Analysis of concrete properties by incorporating wash water

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ABSTRACT: Concrete is an essential material in construction and large companies have opted for industrialized it. For the preparation of industrial concrete quality is required to wash the concrete mixer trucks with great frequency, using potable water. Knowing the water crisis faced by Brazil in recent times, this work aims to reuse the water from these washes for making new concrete. The goal is to reduce the use of drinking water and give a correct allocation to the wastewater, which is currently a major problem for concrete producers industries, generating large costs with waste treatment before disposal.

After the performed aggregate's characterization tests (grown and fine) and water collected according to current regulations in the company that makes industrial concrete. The tapered trunk rebate depending on water levels in manufactured concrete was analyzed. It appears that the fine aggregate is within the optimum zone for sand used in concrete. However, the grown aggregate is outside the usable area for concrete.

For characterization of the fresh concrete the slump was used to measure workability test. All mixes met within the standard established with the same amount of water, demonstrating that not showed significant influences on the workability of the concrete using the concrete mixer truck wash water. All mixes analyzed showed no significant differences in the workability and the mechanical strength. The tests show promise in the use of effluent analyzed for the production of a new concrete, it can be used 100 % substitution of potable water at effluent.

Keywords *Waste water, Concrete mixer truck, Concrete.*

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1 INTRODUCTION

Water is a very important element for human life and is an exhaustible natural resource. This resource has promoted the advancement and the constant civilization development over the centuries. Any variations, both in quality and quantity of it this that cause environmental imbalance directly effects on water availability, in the food production, material resources to the wellbeing, and, above all, on the health of living beings (ANDREOLI, 2003).

According to Bueno (2003), our planet is constituted of 70% water and 30% soil, but of all existent water 97, 61% is salt water and only 2, 39% is freshwater, considering that a great part of the fresh water is distributed in glaciers, icebergs and deep underground, and this is a limited and finite resource. As such, its distribution is not uniform and is available with an easy access to human consumption only in rivers and lakes.

Tundisi (2014) points out that Brazil possess about 12% of all fresh water of our planet, however, its distribution among country regions it is not homogeneous and the lack of water stands out on the north and northeast Brazilian regions, which are the ones that suffers most with the influence of a great variety of climatological process.

The Human Development report (United Nation Program for Development, 2015) highlights that all investments for people life quality through access to the sources of potable water in many countries still aren't enough. It is estimated that about 633 millions of people all over the world yet draw water from unimproved sources of drinking water and the water scarcity affects more of 40% of the population worldwide.

Even knowing the water importance to life survival and development of our society, water continues to be devaluated and mismanaged and the lack of interest can be noticed in many places in our planet, as an example the proper control absence for quality and amount of water resources. The degradation of potable water and absence of residual water management contribute to the growing water crisis, creating a water stress that fatefully is a part of world population reality (UNSGAB, 2015).

According to the National Confederation of Industry report (2013), the growing consumption over the worldwide freshwater resources reflects in increase degradation of supplies sources because of population growth, fast industrialization and climate changes. The degradation is the bigger problem, because of the unprecedented rate of pollution make quality sources (potable water) in unusable sources.

Tundisi (2011) highlights that the main cause of the deterioration of water sources and potable water supply is a result of constant increase in water consumption for several human activities to explore water resources and expand the economic development due to the world's population growth and the need to demands of industrial and agricultural consumption.

According to the United Nation World Report about the Development of Water Resources (ONU, 2015) about 20% of the whole world's aquifer are under exploration, both in surface water as in groundwater and it predicts an increase of 400% of the global water demand by the manufacturing industry between 2000 and 2050, affecting all other sectors, with the most part of this increase in emergent economies and in developing countries.

Mierzwa (2005) stresses that the industry, due to the diversity in activities, mainly those related to the production of consumer goods, consumes great part of planet's freshwater. Among the global economy sectors, the civil engineering sector is the responsible for consuming one third of our planet's natural resources, and among them, consumes about 12% of the total freshwater.

