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# INDUSTRIAL-SCALE APPLICATION OF A CO-PRODUCT BASED ON SUPERABSORBENT POLYMER AND CELLULOSE FIBER AS AN INTERNAL CURING AGENT AND REINFORCEMENT IN CONCRETE

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**ABSTRACT:** The objective of the study is to evaluate the influence of the use of a co-product based on industrial solid waste from superabsorbent polymer and cellulose fiber (referred to as co-product) on an industrial scale as an internal curing agent and reinforcement in concrete for industrial flooring, applied by a partner concrete company in a real project. To this end, based on an experimental dosage study, concretes containing the co-product and a reference concrete were prepared, both with equivalent mechanical strength. The concretes were mixed and poured by a partner concrete company, applied to an industrial concrete floor whose physical and mechanical characteristics were evaluated. This made it possible to prove the equivalence between the concretes in terms of strength, but the Co-product concrete showed reduced shrinkage and proved effective in mitigating cracking, providing greater consolidation of the use of the co-product and an advance in its level of technological maturity.

**KEYWORDS:** Superabsorbent polymer; Cellulose fiber; Co-product; Concrete.

**RESUMO:** O objetivo do estudo é avaliar a influência do uso coproduto à base de resíduos sólidos industriais de polímero superabsorvente e fibra celulósica (denominado como coproduto) em escala industrial, como agente de cura interna e reforço em concreto para pisos industriais, aplicado por uma concreteira parceira em um projeto real. Para isso, com base em um estudo de dosagem experimental, foram preparados concretos contendo o coproduto e um concreto de referência, ambos com resistência mecânica equivalente. Os concretos foram misturados e dosados por uma concreteira parceira, aplicados em um piso industrial de concreto cujas características físicas e mecânicas foram avaliadas. Isso permitiu comprovar a equivalência entre os concretos em termos de resistência, mas o concreto com coproduto apresentou retração reduzida e se mostrou eficaz na mitigação de fissuras, proporcionando maior consolidação do uso do coproduto e um avanço em seu nível de maturidade tecnológica.

**PALAVRAS CHAVE:** Polímero superabsorvente; Fibra de celulose; Coproduto; Concreto.

## 1. INTRODUCTION

Proper curing of concrete is one of the most important processes in the post-concreting period, so that the concrete can achieve the desired mechanical strength and durability. This procedure basically consists of providing sufficient moisture for cement hydration, preventing the evaporation of the water necessary for hydration reactions, allowing the material to develop the appropriate properties (KOPPE, 2016). However, some construction projects perform this procedure for inadequate periods or, often, do not perform it at all. As a result, surface characteristics are commonly affected, leading to increased porosity and, consequently, increased permeability, cracking, and carbonation (HELENE; LEVY, 2013).

In order to combat these problems caused by inadequate concrete curing, the scientific community has been studying the use of promising materials for use as internal curing agents. According to Jensen (2013), these are materials with water retention capacity that, when incorporated into the cementitious matrix, release water and promote hydration from the inside out.

Some of the materials that can be used as internal curing agents are superabsorbent polymers (SAP), which were first used in civil construction to combat autogenous shrinkage in high-performance concrete with a very low water/cement ratio (JENSEN; HANSEN, 2001). SAP is a polymeric material with a high capacity for water absorption and retention within its structure (JENSEN, 2013). Depending on the characteristics of the SAP, water absorption of up to 5000 times its dry mass can occur (KUMM, 2009; JENSEN, 2013). Jensen (2013) defines that an internal curing agent, such as PSA, can be classified as an internal component capable of absorbing water and releasing it gradually as required by the concrete, promoting curing from the inside out.

Another material capable of promoting benefits to the cementitious matrix is cellulose fiber, although it does not have a high enough absorption capacity to justify its exclusive use as an internal curing agent (KAWASHIMA; SHAH, 2011). Cellulose fiber acts as a reinforcement to the cementitious matrix and can bring benefits in terms of durability properties. The high mechanical strength of cellulose fibers, combined with their ability to adhere to the cementitious matrix, provides improvements that are most evident in terms of toughness, flexural strength, and impact resistance, in addition to acting to combat the propagation of cracks in the matrix (SOROUSHIAN; WON; HASSAN, 2012). According to Sika S/A ([2025?]), there are several fibers on the market for use in Portland cement concrete. Each type of fiber, length, and geometry should be adopted according to the properties that one wishes to promote in the mixture. Longer fibers tend to have a more intense effect on the mechanical characteristics of the matrix, while short fibers tend to be used to minimize matrix shrinkage.

Superabsorbent polymer and cellulose fiber can be found together in personal hygiene products (disposable diapers and sanitary pads), as well as in part of the waste from the quality sector of this type of industry, where it is generated in considerable quantities (approximately 6,800 tons, in 2015 alone, by a manufacturer in Brazil (BARTH, 2020). The core of these products is removed from their respective packaging and other materials responsible for their conformation through a decharacterization process (GOMES, 2014). However, this waste can be heterogeneous. Studies conducted by Barth et al. (2024) demonstrate that, through homogenization processes, it is possible to improve the dispersion of materials, making the results obtained by characterization methods reliable. Through the characterization analyses of superabsorbent polymer and cellulosic fiber originating from industrial solid waste from the production of disposable diapers and sanitary pads, and the application of different compositions of these materials in Portland cement concrete, carried out by Barth (2021), it was possible to determine that the co-product developed and applied according to the determinations presented in the research has excellent application potential as a reinforcement and internal curing agent in Portland cement matrices, highlighting benefits such as an increase in the tensile strength of the matrix by up to 50%, a reduction in plastic shrinkage of up to 85%, and a reduction in cracking of up to 85%. It should be noted that these results are only obtained through the synergistic effect between the components of the developed co-product, where PSA acts as an internal curing agent and mitigates shrinkage mechanisms, while cellulose fiber acts mainly to increase tensile strength and dilute internal stresses in the matrix.

