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Study of the Application of Glass Waste in Concrete Production

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***Abstract*— Aiming at sustainable development and preservation of the environment, many governments and NGOs are questioning the high volume of recyclable waste in landfills from the construction industry that are not reused by the industry. In this research, the use of the glass residue in the production of concrete in partial replacement to the aggregate was studied, with the objective in applications in the construction of non -structural parts and components such as the execution of gutters, half-wire and sidewalks. This research sought to analyze the behavior of the compressive strength of the concrete produced with partial replacement of the mineral aggregate by glass residues. The results showed that the compressive strength is strongly influenced by the variation of the amount of glass replacing the mineral aggregate, possibly by the interface between the glass surface and the cement matrix. However, concrete with glass residues partially replacing the mineral aggregate can be a viable alternative in our region, for several applications, especially those that do not require structural function, contributing to more sustainable constructions with use of discarded glasses and reduction of consumption , and consequent mineral exploration, of the pebble dredged from riverb eds.*

***Keywords*— Glass, Concrete, Aggregate.**

I. INTRODUCTION

The construction industry, over the decades, has suffered several advent and its constructive techniques have been improved in parallel. Concrete is one of the materials most used in engineering works and is in constant study. Its great application is due to its durability, ease of taking on different forms and versatility, being therefore used in various forms, whether in structural or non structural parts. The possibility of incorporation of residues into cement-based mixtures is a contribution of the construction industry to the recycling of environmentally harmful waste, and may also improve the performance of the materials with their addition [1].

The incorporation of waste into concrete is a subject that has been studied quite frequently throughout the world. Firstly, because of the need to dispose of the waste, since environmental laws are more stringent every day, and also because concrete is a material that has high "packer" potential, that is, it has a facility to incorporate several types of waste without damage to the environment, in addition to improving some properties.

Glass is one of the most consumed building materials in the world, only in Brazil, according to data from the Business Commitment for Recycling [2]. 54% of the glass produced, about 500,000 tons / year, are incorrectly destined.

In the city of Manaus, with the increase of inhabitants, the capital also saw jump the volume of domestic and industrial waste. At least 72 thousand tons of household waste are generated each month. Incorrect disposal threatens streams, rivers and groundwater, and the municipal landfill, where proper disposal is made, moves to the maximum limit and can only receive garbage for another 4 years. However, there is no definition for building a new landfill to meet demand.

In view of the above, the present work has the objective of presenting a bibliographical review of the technical feasibility of the use of glass waste as a large aggregate in concretes.

II. LITERATURE REVIEW

A brief bibliographic review will be presented, containing the historical context of the civil engineering, concrete of portland cement, constituent materials and properties, concrete resistance, use of glass in concrete.

2.1 HISTORICAL CONTEXT OF CIVIL ENGINEERING

Civil engineering is the branch of engineering that encompasses the design, design, construction and

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maintenance of all types of infrastructure necessary for the well-being and development of society, as well as the preservation of the natural environment. In this way, this area is dedicated to the creation of buildings, bridges, tunnels, power plants, industries and countless other types of structure.

From the beginning of history, humans have started to build their own shelters using the natural elements around them. Subsequently, the structures acquired increasingly complex characteristics reflecting the development of the techniques. It was then used to use scientific knowledge in this area, so that the dimensions, resistance and other attributes of a given work could be estimated. New materials came to be used, especially iron and cement, that allowed the emergence of the great structures that today make up the scenario of the modern world.

When we look for a definition of Engineering we will find: Engineering is the art of applying scientific and empirical knowledge and certain specific qualifications to the creation of structures, devices and processes that are used to convert natural resources into forms adapted to meet human needs.

When defined as art this concept is as old as man, but when considered as a set of knowledge with a strong scientific basis, organized in an organized way, engineering appeared in the eighteenth century. In this way, engineering, whatever it is, consists of the performance of a qualified and qualified professional, who has a diploma and a legal ability to practice the profession [4].

When there were only two civil and military engineering, civil engineering was one of the first to stand out. Military engineering was developed by the people who served the military as civil engineering was exercised by the citizens. Over time civil engineering has been improving and subdividing itself, among the ramifications, today you can find subdivisions like electrical engineering, mechanics, chemistry, naval, mechatronics among others.

According to [5], the English engineer John Smeaton, one of the discoverers of Portland cement (eighteenth century), was the one who first used the term civil engineer as a professional characterization, to distinguish from engineers [6].

