associated companies, some data on their development in recent years both in the national and European level and also include their quality management systems.

In Chapter 2, entitled "Quality Assurance / Quality Control" is given a general explanation with respect to these two concepts. It is also explained the difference between the two, points in common and points of divergence, so that there is no doubt or confusion. Some practical examples are provided to better illustrate the concepts discussed in this chapter.

In Chapter 3, entitled "Concrete" is given a detailed explanation of how it is made concrete, that follows rules, as it is transported and the test subject which is here in Slovakia, particularly in the work that followed, these principles being used in any work involving the company's concrete of this type.

In Chapter 4, entitled "Quality Concrete Tests" are presented all the tests for concrete, being given a brief explanation of what are those tests and witch are the normal values of some of them. There are numerous tests that can be made for concrete, but of course, and in this case, is presented only the tests that the author had access to watch and/or be able to get results for development of check lists, thus making the control of quality of them.

In Chapter 5, entitled "Quality Control Check-Lists" is presented the structure of the check-lists created to insert in the company day life to improve the quality control in the fresh concrete tests.

In Chapter 6, entitled "Application of the Check-Lists, Data Analysis and Final Conclusions", is presented a very simplified data analysis with the results obtained in the application of the check-lists. From the five different concrete tests here chosen the most interest parameters to analyze and see the efficiency of the check-lists in the construction site. In this chapter is also presented the final conclusions to all the developed work during the five months passed in VAHOSTAV – SK.

1.4. THE COMPANY: VÁHOSTAV – SK, A.S. [1], [2]

1.4.1. GENERAL PROFILE

VÁHOSTAV–SK has long belonged among the three leading construction companies in the Slovak Republic thanks to its achievements.

Figure 1.1 – Váhostav-SK symbol

The main production activities include the construction of motorways and roads, water reservoirs, ecological, industrial and municipal structures and the construction of railways.

The joint-stock company VÁHOSTAV-SK focuses on four areas of construction, namely the construction of roads, bridges, tunnels, motorway infrastructure and railways. At the same time they concentrate on the construction of industrial parks with their infrastructure, and ecological and water treatment structures. In their well established cooperation with their partners they provide buildings for immediate occupancy. They focus on a wide range of such buildings including multipurpose structures, logistics and shopping centers, industrial plants, public amenities and housing. The production and assembly of prefabricated units is another significant activity of VÁHOSTAV-SK.

VÁHOSTAV-SK, a.s., odstepný závod – Pozemné stavby, is a branch company located in Bratislava. It is part of their organization chart as well. It includes a specialized department for steal-concrete skeletons that supplies the parent company as well as other construction companies located in Slovakia.

Their construction activity flexibly responds to the investor's portfolio in the Slovak market which is confirmed by the quality management system in accordance with ISO 9001:2000, ISO 14001:2004 and BSi OH SAS 18001.

VÁHOSTAV-SK is an experienced company with a long tradition in the construction market in Slovakia and abroad. In addition it has achieved positive economic results that prove their capability to achieve the outlined goals. They have highly qualified people in all areas of company's management who use the latest construction processes and technology.

In order to achieve the widest possible complexity of construction works and services they provide, they have established several specialized subsidiary companies including VÁHOSTAV-SK-PREFA, s.r.o., IVG VÁHOSTAV-SK, s.r.o., VHS-SK-PROJEKT, s.r.o., and CONTROL-VHS-SK, s.r.o.

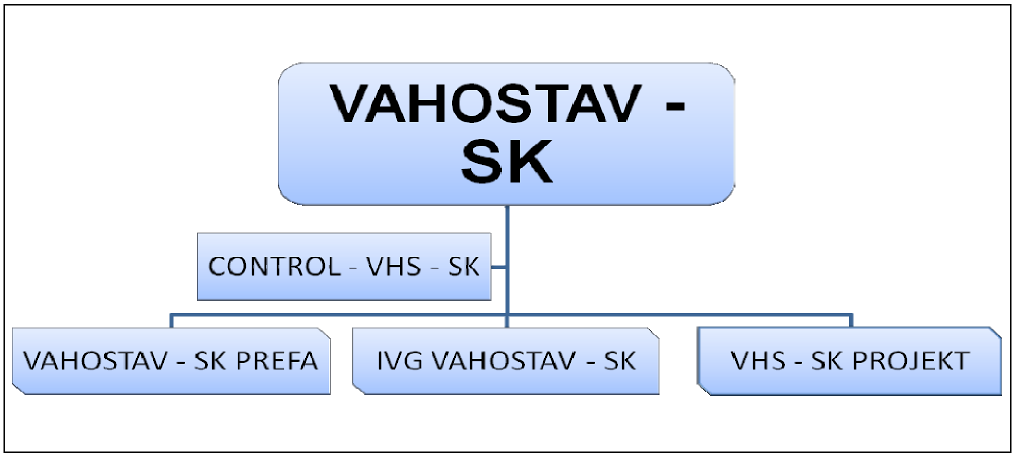


Figure 1.2 – Váhostav-SK related companies

1.4.2. Subsidiary companies

1.4.2.1. VÁHOSTAV – SK PREFA, s.r.o.

Production of transportation concrete, concrete structural elements, bar and spread components, buildings from reinforced concrete, girders for road construction, atypical staircases, pit holes, screws, manhole covers, flow meter pits, silt dewatering and cable tunnels, the atypical custom production and assembly of prefabricates and the assembly of reinforced concrete and steel constructions.

1.4.2.2. VHS – SK PROJEKT, s.r.o.

Complete architectural, design and engineering services and technical consulting for building and engineering construction, technical and energy equipment of buildings and statics, accredited geodetic, cartographic and reprographic services.

1.4.2.3. IVG VÁHOSTAV – SK, s.r.o.

Supply and installation of steel construction, the construction of industrial plants, corniced and armed trolleys, special atypical frameworks and inlet and outlet high-dimension irregularly shaped adaptor pieces for hydroelectric plants and small water stations.

1.4.2.4. CONTROL – VHS – SK, s.r.o.

Field geotechnical testing of mould and soil, consultancy services in geotechnical and non-destructive concrete testing.

1.4.3. Business activities of the company in the last years

1.4.3.1. Engineering and road construction

- The modernization of the Zilina – Krásno nad Kysucou railway line
- The R3 Expressway Trstena – bypass

1.4.3.2. Building construction

- The Bratislava castle renovation “NKP Bratislavský hrad”
- The Jarabiny residential complex, Bratislava
- The 2nd part of the Vlcince V residential complex, blocks of flats A, B and C and technical infrastructure
- Reconstruction of the production hall in the Hnust’a industrial zone, building 940

1.4.3.3. Ecological and water treatment structures

- Nováky – removing the overburden
- The system interconnection of the Martin and Priekopa central heating supply
- The oil tank construction in Bucany, number 502, capacity of 75 000 m^3
- The oil tank construction in Budkovce, number 232, capacity of 50 000 m^3

1.4.4. Last years company numbers

1.4.4.1. Company growth 2006-2008

The following chart shows the overview of the company growth for the period from 2006 to 2008.

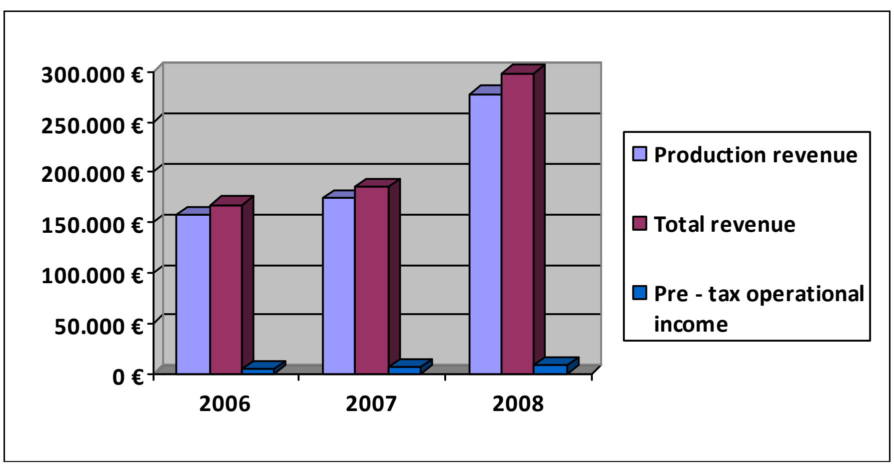


Figure 1.3 – Company growth 2006 – 2008

Table 1.1 – Summary of the 2006 – 2008 growth

	2006	2007	2008
Production revenue	157.457 €	173.960 €	277.778 €
Total revenue	167.474 €	185.195 €	298.486 €
Pre – tax operational income	4.532 €	6.266 €	8.575 €

* in 1.000,00 €

1.4.4.2. Construction production in 2008

The following chart shows the overview of the performance of the construction production in 2008.

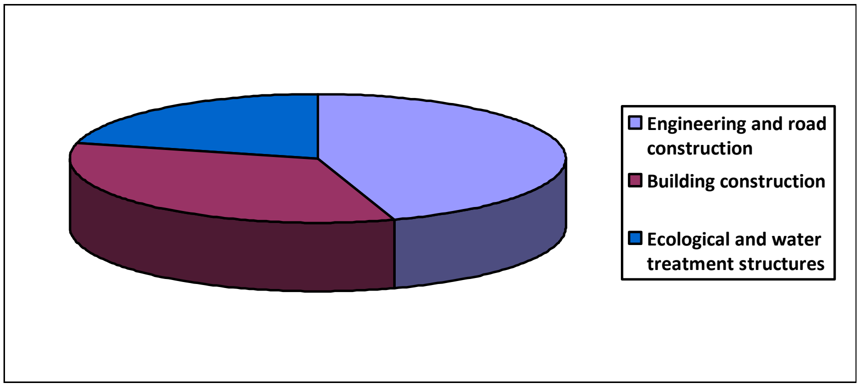


Figure 1.4 – Construction production in 2008

Table 1.2 – Summary of construction production in 2008

Engineering and road construction	122.726 €	45%
Building construction	92.403 €	34%
Ecological and water treatment structures	58.591 €	21%
Total	273.720 €	100%

* in 1.000,00 €

Table 1.2 – Summary of construction production in 2008

1.4.5. Quality management systems

1.4.5.1. Quality management

VÁHOSTAV-SK, a.s. has been certified in and has implemented the following management systems:

- Quality management system: in accordance with ISO 9001:2000
- Environmental management system: in accordance with ISO 14001:2004

- Occupational health and safety management system: in accordance with the British standard BSi OHSAS 18001.

VÁHOSTAV-SK, a.s. has had its management system since 2002. In August 2008 there was a re-certification audit of the integrated management system by the certification company SGS Slovakia.

1.4.5.2. Quality first

Quality is the top priority of VÁHOSTAV-SK's constructions activities. They know that quality and reliability are the main conditions to achieve customer satisfaction and the company's prosperity.

The complex control system is provided by the ministry-accredited branch company CONTROL-VHS-SK, s.r.o. The location of the accredited laboratory enables it to support all their construction work in Slovakia. Laboratories are run by qualified personnel and equipped with the latest technology to provide all the required production and special controls of soil, gravel, bonded and unbounded under layers, and all types of concrete, building steel, ropes, insulation, cement and mortar.

The above described quality control management system ensures compliance with all the requirements arising from the generally binding regulations, contractual terms and conditions and technical – quality parameters, that guarantee the quality of the realized constructions.

1.4.5.3. Environment

A priority of their company is the continuous improvement of activities related to environmental issues, work safety and the quality systems. All the company's activities are managed to keep the negative impact to the environment to a minimum in line with Slovak legislation. As part of their environmental activities is the recycling of other construction waste by the mobile device TEREX PEGSON 900 x 600 m METROTRAK.

VÁHOSTAV – SK, a.s. has implemented the recycled waste collection. Disposal or recovery of waste is carried out only by designated companies.

In water management they fully comply with current legislation. The stress is put on the proper use of hazardous substances during their construction.

In air protection they do not exceed the emission limits of secondary sources of air pollution. They announce the fuel consumption by small sources of air pollution on time.

In nature and landscape protection, their company carries out internal checks at regular intervals.

1.4.5.4. Work safety

Their primary goal in work safety is to evaluate all issues in the complex sphere of occupational health and safety and constantly implement measures to prevent and decrease work injuries and accidents. Stress is put on use of certified safety equipment, work safety and fire protection staff training, compliance with current legislation as well as strengthening the sense of responsibility for health and safety protection of all employees.

A register of identified hazards and risks and a health and safety plan is elaborated for each construction. Compliance with safety and fire protection is controlled through internal audits and controls by designated departments.

1.5. FINAL CONSIDERATIONS

VAHOSTAV – SK is one of the biggest companies in Slovakia. They work not only in Slovakia but also in a lot of countries in Europe. They have also an interesting cooperation with one of the most important companies in Portugal: Mota-Engil. They work together in some constructions in Slovakia and they keep a good relation that can be very interesting for the future partnership Portugal-Slovakia in the next years, with respect in constructions and development of the roads in Slovakia.

2
QUALITY ASSURANCE (QA) / QUALITY CONTROL (QC)

2.1. INTRODUCTION

A QA/QC program contributes to the objectives of good practice guidance, namely to improve transparency, consistency, comparability, completeness and confidence of any construction.

The outcomes of the QA/QC process may result in a reassessment of inventory or source category uncertainty estimates. For example, if data quality is found to be lower than previously thought and this situation cannot be rectified in the timeframe of the current inventory, the uncertainty estimates ought to be re-evaluated.

The terms “quality control” and “quality assurance” are often used incorrectly. The definitions of QC and QA will be used for the purposes of good practice guidance.

Quality control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

a) Provide routine and consistent checks to ensure data integrity, correctness, and completeness;

b) Identify and address errors and omissions;

c) Document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting.

Quality assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, should be performed upon a finalized inventory following the implementation of QC procedures.

Before implementing QA/QC activities, it is necessary to determine which techniques should be used, and where and when they will be applied. There are technical and practical considerations in making these decisions.

2.2. PRACTICAL CONSIDERATIONS IN DEVELOPING QA/QC SYSTEMS

Implementing QA/QC procedures requires resources, expertise and time. In developing any QA/QC system, it is expected that judgments will need to be made on the following:

- Resources allocated to QC for different source categories and the compilation process;
- Time allocated to conduct the checks and reviews;
- Availability and access to information on activity data and other factors, including data quality;
- Procedures to ensure confidentiality of inventory and source category information, when required;
- Requirements for archiving information;
- Frequency of QA/QC checks on different parts of the inventory;
- The level of QC appropriate for each source category;
- Whether increased effort on QC will result in improved results estimates and reduced uncertainties;
- Whether sufficient expertise is available to conduct the checks and reviews.

In practice, the QA/QC system is only part of inventory development process and inventory agencies do not have unlimited resources. Quality control requirements, improved accuracy and reduced uncertainty need to be balanced against requirements for timeliness and cost effectiveness. A good practice system seeks to achieve that balance and to enable continuous improvement of inventory estimates. [3]

Within the QA/QC system, good practice provides for greater effort for key source categories and for those source categories where data and methodological changes have recently occurred, than for other source categories. It is unlikely that inventory agencies will have sufficient resources to conduct all the QA/QC procedures on all source categories. In addition, it is not necessary to conduct all of these procedures every year. For example, data collection processes conducted by national statistical agencies are not likely to change significantly from one year to the next. Once the inventory agency has identified what quality controls are in place, assessed the uncertainty of that data, and documented the details for future inventory reference, it is unnecessary to revisit this aspect of the QC procedure every year. However, it is good practice to check the validity of this information periodically as changes in sample size, methods of collection, or frequency of data collection may occur. The optimal frequency of such checks will depend on national circumstances. [3]

While focusing QA/QC activities on key source categories will lead to the most significant improvements in the overall inventory estimates, it is good practice to plan to conduct at least the general procedures, General QC Procedures, on all parts of the inventory over a period of time. Some source categories may require more frequent QA/QC than others because of their significance to the total inventory estimates, changes in data or characteristics of the source category, including the level of uncertainty. For example, if technological advancements occur in an industrial source category, it is good practice to conduct a thorough QC check of the data sources and the compilation process to ensure that the inventory methods remain appropriate.

It is recognized that resource requirements will be higher in the initial stages of implementing any QA/QC system than in later years. As capacity to conduct QA/QC procedures develops in the inventory agency and in other associated organizations, improvements in efficiency should be expected. [3]

General QC procedures, General Inventory Level QC Procedures, and a peer review of the inventory estimates are considered minimal QA/QC activities for all inventory compilations. The general procedures require no additional expertise in addition to that needed to develop the estimates and compile the inventory and should be performed on estimates developed using or higher tier methods for source categories. A review of the final inventory report by a person not involved in the compilation is also good practice, even if the inventory were compiled. More extensive QC and more rigorous review processes are encouraged if higher tier methods have been used. Availability of appropriate expertise may limit the degree of independence of expert reviews in some cases. The QA/QC process is intended to ensure transparency and quality.

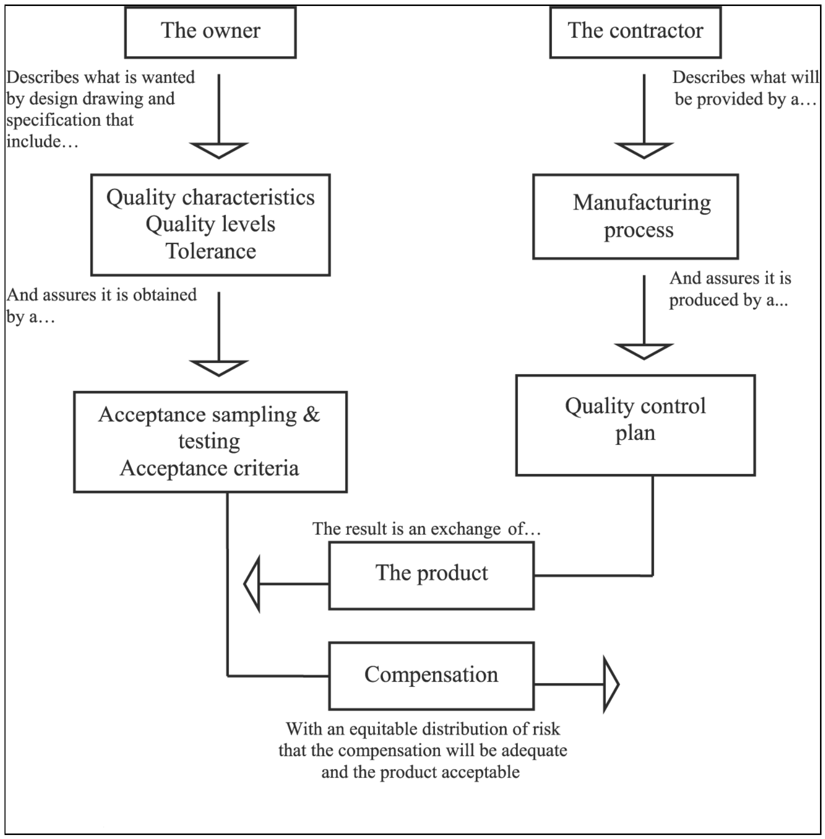


Figure 2.1 – Quality management practice flowchart in highway construction (example)

2.3. Elements of a QA/QC systems

The following are the major elements to be considered in the development of a QA/QC system to be implemented in tracking inventory compilation:

- An inventory agency responsible for coordinating QA/QC activities;
- A QA/QC plan;
- General QC procedures;
- Source category-specific QC procedures;
- QA review procedures;
- Reporting, documentation, and archiving procedures.

2.4. INVENTORY AGENCY

The inventory agency is responsible for coordinating QA/QC activities for the national inventory. The inventory agency may designate responsibilities for implementing and documenting these QA/QC procedures to other agencies or organizations. The inventory agency should ensure that other organizations involved in the preparation of the inventory are following applicable QA/QC procedures.

2.5. QA/QC PLAN [4]

A QA/QC plan is a fundamental element of a QA/QC system, and it is good practice to develop one. The plan should, in general, outline QA/QC activities that will be implemented, and include a scheduled time frame that follows inventory preparation from its initial development through to final reporting in any year. It should contain an outline of the processes and schedule to review all source categories.

The QA/QC plan is an internal document to organize, plan, and implement QA/QC activities. Once developed, it can be referenced and used in subsequent inventory preparation, or modified as appropriate (i.e. when changes in processes occur or on advice of independent reviewers). This plan should be available for external review.

In developing and implementing the QA/QC plan, it may be useful to refer to the standards and guidelines published by the International Organization for Standardization (ISO), including the ISO 9000 series. Although ISO 9000 standards are not specifically designed for emissions inventories, they have been applied by some countries to help organize QA/QC activities.

