Analysis of the resistance of the interlocked floor (paver) of concrete with the addition of the mass.

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Abstract

New elements are needed to contribute to the idea of not reusing the materials, but rather improving their use, the massará for example is known in the region of Teresina-PI is a connecting material, of little consistency, easily disaggregatable (friable), containing white silica pebbles and of little utilização in the region. The interlocked concrete floor presents peculiar characteristics among which are those that configure it as a floor. The work analyzes through a mechanical strength and water absorption test the capacity that the interlocked concrete floor with the addition of massará in its composition offers in relation to bear load. Two traces with massará will be tried and then specimens will be molded to obtain the results of mechanical tests and characterization of the material in the laboratory. After the tests, it was observed the possibility of using it as components in the production of interlocked laying blocks used in construction companies of Teresina - PI.

Keywords: Paver; Massará; Resistance.

1. Introduction

Second Medina & Motta (2015) man for thousands of years built his shelters putting stone on stone, carving them in the dimensions necessary for their comfort and protection, in a similar way to paving. Made from juxtaposed stone, this feat is attributed to the Cretan peoples, inhabitants of the island of Crete, Greece, around 3000 BC Already, at that time, juxtaposed stone was used, supported on a layer of sand to facilitate the fixation and accommodation of the elements in the construction of paths. In this system, precast concrete modular blocks, with different shapes, colors and textures, are juxtaposed and remain fixed due to the friction of the lateral area of the pieces in relation to the adjacent ones, it is quick to perform, has a long service life, low maintenance and high rainwater drainage capacity. Thus, this paving must be designed taking into account factors such as mechanical resistance, mobility and durability of the roads, which

hundreds of people use every day.
Since ancient times, the process of paving roads has become indispensable, from the moment when it was necessary to transport increasingly larger loads, and with the advent of the wheel, the rigidity of the pavements became essential. At that time, stones were used that were carved and prepared manually, wooden blocks coated with bitumen, blocks of solid brick made with clay, stones like “pé-de-moleque” in colonial Brazil, until the post-war period. In the 1950s, the development of the Floor in Precast Concrete Parts, or Interlocking Floor, was essential for the reconstruction of Holland and Germany, where a major development of this structure was possible (Sousa & Ripper, 2009 & Vasconcelos, 2016 & Fernandes ,2015).
Interlocking blocks can be manufactured in any shape. Some models stand out for being more used, they are also known as Pavers and Paviess. They are interlocking, prefabricated, solid blocks that allow you to completely pave a surface. Interlocking is the material's ability to resist individual displacement movements, whether vertical, horizontal, rotational or rotating in relation to adjacent pieces (Fernandes,2015).
The rigid pavement consists of a Portland cement concrete slab that plays the dual role of coating and base at the same time, with the sub-base being the layer used with the objective of improving the capacity to support the energy absorption of the subgrade. In this case, the sub-base is often called the base, and the sub-base for the pavement is not mentioned (Marchioni & Silva, 2011).
The interlocking concrete pavement has peculiar characteristics, among which, those that configure it as a resistant floor, the paver being recommended, as it allows easy installation and maintenance, in addition to being indicated by the Brazilian Association of Portland Cement (ABCP), to assist in the urban rainwater drainage due to permeability, which offers another positive point is the operational improvement for traffic, as a more regular surface is created (guarantee of better displacement comfort), however many doubts arise when buying pavers, there are many manufacturers of this product on the market, however, many do not manufacture in accordance with current standards, causing damage to consumers due to the poor quality of the final product, which has a cheaper price, however, when it is applied to the work,this material has greater wear, a large amount of broken parts and a large dimensional variety (Fioriti, 2007).
Massará is a cohesive material and formed by layers of pebbles in a clayey sand matrix, together with the finer grained material found in the upper layers, it remains, until today, as a stratified material in layers, which have already undergone lithification and are continuously dissected by erosive processes, mainly by rainwater (Peixoto et al., 2007).
According Pine (1989) massará is a binding material, of little consistency, easily disintegrated (friable), containing white silica pebbles, well rounded, used as a constructive material, it is processed by sieving, where all the existing gravel (rolled pebble) is used in the manufacture of concrete. Its sandy-clay matrix is used for landfills and in some cases as a binder in mortars for settlements and coatings.Like objective to return to postpossibility of expansion of use of massará, considering that, the sand used in paver composition comes of Poti river, whose extraction, carried out using dredgers, causes serious environmental damage, such as the disappearance of vegetation.Ibeirinha, as well as contributing to the formation of buradeep waters in the river bed, another negative point is the process of removal of this material which greatly increases the final value in the consumer market, while the massará is extracted from the washing of the pebble and sold at a value well below the value of the sand (Correia & Lages,

1997).

