Manual on risks associated with lack of knowledge and lack of standardization in the use of ready-mixed concrete in construction sites: A useful tool for the user

https://doi.org/10.56238/sevened2024.002-050

Gustavo Thomaz Garcia de Oliveira[1], Ian Felix de Oliveira[2], Roberto Felix de Souza Junior[3] and Sylma Carvalho Maestrelli[4]

ABSTRACT

Ready-mixed concrete is a product that has been widely applied in civil constructions, as they offer some advantages such as reducing the execution time of the work and better-quality control in the concrete manufacturing processes have better quality. Its choice is based on properties such as compressive strength (fck), water/cement factor (w/c), minimum cement consumption per m³ (kg/m³), slump, durability, setting time, among others. To obtain the desired properties for the machined concrete, there is a need for technological control, which covers everything from the choice of component materials to the stages of thickening and curing the concrete. There are standardized procedures for both the concrete company and the professionals involved with the application of ready-mixed concrete. With the growth of the city of Poços de Caldas in recent years, there is a tendency to increase the occurrences related to failures during concreting in small and medium-sized works, in line with the lack of professionals with knowledge and experience that provide better technological control. These possibilities can cause insecurity for future residents, with the appearance of pathologies and even accidents. In view of the above, this work aimed to prepare a practical guidance manual for the general population, with emphasis on the owners who hire the services of the concrete company and the technical managers, to guide them on the actions, control, and responsibilities during the receipt/use of machined concrete.

Keywords: Ready-mixed concrete, Standardization, Manual, Concrete properties.

[1] Bac., Federal University of Alfenas (UNIFAL/MG), Poços de Caldas campus
[2] Bac., Federal University of Alfenas (UNIFAL/MG), Poços de Caldas campus
[3] Bac., Federal University of Alfenas (UNIFAL/MG), Poços de Caldas campus
[4] Profa. Dr., Federal University of Alfenas (UNIFAL/MG), Poços de Caldas campus
E-mail: sylma.maestrelli@unifal-mg.edu.br
LATTES: http://lattes.cnpq.br/0216431851054031

INTRODUCTION

Portland cement concrete is a widely used building material in recent years. Its use on a large scale has some advantages, such as excellent compressive strength after hardening, being economically attractive and being an easy-to-mold material, making it possible to build in various shapes and sizes (LOPES; PEÇANHA; CASTRO, 2020).

Its production can be on a construction site or on an industrial scale, where it is carried out in concrete plants with greater technological control. With regard to its large-scale production, in addition to being an excellent economic thermometer and being able to present benefits in terms of the structural safety of housing, it also serves to warn about the procedures of commercialization, preparation and application. To ensure that concrete is used correctly and efficiently, it is necessary to know its properties, such as workability, cohesion, compressive strength, durability, among others, as well as the appropriate and standardized techniques for its application.

In Brazil, the Brazilian Association of Technical Standards (ABNT) is responsible for these standardizations, which is the National Standardization Forum that has been operating since 1940. This private body is responsible for the elaboration of technical standards , contributing to the development through certification, safety and consumer protection. In the field of civil construction, there are several guidelines established by ABNT for the most diverse stages; from the acquisition of materials, the procedures of preparing the concrete, pouring and curing the concrete. In addition to standardized tests to assess the correct performance and guarantee the quality and durability of the projects.

These standards and guidelines must be known by the technical professionals who accompany the work. But many times, the consumer client does not know the importance of the execution procedures and disregards the information and requests of the professional, because it demands extra cost and does not understand the importance of the process. Therefore, it is necessary that there is knowledge on the part of the general population of the procedures that must be performed during concreting to ensure the quality and safety of the concrete used in the work, as recommended in the standards.

Due to the importance of the product in society and the high consumption of materials that take time to be produced in nature, several studies have been developed focused on improving the properties of concrete. Given the above, this research has as its main focus the elaboration of a manual to improve access to information about the procedures for the use of ready-mixed concrete. In order to assist in the use of concrete, this work presents a practical and easy-to-understand roadmap, containing information and guidance on the different types of concrete, their components, dosing, mixing, transporting, pouring and curing. In addition, topics such as safety in the use of concrete, care during the execution of the work and solutions to possible problems that may arise will be presented here.

This article related to the use of concrete is intended for people whose goal is to execute their first purchase/acquisition of a concreting service, as well as for construction professionals, engineering and architecture students, as well as anyone interested in learning more about the subject. With the knowledge acquired through this material, it is expected that the use of concrete will be more efficient and safer, ensuring the quality of the works and the satisfaction of the customers.

LITERATURE REVIEW

CONCRETE: DEFINITION AND CONSTITUENTS

Concrete is a material made up of cement, coarse aggregate, fine aggregate and water. If it is necessary to make modifications to its properties, it may have additions (silica fume, pozzolans, fly ash, etc.) and other types of additives (BASTOS, 2023).

Regarding the mixture that make up concrete, it can be said that generally 3/4 of the volume of concrete is aggregated. This is due to a few factors, one of which is economic, because in relation to mass per value (kg/$), aggregates are the cheapest components of the concrete composition. For this reason they tend to lower the value of the cubic meter, there is always the need to find the best proportion between the materials (dosage) so that you have the most suitable concrete for the desired use with the best possible value.

The quality of the aggregates should be a selection factor for the composition of concrete, since they can limit its mechanical and chemical resistance. Concretes dosed in plants, which are plants responsible for the dosing, production and delivery to the buyer of concrete in a plastic and non-hardened state (MEHTA; MONTEIRO, 2008) usually have their own laboratories, or contracted ones, to evaluate the quality of the aggregates, because the selection of materials with the best properties and characteristics results in the concrete with the best formulation for certain applications. At first, aggregates were considered inert materials, dispersed in cement paste, and were used mainly for economic reasons. However, it is possible to adopt a contrary view and consider them a building material linked to a cohesive whole through cement paste, in a similar way to masonry (NEVILLE, 2016).

The aggregates that make up the concrete need good mechanical strength and should not have reactive potentiality. The presence of certain minerals in the aggregates with alkaline hydroxides in the internal structure of the concrete enables a chemical reaction called alkali-aggregate reaction (NOGUEIRA, 2010). This reaction forms products that, in the presence of moisture, can generate cracks and consequently compromise concrete structures.

Aggregates also make concrete more durable as the characteristics of volume stability and durability compared to cement paste is higher. Almost mostly, the aggregates are extracted from natural deposits, and can be classified into two types according to the ABNT NBR 7211 standard - Aggregates for concrete - Specification:

a) Coarse aggregate: Aggregate whose grains pass through the sieve with a mesh opening of 75 mm and are retained in the sieve with a mesh opening of 4.75 mm, in a test carried out in accordance with the ABNT NBR NM 248 standard, with sieves defined by the ABNT NBR NM ISO 3310-1 standard. Coarse aggregates usually come from matrix rocks, whose mechanical characteristics are important for concrete, in addition to its characteristics such as high compressive strength, its dimension, tensile strength, among others, are criteria for determining its use in the composite;

b) Fine aggregate: Aggregate whose grains pass through a sieve with a mesh opening of 4.75 mm and are retained in the sieve with a mesh opening of 150 µm, in a test carried out in accordance with the ABNT NBR NM 248 standard, with sieves defined by the ABNT NBR NM ISO 3310-1 standard. In general, fine aggregates are the ones that give concrete the agglutination characteristics of coarse aggregates, and the mixture of cement, water and fine aggregates produce the mortar, responsible for the better distribution of coarse aggregates so that there is homogeneity in the product.

De La Iglesia, Murillo, and Restrepo (2021, p. 2) point out that "the most widely used aggregates in the world come from natural deposits formed in riverbeds or floodplains and are relatively inexpensive, as they generally do not require any industrial process." Currently, there are several special concretes that have additional components, such as fibers, polymers and other additives, so that it can be applied in a specific everyday situation.

Portland cement is a powdery material, consisting of silicates and calcium aluminates, with practically no free lime. These silicates and aluminates, when mixed with water, hydrate and produce the hardening of the dough, providing an increase in mechanical resistance (PETRUCCI, 1998). Thus, cement is the main constituent of concrete with regard to the improvement of mechanical properties , and it is currently possible to achieve mechanical strengths above 60 MPa. This improvement in concrete properties, in general, occurs from small changes/optimizations in the formulation, in the reduction of the water/cement factor (w/c), increasing the workability of the fresh state, reduction of incorporated air, or even setting time, among others.

Additives do not necessarily need to be present in the mixture to characterize a concrete. Although they are not an essential component of concrete mixing, they are important and increasingly widespread components. In several countries, an additive-free mixture may be considered an exception (NEVILLE, 2016).

Additives have numerous functions for concrete, as they can increase mechanical strengths, workability and setting start time and adjust the required properties depending on the application. Its costs are reasonably high, but the benefits that this addition brings are worth it. In mixtures, additives can be used that improve the properties of the concrete, improving connectivity and reducing the water demand in the mixture. Modern complex additives accelerate hardening and can improve its overall mechanical strength (CHIKNOVORYAN; MIZURYAEV; ZHIGULINA, 2020).

TYPES OF CONCRETES

According to Mehta and Monteiro (2008), concrete can be classified according to its specific mass. A concrete with natural sand and crushed aggregates with a specific mass of around 2400 kg/m³ is classified as normal density concrete, being the most used for structural purposes. On the other hand, concrete produced with less dense aggregates and below 1800 kg/m³ are classified as lightweight concrete. Heavy concretes are characterized by concretes produced with denser aggregates and that generally have a specific mass above 3200 kg/m³.