The civil engineer is the only one who is qualified to handle projects and constructions of buildings, roads, tunnels, subways, dams, ports, airports and even power generation plants, as well as being able to choose the most appropriate places for a construction, to verify if the terrain and the material are really suitable for the work, supervising the construction progress [4].

2.2 PORTLAND CEMENT CONCRETE

Portland cement concrete is a product that results from the hardening of the mixture of Portland cement, large aggregate and water, in suitable proportions.

According to [6], the heterogeneity of the materials composing the concretes and the complexity of their behavior, both fresh and in the hardened state, always represents a challenge to the technicians responsible for the elaboration and use of concretes.

2.2.1 Constituent materials and properties

Portland cement concrete consists of two phases: the cement paste, composed of portland cement and water, and the aggregates. The cement, upon contact with the water reacts and acquires some binding properties, resulting from its hydration. The blend hardens to become a solid and strong material.

2.2.2 Portland cement

Portland cement is by definition according to [7] "the product obtained by the pulverization of clinker consisting essentially of hydraulic calcium silicates with a certain proportion of natural calcium sulphate, possibly containing additions of certain substances which modify their properties or facilitate your job ". When mixed with water they moisturize and produce dough hardening, which can offer high strength.

Table 1: Composition of Portland cement.

Name	Initials	Composition	Abbreviation
Tricalcium Silicate	CaO	$3CaO.SiO2$	C3S
Dicalcium silicate	$SiO2$	$2CaO.SiO2$	C2S
Tricalcium aluminate	$Al2O3$	$3CaO.Al2O3$	C3A
Tetracalcium aluminate iron	$Fe2O3$	$4CaO. Al2O3. Fe2O3$	C4AF

Source: Adapted from [3].

2.2.3 Water

Second [8] impurities contained in water can negatively influence the strength of the concrete, cause stains on its surface, or even result in corrosion of the reinforcement. For these reasons, attention should be paid to the quality of the water for kneading and for curing the concrete. As a rule the water should have a pH of 6.0 to 9.0.

2.2.4 Aggregates

Granular material of varying shape and volume, generally inert and having compatible dimensions and properties for use in construction, is known as aggregate.

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According to [9], natural aggregates are found in nature (sand, pebbles) and artificial ones that are obtained by the action of man through industrial processes or the tailings of these.

Until recently, the aggregate was regarded as an inert granular material, dispersed in the cement paste, used primarily for economic reasons. However, this concept has been reformulated and today the aggregate can be considered as a building material connected in a cohesive whole by means of a paste of cement. In fact, the aggregate can not be considered an inert material because its physical, thermal and sometimes also chemical properties influence the performance of the concrete [10].

The concrete can be defined as stone and cement paste, the paste being the bonding element of the stones. There are many voids between the stones to be filled only with the cement paste. For this reason, the small aggregate (sand) is used to reduce the consumption of cement and water, which in excess is harmful to the concrete, as it causes shrinkage, as well as compromising the workability of the concrete. In order to obtain a satisfactory result, the aggregate dimensions must be gradually distributed, promoting the best use of the cement, that is, keeping the resistance constant with the lowest possible cement consumption, which is the most expensive concrete input.

The terminology of the aggregates is defined according to the norm of [11], which classify aggregates as to nature. This standard defines the terms for aggregates most commonly used in concrete and cement mortar:

• Aggregate: granular material, generally inert with dimensions and properties suitable for the preparation of mortar and concrete.

• Natural aggregate: stone material that can be used as it is found in nature and can be subjected to washing, grading or crushing.

• Artificial aggregate: material resulting from industrial process, for use as aggregate in concrete and mortar.

• Recycled aggregate: material obtained from tailings, by-products from industrial production, mining, the process of construction or demolition of civil construction, including aggregates recovered from fresh concrete per wash.

• Special aggregate: aggregate whose properties can give the concrete or mortar a performance that allows or assists in the attendance of specific requests in unusual structures.

• Sand: small aggregate originated through natural or artificial processes of rock disintegration or from other industrial processes. It is called natural sand if it results from the action of agents of nature, from artificial sand when coming from industrial processes, from recycled sand when coming from recycling processes, and sand from crushing when coming from the process of mechanical fragmentation of rock, according to specific rules.

We must keep in mind that a good concrete is not the most resistant, but the one that meets the needs of the work with respect to the piece that will be shaped. Therefore, the consistency and the mode of application accompany the resistance as being factors that define the choice of suitable materials to compose the mixture, which should associate workability with the most economical dosage [12].

