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Use of Concrete Debris: Sub-Base Material for Road Structures

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Abstract

Natural disasters in a very short time are capable of destroying what man has built using different types of resources, the construction of buildings, houses, etc. In their construction processes, they use different materials in a separate way that mixes and this process give them hardness and resistance to these materials. When they are destroyed they lose their individual properties and become waste; this research aims to make a study of the NEVI-12-MTOP standards, to be able to reuse the debris materials generated by the destruction of the earthquake on April 16. A bibliographic search was carried out related to the use given to waste caused by earthquakes in different countries. In the city of Portoviejo, the largest amount of debris was a concrete waste, and it can be concluded that these materials can be used as sub-base material in the road structures, so the reuse method was proposed. In particular, the characteristics of the residual materials were obtained as a result of the analysis of environmental, economic and material safety feasibility.

Keywords

Construction;
Earthquake;
Recycle;
Roads;
Sustainable;

Contents

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1. Introduction

The debris generated by the 16 A Ecuador earthquake was mainly concrete waste that was infrastructure before the catastrophe and due to the great magnitude of the earthquake collapsed generating a large amount of waste.[1] Concrete is one of the most used materials by the human being for construction, almost 80% of civil constructions are made with concrete either simple or as reinforced concrete; then you can understand the reason why so many are generated waste that has as a base element the concrete. Many have already been organizations that are concerned about generating models for recovery and use of this type of waste. Due to a large amount of waste presented, it is estimated that each year, in Europe alone, 1300 million tons of concrete waste is generated,[2] then it is understandable that the same producers and distributors of concrete organizations worry about recycling it.

In countries such as Germany, the United States, Belgium, the United Arab Emirates, the Netherlands and Japan it is very common to use concrete waste.[3] As it is a new field of application in our country, this means that a series of analyzes must be carried out and the research presented will only focus on testing or disapproving the technical feasibility of its use as a subbase for asphalt pavements. It is needed further studies to approve it's environmental, economic and safety feasibility. Currently, work is being done to update the Environmental Standard NADF-007-RNAT-2013 that establishes the classification and management specifications for the RCD. In this last version the standard provides a classification of the RCD and provides the possible uses of the recycled aggregates and in this way help the project engineers. As well as the construction residents and other personnel involved in the construction, to decide on what works or in which sites of the same ones to use them.[4]

The American Concrete Institute accepts the possibility of incurring in this type of reused concrete, the promoters of any design system or alternative materials within the scope of this Regulation, whose suitability has been demonstrated by success in their use, they have the right to present the data. Its design is based (ACI-318, 2014).[5] The analysis is focused on construction. There are many types of analysis. But the one that generates the environmental concerns is the rubble, since not only are residues likely to end up using agriculturally or socially poor productive land. But 0.6% of the constructed it is demolished every year, taking Hong Kong as the city of recommended analysis, and it also has that the built volume goes up by 5%. Therefore, it is conclusive the need for the reuse of these debris.[6]

It is known to recycled concrete as concrete whose useful life has been completed and must be demolished, either for structural reasons or by catastrophes that have damaged. Its shape and no longer fulfills its functions for which it was built, after the demolition of the structure, the concrete must be crushed until the concrete pieces have a shape similar to natural aggregates. One of the properties to be considered in crushed concrete is the relative density, which will decrease as the crushed concrete particles decrease in size.[16,17] These materials can be used as bases and sub-bases in buildings.[18,19]

Aggregates for the construction of granular bases and sub-bases and, in general, for any layer of pavement should be characterized to establish their suitability, and give a useful structural design for the pavement. The mineralogical composition of the aggregates determines to a large extent their physical characteristics and the way they behave as materials for a layer of pavement. The test that determines if the properties of the aggregate are suitable for use as a sub-base vial is the CBR. This test indicates the resistance to shear stress of the soil, and this must be greater than thirty percent to qualify the aggregate as such, to be able to use it in Ecuador as a structural part of asphalt roads.[7,8]

