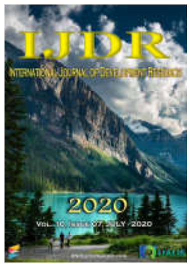
Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 10, Issue, 07, pp. 38474-38483, July, 2020
https://doi.org/10.37118/ijdr.19435.07.2020

ISSN: 2230-9926



RESEARCH ARTICLE OPEN ACCESS

SOIL-CEMENT AND CELLULAR CONCRETE CONSTRUCTION SYSTEM APPLIED TO HOUSING UNITS UNDER CONSTRUCTION IN AMAZONAS - BRAZIL

Doriedson Sousa Dias[1], Renato Acriz Menezes[2], Fabiana Costa Ribeiro[3], João Carlos Silva de Oliveira[4] and Charles Ribeiro de Brito[5]

[1]Master's Degree from the Federal University of Pará (UFPA).Professor - Northern University Center (UniNorte), Brazil
[2]Master'sDegree -Federal University ofUberlândia (UFU), Brazil
[3]Civil Engineer-Pontifical Catholic University of Goiás (PUCGO), Brazil
[4]Master in Process Engineering (UFPA), Professor - Northern University Center (UniNorte), Brazil
[5]Master's degree from the Federal University of Amazonas –(UFAM). Professor - Northern University Center (UniNorte), Brazil

ARTICLE INFO

Article History:
Received 12th April, 2020
Received in revised form
20th May, 2020
Accepted 19th June, 2020
Published online 30th July, 2020

Key Words:

Constructive system. Housing units. Soil-cement. Cellular concrete.

Corresponding author:
Rosane da Silva Santana,

ABSTRACT

Construction systems in the construction industry have evolved significantly in recent decades. However, simplified building systems can also be found that have low construction costs, as well as allowing to meet the housing deficit demand for low-income populations. In this sense, this research aims to present the applicability of the use of soil-cement concrete and cellular concrete in the construction of housing units that serve low-income populations in the state of Amazonas, in urban and rural areas. For this, it was used as methodology, conducting research in scientific works, as well as, description of the application of the constructive method in the field in the "Minha Casa Project", launched by the state government of Amazonas in 2001 for construction under a collective effort regime of popular houses, through the soil-cement and cellular concrete construction system, for low-income families. However, initially, this method did not achieve the expected success, as the beneficiaries did not adapt to the new way of building. However, the expected success was achieved in 2003, where the initial project for the construction of popular houses in soil-cement was continued for the needy population with the application of a new project, called "Citizen Project". In general, it can be concluded that the housing units built by both methods m*et al*l the criteria established by the draft standards. However, the dwellings built by the plastered soil-cement construction system provided better results compared to the construction system with the use of reinforced cellular concrete.

Citation: ***Doriedson Sousa Dias, Renato Acriz Menezes, Fabiana Costa Ribeiro, João Carlos Silva de Oliveira4 and Charles Ribeiro de Brito. 2020*** "Soil-cement and cellular concrete construction system applied to housing units under construction in Amazonas - Brazil*", International Journal of Development Research*, 10, (07), 38474-38483.

INTRODUCTION

The Brazilian housing deficit is a factor that has exerted great pressure on the public sector, most of the times responsible for the problem, arising from social, economic, and cultural issues, intrinsic to the country's own history. In economically developed countries (such as Great Britain, France, Sweden and Canada), or even in many of those that are considered developing countries, in particular those of intermediate income (such as Malaysia, India, Singapore and China), there are systems of provision housing that include social leasing as one of its pillars. For various reasons, it is of general interest that the housing provision system be mixed, including private and public schemes, aimed at promoting "home ownership", as well as "social leasing" and market leasing, under regimes of different properties. In Brazil, there is no tradition of promoting the much-needed public system of housing provision for social leasing (Valença, 2014). The lack of housing does not consist of the fact that social classes in general live in bad, overcrowded, unhealthy houses, and it is not something of the present. It is not even one of the sufferings of modern populations, compared to all the former oppressed classes; on the contrary, it reached all the oppressed classes of all times in a similar way. In the second half of the nineteenth century (Engels, 2015) a conclusion is reached that is still quite current for solving the housing crisis, attesting that it would only be possible if the wage worker could be able to own his own housing property. In Brazil, the Ministry of Cities was created, which aims to gather the resources of the various federal agencies, which are related to urban development, aiming to invest, in a rational way, large numbers in housing. The federal government shows interest in tackling the problem, but it is known that the Brazilian housing deficit is exceptionally large. However, it is important to note that the large Brazilian metropolises have a disorderly urban growth, leading the population to adopt inadequate solutions with housing in places lacking urban infrastructure, such as: basic sanitation, transport, security and public services (Klein, 2004).

For decades, the issue of housing has been a recurring theme, both in the governmental agenda and in academic research. The main focus of attention of public policies in this area has been the provision of housing for the growing number of people living in cities. Rapid urban growth in a context of economic crisis, particularly in cities in developing countries, has meant that affordable and good quality housing is increasingly difficult to obtain (Valença, 2014). In our country, several innovative solutions, with regard to construction systems, are introduced to the market to resolve the issue of the Brazilian housing deficit. However, not all of them meet the minimum desirable requirements for affordable and quality housing (Silva Filho, 2002). The first innovative popular housing, financed by the extinct Banco Nacional da Habitação (BNH), now partially incorporated into Caixa Econômica Federal (CEF), was introduced, without having previously been subjected to a technical assessment to predict its behavior. In fact, it was the construction of the Itaquera housing complex in São Paulo, in the mid-1970s, that served as a great laboratory for new technologies, using different construction systems distributed in 31.860 housing units. The mistakes and successes of this experience, however, were only assessed after the buildings were completed and inhabited (Almeida, 1984).

