ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 11, Issue, 05, pp. 46670-46676, May, 2021
https://doi.org/10.37118/ijdr.21830.05.2021

RESEARCH ARTICLE OPEN ACCESS

VIABILITY ANALYSIS OF THE PARTIAL REPLACEMENT ON NATURAL SAND BY STONE POWDER AND CONSEQUENCES IN CONCRETE RESISTANCE

[*1]Luis Felipe Moreira Bassani, [1]Raphael de Oliveira Melo, [2]Rachel Cristina Santos Pires, [3]José Roberto Moreira Ribeiro Gonçalves, [4]Luciana Carreiras Norte, [5]Everton Rangel Bispo and [6]Fabiano Battemarco da Silva Martins

[1]Graduating in Civil Engineering from Augusto Mota University Center – UNISUAM; [2]Master in Local Development, Civil Engineer and Professor at Augusto Motta University Center – UNISUAM; [3]Master in Agricultural and Environmental Engineering, Environmental Engineering and Professor at IBMR Laureate International University Center; [4]PhD in Biotechnology at National Institute of Metrology, Quality and Technology, RJ, BRAZIL; [5]Doctor in Engineering of Materials and Chemical and Metallurgical Processes by the Pontifical Catholic University of Rio de Janeiro and Professor at Augusto Motta University Center – UNISUAM; [6]Master in Agricultural and Environmental Engineering, Civil Engineer and Professor at Santa Úrsula University- USU and at the Gama e Souza University Center - UNIGAMA

ARTICLE INFO

Article History:

Received 08th February, 2021
Received in revised form
16th March, 2021
Accepted 28th April, 2021
Published online 14th May, 2021

Key Words:

Natural sand; Artificial Sand; Grit; Concrete; Resistance.

Corresponding author:
Luis Felipe Moreira Bassani,

ABSTRACT

Grit, also called artificial or crushing sand, can be an option for the production to Portland cement concrete. Considering the progressive scarcity, the high cost of resources such as natural sands and the environmental impacts of their extraction. This work intends to analyze the feasibility of exchanging natural sand for crushing sand from the region located in Rio de Janeiro. In order to quantify the possible portion for this replacement, three experimental mixeswere performed in the laboratory, where rupture and axial compression were verified.Concrete mixes were produced with different percentages of stone dust (0%, 50% and 100%). After tests, was possible conclude that by increasing the amount of crushing sand, the water retention increases in the concrete, allowing the addition of more water in the mix, within standardized levels. The compressive strength also increases, as the crushing sand, in granulometry properties, fills better the interstitial spaces of the concrete.

Citation: Luis Felipe Moreira Bassani, Raphael de Oliveira Melo, Rachel Cristina Santos Pires, José Roberto Moreira Ribeiro Gonçalves, Luciana Carreiras Norte, Everton Rangel Bispo and Fabiano Battemarco da Silva Martins. 2021. "Viability analysis of the partial replacement on natural sand by stone powder and consequences in concrete resistance", *International Journal of Development Research*, 11, (05), 46670-46676.

INTRODUÇÃO

One of the largest consumers of natural raw materials in the world is the construction industry; Main resources used are: natural sand, mortar and concrete. Thorns (2018), estimated that 25 billion tons of sand and gravel are used each year in the world, 90% extracted from river beds and 10% other sources. Ramadon (2019) says that illegal extraction of natural sand in Brazil, is one of the most lucrative and harmful crimes to the environment, turnovers between 7 and 8 billion reais a year, second drug trafficking and piracy. The high demand for the material implies in constant extraction of aggregates used in its manufacture, which, as they are non-renewable, lead to exhaustion in places near big consumer centers, motivating explorations far from those of their use and causing the increase in transport costs. Benite (2010) qualifies civil construction responsible for approximately one third from gas emissions of planet, most of what are related to process of construction and execution of works.