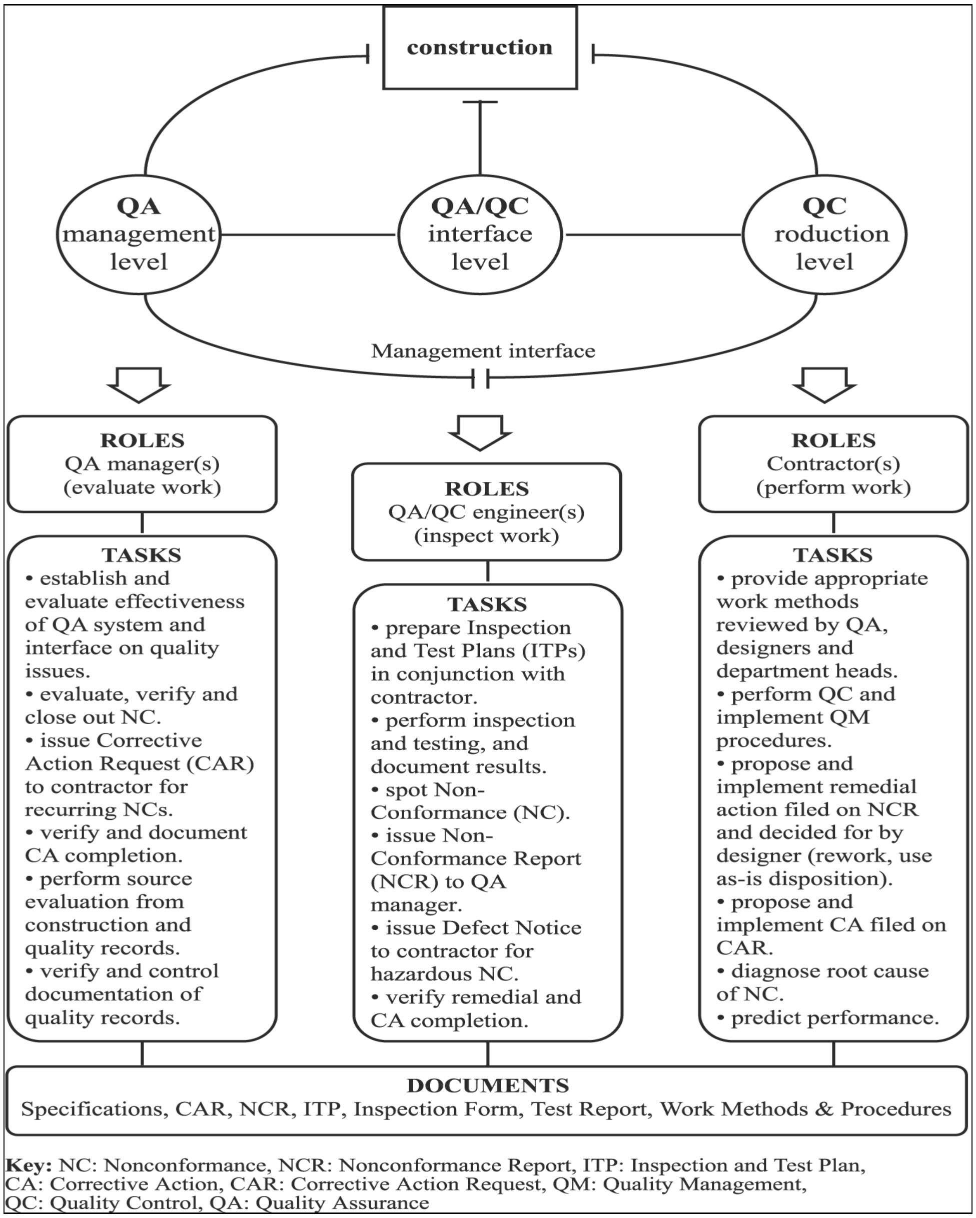


Figure 2.2 – QA / QC plan (practical example) [5]

2.5.1. ISO AS A DATA QUALITY MANAGEMENT SYSTEM [6]

The International Organization for Standardization (ISO) series program provides standards for data documentation and audits as part of a quality management system. Though the ISO series is not designed explicitly for emissions data development, many of the principles may be applied to ensure the production of a quality inventory. Inventory agencies may find these documents useful source material for developing QA/QC plans for greenhouse gas inventories. Some countries (e.g. the United Kingdom and the Netherlands) have already applied some elements of the ISO standards for their inventory development process and data management.

The following standards and guidelines published under the ISO series may supplement source category-specific QA/QC procedures for inventory development and provide practical guidance for ensuring data quality and a transparent reporting system.

- ISO 9004-1: General quality guidelines to implement a quality system.
- ISO 9004-4: Guidelines for implementing continuous quality improvement within the organization, using tools and techniques based on data collection and analysis.
- ISO 10005: Guidance on how to prepare quality plans for the control of specific projects.
- ISO 10011-1: Guidelines for auditing a quality system.
- ISO 10011-2: Guidance on the qualification criteria for quality systems auditors.
- ISO 10011-3: Guidelines for managing quality system audit programs.
- ISO 10012: Guidelines on calibration systems and statistical controls to ensure that measurements are made with the intended accuracy.
- ISO 10013: Guidelines for developing quality manuals to meet specific needs.

2.6. Final considerantions

Companies in the future are increasingly giving importance to its control and quality management, so they are always ahead in their field and that more are in line with the standards, more and more rigid, of a Europe that tend to be more and more global.

Having good systems of quality assurance is increasingly essential for companies where the largest of each branch, as seen by the firm with the author worked with, being no longer sufficient to have a quality department, but a mini-company associated with parent company, which deals only with these issues.

Quality is increasingly a very important word in everyday construction companies. No matter only just makes quickly and with low cost, quality is increasingly valued and the trend is to take on an increasing importance.

3
CONCRETE

3.1. MATERIALS AND PARTS

3.1.1. GENERAL

This entire chapter will explain the main parts of all the production line, used materials, and references to some tests of the concrete. Will be done references to the TS (Technical Specifications) and to STS (Special Technical Specifications), but of course these two documents will not be putted here. It's only references to some values and ideas there are referred there.

The materials used in the production of concrete shall reasonably guarantee its required properties, primarily strength and durability, determined by optimal methods. Requirements on these materials are subject to the Act No.90/1998, of the codes of Slovak law.

Suitability of all concrete components shall be verified by qualifying tests. Use of the components shall be approved by the Provider in accordance with stipulations of Part 0 of Technical Specifications (TS).

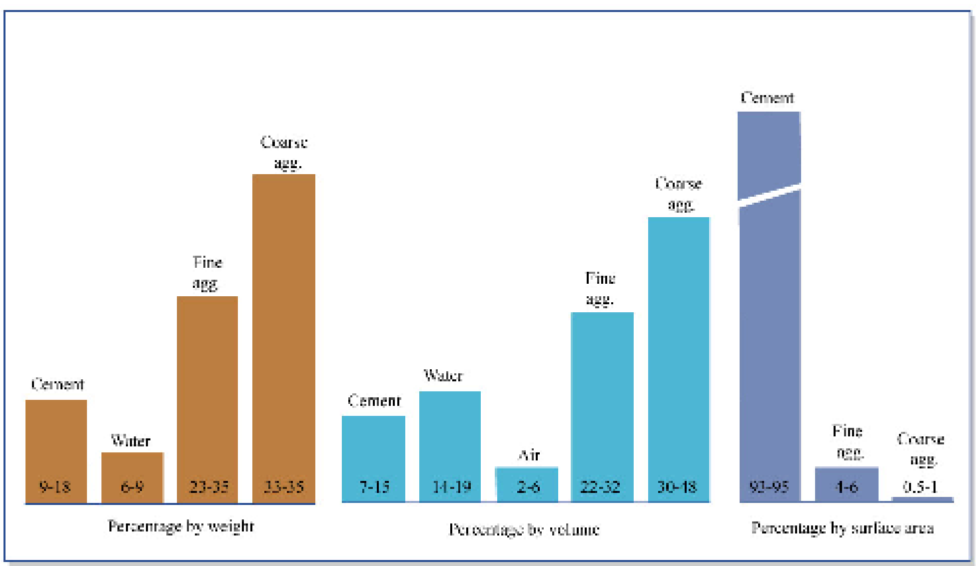


Figure 3.1 – Concrete composition (%) [7]

The essential requirements are specified in STN EN 206-1. The composition of concrete shall consider any special requirements of the concrete components and of the concrete itself in respect of the designed structure, aggressiveness of its ambience and other requirements included in the design documents.

Special requirements applicable to pumpcrete (pumpable concrete) guaranteeing good pumpability are included in Section 2.12 of TS.

3.1.2. Cement

The type and/or class of cement for the individual concrete types are specified in the following standards:

- STN EN 206-1, STN 73 2400,
- STN 73 2400; for prestressed concretes only Portland cements may be used,
- STN 73 1210 or STN EN 206-1 applies to the specification of cement types used in concretes for aggressive chemical environments,
- The requirements for cement to be used in special structures shall be specified in the design documents pursuant to STN EN 197-1, unless shown in Part 15 or in parts of the TS covering the individual structures.

The minimum cement contents are specified in STN EN 206-1. Higher contents may be prescribed by the TS or by the Special Technical Specifications for special structures or special technologies. The recommended maximum types and contents of cement in waterworks grade concrete are specified in STN 73 1210.

3.1.3. Aggregate

To aggregates the applicable stipulations of STN 72 1512, STN EN 932-1 to 6, STN EN 933-1 to 10, STN EN 1097-1 to 8 and other standards (limestone aggregate, dolomitic aggregate, etc.) shall apply. Special requirements applicable to the individual types of concrete are included in the following standards:

a) STN 73 2400, or STN P ENV 13670-1 or STN EN 206-1, or EN 12620,

b) STN 73 2401 – prestressed concretes,

c) STN 73 1210 – watertight durable concrete and special concretes.

Fine aggregate for structures in Class 3 aggressive environments shall contain max. 1 wt. % of mica.

Reactivity tests of aggregate with bases shall be carried out in accordance with STN 72 1160 and STN 72 1179.

Aggregate blends are designated as follows:

- Continuous gradation blends containing several fractions,
- Discontinuous gradation blends, usually containing only two fractions.

Concrete made with continuous gradation aggregate is less susceptible to separation, mainly in the consistency grades S3 and S4 (STN EN 206-1: 2002, Table 3). Concrete made with discontinuous gradation aggregate, with the finest grain of the coarser fraction being four times the size of the largest grain in the finer fraction (i.e. a blend combining e.g. the 0/4 and 16/22 fractions, where 16 : 4 = 4) is slightly denser and stronger but the mix is more susceptible to separation.

Largest grain sizes are specified in STN EN 206-1. The requirements of aggregate composition of impermeable and durable concretes are specified in STN 73 1210.

3.1.4. WATER

Water shall comply with provisions of STN EN 1008. The dosage of water shall depend on the specified water/cement ratio.

The water should be clean and not be modified with any additive.

3.1.5. ADMIXTURES

Admixtures are used to obtain optimal or special properties of the concrete mix and concretes. Their application shall be verified by qualifying test of the concrete. Admixtures may only be used with certificates of homologation.

Plasticizers and superplasticizers shall comply with STN 72 2321 or with STN EN 934-2.

Aerated concrete is produced with air entraining agents conforming to the requirements of STN 72 2322, usually applied in combination with a plasticizer to improve efficiency by generating large numbers of air bubbles sized below 0,1 mm and thus reducing the spatial distribution factor of pores. Their mutual ratio and optimal percentages shall be verified by qualifying tests. Combinations containing a superplasticizer reduce the efficiency of air entraining agents, depending on the mix composition (e.g. in the presence of a deforming agent); therefore in such cases high-quality air entraining agents, characterized by a low pore distribution factor (below 0,15 mm) are generally recommended to prevent increase of this factor in concrete to above 0,20 mm.

Other types of admixtures:

- Setting accelerators,
- Retarders,
- Improvers of water tightness,
- Water freezing point reducers,
- Stabilizers of concrete mix properties,

Such admixtures shall be used in accordance with this Section. The maximum content of chlorides is specified in Section 2.7 of the TS. Imported admixtures shall comply with applicable foreign standards or specifications and shall be incorporated in the list of approved admixtures.

In cases of previous practical experience with specific combinations of domestic and imported admixtures documentation of their suitability is very important. Combinations of admixtures shall be verified by qualifying tests.

3.1.6. ADDITIVES

Additives may be used in the concrete mix in amounts causing no reduction of durability of the concrete or corrosion of the reinforcing steel.

The stipulations of STN 73 2400 or STN P ENV 13670-1 (STN 73 1210 for impermeable and durable grade concretes) are applicable. Fly ash shall comply with STN EN 450 and STN 72 2065. The requirements on ground limestone are specified in STN 72 1220. The suitability of blast-furnace slag shall be verified by tests and shall be approved by the Provider.

3.1.7. CHLORIDES

The stipulation of STN EN 206-1: 2002, Section 5.2.7 of the TS are applicable for the highest contents of chlorides in concrete. The content of chlorides in concrete, expressed by percentage of chloride ions to the weight of cement shall not exceed values specified in Table 10 of TS. The content of chlorides in concrete is determined as the sum of values of chlorides in individual concrete components. For structures with steel reinforcement or other metal inserts the category C1 0.2 shall apply i.e. the highest content of chloride ions to the weight of cement is 0.2%. For structures with prestressed reinforcement the category C1 0.1 shall apply i.e. the maximum content of chloride ions to the weight of cement is 0.1%.

3.1.8. SULPHUR

The highest contents of water-soluble sulphur compounds in the concrete mix (expressed as SO_3) shall not exceed 4% by weight of cement, understood as the sum of SO_3 contents of all mix components.

3.1.9. WATER / CEMENT RATIO

Maximum water / cement ratio values for various aggressiveness levels of the environment are specified in STN EN 206-1: 2002, Table F.1 and supplemented with more detailed requirements for the individual structural concrete types, considering the environmental aggressiveness, in Part 15, Annex 1 of the TS.

3.1.10. CONSISTENCY

Unless specified otherwise by the TS, STN EN 206-1 recommends S3 or F3 consistency of the concrete mix to achieve proper compacting and the required properties of concrete.

Aerated concreted shall be prepared with consistencies enabling optimum aeration and low transport loss of entrained air. S3 or S4 mix consistencies are prepared with improved air entraining agents, or in accordance with producer instructions (e.g. those which apply to aerated pumpcrete).

3.1.11. TEMPERATURE

The temperature range of wet concrete is specified in STN EN 206-1: 2002.

Production of aerated concrete should take the fact in account that temperature influences the efficiency of air entraining agents. These increased amounts of the admixture are required to maintain the volume of entrained air which decreases with increasing temperature.

In Slovak case this parameter is highly important because of the low temperatures registered in that country in some months of the year.

3.1.12. PUMPCRETE (PUMPING GRADE CONCRETES)

The following conditions are recommended for good pumpability:

- Continuous gradation of aggregate in the recommended range of fractions,
- Largest grain of the aggregate should not exceed one third of the pump pipe diameter, and the grains should be suitably shaped (round grains, not oblong),
- The combined amount of cement and filler (i.e. fine aggregate up to 0.25 mm) should be 370 to 460 kg/m3, as bellow this range increased clogging may appear while higher amounts result in decrease mix mobility and increased pump pressure,
- Superplasticizers (if any) should be added to the concrete mix immediately before pumping to fully utilize their effect, which is short duration and must be specified by the producer. For this purpose the mixer truck shall have suitable metering equipment available, and thorough agitation (for at least 10 minutes) must be ensured. The process shall be verified in a site pilot test, and may only be applied with approval of the Engineer.

3.1.13. DURABILITY

The requirements of durability of the concrete, related to environmental conditions of the structure are specified in STN EN 206-1.

Special requirements of concretes are specified in the design documents or in the STS as applicable in the given conditions.

Requirements of resistance of structural surfaces against frost and chemical defrosting agents are specified in Part 15 of the TS or in the design documents. They are expressed in numbers of cycles in the STN 73 1326 resistance test, and by failure values.

3.1.14. PROPERTIES OF CURED CONCRETES

The requirements of fresh and cured concrete properties are specified in STN EN 206-1: 2002, Chapters 5.4 and 5.5.

The relation between the grade and strength of concretes according to STN EN 206-1: 2002, Table 7 (column A), STN 73 2400: 1986, Table 1 (column B), and STN 73 6206 (column C):

Table. 3.1 – Classes of concrete

A (According to Eurocode 2)	B (According to P18-305)	C (Kgf/m2)
	B 5	(80)
	B 7,5	(105)
C8/10 =	B 10 =	(135)
	B 13,5 =	(170)
C/12/15 =	B 15	
C/16/20 =	B 20 =	250
C/20/25 =	B 25	
	(B 28) =	330
C/25/30 =	B 30	
	B 35 =	400
C/30/37		
	B 40	
C35/45 =	B45 =	500
C/40/50 =	B50	
C/45/55 =	B55 =	600
C/50/60 =	B60	
C/55/67		
C/60/75		
C/70/85		
C/80/95		
C/90/105		
C/110/115		

3.1.15. Specification of concrete [8]

For specification of concrete STN EN 206-1, Chapter 6 of this document shall apply.

To project designer is the specifier responsible for concrete specification. The building contractor particularizes the specification of concrete. The engineer shall approve the specification of concrete.

The concrete shall be specified as the type-dependent concrete corresponding to the common classification defined in Chapter 4 and to the requirements of Sections 5.3 to 5.5 or as the concrete of specified composition, defined by the concrete composition. Both the type-dependent concrete and the concrete of specified composition are based on the results of qualifying tests.

The type-dependent concrete shall be specified by the essential requirements according to Section 6.2.2 (strength class, exposure class, highest nominal upper limit of aggregate fraction, category of chloride content, etc.) and if required, by the supplementary requirements pursuant to Section 6.2.3 (cement type, temperature of fresh concrete, strength growth, etc.).

The specified composition concrete shall be defined by the essential requirements in compliance with Section 6.3.2 (content, type and class of cement, water-cement ratio or consistency, type and quantity of admixtures, etc.) and by the supplementary requirements according to Section 6.3.3 if required.

Changes in the concrete specifications shall require approval of the Engineer who may order additional qualifying tests for the purpose. This stipulation does not apply to modifications of the quantity of individual concrete components for production regulation purposes.

3.1.16. Delivery and storage

- Raw materials for concrete mix production

To the storage of raw materials for concrete mix production the requirements of STN EN 206-1 apply.

- Concrete structural elements.

Concrete structural elements are delivered with certificates of homologation, including documents in proof of fulfillment of technical requirements by the elements as specified in the design documents and some Sections of TS. Documents accompanying the delivery of bridge components shall, in addition to the requirements of STN 72 3000, show the following:

- Class (grade) and other properties of the concrete,
- Accuracy class of the structural element,
- Designation of the applicable technological instructions,
- Heat insulation measures depending on the season,
- Documents in proof of compliance of the product quality with the technological instructions, mainly the following:
- Test protocols of the concrete,
- Documents certifying the quality of steel in concrete and prestressed concrete elements,
- Information on prestressing conditions, grouting, anchoring, etc. of prestressed elements.

Elements stored at the site shall be protected from damage and contamination. Elements in transport and storage shall be protected against adverse weather conditions.

3.2. Performance of works [9]

3.2.1. Production of concrete

Requirements of concrete production to be accomplished by experienced professionals at the necessary level of quality are specified in STN EN 206-1. They are mandatory for both transit – mixed concrete production plants as well as for site mixing plants supplying mix for the production of prestressed concrete elements and structures with increased qualitative requirements, e.g. bridges.

Storage requirements are specified in STN EN 206-1.

Production plants storing admixtures shall be equipped with homogenizing tanks situated in the immediate vicinity of the concrete mixer and enabling continuous mixing of the admixtures, e.g. by means of electric mixers. The volume of the homogenizing tank should be equivalent to al least the concrete volume produced in a single day. Admixtures stored in drums shall be mixed (homogenized) before use.

Stockpiles of aggregate situated in plants producing concrete all year shall be protected from snow by roofing or other means of coverage, unless kept in heated bins.

Accuracy of methods equipment and dosage of components is specified in STN EN 206-1.

Mixing methods of concrete mix and specifications of concrete mixers are defined in STN 73 2400 and in STN EN 206-1.

The production of hot concrete mix shall meet the specifications of STN 73 2400.

Figure 3.2 – Concreting Central

3.2.2. Transport of concrete

Figure 3.3 – Supply in the construction site

Transport must not reduce the quality of concrete. The longest transport times of concrete, depending on ambient temperature and on the cement type are specified in STN 73 2400: 1986, Table 4, or in STN P ENV 13670-1. Data applying to the concrete mix are specified in STN 73 2400, or STN EN 206-1 and STN P ENV 13670-1.

3.2.3. Pouring, compacting and curing of concrete

3.2.3.1. Pouring and compacting

Concrete shall be poured in the presence of a competent professional as specified in STN EN 206-1. The same standard specifies the conditions of pouring.

The process of concreting of structures and grouting of construction joint is specified in STN 73 2400: 1986, Chapter 10, or STN P ENV 13670-1.