The lack of a standardization on which manufacturers and builders could rely, directly influenced the quality of the product, leading in most cases to disastrous experiences, with serious losses for all agents involved in the construction process, with the problems of pathologies and high maintenance and replacement costs. Taking into account the concept of standardization, where definitions, characteristics (dimensions, qualities), test methods, rules of employment, etc are fixed; due to these difficulties, there was then a great interest in standardizing the performance evaluation so that the manufacturers of these new systems could guarantee the quality of the final product (Oliveira, 1996). However, BNH at the end of its existence, in an attempt to address the problem of the lack of Brazilian standardization and recognizing the need for new technological solutions that would allow the construction of large-scale buildings, invested in research aiming at the elaboration of criteria to evaluate the performance of innovative construction systems. Internationally, the concept of performance had been used for a long time, but its use in a more systematic way began in the 60s and 70s. Countries like France, England, Germany, Norway, Denmark, United States and Canada were careful to evaluate its new construction systems with the aim of providing the guarantee that a new and unknown product will perform satisfactorily when used in construction (Oliveira, 1996). The first modern evaluation system was established in Europe in the 1960s, the French approval system, developed to reduce restrictions on the introduction of innovative buildings. Established by a decree from the Ministry of Construction, the system is run by the Center Scientifique et Technique du Bâtiment (CSTB), an organization of the French federal government (Oliveira, 1996).

The request to obtain the French certificate of approval, provided only for new construction systems, must be requested by a manufacturer or builder, and the form must specifically mention the area of application and its method of use. The samples are subjected to tests and experiments, in workshops, factories, laboratories or in the workplace and the evaluation is based on safety, usefulness and durability, taking into account the climatic conditions and regulations of existing buildings in construction (Oliveira, 1996). In Brazil, technological innovations were not accompanied by the mentality of evaluating the performance of new construction systems before launching them on the market. Normally, the systems were evaluated only by their initial costs, the operating costs and not even those of maintenance and / or recovery being computed, leaving the concern with the aspects of durability and useful life of the buildings relegated to the background (Almeida, 1984). Concerned with the question of evaluating the performance of the new construction systems, Caixa Econômica Federal (CEF), considered one of the largest housing financial agents, launched on December 18, 2000, general guidelines for the “Analysis of the Performance Guarantee of Constructions Conventional or Innovative” (Klein, 2004).

In parallel, the Institute of Technological Research (IPT) of the state of São Paulo in 1998 presented a text for discussion entitled “Minimum Performance Criteria for Social Housing Ground Floor”, within the Brazilian Program for Quality and Productivity of Housing Construction (PBQPCH). This program was created to stimulate and support actions in the sectors of the production chain, installing and expanding the productivity and quality of the construction sector (Silva Filho, 2002). In July 2004, the Brazilian Technical Standards Association (ABNT) launched the draft standards on 02.136.01.001 (Almeida, 1984), 02.136.01.002 (8), 02.136.01.003 (9), 02.136.01.004 (10), 02.136. 01.005 (11), 02.136.01.006 (12), whose objective is to define the requirements and performance criteria applicable to residential buildings with up to five floors, their elements and components, considering the Ultimate Limit States (ELU) and States Service Limits (ELS). The draft standard consists of the following parts: Part 1 - General requirements; Part 2 - Structure; Part 3 - Internal Floors; Part 4 - Façades and Internal Walls; Part 5 - Coverage; Part 6 - Hydro sanitary systems. In Manaus, the disordered urban growth generated by the migration of families in search of jobs and land, has caused an increase in violence, unemployment and the lack of housing. The environmental aspect has been directly affected, as such social problems have led families to invade certain regions of the forests near the streams, causing both deforestation and pollution.

The use of soil-cement and cellular concrete construction techniques has been aimed at rationalizing and industrializing construction, based on the following premises: developing affordable housing, using new materials of excellent quality and with great durability; to develop technologies using simple construction components with an industrial character, easy to assemble and with the possibility of expanding its original plant, reducing debris, and producing a safe and pleasant home for the user in terms of appearance, conservation and cleaning, thermal comfort and acoustic and watertight. The walls of housing units built in soil-cement were executed in two ways: the first with exposed bricks re-grouted with cement and sand mortar, in the 1: 3 line (Figure 1), while the second with plastered wall (Figure 2) .

Figure 1. Grouted soil-cement wall.

Figure 2. Plastered soil-cement wall

The walls of the housing units in aerated concrete were also executed in two ways: the first refers to the execution of reinforced masonry, that is, placement of welded steel screens on all walls before concreting (Figure 3) , while the second form refers to the execution of partially reinforced masonry, that is, placement of the welded steel screens only in the wall encounters (Figure 4).

Figure 3. Reinforced cellular concrete wall.

Figure 4. Partial lyre in for cedcellular concrete wall.

In this work, structural performance tests were carried out on buildings constructed using the constructive technique of soil-cement and cellular concrete, adopting the procedures indicated in the draft standards in 02.136.01.001 (Associação, 2004), 02.136.01.002 (8), 02.136. 01.004 (10). Such buildings were evaluated by checking whether they meet the minimum structural performance criteria established by the ABNT standard project, through impact action tests (soft body and hard body) and occupancy loads (suspended parts, sleeping net and interaction between walls) and ports).