The aggregates, within this cost-benefit philosophy, must have a varied granulometric curve and must come from deposits near the dosage site. This implies a regionalization in the types of crushed stones, sands and pebbles that can be part of the composition of the trace.

Regarding grain size, the aggregates can be divided into adults and children, being considered as large, the whole aggregate that is retained in the number 4 sieve (square mesh with 4.8 mm side) and small which can get through this sieve [13].

They can also be classified as artificial or natural, being artificial sands and stones from the rock crushing, as they require the man to act to modify the size of his grains. As an example of natural, we have the sands extracted from rivers or ravines and the pebbles rolled, stones from the river bed.

Due to the importance of the aggregates within the mixture, several tests are required for their use and serve to define their granulometry, actual and apparent specific mass, modulus of fineness, clay lumps, organic impurities, pulverulent materials, etc.

Fig. 1: Aggregate metering bay,
Source:[13.]

2.3 CONCRETE DOSAGE

The general purpose of concrete dosing can be summarized in selecting the appropriate components from the available materials and determining the most economical combination that concrete will produce with certain minimum performance characteristics [14].

Still, according to the author, the most important performance requirements are the workability of the concrete in the fresh state, and the strength of the concrete in the hardened state. The workability that is responsible for the ease with which the mixture can be launched, compacted and finished and the resistance, which when reached as needed is related to the durability of the concrete.

The dosage based on previous experiments is called non-experimental dosing, since the experimental dosage is based on scientific studies [15].

2.4 CONCRETE RESISTANCE

One of the main properties of concrete is resistance to mechanical stresses of various types.

2.4.1 Resistance to axial compression

In most structures, the concrete is subjected to stresses that transmit compressive stresses. This fact, together with the fact that the assay is relatively simple and precise, makes the axial resistance the most evaluated property to verify the quality of a concrete, both for the control of the work and for laboratory studies [16].

Several factors may affect the mechanical strength of the concrete, eg water / cement ratio, age, shape and grade of aggregates, type of cement, shape and size of specimens, curing conditions, etc.

2.4.2 Water / cement ratio

Several factors may affect the mechanical strength of the concrete, eg water / cement ratio, age, shape and grade of aggregates, type of cement, shape and size of specimens, curing conditions, etc.

2.4.3 Evidence

For rupture of specimens to compression, the recommendations of [17] should be followed.

Generally, the compressive strength is measured in standard cylindrical specimens measuring 15cm in diameter by 30cm in height, cured in a humid chamber at 20º C.

2.4.4 Age of concrete

The reactions between cement and water progress with time, being, however, asymptotic [18]. Normally 28 days are considered as the standard age, the material being tested at 3 and 7 days, to obtain information about the quality of the concrete more quickly [18].

2.4.5 Specific mass

According to [19], uncoated concrete structures are, to a greater or lesser degree, subject to the action of aggressive agents such as carbon dioxide in the air, sea salt, sulfur gases from a sewage network, etc. , the more porous the concrete, the faster these agents impair the integrity of the part.

• Lightweight concrete is normally between 1440 and 1800 kg / m3

• Structural concretes have a specific mass of the order of 2300 to 2800 kg / m3

• Heavy concrete, used in radiation shielding, has a specific mass around 3360 to 3840 kg / m3.

2.5 USE OF GLASS IN CONCRETE

The historical context and the fundamental elements of the use of glass in concrete will be presented.

2.5.1 The History of Glass

According to [20], it is not known for certain the period and the people who discovered the glass. It is known, however, that Egyptians, Syrians, Phoenicians, Assyrians, Babylonians, Greeks and Romans, already realized works with the glass. Because of this it is not possible to attribute the discovery of glass to a single people and to a single epoch. However, the Roman historian Pliny attributes to the Phoenicians the accidental discovery of glass. The origin would have been casual: preparing a campfire on a beach on the shores of Syria to warm their meals, improvised stoves using blocks of saltpeter and soda. After a while, they noticed that a shiny substance was dripping from the fire, which solidified immediately. The glass would then be discovered

Still in Egypt, Mesopotamia, Syria, or Greece, the production of glass in antiquity required great efforts of artists and workers, mostly slaves. The basic elements of its composition: silica, calcium, lime, barrel and potassium, were basically the same as today, but produced opaque and sandy glass. The small ovens, the clay pot, the difficulty in achieving high temperatures and reaching the required degree of melting made the tasks difficult. With the bellows technique applied to the oven, introduced in Egypt, it was possible to increase the heat and thus to make the glassy mass more pliable, but the glass until the century. VI BC was produced on a reduced scale for use and exclusive adornment of the nobles.