The work developed by Barth (2021), which pointed out the results described in the previous paragraph, pointed out more balanced benefits promoted by the co-product to the cementitious matrix when applied in a composition of 15% PSA and 85% cellulose fiber, by mass. This project, in development since 2012, led to the filing of patent BR 10 2022 012389 6, and is at the end of level 6 on the technology readiness level scale, according to the criteria demonstrated by Manning (2023), meaning that the prototype model of the system has already been demonstrated in a relevant environment for the developed product. This level was obtained by Barth (2021) after obtaining the prototype covering critical industrialization activities (any and all activities capable of causing physical and/or chemical changes in the product) and application in concrete in a dry curing environment (60% RH and 23 ± 2°C), wet curing (100% RH and 23 ± 2°C), and on an industrial pilot scale.

To advance to the technological maturity level (level 7), as well as part of the technology transfer process related to the industrialization stage, it is necessary to demonstrate the prototype in an operational environment.

The development of the project is justified not only by the advancement in the level of technological maturity itself, but also by the development of an alternative for external recycling and reinsertion into a new production chain of industrial solid waste generated in global-scale production processes, as well as by the alteration of the properties of Portland cement matrices, especially those related to the durability of reinforced concrete structures, demonstrating the potential to increase the useful life of this type of structure and minimize the need for maintenance, which may result in a reduction in Portland cement consumption and, consequently, a reduction in energy consumption and $CO_2$ emissions related to this type of industry.

The study, therefore, aims to evaluate the influence of the use of a co-product based on industrial solid waste from superabsorbent polymers and cellulose fiber (referred to as Co-product) on an industrial scale as an internal curing agent and reinforcement in concrete for industrial flooring, applied by a partner concrete company for a real customer.

## 2. MATERIALS AND METHODS

This chapter presents the materials used in the study, the methods applied, and a description of the industrial-scale application. To this end, the program is subdivided into three stages.

The first stage presents the characterization and description of the materials used. The second stage presents the definition of the traits resulting from the experimental dosage study, as well as the methods applied to evaluate the properties of the concrete. Finally, in the third stage, the industrial-scale application process is described.

Due to the set of properties altered by the co-product and strategic project development issues, the operational environment was defined as the application of co-product in Portland cement concrete applied to industrial floors, applied by a concrete company in ready-mix concrete (the main potential customer for the co-product), with surface finishing performed by the customer receiving the concrete.

### 2.1 MATERIALS

The binder used was Portland CP II F-40 cement. This type of binder was chosen because it is the cement used by the partner concrete company in its reference concrete for industrial floors. The decision to use this type of binder in the study also benefits the analyses, as it does not contain pozzolanic additions, allowing for better evaluation of the properties of concrete at early ages. Furthermore, according to Bentz, Lura, and Roberts (2005), it is not influenced by the high chemical shrinkage rates of pozzolanic additions.

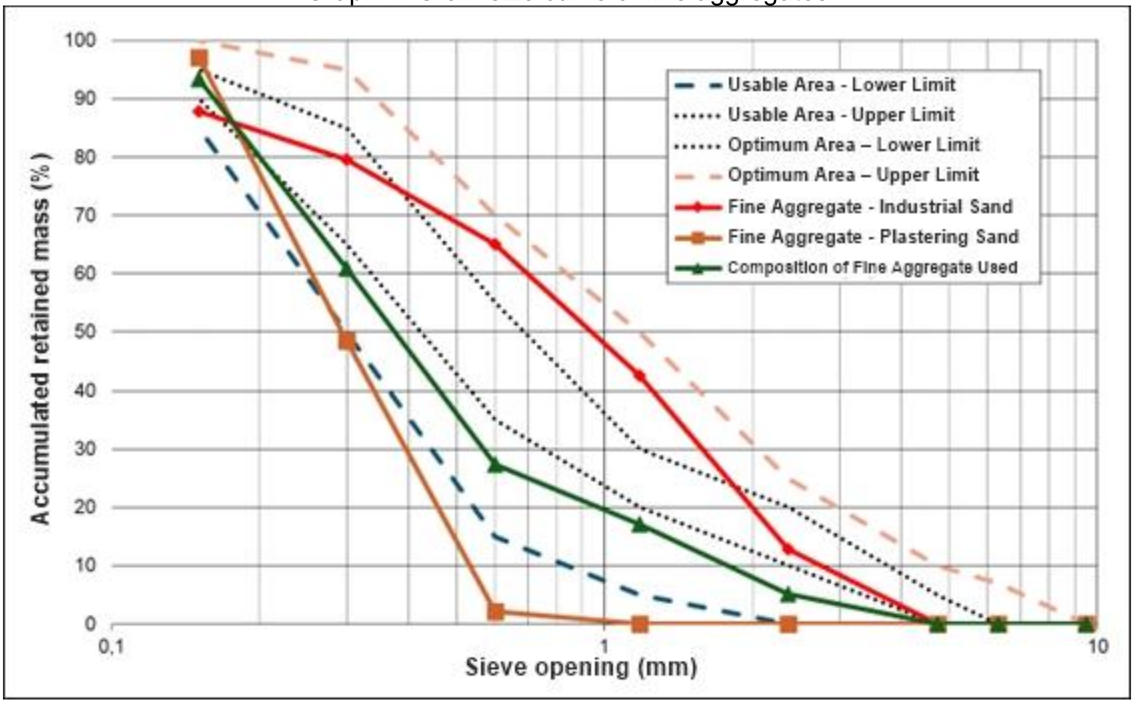
The fine aggregates used in the concrete were plastering sand extracted from a riverbed and industrial sand resulting from the basalt crushing process, according to the nomenclatures adopted by the partner concrete company. Both fine aggregates were characterized according to their particle size distribution, fineness modulus, and maximum characteristic dimension according to ABNT NBR NM 248:2001. Absorption was obtained according to ABNT NBR NM 30:2000. The specific dry and saturated mass with a dry surface were obtained according to ABNT NBR NM 52:2009. The results of the particle size distribution can be seen in Table 1. Table 2 shows the results of specific mass, absorption, and fineness modulus