According to the ABNT NBR 8953 (2015) standard, structural concretes that have a compressive strength of less than 20 MPa are classified as non-structural, while equal to or above this value they can be classified as group I and group II strength classes

Depending on the span to be overcome in the structural design with conventional concrete, the structural element may have significant dimensions, thus ending up that the weight of the element itself makes its execution unfeasible, making it deficient for this application (MEHTA; MONTEIRO, 2008). Also according to the authors, to correct the problem, there are options to replace conventional aggregates with light aggregates, in order to reduce the specific mass of the concrete, the use of superplasticizers or water-reducing additives, which increase the strength of the concrete, and also the combination of these alternatives to further improve the application of concrete.

The main types of special concretes and applications are presented below:

a) Lightweight Structural Concrete: Concrete characterized by low specific mass, reducing approximately two-thirds of the specific mass when compared to concrete made with typical material. They are applied in works that imply a lower total cost;
b) High Strength Concrete: Defined based on the compressive strength value at a given age. They can be applied to any type of structure, but offer the advantage of building thinner pillars;
c) Self-Compacting Concrete: Defined as a fluid concrete, which can be molded without the use of vibrators, avoiding the segregation of coarse aggregate from the mortar. They are applied in submerged concrete, and in densely reinforced structures;

d) High Performance Concrete: Concrete that meets the specific combination of requirements and performance, for specific applications and environments. The main applications are in sophisticated structures such as oil rigs, long-span bridges, and viaducts;

e) Compensated Shrinkage Concrete: Expansive cement concrete, which when employed, due to formwork and reinforcement constraints, will expand by greater or equal amount expected by shrinkage. They are applied to structural elements such as slabs, pavements, prestressed beams and roofs;

f) Fiber Reinforced Concrete - CRF: Concrete that contains cement, water, aggregates and discrete staple fibers, which can be made of steel, plastic, glass and natural materials. Applied to structures that contain appropriately designed continuous reinforcement;

g) Polymer Containing Concrete: There are three categories: Polymeric Concrete (CP), Latex Modified Concrete (CML) and Portland Cement Polymeric Concrete (PPCC);

h) Heavy Concrete for Radiation Shielding: Characterized by the use of heavy aggregates, approximately 50% more than aggregates with normal weight. Commonly used for biological shielding in nuclear power plants, medical facilities, and atomic testing and research facilities;

i) Mass Concrete: Concrete in a massive structure that requires special means to combat heat generation due to volume variation. They are widely used in the construction of dams;

j) Roller Compacted Concrete (CCR): Concrete that is compacted by means of rolling. In the non-hardened state, it must support the roller while it is compacted, and drying enough to prevent sinking of the roller as well as being moist enough to allow for correct compaction and proper distribution of the material.

CONCRETE PREPARATION

Dosage can be defined as the appropriate proportion of the constituent materials such as cement, coarse aggregate, fine aggregate, water and additives. Thus, the structural designer is responsible for the properties of the concrete in the hardened state, while the properties in the fresh state also depend on execution techniques such as transport, pouring and densification of the concrete (HELENE; TERZIAN, 1992).

After defining the formulation (trace) of the concrete to be used, the mass can be prepared both on construction sites and in batching plants. According to the definition of the ABNT NBR 12655 standard (2015, p. 3), the concrete prepared on site is the "concrete prepared by the executor of the work: When the dosage and preparation of the concrete are carried out at the construction site by the builder". On the other hand, there is another type of concrete preparation, in batching plants, which are responsible for dosing and mixing.

PROPERTIES OF CONCRETE

Neville and Brooks (2013) define that a good concrete is one that is satisfactory in its fresh and hardened state, thus satisfying during the stage of launching the concrete mixer until the thickening in the formwork. Thus, in general, there are requirements that must be met in order for the concrete to be classified as acceptable or compliant.

In the fresh state, the property analyzed is the consistency so that the concrete can be compacted correctly. Consistency is directly related to the workability of concrete, which is a property composed of cohesion and fluidity (MEHTA; MONTEIRO, 2008). The cohesion of the mixture measures the segregation and exudation of the mixture. Fluidity, on the other hand, measures the ease of mobility of fresh concrete.

In the hardened state, the main property measured is compressive strength, and it is easy to measure (NEVILLE, BROOKS, 2013). Compressive strength is related to other properties such as specific mass, durability, impermeability, tensile strength, abrasion resistance, impact resistance, modulus of elasticity and others.

Workability

Workability is defined as a physical property of concrete that corresponds to the amount of energy required to cause complete densification of concrete (NEVILLE, 2016). It is an essential property for the maximum possible densification in molds, having as its main factor the water content in the mixture, but which can also be influenced by cement consumption, aggregate characteristics (size and proportion) and additives (MEHTA; MONTEIRO, 2008). The excess amount of water added, despite improving the workability of the concrete, can compromise the mechanical strength of the concrete, due to the formation of voids after the excess water is removed (NEVILLE, 2016).

The workability of fresh concrete determines the ease with which a concrete mixture can be manipulated without segregation that compromises the strength of the concrete (MEHTA; MONTEIRO, 2008).

Workability integrates certain characteristics such as cohesion and consistency. Andolfato (2002, p. 11) defines consistency as a "property related to the degree of fluidity of the mixture". Mehta and Monteiro (2008, p. 330) define consistency as "a measure of the moisture content of the concrete mixture, which is commonly evaluated in terms of slump".

Mehta and Monteiro (2008, p. 330) define cohesion as "a measure of the ease of densification and finishing, generally evaluated by the straightening capacity and by the visual evaluation of the resistance to segregation".

Segregation is defined as the separation of the constituents of a concrete mixture in such a way that their distribution is not uniform, and can be of two types: The first type comes from dry concrete mixtures that cause separation of the coarse aggregates and the mortar, and the second type comes from very fluid mixtures, called exudation (MEHTA; MONTEIRO, 2008).

The other type of segregation, exudation, is defined by Mehta and Monteiro (2008, p. 370) as "a phenomenon whose external manifestation is the appearance of water on the surface after the concrete has been poured and thickened, but before its take-up.

Matrix, reinforcement and interface of concretes

Concrete is a material that has two phases: matrix phase and dispersed phase (also known as reinforcement). The matrix phase corresponds to the continuous phase of the material and involves the dispersed phase, which can be particles, fibers, among others. The properties of concrete are related to these constituent phases and the geometry of the dispersed phase, which are the shape, size, distribution and orientation of the particles (CALLISTER, RETHWISCH, 2012).

The dispersed phase or also called aggregate phase is mainly responsible for some properties of concrete such as unit mass, modulus of elasticity and dimensional stability, based on the density and strength of the aggregates (MEHTA; MONTEIRO, 2008). However, it does not directly influence the strength of the concrete, but it can favor the occurrence of exudation, which is the formation of water on the surface of the concrete after pouring and thickening (MEHTA; MONTEIRO, 2008).

The matrix phase or hydrated cement paste has greater responsibility in the strength and other mechanical properties of the concrete. In its microstructure, it is observed that the poor distribution and heterogeneity of the various phases of the cement matrix can directly impair the mechanical properties of the concrete, and, therefore, it is essential to pay attention to the rheological properties of the cement paste in the fresh state, which in a certain way influences the microstructure of the hardened cement paste (MEHTA; MONTEIRO, 2008).

Thus, this agglomeration can cause the retention of a certain amount of water in the mixture, causing the formation of voids and other defects in its microstructure (CASTRO, PANDOLFELLI, 2009). With this, a relationship between the microstructure and the properties of the material can be established.

Mehta and Monteiro (2008) point out that the desirable characteristics of concrete such as mechanical strength, dimensional stability and durability are dependent on the properties of the hydrated cement paste, which in turn depends on the amount of solids and voids present in the medium. To top it off, the strength is characterized by the Van der Waals interactions, and that the level of interaction depends on the shape and nature of the surfaces involved, between the aggregates and the cement paste. However, many of the properties of concrete are analyzed by the region called the transition zone at the interface. This region corresponds to a separate "phase", which is the area close to the region of the coarse aggregates, and is considered the most fragile part of the concrete (MEHTA; MONTEIRO, 2008).

Soon after compacting the concrete in its fresh state, a layer called film is formed around the constituent aggregates of the concrete, increasing the cement/water ratio. Calcium, sulfate, hydroxyl and aluminate ions combine to form etringite and calcium hydroxide crystals. These crystalline products, in the vicinity of coarse aggregates, are larger crystals and consequently form a more porous matrix of the cement paste. However, with the development of hydration, the smaller crystals fill the voids in the cement paste, increasing its resistance (MEHTA; MONTEIRO, 2008).

The Van der Waals force of attraction is responsible for the contact of hydration with the aggregate and influencing the resistance presented by the transition zone at the concrete interface, being related to the volume and size of the void area in the structure. A problem for concrete interfaces related to low strength is directly connected to micro-cracks that are subject to cracking when subjected to tensile stresses. The amount of microcracks depends on many parameters, including the size of the aggregate and its particle size distribution, cement consumption, water/cement ratio (w/c), degree of densification of the concrete in the fresh state, curing conditions, ambient humidity and thermal history of the concrete (MEHTA; MONTEIRO, 2008).

The transition zone at the interface, therefore, is what causes the concrete to break at lower stress levels than the resistance of the other main constituents and which do not require a very high energy level, presenting an inelastic behavior in uniaxial compression (MEHTA; MONTEIRO, 2008).

In some constructions with concrete structures, reinforcement applications are required to increase load resistance, decrease deterioration losses, correct design deficiencies, or increase ductility (FUGIYAMA et. al., 2021). As a structural material, concrete has some limitations and disadvantages such as low tensile strength, thermal contractions, and expansions. To improve these deficiencies, reinforcements and additives such as steel, glass, nylon and polyethylene can be used, as well as prestressed concrete and post-tensile concrete manufacturing techniques (CALLISTER, RETHWISCH, 2012).