The discovery of the technique of blowing (hollow glassware: bottles, pots, cups, bulbs, etc.) in Syria and Alexandria, when Rome already extended its hold on the Middle East, marks a great moment in the history of glass. Around the year 100 BCE the Romans began to produce glass by blowing it into pressed molds, greatly increasing the possibility of manufacturing in series of manufactures (simple vessels and exquisite objects of art). They were the first to invent and use window glass.

According to [20] the history of the glass industry in Brazil began with the Dutch invasions (1624/35), in Olinda and Recife (PE), where the first glass workshop

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was assembled by four artisans who accompanied Prince Maurício de Nassau. The workshop made windows for windows, glasses and jars. With the departure of the Dutch the factory closed.

he glass returned to enter the economic map of the country from 1810, when on January 12 of that year, Portuguese Francisco Ignacio da Siqueira Nobre received a royal license authorizing the installation of a glass industry in Brazil. The factory installed in Bahia produced smooth glass, white glass, bottles, bottles and bottles. It came into operation in 1812. In 1825 closed due to major financial, bureaucratic, labor and competition, foreign competition and the ire of the Portuguese.

In 1895, it was founded in São Paulo the Vidraria Santa Marina, today one of the great industrial groups of the country. By 1900, the plant already produced 20,000 bottles of green glass per day. In 1903, Santa Marina became a joint-stock company and five years later produced one million bottles a month, 2 m² of glass for glass in 24 hours and employed 650 workers. High productivity for a factory that only in 1921 would install automatic machines with daily capacity of 460 thousand bottles.

2.5.2 Definition

Glass is an inorganic, homogeneous and amorphous substance, obtained by cooling a melt. Its main qualities are transparency and hardness. Glass is distinguished from other materials by several characteristics: it is neither porous nor absorbent and is a good insulator (dielectric). It has low index of expansion and thermal conductivity, supports pressures from 5,800 to 10,800 kg / cm2.

In general, the glasses have as main constituent the silica or silicon oxide - SiO2 (Table 3). According to [21] the glass in the amorphous state consists essentially of silica (SiO2 - 72.5%) and a lower percentage of sodium (Na2O - 13.2%) and calcium (CaO - 9.18%).

Table 2: Chemical composition of glass.

COMPOUND	(%)
SiO_2	72
Na_2O	14
CaO	9
Al_2O_3	0,7
MgO	4
K_2O	0,3

Source: [23].

In Table 2 it is possible to visualize some chemical compositions of glass investigated by different authors, in studies with application of the glass residue in the production of other materials.

Table 3: Compositions of glass residue used in research.

Compound (%)	TOPÇU e CANBAZ (2004)	SHAYAN e XU (2006)	FEDERICO e CHIDIAC (2009)
SiO_2(%)	70-75	72,4	63,79
Na_2O(%)	12-18	13	11,72
CaO(%)	5-14	11,5	13,01
Al_2O_3(%)	0,5-2,5	1,45	3,02
Fe_2O_3(%)	-	0,48	1,57
MgO(%)	-	0,65	0,89
K_2O(%)	0-1	0,43	0,54
SO_3(%)	-	0,09	0,165

Source: [23].

Table 3 shows the chemical composition of the cements used in some researches focusing on the use of glass residues in order to compare them with the chemical composition of the glass residue.

With the Tables presented, an initial comparison of the main components of the composition of the glass residue and the cement can be made. The oxides SiO2, Al2O3 and CaO are part of the ternary system of the chemical composition of the main cements found in the Brazilian market and when analyzing the chemical compositions of the glass residue presented in Table 4, it is verified that the added oxides exceed 70% of the total, which indicates this residue as a cementitious material. In this way, it is possible to conclude that the substitution of glass residue by cement in mortar and concrete has a high probability of being viable.

According to [20] the glass can be classified in three types as to the variation of the chemical composition:

• Sodium-calcium glass whose application is in general packaging, bottles, pots, automobile industry, civil construction and household appliances;

• Boron-Silicate glass, whose application is in the manufacture of household utensils (Ex. Pans), has the characteristic of resisting thermal shock besides presenting an attractive beauty;

• Lead glass for the manufacture of glasses, cups, chalices and handmade pieces.