Prior to commencement of concreting works the requirements specified in the TS, in the applicable standards and in the design documents shall be controlled in respect of the structure and of its constructional specificities. In particular, the Contractor and the Engineer shall control the following:

- Fulfillment of all requirements in respect of quality of concrete, performance of work and adherence to dimensional tolerances by the parts of the structure built before commencement of the present works,
- Due presentation and approval of the results of qualifying tests and of the composition of the designated mix, including the information whether the mix shall be supplied by the mixing plant specified in the qualifying test report,
- Approval of technological instructions or technical conditions (in cause of special concreting works), or of the technological process to be applied in the works, including identification of the reserve mixing plant selected to supply mix of the same composition in case of interruption of mix deliveries for structures requiring continuous pouring,
- Submission of documents in proof of the quality of reinforcing steel, documents and/or tests in respect of splicing of reinforcement steel,
- Provision of conditions enabling proper treatment of the structure and execution of control tests and/or measurements,
- Fulfillment of requirements specified in STN 73 2400 or STN P ENV 13670-1, special requirements of design documents and/or general specifications of Part 0 of TS, mainly the following:
    a) Formwork dimensions and placement of reinforcement steel,
    b) Removal of dust, sawdust, snow, ice and residual tying wire from the formwork and base,
    c) Treatment of the set concrete in constructions joints,
    d) Wetting of the formwork or base,
    e) Formwork strength parameters,
    f) Control openings,
    g) Sealing ability of the formwork to prevent leakage of cement paste,

h) Surface treatment of the formwork,

i) Removal of surface impurities from the reinforcing steel preventing bonding of the concrete (e.g. oil, ice accretion, paint, loose, rust),

j) Distance pieces (location, stability, cleanness),

k) Measures to provide for efficient transport, compacting and treatment of the concrete to required consistence,

l) Professional qualification of employees,

- Control and verification of the following parameters shall be carried out in respect of transport of the concrete mix, its pouring, compacting and curing:

  a) Homogeneity of the concrete in transport and at the time of pouring,

  b) Uniform spread of concrete in the formwork,

  c) Uniform compacting under avoidance of segregation,

  d) Maximum height enabling throwing of the concrete,

  e) Thickness of the concrete layer,

  f) Pouring speed and filling of formwork in respect of pressures generated by the concrete,

  g) Workability time of the concrete, considering the mixing time or site delivery time,

  h) Special measures to be applied in winter or hot weather concreting,

  i) Special measures applying to extreme climatic conditions, e.g. torrential rain,

  j) Specification of construction joints (locations),

  k) Treatment of construction joints before setting of the concrete,

  l) Surface treatment as specified by the design documents, by the TS or by the Engineer,

  m) Concreting method and time of curing under consideration of the ambient environment and strength development,

  n) Prevention of damage to the freshly placed concrete by vibration or impacts.

3.2.3.2. Curing of the concrete

Curing of the concrete is specified in STN EN 206-1. Curing in cases where the applicable principles were not included in the quoted standard shall be accomplished in accordance with the respective stipulations of STN 73 2400: 1986, Chapter 11, or STN P ENV 13670-1. Minimum curing times in days for exposure class for individual rates of concrete strength growth are shown in STN P ENV 13670-1.

Curing with the use of coatings creating vapor-proof protective layers shall comply with STN 73 6180. Any imported materials to be used shall be verified and included in the list of approved materials.

3.2.4. PRECAST ELEMENTS

3.2.4.1. Production of precast elements

Precast elements shall be produced on the basis of working documentation (shop drawings), comprising mainly shape and reinforcement drawings, static calculations and further details. Such documentation shall be prepared when precast elements are to be produced on the basis of other than the technological documentation of the producer.

Working documentation (detail design) shall be prepared under consideration of specified tolerances (accuracy class) of the production and erection dimensions, of permitted deviations in the placement of reinforcing steel, of requirements relating to aggressive environments, general appearance and requirements of surface structure and/or surface treatment of the part.

Elements designed for use in road construction shall be supplied by production plants having a quality management system introduced, or by production plants issuing product certificates. The same shall apply to prestressed as well as post-stressed elements.

In cases when fulfillment of this requirement is temporarily impracticable, detailed conditions and principles of quality control and acceptance system of the elements shall be defined in the STS and included in the Contract.

The requirements of STN 73 3000 apply to the production, control and delivery of structural elements made from compacted plain, reinforced and prestressed concrete, along with the related standards STN 73 2401 and STN EN 206-1 determining the properties of the concrete.

Specials requirements of prestressed and post-stressed concrete elements are specified by Part 15 of the TS or by the design documents.

The properties of concrete designed for the individual types (specified by purposes of use) of elements are shown in Part 15 and further applicable parts of the TS.

3.2.4.2. Properties of concrete structural elements

Physical – mechanical properties of the concrete and resistance of concrete elements to the designated environment shall be in accordance with their required durability and service life, as specified in the design documents. The same applies to other parameters and to the production of elements. Detailed requirements are shown in Part 15 of the TS or in other parts applicable to concrete structures.

Durability of structural elements in aggressive environments is evaluated in accordance with STN EN 206-1: 2002, Table 1. All concrete to be used in the production of elements designed to drain roads where defrosting agents are routinely used, or for channels and wells used to drain water-containing chlorides shall be NaCl resistant (Class 3 of aggressiveness) in accordance with Section 2.13.

Figure 3.4 – Structural element (bridge)

Elements lacking the required resistance may be protected by secondary measures against corrosion. The Engineer shall approve secondary corrosion protection. Structural elements shall show no surface cracks reducing their functional or static proficiency or their designed service life.

Fair-faced structural elements or elements exposed to the weather and showing surface haircracks wider than 0.1 mm are generally considered not resistant to water and chemical defrosting agents pursuant to Annex 1 of STN 73 1326: 1985, or to effects of gaseous environments.

The requirements of minimum coverage of reinforcing steel in precast elements from reinforced and prestressed concrete are specified in Part 15 of the TS as the lowest distance between the surface of the element and the nearest steel surface (stirrup). When sufficient coverage cannot be guaranteed, the Engineer thereof may approve reduced coverage with long-term secondary protection of specific elements or parts. The efficiency of the secondary protection (equivalent depth of concrete layer) shall de documented by the test results of producer.

The requirements of aggregate specified in Section 3.1.3. of this document may deviate in justified cases (e.g. production of thin-walled reinforced elements) by using, for example, max. 8 mm HDK aggregate.

Chemical substances used for stripping, surface protection and other purposes in the production, curing and erection of concrete structural elements shall be selected and applied in accordance with STN 72 3000 and with the following conditions:

The maintenance of structures built from precast elements must not be aggravated or precluded by the use of chemicals, e.g. impregnating agents to increase surface resistance, or of coatings and paints designed to extend service life of the concrete, etc.,

Subsequent technological adjustments, e.g. insulation, coupling with monolithic parts of the structure, etc. must not be precluded by the use of such chemicals.

3.2.4.3. Curing of elements

The stipulations of Section 3.2.3.2. of this text shall apply.

Hot curing of aerated concrete elements shall in all cases be verified in tests designed to define the conditions of curing (seasoning of the concrete mix, rate of increase and highest value of temperature, cooling rate, differential temperatures in the element, etc.) to prevent disruption of air bubbles and to ensure resistance of the concrete against NaCl as specified in Section 3.1.13. Resistance of hot cured elements to NaCl shall not be implied unless documented by qualifying tests.

3.2.4.4. Marking of elements

In addiction to marking specified by STN 73 3000 and the Act No. 90/1998, of the codes of law, elements to be used in load bearing structures and substructures of bridges shall show the identification number of the element permanently marked thereon at accessible positions. Should such marking be impracticable, a drawing showing the sequence of placement of the structural elements shall be prepared and presented to the Engineer.

3.2.4.5. Erection of structures from elements

Part 15 of TS, design documents and the STN applicable to the type of construction apply to the erection of structures from structural elements. Assembled above-ground structures shall be erected in accordance with the revised branch standard STN 73 2480.

Bridge structures shall be erected in accordance with technological instructions pursuant to Section 3.2.4.2. or with the specified assembling, grouting and prestressing conditions. Incorporation or assembly of structural elements shall require written approval by the Engineer, based on the following:

- Successful acceptance of the elements in the sense of Section 3.2.5., or submission of the product certificate of homologation,
- Satisfactory results of inspection of the structure or parts thereof designed for the placement or assembly of elements (results of control tests or of geodetic measurements, visual inspection, etc.) accomplished by the Engineer,
- Satisfactory results of control of documentation certifying the relevant materials and equipment and measures relating to the subsequent assembly.

3.2.5. Porous concrete

Porous concrete designed for purposes of drainage shall generally meet the requirements of STN 73 6124 and Part 6.1:2003 of the TS. Porous concrete produced in accordance with the quoted branch standard and Part 6.1 may also be used for other than the above-specified purposes.

When using porous concrete in monolithic or precast elements of auxiliary structures or parts thereof (e.g. replacement of fillets with layers protecting and draining bridge end abutments, etc.) the following principles apply:

- Immersion vibration shall be replaced by surface vibration, compacting, rolling or leveling to shape,

- Compression strength is the single key design parameter of the concrete; Class B5 requirements must be met after 28 days, controlled in specimens according to STN 73 6124,
- Void age of test specimens or of inbuilt concrete shall be at least 20%,
- Porous concrete to be used in structural elements designed to withstand freezing cycles shall be produced with air entraining agents for aerated jointing mortars. Void age of the mortar shall be 8 to 10%,
- The following concrete composition is recommended:
    - Fine (0/4) aggregate
    - HDK 8/16 aggregate
    - HDK 16/32 aggregate
    - Cement (PC, SC)
    - Water
    - Admixtures: as proposed by qualifying tests,
- Curing shall proceed in accordance with STN 73 6124,
- Control tests shall be carried out in accordance with STN 73 6124.

3.2.6. Climatic restrictions

The requirements of Part 15 of the TS apply to concrete structures.

Conditions of concreting at low or high ambient temperatures are specified in STN 73 2400, Chapter 12, or STN P ENV 13670-1, STN 73 1210 and STN EN 206-1.

3.2.7. Monitoring of deformation

Monitoring of deformation is specified in part of the TS covering the applicable roadwork structures.

3.2.8. Tolerances

The stipulations of Part 15 of the TS apply to tolerances of concrete structures.

STN 73 0280 applies to the dimensional and shape accuracy of concrete elements; in bridge applications the requirements of the quoted standard may be specified in more detail in the technological instructions of production of the elements.

Products of at least accuracy class 10 pursuant to STN 73 0220, Table 1, or STN 73 0210-1 may be used in cases where no accuracy class of elements was specified by the design documents or part 15 of TS.

The following maximum tolerances are permitted:

- Accuracy class 10 (all dimensions of precast concrete elements designed to drain surface water; straightness of the longitudinal axis in precast piles, concrete crash barriers),

- Accuracy class 9 (precast elements of bridge supports, noise barriers, concrete crash barriers, abutment and prop walls, underpasses and culverts, bridge fillets and parapets, waterworks structures, reinforced concrete bearing structures and other similar products),
- Accuracy class 8 (prestressed concrete elements of load bearing structures and bridge supports).

Design documents of elements shall specify no lower accuracy classes (i.e. excessive tolerances and lower quality) than shown under a), b) and c) above. Elements produced at variance with these requirements neither shall nor be used without approval of the Engineer.

The Contractor shall prepare technical and technological documentation (technological instructions) of production, and submit it for approval to the Engineer prior to commencement of production of precast elements for bridges and other important structural elements (including prestressed or post-stressed) for selected structures, specified in the STS. Such documentation shall include detailed technical conditions specifying the qualitative parameters, quality control system, permitted tolerances of production and assembly, curing methods and times, conditions of delivery, etc., and shall be incorporated in the Contract.

The above documentation shall be adhered to by both producers of structural elements and by the Contractor.

3.3. TESTING AND ACCEPTANCE

3.3.1. CONTROL AND TEST SCHEDULE (CTS)

Prior to commencement of works the Contractor shall elaborate the control and test schedule in terms of STN ISO-9000 – 9004 including table and frequency of the respective controls and tests of concrete components, fresh and hardened concrete, and individual structural elements. CTS specify the requirements and criteria of the applicable STN and TS which shall be met, as well as the quality control system and personnel responsible for the execution of the respective controls and tests.

Elaborating the control and test schedule for concrete and concrete structures the requirements of STN 73 2400, STN 73 2401, STN EN 206-1 and STN P ENV 13670-1 are considered to the scope determined by the Engineer with respect to the extent, demands, importance, and service conditions of the construction.

3.3.2. TYPES OF TESTS

The following tests of fresh and hardened concrete shall be performed in accordance with STN 73 2400, or STN P ENV 13670-1, STN EN 206-1 and provisions of the Act No.90/1998, of the codes of law:

- Qualifying tests,
- Control tests,
- Acceptance tests,
- Arbitral tests.

Figure 3.5 – Váhostav-SK field test

3.3.3. Qualifying tests

Qualifying tests are prescribed to demonstrate, by the Contractor, properties of fresh and hardened concrete and fulfillment of the requirements specified in STN, TS and STS.

The cube strength of the proposed concrete shall comply with STN 73 2400 or STN EN 206-1; for the equivalent concrete grade ranging from B 15 to B 60 (STN 73 2400: 1986) or C8/10 to C100/115 (STN EN 206-1:2002). Criteria for acceptance of qualifying tests are specified in STN 73 2400, Chapter 15 and STN EN 206-1, Annex A (normative). The parameters of other specified properties of the concrete mix and concrete should be specified in the conditions of qualifying tests.

In aerated concretes the following properties shall be subject to qualifying tests:

- Surface resistance of the specimen against frost and defrosting chemicals, tested in accordance with STN 73 1326 (other test methods may be used in agreement with the Engineer). Test specimens representing cuts from a 150 mm diameter cylinder, approximately 50 mm thick and 300 mm long shall be used. Test cubes of 150 mm edge length may also be used.

  Resistance shall be determined in concretes containing minimum air volumes pursuant to STN EN 206-1, Table F.1. The resistance parameter of concrete specimen shall exceed the value required by the design documents or by Part 15 of TS by at least 50% (e.g. when 75 cycles are required by design documents, the specimen shall resist 75 x 1.5 = 113 cycles).

- The cube (cylinder) strength shall be tested in specimens containing maximum air volume in the fresh concrete, with contents increased by 3% by volume against the requirements of STN EN 206-1, Table F.1.

Reports of the results of qualifying tests shall show at least the following (numerical) data:

- Cube (cylinder) strength of the concrete according to Sub-Chapter 3.3.3,
- Volume weight of the concrete and the designated mix,
- Consistency of the designated mix,

- Surface resistance of the concrete according to Sub-Chapter 3.3.3,
- Data on other properties of the concrete in accordance with STN 73 2400, STN EN 206-1, TS or STS (e.g. watertightness, impact strength, tensile strength, surface layer tensile strength, elasticity modulus, absorption, volume stability, abrasion resistance, incremental strength, coefficient of permeability in porous concretes, etc.).
- Data characterizing the components used to prepare concrete specimens for qualifying tests,
- Correction factors for non-destructive tests of concretes.

All parameters shall be certified by test protocols and evaluated, showing the applicable conclusions (statements of achievement of properties specified by the design documents and component suitability). The qualifying test report shall include instructions applicable to regulation of the concrete mix composition by combining various admixtures, as well as the type and amount of control tests, unless already specified by the TS, STS or by the STN EN 206-1 or when they differ from the standard values.

Reports of the qualifying tests shall be submitted for approval to the Engineer according to stipulations of Part 0 of TS.

Prior to commencement of concreting the designated mix composition shall be verified and adjusted by a trial run performed in actual site conditions. This shall mainly apply to aerated concretes.

3.3.4. Control tests

Suitable accessories enabling sampling from storage, silos and bins shall be available. Respective sampling shall be performed in accordance with the requirements of applicable STN, TS, (STS) and according to the directions of the Engineer.

3.3.4.1. Concrete

Production quality and conformity shall be controlled according to STN EN 206-1: 2002, Chapter 8, STN ENV 13670-1 and STN 73 2400, in the range predetermined by the Control and Test Schedule.

Conformity of the concrete strength with grade-dependent requirements as specified by the quoted standard shall be controlled and evaluated in “units”, characterized as follows:

- Same concrete type,
- 450 m^3 maximum volume according to STN EN 206-1,
- One week maximum production time according to STN EN 206-1.

The structure shall be divided prior to commencement of concreting work into “units” by volumes as shown above. Detailed division may follow in the course of concreting works.

The number of compressive strength control tests on cubes or cylinders is specified in STN EN 206-1 (STN 73 2401 for structures from prestressed concrete).

Tests of watertightness shall be executed in accordance with STN EN 206-1, Table F.1 and Table 17 in numbers corresponding to individual conditions of the structure, the concreting process, concrete properties, etc. and in accordance with the requirements specified in the STS. This test in not required when the surface resistance test of the concrete against frost and defrosting chemicals is simultaneously executed in the sense of this chapter.

The number of surface resistance tests against frost and defrosting chemicals shall be as specified by the STS but at least one test for each 50 m^3 of concrete of the same composition, or for one month of concreting of the same structure (at least one test per bridge) shall be made. Conformity shall be deemed satisfactory when the sample (control sample or specimen sampled from the structure) resistance was found not below the value specified in the design documents.

Conformity tests for strength, consistency, water/cement ratio, air contents of fresh concrete, watertightness and content of chlorides are specified in STN EN 206-1.

3.3.4.2. Concrete elements

Prior to commencement of production of precast elements the Contractor shall identify, sufficiently in advance, the producer to the Client and inform the latter of the time and location of production.

The Engineer is entitled to control the production and qualitative level of materials as well as the product parameters, results of tests, the overall control system of the producer, level of quality of the concrete mix production equipment and the production technology (processing of concrete, curing, heating, etc.).

In addition to the requirements specified in STN 72 3000 applicable to all elements the stipulations relating to the tests of concrete and its components, reinforcement, prestressing, grouting, etc. of the TS shall apply. The method and scope of the concrete quality control in bridge elements are also shown in more detail in the technological instructions of the producer applicable to the production and erection of such elements.

Figure 3.6 – Concrete element (support wall)

The Engineer is entitled to determine in the STS (incorporated in the Contract) the type and number of control or acceptance tests, depending on the importance of individual elements. The same shall apply to the definition of requirements for tests of completed elements.

Tests of dimensional and shape accuracy of elements shall be made in accordance with STN 73 0280. The requirements may be respecified in more detail in the technological instructions of production.

3.3.4.3. Non-destructive tests of concrete

This section covers in particular the non-destructive tests of concrete in relation to structures and structural elements. Tests using specimens shall be made for calibration and detailed specification purposes of the test methods.

Non-destructive concrete tests in structures and elements are usually carried out in the following cases:

- When no control tests were carried out as required by STN 73 2400 or STN P ENV 13670-1, STN 73 2401, STN EN 206-1, by the design documents, by the technological regulations of production and assembly or by this part of TS, or when such tests were carried out to an insufficient range or in case of doubt of the quality of execution of the control tests by the Contractor,
- When the results of the control tests showed that the concrete failed to meet the qualitative parameters required by applicable documentation,
- Supplementary identification of inadequacies in the production technology, transport, compacting or curing of the concrete, mainly under adverse climatic conditions,
- Appearance of structural defects influencing the static integrity of service life of the structure,
- Reconstruction or change of documentation resulting in higher effective loads,
- Verification of efficiency of certain technological measures (e.g. addiction of admixtures), of concrete homogeneity or of increased values of specific parameters (e.g. compressive strength) under actual site conditions,
- Orientation verification of the concrete strength.

Non-destructive tests of concrete shall be carried out in accordance with STN 73 2011 and STN 73 1370, as well as with other related standards.

Non-destructive tests of concrete using the methods No. 1, 2, 3, 4, 5, and 6 (see below) may only be carried out by qualified staff. In cases of arbitration testing the non-destructive tests shall be executed by an accredited testing institute or by an independent professional institution in compliance with Part 0 of TS.

The Engineer may determine in the STS further mandatory parameters of concrete quality in the structure or element in excess of requirements of the applicable standards and regulations, including nominal values e.g. of the homogeneity or volume weight of the concrete. In such cases the design documents shall specify in advance the control and testing conditions and methodology, with preference given to certain non-destructive test methods.

Non-destructive test methods of concretes:

Review of main test methods:

- Rebound test – Schmidt impact hammers

- Local failure test
- Ultrasonic pulse test
- Radiometric and radiographic tests
- Location of reinforcement by electromagnetic induction test
- Tensile strength tests in the surface layer, layer – base bond strength tests

Test methods:

- Test using rebound methods with Schmidt impact hammers are carried out in accordance with STN 73 1373 to determine the strength and homogeneity parameters of concretes and mortars. In addiction to hardness testing equipment specified in the quoted standards, type Schmidt P and PT pendulum hammers might be used for the above purposes, using a general calibration factor shown in the documentation of the testing equipment.

  STN 73 1373 is supplemented as follows below in respect of preparation of all test positions in all types of hardness testing equipment. Is also possible to find these tests according to the European Norm EN 12504 parts 1, 2, 3 and 4.

  Remove the concrete surface layer in the test position (including any carbonated or otherwise deteriorated surfaces) by dry grinding until the concrete structure is clearly visible, preferably using an air-cooled planar diamond grinder. When using carborundum grinders care must be taken to prevent damage to the concrete surface, e.g. by overheating, and to obtain an even and smooth surface.
- Local failure tests are used to determine strength parameters of concretes (by prior agreement of the Contractor with the Engineer, whereby the agreed quantity of concrete test specimens shall be prepared in the course of works from the same designated mix as used in the structure in order to determine the calibrating factors).
- Ultrasonic pulse tests are carried out in accordance with STN 73 1371 and STN 73 2011 to determine the strength, homogeneity, compacting, structural changes, defects and failures of the concrete in structures.
- Radiometric and radiographic testing is executed in accordance with STN 73 1375 and STN 73 1376 to determine the volume weight and humidity of the concrete, area, shape and amount of reinforcing steel in the structures made from plain, reinforced and prestressed concretes, and to identify defects and faults.
- The electromagnetic induction test is carried out according to STN 73 2011, Annex 1, to determine the location, diameter and amount of reinforcing steel and thickness of its coverage in concrete structures and elements. The results approved by the Engineer may be verified by direct measurement of the required parameters by destructive probing after removal of the concrete cover.
- The surface layer tensile strength test method according to STN 73 1318, Annex 2, is also considered a non-destructive test (similarly to the local failure test) as the concrete surface is only affected to the approximate depth of 5 – 10 mm, depending on the concrete properties. The test results are used to verify the surface layer tensile strength parameter which is of importance for certain subsequent technological steps (establishment of insulation layers, coatings, etc.).