Table 1: Fine aggregate particle size distribution

| **Sieve opening (mm)** | **Plastering sand** | | **Industrial sand** | |
|---|---|---|---|---|
| | **Mass (%)** | | **Mass (%)** | |
| | **Retained** | **Accumulated** | **Retained** | **Accumulated** |
| 6.3 | 0 | 0 | 0 | 0 |
| 4.75 | 0 | 0 | 0 | 0 |
| 2.36 | 0 | 0 | 13 | 13 |
| 1.18 | 0 | 0 | 30 | 43 |
| 0.6 | 2 | 2 | 22 | 65 |
| 0.3 | 46 | 49 | 15 | 80 |
| 0.15 | 49 | 97 | 8 | 88 |
| Background | 3 | 100 | 12 | 100 |
| Total | 100 | 100 | 100 | 100 |
| Maximum characteristic dimension (mm) | 0.6 | | 4.75 | |

Source: Authors.

Graph 1: Grain size curve of fine aggregates




Source: Authors.

Table 2: Characterization of fine aggregates

| Characteristic | Result | |
|---|---|---|
| | Plastering sand | Industrial sand |
| Saturated specific mass dry surface | 2.58 g/cm³ | 2.45 g/cm³ |
| Specific mass dry aggregate | 2.57 g/cm³ | 2.43 g/cm³ |
| Absorption | 0.24 | 0.76 |
| Modulus of fineness | 1.48 | 2.88 |

Source: Authors.

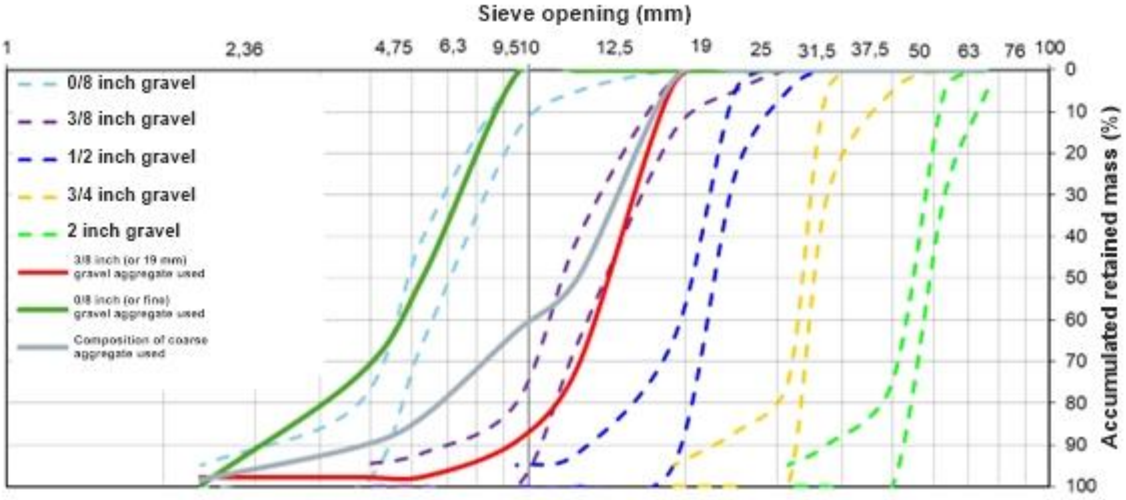
The coarse aggregates used in the concrete were fine gravel and 19 mm gravel, both of basalt origin, according to the nomenclature adopted by the partner concrete company. Both coarse aggregates were characterized according to their particle size distribution, fineness modulus, and maximum characteristic dimension in accordance with ABNT NBR NM 248:2001. Absorption was obtained according to ABNT NBR NM 53:2009. The specific dry and saturated mass with a dry surface were obtained according to ABNT NBR NM 53:2009. The results of the particle size distribution can be seen in Table 3 and Graph 2, while Table 4 shows the results of specific mass, absorption, and fineness modulus.