In this parcel, stone powder, considered a waste and its production process is configured as sustainable, as this is discarded in crushed sand as fine aggregate, can be included in the production of concrete. and mortars. Basic product by civil construction industry, concrete based on Portland cement uses, per cubic meter, an average of 42% coarse aggregate (gravel), 40% sand, 10% cement, 7% water and 1% chemical additives. So, it is possible to verify that 70% of the concrete are aggregates. According to Giammusso (1992), any natural or artificial mineral material, chemically inert in relation to cement, can be used as an aggregate for concrete. Even those that can react, according to the researcher, can be used to neutralize the effects from reactivity. According its origin, aggregates are classified as grain size and apparent specific weight. ABNT NBR 7225 (1993) defines aggregate natural material as suitable properties or artificial stone fragmentation, specified inmaximum nominal dimension less than 152 mm and minimum nominal dimension equal to or greater than 0.075 mm (ABNT, 1993).

Knowledge of properties are required for each application of aggregates. Technological characterization of aggregates as construction material is developed by appropriate techniques allowingto know the properties from all of them or in an isolated way. All aggregates must be technologically characterized before its use in construction.The standard requires a characterization performed by standard procedures, called normalization, and the product is called a standard. Standardization makes the results more homogeneous and precise, such as: execution of tests and analyzes; designation of materials and processes, iconographic and mathematical representation of properties; quality specification required for materials and services and other procedures. The solution to the impacts of high exploitation of natural sand can be replace it with stone dust. In developed countries, this replacement has been done since the 1970s, approximately ten years after the large-scale production of the first equipment used in fine material crushing, enabling production of stone powder in commercial scale, contextualizes Almeida & Sampaio (2002). In Brazil, Andriolo (2005) reports use of stone powder in concrete in the 1980s, supported by technical studies carried out at Itaipu hydroelectric plant with technical and economic advantages. The author also discusses that more advanced studies were desenvolved by engineers from Norberto Odebrecht construction company, in the Capanda´s dam construction, Angola 1987. ABNT NBR 7211 (2005), relates characteristics from production of small and large natural origin aggregates, obtained in fragments resulted for crushing of rocks, defining the sand or small aggregate as being from natural origin or resulting crushing of stable rocks and can be a mixture of both. Gravel sand has a powdery material covered with powder, passing through # 200 sieve, so considering a harmful substance for concrete, when in quantities greater than specified by the standard: 3% for concrete subjected to surface wear and 5% for concrete protected from this wear. Shapes grains directly affect compressive strength of the concrete, an indispensable factor that must be proven for elaboration from a structural project, allowing evaluation of the entire safety structure. ABNT NBR 6118 (2003) defines the acronym FCK from English, Feature Compression Know into Portuguese as Characteristic Resistance of Concrete to Compression, which are statistical techniques and concrete quality control dimensioning. When a concrete uses stone powder, it will have a very lamellar aggregate, where the thickness is small in relation to other dimensions, like less workability, a fact that does not occur when use aggregates with cubic or round characteristics, which will have a better interaction between the other components and lower percentage of interstitial spaces in concrete. Stone powder as fine aggregate in concrete is attractive in economic aspects and its durability characteristic, however, environmental consciousness is strong, but financial benefits are even greater, considering quarries may sell a product considered being waste and worthless, causes troubles with cost reduction in the form of storage and small environmental impacts. This study proposes use data extracted from trace letters after tests by standards ABNT NBR NM 67 (1998) which determines the concrete consistency and ABNT NBR 5739 (2018) by measuring the compression capacity of the concrete, which hás the appropriate parameters of concrete as a final product, allowing the commercialization and direct material application. In this analysis, comparisons between traits will be evaluated:

1	Trace by 100% natural sand as fine aggregate from concrete;
2	Trace with 50% stone powder and 50% natural sand;
3	Trace with 100% artificial sand

Parameters for analyzing traces using stone powder in their constitution are:

Range of a resistance of 30 Mpa (measured in Megapascal. 1 MPa resistant equals approximately to 10 kgf / cm²);

Tolerated difference for concrete acceptance from 10 cm with a coverage of more or less 2 cm.