When appropriate, the above test may, by agreement of the Engineer and the Contractor, be executed in accordance with STN EN 1015-12, STN 73 2577 or STN 73 1344. The method is also used to verify the adhesive power of paint, protective coating, cement finish, mortar, lining and other surface treatment to the concrete surface of structures and structural elements.

The details (drilling, influence of humidity of the concrete, of the ambient temperature, method of evaluation of the measured values, etc.) of the test methods to be used shall be agreed in advance between the Engineer and the Contractor.

Any damage or change of the surface of structures in the course of the above tests shall be repaired. The method and time of repair shall be agreed in advance between the Engineer and the institution or natural person appointed to carry out the repair. The selected method of repair of the structure surface shall, in principle, not reduce the service life or impair the appearance and/or utility value of the structure. The repaired place shall have the same service life as the repaired structural element itself.

3.3.5. Acceptance and approval of works

3.3.5.1. Acceptance of concrete and of the structure

The principles of acceptance of the individual components of the concrete mix, of the designated mix itself and of the concrete are described in Sections 2 and 3 of Part of TS and in the applicable standards, in particular in STN EN 206-1, STN 73 2400 or STN P ENV 13670-1, STN 73 2401 and STN 73 1210.

Acceptance and control shall be accomplished continuously by the Engineer in accordance with criteria specified in the individual chapters of the applicable STN and of the TS, pursuant to scope of controls and eventual acceptance tests scheduled by him.

To the approval and acceptance of concrete structures the requirements of Part 15 of the TS shall apply.

3.3.5.2. Approval of elements

In absence of certified Quality Assurance Procedures, precast elements of bearing structures and bridge substructures abutment and prop walls of other precast elements specified by the Engineer prior to commencement of their production shall be approved by the latter at the production unit.

The Contractor shall submit the certificate of homologation and completeness of the individual precast elements for approval. The certificate shall include documents in proof of the concrete quality, of the results of conformity control in accordance with STN EN 206-1, of the reinforcing steel, prestressing, grouting, quality of any surface treatment, control and evaluation of dimensional tolerances, of the quality of jacking anchorage, etc. The process of approval of the precast elements shall be recorded in the site log. Any elements not accepted shall be distinctly marked and shall not be delivered or built in. unless the elements were accepted at the production plant, acceptance shall be carried out at the site.

Precast elements of bridge bearing structures, or those selected by the representative of the Engineer, shall be inspected visually for possible changes (mainly due to transport, storage and handling) prior to issuance of the approval of use.

Unless specified in more details by Part 15 of the TS, the Contractor shall measure the deflection and other statically important geometrical parameters of beams and similar elements at the production unit before delivery in accordance with the design documents or technological production regulations. The measured values shall be submitted to the Engineer at acceptance of the elements.

3.4. FINAL CONSIDERATIONS

Concrete is the most important element in this type of road works. In all works of art he is present, and has enough specific requisites for each of its uses. This chapter presented fairly general technical specifications for its correct use in any type of work. Is an element that cannot be overlooked its quality control, because it often depends on all the support of any work. Requires a lot of care both in their manufacture, use of correct materials in correct quantities, transport and then application work. There are numerous tests to be able to control the quality control tests on the fresh concrete in the first instance and in-situ, and then testing the hardened concrete, which are laboratory and greater complexity.

In the following chapters will refer to some of these tests, including tests in-situ, for which will be set up check-lists, in order to get to a better control of their quality before they are implemented on site. Are also referred some of the tests in the laboratory, although this branch did not have the desired access, so he could perform well there, better control of its features.

4
QUALITY CONCRETE TESTS

4.1. GENERAL

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer. QC is similar to, but not identical with, quality assurance (QA). QA is defined as a procedure or set of procedures intended to ensure that a product or service under development (before work is complete, as opposed to afterwards) meets specified requirements. QA is sometimes expressed together with QC as a single expression, quality assurance and control (QA/QC).

In order to implement an effective QC program, an enterprise must first decide which specific standards the product or service must meet. Then the extent of QC actions must be determined (in example, the percentage of units to be tested from each lot). Next, real-world data must be collected (for example, the percentage of units that fail) and the results reported to management personnel. After this, corrective action must be decided upon and taken (for example, defective units must be repaired or rejected and poor service repeated at no charge until the customer is satisfied). If too many unit failures or instances of poor service occur, a plan must be devised to improve the production or service process and then that plan must be put into action. Finally, the QC process must be ongoing to ensure that remedial efforts, if required, have produced satisfactory results and to immediately detect recurrences or new instances of trouble.

Essentially, quality control involves the examination of a product, service, or process for certain minimum levels of quality. The goal of a quality control team is to identify products or services that do not meet a company's specified standards of quality. If a problem is identified, the job of a quality control team or professional may involve stopping production temporarily. Depending on the particular service or product, as well as the type of problem identified, production or implementation may not cease entirely.

Usually, it is not the job of a quality control team or professional to correct quality issues. Typically, other individuals are involved in the process of discovering the cause of quality issues and fixing them. Once such problems are overcome, the product, service, or process continues production or implementation as usual.

Quality control can cover not just products, services, and processes, but also people. Employees are an important part of any company. If a company has employees that don't have adequate skills or training, have trouble understanding directions, or are misinformed, quality may be severely diminished. When quality control is considered in terms of human beings, it concerns correctable issues. However, it should not be confused with human resource issues.

Often, quality control is confused with quality assurance. Though the two are very similar, there are some basic differences. Quality control is concerned with the product, while quality assurance is process–oriented.

Quality control is the branch of engineering and manufacturing which deals with assurance and failure testing in design and production of products or services, to meet or exceed customer requirements.

4.2. IMPORTANCE OF QUALITY CONTROL OF FRESH CONCRETE

The final quality of a concrete structure depends both on the control of their properties in fresh and in its hardened state. Mistakenly, many times, the control technology is limited to tests of compressive strength (hardened concrete), as this parameter alone could ensure the quality of the concrete

The concrete, and even their marketing, to be governed exclusively by the resistance characteristic (fck) may not have such properties that lead to good performance and a satisfactory durability. Thus, other aspects must be taken into consideration when is important to get real quality, including control of the properties of fresh concrete, as these are fundamental to the implementation of structures and properties of hardened concrete structure. [10]

The control of fresh concrete can not rely exclusively on test Abatement Stem Cone (Slump Test), as this methodology measures only one parameter of the mixture which is its consistency. Other features also responsible for the quality of concrete should be checked in the material before its hardening process, among which one can cite the workability, cohesion, segregation, exuding the air incorporated as the most important.

The quality of the finished structures is closely linked to the quality of fresh, determining whether or not the presence of failures of concrete, segregation, exudation and voids in concrete.

4.2.1. WORKABILITY

Working properly in every situation of concrete is essential to obtain a final product quality. The workability is a property of freshly mixed concrete which determines the ease and homogeneity with which the material can be mixed, cast, dense and over.

Obtaining a concrete with adequate workability, contrary to what people think, does not depend solely on the amount of water used. Not always the amount of water in the mixture leads to a greater workability and can often lead to exudation, segregation, or simply to an increase in the allowance. The working time depends on a proper selection and proportion of materials and often the use of admixtures and additives. The contents of pulp, cement and aggregates, depending on the desired workability, must be reconciled. This is achieved through the knowledge of the characteristics of each component and their correct proportioning the mixture.

There is an acceptable test to directly determine the workability of concrete. However, numerous attempts have been made to correlate the workability with some physical quantity easy to be determined. Among the tests that indirectly indicate the workability of concrete pumped conventional one can cite the test Abatement Trunk Cone. [11]

4.2.2. LOWERING TEST (SLUMP TEST)

The test Abatement Trunk Cone measures the consistency and fluidity of the material, allowing them to control the uniformity of concrete. The main function of this essay is to provide a simple and convincing method to control the uniformity of the production of concrete in different concreting. Since, in strength, has obtained a workable concrete, the constancy of the tax relief will indicate the uniformity of workability.

Basically consists of completing a truncated cone in three layers of equal height, in each layer data 25 strokes with a rod pattern. The value of the rebate is a measure of the density of the concrete after the removal of mold taper.

Figure 4.1 – During the slump test

The term workability is therefore more subjective than physical, and the most important physical component of the workability is consistency, a term applied to the concrete, resulting intrinsic properties of the mixture cool, related to the mobility of the mass and cohesion among the elements components, with a view to uniformity and compactness of the concrete, in addition to good performance during the implementation of the structure.

Mixtures with stiff consistency have zero abatement, so that is not possible to see these cases variations of workability. Already rich mixtures, such as those commonly used in concrete for construction, can be satisfactorily measured with this test.

Considering the specifications of the concrete used in construction, although the paper presents some limitations due to its ease of implementation, it is very useful for quality control of fresh concrete. However, one must be assured that the concrete was dosed properly and checked for workability during its preparation.

4.2.3. TESTING CONTROL ACCEPTANCE OF FRESH CONCRETE

For concrete prepared by the performer of the work tests must be conducted whenever altered the moisture of the aggregates, the first mixed day after interruptions in the production of 2 hours or the exchange operator. For specific information provided by companies of concrete (concrete producers) tests must be conducted every concrete truck that comes to work.

4.2.4. OTHER TESTS

There are several other tests (some of them are cited below) that indirectly assess the workability of concrete. In Central Concrete and Dosing Studies suggest that they are used also other parameters than Slump, for the evaluation of its workability.

Test Factor density - is one of the most appropriate tests to measure the workability. Uses a reverse approach of others, i.e., determine the degree of densification obtained when applying a lot of work.

Remolding test - a table of hits is used to evaluate the workability based on the work of changing the form of a sample of concrete. It is a good test laboratory, mainly for evaluation of dry mixes.

Spread Table test - can be performed by one person and requires few materials, enabling them to be used on construction sites, and not only in laboratories. It consists of a base, which should be a square of 1000 x 1000 mm, which does not absorb water or cause friction with the concrete, and a truncated cone with materials of similar characteristics of the base. This test is indicated to assess the workability of concrete self-adensable or fluids. Spread The test is used to measure the capacity of the concrete self-adensable flow freely without segregating. The determination of the consistency of concrete by scattering the table Graff is applicable to mixtures that achieve the minimum spread of 350 mm, but limited to the size of the table of 700 mm. Is possible to say, roughly, that the slump flow test is an adaptation of these two tests, for a concrete too fluid.

4.2.5. COHESION

A property closely related to the workability is cohesion. The lack of cohesion of the mixture can cause the breakdown of fresh concrete, altering its physical composition and its homogeneity. The ideal case is one that provides adequate cohesion and workability.

Concrete together is what may be homogeneous, without separation of the mixture of materials at all stages of its use, whether in production, transportation, release, or even in the density during the concreting of the structure.

Cohesion depends on the proportion of fine particles in the mixture and, in particular in mixtures with low content of cement should be given to the major fractions in the thin end of the grading curve. It is often necessary to make several trial mixtures with different proportions of coarse aggregate and kids to find a suitable mixture with cohesion.

There are no standardized tests to measure, in a simple manner, the cohesion of a mixture. However, practical tests as to slam the stem test of subsidence, laterally, in particular, may indicate, empirically, the cohesion of the material. It is recommended that these aspects are verified in-dosing trial and in the conduct of work in relief.

4.2.6. SEGREGATION AND EXUDATION

Segregation is defined as the separation of the components of the fresh concrete so that their distribution is more uniform. There are basically two forms of segregation. The first, typical of poor and dry concrete, large grains tend to aggregate to separate from the others during the launch operations with too much energy or vibration. The second, very common in plastic mixtures, manifested by the clear separation of the pulp mixture, and also known as exudation

Exudation is a particular form of segregation, where the water mixture tends to rise to the surface of concrete recently launched. This phenomenon is caused by the inability to fix the solid all the water and the mixture depends to a large extent, the properties of cement.

As a result of exudation, has the appearance of water on the surface of the concrete after it has been released and dense, and the emergence and expression of several other problems such as weakening of adhesion paste-aggregate (transition zone), increased permeability of concrete and, if water is prevented from evaporating, the layer that is superimposed, could result in a weak layer of concrete, porous and low durability.

There are no standardized tests for measuring segregation. Thus, visual observation of the consistency of fresh concrete or hardened and the extraction of evidence of the hardened concrete are given for the assessment of damages to the structure of this phenomenon. It should be noted also that poorly measured concrete lead to segregation and any seepage.

Segregation and sweating may be reduced or eliminated through greater control of dosage and delivery methods and densification of the concrete more efficient and well executed.

4.2.7. AIR ENTRAINMENT

Is possible to find voids filled with air in the concrete in two ways: by air bubbles embedded or through empty air trapped.

Air bubbles have dimensions embedded between 100um and 1mm in diameter, while the trapped air voids are larger, being between 1 mm and 10 mm.

The voids of trapped air, which in most cases are caused by a deficiency in the dosage and choice of materials, they are detrimental to the quality of concrete, compromising the mechanical properties of compressive strength and modulus. A negative for the presence of trapped air voids in concrete is the final appearance, with the formation of macro-surface bubbles. In the case of concrete the presence of macro-bubbles surface is totally undesirable.

Figure 4.2 – Air entrainment test procedure

As the air bubbles incorporated may be twofold. The first, with the natural incorporation of small amounts of air, spread by micro-bubbles in the mass of concrete. The second, through the use of air-entraining agent to the concrete.

The incorporation called natural, and the presence of air voids embedded stems from factors such as type and fineness of the binders and fine aggregates, strength of materials, type and degree of compaction applied, temperature and mixing time of concrete.

The incorporation of additives is given in special cases with the objective of reducing the size of macro-bubbles (voids of trapped air), increased workability of the concrete, reducing the consumption of cement and improves the quality of the concrete and the action of ice and thawing. Within acceptable limits for intakes of up to 6% of additives, each increment of the incorporation of air in 1% may be allowed to reduce water mixture up to 3% and the percentage of sand up to 1% leading to improvements the compressive strength of concrete.

The control of air content is fundamental to corporate quality control of concrete, whether to check the maximum and minimum desirable air incorporated or to identify levels of air voids in concrete.

The equipment used to perform the test for measurement of air into the concrete, which consists of a hermetically sealed container that is filled with fresh concrete. Through holes are injected into the water in a closed container in order to expel the air from the concrete. In air flow gauges detect the substance released and indicate the percentage of air in the mixture.

Figure 4.3 – Air entrainment test procedure 2

Conventional concrete contain within it, even without the use of air-entraining agent, 1 to 3% by volume in air trapping due to the mixing process and its consistency. In the case of concrete produced in central and transported by truck mixer this percentage can reach the order of 4%. Percentage of incorporated air above 5% may harm the mechanical performance of the material.

The application of air-entraining concrete makes it possible to transform the macro-bubbles incorporated into the mixture in micro-bubbles, and raise the air content in concrete. In these cases the bubbles generated are small, around 0.2 mm, and can contribute greatly to the workability of concrete, without necessarily bring reductions of resistance.

The content of air in concrete is therefore an issue of extreme importance to its final quality. Control of the percentage of air in fresh concrete to gauge the strengths, the additions of additives and, consequently, the quality of the material. Values of air above those provided in the dosage of the material indicate that the individual may suffer mechanical damage, such as reduced compressive strength and modulus of elasticity, or aesthetic as the formation of macro-surface bubbles.

In the case of the use of additives developers, the question is reversed, since the incorporation of values below their estimated could compromise the workability and resistance to the action of frost and defrost (common in countries with cold climates or in cases of special projects such as cold storage).

4.3. Tests of fresh concrete at the concrete mixing plant or on the building site – measuring of workability [12]

The following fresh concrete tests were the ones that were possible to see and follow. So it will be described more carefully, and with this base it will be created the quality check-lists, explained in the chapter 5.

- Lowering test
- Vêbê test
- Degree of compactness
- Table spreading test
- Air entrainment test

4.3.1. Lowering test (slump test)

4.3.1.1. Principle

The fresh concrete is compacted inside a mold with a cylindrical-conical shape. When the cone is removed, raising it, the lowering of the concrete provides a measure of it consistence.

4.3.1.2. Scope

- Maximum dimension of the aggregate ≤ 40mm.
- Lowering between 10mm and 200mm.

If after one minute the lowering still not stable, this test is not adequate to measure consistency.

4.3.1.3. Execution times

Execute the whole operation of mold in 5 to 10s, through a steady upward movement without transmitting torsional or lateral movement to concrete.

Execute the whole operation, from the beginning of the fill until the removal of the mold, without interruption for 150s.

4.3.1.4. Equipment

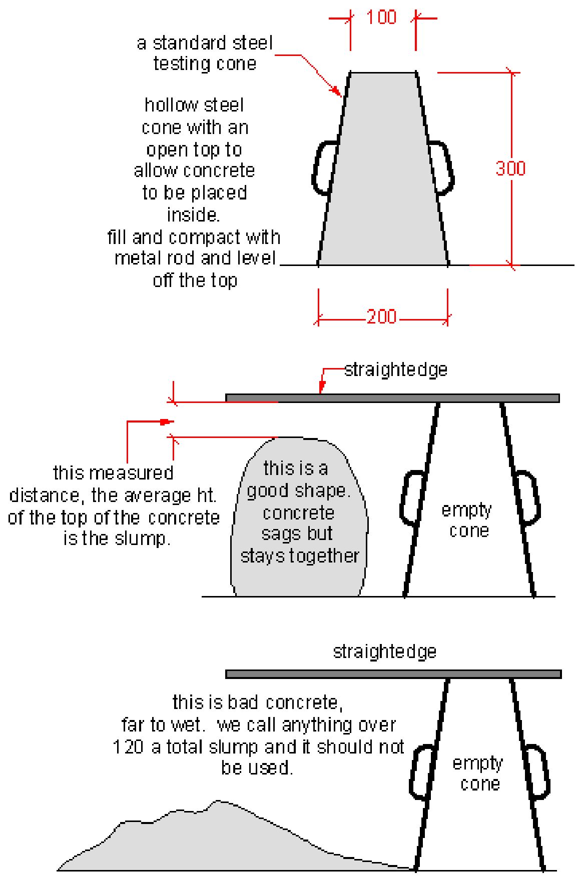


Figure 4.4 – Slump test procedure [13]

- Mold (truncated cone): cone of Abrams

d = 100 ± 2mm; D = 200 ± 2mm; H = 300 ± 2mm; and ≥ 1,5mm; two handles near the top and fasteners or tabs to set foot near the base.

- Graduated scale from 0 to 300mm

divisions = 5mm, marked with zero at the extreme.

4.3.1.5. Technique

1. Take a representative sample of mixing
2. Fill the mold in three layers tamper with 25 hits and surface settlement of the 3rd layer.
3. Removal of mold and measurement of the h difference, which is rounded to 100mm.

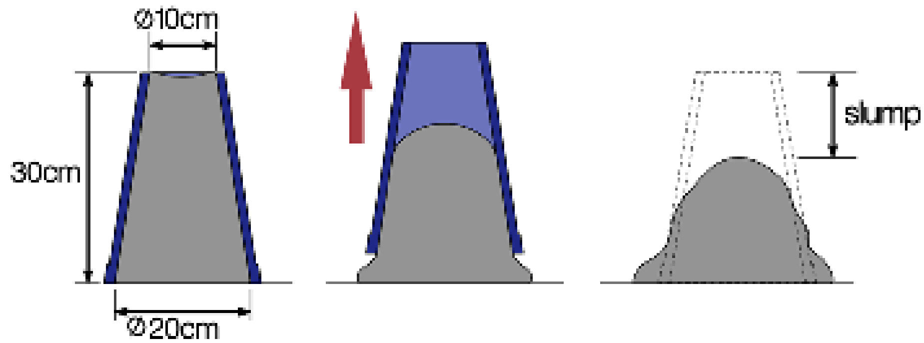


Figure 4.5 – Slump test technique [14]

The test is only valid in the case of a downturn in real, in which the concrete remains essentially intact and symmetrical.

If the specimen deform must be taken to another sample and repeat the procedure. If in two consecutives tests verify the deformation of a portion of the concrete mass of the specimen, the concrete does not show the plasticity and cohesion appropriate to this test.

Figure 4.6 – Slump test procedure 2

Immediately after removing the mold, measure and record the drawdown, determining the difference between the height of the mold and the highest point of the sample that lowered.

4.3.2. VEBE TEST

The time is measured in seconds, it takes the disc to fall freely on the sample of concrete by the time the disc stops down and there are no bubbles or voids under the transparent disc.

Figure 4.7 – Vebe consistometer [15]

4.3.2.1. Principle

The fresh concrete is compressed into a mold for the drawdown test. The mold is removed vertically and a transparent disc is placed on top of concrete and carefully lowered to contact with the concrete. There is the lowering of the concrete. It connects the vibrating table and measure the time required for the underside of the transparent disc is fully in contact with the grout.