As regards its physical characteristics, glass has [22]:

• Dilation coefficient = 9x10-6 ° C-1;

• Modulus of Elasticity = 75 GPa;

• Breakdown Voltage = 1,800 Kgf / cm²;

• Compression Voltage (Tempered Glass) = 1000 Kgf / cm².

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2.6 RULES APPLICABLE TO GLASS

The publication of two new standards in Brazil intends to move the glass market to buildings. This is the NBR 16,023 - coated glass for solar control (Requirements, classification and test methods) and NBR 16015 - Insulating Glass (characteristics, requirements and test methods), both in force since the first half of 2012.

Until then, the two products, already used in architectural projects, did not have national technical parameters for their evaluation. With both texts, the sector intends to guarantee the manufacture of quality products and their correct and safe use.

The expectation is that companies have the standards as a reference for the quality of their products, while consumers also have safe parameters for evaluation, the technical manager of the Brazilian Association of Flat Glass Processors and Distributors (Abravidro) and coordinator of the Brazilian Glassware Committee Plans (CB-37) of the Brazilian Association of Technical Standards (ABNT).

Some Brazilian standards applicable to glass are listed in Table 4, mainly those related to glass requirements and specifications.

Table 4: Standards applicable to glass in Brazil.

Standard	Description
NBR 11706 - Glass in construction (ABNT, 1992)	It sets the required conditions for flat glass applied in civil construction.
NBR14207- Bathroom cabinets made of safety glass (ABNT, 2009)	Specifies the minimum safety requirements for materials used in the design and installation of bathroom boxes made from safety glass panels for use in apartments, houses, hotels and other residences.
NBR14564: Glass for shelving systems - Requisitos e métodos de ensaios (ABNT, 2000)	Specifies the performance requirements and linear measurements required to ensure the safety of the flat glass application used in the composition of shelving systems that have the glass as a component of use applied to their use.
NBR14697 - Laminated glass (ABNT, 2001)	Specifies the general requirements, test methods and care required to ensure the safety and durability of laminated glass in its applications in the civil construction and furniture industry, as well as the methodology of classification of this product as safety glass.
NBR14698 - Tempered glass (ABNT, 2001)	It specifies the general requirements, test methods and care required to ensure the safety, durability and quality of flat tempered glass in its applications in civil construction, the furniture industry and white goods appliances.
NBR NM293 - Terminology of flat glass and accessories to your application (ABNT, 2004)	Establishes the terms applicable to flat glass products in plates and accessories used in construction.
NBR NM294 - Float glass (ABNT, 2004)	It establishes the dimensions and quality requirements (in relation to optical and appearance defects) of colorless and colored float flat glass for the architecture and decoration markets.
NBR NM298 - Classification of flat glass for impact (ABNT, 2006)	Establishes classification of flat glass products, requirements and test methods for flat glass to be considered as safety glass.

Source: Authors, (2019).

2.7 THE RECYCLING OF THE GLASS

The growth of the population and the world economy has led to a considerable increase in material consumption. The generation of waste becomes inevitable and the search for alternatives of disposal of this waste becomes increasingly common among the industries.

The concern with waste in general is relatively small in Brazil when compared to other countries in Europe. There are many studies in Brazil about the use of waste in the production of new materials, but there is no government policy to encourage the purchase of environmentally sound products that favor products containing residues. Table 5 shows the recycling rates of glass containers in several countries, in which Brazil is one of the countries where recycling is very low.

Table 5: Recycling of glass packaging in the world in 2011.

Countries	Index (%)
Belgium	96
Sweden	91
Netherlands	91
Germany	81
Czech republic	78

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Italy	74
Brazil	47
France	68
Lithuania	67
UK	61
Portugal	57
Estonia	41
Slovakia	37
Bulgaria	34
Hungary	34

Source: adapted from [24].

As a rule, waste should be treated and deposited at the place where it was generated. However, this rarely happens due to the lack of planning of the industries at the time of project design. Such weakness leads industries to seek final disposal for waste generated away from the place of shipment.

2.8 APPLICATIONS IN CIVIL ENGAGEMENT

2.8.1 Applications

Currently, glass is widely used in civil construction because it is a high-tech, multifunctional and aesthetic material. It is a material that does not require finishing and the necessary maintenance consists only of periodic cleaning [25].