Artificial sand called stone powder and used in this study was obtained in the field, of Santa Luzia quarry, located in the city of Itaguaí, in the state of Rio de Janeiro, and where data were collected through the tests of slump and compression.

LITERATURE REVIEW

Aggregates: Aggregates are obtained from nature in granular form, with varied geometry and volumes, however, dimensions and properties are established according to the purpose in civil construction. It is possible to cite as an example: crushed stone, natural sands and gravel, which can be obtained from ground rocks. These aggregates can be natural or artificial: The one found in nature as particles is called sand. The artificial, comes from industrial processes, and is called as powder of stones from the crushing of rocks (SERPA & REZENDE, 2017):

> ABNT NBR 7211 standard from Brazilian Association of Technical Standards (ABNT) requires characteristics in the reception and production of aggregates, giblets and coarse grains, from natural origin, found fragmented or resulting from rocks crushing. Defines sand or fine aggregate as natural origin sand or resulting from the stable rocks crushing, or from the mixture of both, which grains pass through 4.8 mm ABNT sieve and are retained in the 0.075 mm ABNT sieve.

Crushing: In rock fragmentation process for gravel production, a large amount of waste is produced in fine waste particles, deposited in quarries and mining companies, and proposes a utility means benefiting tenvironment and increase companies profits that would not use this material (NEVILLE, 2015).

CP III Cement: Cement has the function of hydraulic binder, it is indispensable for the aggregates connection as ABNT NBR 16697 (2018), Portland cements are classified according to the type, corresponding to other elements additions that characterize them. In this study, it is possible to identify the CP III, following the criterias:

PC: Portland cement andIII: Classifies a subtype cement having a percentage of blast furnace slag in its composition.

Chemical additive for concrete: In the concrete traces from this research, MIRA SET 28,was additive used, according to the manufacturer GCP (2018), the product must represent up to 1.0% in proportions of concrete elements, intends reduce the amount of water used, promoting high dispersing power and good slump maintenance according to ABNT NBR 11768-1 (2019) which defines it as a plasticizer additive, that does not change concrete consistency in fresh state, reduces water content and interferes in the concrete consistency, increasing the slump (ABNT, 2019).

Feasibility analysis: Feasibility analysis of replacing natural sand for gravel sand, comes from results and from materials that constitute proposed concrete mixes, producing a parallel between characteristics of mixes produced with the natural sand incorporated to other components amd compared with the analyzes of those made with crushed sand, according to Araújo et al. (2018). In order to evaluate different performances and behaviors over the time of each of these concretes.

Concrete elements dosing: Concrete dosing execution is extremely important, guarantees the production of safe and durable structures. Very heterogeneous materials constituting concrete, can be complex in their results, both in fresh and hardened state and represents a challenge in the manufacture and using concrete. In each concreting there is a specific dosage, depending on factors, such as: size of the pieces to be concreted; desired resistance; adequate workability; available equipment; type, brand, class and age from cement to be used; aggregate characteristics; sand moisture and environment conditions where concrete will be used. (HELENE & TERZIAN, 1995).

FCK 30 concrete with gravel 0 or 1: The concrete with FCK 30 MPa, used in the analysis, is applied in the concreting of residential above two floors, specifically in types of surface foundations, for example: buckets, shoes and radier; paving surfaces suitable for heavy vehicle traffic such as trucks; And in large structures that need great resistance (SANTANA, 2019).

METHODOLOGY

The slump test, is a technological control used to measure the consistency of the concrete and before its application. ABNT NBR NM 67 (1998) determines the conditioning and the location of the sample withdrawal that must be molded in a conical trunk with the smaller base facing upwards and following the dimensions:

Base diameter of 20cm;
Top diameter of 10 cm and height of 30 cm;

In this mold, it is necessary to fill 10 cm in height with the concrete sample, then compact with twenty-five strokes using a 16 mm diameter bar. Redoing the procedure for the two 10 cm layers until completing 30 cm, according to standardizations. The difference in height between the compacted mold and the conical cone filled with fresh concrete, translates the slump in centimeters (cm). In this case, anacceptance of 2mmcoverage the concrete.