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The civil construction besides being one of the segments that most consume planet's natural resources, mainly water, also contributes to the environment's pollution and it is further aggravated in Brazil that is facing several problems referring to the low water levels in the rivers, in the last few years. As concrete is indispensable to the sector, large developers opt for industrialized concrete that are produced by concrete industries. For the confection of this material, they end up consuming a large quantity of potable water.

The concrete transport to its final destination is on account of the concrete mixer trucks, which are loaded with concrete in the concrete's company and, before leaving to perform the delivery, need a wash to remove the excess concrete that stays deposited on the external part of the truck. After the delivery, it must be cleaned again before returning, to prevent soiling the city with this material. Once it arrives in the concrete's company, it must be fully washed, so the remaining concrete will not damage the truck's accessories, such as the rail, hopper and the balloon.

Silva e Violin (2013) stand out that for the confection of 1 m^3 of concrete dosed in central is spent on average 211 liters of potable water. Cardoso (2015) highlights that for the washing of concrete mixer trucks it is used a large amount of water that potentially contributes on the generation of harmful waste for the environment. Ekolu e Dawneerangen (2010) estimate that for the washing of the concrete mixer truck's roll, chute and funnel, in the process of concrete's fabrication, per day, are used around 1000 potable water liters. For that reason, the concern with technological development and the urgent necessity of rational use of natural resource, for example, the rational use of water in concrete's fabrication process, showing the reutilization possibilities of this resource without harming the environment (Concreto & Construção, 2009).

Given the above, and knowing of the water crisis faced by the country in recent times, this work seeks to reuse the water from the washing of concrete mixer trucks to the confection of new concretes. The goal is to diminish the use of potable water and also give a proper destination to the residual water, which currently is a big problem for de concrete industries, creating great costs, because the residue needs treatment before disposal.

2 METHODOLOGY

Knowing the high consumption of potable water in concrete production and thinking of finding an alternative to minimize the use of this natural resource, and create a possible solution for the proper destination of wastewater, coming mainly from concrete mixer trucks washing step, started this study. The research was also motivated by the high cost of treatment of the effluent for the concrete producers companies.

2.1 Water collection

The wastewater from the wash concrete mixer truck was collected in a concrete producer company, in the Vale dos Sinos region, Greater Porto Alegre, Rio Grande do Sul, as Figure 1. This procedure was performed in a decanter located in the company's courtyard, according to instructions of the laboratory called Analytical Center of the Feevale University, that subsequently performed the analysis used in this study.

Figure 1. Wastewater being collected in the concrete producer company.

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Consumption for washing concrete mixer trucks in the company which the samples were collected it is about 7000 liters of potable water per day, according to data collected on site. This effluent must be deposited in a decanter tank and then be treated so it can return to nature, generating a costly process for the enterprise.

2.2 Classification, characterization and storage of used aggregates

The Construction Techniques Laboratory of the Feevale University provided all of used aggregates for the studies. First, we performed a material quantitative to be used throughout the study. All the material was separated and stored to maintain regularity. To remove impurities and dusty materials the coarse aggregate went through a washing process, as shown in Figure 2. After washed, the aggregate was distributed in a heated room, with temperature of 30ºC, for 10 days, for drying. Fine aggregate has passed for the same drying process before storage.

Figure 2. Coarse aggregate being washed

The aggregates were stored in 200 liter drums and underwent characterization tests, wich they were submitted to tests to determinate the particle size distribution for coarse and fine aggregate, according to NBR NM 248 (ABTN, 2003), specific mass for fine aggregates, NBR 9776 (ABNT, 1987), specific mass for coarse aggregate NBR NM 53 (ABNT, 2009), unit mass for coarse and fine aggregate, NBR NM 45 (ABNT, 2006).

2.3 Cement

The cement used was the Votoran brand, classified as CPIV-32-RS, provided by Rio Branco unit. Lots of cements used were L05-170604 e L010-1212074104. Their characterization is determined by NBR 5736 (ABNT, 1991), according to tests performed by the manufacturer, Tables 1, 2 and 3.