Curing of concretes

According to Neville (2013, p. 334), "curing is the name given to the procedures adopted to promote cement hydration and consists of controlling the temperature and the inflow and outflow of water from the concrete". Its purpose is to control temperature and moisture loss in order to achieve the desired resistance (MEHTA; MONTEIRO, 2008).

The curing procedure aims to keep the concrete saturated with the cement's hydration products. It consists of adding water to the concrete to replace the evaporated water through self-desiccation (NEVILLE; BROOKS, 2013). For the construction of concrete structures, it is interesting to avoid early demolding, since this would cause the evaporation of water from the concrete in the early ages (GRILLO, 2014 *apud* ISAIA, 2011).

According to Pacheco and Helene (2013), several procedures can be adopted for concrete curing: impoundment or immersion, spraying of water or water mist (spray), saturated coatings that retain moisture, and sealing of the concreted surface through an application of a paper blanket. The authors also point out that inadequate curing causes premature drying, facilitating the attack of aggressive agents and the appearance of cracks, compromising the durability of the structure, with the emergence of pathologies that can generate discontent for future residents.

Compressive strength

Resistance is defined as any material that withstands stresses without breaking, which are identified with the appearance of cracks, and the microstructure of concrete has many cracks even before exerting stress on the material.

The compressive strength of concrete has been used as the main parameter for dosing and quality control of concrete in construction sites due to the simplicity of molding cylindrical specimens and the sensitivity of resistance to changes in the mixing trace, in addition to the importance of this property in structural projects (HELENE; TERZIAN, 1992).

Many of the properties of concrete, such as modulus of elasticity, tightness or impermeability, and resistance to weathering, including aggressive waters, are correlated with strength and, therefore, can be deduced from mechanical compressive strength data (MEHTA; MONTEIRO, 2008).

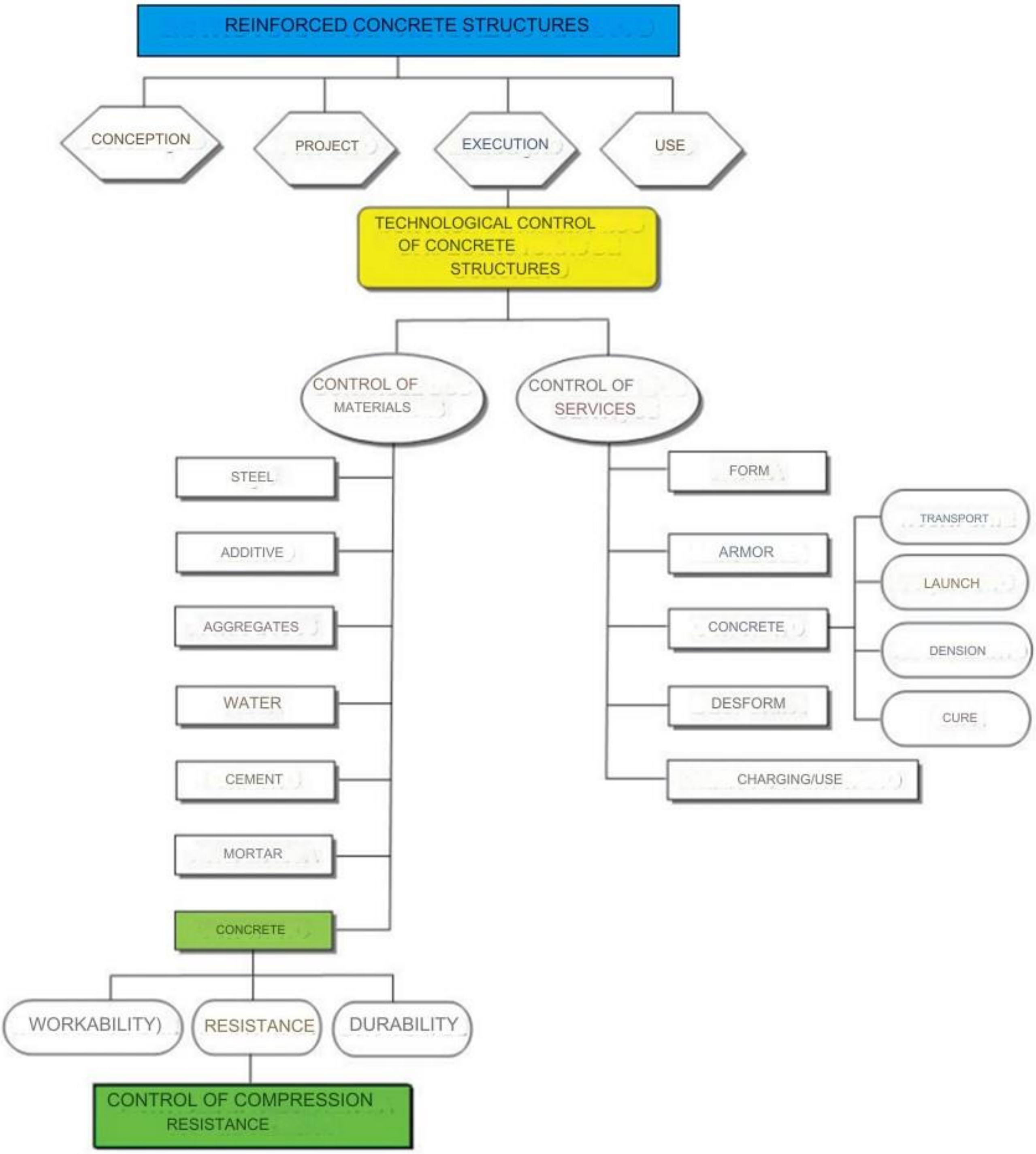
The structure of the concrete must approach the strength-porosity relationship seriously, and since the pores in the component phases, near the transition zone, are limiting the strength. In concrete containing low porosity or high-strength aggregates, the strength of the material will be governed by the strength of both the matrix and the transition zone at the interface (MEHTA; MONTEIRO, 2008).

When applying stresses to concrete, the response depends not only on the type of stress applied, but on the combination of factors that affect the porosity and proportion of the concrete traces, the degree of compaction, and conditions for curing. For the strength of the material, the water/cement ratio (w/c) and porosity are extremely important because they directly affect the cement mortar matrix and the transition zone at the interface of the matrix and coarse aggregate.

The ABNT NBR 5738 (2015) standard – Molding and curing of cylindrical or prismatic concrete specimens – establishes the necessary procedures for molding and curing cylindrical or prismatic concrete specimens, and the ABNT NBR 5739 (2018) standard – Compression Tests of Cylindrical Specimens – prescribes the compression test method of specimens.

As highlighted by Helene and Terzian (1992, p. 104), "there are several factors that intervene in the strength of the concrete structure; from the heterogeneity of the materials to the transport, pouring, thickening and curing of the concrete on site". Figure 1 shows a block diagram showing the factors that interfere with the control of concrete strength.

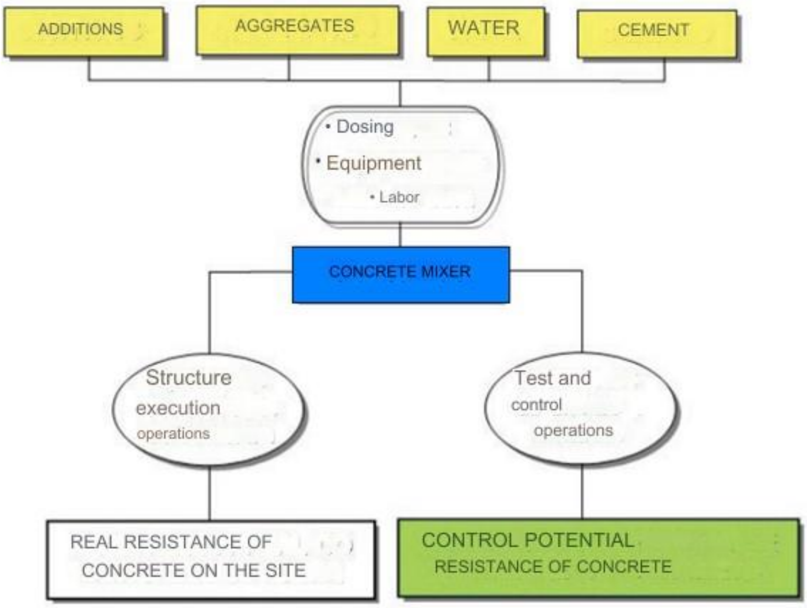
Figure 1 - Diagram of concrete strength control blocks.



Fonte: adaptado de PACHECO, HELENE, 2013.

The compressive strength measurement is obtained by sampling the concrete mixer outlet, as shown in the block diagram in figure 2.

Figure 2 - Compressive strength of concrete obtained from the concrete mixer.



Fonte: adaptado de PACHECO, HELENE, 2013.

According to figure 2, the mixture of constituent materials made in the concrete mixer has two destinations: Part of the mixed concrete is collected by means of samples that are subjected to testing and control operations. The remaining material is directed to a certain structural component.

A sample must be taken from each batch, with the number of specimens that depend on the type of resistance control, which can be: Statistical control by partial sampling or statistical control by total sampling. Partial sampling control is a calculation method that makes an estimate of the characteristic resistance (*fck*). As for the control by total sampling, the removal of samples must be carried out at each concrete, and the statistical value (*fck*) equal to that obtained by the specimen that represents the concrete of the concrete is admitted (NBR 12655, 2022).

During the sampling stage, each specimen consists of two specimens of the same knead for each age of rupture, molded in the same act. The two specimens are subjected to compression tests, and the highest value is adopted as resistance.

The result obtained in the test and inspection operations is the reference value for the design of the structure. However, generally, the conditions of the specimens are different from the actual structural conditions, such as geometry, densification and finish (HELENE; TERZIAN, 1992).