2. Research Method

For the development of the research, a bibliographic analysis related to the use of the rubble materials produced in an earthquake was carried out.[20] It was studied to take advantage of the accumulated residuals in the streets; the NEVI-12-MTOP norms were implemented and compared the results with similar research experiences; Also, different technical methods will be applied that will give a solution to the use of the accumulated material.[21]

A solution was investigated to reduce the debris caused, the result of the economic and environmental impact was taken into account. A quantitative investigation was carried out, a selection and collection of material were made for the San Agustín quarry's sub-base road that will serve to replace its aggregates by crushed concrete percentage; besides carrying out the tests of liquid and plastic limits where the sampling process of the standards A.A.S.H.T.O. T-089 and A.A.S.H.T.O. T-090.[9] The concrete debris, after being chosen transported to the crushing site. It was sieved, and sizes separated the pieces into screens of 2 ", 1 ½", No. 4, No. 40 and No. 200.[22,23] The sample used to be replaced donated from the San Agustín quarry. All the material collected was separated by the sieves 2 ", 1 ½"; No. 4, No. 40 and No. 200 and classified as through material and retained material.[10,24]

3. Results and Analysis

3.1 Design of replacement percentages

The criterion for using the sieves was based on these, which govern the granulometry of the sub-base class two. They are granular materials of better quality than the sub-base class three. The result of the granulometric belt was better graded.[25] The sieves were used to separate the pieces of crushed concrete by sizes correlated to those found in the granulometry of a sub-base. Classifying them in material and retained material for each respective size, in Table 1 the limits of Atterberg for a replacement of natural aggregates with recycled concrete.

The natural aggregates, for each intern and retained of each sieve, were replaced by gravimetric methods for crushed concrete corresponding to the size that dictated the separation of material through and retained from the sieves. Respectively, 30 percent and 50 percent of each portion was replaced and again mixed to perform the corresponding tests.

Table 1
Results of Atterberg Limits for a replacement of natural aggregates per recycled concrete by 30%

Presentation and evaluation of results				
Test	Replacement samples (30%)	Evaluation	San Agustín quarry material sample (%)	Permissible values MTOP, Ecuador (%)
Limit liquid	21	Comply	31,86	25
Limit plasticity	3	Comply	5,59	6

The natural aggregates, for each intern and retained of each sieve, were replaced by gravimetric methods for crushed concrete corresponding to the size that dictated the separation of material through and retained from the sieves. Respectively, 30 percent and 50 percent of each portion was replaced and again mixed to perform the corresponding tests. In Table 2, the results of Atterberg Limits for a replacement of natural aggregates by recycled concrete by 50% are shown.

Table 2
Resultados de Límites de Atterberg para 50%

Presentation and evaluation of results				
Test	Replacement samples (50%) of their aggregates	Evaluation	Sample of San Agustín Quarry material without altering	Permissible values MTOP, Ecuador 2012
Limit liquid	18,00	Comply	31,86	25
Limit plasticity	1,08	Comply	5,59	6

Figure 1 shows a comparison of the Atterberg limits in samples, with 30%, 50% replacement, and original sample results comparing the liquid limit and plasticity (Ip) values