The glass can be applied in: facades, coverings, guardrails, floors, shop windows, partitions, shields, viewers of swimming pools, boxing for bathrooms, wall cladding, among others.

2.8.2 Glass in the production of concrete

Concrete is one of the most used materials in civil construction, in Brazil and in the world. It consists, basically, of a mixture of binder, large aggregates, small aggregates and water. Additives and additions are used when different properties are required in their properties. Its basic constituents, besides being cheap products, are easily found throughout the world market.

The recycling process needs to be managed properly. This process can generate environmental hazards that are much more aggravating than the waste itself prior to recycling, depending on variable factors such as the type of waste, technology used and the proposed use of the recycled waste [26].

The lack of correct and judicious management of Civil Construction Waste (RCC) can generate several kinds of contamination, which can cause serious risks to man and the environment, both in the recycling process and in its post-recycling use, as well as in the deposition irregular and large volume generation. But it is the deposition in irregular areas and the immense generation of waste that will lead to the greatest and main environmental risks, the problems of basic sanitation and health to the man. Thus, residues can cause blockage of pathways, floods, proliferation of diseases and vectors, environmental degradation, etc.

According to [27], construction activities generate great impacts to the environment, such as the proliferation of disease vectors, which will increase the deficiency of urban local sanitation, because the RCCs do not receive adequate solutions.

Researches related to the replacement of some concrete elements by small aggregates of glass have been carried out, with the main objective being the reuse of discarded glass in the construction industry and those coming from the garbage, which help to solve the environmental impact caused by this material, in the reduction consumption of natural resources, reduction of environmental pollution, among others. Brazil produces an average of 800 thousand tons of glass a year, of which 220 thousand tons are recycled [28]. Of the total, 40% come from the packaging industry, 40% from the diffuse market, 10% from the "cold channel" (bars, restaurants, etc.) and 10% from industry refuse.

One of the factors that makes this process limited is the high cost of glass waste, the most feasible landfill option, and the waste mix, taking into account that different staining glass also has different properties. The insertion of these wastes in civil construction has been applied in order to give destination to this material that is most often discarded incorrectly, since the landfills are already with reduced capacity and in the next years tends to stay home more overloaded. Taking into consideration all the materials deposited in nature, the villain among them is the glass, which takes 4,000 years to decompose [29].

The glass has in its composition a mixture of silica or silicon oxide (SiO 2) and calcium oxide. Being the same, composed of 72% of silica ($SiO2$), predominant compound in the sand, and that is one of the most abundant elements in the planet. It possesses in its chemical property high melting point 1830ºC and specific high mass of 2200 Kg / m³.

2.8.3 Replacement of the natural heavy aggregate by glass

Initially, it is necessary to clean the material, by removing labels and immersing in water to remove waste. Then, these glass residues are milled by hand, acquiring different grain sizes [30].

Cylindrical specimens measuring 15 x 30 cm, of Portland cement concrete, with a conventional trace composition and with different glass proportions, are used. As shown in figure 2 below.

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Fig. 2: Materials used for test specimens

In figure 2 are the materials in the form, where each of the materials were separated by volume.

The molding and curing of the specimens used in the simple compression test have to be in accordance with the recommendations of [17]. Table 6 shows results obtained from the substitution of the natural aggregate by glass, in percentages 0%, 33% and 67%.

Table 6: Results obtained by the compression test.

Ordem	Ensaio	Moldagem		Corpo de Prova		Slump	Ensaio de Compressão			
		Data	hora	Número	Vidro	(mm)	Data	Idade	Carga (N)	Tensão (MPa)
1	01220-B/18	04/05	11:03	1	0%	10	11/05	7	264.938	15,00
2	01220-B/18	04/05	11:25	2	0%	11	11/05	7	280.834	15,90
3	01220-B/18	04/05	11:36	3	0%	10	11/05	7	298.496	16,90
4	01221-B/18	04/05	12:22	4	33%	12	11/05	7	310.860	17,60
5	01221-B/18	04/05	12:31	5	33%	12	11/05	7	305.561	17,30
6	01221-B/18	04/05	12:34	6	33%	13	11/05	7	309.094	17,50
7	01222-B/18	04/05	13:04	7	67%	14	11/05	7	284.366	16,10
8	01222-B/18	04/05	13:23	8	67%	13	11/05	7	287.899	16,30
9	01222-B/18	04/05	13:26	9	67%	14	11/05	7	286.133	16,20

Source: Authors, (2019).