Durability

The durability of concrete in structures is attributed to its ability to resist aggressions from the external environment, some of which are of a physical or chemical nature, and are generally associated with expansive phenomena inside the already hardened concrete (FUSCO, 2008).

The concrete structure must maintain its characteristics of mechanical strength and usefulness over the estimated time, having a long and lasting useful life, withstanding the deterioration process while exposed and consequently identified with a durable concrete.

Concrete can have inadequate durability in which it arises through internal or external deterioration, being of a physical nature (effects of high temperature or differences between the coefficients of thermal expansion of the aggregate and the hardened cement paste), mechanical (derived from impacts, abrasion, erosion and cavitation) or chemical (alkali-silica and alkali-carbonate reactions) where aggressive ions such as chlorides are used, sulfates, carbon dioxides (carbon dioxide) and liquids or gases (industrial or natural).

The durability of concrete considers three large fluids that penetrate the structure, moving in different ways and dependent on the structure of the hydrated cement paste, namely:

(a) pure water or water with aggressive ions;

b) Carbon dioxide;

c) Oxygen.

The ease of penetration and movement of these fluids in a liquid or gaseous state internally in the concrete, generating a flow through a porous medium will determine the permeability of the concrete. It is noted that these internal flows do not occur only by the flow through pores, but other existing flow media, such as diffusion and sorption, causing the results of penetrability of the concrete.

The important pores for permeability are the continuous pores with a minimum diameter of 120 or 160 mm, on the other hand, the irrelevant pores will be discontinuous pores because they have adsorbed water and narrow openings. The concrete aggregate in general also presents discontinuous behavior, where they are surrounded by the cement paste and do not influence the permeability. For this reason, the discrete air bubbles involved in the concrete also do not cause changes in permeability.

TECHNOLOGICAL CONTROL OF CONCRETE AND ITS BARRIERS

The acceptance control of the concrete is done based on the fulfillment of the specified properties. The purpose is to judge whether the concrete conforms to what is specified or not (HELENE, TERZIAN, 1992). Therefore, quality control of concrete during use in structures is essential to ensure the satisfaction of specified requirements.

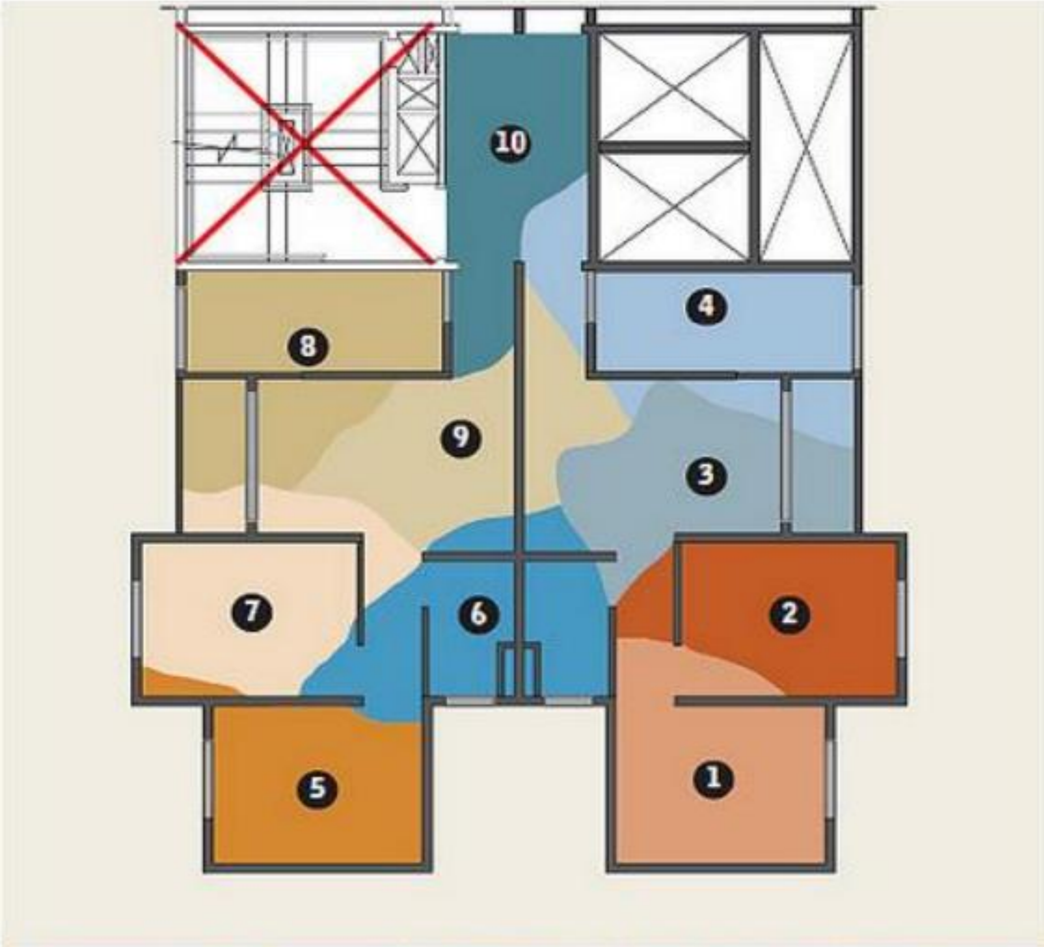
For the technological control of the concrete, some parameters are analyzed, such as cement consumption determined by the plant, the water/cement factor (w/c), the slump in the fresh state, concrete mapping, specimen molding and compression tests. These indicators are a way to evaluate the quality of the concrete that is being delivered, in order to verify the fulfillment of the desired properties, and consequently, ensuring better performance of the structure.

Traceability is a type of concrete control in which the application history is recorded. The most used model is the elaboration of concrete maps, where the elements that will be concreted are marked on plans, and associated with the material that is being used. The tool assists in the study of a possible non-conformity that may occur to treat the problem (ZALAF, FILHO, BRAZ, 2014). Figure 3 represents an example of a concreting map.

In the concrete industry, quality goes through the control of raw materials, the mixing process, execution steps and conformity tests (SCHUTTER; LESAGE, 2018). Generally, in large-scale works, there is a very rigorous process with the quality of the concrete worked, as these are constructions that need a more resistant concrete due to the scale and structure. However, in small and medium-sized works, in general, there is not a very effective control. According to Gomes Neto (*apud* RIBEIRO et al., 2016, p. 734), "small and medium-sized works, in most cases, neglect the normative specifications regarding the technological control of concrete, including the connivance of those responsible for it".

The increase in the water/cement ratio (w/c) modifies the mechanical properties of the concrete, causing the formation of voids that decrease the mechanical strength. When there is an excess of water added to the mixture, it may not meet the pre-established parameters for application (BARBOZA, et. al., 2017).

Figure 3- Example of a concreting map.



ÁREA	DATA	HORA DE INÍCIO	Nº DO CAMINHÃO	NOTA FISCAL
1	15/06/2011	07:05	125	51-99.888
2	15/06/2011	07:45	213	51-99.891
3	15/06/2011	08:20	079	51-99.892
4	15/06/2011	08:55	198	51-99.894
5	15/06/2011	09:25	015	51-99.895
6	15/06/2011	10:30	110	51-99.899
7	15/06/2011	11:05	154	51-99.902
8	15/06/2011	11:40	212	51-99.907
9	15/06/2011	12:10	213	51-99.908
10	15/06/2011	12:35	125	51-99.915

Source: ZALAF, FILHO, BRAZ (2014).

According to Magalhães (2014), in some Brazilian works, those responsible for concreting, due to the lack of technical knowledge, still require the addition of additional water to increase the slump, facilitating the process of pouring and thickening the concrete. According to the ABNT NBR 7212 (2021) standard, this fact exempts the company responsible for supplying the concrete from any responsibility for the characteristics specified in the request, and this fact must be documented.

This work sought to develop an orientation manual for users of ready-mixed concrete on site, in order to explain and establish a script of indispensable procedures to ensure the correct execution of the use of ready-mixed concrete, avoiding compromising its quality.

METHODOLOGY

THE CREATION OF THE USER MANUAL

This work was based on the creation of a proposal for a practical manual for receiving concrete whose objective was to guide professionals, consumers and people in general related to the use of ready-mixed concrete. The manual will also serve to convey the legal responsibilities of workers according to their category, as well as the consequences and possible losses that may occur in the event of some execution failures.

The construction of this manual was conceived based on information based on the professional experience of the authors, who came across several execution errors along the journey and who demonstrated a lack of effective technological control in medium and small works. Given the seriousness of the problem, the work in question proposes a simple but very didactic solution as an instrument to help prevent, treat and solve the problem.

The development of this manual was carried out by establishing a division of phases of the use of ready-mixed concrete. These phases consisted of purchasing, applying and post-applying. Thus, the specific objective of this model was to clearly clarify the process as a whole, but organized in a logical and sequential way, in accordance with the stages of beginning, development and end of the work.

To assist in the construction of this manual, several articles, periodicals, books, technical standards, monographs and municipal legislation were consulted in order to establish the appropriate recommendations, supported by specific bibliography that address the subject.

As a benefit, this user manual proposes, in the background, an awareness of the professionals regarding the responsibilities and importance of the correct fulfillment of all stages, since they are dealing directly with the safety of the future residents of such enterprises. At the same time, this manual warns about the dangers of quality control deficiencies, common in small and medium-sized construction sites, usually caused by employees who lack information and guidance.