Table 3: Coarse aggregate particle size distribution

| Sieve opening (mm) | Fine Gravel | | 19 mm Gravel | |
|---|---|---|---|---|
| | Mass (%) | | Mass (%) | |
| | Retained | Accumulated | Retained | Accumulated |
| 19 | 0 | 0 | 3 | 3 |
| 12.5 | 0 | 0 | 67 | 71 |
| 9.5 | 1 | 1 | 18 | 89 |
| 6.3 | 49 | 49 | 9 | 98 |
| 4.75 | 24 | 73 | 0 | 98 |
| 2.36 | 27 | 100 | 0 | 98 |
| Fund | 0 | 100 | 2 | 100 |
| Total | 100 | 100 | 100 | 100 |
| Maximum characteristic dimension (mm) | 9.5 | | 19 | |

Source: Authors.

Graph 2: Grain size curve of coarse aggregates




Source: Authors.

Table 4: Characterization of coarse aggregates

| Characteristic | Result | |
|---|---|---|
| | **Fine Gravel** | **19 mm Gravel** |
| Saturated specific mass dry surface | 2.56 g/cm³ | 2.56 g/cm³ |
| Specific mass dry aggregate | 2.68 g/cm³ | 2.64 g/cm³ |
| Absorption | 3.01 | 1.93 |
| Modulus of fineness | 5.73 | 6.79 |

Source: Authors.

The material designated as a co-product is composed of 15% PSA and 85% cellulose fiber, by mass. The process for obtaining and applying the co-product is registered with the INPI under No. BR 10 2022 012389 6. The consumption of the co-product varies according to the characteristics of the liquid used in the pre-hydration process. However, for simplicity, an average absorption value was adopted considering water from the public supply system, which leads to a consumption of 2.43 g of co-product per kg of cement. The hydration water for the co-product used in industrial-scale application was added at the beginning of the mixing process, directly into the concrete mixer truck, together with the co-product, and mixed for 10 min until the rest of the loading was completed. The water used in the hydration of the co-product, in accordance with the criteria recommended by ABNT NBR 6118:2023, was fully calculated as mixing water, i.e., included in the determination of the w/c ratio.

## 2.2 METHODS

This item addresses the methods used to determine the physical and mechanical characteristics of the concrete produced.

### 2.2.1 Definition of mix designs

Initially, an experimental dosage study was conducted to define the reference mixes and those with the co-product. For this purpose, rich, intermediate, and poor concretes were made, starting from the intermediate mix, according to the commercial standard mix corresponding to class C30 for floors, used by the partner concrete company, where for the rich and poor mixes, the aggregate content was varied by -1 and +1, respectively. For the sand and gravel ratios, a granulometric composition used by the partner concrete company in the respective mix was also used, with 60% plastering sand and 40% industrial sand for the sand. For the gravel, these ratios were 30% fine gravel and 70% 19 mm gravel, both ratios by mass. To adjust the workability, obtained through consistency by cone slump according to ABNT NBR 16889:2020, aiming at a consistency of 120 ± 20 mm, a superplasticizer additive was used.

It should also be noted that, both for the study to define the mix designs and for industrial-scale application, the moisture content of each respective aggregate was determined in order to allow its application in saturated dry surface conditions. In other words, if the moisture content was lower than its absorption, the necessary amount of water was added during mixing so that the aggregates would reach this condition. If the respective aggregates had moisture content higher than their absorption, the excess water was accounted for in the mixing water, respecting the w/c concept described by ABNT NBR 12655:2022.

Through this experimental dosage study, respecting the criteria established by ABNT NBR 6118:2023 and the preparation condition A established by ABNT NBR 12655:2022, the unit mixes for the reference concrete and for the concrete with co-product were prepared, dosed in such a way as to comply with the criteria of the standard for a C30 class concrete in class III environmental aggressiveness. The unit mix of the concretes can be seen in Table 5.

Table 5: Unit mixes for concrete

| Mix | Class | C | a | | b | | w/c | Water content (%) | Additive content (%)(adt/Cc) | Co-product content(kg/m3) | Cc (kg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $a_{plast.}$ | $a_{ind.}$ | $b_{0/8}$ | $b_{3/8}$ | | | | | |
| Reference | C30 | 1 | 1.62 | 1.08 | 1.04 | 2.42 | 0.58 | 8.07 | 0.40 | - | 292.50 |
| Co-product | C30 | 1 | 1.72 | 1.15 | 1.08 | 2.53 | 0.60 | 8.06 | 0.45 | 0.68 | 280.07 |

Source: Authors.

### 2.2.2 Compressive strenght

During industrial-scale application, two cylindrical test specimens were molded to determine the compressive strength at 28 days for each truck, following the sampling criteria established by ABNT NBR 12655:2022. The test specimens were molded and kept in a saturated environment until the test age, following the criteria determined by ABNT NBR 5738:2016. The compressive strength of the test specimens was obtained in accordance with ABNT NBR 5739:2018.