According to slaughter tests, line 1 reached an initial 17 cm and a final 12 cm abate as shown in Figure 1.

Source: Personal Archive (2020)

Figure 1. Abatement of the line with 100% natural sand as fine aggregate

Line 2 started and ended with the mark of 11.5 cm of final slaughter of 12 cm, represented in Figure 2.

Source: Personal Archive (2020)

Figure 2. Abatement of the mix with 50% of natural sand and 50% of stone powder as fine aggregates

Trace 3 showed a 15 cm reduction ending with 10 cm, represented in Figure 3.

Source: Personal Archive (2020)

Figure 3. Abatement of the trace with 100% of stone powder as fine aggregate

Resistance Concrete Compression Test: The compression test of cylindrical specimens is regulated by ABNT NBR 5739 (2018), indicates what stress the resist concrete can support, a tension thatresults from the division between the force and the area operation. The performance uses cylindrical specimens that are inserted in a compression machine that allows the controlled application of the force in kgf on the specimens, in the laboratory by axial compression. Thus, machine applies forces on the specimen until it breaks, and the resistance is obtained by calculating: Force exerted in kgf by the area of the top of the specimen in cm², resulting in kgf / cm² it is possible to establish the stress rupture in MPa, dividing by 10. In the laboratory, to analyzes and obtain a parameter of comparative effect with the traces using stone powder, initially the test was used natural sand in its entirety as fine aggregate constituting the concrete, (Figure 4), supporting an average axial shitting of 38.35 MPa after the 28-day cure.

Source: Personal Archive (2020)

Figure 4. Trace compression test with 100% natural sand as fine aggregate

Then, under the same trace conditions, containing 100% natural sand, the test process used 50% natural sand and 50% stone powder, totaling the fine aggregate of the resisted trace, with 28 days of curing and resulting the average load of 41.3 Mpa, (Figure 5). The third analysis from compression used 100% stone powder, meaning the only fine aggregate that constitutes the concrete mix and after 28 days of curing, resisted an average load of 42.75 Mpa (Figure 6).

- Gravel 1;
- Depreciation: 10 ± 2 cm;
- Plasticizer additive;
- CPIII-E-40-RS-Votoran Cements.

Source: Personal Archive (2020)

Figure 5. Trace compression test with 50% natural sand and 50% stone powder as fine aggregates

Source: Personal Archive (2020)

Figure 6. Trace compression test with 100% stone powder as fine aggregate

Table 1. Description of Trace 1, with 100% natural sand in the concrete

Material	Descrição/procedência	(Kg/m³)	Traço unitário (m³)	Betonada 0,018 (m³)
Aglomerante / Cimento	CPlll-40-RS-Votoran	355	1,00	6,390
Agregado Miúdo / Areia	Areal Atlântico Sul	749	2,11	13,482
Agr. Graúdo/Brita 1	Mineração Santa Luzia	1019	2,87	18,342
Água	Poço	195	0,55	3,510
Aditivo 1	Mira Set 28 - Grace	2,13	0,006	38,34

Table 2. Data obtained in Trace 1, with 100% natural sand in the concrete

Data	Hora da 1º água	Umidade do Ar (%)	Temperatura Ambiente (cº)	Nº de CPs Moldados
12/02/2020	08:00	21	22	8

Source: Personal Archive (2020)

Table 3. Data from the Slumptest test of Trace 1, with 100% natural sand in the concrete

Data from the Slumptest test of trace 1, with 100% natural sand in the concrete			
Slump Test	Hora	Abatimento (mm)	Tempo (minutos)
Inicial	08:05	170	0
Final	08:20	120	60