In Teresina, the use of paver grew from the 1990s to the 2000s through the increase of municipal laws on restrictions on the waterproofing of private urban areas: large supermarket chains, hypermarkets, shopping malls, residential condominiums, clubs, etc. These places started to use this form of paving as an alternative to a floor in which there is no accumulation or runoff of surface water in large proportions, as occurs in the most common pavements: cemented floors, asphalt and ceramic ornaments.

Two formulations of samples of paver with massará will be made, tests of granulometry of the massará, mechanical resistance were carried out, water absorption at the LABORATORY OF MATERIALS AND SOILS OF THE FACULDADE SANTO AGOSTINHO, to verify through the mechanical resistance test that the pavers made are in accordance with Brazilian standards, based on this result, the objective of this work is to study improvements in dosage (mixtures of components: cement, gravel, sand/massará and water) of these concrete pieces for paving so that factories located in the city of Teresina-PI start to produce a concrete block as specified by standard NBR 9781/13.

1.1 Interlocked blocks

According to Medina & Motta (2015) in their discussion on the topic, concrete paving pieces are in the process of expansion, the use of precast concrete pieces - PCC - in interlocking pavements, initially restricted to pedestrian walkways and parking lot, its use expanded to streets, highways and airfield taxiways.

Paving a traffic lane is a work that entails, above all, the operational improvement for traffic by creating a regular surface providing conditions for the mobility of vehicles and pedestrians. According to Senço (2007), the pavement is a structure built on earthworks and destined, economically, technically and simultaneously to:

a) resist and distribute the vertical efforts from traffic;

b) improve rolling conditions in terms of comfort and safety;

c) resist horizontal efforts (wear), making the bearing surface more durable.

According to Baldo (2007), paving aims to provide comfortable and safe traffic, with structures and materials capable of withstanding the efforts resulting from the action of traffic combined with weather conditions, at a minimum cost, that is, seeking whenever possible , the use of material, ensuring a good performance in terms of operating and maintenance costs throughout the life of this infrastructure. The immediate objective in choosing and selecting the types of pavements to be used minimizes the cost of applied materials, this issue is crucial for agencies and operators, with inevitable consequences for users and constitutes an important factor in the project design.

The paving system in interlocking or articulated concrete blocks, although resulting in a coating composed of prefabricated elements with concrete, presents a behavior as a coating layer very similar to asphalt concrete layers, imposing vertical pressures on the underlying layers of the same intensity. The study of soils for this type of pavement is fundamental both from the point of view of material and project analysis, there is no pavement without a foundation, that is, without subgrade, sub-bases and pavement reinforcements, which is why any related study paving never does without an adequate study of the soils used in the works. The rolling layer of the interlocking pavement is formed by pavers, laid on a thin layer of sand. Several advantages of paver application are known, such as ease of application and maintenance, since the pavement can be installed and removed at any time, the ability to generate savings in public lighting, as it is capable of increasing reflection by up to 30% compared to other pavements (Marchioni & Silva 2011). Creates paved spaces with a beautiful aesthetic effect, as there are several forms of these pieces, currently in the world more than 100 models of pavers, including with different purposes. In addition to the traditional pieces used only as paving, there are ecological floors that allow the use in intercropping with grass, and floors with specific purposes such as permeable, draining, traffic segregation, guidance for the visually impaired, among others. Prisma models are more common in Brazil, but some companies are already anticipating launching new models and color options, such as mixed, vital, pope, for example. According to Fernandes (2015) the names of the dimensional models of the pavers vary a lot from region to region and his work aims to contribute to unify this language in favor of the most common name for each model, so that they can be better known, and with that, they develop more quickly. This is exactly what Martins (2014) points out that the manufacture of pre-molded parts intended for paving urban roads, such as sidewalks, streets, parks, parking lots, must meet dimensional and compressive strength requirements. These specifications are contained in NBR 9781/13: Concrete Parts for Paving – Specification and test methods. Regarding the dimensions, the specific standard that the pieces must have a regular geometric format, maximum length of 400 mm, minimum width of 100 mm and minimum height of 60 mm. The maximum variations allowed in dimensions are 3 mm in length and width of the pieces and 5 mm in height. The characteristic compressive strength must be greater than or equal to 35 MPa, for light vehicle requests, and greater than or equal to 50 MPa, when there is wear due to friction and heavy vehicle traffic. The concrete used to make the pieces must consist of Portland cement, natural or artificial aggregates and water, with the use of additives and pigments being allowed. Precast concrete parts that have a length/thickness ratio of less than 4 are suitable for vehicular traffic and are used on the permeable interlocking pavement. (ABCP, 2011). ICPI (2011), on the other hand, shows that, for this use, the aspect ratio (length/thickness) must be less than or equal to 3. From the perspective of manufacturing a quality paver, well-dosed traces will be necessary, following all the aforementioned adjustments, that is, pieces with dimensions without variations, ideal resistance, which is important to have a good floor.