Table 1. Chemical characterization of cement

Chemical characterization	%
MgO	5,20
SO_3	2,16
RF	3,40
RI	23,49

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Table 2. Physical characterization of cement

Physical property	Value	Unit
Fineness #200	0,84	%
Fineness #325	4,18	%
Blaine	4607,86	cm^2/g
Water Consistency	29,91	%
Setting time – beginning	252,50	Min
Hot expansion	0,00	Mm

Table 3. Mechanical characterization of cement

Time (days)	Compressive strength (Mpa)
1	12,89
3	32,76
7	28,68
28	40,82

After performing quantitative calculations, it was separated the needed amount for testing, in this case, two cement bags of 50 kg each. These packages were individually wrapped in plastic bags and secured with the aid of masking tape, and has been properly identified.

All cement bags were stored on wooden pallets and in dry location, preventing damage to the material.

2.4 Additive

The additive added to the mix was made possible by the concrete producer company and it is, according to information from Viapol, the manufacturer, is a Plasticizer additive - Polyfunctional, used in concrete. It is a liquid material, free from chlorides, with a specific mass of about 1,2 g/cm^3 and its color is dark brown.

The company generating the liquid effluent provided the feature that it was used in this study, the feature was calculated aiming to use the specified additive.

2.5 Water

It was used two types of water in the research, a potable water from public supply in the city of Novo Hamburgo – RS, Brazil, called water reference, and reuse of water washing of concrete mixer truck, known as effluent.

The water used on the study were tested for the pH, color, turbidity, total solids and density, all analyzes were performed at the Analytical Center of the Feevale University.

2.6 Mix

The feature used in all samples were provided by the concrete producer company, having only to be determined the amount of water to be employed, because the settlement was fixed as the company's own data. The mass feature was 2,32 : 0,58 : 1,73, as shown in Table 4, were values correspond to the cement, fine aggregate and coarse aggregate. The water/cement relation (w/c) was 0,53 plus plasticizer additive.

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Table 4. Amount of each material used in the mixture.

Material	Feature	Mass Kg
Cement	1	3,996
Fine aggregate	2,32	9,271
Coarse aggregate (crushed stone type 0)	0,58	2,317
Coarse aggregate (crushed stone type 1)	1,73	6,913
Additive	-	0,020
Water	0,53	2,100

It was used in the study three different features: a reference feature (just with drinking water, from public water supply in the city of Novo Hamburgo), feature 50% (half drinking water and half effluent, collected from the concrete mixer truck's washing) and the feature 100% (with only the effluent). Figure 3 shows the water samples used in each feature.

Figure 3. Samples with the three water contents: 0% (reference), 50% and 100%

2.7 Characterization of fresh concrete

To characterize the fresh concrete was determined the consistency for Slump Test, to analyze the concrete's workability, of all features under study (Figure 4).

Figure 4. Determination of consistency through Slump Test.

Therefore, the current standard NM 67 (ABNT, 1996) was consulted and applied. The reference used was 120 mm ± 20 mm, as specified by the concrete producer company in question.

2.8 Characterization of concrete in hardened state

For each feature six samples were cast, for ages of 7, 14, 28 63 and 91 days. The casting and curing of the samples have been performed according to NBR 5738 (ABNT, 2003) with cylindrical samples, 100 mm in diameter and 20 cm in height, as shown in Figure 5. Densification was manually, with stem. As the standard requires a temperature control of the storage environment and the laboratory did not have any device able to meet this demand, there was an adaptation of the standard in relation to this criterion. For this, the

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air conditioner on site was kept on to make the temperature stabilized at about 30° C with varying ±5 °C.

Figure 5. Samples in placeholder in the laboratory, waiting to be extracted from the mold.

For the characterization of hardened state was performed the compressive strenght test. NBR 5739 (ABNT, 2007) lays down the guidelines for the execution of the samples compression test (Figure 6) and the assay was performed according to it, as well as the preparation of the bases (Figure 7) that followed NBR 5738 (ABNT, 2003).

Figure 6. Sample tore.

Figure 7. Sample being rectified, to prepare de base.

3 RESULTS

3.1 Water

Table 5 shows the results of tests conducted by the Analytical Center of the Feevale University with samples of waste and potable water.