Table 4

Data from the axial compression test of Trace 1, with 100% natural sand in the concrete											
3 Dias			7 Dias			14 Dias			28 Dias		
CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)
1	14,465	18,4	1	22,025	28,0	1	23,940	30,5	1	30,060	38,3
2	14,006	17,8	2	23,850	30,4	2	27,370	34,8	2	30,161	38,4

Source: Personal Archive (2020)

RESULTS AND DISCUSSION

Initially, tests were performed to verify slump characteristics, incorporated air and resistance to axial compression, which collected materials from the concrete plant, located in the city of Itaguaí, in Rio de Janeiro, for concretes with the same trace:

- 30 Mpa FCK;
- 0.55 Water / cement;

In order to minimize errors and validate it, all moldings were performed by the same professional, as well as the press used was the same for all cases for a better analysis of the results and identification from features leads, having different effects. The following are the data from the results test:

Trace Tests 1: The general data of mix test has 100% natural sand as fine aggregate of the concrete is presented in table 1, the conditions test by table 2, the slump test by table 3 and in table 4 the axial compression test, respectively:

Table 5. Description of Trace 2, with 50% natural sand and 50% stone powder in concrete

Description of Trace 2, with 50% natural sand and 50% stone powder in concrete				
Material	Descrição / procedência	(Kg/m³)	Traço unitário (m³)	Betonada 0,018 (m³)
Aglomerante / Cimento	CPlll-40-RS-Votoran	355	1,00	6,390
Agregado Miúdo / Areia	Areal Atlântico Sul	396	1,11	7,128
Agregado Miúdo / Areia Artificial	Mineração Santa Luzia	396	1,11	7,128
Agr. Graúdo / Brita 1	Mineração Santa Luzia	977	2,80	17,586
Água	Poço	195	0,50	3,510
Aditivo 1	Mira Set 28 - Grace	2,13	0,006	38,34

Source: Personal Archive (2020)

Table 6. Data obtained from Trace 2, with 50% natural sand and 50% stone powder in concrete

Data obtained from Trace 2, with 50% natural sand and 50% stone powder in concrete				
Data	Hora da 1º água	Umidade do Ar (%)	Temperatura Ambiente (cº)	Nº de CPs Moldados
12/02/2020	14:45	23	24,2	8

Source: Personal Archive (2020)

Table 7. Data from the slumptest of Trace 2, with 50% natural sand and 50% stone powder in concrete

Data from the slumptest of Trace 2, with 50% natural sand and 50% stone powder in concrete			
Slump Test	Hora	Abatimento (mm)	Tempo (minutos)
Inicial	14:50	155	0
Final	14:05	115	60

Source: Personal Archive (2020)

Table 8. Axial compression data for Trace 2, with 50% natural sand and 50% stone powder in concrete

Axial compression data for Trace 2, with 50% natural sand and 50% stone powder in concrete											
3 Dias			7 Dias			14 Dias			28 Dias		
CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)
1	14,798	18,8	1	23,829	30,3	1	30,466	38,8	1	32,399	41,2
2	15,038	19,1	2	24,188	30,8	2	28,981	38,5	2	32,537	41,4

Source: Personal Archive (2020)

Table 9. Description of Trace 3, with 100% stone powder in concrete

Description of Trace 3, with 100% stone powder in concrete				
Material	Descrição/procedência	(Kg/m³)	Traço unitário (m³)	Betonada 0,018 (m³)
Aglomerante / Cimento	CPlll-40-RS-Votoran	355	1,00	6,390
Agregado Miúdo / Areia Artificial	Mineração Santa Luzia	722	2,17	12,996
Agr. Graúdo / Brita1	Mineração Santa Luzia	1000	2,82	18,000
Água	Poço	195	0,55	3,510
Aditivo 1	Mira Set 28 - Grace	2,13	0,006	38,34

Source: Personal Archive (2020)

Table 10. Data obtained in Trace 3, with 100% stone powder in concrete

Data obtained in Trace 3, with 100% stone powder in concrete				
Data	Hora da 1º água	Umidade do Ar (%)	Temperatura Ambiente (cº)	Nº de CPs Moldados
12/02/2020	16:00	26	25,5	8