4.3.2.2. Scope

- Maximum dimension of the aggregate ≤ 63mm.
- Vebe workability ≥ 5s and ≤ 30s.

4.3.2.3. Sampling

Obtained according to the standard.

4.3.2.4. Execution times

Operation unmold, mold test lowering 5 to 10 seconds.

Total test duration 5 min.

4.3.2.5. Report

- Record type of drawdown obtained.
- Measurement of true lowering, to the nearest 10mm vebe time in seconds.

4.3.3. COMPACTNESS DEGREE

4.3.3.1. Principle

The fresh concrete is placed in a container, with a help of a spoon, carefully to avoid any compression. When the container is full, the upper surface is cleaned at the upper edge of the container. The concrete is compacted by vibration, and the degree of compactness measured by the distance between the surface of the compressed concrete and the upper container.

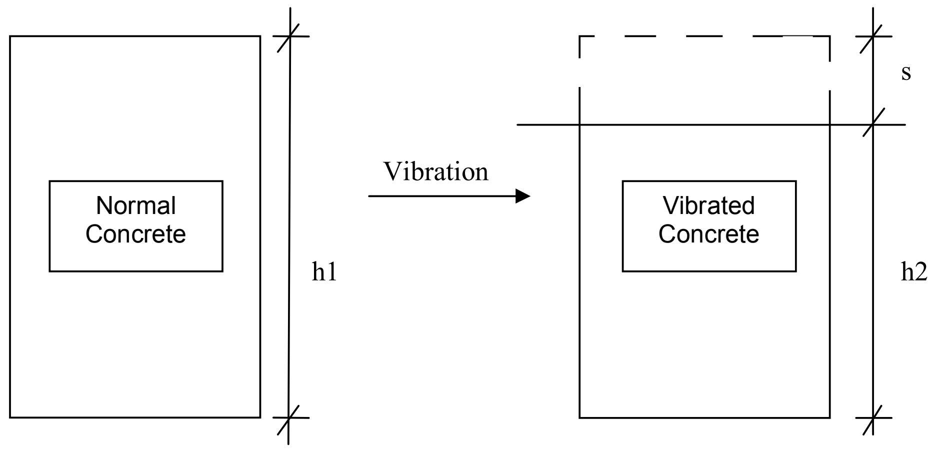


Figure 4.8 – Degree compactness scheme

4.3.3.2. Scope

- Maximum dimension of the aggregate ≤ 63mm.
- Degree of compactness ≥ 1,04 and ≤ 1,46.

4.3.3.3. Sampling

Obtained according to the standard.

4.3.3.4. Report

Determine the value s (mm) corresponding to the average of 4 values of the distance between the surface of the compressed concrete and the upper container.

$$\text{Degree of compactness} = h_1 / h_2 = h_1 / h_1 - s$$

h_1 – height of the container (mm)

h_2 – height of the compressed concrete (mm)

s – average (mm) the distance between the surface of the compressed concrete and the upper container.

The result is presented rounded to the nearest hundredths.

4.3.4. SPRAYING TABLE TEST

4.3.4.1. Principle

Determines the consistency of wet concrete through the spreading of the wet concrete on a plane table subject to blows. Concrete is placed in the mold on the table in 2 layers (10 strokes). It removed the mold and raised the top plate every 2 to 5 seconds, 15 times.

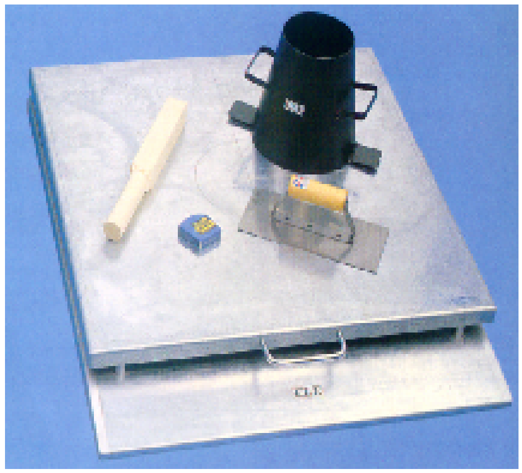


Figure 4.9 – Material for spraying table test [15]

The diameter of scattering is determined by the average of two diameters measured.

4.3.4.2. Scope

- Maximum dimension of the aggregate ≤ 63mm.
- Scattering values ≥ 340mm and ≤ 600mm.
- Not applicable to aerated concrete or without fines.

It is measured with a ruler the diameter of the cake in 2 directions parallel to the sides of the table to the nearest 10mm, the average is taken to approximate to 10mm. the value obtained corresponds to the diameter of spreading. The result is presented to the nearest 10mm.

4.3.5. AIR ENTRAINMENT TEST

4.3.5.1. Pressure type "B" meter

A sample is removed from the truck. That sample is putted on the device, by parts and is compressed with some stick to avoid that the air stays inside the sample.

Figure 4.10 – Press-Ur-Meter [16]

The sample is smoothed to the top. The top of the device is putted correctly and then closed. After this the water is inserted in one of the holes of the device until start to go out from the other hole. After this the worker can do the reading of the percentage of air inside the sample.

Figure 4.11 – Air entrainment test reading

4.4. CLASSIFICATION OF CONSISTENCY

Table 4.1 – Classes of lowering

Class	Lowering
S1	10 a 40
S2	50 a 90
S3	100 a 150
S4	≥ 160 (160 a 210)
S5	≥ 220
The measured drawdown should be rounded to the nearest 10mm	

Table 4.2 – Vebe Classes

Class	Vêbê in seconds
V0	≥ 31
V1	30 a 21
V2	20 a 11
V3	10 a 5
V4	≤ 4

Table 4.3 – Classes of compactness

Class	Degree of compactness
C0	≥ 1,46
C1	1,45 a 1,26
C2	1,25 a 1,11
C3	1,10 a 1,04

Table 4.4 – Classes of scattering

Class	Scattering diameter, mm
F1	≤ 340
F2	350 to 410
F3	420 to 480
F4	490 to 560
F5	560 to 620
F6	≥ 630

Table 4.5 – Classification of consistency

Consistency	Lowering (cm) (slump)	Vêbê	Degree of compactness
Wet earth	-	≥ 5	≥ 1,25
Plastic	1 to 5	≤ 5	1,25 to 1,11
Soft (very plastic)	5 to 16	-	1,10 to 1,04
Fluid	/ 16	-	-

4.5. LABORATORY TESTS – HARDENED CONCRETE

4.5.1. SCHMIDT HAMMER TEST

A Schmidt hammer, also known as a Swiss hammer, is a device to measure the elastic properties or strength of concrete or rock.

The hammer measures the rebound of a spring loaded mass impacting against the surface of the sample. The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion chart, the rebound value can be used to determine the compressive strength. When conducting the test the hammer should be held at right angles to the surface which in turn should be flat and smooth. The rebound reading will be affected by the orientation of the hammer, when used in a vertical position (on the underside of a suspended slab for example) gravity will increase the rebound distance of the mass and vice versa for a test conducted on a floor slab. The Schmidt hammer is an arbitrary scale ranging from 10 to 100. Schmidt hammers are available from their original manufacturers in several different energy ranges. These include: (i) Type L-0.735 Nm impact energy, (ii) Type N-2.207 Nm impact energy; and (iii) Type M-29.43 Nm impact energy.

Figure 4.12 – Schmidt hammer test [17]

The test is also sensitive to other factors:

- Local variation in the sample. To minimize this it is recommended to take a selection of readings and take an average value.
- Water content of the sample, a saturated material will give different results from a dry one.

Prior to testing, the Schmidt hammer should be calibrated using a calibration test anvil supplied by the manufacturer for that purpose. 12 readings should be taken, dropping the highest and the lowest, and then take the average of the ten remaining. Using this method of testing is classed as indirect as it does not give a direct measurement of the strength of the material. It simply gives an indication based on surface properties; it is only suitable for making comparisons between samples.

This test was possible to see the results paper but was not possible to enter in the laboratory like it will be explained in the next sub-chapter.

4.5.2. Tests of compressive strength of concrete through the destructive method and Density of hardened concrete determined on testing samples

These two tests were not possible at all to obtain any more information than the paper with the results. The access to the laboratory is very restricted so the only thing is possible is do reference to them because they allow to show the results. The results are showed in final of this chapter.

4.5.3. Test of frost resistance of concrete

Water activity and de-freezing substance resistance of concrete surface: data on water activity and de-freezing substance in Annex. Following the certificate interpretation of the test performance, the composites met the requirements of Technical Standard STN 73 1326 (water activity and de-freezing substance resistance of concrete surface) for degree 3 – disrupted; and thereby met the requirements of the STN 73 6123 building of pavement; cement-concrete covers of pavement.

Test of frost resistance: results of frost resistance testing showed that the requirements of the technical standard were not fulfilled, because after 100 cycles of stress the composites were destroyed (Fig. 4.13).

Figure 4.13 – Composites after 100 cycles of stress

These three tests were not possible to follow so no check-lists will be created for them.

4.6. LABORATORY CONCRETE TESTS RESULTS

Next are presented the pages the author had access concerned to the 3 laboratory concrete tests that are referred above.

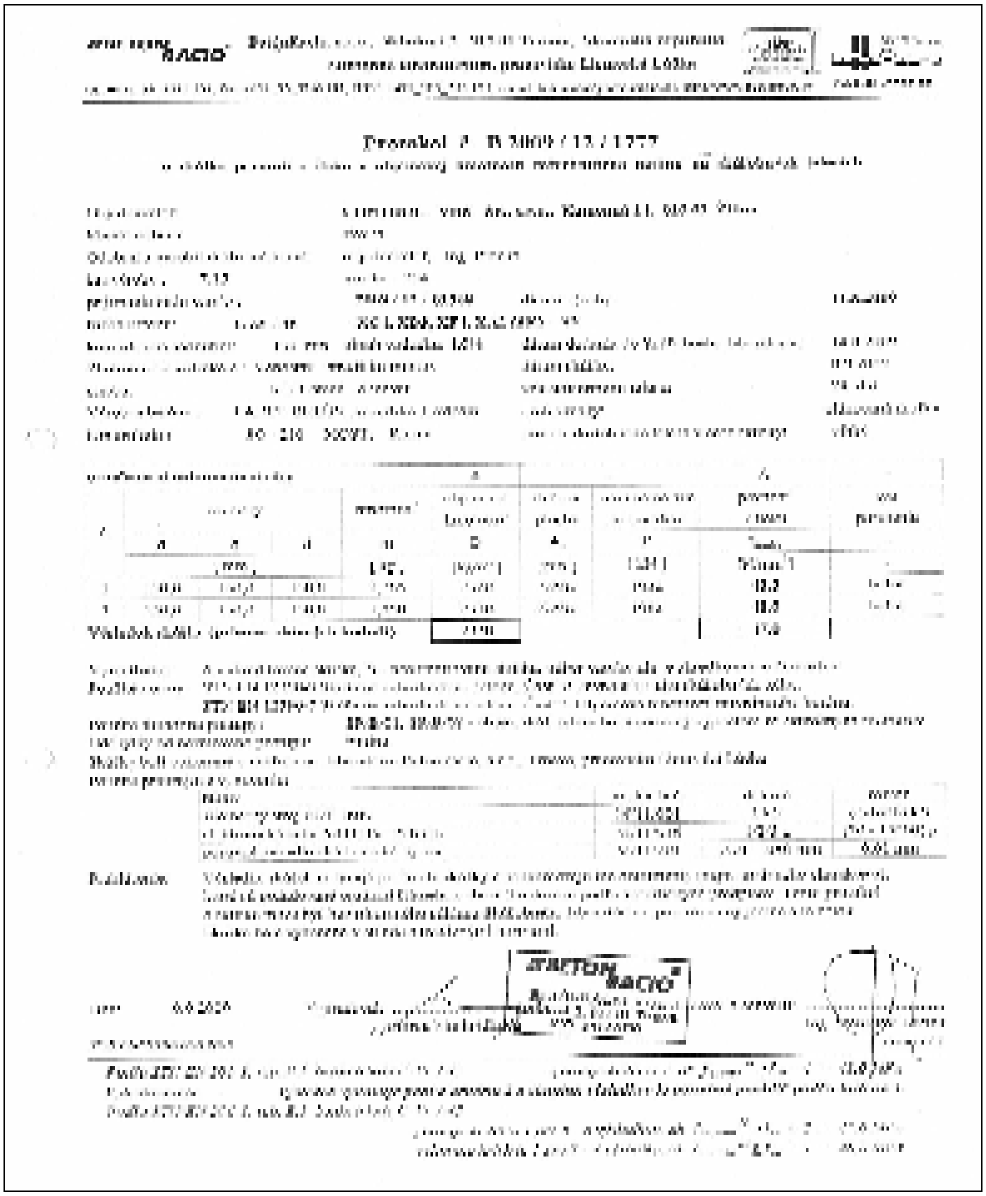


Figure 4.14 – Test of compressive strength and Density of hardened concrete

Is possible to see that for this type of test the company has some kind of check-list prepared, where they note the results so they can control the quality of the hardened concrete tested.

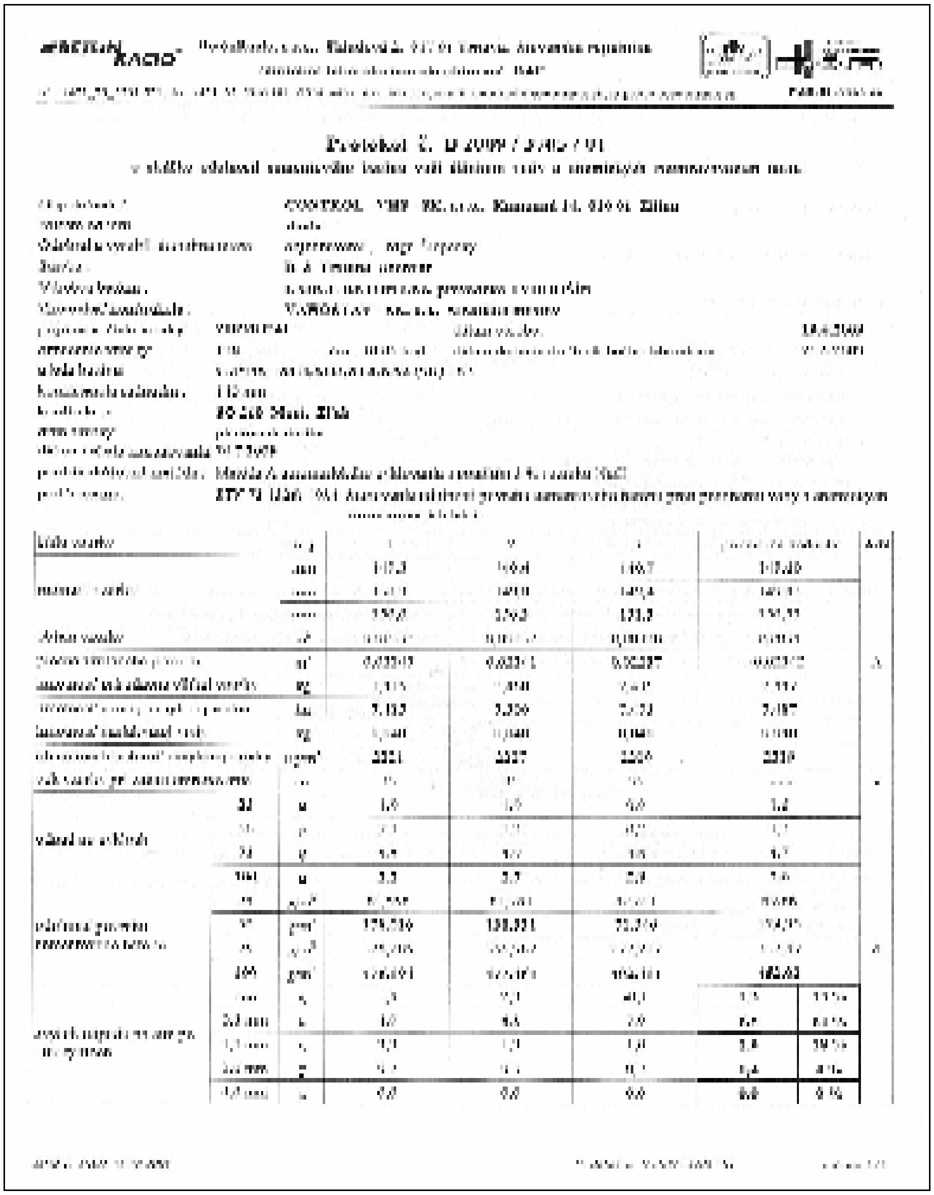


Figure 4.15 – Test of frost resistance of concrete (part 1)

The frost resistance test is a test only done in countries where the environment can be very aggressive because of the negative temperatures. They need to test the concrete for resisting the frozen temperatures, to assure the concrete will not “crack” in any situation.

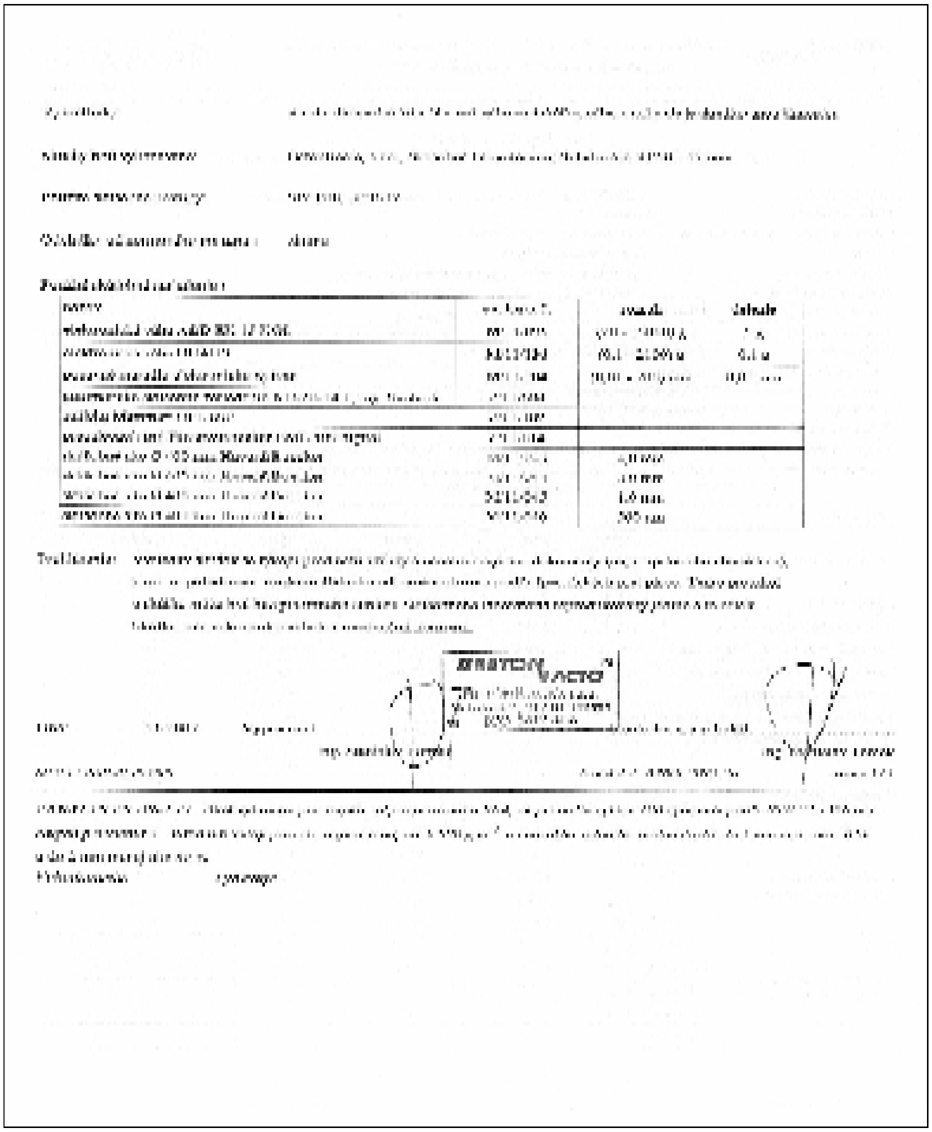


Figure 4.16 – Test of frost resistance of concrete (part 2)

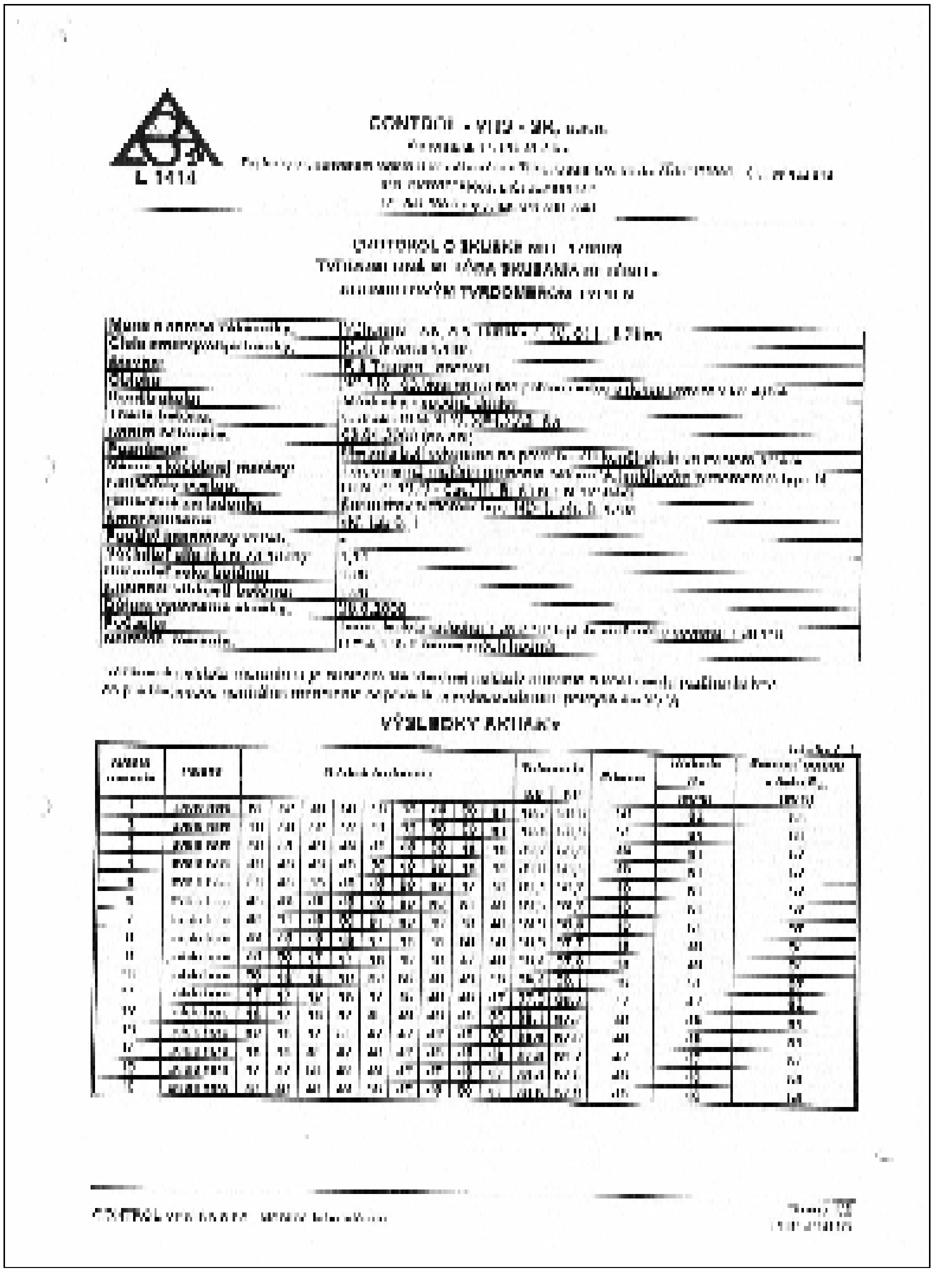


Figure 4.17 – Schmidt hammer test results (part 1)

This two pages concern to the Schmidt hammer test and like in the other laboratory tests the company has already this kind of check-list prepared, with space for many attempts and for the respective results.