RESULTS AND DISCUSSIONS

USER MANUAL

The manual prepared by the authors of this work was created taking into account some stages of the entire process that involves the execution of a civil work. Concrete can be used in foundations, reinforced concrete structures, subfloors and sidewalks/pavements. And in all these stages there will be the need for control from the request of the machined concrete to the curing procedures, divided into purchasing, application and post-application in this manual. It should be noted that, despite being a part of a complete execution of a work, this phase is crucial and extremely important for the structure of the building, ensuring economy and safety. The following is each topic with its respective factors, variables, and responsibilities, as well as associated examples.

Acquisition/Purchase of Ready-Mix Concrete

Before a careful search to define a concrete supplier, the user must understand when to place a concrete order in front of a concrete plant. As the structure of a building is composed of some structural parts such as slabs, beams, pillars and footings, these pieces must be properly prepared for the pouring of concrete, with all the shoring and forms for framing the structural elements in the projected dimensions and positions. It is worth mentioning that ready-mixed concrete is not transported in volumes lower than $3m^3$ in the concrete mixer truck (ABNT NBR 7212, 2021), so it is necessary to have this consumption in order to be viable to purchase ready-mixed concrete.

When assessing that the progress of the work requires a request for a concreting service, a detailed research on the concrete plant options available in the region and search for commercial references is recommended. By means of some criteria, it is possible to define with a technical basis the choice of the most reliable ready-mixed concrete supplier for concreting. The following are several key points for a good choice of concrete plant.

Research

Researching evaluations in online *reviews* and consultation with other customers can be a very positive indicator in defining a ready-mix concrete supplier. Based on this information, there is a greater probability of choosing a concrete supplier that is more competent from the point of view of quality of service provided; And well-evaluated companies generally have a more rigorous work model in the processes of choosing raw materials, preparation, mixing, and greater security in the supply of concrete. As parameters, the customer can request information about carrying out tests on the samples they sell, tests on the aggregates that are used as requested by ABNT NBR 12655:2022.

Another recommendation is to avoid changing suppliers during the continuity of the work, since they can cause warranty losses, contract breaches, in addition to being economically unviable.

With a concrete plant previously chosen and recommended, the person interested in purchasing the concrete can contact the company through email, phone, websites or other forms of service, which may vary from company to company. On social media and the internet, this company contact information is usually available.

During the service, it is essential that the user is able to extract some information from the concrete plant. As mentioned in the manual of concrete dosed in plant, of the Brazilian Association of Concrete Services Companies of Brazil (ABESC, 2007), it should be taken into account when choosing the concrete supplier whether it has testing and control laboratories, as well as the degree of control, automation and computerization of the tests; technical manager; whether the company has an environmental control policy; transportation equipment; Bombs; concrete mixer trucks and other equipment necessary for the provision of concreting service. It should be noted that not all information will be made available to the customer, but the customer must pay attention to ensure that there is security in the provision of the service.

Price

Obviously, the cost must be considered when hiring a service. However, in this case, it is essential that this factor does not compromise the quality of the machined concrete, as the risks of insecurity caused by non-conforming concretes come from a lack of standardization. Another relevant aspect is the possibility of additional expenses and revalidation of projects as a correction of a concrete incompatible with the one specified. Therefore, the recommendation is that price should not be the main selection criterion.

Location

As observed by the ABNT NBR 7212 (2021) standard, there are time limits established for delivery and pouring of concrete. Therefore, both the location of the plants and the probable unforeseen events or delays during supply must be analyzed, establishing a safety margin that does not compromise the delivery of the concrete.

Item 4.5.2 of the ABNT NBR 7212 (2021) standard establishes a maximum time of 90 minutes from the beginning of the mixture to the delivery of the concrete; and item 4.5.3 determines that the maximum time for pouring and thickening the concrete must be 150 minutes, counted from the beginning of the mixing. It should be noted that, if the deadlines are not met, the concrete should not be accepted, which will not cause harm to the buyer.

Contract

After selecting your supplier, you must provide the necessary information so that the concrete company can draw up the service contract. Although neglected by many consumers, seen as a bureaucratic procedure and an "irrelevant" step, the contract has a legal basis and protects the customer and the concrete company through the duties of both. The recommendation is that the contract be read carefully, and all additional negotiation be documented, which can also be by email or messaging apps. All of this documentation may be required in potential lawsuits.

The formulation of the contract covers some details that must be defined such as: elements to be concreted, volumes and places of delivery, alignment of the execution planning, definition of those responsible for the work, definition of the testing laboratories and the types of tests to be performed, including the breaking ages (7 or 28 days), designation of a professional from the contractor to monitor the tests, dates of receipt of test reports and other actions (SANTOS, 2021b).

The user should pay attention to some main contract settings. The definition of a professional responsible for receiving the concrete and some clauses related to specimens, compression tests, concrete pouring and the definitions of the responsibilities of both parties can ensure a greater guarantee of a quality service provided , in accordance with the design parameters and normative procedures, which guarantee the specified strength and workability.

When the contract is drawn up, the concrete batching plant becomes responsible for the characterization of the constituent materials, storage of the materials, dosing study, adjustment of the trace (formulation), preparation and transportation of the concrete. The technical person responsible for the work or the owner may have access to the documentation relevant to compliance with the provisions established in the contract (SANTOS, 2021b).

Request

The request for the supply of concrete can be made by informing the chosen company about some project parameters. According to the ABNT NBR 7212 (2021) standard, concrete can be requested by informing the characteristic compressive strength (*fck*) at a certain age of compression (7 or 28 days, usually at 28 days), slump value of fresh concrete (by means of a slump class), environmental aggressiveness class and maximum dimension of the aggregate. It can also be done by informing the concrete company of the cement consumption per cubic meter of concrete, or by the composition of the concrete trace.

The request is made by informing the concrete company of the desired specifications, such as the date of application, volume of concrete, start and end time, desired interval between trucks, elements that will be concreted, means of transport and other characteristics of the concrete (REGATTIERI; MARANHÃO, 2011). Regarding the amount of concrete required, the request must be made informing the volume of concrete required in cubic meters, with multiple values of 0.5 (ABNT NBR 7212, 2021).

Other characteristics, based on the ABNT NBR 7212 (2021) standard, may be requested during the concrete request, namely: type of cement, type and content of additive, type and content of addition, maximum water/cement ratio (w/c), maximum or minimum cement consumption, incorporated air content, type of discharge (pumped, conventional, projected, etc.), special characteristics and special properties or conditions.

The location and delivery schedule of the concrete must be informed by the contractor, and this information must be in accordance with the contract signed between the parties and the order made by the contractor. It is recommended that the request be made at least 48 hours before the use of the machined concrete, as there is a greater guarantee of service at the desired time.

When placing an order for concrete, the user must know exactly which places are to be concreted, calculating the volume of concrete required for the service based on the dimensions of the elements to be concreted. Before the concrete order is made, the technical manager must make a survey of all the actions that need to be done before the application, which is called the concrete plan. The concreting plan is a series of actions programmed so that the concreting service is efficient and has guaranteed quality (SANTOS, 2021b). Among the main actions, the following stand out:

a) Meeting for alignment between the user and the concrete plant (48 hours before application);

b) Verify that the approved projects are available on site;

c) Conditions of access to the work;

d) Availability of tools, materials and equipment close to the place where the concreting is used;

e) Molds for specimen, consistency and thermometer tests;

f) Circulation of concrete mixer trucks at the construction site;

g) Water and power sources near the site.

Application

For the application of concrete, the ABNT NBR 12655 (2022) standard establishes some attributions and responsibilities of some professionals involved with concreting, such as the person responsible for the structural design, the execution of the work, the receipt of the machined concrete and the concrete batching plant.

The person responsible for the structural design must define the characteristic compressive strength (*fck*) of the concrete, as well as some requirements regarding durability, deformation and other properties related to the structure of the building.

It is up to the professional responsible for the execution to choose the type of concrete to be used in the work, define the consistency class, maximum dimension of the aggregate, choose the materials used, and care in relation to the processes of deforming and shoring removal of structural elements.

On the other hand, the person responsible for receiving the concrete is the technical person responsible for the work designated by the owner. The owner of the work, in the absence of the technical manager, can decide on the acceptance or rejection of the concrete, duly guided by him. At the time of receipt, it must be checked that the concrete delivered has the information contained in the delivery document.

The operations after the arrival of the concrete mixer truck at the construction site, such as launching, densifying, internal transport, finishing, curing and deforming are the duties of the person responsible for the execution of the work, duly registered in the contract. Therefore, the user must understand the responsibilities of each professional who is part of the application of ready-mixed concrete.

The following are some important items of the application. The recommendations are supported by the ABNT NBR 7212 (2021) standard, which regulates the execution of batched concrete in a plant, and describes some standardized procedures for receiving ready-mixed concrete.

Preparation (site to be concreted)

It is necessary to check all the shoring of the forms corresponding to the structural parts that will be concreted, verify that the dimensions of the forms are in accordance with the project and if they present any risk of concrete leakage. In addition, it is necessary to apply a release agent to prevent the concrete from adhering to the forms to avoid problems at the time of demolding and removal of the shoring (ABESC, 2007).

Regarding the reinforcement, it is necessary to check the correct positioning of the hardware, quantity, gauges, dimensions of the bars, and if they are in accordance with the structural design. As for planning, the concreting team must be properly dimensioned, with well-distributed tasks (ABESC, 2007).

With regard to the necessary tools, the equipment must be purchased in advance if they are not available on site, both for transporting concrete on site, such as pumps, conveyors, trolleys, winches, crane, bucket, etc., as well as auxiliary tools, such as buckets, hoes, shovels, planers, pointers, etc., and it is also recommended to reserve some equipment, such as vibrators, hoses etc. Consistency test tools as well as cylindrical specimen molds must also be available at the time of concreting, as specified by ABNT regulatory standards.