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Table 5. Test results of water samples

Material	Waste Water	Potable water	Unit
Density	0,99752	0,99597	g/cm^3
pH	11,64	6,88	-
Color	14	5	Pt-Co
Turbidity	3,3	0,6	NTU
Total Solid	2526,0	4,0	Mg L^{-1}

FONTE: Analytical Central of Feevale University

With the results, it is clear that both types of water samples used are in accordance with Ordinance nº 2914 of the Ministry of Health, December 12, 2011, considering the analyzed parameters.

NBR 15900-1 (ABNT,2009), responsible for determining the water requirements for kneading concrete, shows that water pH should be greater than or equal to 5 and a maximum of solid material should not exceed the value of 50 000 mg/L. As shown in Table 2, both samples used meet this determination.

3.2 Slump Test

Table 6 presents Slump Test results, where we can verify that all samples obtained within the established limit values of 120 mm ± 20 mm, not getting results with significant difference among analyzed features. This test demonstrates that reuse of water from concrete mixer truck wash does not significantly alter the concrete's workability.

Table 6. Results of consistency through slump test

Feature	7 Days (mm)	14 days (mm)	28 days (mm)	63 days (mm)	91 days (mm)
0% (Ref.)	125	100	100	100	105
50%	115	110	105	120	120
100%	110	105	105	135	115

It is clearly observed that the total solids in the wastewater samples did not alter concrete's workability significantly.

3.3 Strength of concrete compression

In the case of maximum compressive stress at rupture of samples, Table 7 presents the results for each feature and their respective ages. It can be seen in Graphic 1 that there was a gradual increase in tensions especially at early ages. This is due the cement used is pozolanic, type CPIV, which composition has a slow curing over time. We can see that from de age of 63 days of curing the resistance is practically stabilized. The concrete's resistance trend that used this type of cement is linear growth from de 28 days following that behavior throughout its life.

Table 7. Results of maximum rupture tension from the samples, unit: MPa

Feature	7 Days	14 Days	28 Days	63 Days	91 Days
0% (Ref.)	20,88	22,96	32,96	38,26	38,26
50%	20,55	23,97	33,24	38,30	38,13
100%	19,64	24,11	32,22	38,34	38,18

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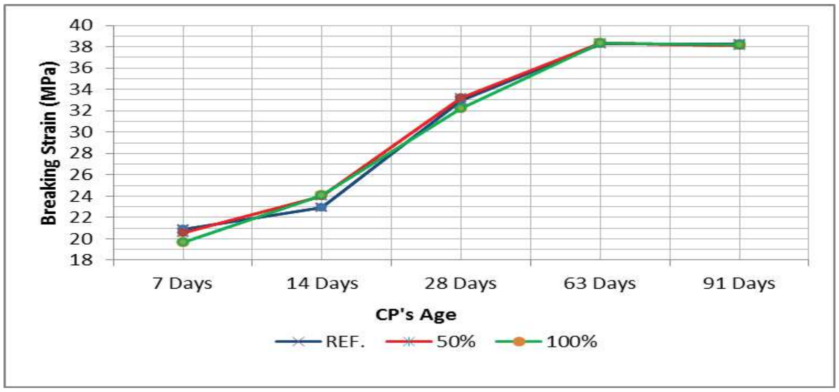
Graphic 1. Sample's Breaking Strain



It can be seen in previous images that concrete's resistance with the feature of 100% (residual water) was close to the feature 0% (drinking water). Satisfactory results, showing that the analyzed water did not significantly influences the compressive strength of the examined ages.

All analyzed features showed no significant differences in the workability and mechanical resistance. The performed tests showed good perspective in using the studied effluent for the production of a new concrete, it can be used 100% substitution of potable water at effluent.

4 JUSTIFICATION

The project was carried out aiming environmental concern, because construction industry is very harmful to nature, seen that it possesses a high consumption of raw materials and a large waste of drinking water, mainly in activities that do not add value, in this case, the step of washing of concrete mixer truck.

Water resulting of this process can be used to produce new concrete, helping to reduce company's cost for treating this effluent and consuming less drinking water in the concrete's production, furthermore, it reduces the amount of waste to be treated and disposed of in the environment.

In this regard, the work obtained good results, as were maintained concrete's properties with the incorporation of wastewater when compared to the reference concrete, and in some tests even improved these properties.

REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 5736: *Cimento Portland pozolânico*. Rio de Janeiro, 1991.

______. NBR 5738: *Concreto – Procedimento para moldagem e cura de corpos-de-prova*. Rio de Janeiro, 2003.

______. NBR-5739: *Concreto – Ensaio de compressão de corpos-de-prova cilíndricos*. Rio de Janeiro, 2007.

______. NBR 9776: *Agregados – Determinação da massa específica de agregados miúdos por meio de frasco chapman – Método de ensaio*. Rio de Janeiro, 1987.

______. NBR 15900-1: *Água para amassamento de concreto – Partes 1,2,3*. Rio de Janeiro, 2009.

ISBN: 978-85-92631-00-0

______. NBR NM 45: *Agregados – Determinação da massa unitária e do volume de vazios*. Rio de Janeiro, 2006.
______. NBR NM 53: *Agregado graúdo – Determinação da massa específica, massa específica aparente e absorção de água*. Rio de Janeiro, 2009.
______. NBR NM 67: *Concreto – Determinação da consistência pelo abatimento do tronco de cone*. Rio de Janeiro, 1996.
______. NBR NM 248: *Agregados – Determinação da Composição granulométrica* . Rio de Janeiro, 2003.
ANDREOLI, C. V. *Mananciais de abastecimento: planejamento e gestão. Curitiba: Sanepar Finep*, 2003. P 35.
BUENO, L. A água e a vida. Artigo Embrapa 2003. Disponível em: www.ainfo .cnptia.embrapa.br. Acesso em: 17/04/2016.
CARDOSO, V.A.V.P. *Utilização de Lavagem em Betoneiras na Produção de Concreto Fresco. Ribeirão Preto*, 2015. 15º Congresso Nacional de Iniciação Cientifica – Universidade São Judas Tadeu.
CONCRETO & CONSTRUÇÃO. ABNT NBR 15900 – *Água de amassamento do Concreto. Ibracon*, 2010.
CONFEDERAÇÃO NACIONAL DA INDÚSTRIA. The Ceres Aqua Gauge: a framework for 21st century water risk management. Brasília, 2013. 107 p.
UNSGAB - CONSELHO DE ASSESSORAMENTO DO SECRETÁRIO-GERAL DA ONU PARA ASSUNTOS DE ÁGUA E SANEAMENTO . A Jornada do UNSGAB. Nova Iorque, 18 de novembro 2015. Disponível em www.arquivos.ana.gov.br. Acesso em: 13/04/2016.
EKOLU, S.; DAWNEERANGEN, A. *Evaluation of Recycled Water Recovered from a Ready-Mix Plant for reuse in Concrete.* Journal of the South African Institution of Civil Engineering 2010. Vol.52 (2), 77-82.
MIERZWA, J. C. Água na indústria: uso racional e reúso. São Paulo: Oficina do Textos, 2005. 143p.
PROGRAMA DE AVALIAÇÃO MUNDIAL DA ÁGUA DAS NAÇÕES. Unidas. Relatório Mundial das Nações Unidas sobre Desenvolvimento dos Recursos Hídricos - Água para um mundo sustentável 2015. Disponível em: www.unesco.org. Acesso em: 17/04/2016.
PROGRAMA DAS NAÇÕES UNIDAS PARA O DESENVOLVIMENTO. Relatório do Desenvolvimento Humano 2015. Disponível em: www.pnud.org.br. Acesso em: 23/03/2016.
SILVIA, R.R.; VIOLIN, T.Y. R. *Gestão da Água em Canteiros de Obras de Construção Civil*. VIII EPCC. Maringá: CESUMAR, 2013.
TUNDISI, J. G. Recursos hídricos no Brasil: problema, desafios e estratégias para o futuro. Rio de Janeiro: Academia Brasileira de Ciências, 2014. 75 p.
TUNDISI, J. G; TUDISI, T. M. Recursos hídricos no Século XXI. São Paulo: Oficina de Texto, 2011. 328 p.
UNITED NATIONS ENVIRONMENT PROGRAMME. Bildings investing in energy and resource efficiency. Disponível em: www.unep.org. Acesso em: 13/02/2016.