BIBLIOGRAPHIC REVISION

SOIL-CEMENT

Material basically obtained by mixing soil, water and cement widely used for the construction of dwellings in popular houses because it presents itself as a low cost alternative material that enables large-scale construction in the construction of warehouses, warehouses, warehouses, aviaries and , mainly in programs for the construction of popular houses in poor areas as well as in rural areas. Soil-cement is the material obtained by the intimate interaction of soil, Portland cement and water and, which is a physical-chemical process of stabilization and reorientation of solid soil particles with the deposition of cemented substances in the inter-granular contacts, thus changing the relative quantity of each of the three phases (solid, liquid and gaseous) that make up the soil (Albuquerque, 2020). Soil-cement is a material resulting from the homogeneous, compacted, and cured mixture of soil, cement and water, in adequate proportions. The product resulting from this process is a material with good resistance to compression, good index of impermeability, low index of volumetric shrinkage and good durability (Albuquerque, 2008).

The soil, because it is easily accessible material and found in any place where it is desired to carry out construction of small buildings at low costs, constitutes the largest portion of the mixture of soil-cement compound and, it presents great advantages for the construction of these types of buildings. Soil is the basic element for obtaining soil-cement. The cement is dosed in an amount that varies from 5% to 10% of the weight of the soil, enough to stabilize it and confer the desired resistance properties for the compost (Grande, 2003). The cement added to the soil ensures that the material does not have considerable volumetric variations due to absorption and loss of moisture, as well as increased resistance to compression, greater durability as a result of less permeability and allows the material not to deteriorate when submerged in the water (Faria, 1990). The type of soil used in the mixture, the cement content, the amount of water added, the way it is mixed and compacted, storage and curing are factors that must be carefully considered in order for the final product , the cementitious brick, has excellent quality and consequently greater durability. The soil-cement mixture is subjected to compaction at an optimum moisture content to obtain maximum density, in order to form a structurally resistant and durable material, used in the form of bricks, blocks and monolithic walls, presenting good resistance to compression, good impermeability index and low volumetric shrinkage index (Lopes *et al*., 2003).

To perform the correct dosage of the soil-cement it is necessary to carry out a pre-established sequence of tests, the results being interpreted through technical standards. The result of a dosage study would be the fixation of three basic requirements, namely: the cement content to be added to the soil, the moisture to be incorporated into the mixture and the desired specific mass. The most sandy soils are those that stabilize with smaller amounts of cement, however the presence of clay in its composition is necessary, aiming to give the mixture, when moistened and compacted, sufficient cohesion for the immediate removal of the forms (Associação Brasileira De Cimento portland, 1980). The use of soil-cement bricks produced by means of manual presses has advantages over the conventional system, among which are loss control, availability of supply, low cost, durability and structural safety, transportation savings, when produced on-site site, and low aggressiveness to the environment, as it does not require burning (Grande, 2003). The effectiveness of structural stabilization of pressed earth bricks, with or without additives, is commonly evaluated through destructive physical-mechanical tests such as: simple compression resistance tests, water absorption capacity and durability (Ren, 1995).

Soil: The soil suitable to produce soil-cement bricks must have an amount of sand around 50% to 70%, and must be free of organic matter (roots, leaves, etc.), chlorides and sulfates. The soil with the ideal granulometry for the mixture should be predominantly sandy, with clay in a lower percentage, so that there is cohesion between the grains. As the clay content of the soil increases, the need for cement consumption for its stabilization increases (Grande, 2003). The soil used for the production of soil-cement bricks can be extracted at the construction site or from deposits, provided that a sample is sent to the laboratory, in order to carry out particle size and chemical characterization tests, as explained above. only after the results of the laboratory tests and all conditions are verified that the soil will be released to produce soil-cement bricks (Mercado, 1990). Fine soils normally require higher levels of cement. In such cases, it becomes necessary to mix granular soils, sand, in quantities capable of producing a mixture that meets the recommended characteristics. It is important to highlight that it is not any type of soil that is appropriate, and its choice must be made by knowing its characteristics, which in summary are workability, granulometry and chemical characterization (Grande, 2003). In general, the most suitable soils for the manufacture of bricks and the construction of monolithic soil-cement walls are those that have the following characteristics:

% passed through the 4.8 mm sieve (no. 4) ……............ 100%
% passed through the sieve 0.075 mm (b. 200) ..... 10% to 50%
Liquidity limit (LL)... = 45%
Plasticity index (PI) .... = 18%

In general, good soils have: 45% to 85% sand, 20% to 50% silt and clay, clay content less than 20% and LL = 45% (Grande, 2003).

IMPORTANT FACTORS FOR EMPLOYMENT OF SOIL- CEMENT

A factor of great importance that must be considered when using soil cement is durability. There is no point in obtaining a mechanical resistance specified by standard if the final product over time loses its physical and chemical characteristics (Faria, 1990). The choice of a suitable soil, for the correct production of soil-cement blocks, from dosing to curing, are steps that will determine greater or lesser durability. Another point of fundamental importance for obtaining soil-cement bricks with better resistance and durability is the homogenization of the mixture of soil and cement. Only in this way, it will be avoided that the bricks have different contents of cement coming from the same mixture (Faria, 1990). The soil-cement mixing procedures for the production of bricks, blocks or wall panels must be: soil preparation (removal, spraying and sieving), repair of the mixture (dry homogenization and moisture homogenization) and molding (effective use) (Garcia, 2000). Compaction is especially important for the soil bricks to achieve satisfactory strength. It is necessary that the press that produces the bricks, be it manual or hydraulic, apply the same compaction load, ensuring that the bricks have the same strength and dimensions (Grande, 2003). It is also known that the resistance is directly proportional to the degree of compaction of the mixture, as it is no use having a mixture with a high cement content if the load applied for pressing the mixture is not sufficient. The moisture needed for hydrating the cement can be satisfactorily supplied by the optimum compaction moisture. However, it is necessary to emphasize the importance of homogenizing the mixture, so that all cement can come into contact with the soil, thereby ensuring the quality of soil-cement bricks (Grande, 2003).

