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Handling of Concrete with Addition of Residual Ceramic Material in Different % Replacing Conventional Stony Aggregate

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Abstract

A conventional concrete mixture elaborated according to the parameters described in the Colombian Technical Standards NTC under the conditioning established by the Quake Resistant Standard NSR-10 that regulates our country. A residual ceramic sample was taken from elements of masonry and tiles from the brick industry Santa Rosa, the obtained material was taken to the crusher La Victoria, where the milling process and reduction of particles was performed as well as to the conventional mineral aggregates. The granulometry was performed to the coarse aggregate of the crushed ceramic material according to the NTC-77, simultaneously the respective test to determine its physical properties according to the stipulated by the same standards were performed. Designs of experimental mixtures were made, 10, 20-100% of the weight of the conventional concrete coarse aggregate was replaced by its equivalent in ceramic coarse aggregate. To the designs of both conventional and experimental mixtures, the test of concrete setting was performed with the help of the concrete slump test to determine its handling. The results obtained by the test performed to the different mixtures were portrayed in a table, were the obtained data for the conventional concrete mixture was used as a comparative base for the rest of the data.

Keywords: Concrete, Residual ceramic, Aggregates

1 Introduction

From its elaboration both outside and inside construction, the regressive time begins for the usage of the concrete, characteristic that makes it a material of prompt use due to the physicochemical processes that are activated when the cement material has direct contact with water. The loss of work capacity with concrete with time, often known as slump loss, is important in the practice of construction, particularly in the case of premixed concrete, where long distance conveys and delays in the construction are common [1].Curing, name given to the hardening process, or change of state of the concrete, sets the consistency of the material for its usage, transition of the state of the concrete which only lasts a couple hours, depending on the type of additives, the proportion of the mixture and the surrounding, this being insignificantly short compared to the expected useful life of any concrete structure [2].

In its fresh state, the concrete mixture allows an easy handling, characteristic that allows its mixing, transportation, and emptying. In its hardened state concrete puts on evidence the curing process, where on early stages tends to have low resistance, but after 14 to 28 days, a there is a notorious increase of considerable resistance in its mechanic properties. Its unique combination of resistance, economic viability, availability of raw materials, workability and durability make concrete an ideal candidate for an ample variety of applications to civil infrastructure [3]. The concrete workability is directly related to its fresh state and fluidity, the last one depending on the variables that go from the size of the infrastructure to be built, to the quantity of elements present within the mixture, the ease of pouring and the accommodation of the mixture. During this period, the concrete is in the transition from a fluid or weak plastic to a solid material and is especially vulnerable to cracking [4].

With the development of the economy, the fast-growing urbanizations have given place to new large-scale constructions, especially in countries with emerging economies. These constructions require great quantities of consumption and production of natural aggregates, which can be understood as an intensification of scare natural resources and the difficulty of sustainable development [5]. The usage of recycled or reused aggregates in the mixtures of concrete is a viable and sustainable alternative for the conservation of natural resources that have been traditionally exploited for the extraction of this type of mineral material, which is important for the elaboration of different designs for concrete mixtures. The use of concrete with recycled aggregates through the partial or total substitution of natural aggregates, conventionally used, is a popular focus that reduces the consumption of natural resources through the reutilization of concrete residues [6].

The use of residues from industrial processes or crushing of defective ceramic materials has also been a field of exploration that has caught the attention of researchers in their urge of protecting natural resources, developing research projects that have generated results of interest for the implementation of these residues in the elaboration of concrete mixtures giving a good use to the residual material. The brick companies of the city of Cucuta fabricate most of the ceramic material represented in masonry and tile elements for floors and plates, used in constructive activities of the city and nearby towns, present about 5 to 10% of defective of useless production in their product elaboration. This waste is currently used as filling material in engineering constructions, where its value both in cost as in importance of usage is low.

The research about the use of recycled brick aggregate begins at the end of the 90´s decade. It has been suggested that, although the mechanical properties of the recycled aggregate concrete are generally inferior to the conventional concrete, there is a great potential to incorporate ceramic waste elements in structural applications for concrete [5]. The present research demonstrates the malleability of concrete in its fresh state with the incorporation of non-conventional aggregates from ceramic waste material from the brick company Santa Rosa in the city of Cucuta. The incorporation of non-conventional material was made gradually, replacing 10% to 100% of the natural coarse aggregate in a conventional concrete mixture for ceramic waste aggregate. A potential destination for the recycled material is the replacement of arid aggregate for structural concrete, an alternative that is included in the different structures that can be elaborated with this material [7].

2 Methodology

A conventional concrete mixture was elaborated with Portland cement type I classified according to the *NTC-30* and *NTC-180*. The stony material went under granulometric test for fine and coarse aggregates contemplated in the Colombian Technical Standard *NTC-77*. Also, the natural aggregates went under the natural humidity test *NTC-1776*, density and absorption*NTC-237; NTC-176*, unitary mass and gaps *NTC-92* and resistance to abrasion *NTC-98*. A technical visit made to the brick company Santa Rosa in the city of Cucuta was performed, where 10 m3 of ceramic waste material was extracted from the production of defective masonry and tiles.