1.2 aggregates

Aggregates for civil construction are mineral materials, inert solids that, according to appropriate particle sizes, are used to manufacture resistant artificial products by mixing with hydraulically activated binder materials or bituminous binders (Ribeiro, 2009). It is generally granular, without defined shape and volume, with characteristic dimensions and properties suitable for the preparation of mortar and concrete (NBR 9935/05).

The NBR 7211 (ABNT, 2005) defines fine aggregate as aggregate whose grains pass through a sieve with a 75 mm mesh opening and are retained in a sieve with a 0.15 mm mesh opening. Also according to NBR 7211 (ABNT, 2005) the aggregate must be composed of hard, compact, stable, durable and clean mineral grains, and must not contain harmful substances. Natural sand is exploited in our rivers in order to degrade them, devastating the riparian forest, silting up its banks and reducing the oxygenation of its waters, thus causing the disappearance of food for the riverside population. To get an idea, annually, more than

391.765,746 m³ are removed from the various rivers in this country, according to data from the National Department of Mineral Production (DNPM – 2014), for use in civil construction. In recent years, the depletion of deposits of natural fine aggregate near major consumer centers, the increase in transport costs, the intensification of commercial competition between concrete producers and the awareness of society, which demands environmental protection laws, have contributed to a better understanding of the importance of aggregates. (Sbrighi, 2005).

Aggregates must be adapted to certain standards for optimal use in engineering: clean, hard, resistant, durable, with particles free of substances or layers of clays and free and other fine materials in quantities that could affect hydration and bonding with the cement paste. According to Giaccio et al., the properties of concrete depend on the properties of its components (paste matrix and aggregates and the interactions between them), the difference in hardness between the aggregates and the paste matrix produces stress concentrations at the interfaces that may differ from material stresses, with the possibility of cracking in concrete, mortar and aggregate particles, and these effects are intensified with the increase in aggregate size, especially when this value is greater than 5 mm (coarse aggregate). Zhou et al., studying the effect of different types of coarse aggregates on the modulus of elasticity and compressive strength of high-performance concrete, concluded that the type of aggregate influences both the modulus and strength of concrete.

1.3 cement

Cement is a type of binder obtained from a mixture (called clinker) between limestone powder and clay minerals which, when reacted with water, form a gelatinous paste that hardens and becomes rigid after simple drying. To improve product quality, cement may also contain some small amounts of other binding materials such as lime and gypsum. In Brazil, and in the world, the most commercialized cement is Portland type, a patent created by a British builder who discovered that the solid generated after cement hardening has similar properties with rocks that occur on the British island of Portland (Hagemann, 2011).

According to Souza et al. (2008), Portland cement composed of pozzolan (CP II Z-32), has acceptable properties for the manufacture of soil-cement, in addition to the ease of obtaining the material due to its high rate of use in the construction market, corresponding to approximately 75% of industrial production. Cement is one of the components in the manufacture of interlocking blocks, so it is important to verify the content necessary for incorporation into the aggregate along with water, since the mechanical strength is influenced by the amount of cement (Carvalho, 2019).