### 2.2.3 Drying shrinkage

Drying shrinkage was determined in the laboratory using four test specimens per mix, molded immediately before the concrete was poured, demolded at 24 hours of age, and kept in the laboratory under two curing conditions (dry 60 ± 5% RH and 23 ± 2 °C, and wet 100% RH and 23 ± 2 °C). The test ages were 1, 3, 14, 20, and 28 days. The test followed the guidelines of the American standard ASTM C157/C157M:2017, using prismatic test specimens measuring 7.5 x 7.5 x 28.5 cm. The readings were taken using a precision meter, mounted on a metal base with adjustable positioning of the test specimen.

Four test specimens were molded and analyzed for each proposed mix, two of which were subjected to wet curing and two to dry curing. Ten readings of horizontal dimensional variation were taken on each test specimen analyzed at each age. Based on the ten measurements, the average was calculated and used in the unidirectional deformation calculation process as described in ASTM C157/157M:2017, using Equation 1.

$$\Delta Lx = \frac{\frac{L_{jc} - L_{oc}}{G}}{0{,}000001} \qquad (1)$$

Where:

ΔLx = unidirectional deformation after deformation (μm/m);

Ljc = initial reading on the comparator at age j (days) in mm;

Loc = initial reading on the comparator after deformation in mm;

G = initial reference length (250 mm).

### 2.2.4 Industrial-scale application

For industrial application, 16 m³ of concrete containing co-product was produced – totaling approximately 160 m² of concreted area – where co-product was introduced into the concrete mixer truck prior to the addition of the other materials, and its respective hydration water was added, maintaining slow rotation of the drum for 10 min to hydrate the internal curing agent. For the Reference concrete, 112 m³ of concrete was produced. Both concretes were applied on the same day and, for the purpose of comparing properties, the analysis samples were removed from two nearby trucks, with "truck 1" referring to the collection of the concrete sample containing the co-product and "truck 3" referring to the collection of the Reference sample, in order of departure from the partner concrete batching plant. The two trucks containing the co-product and the third truck containing the Reference concrete were mapped during their application.

The industrial application was carried out in the city of Bom Princípio, Rio Grande do Sul, on March 31, 2023. Authorized by the competent municipal agency in accordance with the consent granted by the Municipal Government of Bom Princípio, through the Secretariat of Economic Development and Environment (SDEMA).

The concrete was mixed at the partner concrete plant's batching plant. It was mixed and transported in an 8 m³ capacity concrete mixer truck. The concrete containing co-product and the third truck containing the Reference concrete were mixed between 4:30 a.m. and 6:30 a.m. on the respective day of execution.

According to INMET data, at 7:00 a.m. on March 31, 2023 (approximate time of delivery of the first three concrete trucks), the air temperature was 20.9 °C and the relative humidity was 96%. On that day, the peak of environmental aggressiveness for the concrete occurred at 6:00 p.m., reaching 30.9 °C and 54% RH. It should also be noted that, on the day after the concrete was poured, the RH was below 60% for 8 hours (with a minimum of 46%). In the three days following the concrete pouring, there were periods of the day with RH < 60% (min. of 42% on 04/03/2023 at 5:00 p.m.). There was no record of precipitation until 14 days after the concrete pouring. At 14 days, a visual analysis of the concreted area was performed to identify and quantify possible cracks, monitored and validated by representatives of the financing company and the company purchasing the concrete (end customer).

## 3. ANALYSIS AND DISCUSSION OF RESULTS

This section presents and discusses the results of the methods presented.

Compressive strength was obtained in accordance with item 2.2.2, performed by the partner concrete company, where Table 6 shows the compressive strength results for the concrete in two samples per concrete mixer truck, where trucks 1 and 2 refer to concrete with co-product and trucks 3 and 4 refer to Reference concrete.

Table 6: Compressive strength of concrete

| Mix | Truck | Compressive strength (MPa) | |
|---|---|---|---|
| | | Sample 1 | Sample 2 |
| Co-product | 1 | 24.2 | 24.9 |
| | 2 | 24.2 | 22.9 |
| Reference | 3 | 21.8 | 23.2 |
| | 4 | 25.2 | 23.7 |

Note: Two test specimens were molded per truck, named "Specimen 1" and "Specimen 2."
Source: Authors.

In relation to compressive strength, it can be seen that when comparing the results between trucks that had their dosages, mixtures, and pours at similar times, there was no significant variation at 28 days between the concrete containing the co-product and the Reference concrete, where the Co-product concrete had an average result of 24.05 MPa and the Reference concrete had 23.47 MPa. This was expected, confirming the equivalence of the concrete's strength.