Mixing

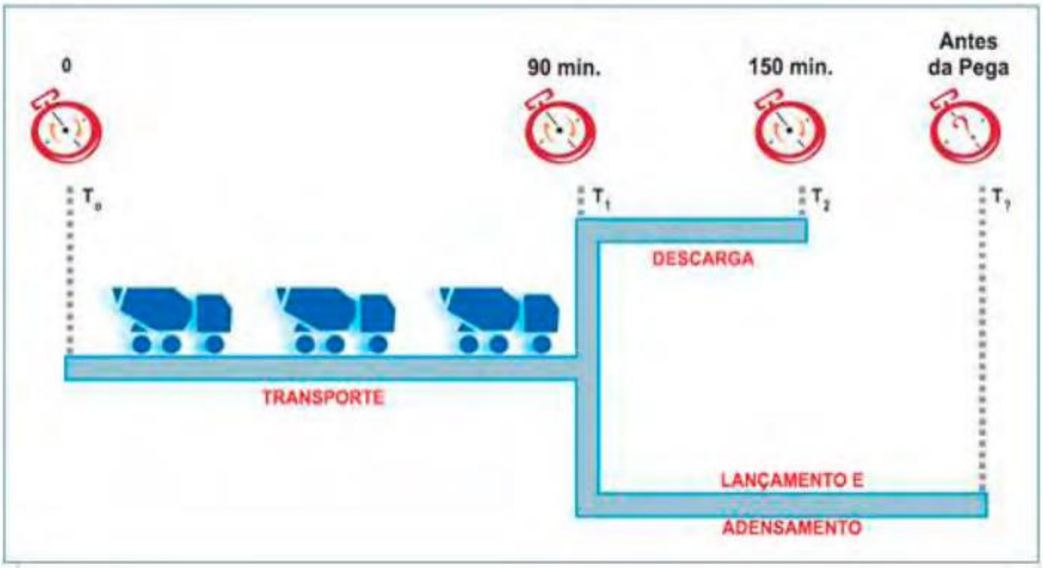
With the approach envisaged for machined concrete, the concrete companies are responsible for the preparation of the concrete. Based on the main information provided by the contractor, the company is in charge of carrying out the mixing in concrete mixer trucks, with the responsibility of delivering the material before the start of picking, in places and times determined according to the schedule and the request made by the contractor. Therefore, the great contribution of the person responsible for receiving it is to charge, through documentation, that the concrete is with the desired specifications, and respecting the contract signed between the parties.

Transport to the application site

The ABNT NBR 7212 (2021) standard proposes that trucks for transporting concrete can be vehicles equipped with an agitation device or not. The stirring device serves to delay the thickening and the beginning of the concrete grip, favoring its application. In order for the concrete to have an adequate workability at the time of application, this standard defines maximum transport times, pouring and thickening of the concrete through the use of concrete mixer trucks for transport.

The conveying time from mixing (from the first addition of water) to the delivery of the concrete should be less than 90 minutes. If the transport time exceeds this maximum time, concrete should not be accepted. The total time from the first addition of water in the concrete mix to the end of pouring and thickening the concrete should be a maximum of 150 minutes. In this way, there is a guarantee that the concrete has been poured and thickened before the material begins to set. In the face of some special situations, such as the use of additives, environmental conditions or some type of specific cement used, there may be a change in the deadlines, but these changes must be agreed between the contractor and the concreting services company (NBR 7212, 2021). Figure 4 illustrates the timeline with the limits for transporting and pouring the ready-mix concrete:

Figure 4 - Times involved in delivering the concrete.



Cast iron: BARBOZA et. al., 2017.

Checking (invoice)

The information contained in the delivery document must be checked, such as the start time of the mixing, the time of departure of the concrete mixer truck from the concrete mixer, the volume of concrete being delivered, water/cement factor (w/c), characteristic compressive strength (*fck*) or cement consumption per cubic meter of concrete, consistency class, maximum characteristic dimension of the coarse aggregate, additive, when applicable and maximum amount of water that can be added before application. At this point, it is also necessary to make an assessment regarding the amount of water contained in the concrete, and see if there is excess or lack of water in the mixture. During the journey, the concrete can lose water through evaporation, and, to compensate, water can be added before the start of pouring, so that it does not exceed the value specified in the concrete trace and in the consistency measure (SANTOS, 2021b).

The person responsible for receiving the ready-mixed concrete, when noticing that there is some discrepancy in the information in the delivery document and the order, or the consistency and volume values provided do not meet the information on the invoice, should not accept the concrete, unless the person responsible for the work authorizes the launch, duly recorded in the delivery document. The authorization requires consultation with the person responsible for the project, because it can significantly impact the value of (*fck*) of the concrete used (ABNT NBR 7212, 2021).

The verification of the concrete volume at the time of delivery can be done by means of the specific mass of the concrete, by calculating the absolute volume of the concrete constituents, direct measurement in a container with a defined volume or by the volumes of the formwork and molds. The volume of concrete that can be transported by concrete mixer trucks must be greater than 3 cubic meters (ABNT NBR 7212, 2021).

Another document that must be made available by the concrete company is the trace letter. The trace letter is a document that must be available by the concrete company, and must contain the following information: date of preparation of the trace letter, identification code of the trace, specifications of the concrete, materials used, input suppliers, mass quantity of each concrete component and signature of the technical responsible (ABNT NBR 7212, 2021).

Consistency Testing

This test shall be carried out after verification of the requirements and information contained in the delivery document. This test is quite simple and consists of obtaining the workability measurement of the concrete.

The consistency test is regulated by the ABNT NBR 16889 (2020) standard. After unloading at least 50 liters of concrete from the concrete mixer truck, the sample can be taken for testing (ABNT NBR 16886, 2020, p.1), a minimum sample of 50 liters must be collected for consistency tests. Then a sheet of metal should be placed on a horizontal, level surface, and the operator should position the feet on the lower flaps of the cone. Next, the cone should be filled in 3 equal layers, applying 25 strokes with the tamping rod evenly distributed when completing each layer.

In the first layer of concrete inserted inside the cone, the rod must penetrate the entire thickness. For the remaining layers, the rod must be penetrated until it reaches the bottom layer. After the procedure done with the last layer, it is necessary to remove the excess and smooth the surface with a metal ruler. After that, the cone must be removed in the vertical direction, and resting the rod on the inverted cone, measure the distance between the bottom of the rod and the axis of the concrete specimen. If there is a difference between the peaks of the material, it is interesting to measure at least 3 heights along the material and average the height.

Although it is a fairly simple test, some mistakes can be made, such as incorrect slump measurement, with the metal ruler out of the vertical position, uneven surface, single fill, etc.

Molding of specimens

The ABNT NBR 5738 (2015) standard establishes the conditions for the preparation of cylindrical or prismatic specimens. Before the work begins, the necessary equipment for this test must be provided. Generally, the testing instruments are standardized and the user has several options regarding the dimensions of the molds.

The number of copies will depend on the technological control model of the work. Each specimen consists of at least two specimens, of the same concrete, for each age of rupture. After molding and initial curing, the specimens are transported to the testing laboratory, and they are cured to the established breakage ages.

In the removal of the concrete sample, there is another technical standard, the ABNT NBR 16886 (2020) standard, which directs a test method for sampling fresh concrete. It is recommended that the sample be taken after the discharge of at least 50 liters of concrete and between 30 and 70% of the volume of concrete delivered, with a minimum quantity of 50 liters and a volume equivalent to 1.5 times the volume required for specimen samples. In order to control the subsequent compression tests, it is essential to note some important information such as the date, time of the addition of the complementary water and the structural part of the concrete application. In order to carry out the molding, it is recommended to have a level place, with no interference, and close to the place where they will be stored for the first 24 hours.

When filling, each layer must be well distributed within the mold so that the thickening can be done. For manual thickening with the tamping rod, in each layer, tamping strokes must be applied, well distributed within the mold, and always avoiding the penetration of the rod into the lower layer. For vibratory thickening, it should only be used for the time necessary for the correct thickening of the concrete in the mold, preventing the vibrator from touching its sides and the bottom of the mold. The filling should not be interrupted, so that the beginning of the "setting" of the concrete does not occur. When the mold is finished, the last layer must exceed the height of the mold so that the upper part can be smoothed with a trowel (ABESC, 2007).

Once the molding process is complete, cylindrical specimens should be stored with a non-reactive, non-absorbent material to prevent water loss and protect the specimen. The time required for the beginning of deforming is 24 hours for cylindrical specimens and 48 hours for prismatic specimens (ABNT NBR 5738, 2015).

After the initial cure period of the specimens, they must be identified for control and then transported to the test laboratory defined at the time of the formalization of the contract. Samples should be transported in rigid boxes containing wet sawdust or sand. This last step already corresponds to the laboratory test, and therefore has not been explored in depth in this article.

Compression tests are performed by the laboratory, and the ABNT NBR 5739 (2018) standard regulates how this test should be performed. The results should be documented with the following information, as pointed out by Santos (2021b):

(a) specimen identification number;

(b) date of moulding;

(c) the age of the specimen;

d) Date of the test (ABNT NBR 5739);

(e) dimensions of the specimens;

f) Testing machine class;

g) Result of the compressive strength of the specimen and the specimen.

Concrete pouring and thickening

During casting, the operator must avoid the accumulation of concrete at certain points on the formwork and water on the surface. The filling should be done by layering, and casting the new layer on top of the previous one, before the bottom layer enters the "sticking" period.

The densification process consists of moving the concrete after pouring to eliminate air bubbles, forming a more homogeneous mixture with a linear appearance (SANTOS, 2021b). For this, vibrators are used, among which are chosen according to the dimensions of the concrete pieces, as well as vibration time and vibration spacing.

When performing densification by means of a vibrator, care must be taken to quickly place the vibrator on the concrete and remove it slowly, for a natural thickening. It is also recommended that there be no formation of concrete mounds, so that some region is poorly compacted (SANTOS, 2021b). Also during the pouring and thickening process, a vibrating ruler can be used, which assists in the concrete thickening process, finishing and leveling the concrete surface.