2. Methodology

As for the approach, this work is qualitative with emphasis on material research in the field, verification of samples in the laboratory, observation and photographic record. The study is established in ABNT NBR 7214:2015 which specifies the standards to verify whether a material can be used as fine aggregate. To carry out this work, the procedures we will use are: field research, laboratory analysis, document research, photographic record and observation. In documentary research, materials already produced by other points of view are used, such as books, dissertations and scientific articles. 30 samples of interlocking floor were made in type I rectangular precast concrete pieces with dimensions 9.7cm x 19.7cm x 6cm according to NBR 9781 (2013) produced in a factory in Teresina-PI, in all of them the mechanical method was used to mix the materials and manufacture the products, 10 samples used sand from dredgers, gravel and gravel powder from Teresina suppliers (trace: 5kg of cement, 10kg of sand, 10kg of gravel and 3l of water), the other 20 were added proportions of mortar, 10 samples with 50% (trace: 5kg of cement, 5kg of sand, 5kg of mortar, 10kg of gravel and 3l of water) of mortar and the other 10 with 20 % (trace: 5kg of cement, 8kg of sand, 2kg of mortar, 10kg of gravel and 3l of water) of mortar. The tests were carried out at the UNIFSA building materials laboratory in Teresina-PI and all 30 pieces with their curing periods already consolidated. gravel and gravel powder from Teresina suppliers (trace: 5kg of cement, 10kg of sand, 10kg of gravel and 3l of water), the other 20 were added proportions of massará, 10 samples with 50% (trace: 5kg of cement , 5kg of sand, 5kg of gravel, 10kg of gravel and 3l of water) of massage and the other 10 with 20% (trace: 5kg of cement, 8kg of sand, 2kg of gravel, 10kg of gravel and 3l of water) of will massacre. The tests were carried out at the UNIFSA building materials laboratory in Teresina-PI and all 30 pieces with their curing periods already consolidated. gravel and gravel powder from Teresina suppliers (trace: 5kg of cement, 10kg of sand, 10kg of gravel and 3l of water), the other 20 were added proportions of massará, 10 samples with 50% (trace: 5kg of cement , 5kg of sand, 5kg of gravel, 10kg of gravel and 3l of water) of massage and the other 10 with 20% (trace: 5kg of cement, 8kg of sand, 2kg of gravel, 10kg of gravel and 3l of water) of will massacre. The tests were carried out at the UNIFSA building materials laboratory in Teresina-PI and all 30 pieces with their curing periods already consolidated. 8kg of sand, 2kg of massará, 10kg of gravel and 3l of water) of massará. The tests were carried out at the UNIFSA building materials laboratory in Teresina-PI and all 30 pieces with their curing periods already consolidated. 8kg of sand, 2kg of massará, 10kg of gravel and 3l of water) of massará. The tests were carried out at the UNIFSA building materials laboratory in Teresina-PI and all 30 pieces with their curing periods already consolidated.The first stage of the study included the characterization ofwill massacre him to make thes interlocked blocks with the objective of identifying and classifying this material for later production of specimens. The soil sample is known in the region as massará, which is a generally sandy clay material found easily in the city of Teresina-PI and surroundings.

For the granulometry test, 100g of the washed massará sample was used and passed through sieves 3.8, 4, 8, 16, 30, 40, 60, 80, 100 and 200mm, in order to characterize them in terms of distribution and solid particle sizes as shown in figures 1:

Figure 1 - Particle size analysis of massará

Source: author -2019

Particle size analysis consists of determining the particle size of the fine aggregate. Aggregate samples were collected according to NBR 7216 (1987). The massará went through a washing process using a 200 (0.074mm) sieve to extract all the powdery material from its composition. After they remained in an oven for drying for a period of 24 hours, the normal series with circular mesh sieves was used, following all the parameters of the ABNT BNR NM 248 (2003) and ABNT NBR NM ISSO 3310-1 standards.

After making the interlocked blocks 10 samples of the interlocking blocks were placed, being 3 without addition of massará, 3 with 50% of massará and 3 with 20% of massará in an oven at 100 ºC for 24 h of drying in order to remove the moisture for the test. water absorption after dry weighing the specimens were placed in a tank with water (figure 2) to fill all their pores with water.According to ABNT NBR 9781:2013 the sample of concrete parts must present water absorption with an average value less than or equal to 6% and no individual value greater than 7% being admitted.

Figure 2 - Tank with water where the concrete parts were immersed.

Source: Author 2019

Meanwhile, the three pieces of each formulation were weighed wet and then dried with a cloth to remove excess water. Weighing was carried out on a “Mars scientific” scale with a precision of 1g. After noting the wet masses of the materials, they were placed in a 150 liter Sterilization and Drying Oven, No. 5 MEDCLAVE (figure 3) for drying at 100 Celsius for another 24 h.