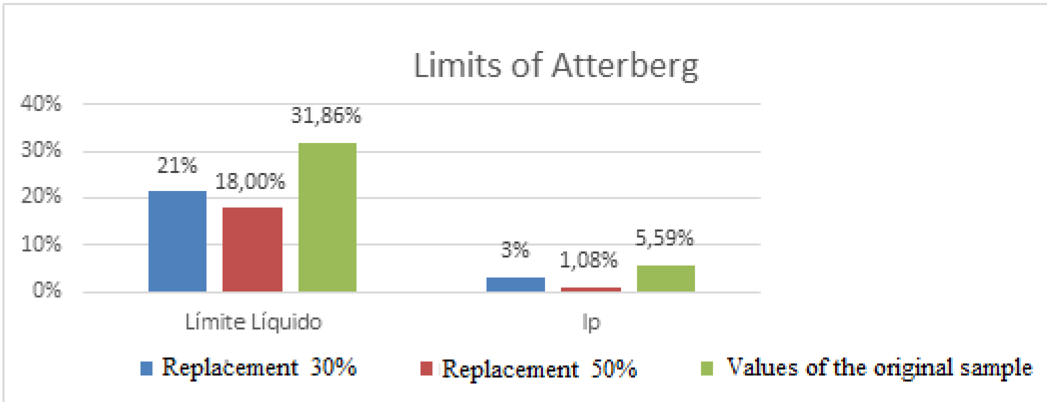

Figure 1. Comparison of results of Atterberg limits

The material resulting from the design of recycled sub-base with a 30% replacement presented a liquid limit of 21%, which, compared to the liquid limit that the material of the quarry originally had: 31.86%, means a decrease of 33, 14%, then the addition of crushed concrete improves this characteristic.

The material resulting from the design of recycled sub-base with a 30% replacement presented a plastic index of 3%, which, comparing it with the plastic index that the material of the quarry had originally: 5.59%, means a decrease of 46%, then the addition of crushed concrete improves this feature. The material resulting from the design of recycled sub-base with a 50% replacement presented a liquid limit of 18%, which, compared to the liquid limit that the material of the quarry had originally: 31.86%, means a decrease of 43.5%, then the addition of crushed concrete improves this feature. The material resulting from the design of recycled sub-base with a 50% replacement presented a plastic index of 1.08%. It is compared to the plastic index that the material of the quarry had originally: 5.59%, means a decrease of 80%, so it makes it NP (non-plastic), then the addition of crushed concrete improves this feature

3.2 Dynamic Abrasion

For the study of dynamic abrasion, the Los Angeles wear test was carried out according to the standard A.A.S.H.T.O. T-96, obtaining the results shown Table 3 and 4.

Table 3
Los Angeles Sample Attrition test result with 30% replacement of its aggregates versus the Los Angeles Attrition Sample test result

Presentation and evaluation of results				
Test	Replacement samples (30%) of their aggregates	Evaluation	Sample of San Agustín Quarry material without altering	Permissible values MTOP, Ecuador 2012
Aggregate Wear	16,96	No Cumple	50,00	50

Table 4
Los Angeles Sample Attrition Test Result with 50% Replacement of Aggregates versus Los Angeles Wear Testing Sample of Quarry Sample

Presentation and evaluation of results				
Test	Replacement samples (50%) of their aggregates	Evaluation	Sample of San Agustín Quarry material without altering	Permissible values MTOP, Ecuador 2012
Aggregate Wear	22	Fails	50,00	50

Figure 2 shows a comparative analysis of Los Angeles wear test results of samples with 30%, 50% replacement and original quarry sample