Post application

After the process of applying machined concrete, there are procedures that, when performed correctly, can prevent the appearance of cracks and other pathologies in the building. At this stage, the curing and demolding of the structural parts complement and ensure a well-executed concreting. The following are some recommendations for some cases of non-compliance.

Healing

The concrete, after being applied and thickened, must be subjected to some care so that the strength gain and shrinkage are monitored.

The curing procedure consists of keeping the concrete moistened during water loss. The technique is little commented on in the ABNT NBR 14931 standard, however, it is extremely important for concretes applied with thicknesses of less than 30 centimeters, where water loss is severe.

To prevent this unwanted evaporation of water from the concrete, there are two main techniques: the application of chemicals or the addition of water to the concreted surface at regular intervals of time.

The application of chemicals forms a layer that prevents the evaporation of water from the concrete, which is widely used in industrial flooring. However, its cost is high and for this reason it is little used in medium and small works. On the other hand, the direct application of water to the concreted part in regular periods of time is usually a very viable alternative. In the first 3 days after launch, the recommendation is that the structural element be abundantly irrigated with water, so that there is no loss of resistance due to lack of hydration.

Demolding

According to NBR ABNT 15696 - Formwork and shoring for concrete structures - Design, dimensioning and executive procedures, the deformation must follow the planning previously described by the technical responsible for the work, without carrying out additional actions. During the stage, it should be checked if the concrete presented any pathologies during its drying period, which can be: different appearance or color, brittle parts, friction on its surface, etc.

The recommendation is that deforming should not be done if there are doubts regarding the strength of the structural element and whether it supports the actions that will be subject during the process. Ideally, the removal of forms and struts should be done after 28 days, since there is a certain security regarding the achievement of the specified value of (*fck*).

In some cases, there is a need to remove the disforms before the 28-day period. For these situations, there are some stipulated minimum requirements: Deforming lateral (vertical) forms of slender elements can be done after 48 hours from the date of concreting. The removal should be done in such a way that there is no need for friction on the concrete structure. First, the tensioners and latches must be removed and the behavior must be evaluated. The use of tools that force the forms such as crowbar levers is not recommended, as the structural element has not yet acquired great resistance. A minimum possible parallel displacement should be caused so that the form detaches from the structure without damaging the concrete surface.

After 7 days, the ready-mix concrete should probably have a strength equivalent to half of its maximum strength if the curing procedures have been respected, and therefore up to 50% of the struts can be removed. The struts should be removed in places where the distributed load is the lowest in the entire structural element, and for cases when there is no possibility, it is recommended to remove them after 28 days.

Results of compression tests

From the results of the compression tests, the strength of the concrete can be classified as compliant, when it meets the specified (*fck*), or non-conforming, when the expected results have not been achieved. For the determination of *the fck*, the ABNT NBR 12655 (2022) standard establishes a methodology for calculating the characteristic strength of the concrete, which depends on the type of concrete strength control, which can be by partial or total sampling.

When the technological control of concrete involves the sampling of concrete by partial sampling, NBR 12655 (2022) specifies that at least six specimens must be removed for group I concretes and twelve specimens for group II concrete. The following equation shall be used for the estimation of compressive strength ():f_{ckest}

$$f_{ckest} = 2\frac{f_1+f_2+\cdots+f_{m-1}}{m-1} - f_m \qquad (1)$$

Where:

m = . The highest value of n is discarded if it is odd.$n/2$

f_1, , ... They are values of the resistance of the specimens, in ascending order.$f_2 f_m$

For a number of specimens greater than 20, the following expression shall be used:

$$f_{ckest} = f_{cm} - 1{,}65 S_d \qquad (2)$$

Where:

f_{cm} is the average strength of the specimens of the batch, in Megapascal (MPa);

S_d, is the standard deviation of the sample of specimens, in Megapascal (MPa).n

For the technological control that involves total sampling, samples are taken from all concretes whose specimens represent the compressive strength of the concrete of that concrete. Therefore, for 100% sampling, the characteristic compressive strength is given by:

$f_{ckest} =$ (3) $f_{c,betonada}$

Where:

$f_{c,betonada}$ is the value of the compressive strength of the specimen, in Megapascal (MPa).

By the equations of estimation of (*fck*) of the concrete used, the total sampling provides a saving of cement consumption, because for the control by partial sampling, it is necessary to consider the standard deviation of the specimens with a factor of 1.65, which results in a statistical (*fck*) above the one obtained directly with the specimen, and it is necessary to add a greater amount of cement to reach the specified (*fck*).

Regarding the compression tests, the tests in 7 after application already show a forecast on the value of (*fck*) that can be reached at 28 days, and in this way already evaluate the commitment of the supplier and obtain evidence about possible failures in concrete manufacturing processes.

For cases in which the statistical (*fck*) does not reach the strength specified in the structural design, Pacheco and Helene (2013) indicate that some actions should be taken in cases of non-conforming concrete, namely:

a) Design review, considering the value of (*fck*) obtained with the molded specimens at the time of receipt of the ready-mixed concrete, to ensure that the structure is not compromised with a characteristic strength value below that specified;

b) If structural insecurity remains, the structure must be inspected on site and other tests must be carried out such as sclerometry, a non-destructive test that measures the hardness of the concrete surface, pacomthyria, which is a non-destructive test that measures the amount of reinforcement and concrete covering in a given structure, or ultrasound, which serves to evaluate the compressive strength or homogeneity of the concrete;

c) If the tests described above are not met, a destructive test must be carried out in accordance with the ABNT NBR 7680-1 standard – Extraction, preparation, testing and analysis of cores of concrete structures Part 1: Axial compressive strength (2007): The concrete core is a specimen extracted directly from the structure, previously planned, so that the extraction does not impair the structural performance and durability of the structure. The borehole must be re-established with the concrete compatible with the one extracted, to try to maintain the same conditions before extraction;

d) If the non-conformity persists, the correction alternatives are to determine the restrictions on the use of the structure, prepare a project to reinforce the structure, and even, in extreme cases, partially or totally demolish the structure.

CONCLUSIONS

The construction of the manual allowed for a clearer and more summarized approach to the most important aspects of receiving ready-mixed concrete. The elaboration was based on the consultation of the most diverse works related to the subject, and which sought to gather the main information regarding the use of ready-mixed concrete.

It is intended that this practical guide is a device that can be used on the construction site, to serve as a reference when doubts arise on the subject or when the professional is faced with a situation of insecurity regarding his attributions. However, it is expected that future studies can be developed on other stages of the construction of a project, such as topography, masonry, reinforcement, coatings, etc., so that there is no gap between professionals and ABNT technical standards.

REFERENCES

1. ASSOCIAÇÃO BRASILEIRA DAS EMPRESAS DE SERVIÇOS DE CONCRETAGEM DO BRASIL. *Manual concreto dosado em central*. São Paulo, 2007. Disponível em: https://www.abesc.org.br/assets/files/manual-cdc.pdf. Acesso em: 10 de agosto de 2023.

2. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 7211: Agregados para concreto - Especificação*. Rio de Janeiro: ABNT, 2022.

3. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 7212: Execução de concreto dosado em central - Procedimento*. Rio de Janeiro: ABNT, 2021.

4. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 12655: Concreto de Cimento Portland – Preparo, controle e recebimento – Procedimento*. Rio de Janeiro: ABNT, 2022.

5. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 5738: Modelagem e cura de corpos-de-prova cilíndricos ou prismáticos de concreto*. Rio de Janeiro: ABNT, 2015.

6. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 5739: Concreto – Ensaios de compressão de corpos de prova cilíndricos*. Rio de Janeiro: ABNT, 2018.

7. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 15577-1: Agregados – Reatividade álcali-agregado Parte 1: Guia para avaliação da reatividade potencial e medidas preventivas para uso de agregados em concreto*. Rio de Janeiro: ABNT, 2018.

8. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 8953: Concreto para fins estruturais – Classificação pela massa específica, por grupos de resistência e consistência*. Rio de Janeiro: ABNT, 2015.

9. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 16886: Concreto – Amostragem de concreto fresco*. Rio de Janeiro: ABNT, 2020.

10. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 16889: Concreto - Determinação da consistência pelo abatimento de tronco de cone*. Rio de Janeiro: ABNT, 2020.

11. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 7680-1: Concreto — Extração, preparo, ensaio e análise de testemunhos de estruturas de concreto Parte 1: Resistência à compressão axial*. Rio de Janeiro: ABNT, 2015.

12. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *ABNT NBR 15696: Formas e escoramentos para estruturas de concreto – Projeto, dimensionamento e procedimentos executivos*. Rio de Janeiro: ABNT, 2009.

13. ANDOLFATO, R. P. *Controle tecnológico básico do concreto*. Ilha Solteira: UNESP, 2002, 30 p.

14. BARBOZA, L. S. et. al. Influência do tempo máximo de mistura e transporte especificado pela ABNT NBR 7212:2012 na resistência a compressão de concretos usinados. *Revista de Engenharia Civil IMED*, *v. 4*, *n. 2*, 2017. DOI: https://doi.org/10.18256/2358-6508.2017.v4i2.2075. Disponível em:

https://seer.atitus.edu.br/index.php/revistaec/article/view/2075. Acesso em: 14 mar. 2023.

15. BASTOS, P. S. *Fundamentos do concreto armado*. Universidade Estadual Paulista, Bauru, SP, 2023, 90 p.

16. BORGES, D. C. et al. Evaluation of a proposed model for concrete at mesoscopic scale. *Ibracon Structures and Materials Journal*, *v. 10*, *n. 5*, 2017. DOI: [10.1590/S1983-41952017000500009](https://www.scielo.br/j/riem/a/jS9FrrVQLQnzk5TkkfVbWLM/?lang=en). Acesso em: 17 jul. 2023.