Cement: The word cement comes from the Latin Caementu, which in old Rome designated a kind of natural rock stone and not squared. The origin of cement dates to around 4.500 years. The monuments of ancient Egypt already used an alloy consisting of a mixture of calcined plaster. The great Greek and Roman works, such as the Pantheon and the Coliseum, were built using volcanic soil from the Greek island of Santorini or near the Italian city of Pozzuoli, which had water hardening properties (Sindicato Nacional Da Indústriado Cimento (Snic)., 2020). The great step in the development of cement was taken in 1756 by the Englishman John Smeaton, who managed to obtain a resistant product by calcining soft and clay limestones. In 1824, the English builder Joseph Aspdin jointly burned limestone and clay, turning them into fine powder. The mixture obtained, after drying, became as hard as the stones used in the constructions, did not dissolve in water and was patented with the name of Portland cement, for presenting color and properties of durability and solidity similar to the rocks of the British island of Portland (Sindicato Nacional Da Indústriado Cimento (Snic)., 2020).

The national market has eight options, which serve the most varied types of works with equal performance. Portland cement (CP-I) is a reference, due to its characteristics and properties, to the eleven basic types of Portland cement available in the Brazilian market. Portland cement is one of the most important building materials and universally used by humanity. It is characterized as a fine powder with binding, or binding properties, which hardens under the action of water. Once hardened, even if it is again subjected to water, port land cement no longer decomposes (Associação brasileira de cimento Portland, 2002). Portland cement composed with the addition of carbonate material (CP II-F) is added with carbonate filler. This material consists of ground rocks where they contain calcium carbonate (example: limestone). this addition makes the concretes and mortars easier to work with, as their particles have appropriate dimensions to fit the particles of the other cement components (Pereira, 2013). Its use is recommended for floors and bricks of soil-cement (material obtained by mixing soil, cement and water), besides being able to be used in the preparation of mortars for laying, covering, reinforced mortar, simple, reinforced, prestressed, projected concrete, rolled, thin, concrete-mass (concrete that requires heat control of cement hydration to prevent the appearance of cracks that damage the structure), precast elements, artifacts, concrete floors and pavements, among others (Pereira, 2013) . For the presentation of this work, the type of cement used for the manufacture of soil-cement bricks and the production of cellular concrete was Portland CP II F32 cement, which has the following characteristics (Figure 5).

Water: The water to be used to produce the soil-cement bricks must be clean and without soil, oil, branches, leaves and roots. In other words, good water for soil-cement is drinking water. Never use wastewater (from human or animal sewage, kitchen, factories, etc.) to produce the soil-cement bricks (Souza, 2020). The addition of water is a parameter that must be clarified, as it is the main control factor of the mixture. It can be said that the correct determination of the amount of water necessary for the best performance (the best compaction) of the mixture is as important, or even more, as the cement content.

Portland cement type	Initials	Composition (% by mass)				Brazilian Standard (NBR)
		Clinker + Plaster	Blast furnace slag (acronym E)	Pozzolanic material (acronym E)	Carbonic material (acronym F)	
Common	CP I	100	-			5732
	CP I-S	99-95	1-5			
Composition	CP II-E	94-56	6-34	-	0-10	11578
	CP II-Z	94-76	-	6-14	0-10	
	CP II-F	94-90	-	-	0-10	

Figure 5: Composition of common and compound port land cements (22).

Models of soil-cement bricks: Figure 6 shows the soil-cement brick model used in the construction of popular houses. The dimensions of the bricks commonly used in works are: 10 x 20 x 5.0 (cm), 12.5 x 25 x 6.25 (cm) and 15 x 30 x 7.5 (cm) (Grande, 2003).

Figure 6. Modelofsoil-cementbricks. Source: (25), (2017).

Figure 7 shows the half brick and the channel in soil-cement that are integral parts of the masonry in soil-cement.

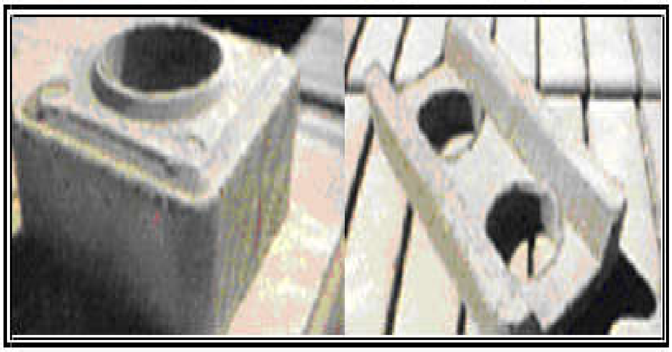


Figura 7. Modelo de tijolos de solo-cimento (25).

MATERIALS AND METHODS

Soil-Cement In The State Of Amazonas: Soil-cement began to be used in the state of Amazonas in 1948, in the form of monolithic walls, when the famous Adriano Jorge hospital, of the national tuberculosis service, was built in Manaus, a 10.800 m² building.In 2001, the government of the state of Amazonas launched the "Minha Casa Project", which aimed to build low-income bricks low-income homes. The construction of popular houses in soil-cement began in March 2002, ending in November of the same year, with an incredibly positive balance of 2.833 houses built.