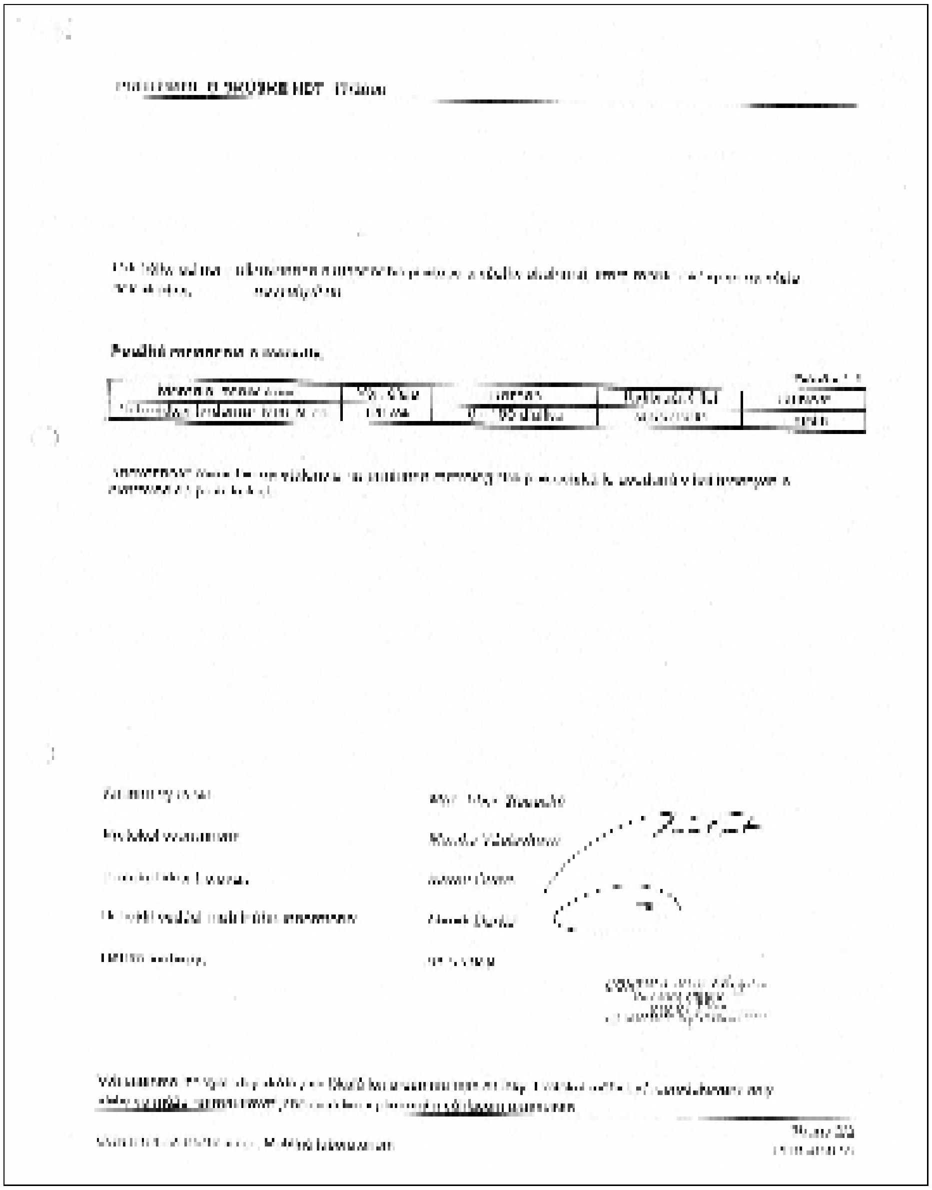


Figure 4.18 – Schmidt hammer test results (part 2)

4.7. Final considerations

All the tests that are presented in this chapter were the ones that the company gave access to.

Like is referred in point 4.5.2 those two tests was only possible to get the results so is not allowed give any more information about that because of many restrictions to the laboratory access.

The fresh concrete tests were verified and seen in the construction site.

5
QUALITY CONTROL CHECK-LISTS

5.1. OBJECTIVE OF THE CHECK-LISTS

Once presented the process of execution of the concrete tests described in the previous chapter, is very important to explain each part of the check-lists that created for the quality control of the concrete in the construction site.

Like described above, quality control of the concrete is an essential mechanism so the concrete that the putted in construction is corresponding to the concrete described in project, and that concrete have the correct properties to be correctly used.

The existence of information compiled in a synthesized before the start of the work allows the controller gain immediately, a perception of the main activities to be inspected and recognize the importance in recording information associated with them during the tests. In fact, these elements should be prepared well in advance so that when the work is to start the controller has already studied the findings critical process implementation and thus have the alert mechanisms to guide their actions and that possible to know beforehand what the jobs that requires his full monitoring on the ground. The check-lists, are the physical support of the inspection process and seek, briefly, check the following objectives: [18]

- Guide and structure the work of the inspection team carrying out its business;
- Combating check failures by forgetfulness or negligence (memory aid);
- Contributing to the credibility of the review in the production process;
- Improving the quality of work;
- Serve as a database to identify the most frequent failures.

The adoption of suck check-lists in the quality control of the concrete is very pertinent, because in this kind of constructions, the concrete is the main component, so is the higher priority that this component shall be verified correctly before get applied in the field.

These check-lists will be applied in the construction after the concrete arrive to the construction site and before the concrete pumping starts, so the concrete quality can be verified. If the quality does not correspond to the normal parameters the concrete is sending away, and the pumping will be suspended until the next concrete truck arrive with more concrete that have to be again verified before the works get started.

In the flowchart showed bellow is possible to understand where the check-lists that created will be applied, so the normal schedule of works can continue without any problem.

5.2. UTILITY OF THE CHECK-LISTS

In the line of work, if the measuring material is not calibrated and the concrete samples randomly chosen, the introduction of the check-lists is not interesting at all.

So it is possible to define some scheme where is showed the importance of this two parameters for the quality concrete control.

Material Concrete Check-Lists

Figure 5.1 – Utility of the Check-Lists scheme

5.2.1. MEASURING MATERIAL

All the measuring material, like graduated scales, vebe consistometer, cone of Abram and the press-u-meter need to be correctly calibrated so the tests can be done according the parameters.

Normally this calibration is done in the laboratories one time per year, and if the material is according to the rules is putted some stick easy to identify when the material is used in the construction site.

So it's obligation to the controller verify if the calibration is update.

5.2.2. CONCRETE SAMPLES

The concrete is normally tested 4 times for each type of concrete. When the construction receive some kind of concrete, i.e. C30/37, the controller are directed to the construction site so then can run a battery of four tests, only to that specific concrete.

The battery of tests is done every time that a new type of concrete arrives to the construction site.

Normally the same type of concrete arrives in different trucks so it's recommended that the battery of four tests be done to four different trucks.

5.2.3. CHECK-LISTS

With the material of measuring and the concrete according to the rules, the application of the check-list can be done correctly.

5.3. INSERTION OF THE CHECK-LISTS IN THE LINE OF WORK

The check-lists were prepared to facilitate all line work in the construction site.

Next is presented the flowchart where is possible to understand the big importance of this check-lists in the line of work. They permits that the quality control is done without big interference in the pump concrete work.

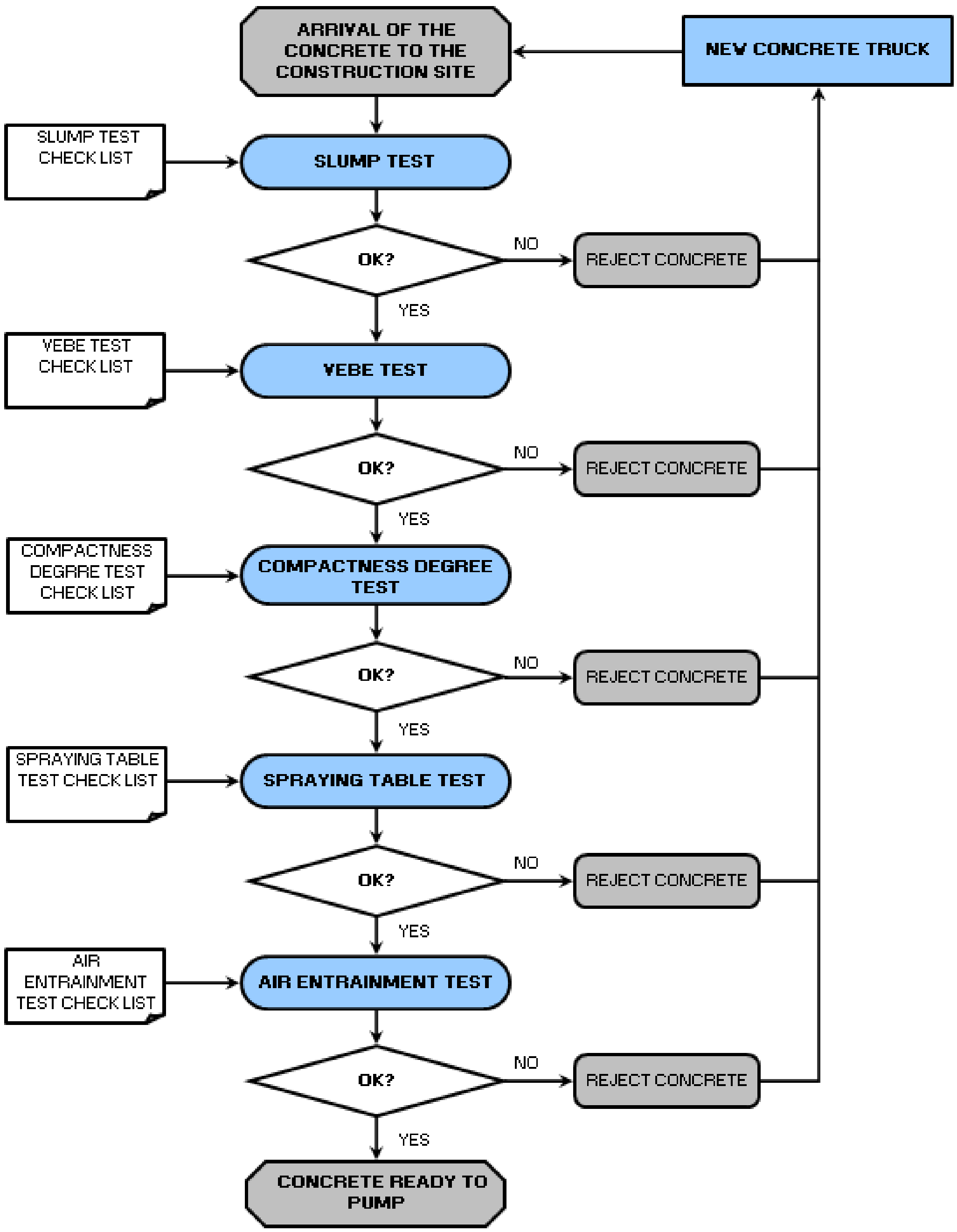


Figure 5.2 – Flowchart for the quality control of the fresh concrete

Like is showed on the flowchart when some concrete is rejected all the truck is going back. A new truck has to come to the construction site and the batteries of tests need to begin from the start. For the concrete be approved to pump is necessary to pass this five test. If some of the tests fail the concrete is not able to approve for pumping.

Figure 5.3 – Concrete ready for pumping

After all this process the controller work doesn't finish. Is important to assure that the pump is done correctly to know that the quality of the construction is assured.

5.4. CHECK-LISTS STRUCTURE

The methodology for the preparation of Check-lists was the preparation of information which relevance would require them to be included in a document of this nature, the suppression of fields that would only be specific to a particular activity, in the form of organization, and the definition of a form that has become appealing, while leveraging a filling easy and almost intuitive.

It should be noted that although the structure of the material follow an objective ranking of the most important things to record, its definition was also based on subjective criteria of experience and personal taste that could make them less appealing to some professionals who have their work organized according to another methodology. However, in the case of a work aimed at the practical implementation of an academic study, it is believed that the structure of perception is developed quickly and easily understandable by potential users. The power of synthesis was actually one of the key assumptions underlying the preparation of the material as it is assumed that checks in elongated forms very extensive and lead to disinterest in their fulfillment, making its application in everyday work. [17]

Given the volume of information to be included in the check-lists and their organization the author opted for a provision on a table, and the inclusion of the fields that are described below.

The first section of the check-list, "Title", is composed by four fields. The left is prepared to receive the identification of the supervisory company with its symbol, the central means the check-list and type of test to be performed and the right is the internal reference of the item. In the example was chosen to play the "Slump test" check-list.

TITLE

Company Symbol:	**QUALITY CHECK LIST - CONCRETE TEST'S**	**Reference:**
	Lowering Test (Slump Test)	

Figure 5.4 – First section of the Check-List.

The second section has, on the left, the fields to identify the Road, the Construction Owner, the Constructor and the Concrete Supplier. On the right appears the name of the Controller who prepared the check-list. The controller has the right to fill the check-list and sign it at the end, to prove that the control was done. In the Construction Owner and Constructor field, it will be good that booth of signatures can be there, so it will be knowledge of everybody in the construction the application of the specified check-list.

IDENTIFICATION

Road: ______________________

Construction Owner: ______________________

Constructor: ______________________

Concrete Supplier: ______________________

Controller:

Figure 5.5 – Second section of the Check-List.

The project references are included in the third section, where it's possible to find two different fields that are connected. The first one is the indication of the specifications book pages where the artwork is referred, and the second one is the drawings references of that same artwork, so the person who is filling the check-list can easily understand where the concrete will be applied. The third field is the norm related with the specified concrete test above. The last field is related with the place where the concrete will be applicated in the art work,

PROJECT REFERENCES

Specifications Book:	______________________	(image)
(Pages)		
Drawings:	______________________	
(Reference)		
Norme:	______________________	
Local of concrete application:	______________________	

Figure 5.6 - Third section of the Check-List.

The acts register is the first part of the check-list that permit the user do four different registers of results in the same document.

This part is composed by five fields, first of them is the localization to define the place where the test is being done, the second one is the date, third one the hour, and then the fourth one is a very important one, because the country where the check-lists are being used is a country where the weather conditions is one of the most important things for this kind of concrete test. So for this field was created some code from "A" to "E" being A the best and E the worst conditions. The last field is about the concrete type (C30/35), for example.

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

Figure 5.7 - Fourth section of the Check-List.

The Control Points are the fifth, and the most important part of the check-list. Have a little note explaining the 3 different marks that the controller can put in the fields that will appear. Can be "Check", "Not Check" and "Canceled". Is not any more option available because, and after some test, was possible to understood that any other option make sense in this type of control. So the controller can mark the fields with "Check" if everything is ok, "Not Check" if something went wrong, and "Canceled" if for example the weather conditions are so bad that is not possible at all to realize the test.

CONTROL POINTS

√ Check	× Not Check	/ Canceled

Figure 5.8 – Top of the fifth section of the Check-List.

Inside of this fifth part are included some sub-parts that are the main body of all check-list because they are referred to the test itself.

The first of that sub parts is about the workers present on the test. The controller only has to mark if the needed people for the test are or not present in the test when it need to be done.

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		
Helper	Visual	Yes/No	I		
			II		
			III		
			IV		

Figure 5.9 – First Sub-part of the fifth section of the Check-List.

The second one is about the scope. In this section are marked the most important fields of all check-list and the controller need to write down the results of the tests in the right part of the section, where it's possible to see the Observations space. According with the observation of the results the controller decides to put "check" or "not check" in the respective verification.

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Maximum Dimension of the Aggregate	Visual	≤ 40 (mm)	I		
			II		
			III		
			IV		
Lowering	Measure	[10,200] (mm)	I		
			II		
			III		
			IV		

Figure 5.10 – Second Sub-part of the fifth section of the Check-List.

The third sub-part of this fifth section is about the execution times of part, and all procedure of the test.

Execution Times

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Execute the whole operation of mold	Clock	6 to 10 seconds	I		
			II		
			III		
			IV		
Execute the whole operation	Clock	< 150 seconds	I		
			II		
			III		
			IV		

Figure 5.11 – Third Sub-part of the fifth section of the Check-List.

The fourth and last sub-part is the equipment part, where the controller needs to supervise if all the material is in the field, so the workers can do the test correctly.

Equipment

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Mold (truncated cone): Cone of Abram	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		
Graduated scale from 0 to 300 (mm)	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		

Figure 5.12 – Fourth Sub-part of the fifth section of the Check-List.

The sixth section of the check-list is simply for observations that the controller need to be important for the control of the test. Some brief note can be written down if the responsible think that something is not according the normal procedures, or if some external interference occurs during the test time.

OBSERVATIONS

Figure 5.13 – Sixth section of the Check-List.

The last section of check-lists is the authentication part where the responsible and the controller need to sign to prove that the test and also the supervision, here done in the terms of the law, and without any interference. With these two signatures, is possible to prove that all the supervision was finished and correctly done.

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				

Figure 5.14 – Seventh section of the Check-List

5.5. Final considerations

The final balance about all the experience of going to the construction site around 8 times in all semester is very positive.

Every engineer, worker and cooperator of the construction was very kind and allows taking a lot of photos and getting much information.

Was possible to see some of the concrete tests in real time and understand better the way that a construction like a big motorway is done in Slovakia.

With all of this information collected during these five months is now possible to produce some check-lists to improve the concrete tests.

6
APPLICATION OF THE CHECK-LISTS, DATA ANALYSIS AND FINAL CONCLUSIONS

6.1. APPLICATION OF THE CHECK-LISTS IN THE CONSTRUCTION SITEG

The check-lists were applied in the R3 Expressway Trstena – bypass one of the biggest constructions, at the moment, in the north of Slovakia.

Figure 6.1 – R3 Expressway Trstena - bypass

Is an Expressway with more or less 16 km, and give a big solution to the road users, don't pass the center of the Trstena city and have a big alternative to get near the Slovak-Polish border, avoiding the traffic problems in that area.

In the next pages will be presented the check-lists used in the construction site, during around 15 days, concern to the five fresh concrete tests spoken before in the chapter 4.