The material waste was taken to crusher La Victoria, in the same city, where the processes of crushing and reduction of particles in the ceramic waste aggregate were exposed just like in the mineral aggregate. The crushed ceramic material went under granulometric analysis for coarse aggregates following the indications described on the Colombian Technical Standard *NTC-77*. This material was also subject to the same test performed on the mineral material used in the *CCM*. After the material was analyzed, 10 experimental mixtures were made (*EM+*) which 10%, 20%-100% of non-conventional coarse aggregate was incorporated in relation to the weight of natural coarse aggregate of the *CCM*.

The malleability of the *CCM* and the *EM+* was determined through the consistency test with the help of the Concrete Slump Test. The flow table test, standardized as *ASTM C1611*, is the simplest and most ample test used for laboratory and field tests [8]. The results obtained in the tests to the different mixtures were presented in a comparative figure where conclusions of interest were obtained.

2.1. Analysis of physical properties of the aggregates

Table 1. Physical properties of conventional and non-conventional aggregates

	Natural Aggregate CCM		EM+ Aggregate
Test	Fine	Coarse	Coarse
Apparent Density	2.496	2.576	2.196
SSS Density	2.596	2.613	2.380
Nominal Density	2.633	2.666	2.683
Water absorption	2%	1.2%	8.2%
Natural Humidity	4.7%	0.2%	1.5%
Compact Bulk Density	1.710	1.593	1.333
Loose Bulk Density	1.580	1.483	1.213
Gaps under compact condition	31%	39%	40%
Gaps under loose condition	37%	43%	45%
Wear to abrasion 100 loops	N/A	7%	6%
Wear to abrasion 500 loops	N/A	30%	33%

2.2. Granulometric analysis fine material

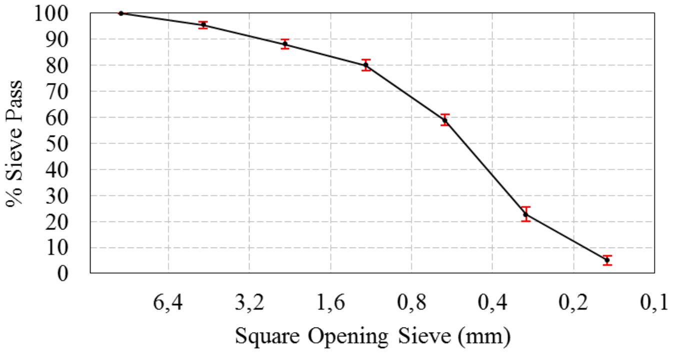

Figure 1. Granulometric analysis fine aggregate

2.3. Granulometric analysis of natural crushed coarse aggregate

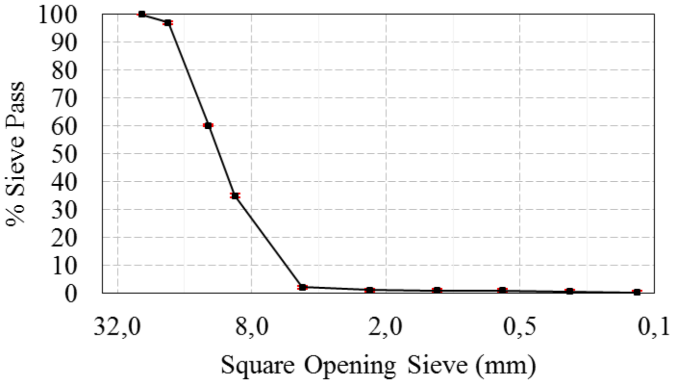

Figura 2. Granulometric analysis coarse aggregate

2.4. Granulometric analysis crushed ceramic aggregate (coarse)

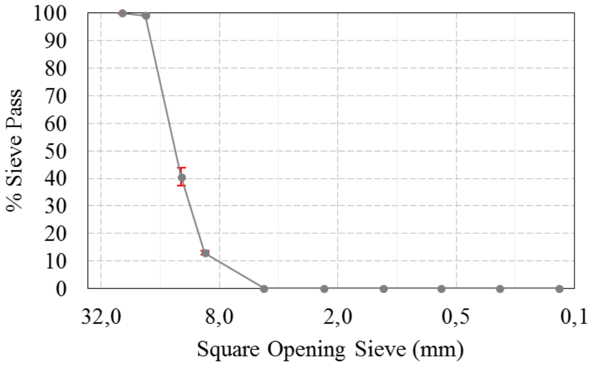

Figura 3. Granulometric analysis of coarse ceramic aggregate

3 Results

3.1. Representation of % of material for replacement

A descriptive table was created showing the *CCM* and the representation of % of the natural coarse aggregate replaced with the residual coarse aggregate from the brick company Santa Rosa, from which a design of the mix *EM+* was elaborated for each of the substituted %.