This project aimed to build houses in a joint effort, where a team composed of engineers, masters, masons, and servants, would teach the beneficiaries how to build their houses. However, this method did not achieve the expected success, as the beneficiaries did not adapt to this way of building, forcing the government to hire an expressive number of professionals, for the smooth running of the project. These popular houses were built both in the capital and in the interior of the state. In Manaus, the houses were built in the neighborhoods União da Vitória, New Forest, João Paulo, Cidade de Deus, Amazonino Mendes and Grande Vitória, where we tried to take advantage of the existing infrastructure, replacing houses that were in a bad state of conservation, often built of styrofoam or cardboard, for houses of soil-cement bricks. The municipalities in the interior that benefited from the construction of popular houses in soil-cement bricks were Santa Izabel do Rio Negro, Barcelos and São Gabriel da Cachoeira. In 2003, a new administration took over the state government, continuing the project to build popular houses in soil-cement for the needy population. The new project, called “Citizen Project”, launched by the Superintendence of Housing and Land Affairs of the State of Amazonas (SUHAB), in addition to providing more dignified housing for the low-income population, sought to remove families who lived on the banks of rivers and streams, taking them to a place with a complete infrastructure, thereby avoiding the pollution of these places. The current government has already built 2.275 low-income houses, as shown in Figure 8.

Figure 8. Soil-cement house ready to be delivered to the population

Thus, from January 2003 to August 2005, the state government built four housing developments that are part of the “Citizen Project”, already delivered to the low-income population. The first is the “Conjun to Cidadão”, with 478 housing units delivered in September 2003, the second is the “Conjunto Amine Lindoso”, with 73 properties for people with leprosy, delivered on october 4, 2003, the third is the “Conjunto Carlos Braga”, with 404 houses delivered on august 20, 2004, and the four this “Conjun to João Paulo II”, with 1.320 houses delivered on November 27, 2005. It is important to highlight that the first three sets were built using the constructive technique of soil-cement, while the fourth set was built in aerated concrete. The area of the house is 33m^2, builton a 128 m^{2}plot, meeting the standards of the Manaus master plan. Each house has a bedroom, a bathroom, a kitchen, a living room and a service area, and the population is delivered free of charge. In the state of Amazonas, there are very few private constructions that apply soil as a constructive technique. Among the few existing works, we high light the construction of an industrial shed (Figure 9) using soil-cement bricks as sealing masonry associated with there ticulated structure.

Figure 9. Industrial shed made of soil-cement bricks

CELL CONCRETE

Foamy cellular concrete is light concrete obtained by introducing air, with millimeter dimensions, homogeneous, uniformly distributed, stable, incommunicable and unformed at the end of the process, whose apparent mass density in the fresh state must be between 1.300 kg/m^3 and 1.900 kg/m^3. It is also noteworthy that air bubbles can be obtained in the form of a pre-formed foam or generated inside a mixer by its mechanical action, due to a foaming agent (Associação Brasileira De Normas Técnicas, 1990). Thanks to the extraordinary lightness by the incorporation of air, foamy cellular concrete was used, initially, for filling slab openings, as a thermal insulator, and for the mechanical protection of waterproofing layers. For structural purposes, foamy cellular concretes can be used with great efficiency, being a material composed of conventional aggregates (sand/gravel), Portland cement, water and tiny air bubbles uniformly distributed in its mass (Associação brasileira de cimento Portland, 2002). As they are totally fluid, cellular concretes are self-compacting, eliminating the need for vibration of their mass (the use of a vibrator is prohibited, since this would destroy air bubbles, de-characterizing cellular concrete). This factor represents a significant gain in the construction process, since, in addition to the greater speed, it preserves the useful life of the molds (Ferreira, 1986). Portland concrete must contain cement, water, and aggregates, where cement and water form a more or less fluid paste, depending on the percentage of water that surrounds aggregate particles with different dimensions. This mixture, in the first hours, has the ability to be molded in any shape.

Over time, the mixture hardens due to the irreversible reaction of water with cement, acquiring mechanical resistance capable of making it a structural material of excellent performance, under the most diverse exposure environments (Helene, 2007). Within the concrete class, lightweight concrete has gained ground due to its physical and chemical characteristics. The oldest records on lightweight concrete report a patent from 1889 by an inhabitant of Prague. According to (Bessey, 1968), concrete with light aggregate was used by the Romans, 2.000 years ago, for the construction of the “Pantheon” dome. It is assumed that, in addition to low specific gravity, the Romans believed in the durability of this material (Ferreira, 1986). In this context, the present work aims to approach in a generic way the theme of concrete cell production. Which is a product basically formed by air or gas bubbles in a solid matrix, usually cementitious, which can be incorporated into the matrix by chemical or mechanical processes. Despite its excellent advantages in its use as a low specific weight thermal insulator, it has still been little used in the precast industry in civil construction, whether as a masonry block or partition panels (Allende, 2005). Cellular concretes can be divided into two large groups, aerated with foam agent (pre-formed foam) and chemically aerated (also called gaseous), where the differences are in the shape of the pores and their origin. Figure 10 shows a flowchart for distributing cellular concrete according to how it was obtained (Melo, 2009).

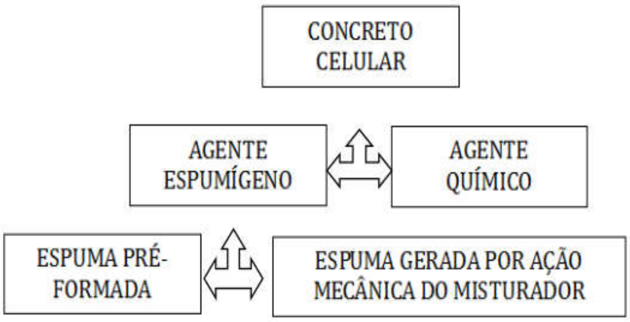


Figure 10. Classification of cellular concrete Source: (31), (2009)

Aerated concrete has advantages and disadvantages in the application. Its closed pore structure guarantees an excellent degree of thermal and acoustic insulation, in addition to good resistance to water absorption. Another great advantage is its fire resistance, conferred by its completely inorganic composition. However, all of the seproperties are obtained at the expense of the material's mechanical resistance, which decreases with the increase in its porosity (Goual, 2006).