2.8.4 Use of glass in mortars

The glass residue was used as a partial substitute for the small aggregate and / or cementitious material. The criterion for choosing which substitution would be made was mainly due to the size of the particles of the glass residue. Sometimes a milling process was necessary in order for the glass particles to have the desired size. According to [31], particle size plays a very important role since it influences possible alkali-silica (RAS) reactions, thus impairing the mechanical performance and durability of the cementitious matrix.

In their work [32] they used the ground glass residue (pass through sieve # 200) in percentages of 5 and 10% in substitution of Portland cement and of the small aggregates in mortars. It was found that only the sand substitutions by the ground glass showed a gain in the considerable compressive strength and that they exceed the results of the reference samples as shown in Table 7.

Table 7: Results of the tests of compressive strength (in MPa) at the different ages of rupture.

TRACE OF MORTAR – (Cement and Sand- CS) Replacing	BREAKING TIME		
	07 days	28 days	58 days
REF – CS	57,08	59,77	65,17
CIM5 - CS and 5% glass rep. the cement.	47,13	53,54	64,59
CIM10 - CS and 10% glass rep. the cement.	41,01	49,63	60,76
ARE5 - CS and 5% glass rep. sand.	51,06	57,50	73,77
ARE10 - CS and 10% glass rep. sand.	49,52	55,74	78,07

Source: Authors, (2019).

III. APPLICATION METHODOLOGY

The study was developed according to the design of a bibliographical research with a qualitative approach. The bibliographic research is developed based on material already elaborated, consisting mainly of books, scientific articles, theses and dissertations. The main advantage of this type of research is that it allows the researcher to cover a much wider range of phenomena than could be investigated directly.

The qualitative approach consists of analyzing the data working with all the material acquired during the research. This analysis must be present in the various stages of the research, becoming more systematic and formal after the finalization of the data collection.

3.1 SOURCES OF DATA

The sources should provide the appropriate answers to the resolution and/or understanding of the proposed problem.

In this study, a bibliographic survey of the subject was carried out to identify possible uses of glass as a substitution of raw materials for concrete production. According to the flowchart in Figure 3 below.

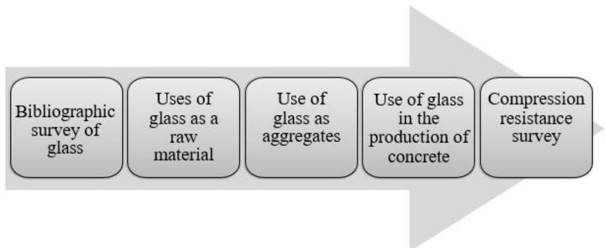

Fig.3: Study Flow Chart.

Source: Authors, (2019).

According to the literature analyzed, the authors in Table 8 investigated the use of glass in concrete production:

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Table 8: Glass studies in the production of concrete.

Author	Title
LORENA, 2013	Study of the application of laminated glass waste in concrete production
ARTUR,2016	Evaluation of the use of common glass as Pozolana and evaluation of the use of tempered glass juice as aggregated graft in concrete.
LAYS,2018	Study of resistance to concrete compression produced with tempered glass residue

Source: Authors, (2019).

According to [33] the concrete used in the experimental program contemplated the partial substitution of the aggregate (grit) for ground glass, in proportions 0%, 33% and 67%. The glass used was tempered, and this material was chosen because of its abundance and because it does not have a suitable destination in the region. The methodology used to evaluate the possibility of using the glass in obtaining the concrete is demonstrated in the flowchart shown in Figure 4 below.

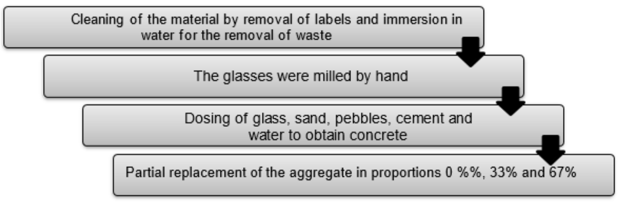

Fig.4: Flowchart of the use of glass methodology in obtaining concrete.

Source: Authors, (2019).

For this review we verified the studies performed by [33], using test bodies molded according to [36], as well as curing and determination of the compressive rupture load. The results, individual compression strength, mean compressive strength of cylindrical specimens and maximum standard deviation were in accordance with [36], the study used the methodology in figure 5 below.