Source: Personal Archive (2020)

Table 11. Data from the Slumptest test of Trace 3, with 100% stone powder in concrete

Data from the Slumptest test of Trace 3, with 100% stone powder in concrete			
Slump Test	Hora	Abatimento (mm)	Tempo (minutos)
Inicial	16:05	150	0
Final	16:20	100	60

Source: Personal Archive (2020)

Table 12. Axial compression test data of Trace 3, with 100% stone powder in concrete

Axial compression test data of Trace 3, with 100% stone powder in concrete											
3 Dias			7 Dias			14 Dias			28 Dias		
CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)	CP	Carga (Kgf)	(Mpa)
1	11,570	14,7	1	22,938	29,2	1	28,015	36,7	1	33,425	42,5
2	11,860	15,1	2	21,663	27,6	2	28,660	36,5	2	33,778	43,0

Source: Personal Archive (2020)

The general data of the mix test that has 50% natural sand and 50% stone powder as fine aggregate of the concrete is presented in table 5, the test conditions by table 6, the data from slump test by table 7 and the axial compression test data by table 8, respectively:

Trace Tests 3: General data of mix test with 100% stone powder as fine aggregate of the concrete is presented in table 9, test conditions by table 10, data related to the slump test by table 11 and data of the compression test axial by table 12, respectively:

CONCLUSION

This research replace natural sand with stone powder, obtained from deposits at Santa Luzia Mineração company, following concrete analysis standards established by the ABNT NBR NM 67 (1998) which regulate consistency, and ABNT NBR 5739, (2018) regarding strength and axial compression and for these are following considerations:

The properties of concrete with Portland cement in the fresh state suffer more unfavorable influences when compared to the same material in the state hardened with crushed aggregates. Because of the geometry of the particles, the artificial aggregates have less spherical shapes, requiring more water for the same consistency; Consistency regarding, by the experimental traces using concrete in the fresh state, a lower abatement is identified when stone powder is inserted partially or integrally in the portion related to fine aggregate of the sample. Although the abatement results in a lower measure when compared to concrete with natural sand, the lines and fits standards required by ABNT NBR NM 67 (1998); Mechanical tests of axial compression have shown that concretes containing stone powder have greater resistance to compression compared to concretes containing only natural sand, which may allowwith normative parameters, a decrease in cement consumption, therefore the choice of powder stone is a great importance to minimize final cost of concrete; Compared to trace 2 (50% stone dust) with trace 3 (100% stone dust), trace 2 showed a higher final slump, because it still has natural sand in its composition. However, it showed less resistance to axial compression; Trace 3 compared to trace 2, obtained a lower final slump, proposing that using only stone powder as fine aggregate in the trace, results in a lower final slump, but the result of axial compression is greater. This work intends to analyze the feasibility of exchanging natural sand for crushing sand from the region located in the lowlands of Rio de Janeiro, in the State of Rio de Janeiro. This work intends to analyze the feasibility of exchanging natural sand for crushing sand from the region located in the lowlands of Rio de Janeiro, in the State of Rio de Janeiro.

REFERENCES

Aggregates for Civil Construction. National Mining Agency, National Department of Mineral Production, Statistics Series and Mineral Economy.

ALMEIDA, S. L. M., SAMPAIO, J. A. Obtenção de areia artificial com base em finos de pedreiras. São Paulo, Revista Areia & Brita, 2002.