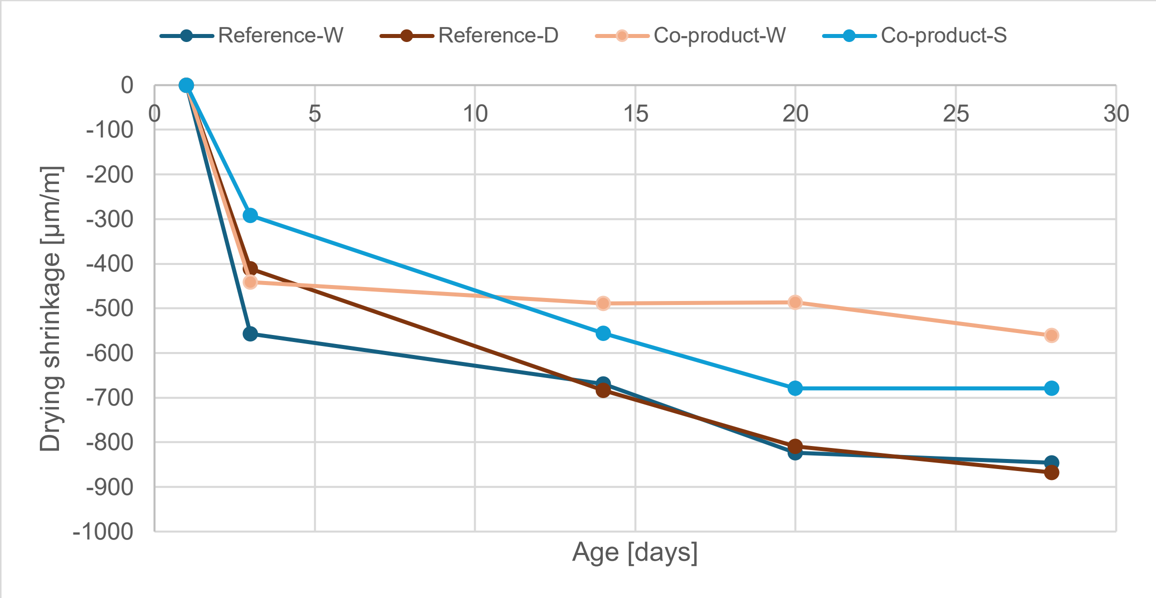
Drying shrinkage was determined in the laboratory with test specimens molded immediately before the concrete was poured (collected from trucks 2 and 3). These specimens were demolded at 24 hours of age and kept in the laboratory under the curing conditions described in item 2.2.3. The results can be seen in Table 7 and Graph 3.

Table 7: Drying shrinkage of the concretes

| Mix | Drying shrinkage (µm/m) | | | | |
|---|---|---|---|---|---|
| | 1 day | 3 days | 14 days | 20 days | 28 days |
| Reference-W | 0 | -557.4 | -669.4 | -823 | -845.8 |
| Reference-D | 0 | -411.6 | -684.2 | -808.8 | -867.6 |
| Co-product-W | 0 | -440.6 | -488.4 | -486.6 | -560.8 |
| Co-product-D | 0 | -291.6 | -555.4 | -679.2 | -679.2 |

Note: The suffix "W" refers to wet curing and "D" to dry curing.
Source: Authors.

Graph 3: Drying shrinkage of concrete

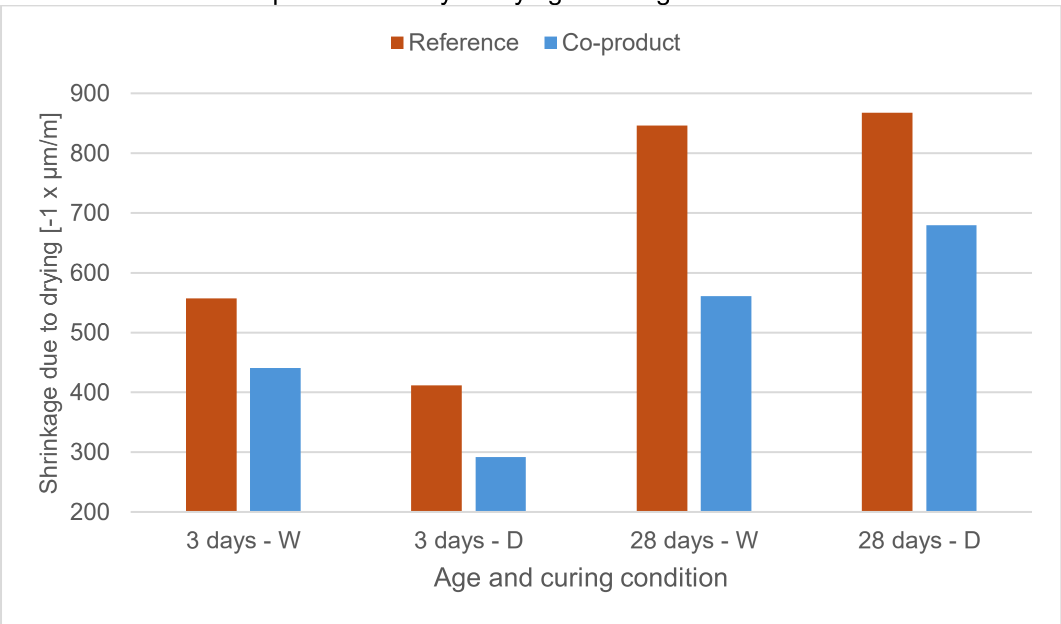



Note: The suffix "W" refers to wet curing and "D" to dry curing.
Source: Authors.

The analysis focused on ages of 3 and 28 days, considered strategic for the property evaluated. Until the third day, the shrinkage rate is more pronounced compared to later ages, in addition to the concrete presenting a low degree of hydration. This implies less formation of hydration products, resulting in reduced mechanical strength and, therefore, greater susceptibility to cracking, since the material has a lower capacity to withstand internal stresses—which, in turn, manifest themselves more intensely during this period. On the other hand, the age of 28 days was highlighted as representing a possible point of stabilization of shrinkage, due to the advancement of the hydration process of the cementitious matrix.