GENERAL CHARACTERISTICS OF THE CELLULAR CONCRETE: Aerated concrete generally presents the characteristics shown in Table 1 (Associação, 2002).

Table 1. Characteristics of cellular concrete (33).

28 day-old endurance	F_{ck} 2,5 Mpa
Modulus of elasticity	~ 5 GPa
Especific mass	(1300 a 1900) kg/m^3
Water absorption	(22 a 28) % (em massa)
Void volume	(35 a 45) %
Portland cement	(280 a 320) kg/m^3
Sand: Fineness Module (MF)	1,7 a 3,4
Water	(160 a 180) l/m^3
Foam additive	0,6 l/m^3
Superplasticizer additive	2 l/m^3
Polypropylene fibers	1 kg/m^3

Binder: (Associação Brasileira De Normas Técnicas, 1990) states that any type of Portland cement can be used as a binder for the production of cellular concrete, noting that only cements that meet the specifications of NBR 5732 (ABNT, 1980), NBR 5733 (ABNT, 1980) should be used , NBR 5735 (ABNT, 1980) and NBR 5736 (ABNT, 1980).

Aggregates: The aggregate used to make cellular concrete is the fine aggregate. The fine aggregate used is sand, with the same specifications as to produce concrete and mortar. Practice has shown that the use of sand with medium grain sizes (fineness module between 2.60 and 2.70), results in mixtures with more advantageous mechanical and economic characteristics, for the desired product quality level (Associação, 2002).

Foam: The foam is obtained by foaming agents, which are products of chemical composition capable of producing stable air bubbles inside the cement and mortar paste (Associação Brasileira De Normas Técnicas, 1990). There are two types of foam extract: synthetic and organic. The foam extract must have a chemical composition capable of producing stable air bubbles in the concrete. They must resist the efforts generated by mixing, pumping and launching the material. Changing the specific gravity of the concrete until the start of the cement setting is the most appropriate way to assess the stability of a foam (Ferreira, 1986). The foam can be pre-formed for later incorporation into the mortar or generated within it by stirring in a special mixer. In both cases, the validity periods of the foaming agents, specified by the manufacturers, must be respected. Figures 11 and 12 show, respectively, the foam of synthetic origin, fundamental to produce cellular concrete, and the mixer, equipment where foaming agents are formed to be added to the mortar.

Figure 11. Foamy material.

Figure 12 - Foam generator

Obtaining electricity from wind has many benefits being that function of system involves several physical and fundamental content. The basic principles for generating electrical energy from wind relate intimamentecom major themes studied by physics that can will serve as an auxiliary to the study of such content. The physical study of contemplating the wind passes by themes such as the formation of the wind, the mechanically made wind energy, the transmission of energy and asua transformation into electricity (58). The incorporation of fibers in cellular concrete aims to combat the stresses generated by temperature variations and shrinkage due to loss of water from the mass in the early ages, to increase the tensile strength in order to distribute any micro-cracks and, at greater ages, to increase the capacity of the material to support stresses due to impacts (bentur, 1990). However, the cellular concrete walls of "Conjunto Nova Cidade" have shown a high cracking rate, compromising the tightness, safety of use and aesthetics of the wall, thus produced. Shrinkage during drying is considered to be a possible cause for cracking of cellular concretes, because when rapid drying occurs, the tensile strength of the concrete is insufficient to resist the forces caused by rapid shrinkage, resulting in cracking (Barros, 1990). The loss of water (initial shrinkage) plus exothermic reactions result in internal stresses that cause the grains to approach, thus, when the concrete is young, of low resistance, cracks occur, since the largest portion of shrinkage occurs in the early ages, mainly for lighter mixes (Teixeira, 1992). Cellular concretes cured in the open air have yet another adverse factor that increases their retraction, that is, by having its porous structure, the carbon dioxide in the atmosphere has easy access to the interior of the mass, which causes carbonation, which is aggravating the process (Associação brasileira de cimento Portland, 2002). Fiber-reinforced concrete has the ability to reduce the effects of shrinkage, not shrinkage itself, as fibers act by reducing the thickness and length of cracks, but do not eliminate them (Padron, 1990). When studying the influence of the content of polypropylene fibers in cellular concrete, (38) they were able to observe that the specimens kept in a dry chamber were the ones that presented greater surface cracking area, while those that were kept in a humid chamber offered a low cracking area. Figure 13 shows the fiber packs that are used in cellular concrete.

Figure 13. Packaging of polypropylene fibers

Additions: There are several types of additives for aerated concrete, each intended for a purpose, with the objective of giving concrete a certain characteristic such as increased resistance to mechanical efforts, improved workability, decreased hygroscopy, decreased shrinkage, increased durability , possibility of removing crimps and molds in the short term, decreased heat of hydration, retardation or acceleration of the handle, etc. (Ferreira, 1986). In the mixture, a super fluidizer is used, with the function of reducing the water-cement ratio, without the cellular concrete losing its workability, as well as increasing the initial resistance. With this, the retraction by hygroscopy becomes exceedingly small, in effect, the internal stresses decrease, tending to avoid the appearance of cracks. Super fluidizers make cellular concrete a low-viscosity liquid, which can be self-leveling and melted instead of vibrated (Teixeiram 1992). Although super-fluidizers reduce the water needed for mixing by up to 30%, reaching water / cement ratios of 0.28 to 0.30 and, consequently, high initial and final strengths, also with common cement and normal consumption, thereby allowing a faster deformation (Ripperm 2001).