Figure 3 - Oven for drying wet parts

Source: Author 2019

After the water absorption test, 21 pieces of each formulation were removed, already saturated, and they were broken in the 120/150 TON Digital Manual Hydraulic Press - I-3001-R CONTENCO (figure 4) in the press, an adaptation was made with a steel disc 20 (twenty) mm thick stainless steel to compress the part over its entire surface area. ABNT NBR 9781:2003 stipulates that the characteristic compressive strength (fpk) at 28 days of the parts must be greater than or equal to 35 MPa for pedestrian traffic, light vehicles and line commercial vehicles and must be greater than or equal to 50 MPA for special vehicle traffic and requests capable of producing accentuated abrasion effects.

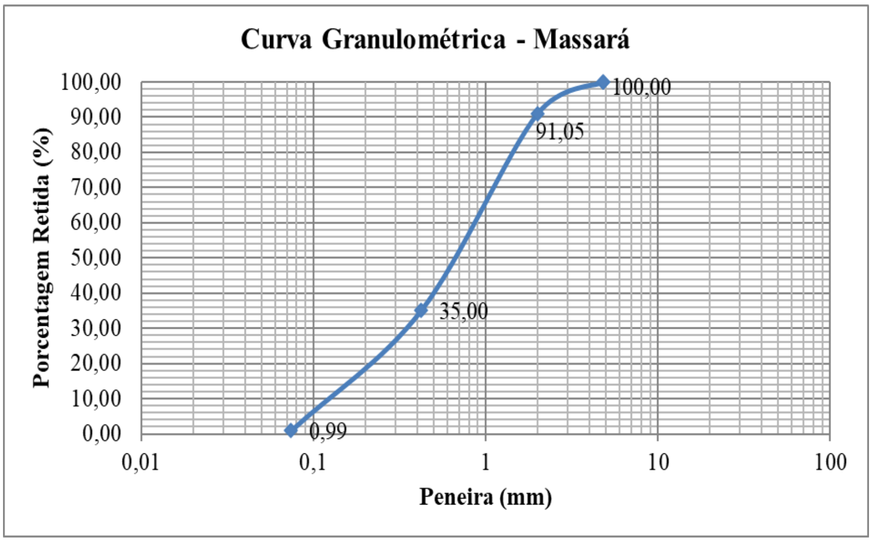
Figure 4 - Hydraulic press used to break the parts

Source: author 2019

3. Results

Graph 1 shows the results of the granulometric test by sieving the massará sample, it is possible to see that the sieving showed a higher concentration of silicon oxide, characteristic of sandy soils. The soil is deficient in fine particles, that is, low clay in the soil.

Graph 1- result of the massará granulometry test



Source: Author 2019

To verify the water absorption of the pieces, the method established by the ABNT NBR 9781:2013 standard was used. The following results were found for each sample presented in table 1.

Table 1- Absorption of parts in percentage

0% massará			50% of massará			20% of massará		
wet mass (g)	dry mass (g)	moisture	wet mass (g)	dry mass (g)	moisture	wet mass (g)	dry mass (g)	moisture
2739	2686	1.97%	2672	2635	1.40%	2302	2251	2.27%
2758	2698	2.22%	2760	2719	1.51%	2359	2315	1.90%
2692	2625	2.55%	2740	2710	1.11%	2416	2360	2.37%

Source: Author 2019

According to table 1, it was observed that all tested parts had moisture below 6% on average. For the simple compression test according to the ABNT NBR 9781:2003 standard, we have the results in Mpa in table 2.

Table 2 - Breakdown stress of parts

Samples	0% massará	50% of massará	20% of massará	Unit
1	18.20	32.01	19.46	MPa
two	16.11	21.48	16.99	MPa
3	16.67	29.80	29.87	MPa
4	18.63	41.08	14.96	MPa
5	17.29	21.92	18.31	MPa
6	14.17	26.47	12.73	MPa
7	14.92	27.87	13.40	MPa

Source: Author 2019

According to the results presented in table 2, when analyzing the compression test on each sample, it can be seen that the mixture with 50% addition of mass in the composition of the production of interlocked blocks has good resistance compared to conventional samples produced in the company that in this work we called sample of interlocking blocks with 0% mass, so we have a very resistant concrete block in relation to what is already well known in the market in the region.

4. Conclusion

From the results obtained in the tests, it was verified that the interlocking blocks using massará in the mixture for making the precast pieces for paving under study culminated in a satisfactory result from the point of view of the standard used as a base. Within this context, we can present companies that can use a material with good resistance, economic, easy access and that causes less damage to the environment by reducing the amount of sand coming from rivers. Presenting as an incentive to continue the research, which has as its main objective a more efficient and economical dosage for precast concrete floors used in Teresina-PI.

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