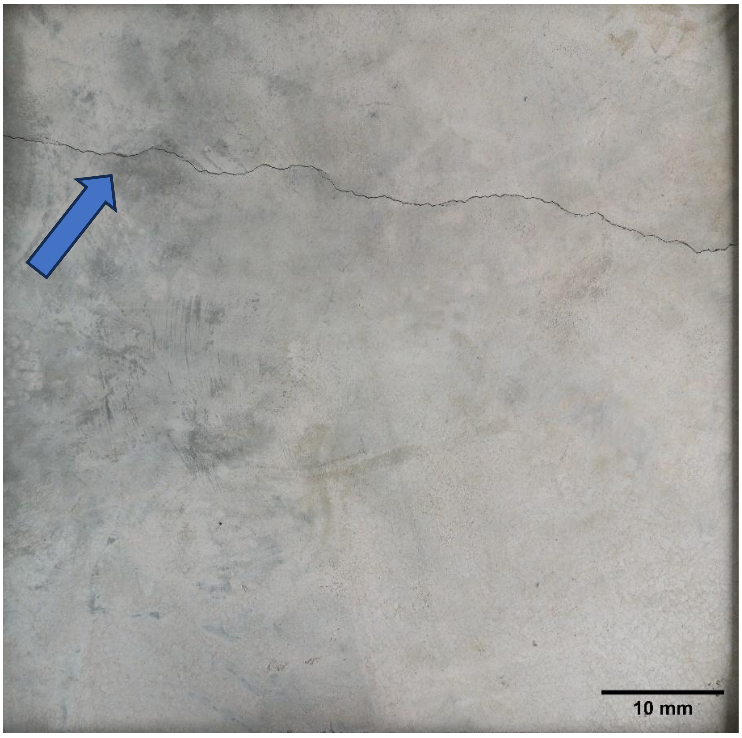
Comparing the Co-product and Reference concretes, in a wet curing situation (ideal hydration condition), at 3 days the Co-product concrete showed 21% less shrinkage than the Reference concrete, while at 28 days the Co-product concrete showed 34% less shrinkage than the Reference concrete. Under dry curing conditions (a curing situation closer to the reality of application), the Co-product concrete showed 29% less shrinkage than the Reference concrete at 3 days, while at 28 days, the Co-product concrete showed 22% less shrinkage than the Reference concrete. These results can be better understood through Graph 4.

Graph 4: Summary of drying shrinkage of concretes




Note: The suffix "W" refers to wet curing and "D" to dry curing.
Source: Authors.

At 14 days, a visual analysis was also performed on site. Due to the extensive concrete area, it was not possible to perform a detailed photographic analysis to quantify cracks. Therefore, the crack analysis at 14 days in the concrete area was performed semi-quantitatively. Figure 1 illustrates a crack segment present in the area concreted with Reference concrete.



**1 : Crack segment in the Reference concrete. Source: prepared by the authors.**

At the time of the analysis, at 4:30 p.m. on April 15, 2023, the following were present: a representative from UNISINOS; a representative from the partner company that manages the solid waste used in the Co-product; and a representative from the end customer. It was evaluated and confirmed by all those present that the area concreted with concrete containing the co-product did not present cracks visible to the naked eye. In the area concreted using the Reference concrete, among the cracks visible to the naked eye (similar to the segment shown in Figure 1), approximately 16 linear meters of cracks were observed.

It should also be noted that the area concreted with co-product was the first to be poured, leveled, and polished, remaining exposed to the aggressive environment longer than the area with Reference concrete. It should also be noted that the area concreted with co-product did not have any shaded areas, while part of the area containing Reference concrete did have shaded areas. Both the location within the floor concreting area and the concreting sequence were determined in order to subject the concrete containing co-product to possible situations of greater environmental aggressiveness than the Reference concrete.

## 4. FINAL CONSIDERATIONS

The application of the co-product on an industrial scale, while still fresh, proved successful, as it did not impair the mixing, pouring, leveling, and polishing of the concrete in relation to the Reference concrete. The technological control carried out by the partner concrete company demonstrated equivalence in compressive strength between the Co-product concrete and the Reference concrete, which highlights the success in the definition and development of the experimental dosage study.

The drying shrinkage of the concrete on an industrial scale showed that in a wet curing situation (ideal hydration condition), after 3 days, the Co-product concrete showed 21% less shrinkage than the Reference concrete, while after 28 days, the Co-product concrete showed 34% less shrinkage than the Reference concrete. Under dry curing conditions (a curing situation closer to the reality of application), the co-product concrete showed 29% less shrinkage than the reference concrete after 3 days, while after 28 days, the co-product concrete showed 22% less shrinkage than the reference concrete. The reduction in matrix shrinkage promoted by the use of the co-product, combined with the potential increase in tensile strength—based on the results of the concrete in the experimental dosage study and the references used—prevented the appearance of cracks for at least 14 days in the concrete area containing the co-product in the concrete floor, while cracks appeared in the area containing Reference concrete.

The results obtained in this study confirm the advancement in technological maturity of the project for the development of a co-product from industrial solid waste of superabsorbent polymer and cellulose fiber for use as an internal curing agent and reinforcement in Portland cement matrices, at the end of level 7. In other words, the prototype (co-product) was demonstrated in an operational environment (concrete mixed and poured by a concrete mixer and applied on an industrial scale). The study also promoted technological adaptation related to technology transfer, in addition to the possibility of comparison with equivalent concretes, reinforcing its benefits in relation to conventional concrete.