RESULTS AND DISCUSSION

Cellular concrete in amazonas: The technology in cellular concrete began to be used in the state of Amazonas, as masonry for popular housing, since 1982. Where, an Amazonian construction company was the pioneer in the use of cellular concrete, having produced in the period from 1982 to 1988, 1.200 houses in the "Conjunto New City Housing(40) (Figure 14).

Figure 14. Housingunit of the Nova Cidade complex

During the years 2000 to 2004, 8.595 housing units were built in cellular concrete in the "Conjunto Nova Cidade". Most of these houses were handed over to the most diverse classes of state civil servants (civil and military police, teachers, etc.). Another part of this very expressive number was also delivered to the low-income population that lives on the banks of rivers and streams, moving them to the houses of the "Conjunto Nova Cidade" (Figure 15).

Figure 15. Housingunitof Conjunto Nova Cidade.

The launch of the "Citizen Project" by the Government of the State of Amazonas, in 2003, in addition to building popular houses in soil-cement bricks, also started to use the same construction system used in the "Conjunto Nova Cidade". These houses, built in cellular concrete, have the same model and objective (to remove the families that live on the banks of the streams for these groups) as the houses built in soil-cement masonry. At the beginning of 2004, continuing the "Citizen Project", the State Government of Amazonas started the construction of the fourth Citizen Complex, the "João Paulo II Housing Complex".

This set was built using the cellular concrete technique with 1.320 housing units, adopting the same model as the other “Citizen Set”. The fifth “Conjunto Cidadão” started in January 2006, where 1.422 housing units are being built in cellular concrete masonry. It is also noteworthy that some private construction companies in Manaus use the technique of cellular concrete, for construction of houses for the middle class

Conclusion

With the completion of this study, it is notorious, due to the numbers presented of the residential units for low-income population, built over the years, more specifically, between the years 1982 and 2004, in the state of Amazonas, that both construction systems (soil-cement and cellular concrete), meet the specifics as to the minimum requirements necessary for building large-scale homes that, could satisfactorily, meet housing programs for the construction of homes for the population of the state of Amazonas. However, because it is a system that requires special techniques, it was not successful to be maintained by the government of the state of amazonas, public policies exclusively for this purpose. Because, being a state with a great territorial extension, such construction methods could never be applied in the construction of popular houses in the state of amazonas, precisely, due to the difficulty of specialized labor in the interior of the state, as well as, high logistics cost to take these construction methods to the interior of Amazonas. However, this study fulfills its objective in presenting the methods discussed here, so that it can serve as the basis for new studies and development that enable an improvement and improvement of the construction methods discussed here.

BIBLIOGRAPHIC REFERENCIES

(Faria, 1990) FARIA, J. R. G. Unidade de produção de tijolos de solo estabilizado. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. São Paulo. 1990.

__________. Projeto 02.136.01.002: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 2: Estrutura. Rio de Janeiro, 2004.

__________. Projeto 02.136.01.003: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 3: Pisos Internos. Rio de Janeiro, 2004.

__________. Projeto 02.136.01.004: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 4: Fachadas e Paredes Internas. Rio de Janeiro, 2004.

__________. Projeto 02.136.01.005: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 5: Coberturas. Rio de Janeiro, 2004.

__________. Projeto 02.136.01.006: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 6: Sistemas Hidro sanitários. Rio de Janeiro, 2004.

ALBUQUERQUE, L.Q.C; BISCARO, G.A; NEGRO, S.R.L; *et al*.Resistência a compressão de tijolos de solo-cimento fabricados com o montículo do cupim.Ciência e Agrotecnologia, Lavras, v. 32, n. 2, p. 553-560, mar./abr., 2008.Available in:<http://www.scielo.br/pdf/cagro/v32n2/32.pdf>. Access in: 12 mai. 2020. (Grande, 2003) GRANDE, F. M. Fabricação de tijolos modulares de solo-cimento por prensagem manual com e sem adição de sílica ativa. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. São Paulo. 2003.

Allende, K.A; Freitas, I.M.; Darwish, F.A.I. Otimização da produção do concreto celular espumoso orgânico com adição de cinasita ou rejeito plástico e areia. In: XXII SIMPEP Bauru, SP, Brasil, 07 a 09 de novembro de 2005.

Almeida, R. A Importância da Avaliação de Desempenho e o Controle da Qualidade. Construção São Paulo, Suplemento PINI, Sistemas Construtivos. p. 6-7. São Paulo, 1984.

Assayag, M. Desperdício na Construção Civil em Manaus: Estudo de Habitação Popular com Paredes de Concreto Celular. Dissertação (Mestrado). 144 f. Faculdade de Tecnologia. Universidade Federal do Amazonas. Manaus, 2003.

Associação Brasileira DE Cimento Portland. Manual Técnico para Implementação - Habitação 1.0 Bairro Saudável. População Saudável. Publicações ABCP. São Paulo. 2002.

ASSOCIAÇÃO BRASILEIRA DE CIMENTO PORTLAND. Dosagem das misturas de solo-cimento:normas dedosagem e métodos de ensaio. São Paulo, 1980.

Associação Brasileira DE Cimento Portland.Guia básico de utilização do cimento Portland. 7.ed. São Paulo, 2002. 28p. (BT-106).

Associação Brasileira DE Normas Técnicas. NBR 12646: Paredes de concreto celular espumoso moldadas no local. Especificação. Rio de Janeiro, 1990.