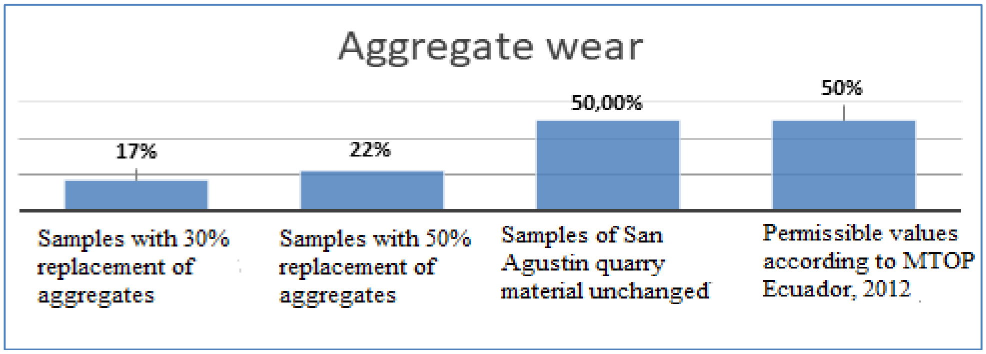

Figure 2. Comparison of Los Angeles wear test results

The material resulting from the design of recycled sub-base with a 30% replacement had a 17% dynamic wear. Therefore this design complies with the characteristics that the Ecuadorian norm dictates of not being greater than 50% for sub-base.[9] (Ecuadoran road vial nevi-2012). The material resulting from the design of recycled sub-base with a 50% replacement had a 22% dynamic wear. Therefore this design complies with the characteristics that the Ecuadorian norm dictates of not being greater than 50% for sub-base.[9] (Ecuadoran road vial nevi-2012).

3.3 Maximum dry density and optimum humidity

The analysis of maximum dry densities and optimum humidity were determined by the AASHTO Modified Proctor test. T-180.[9] Table 5 shows an analysis of maximum dry densities and optimal humidities in replacement of 30% of aggregates versus maximum dry densities and optimum humidities of the original quarry sample. The table shows the maximum dry densities and optimum humidity of the original sample of the quarry. Table 6 shows the analysis of maximum dry densities, optimal humidities in replacement of 50% of aggregates versus maximum dry densities and optimum humidities of the original simple.

Table 5
Maximum dry densities and optimum humidity of the original quarry sample

Presentation and evaluation of results				
Test	Replacement samples (30%) of their aggregates	Evaluation	Sample of San Agustín Quarry material without altering	Permissible values MTOP, Ecuador 2012

Dry maximum density	1854,00	Less	1984,00	s/n
Optimum Humidity	11,30 %	Less	11,33 %	s/n

Table 6
Analysis of maximum dry densities and optimum humidity in replacement

Test	Presentation and evaluation of results Replacement samples (50%) of their aggregates	Evaluation	Sample of San Agustín Quarry material without altering	Permissible values MTOP, Ecuador 2012
Dry maximum density	2008,00	Mayor	1984,00	s/n
Optimum Humidity	11,50 %	Mayor	11,33 %	s/n

In figure 3, the comparative chart of maximum dry density and optimum moisture test results of samples with 30%, 50% replacement and original quarry sample studied is shown. As the material resulting from the sub-base design is observed recycled with a 30% replacement presented a maximum dry density of 1854kg / m3, comparing it with the maximum dry density of the original quarry material: 1984kg / m3, noticing that it decreases by 6.5%.

It is also observed that the material resulting from the design of recycled sub-base with a 30% replacement presented an optimum humidity of 11.3%. Comparing it with the original optimum moisture of quarry material 11.33% means an increase of 0.26%. Therefore the addition of crushed concrete does not significantly affect this characteristic.

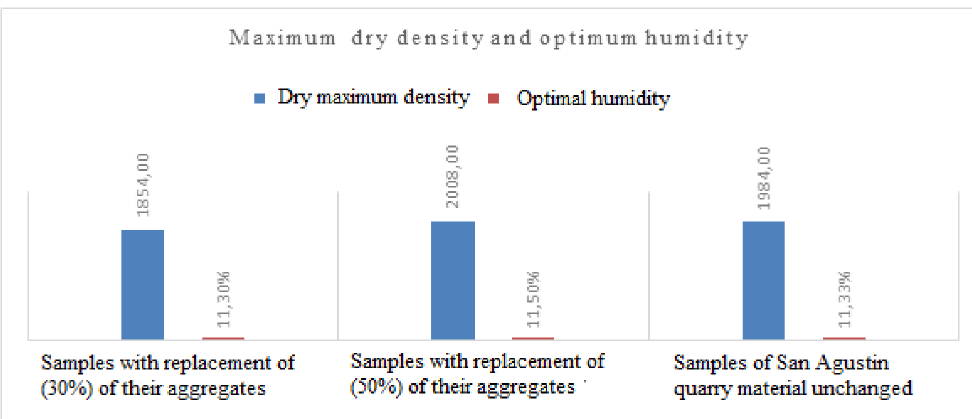

Figure 3. Comparative graph of test results of maximum dry density and optimum humidity of samples with replacement of 30%, 50% and original sample of quarry