## REFERENCES


AMERICAN SOCIETY FOR TESTING MATERIALS. ASTM C157 / C157M-17: standard test method for length change of hardened hydraulic-cement mortar and concrete. West Conshohocken, PA: ASTM International, 2017.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 12655: concreto de cimento Portland – preparo, controle, recebimento e aceitação – procedimento. Rio de Janeiro: ABNT, 2022.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 16889: concreto – determinação da consistência pelo abatimento de tronco de cone. Rio de Janeiro: ABNT, 2020.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 5738: concreto – procedimento para moldagem e cura de corpos de prova. Rio de Janeiro: ABNT, 2016.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 5739: concreto – ensaio de compressão de corpos de prova cilíndricos. Rio de Janeiro: ABNT, 2018.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NBR 6118: projeto de estruturas de concreto — procedimento. Rio de Janeiro: ABNT, 2023.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NM 248: agregados – determinação da composição granulométrica. Rio de Janeiro: ABNT, 2001.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NM 30: agregado miúdo — determinação da absorção de água. Rio de Janeiro: ABNT, 2000.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NM 52: agregado miúdo — determinação da massa específica, massa específica aparente. Rio de Janeiro: ABNT, 2009.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). NM 53: agregado graúdo — determinação da massa específica, massa específica aparente e absorção de água. Rio de Janeiro: ABNT, 2009.

BARTH, M. E. et al. Analysis of water absorption in industrial waste of superabsorbent polymer and cellulosic fiber. Revista Matéria, v. 29, n. 1, 2024.

BARTH, M. E. et al. Relações simbióticas na aplicação de coproduto a partir de resíduo industrial de polímero superabsorvente e fibra celulósica (PSAR) como agente de cura interna em matrizes de cimento Portland. In: FÓRUM INTERNACIONAL DE RESÍDUOS SÓLIDOS (FIRS), 11., Porto Alegre, 2020. Anais [...]. Porto Alegre: Instituto Venturi, 2020.

BARTH, M. E. Utilização de resíduo industrial de polímero superabsorvente e fibra celulósica como agente de cura interna em concretos de cimento Portland. 2021. 255 p. Dissertação (Mestrado em Engenharia Civil) – Programa de Pós-graduação em Engenharia Civil, Universidade do Vale do Rio dos Sinos, São Leopoldo, 2021.

BENTZ, D. P.; LURA, P.; ROBERTS, J. W. Mixture Proportioning for internal curing. Concrete International, v. 27, n. 2, p. 35-40, 2005.

GOMES, L.M. Avaliação da potencialidade de resíduo sólido de base celulósica advindo do setor de higiene pessoal testando sua adição em argamassa de revestimento. 2014. 117 p. Dissertação (Mestrado em Engenharia Civil) – Programa de Pós-graduação em Engenharia Civil, Universidade do Vale do Rio dos Sinos, São Leopoldo, 2014.

HELENE, P. R. L.; LEVY, S. Boletín técnico – curado del hormigón. associación latinoamericana de control de calidad, patología y recuperación de la construcción. México: ALCONPAT, 2013.

JENSEN, O. M. Use of superabsorbent polymers in concrete. Concrete International, p. 48-52, jan. 2013. Disponível em: http://procureusa.com/distributors/ wp-content/uploads/2014/04/SAPs-In-Concrete.pdf. Acesso em: 20 jun. 2020.

JENSEN, O. M.; HANSEN, P. F. Water-entrained cement-based materials I – principles and theoretical background. Cement and Concrete Research, v. 31, n. 6, p. 647-654, 2001.

KAWASHIMA, S.; SHAH, S. P. Early-age autogenous and drying shrinkage behavior of cellulose fiber-reinforced cementitious materials. Cement and Concrete Composites, v. 33, p. 201-208, 2011.

KOPPE, A. Utilização de resíduo à base de polímero superabsorvente e fibra celulósica como agente de cura interna em matrizes de cimento Portland. 2016. Dissertação (Mestrado) – Programa de Pós-graduação em Engenharia Civil, Universidade do Vale do Rio dos Sinos, São Leopoldo, 2016.

KUMM, T. C. Influência do emprego de polímeros superabsorventes nas propriedades de materiais à base de cimento Portland. Dissertação (Mestrado em Engenharia Civil) – Universidade Federal de Santa Catarina, Florianópolis, 2009.

MANNING, C. Technology Readiness Levels. In: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA). Technology Readiness Levels. [S. l.], 2023. Disponível em: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/. Acesso em: 27 abr. 2025.

MASUDA, F. Trends in the development of superabsorvent polymers for diapers. Superabsorbent Polymers, v. 573, p. 88-98, 1994.

SIKA S/A. Concreto Reforçado com Fibras. In: SIKA S/A. Concreto Reforçado com Fibras. São Paulo, [2025?]. Disponível em: https://bra.sika.com/pt/concreto-reforcado-com-fibras.html#macrofibras. Acesso em: 27 abr. 2025.

SOROUSHIAN, P.; WON, J. P.; HASSAN, M. Durability characteristics of CO2-cured cellulose fiber reinforced cement composites. Construction and Building Materials, v. 34, p. 44-53, 2012.

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