17. CALLISTER Jr, W. D.; RETHWISCH, D. G. *Ciência e Engenharia de Materiais: uma introdução*. 8. ed. Rio de Janeiro: LTC, 2012. 817 p.

18. CASTRO, A. L.; PANDOLFELLI, V. C. Revisão: Conceitos de dispersão e empacotamento de partículas para a produção de concretos especiais aplicados na construção civil. *Cerâmica*, *55*(333), 2009. DOI: [10.1590/S0366-69132009000100003](https://www.scielo.br/j/ce/a/6jsRNJDKJHCNCczb3fMfLFv/abstract/?lang=pt). Acesso em: 17 jul. 2023.

19. CHIKNOVORYAN, A. G.; MIZURYAEV, S. A.; ZHIGULINA, A. Y. Optimization of technological parameters of reinforced concrete production. *IOP Conference Series: Materials Science and Engineering*, *v. 1015*, 2021. DOI [10.1088/1757-899X/1015/1/012067](https://iopscience.iop.org/article/10.1088/1757-899X/1015/1/012067). Acesso em: 05 mar. 2023.

20. Cimento e concreto. *Casa & Construção*. Disponível em: https://www.cec.com.br/dicas-reforma-cimento-e-concreto?id=242. Acesso em: 16 dez. 2023.

21. Exsudação. *Clube do Concreto*, 2013. Disponível em: http://www.clubedoconcreto.com.br/2013/11/exsudacao.html. Acesso em: 17 dez. 2023.

22. DE LA IGLESIA, J.; MURILLO, M.; RESTREPO, D. B. Study of the importance of core cylinders in the monitoring of the compressive strength of the concrete. *IOP Conference Series: Materials Science and Engineering*, *v. 1126*, 2021. DOI [10.1088/1757-899X/1126/1/012050](https://iopscience.iop.org/article/10.1088/1757-899X/1126/1/012050). Acesso em: 06 mar. 2023.

23. DE SCHUTTER, G., LESAGE, K. Active control of properties of concrete: a (p)review. *Materials and Structures*, *v. 51*, n. 123, 2018. DOI: [https://doi.org/10.1617/s11527-018-1256-2](https://link.springer.com/article/10.1617/s11527-018-1256-2#citeas). Acesso em: 06 mar. 2023.

24. FUGIYAMA, M. M. et al. Estudos numérico-experimentais de vigas de concreto armado com reforço de fibra de carbono. *Revista Matéria*, *v. 26*, n. 04, 2021. DOI: [10.1590/S1517-707620210004.1393](https://www.scielo.br/j/rmat/a/6TxPDZvDWS49m5r8KrwKnLR/abstract/?lang=pt). Acesso em: 19 jun. 2023.

25. FUSCO, P. B. *Tecnologia do Concreto Estrutural*. São Paulo: PINI, 2008. 179 p.

26. GOMES NETO, D. de P. et al. Sergipe. ANAIS DO 51º CONGRESSO BRASILEIRO DO CONCRETO - CBC2009 – 51CBC0096. IBRACON, 2009.

27. GRILLO, R. H. F. Estudo da influência de aditivos redutores de água em concretos da construção civil. 2014. 72 f. Tese (Mestrado em Ciência e Engenharia de Materiais) - Universidade Federal de Alfenas, Poços de Caldas, MG, 2014.

28. HELENE, P.; LEVY, S. Curado del Hormigón. In: HELENE P.; TUTIKIAN, B. Boletín técnico. Mérida: ALCONPAT INTERNACIONAL, 2013, cap. 8, 10p.

29. HELENE, P.; TERZIAN, P. *Manual de Dosagem e Controle do Concreto*. São Paulo: PINI; Brasília, DF: SENAI, 1992. 349 p.

30. LISBOA, E. S.; ALVES, E. S.; MELO, G. H. A. G. *Materiais de Construção: concreto e argamassa*. 2. ed. Porto Alegre: SAGAH, 2017. 227 p.

31. LOPES, H. M. T.; PEÇANHA, A. C. C.; CASTRO, A. L. Considerações sobre a eficiência de misturas de concreto de cimento Portland com base no conceito de empacotamento de partículas. *Revista Matéria*, *v. 25*, n. 01, 2020. DOI: [10.1590/S1517-707620200001.0874](https://www.scielo.br/j/rmat/a/nDMHgssYDsY6zL5fs6gp9gS/). Acesso em: 19 jun. 2023.

32. MAGALHÃES, F. C. A. A problemática dos concretos não conformes e sua influência na confiabilidade de pilares de concreto armado. 2014. 262 f. Tese (Doutorado em Engenharia Civil) - Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, 2014.

33. Manifestação patológica: segregação do concreto (bicheira no concreto). *Tecnosil*, 2023b. Disponível em: https://www.tecnosilbr.com.br/category/recuperacao-de-estruturas. Acesso em: 17 dez. 2023.

34. MASCOLO, R.; MASUERO, A. B.; DAL MOLIN, D. C. C. Ready mixed concrete: variability analysis of the compressive strength and physical properties along the unloading of the truck mixer. *Ibracon Structures and Materials Journal: v. 6*, n. 2, 2013. DOI: [10.1590/S1983-41952013000200003](https://www.scielo.br/j/riem/a/LGwCXmK96cvPmbKcWBGgY7R/?lang=en). Acesso em: 06 mar. 2023.

35. MEHTA, P. K.; MONTEIRO, P. J. M. *Concreto: Microestrutura, Propriedades e Materiais*. 3. ed. São Paulo: IBRACON, 2008. 674 p.

36. NEVILLE, A. M. *Propriedades do concreto*. 5. ed. Porto Alegre: Editora Bookman, 2016. 888 p.

37. NEVILLE, A. M.; BROOKS, J. J. *Tecnologia do concreto*. 2. ed. Porto Alegre: Editora Bookman, 2013. 448 p.

38. NOGUEIRA, K. A. Reação álcali-agregado: Diretrizes e requisitos da ABNT NBR 15577/2008. 2010. 81 f. Tese (Especialização em Construção Civil) - Universidade Federal de Minas Gerais, Belo Horizonte, MG, 2010.

39. O que é adensamento de concreto e por que esse processo é tão importante? *Tecnosil*, 2023a. Disponível em: [https://www.tecnosilbr.com.br/o-que-e-adensamento-de-concreto-e-por-que-

esse-processo-e-tao-importante](https://www.tecnosilbr.com.br/o-que-e-adensamento-de-concreto-e-por-que-esse-processo-e-tao-importante). Acesso em: 17 dez. 2023.

40. OLIVEIRA, T. B. Proposta de plano de execução de concretagem em obras prediais. 2021. 80f. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) - Centro Federal de Educação Tecnológica de Minas Gerais, Varginha, MG, 2021.

41. PACHECO, J.; HELENE, P. Control de la Resistência del Hormigón. In: HELENE P.; TUTIKIAN, B. Boletín técnico. Mérida: ALCONPAT INTERNACIONAL, 2013, cap. 9, 18p.

42. PETRUCCI, E. G. R. *Concreto de Cimento Portland*. 13. ed. São Paulo: GLOBO S. A., 1998.

43. RAMBO, A. C. Efeito do fogo sobre estruturas de concreto armado. *Salão do Conhecimento*, *v. 6*, n. 6, 2020. Disponível em: [link](file:///C:/Users/ianfe/Downloads/18556-Texto%20do%20artigo-51705-500414-2-20201021.pdf). Acesso em: 08 out. 2023.

44. REGATTIERI, C. E. X.; MARANHÂO, F. L. Produção e controle de concreto dosado em central. In: ISAIA, G. (Ed.). *Concreto: Ciência e Tecnologia*. São Paulo: IBRACON, 2011.

45. ROSA, F. A.; LOPES, A. A. Análise de resistência à compressão e características do concreto produzido em obras de pequeno porte na região norte da cidade de Maringá-PR. *Revista Uningá Review*, *v. 28*, n. 03, 2016. Disponível em: [link](https://revista.uninga.br/uningareviews/article/view/1892/1490). Acesso em: 29 ago. 2023.

46. SANTOS, D. A. Manual do concreto usinado: Um manual de ajuda para os operadores de concreto. Marabá, PA: Ed. Dos Autores, 2021b. Disponível em: [link](https://profnit.org.br/wp-content/uploads/2022/07/DALILA-AMORIM-DOS-SANTOS_PRODUTO.pdf). Acesso em: 29 ago. 2023.

47. SANTOS, D. A. Transferência tecnológica e lições aprendidas em canteiros de obras: elaboração de manual de operação técnica do gerenciamento de controle tecnológico do concreto usinado. 2021. 50 f. Tese (Mestrado em Propriedade Intelectual e Transferência de Tecnologia para Inovação) - Universidade Federal do Sul e Sudeste do Pará, Marabá, PA, 2021a.

48. Traço de concreto: controle de qualidade do concreto. *Mapa da obra*, 2017. Disponível em: [link](https://www.mapadaobra.com.br/inovacao/traco-de-concreto-controle-de-qualidade-do-concreto). Acesso em: 29 ago. 2023.

49. TUTIKIAN, B. F.; HELENE, P. Dosagem dos Concretos de Cimento Portland. In: ISAIA, G. *Concreto: Ciência e Tecnologia*. Rio de Janeiro: IBRACON, 2011.

50. ZALAF, R. S.; FILHO, S. R. M.; BRAZ, T. C. Estudo do controle tecnológico e recebimento do concreto em obra. 2014. 91f. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) - Escola de Engenharia Civil da Universidade Federal de Goiás, Goiânia, GO, 2014.