ANDRIOLO, F. Usos e abusos do pó de pedra em diversos tipos de concreto. São Paulo, EPUSP, 2005. Uses and abuses of stone powder in different types of concrete

ARAÚJO, A. E. V.; GOMES, C. R. F.; NETO, G. B. M.; PINA, A. P. P.; NUNES, A. M.; COSTA, J. G.; SANTOS, A. F.; PAVÃO, J. M. S. J. Análise sustentável da substituição da areia natural por resíduos de pedreira nos concretos de cimento Portland. Alagoas, Revista Educação Ambiental em Ação, 2018.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 11768-1: Aditivos químicos para concreto de cimento Portland - Requisitos. ABNT, 2019.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 16697: Cimento Portland – Requisitos. ABNT, 2018.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 6118. Projeto de estruturas de concreto – Procedimento. ABNT, 2003.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 7211: Agregados para concreto – Especificação. ABNT, 2005.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 7225: Materiais de Pedra e Agregados Naturais – Terminologia. ABNT, 1993.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR NM 67. Concreto - Determinação da consistência pelo abatimento do tronco de cone. ABNT, 1998.

BENITE, A. As emissões de carbono e a construção civil. Revista Buildings. São Paulo, 2010.

BENITE, A. Carbon emissions and civil construction. Buildings Magazine. São Paulo, 2010.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 11768-1: Chemical additives for Portland cement concrete - Requirements. ABNT

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 16697: Portland cement - Requirements. ABNT,

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 5739: Concrete - Cylindrical specimen compression test - Test method. ABNT

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 6118. Design of concrete structures - Procedure. ABNT,

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 7211: Aggregates for concrete - Specification. ABNT

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR 7225: Stone Materials and Natural Aggregates - Terminology. ABNT,

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS - ABNT NBR NM 67. Concrete - Determination of consistency by cutting the cone trunk. ABNT

GIAMMUSSO, S. Manual do concreto. Ed. Pini. São Paulo, 1992.

GIAMMUSSO, S. Manual of concrete. Ed. Pini. Sao Paulo

HELENE, P; TERZIAN, P. Manual de dosagem e controle do concreto. Ed. Pini. São Paulo, 1995. Concrete dosing and control manual. Ed. Pini.

Illegal sand extraction in Brazil and worldwide. Action against environmental crimes, minerals and wild animal trafficking SANTANA, D.Concreto de 20 ou 30 Mpa. Engenheiro de Alto Rendimento. Goiás, 2019.Disponível em: https://engenheirodealtorendimento.com.br/concreto-de-20-ou-30-mpa/. Acesso em: 01 de abril de 2020. 20 or 30 Mpa concrete. High Performance Engineer

NETO, G. Estudo da substituição de agregados miúdos naturais por agregados miúdos britados em concretos de cimento Portland. Paraná: UFPR, 2006. p. 29-31.

NEVILLE, A. Propriedades do Concreto. 5ª Ed. Bookman. São Paulo, 2015. Concrete Properties RAMADON, L. A extração ilegal de areia no Brasil e no mundo.Ação contra os Crimes Ambientais, Minerais e Tráfico de Animais Silvestres. Rio de Janeiro, 2019.

Obtaining artificial sand based on fines from quarries. São Paulo, Areia & Brita Magazine

SBRIGHI, C. A importância dos conceitos tecnológicos na seleção dos agregados para argamassas e concretos. Revista Areia & Brita. EMC-Editores. São Paulo, 1999.

SERPA, H; REZENDE, M. Agregados para a Construção Civil. Agência Nacional de Mineração, Departamento Nacional de Produção Mineral, Série Estatísticas e Economia Mineral. Distrito Federal, 2017.

Study of the substitution of natural small aggregates by small aggregates crushed in Portland cement concrete. Parana: UFPR

Sustainable analysis of the replacement of natural sand by quarry residues in Portland cement concretes. Alagoas, Revista Educação Ambiental em Ação, ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS – ABNT NBR 5739: Concreto -

Ensaio de compressão de corpos de prova cilíndricos – Método de Ensaio. ABNT, 2018.

The importance of technological concepts in the selection of aggregates for mortar and concrete. Areia & Brita magazine. EMC-Editores

THORNS, E. A próxima crise da sustentabilidade: nós estamos usando tanta areia que ela pode realmente acabar.ArchDaily Brasil. São Paulo, 2018.

****