Table 2. Representation of % of replaced coarse aggregates

	% Crushed Coarse Aggregate	
Design of mix	Natural	Ceramic
CCM	100	0
EM+10	90	10
EM+20	80	20
EM+30	70	30
EM+40	60	40
EM+50	50	50
EM+60	40	60
EM+70	30	70
EM+80	20	80
EM+90	10	90
EM+100	0	100

3.2. Design of Experimental Mixtures

The designs of the experimental mixtures were made taking as a base the *CCM* to which in % (P.R), the natural coarse aggregate (*NTA)* was replaced by crushed ceramic coarse aggregate (*CTA*) from the brick company Santa Rosa in the city of Cucuta. The table also shows the weight of the fine aggregate (FA) along with the weight of the cement and the total weight of the mixture (TWM). A good design of mixture allows the concrete to fulfill its workability and hardening properties [9].

Table 3. Design of Experimental Mixtures

			Weight (Kg)				
Mix	P.R (%)	Water (L)	Cement	FA	NTA	CTA	TWM
CCM	0	207.24	393.56	716.04	926.63	0.00	2243.47
EM+10	10	207.56	393.56	718.66	833.967	92.663	2246.41
EM+20	20	207.86	393.56	721.28	741.304	185.326	2249.33
EM+30	30	208.29	393.56	721.28	648.641	277.989	2249.76
EM+40	40	208.59	393.56	723.89	555.978	370.652	2252.67
EM+50	50	208.90	393.56	726.50	463.315	463.315	2255.59
EM+60	60	209.22	393.56	729.11	370.652	555.978	2258.52
EM+70	70	209.62	393.56	729.11	277.989	648.641	2258.92
EM+80	80	210.04	393.56	729.11	185.326	741.304	2259.34
EM+90	90	210.35	393.56	731.73	92.663	833.967	2262.27
EM+100	100	210.66	393.56	734.34	0.00	926.63	2265.19

3.3. Settling by % of substituted coarse aggregate

The mixture designs of *CCM and EM+* went through a settling test with the help of the concrete slump test. The figure shows the settling of the *CCM* which was taken as reference for its comparison with the results of the *EM+*. The settling test is commonly used to measure the elastic limit of the fresh concrete. In this test, a container is filled with concrete to liberate the material and allow it to spread itself by gravity; the vertical distance on which the concrete falls, "slump height", it is measured as an indicator of the elastic limit [10].

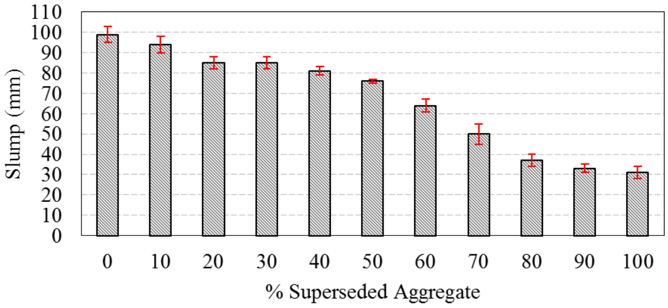

Figura 4. Average degradation coarse agregate

4 Conclusions

In the water absorption test, the CTA presents the highest % with regard to the NTA, therefore, the designs of the mix EM+ evidence a progressive increase in the incorporation of liquid. The natural humidity of the CTA overcomes the NTA by 1.3%, situation that varies with the water quantity added to the mix with the purpose of attending the water demand expected by the design in an efficient manner. The NTA overcomes compact and loose bulk density by 0.26 and 0-27 respectively, situation that increases the volume unit of the CTA in the EM+. The gaps in compact and loose condition of the CTA overcome the NTA with a minimum %, 1% and 2% respectively, these percentages corroborate the increase of volume of CTA in the EM+.

In the test to determine the degradation due to abrasion of the material elaborated in the Los Angeles machine, facing the aggregates of 100 revolutions with 11 spheres, the NTA presented a 7% of degradation with respect to the CTA which showed a 6%, the NTA surpassing with a minimum difference of 1% in relation to the CTA. At 500 revolutions with 11 spheres, the CTA presented the most degradation of 33%, the NTA evidenced a 30%, overcoming by 3% the degradation of CTA with respect to NTA.The settling of the conventional concrete mixture demonstrated to be more accentuated than the data obtained for the EM+, compared to the EM+100 a considerable difference is noted at first glance, the difficulty of workability of the mixture in relation to the rest.

The EM+10 presents a minimum settling difference with respect to the conventional mix with only 5mm of settling, a characteristic of the concrete that allows its usage in structures of reduced thickness where concretes with that range of settling are available. The experimental mixtures could be implemented in concretes where its settling range is stipulated by the design of mix to be elaborated. For example, in concrete elements where considerable thicknesses can be accommodated through the usage of vibrators.The incorporation of ceramic waste material in concrete mixtures influences directly on the workability and malleability of the mixtures. Given the physical characteristics of the non-conventional crushing, it is supposed to have a greater demand of water for the obtention of an adequate settling for the mixtures.

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