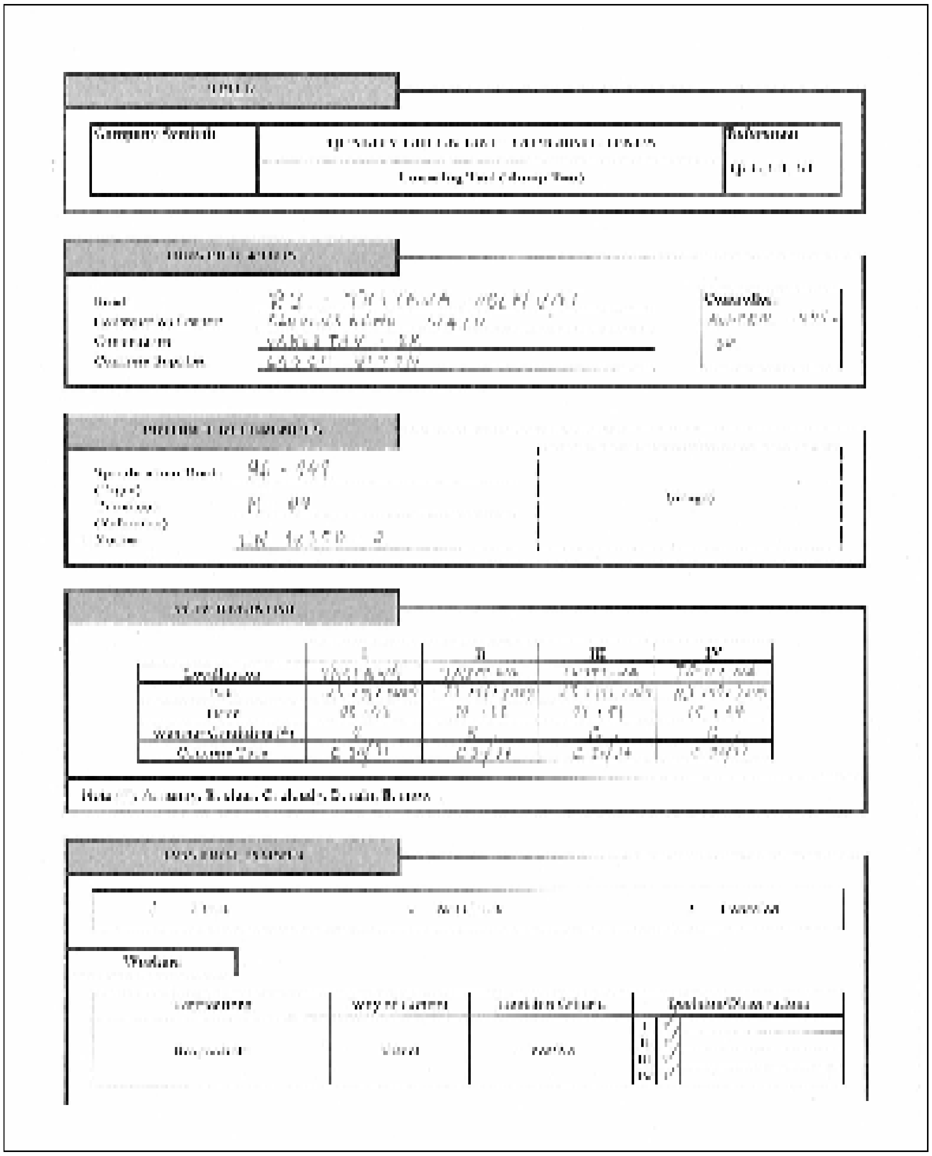


Figure 6.2 – Lowering test check-list application (part 1)

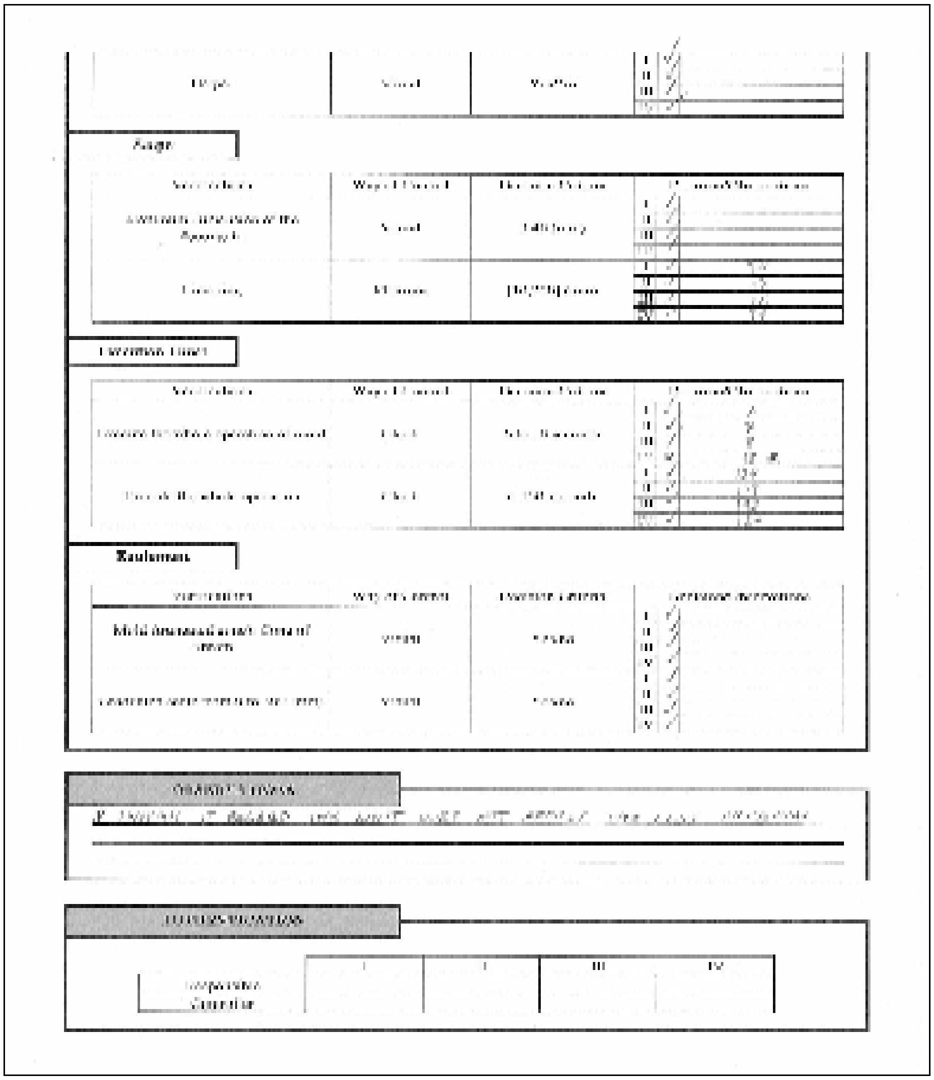
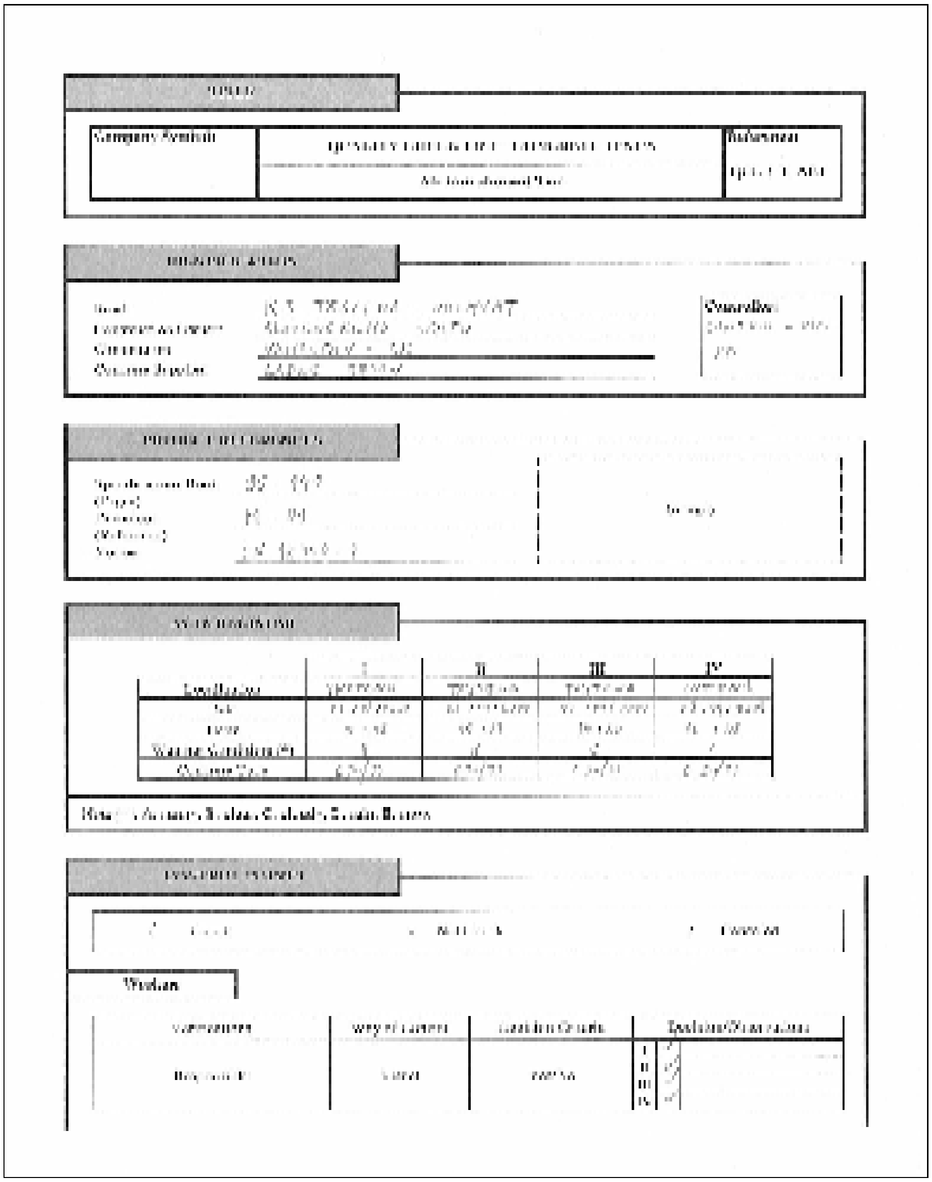


Figure 6.3 – Lowering test check-list application (part 2)


Company Symbol

Reference

Controller

Worker

Figure 6.4 – Air entrainment test check-list application (part 1)

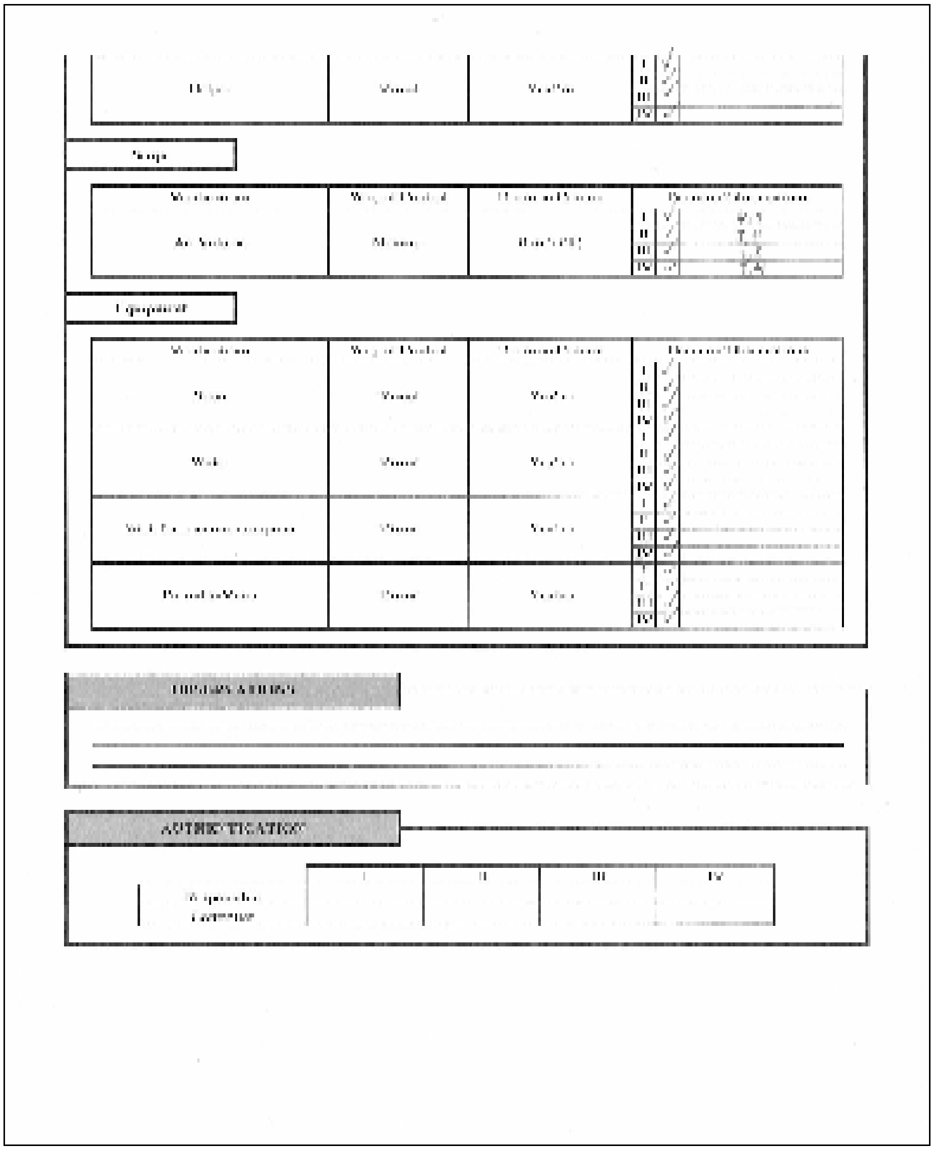


Figure 6.5 – Air entrainment test check-list application (part 2)

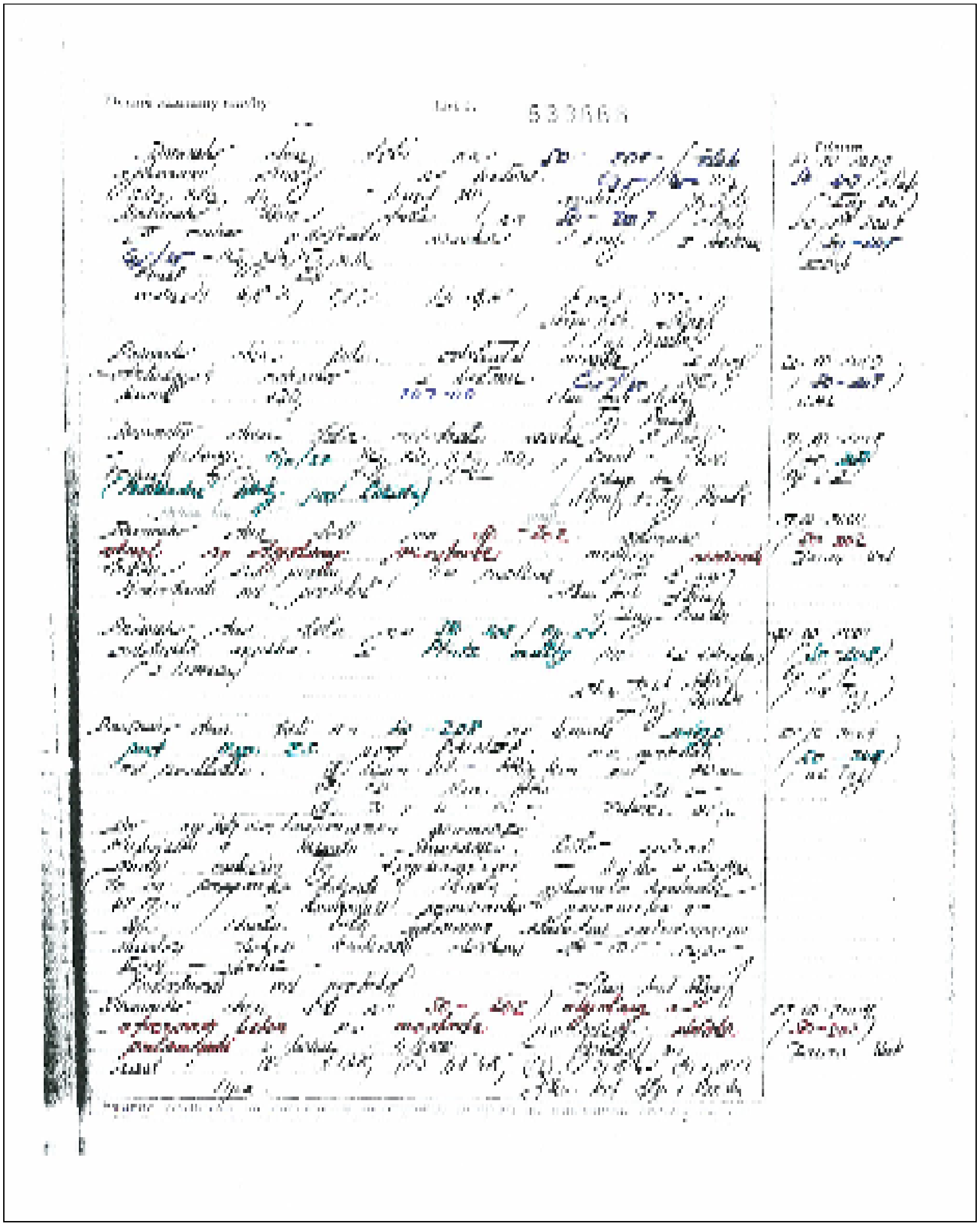


Figure 6.6 – Page from the construction site used before the proposed check-lists (various tests)

6.2. DATA ANALISYS

In this final chapter are presented the data analysis for the application of the check-lists that were created for the fresh concrete tests. All the tests were done in the bridge M – 09, one of the biggest bridges of the all road.

Is a simple graphic presentation, where is possible to see that the values obtained are inside the parameters that were supposed to obtain. These tests are very simple tests, so the percentage of error is very few. Is important to say that, and according to information from the concrete supplier, 1 in 40 concrete trucks are rejected and turned down to the factory.

As is possible to see bellow, were done tests in 3 different days, during 2 weeks, to 3 types of concrete, so is possible to see clearly the differences between this 3 types of concrete. Is expectable that the concrete C 35/45 present results of major capacity, because is the concrete used in the bridge itself. The concrete C 30/37 is a medium concrete that presents the medium values in almost every parameters, being the concrete used in the pillars for example. The last type of concrete is the C 25/30 the most weak concrete from the three and is normally used in the foundations of the artwork.

6.2.1. SLUMP TEST

For the slump test the more interesting parameters to analyze are the lowering and also the total time of the execution of the test.

In the 2 graphics presented is possible to see that all the parameters are inside the normal values (see in the chapter 4).

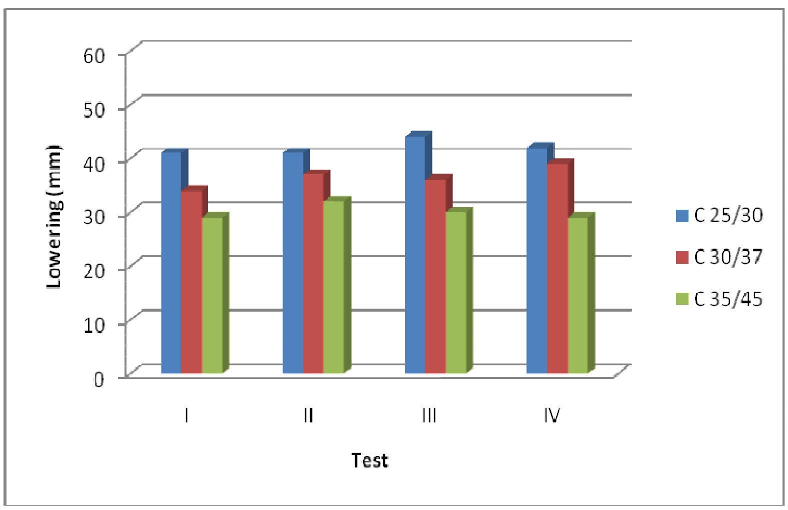


Figure 6.7 – Lowering (Slump test)

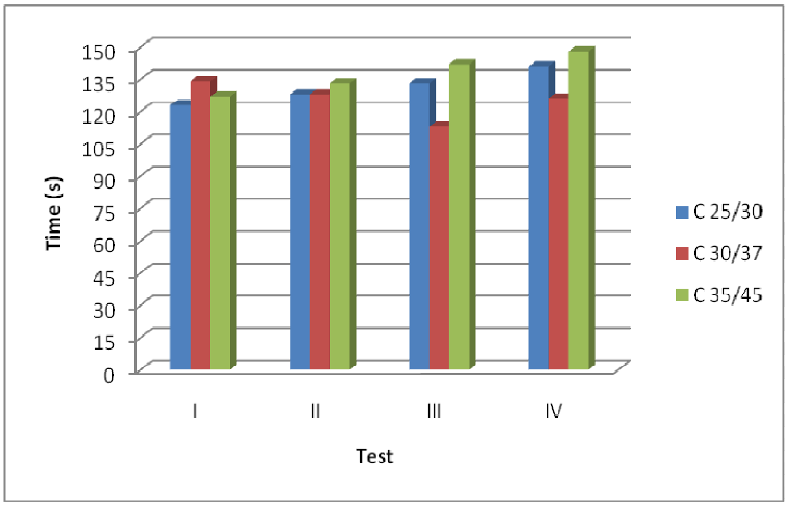


Figure 6.8 – Execute the whole operation (Slump test)

6.2.2. Vebe test

For the vebe test the more interesting parameters to analyze are the workability and also the total time of the unmold operation.