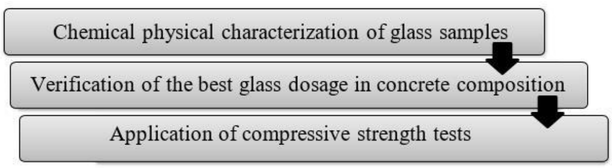

Fig.5: Flow diagram of the use of glass in the production of concrete.

Source: Authors, (2019).

IV. RESULTS AND DISCUSSIONS

The results of the research on the use of glass in concrete will be presented.

4.1 USE OF GLASS IN CONCRETE PRODUCTION.

The results indicate the possibility of replacing the large aggregate with the glass, however, it is necessary to test the best glass dosage for the substitution. According to [32], after analyzing the obtained results, it was verified the great potential of use of glass residue in partial replacement of the large aggregate as shown in figure 6, which in our region replaces the rolled pebble dredged river, with this combination of a more suitable solution for the disposal of glass, as well as the reduction of environmental impact with the exploitation of the pebble.

Fig.6: Glass as a large aggregate.

Source: [32.]

According to the same author we can analyze that the substitutions 0%, 33% and 67% predict that for a percentage replacement tempered glass, we will get a maximum resistance that can reach the value of 17.53Mpa.

According to [33] Tempered glass chips have an advantage over common gravel, which has its actual specific gravity value around 2.98 g / cm³, which shows a difference of 21.81% in the mass of these aggregates . Therefore a structure using as a large aggregate the glass shard would have its own reduced weight.

However, for [34] it was observed that the partial replacement of the cement by the laminated glass residue in proportions of 0, 5, 10 and 15% in the prepared concretes did not produce a considerable improvement in the properties analyzed. However, it also did not generate significant losses in the physical and mechanical properties in relation to the reference trait that in the case was the conventional one.

According to the studies of [33] the specimens were molded with the 1: 2: 3 trace in volume, and replacement occurred by volume withdrawal of gravel and the same volume of glass scrap was added. The obtained resistance can be verified next. The water cement ratio was 0.5.

In this respect [33], the use of heavy aggregate concrete from tempered glass scrap is likely to be suitable for non-structural purposes. The concrete produced with 20% of glass scrap replacing the brittle, due to its resistance and decrease of density and 100% of substitution, although it was not the best replacement percentage, nevertheless, presented resistance close to 20 Mpa.

According to [33] and [34], the concrete having partial replacement of the large aggregate by the glass can be used for non-structural purposes, since for structures it needs to reach more than 20 MPa.

In practice according to [33] the use of this material would also occur in the production of pavers or sidewalks, as it would be easy to measure a concrete in which the necessary resistances are met, in addition to the fact that a recycled material is being used. Figure 7 shows possible occasions where glass as a bulk aggregate in concrete can be applied.

Fig.7: Concrete paving.
Source: Authors, (2019).

Another option for using concrete using glass as an aggregate is the pavers. According to [35], the name given to precast concrete or parallelepiped blocks is available in different thicknesses for use in various design types. The blocks are docked and there is no need for anything to make them stick or stick to the surface. What holds them to the ground is the friction between the pieces.

V. CONCLUSION

Sustainable actions are practiced in the civil construction, but still in considerably reduced volumes, in addition it is an environment in which there is a constant collection by lower costs and wastes, greater uses, turned all more for the financial economy of the enterprises than for the environmental question.

Considering that concrete is one of the most consumed products in the world, and that its composition is composed of materials extracted from nature in a non-renewable way, any alternative that allows saving of natural or financial resources, is of extreme value, especially when can combine a possible reduction of the extraction of such natural resources with a convenient and efficient destination of waste such as glass, which in the form of waste would be deposited in nature in an inefficient and polluting manner.

The literature review showed that the glass residue generated is a serious environmental problem, and it is necessary to seek alternatives for its use, in order to minimize the impacts caused by its disposal in an incorrect way.

This literature review has shown that for the determination of possible uses of glass from discards it is necessary, first, to characterize the glass, studies using molded test bodies as well as curing and determination of the compressive rupture load.

Another important factor for deliberation of possible uses of glass for concrete is the determination of the best dosage of glass to be used as an input to ensure the quality and durability required for the final product and the performance of technological tests that guarantee the quality of use.

Concrete with glass residue can be a viable alternative for several applications, especially those that do not require structural function.

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