Associação Brasileira De Normas Técnicas. Projeto 02.136.01.001: Desempenho de edifícios habitacionais de até cinco pavimentos - Parte 1: Requisitos Gerais. Rio de Janeiro, 2004.

BARROS, M. M. S. B. Desenvolvimento de um método construtivo para produção de vedações verticais de concreto celular. São Paulo, EPPUSP-PCC. Relatório CPqDCC n. 20095 – EP-GETHAL-01. 1998.

Bentur, A.; Mindess, S. Fiber reinforced cementius composites. Editora Elsevier. London. 1990.

Bessey, G. E. The world development and economic significance of the aerated concrete industry. In: International Congress on Lightweight Concrete, 1. 1968, London. Proceedings... London: Cement and Concrete Association, 1968. v. 1, p. 203-212.

Construções, E. Tijolos ecológicos. Florianópolis, 2017.Available in:<http://www.ecologicconstrucoes.com.br/>. Access in:16 jun. 2020.

Engels, F. Sobre a questão da moradia; tradução Nélio Schneider. 1 ed. São Paulo: Bom tempo, 2015. 158 p.

Ferreira, O. A. R. Concretos celular espumoso. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. São Paulo. 1986.

GARCIA, P. D. Contribuições ao estudo da resistência à compressão de paredes de alvenaria de blocos cerâmicos estruturais. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. São Paulo. 2000.

Goual, M.S.; Bali, A.; Barquin, F.; Dheilly, R.M.; Quéneudec, M. Isothermal moisture properties of Clayey Cellular Concretes elaborated from clayey waste, cement and aluminium powder. Cement and Concrete Research, v. 36, p. 1768 -1776, 2006.

Helene, P; Andrade, T.W.C.O. Concreto de cimento Portland.in: Materiais de Construção Civil e Princípios de Ciência e Engenharia de Materiais.São Paulo: IBRACON, 2007, v. 2, p. 905-944.

Klein, d. L.; klein, g. M. B.; lima, r. C. A. Sistemas construtivos inovadores: procedimentos de avaliação. In: ii seminário de patologia das edificações "novos materiais e tecnologias emergentes" da ufrgs – leme/ufrg, 2004, rio grande do sul. Anais eletrônicos do ii seminário de iniciação científica (cdrom), rio grande do sul: ufrgs, 2004. N.p.

Lawrence, K; Lordeleem Júnior, A. C.; Barros, M. M. B. A Influência do Teor de Fibras e de Cimento nas Características do Concreto Celular. In: CONGRESSO Latino Americano - Tecnologia E Gestão Na Produção De Edifícios, Pcc-Usp, São Paulo, 1998.

LOPES, W. G. R.; FREIRE, W. J. Análise comparativa dedois métodos usados para avaliar a aderência de taliscasde bambu encravadas em solo-cimento. In: CONGRESSOBRASILEIRO DE ENGENHARIA AGRÍCOLA CONBEA,32., 2003, Goiânia, GO. Anais. Goiânia: CONBEA, 2003.

Melo. G.F. Concreto Celular Polimérico: Influência da adição de resíduo de poliéster insaturado termofixo. Natal: UFRN, 2009. 83 p. Tese (Doutorado) - Centro de Ciências Exatas e da Terra, Universidade Federal do Rio Grande do Norte, Natal, 2009.

MERCADO, M. C. Solo-cimento: Alguns Aspectos Referentes à sua Produção e Utilização em Estudo de Caso. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. São Paulo, 1990.

Oliveira, F.L. Avaliação do Desempenho Estrutural de Sistemas Construtivos Inovadores: Estudo de Caso. Dissertação de Mestrado - Escola Politécnica, Universidade de São Paulo. São Paulo, 1996.

Padron, I.; Zollo, R. F. Effect of synthetic fibers on volume stability on cracking of Portland cement concrete and mortar.ACI MaterialsJournal, v. 87, n. 4, p. 327-32, jul.andaug. 1990.

Pereira, A.C; *et al.*Cimento Portland. Universidade do Estado do Mato Grosso Campus Universitário de SINOP. Sinop, 2013.Available in:<http://sinop.unemat.br/site_antigo/prof/foto_p_downloads/fot_7092cimento_pobtland_pdf.pdf>.Access in:16 jun. 2020.

REN, K. B.; KAGI, D. A. Upgrading the durability of mudbricks by impregnation.Buildingand Environmental, (S.l.),v. 30, n. 3, p. 433-440, 1995.

RIPPER, E. Manual prático de materiais de construção. São Paulo, Editora Pini, 2001.

Silva filho, l. C. P.; graeff, a.; klein, d. L; campagnolo, j. L. Análise de um sistema construtivo Inovador Formado por Paredes de PVC com Concreto Leve. CBCIMAT 2002, Congresso Brasileiro de Engenharia e Ciências dos Materiais. Anais em CD-ROM, Natal, Brasil, 2002.

Sindicato Nacional DA Indústriado Cimento (SNIC). SNIC 50 Anos. Rio de Janeiro 2006b Acesso em <www.snic.org.br>.Access in:15 jun. 2020.

Souza, V. C. M. DE; Ripper, T. Patologia, recuperação e reforço de estruturas de concreto. São Paulo, Editora Pini. 1998.

Teixeira Filho, F. J. Considerações sobre algumas propriedades dos concretos celulares esponjosos. Dissertação (Mestrado) - Escola Politécnica, Universidade de São Paulo. 1992.

Valença, M.M. Alternativa de provisão habitacional no Brasil e no mundo. Mercatour.ufc.br, 2014. Available in:<http://www.scielo.br/pdf/mercator/v13n3/1676-8329-mercator-13-03-0007.pdf>. Access in:07 nov. 2019.

****