In the 2 graphics presented is possible to see that all the parameters are inside the normal values (see in the chapter 4).

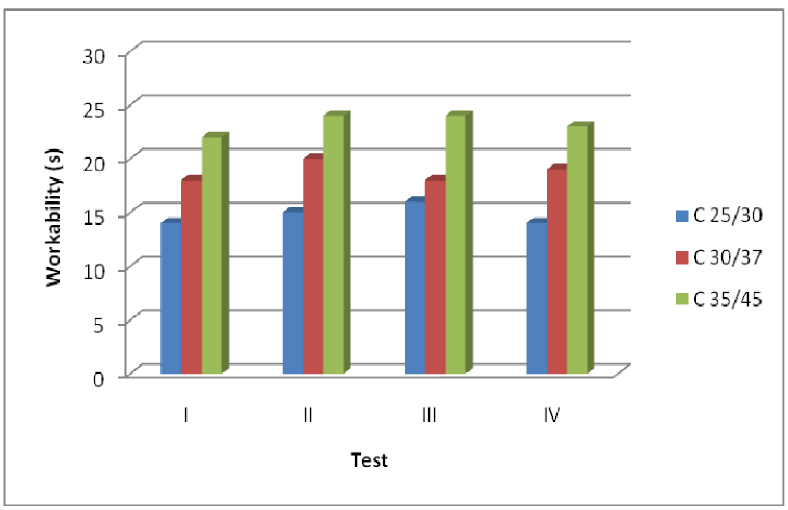


Figure 6.9 – Workability (Vebe test)

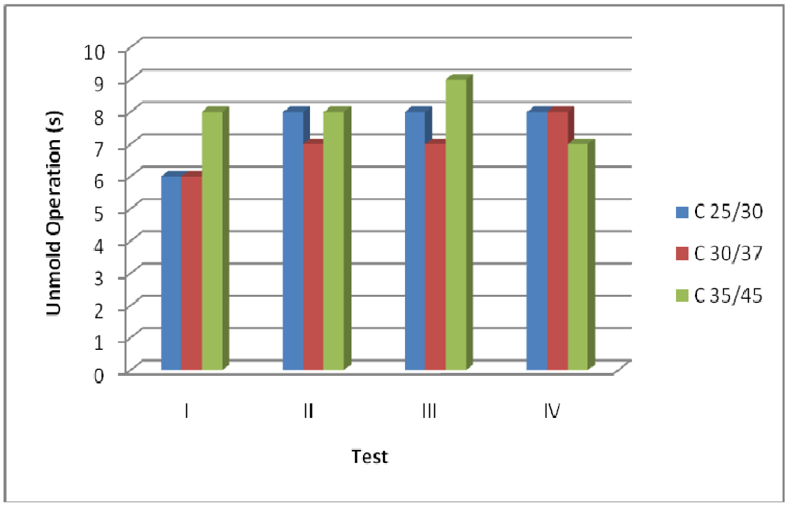


Figure 6.10 – Unmold Operation (Vebe test)

6.2.3. Compactness degree test

For the vebe test the more interesting parameter to analyze is the degree of compactness.

In the graphic presented is possible to see that all the parameters are inside the normal values (see in the chapter 4).

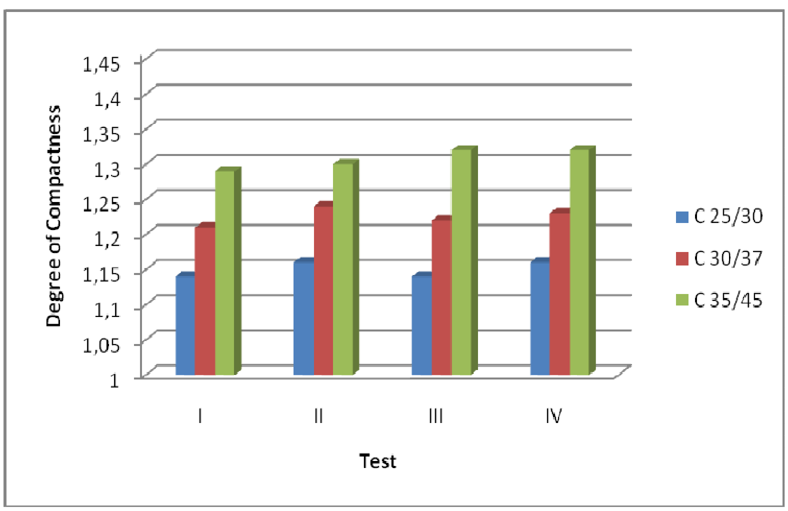


Figure 6.11 – Degree of Compactness (Comp. Degree test)

6.2.4. Spraying table test

For the spraying table test the more interesting parameters to analyze are the scattering values and the time of remotion of the mold and raised to top plate.

In the 2 graphics presented is possible to see that all the parameters are inside the normal values (see in the chapter 4).

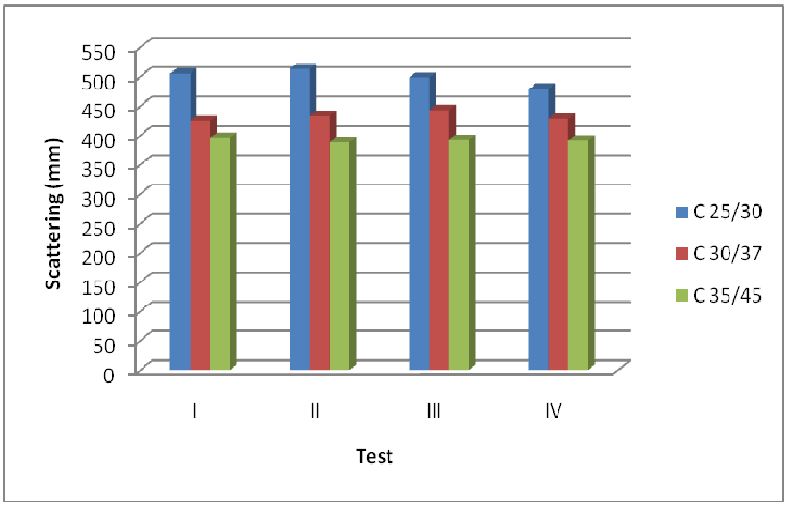


Figure 6.12 – Scattering (Spraying Table test)

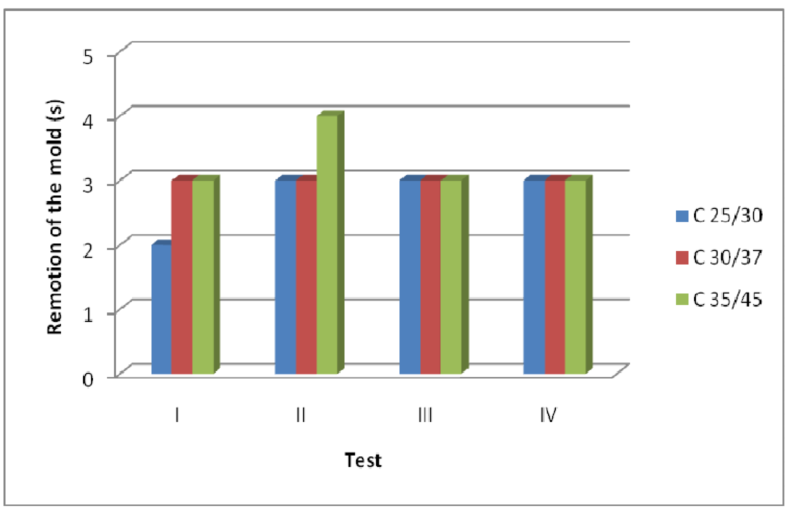


Figure 6.13 – Remotion of the Mold (Spraying Table test)

6.2.5. Air entrainment test

For the spraying table test the more interesting parameter to analyze is the air volume in percentage.

In the graphic presented is possible to see that all the parameters are inside the normal values (see in the chapter 4). The minimum value for this test is 2% so as we can see in the chapter bellow all the tests are above of this parameter.

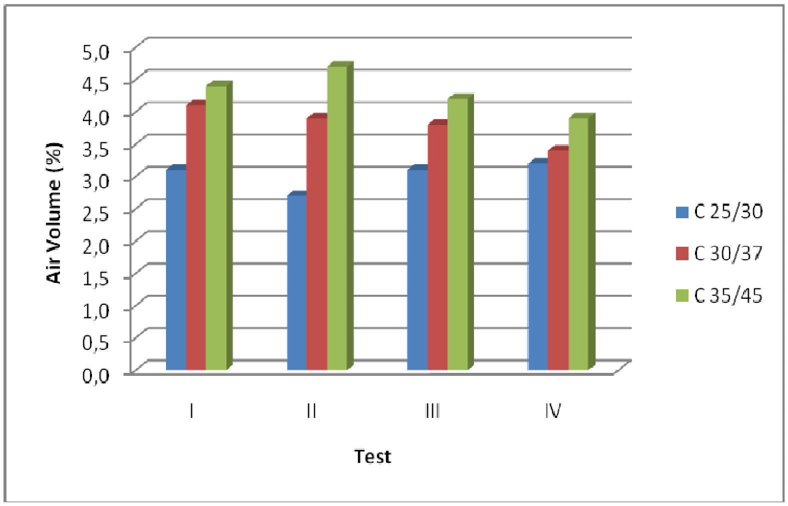


Figure 6.14 – Air Volume (Air Entrainment test)

6.3. Final conclusions

VAHOSTAV – SK is one of the biggest companies in Slovakia. They work not only in Slovakia but also in a lot of countries in Europe. They have also an interesting cooperation with one of the most important companies in Portugal: Mota-Engil. They work together in some constructions in Slovakia and they keep a good relation that can be very interesting for the future partnership Portugal-Slovakia in the next years, with respect in constructions and development of the roads in Slovakia.

Companies in the future are increasingly giving importance to its control and quality management, so they are always ahead in their field and that more are in line with the standards, more and more rigid, of a Europe that tend to be more and more global.

Having good systems of quality assurance is increasingly essential for companies where the largest of each branch, as seen by the firm with the author worked with, being no longer sufficient to have a quality department, but a mini-company associated with parent company, which deals only with these issues.

Quality is increasingly a very important word in everyday construction companies. No matter only just makes quickly and with low cost, quality is increasingly valued and the trend is to take on an increasing importance.

Concrete is the most important element in this type of road works. In all works of art he is present, and has enough specific requisites for each of its uses. This chapter presented fairly general technical specifications for its correct use in any type of work. Is an element that cannot be overlooked its quality control, because it often depends on all the support of any work. Requires a lot of care both in their manufacture, use of correct materials in correct quantities, transport and then application work. There are numerous tests to be able to control the quality control tests on the fresh concrete in the first instance and in-situ, and then testing the hardened concrete, which are laboratory and greater complexity.

Will be referred some of these tests, including tests in-situ, for which were set up check-lists, in order to get to a better control of their quality before they are implemented on site. Are also referred some of the tests in the laboratory, although this branch did not have the desired access, so he could perform well there, better control of its features.

All the tests that presented were the ones that the company gave me access to.

Those two tests were only able to get the results so is not possible to give any more information about that because of many restrictions to the laboratory access.

The final balance about all the experience of going to the construction site around eight times in all semester is very positive. Every engineer, worker and cooperator of the construction who was involved with the author was very kind and allowed to take a lot of photos and get much information. Was possible to see some of the concrete tests in real time and understand better the way that a construction like a big motorway is done in Slovakia. With all of this information absorbed during these five months was able to produce some check-lists to improve the concrete tests.

The balance of the implementation and discussion of the check-lists in this specific road showed that the fresh concrete tests can be very improved. Maybe not the way that the tests are realized, because one of the conclusions is that the check-lists are very complete, with simple language, and very simplified in it structure, so the controller can easily confirm the correct or not correct development of the procedure.

When, and after collect the opinion of a couple of workers, the tests are done, should exist in the construction site a specific place, where the tests can occur with the minimum exterior influence possible, so the results can be more and more correct, giving to the controller a better idea of the quality of the tested fresh concrete. If a place like this can exist in the construction site other factor that can be much reduced is the weather conditions, that sometimes, and it was proved in the use of the check-lists, influences the realization and the results of the tests.

Other important conclusion that was possible to take after this 15 days experience, is the fact of the concrete supplier had access to the filled check-lists, so they can try to improve the concrete production, so they can reduce the number of rejected trucks, that is always a problem to this kind of construction. The responsible of the concrete supplier company, came one day to the construction site, only to speak directly with me, to say that he will use the check-lists to do some statistic of the main problems occurred with the concrete quality, so they can improve it, for reducing the quantity of rejected concrete by the construction owners.

For the company the author was working to (Váhostav – SK), the reactions were very positive. They didn’t have anything similar; they just registered the tests results in some paper (Fig. 6.6), without any organization, and then they archive them in some book related to the construction. The responsible for the author stay in Váhostav – SK, Mr. Masa, told that they will propose the adoption of the check-lists for future constructions, because, and like that feedback was given before, they are very clear, simple and intuitive, in the tests procedures and also in the structure.

As a final conclusion about the work, is fair to say that the author was very well received in this Slovak constructions reality. Is, without any doubt, a country with a lot of potential for the roads constructions, and in those 5 months stay, a lot of contribute was given to improve their quality control conditions, in concern of fresh concrete tests.

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ANNEX 1

QUALITY CHECK-LISTS

Summary of Check-Lists developed for Quality Control of Concrete

Designation	Reference	Available
Quality Check-Lists		
Lowering Test (Slump Test)	QCL_CT_ST	in Annex
Vebe Test	QCL_CT_CDT	in Annex
Compactness Degree Test	QCL_CT_CDT	in Annex
Spraying Table Test	QCL_CT_STT	in Annex
Air Entrainment Test	QCL_CT_AET	in Annex

TITLE

Company Symbol:	QUALITY CHECK LIST - CONCRETE TEST'S	Reference:
	Lowering Test (Slump Test)	QCL_CT_ST

IDENTIFICATION

Road: ______________________

Construction Owner: ______________________

Constructor: ______________________

Concrete Supplier: ______________________

Controller:

PROJECT REFERENCES

Specifications Book: ______________________
(Pages)

Drawings: ______________________
(Reference)

Norme: ______________________

(image)

Local of concrete aplication: ______________________

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

CONTROL POINTS

√ Check × Not Check / Canceled

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		

Helper	Visual	Yes/No	I		
			II		
			III		
			IV		

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Maximum Dimension of the Aggregate	Visual	≤ 40 (mm)	I		
			II		
			III		
			IV		
Lowering	Measure	[10,200] (mm)	I		
			II		
			III		
			IV		

Execution Times

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Execute the whole operation of mold	Clock	6 to 10 seconds	I		
			II		
			III		
			IV		
Execute the whole operation	Clock	< 150 seconds	I		
			II		
			III		
			IV		

Equipment

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Mold (truncated cone): Cone of Abram	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		
Graduated scale from 0 to 300 (mm)	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		

OBSERVATIONS

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				

TITLE

Company Symbol:	QUALITY CHECK LIST - CONCRETE TEST'S	Reference:
	Vebe Test	QCL_CT_VT

IDENTIFICATION

Road: ____________________

Construction Owner: ____________________

Constructor: ____________________

Concrete Supplier: ____________________

Controller:

PROJECT REFERENCES

Specifications Book: ____________________
(Pages)

Drawings: ____________________
(Reference)

Norme: ____________________

(image)

Local of concrete aplication: ____________________

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

CONTROL POINTS

√ Check × Not Check / Canceled

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		

Helper	Visual	Yes/No	I		
			II		
			III		
			IV		

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Maximum Dimension of the Aggregate	Visual	≤ 63 (mm)	I		
			II		
			III		
			IV		
Vebe Workability	Clock	[5,30] (sec.)	I		
			II		
			III		
			IV		

Execution Times

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Operation Unmold, mold test lowering	Clock	5 to 10 seconds	I		
			II		
			III		
			IV		
Total test duration	Clock	5 minutes	I		
			II		
			III		
			IV		

Equipment

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Vebe Consistometer	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		
	Visual	Yes/no	I		
			II		
			III		
			IV		

OBSERVATIONS

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				

TITLE

Company Symbol:	QUALITY CHECK LIST - CONCRETE TEST'S	Reference:
	Compactness Degree Test	QCL_CT_CDT

IDENTIFICATION

Road: ____________________

Construction Owner: ____________________

Constructor: ____________________

Concrete Supplier: ____________________

Controller:

PROJECT REFERENCES

Specifications Book: ____________________
(Pages)

Drawings: ____________________
(Reference)

Norme: ____________________

(image)

Local of concrete aplication: ____________________

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

CONTROL POINTS

√ Check × Not Check / Canceled

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		

Helper	Visual	Yes/No	I		
			II		
			III		
			IV		

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Maximum Dimension of the Aggregate	Visual	≤ 63 (mm)	I		
			II		
			III		
			IV		
Heigh of the container (h1)	Measure	400 (mm)	I		
			II		
			III		
			IV		
Degree of Compactness	Calculate (*)	> 1,04 and < 1,46	I		
			II		
			III		
			IV		

(*) Determine the value "s" (mm) corresponding to the average of 4 values of the distance between the surface of the compressed concrete and the upper container.

Degree of compacness = h1 / h2 = h1 / (h1 - s)

h1 - height of the container (mm)
h2 - height of the compressed concrete (mm)
s - average (mm) the distance between the surface of the compressed concrete and the upper container

The result is presented rounded to the nearest hundredths.

Equipment

Vibrator	Visual	Yes/no	I		
			II		
			III		
			IV		
Container	Visual	Yes/no	I		
			II		
			III		
			IV		
Spon	Visual	Yes/no	I		
			II		
			III		
			IV		

OBSERVATIONS

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				

TITLE

Company Symbol:	QUALITY CHECK LIST - CONCRETE TEST'S	Reference:
	Spraying Table Test	QCL_CT_STT

IDENTIFICATION

Road: ______________________

Construction Owner: ______________________

Constructor: ______________________

Concrete Supplier: ______________________

Controller:

PROJECT REFERENCES

Specifications Book: ______________________
(Pages)

Drawings: ______________________
(Reference)

Norme: ______________________

(image)

Local of concrete aplication: ______________________

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

CONTROL POINTS

√ Check × Not Check / Canceled

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		

Helper	Visual	Yes/No	I		
			II		
			III		
			IV		

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Maximum Dimension of the Aggregate	Visual	≤ 63 (mm)	I		
			II		
			III		
			IV		
Scattering Values	Measure (*)	> 340 and < 600 (mm)	I		
			II		
			III		
			IV		

(*) It is measured with a ruler the diameter of the cake in 2 directions parallel to the sides of the table to the nearest 10mm, the average is taken to approximate to 10mm. the value obtained corresponds to the diameter of spreading. The result is presented to the nearest 10mm.

Execution Times

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Remotion of the mold and raised to top plate	Clock	Every 2 to5 seconds	I		
			II		
			III		
			IV		
Repetion time of the remotion procedure	Count	15 times	I		
			II		
			III		
			IV		

Equipment

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Mold (truncated cone): Cone of Abram	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		
Graduated scale from 0 to 300 (mm)	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		
Speading table	Visual	Yes/no	I		
			II		
			III		
			IV		
Spon	Visual	Yes/no	I		
			II		
			III		
			IV		

OBSERVATIONS

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				

TITLE

Company Symbol:	QUALITY CHECK LIST - CONCRETE TEST'S Air Entrainment Test	Reference: QCL_CT_AET

IDENTIFICATION

Road: ____________________

Construction Owner: ____________________

Constructor: ____________________

Concrete Supplier: ____________________

Controller:

PROJECT REFERENCES

Specifications Book: (Pages) ____________________

Drawings: (Reference) ____________________

Norme: ____________________

Local of concrete aplication: ____________________

(image)

ACTS REGISTER

	I	II	III	IV
Localization				
Date	/ /	/ /	/ /	/ /
Hour	:	:	:	:
Weather Conditions(*)				
Concrete Type				

Note (*): A: sunny; B: clear; C: cloudy; D: rain; E: snow

CONTROL POINTS

√ Check × Not Check / Canceled

Workers

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Responsible	Visual	Yes/No	I		
			II		
			III		
			IV		

Helper	Visual	Yes/No	I	
			II	
			III	
			IV	

Scope

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Air Volume	Measure	0 to 5 (%)	I		
			II		
			III		
			IV		

Equipment

Verifications	Way of Control	Decision Criteria	Decision/Observations		
Spon	Visual	Yes/no	I		
			II		
			III		
			IV		
Water	Visual	Yes/no	I		
			II		
			III		
			IV		
Stick for concrete compress	Visual	Yes/no	I		
			II		
			III		
			IV		
Press-Ur-Meter	Visual	Calibration Yes/no	I		
			II		
			III		
			IV		

OBSERVATIONS

AUTHENTICATION

	I	II	III	IV
Responsible				
Controller				