The material resulting from the design of recycled sub-base with a 50% replacement presented a maximum dry density of 2008 kg / m^3, comparing it with the maximum dry density of the original quarry material: 1984 kg / m^3, it increases by 1.2%, so both the addition of crushed concrete positively affects this characteristic. The material resulting from the recycled sub-base design with a 50% replacement presented an optimum humidity of 11.5% which, compared to the original optimal moisture of the quarry material: 11.33%, means an increase of 1.5%. Therefore the addition of crushed concrete negatively affects this feature.

3.4 Aggregate carrying capacity

For the study of bearing capacity were determined according to the C.B.R test, AASHTO standard. T-193,[11] as shown in Figure 4. It is allowed determining the resistance to cut of a soil and aggregates compacted in the laboratory, with optimum humidity under different energies of compaction where they are subjected to shear stresses, and their quality is evaluated. This value simply measures the ratio of the unit load where its unit of measurement is in pounds/inches 2 which achieves a minimum penetration depth of the piston to the ground in an area of 19.4 cm2.[12]

Table 7
Carrying capacity of the aggregates

Presentation and evaluation of results						
Test	Replacement samples (30%) of their aggregates	Evaluation	Sample with replacement of (50%) of its aggregates	Evaluation	Sample of San Agustín quarry material without altering	Permissible values MTOP, Ecuador, 2012
CBR (%)	44	Higher	33	Higher	32,03	30

Figure 5 shows the comparisons of the results of the CBR test of the samples with replacements and the original of the quarry

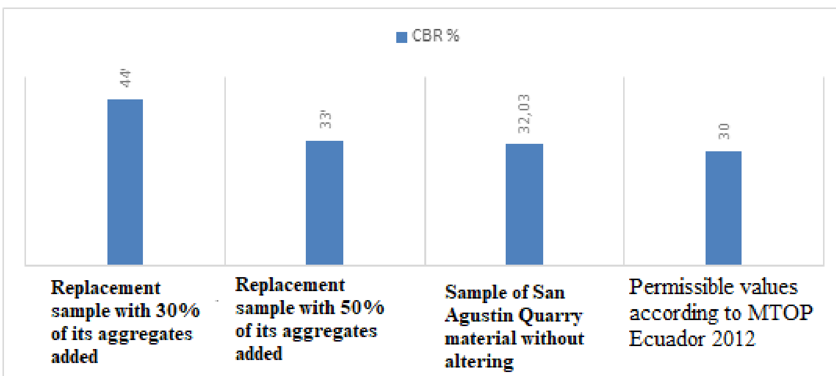

Figure 5. Comparison of CBR test results of samples with replacement and the original quarry

The material resulting from the recycled road sub-base design with a 30% replacement had a CBR of 44%, is characterized by this data as a granular sub-base of "good" quality, the addition of crushed concrete improved this characteristic by 27.2%.

The material resulting from the class 3 granular sub-base design recycled with a 50% replacement had a C.B.R. of 33%, is characterized by this data as road sub-base of "good" quality; the addition of the crushed concrete increased the CBR. The original material from the quarry of 32.03% improved this characteristic by 27.2%. These studies allowed us to take advantage of the residual material, as well as demonstrating that the environmental impact of the streets of the city. It was reduced with the re-use of waste material from the construction turned into rubble, the applied techniques can be applied to any construction waste. After a demolition, contributing to the improvement of the environment and the landscape.

4. Conclusion

The materials from the quarry of San Agustín showed adequate characteristics to make combinations with the generated debris, being able to be used as part of a mixture of recycled material to create sub-base of roads for complying with the Ecuadorian road norm for this type of aggregates. The combinations resulting from this research positively affect the original characteristics of natural quarry aggregates, increasing the usable volume of material and resulting in a reduction in production costs.

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