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RESEARCH ARTICLE

PROCESSED COARSE AGGREGATE AS BASE COURSE IN CONCRETE ROADS

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ABSTRACT

The study aimed to utilize the waste crushed concrete pavement as recycled or processed coarse aggregate for base course in concrete roads. Specifically, it aimed to determine the physical properties of the processed aggregate derived from waste crushed concrete pavement in terms of gradation, abrasion loss, Atterberg's Limits, Compaction test, California Bearing Ratio and Field Density Test. The study used the 65%/35% and the 50%/50% processed aggregate – natural aggregate proportioning and compared their physical properties with the natural aggregates in terms of the aforementioned parameters using ANOVA. A cost analysis was also conducted to determine the feasibility of the study. The 100 percent processed waste crushed concrete pavement aggregate passed the Particle size analysis test but failed in the Abrasion test. The 65 percent processed waste crushed concrete pavement aggregate blended with the 35 percent natural Daguitan aggregate y weight passed all the tests except the California Bearing Ratio test. The 50 percent processed waste crushed pavement aggregate blended with the 50 percent natural Daguitan aggregate by weight passed all the laboratory tests required of Item 201 (Base Course) materials. It can therefore be utilized as coarse aggregate for base course. The cost of obtaining one cubic meter of natural base course material is P850.00/cubic meter which is obviously more expensive than the processed aggregate which will cost only P600.00/cubic meter to process.

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INTRODUCTION

One of the main problems facing the country's construction industry right now is the dwindling supply of aggregate resources. Rapid urbanization is one of the main culprits in the diminishing supply of the country's aggregates. Aggregates, commonly known as sand and gravel, are inactive materials, which combined with Portland cement and water, produces concrete, mortar or plaster. There are essentially two types of aggregates, namely, the coarse aggregates and the fine aggregates. The fine aggregates and the coarse aggregates are known as sand and gravel. They make up approximately seventy-five percent of the concrete, a main construction material used in both vertical and horizontal construction. The fine and coarse aggregates that form an integral part of the concrete prevalently used as construction materials nowadays can be obtained by quarrying the river.

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Quarrying, otherwise known as the open pit mining of sand and gravel from the river, is a very negative environmental activity. Aside from the fact that it ultimately leads to the destruction of the river itself, it also lessens the water quality of the river, promotes rapid erosion and contributes to a host of other environmental-related problems like the exhaustion of aggregate resources. It should be noted that although these aggregate resources can be replenished, it takes Mother Nature several years, perhaps even centuries to replace them. It should therefore be one of the primary concerns of the Civil Engineers, the Contractors and the other people involved in the construction industry to reduce the consumption of aggregate resources as well as to reuse or recycle the said material. This can be achieved by either extending the life of the concrete structures or by recycling concrete waste materials as much as possible. The researcher wanted to determine if concrete waste, in particular concrete waste pavement resulting from the reblocking of roads, could be recycled and used as base course for highway concrete roads. Concrete waste comes from the destruction and demolition of numerous engineering structures like roads, buildings, houses, bridges, etc.

In the Leyte and Samar region, one of the more visible concrete wastes are the concrete pavement wastes resulting from the reblocking of roads. Reblocking is the economical process of replacing the defective portions of the road only. Since concrete waste constitutes for a substantial portion of the total waste generated by the construction industry, it is therefore important to study how these concrete waste can be recycled, improved and used as base course for roads and highways. The concrete waste pavements resulting from the reblocking of roads and highways litter the cities, towns and country sides of Leyte and Samar. They are not only considered as eyesores; they also are potential traffic hazards. It is also worthy to note that these disintegrated by natural processes. Hence, they are also future environmental concerns of Region VIII. Notwithstanding all the problems presented by the concrete waste materials, however, the researcher could still see a window of opportunity regarding this matter. By aiming to process concrete and utilize it as base coarse material, he is not only taking care of a perennial garbage problem, he is also be able to help preserve Mother Nature's dwindling aggregate resources.

General Objective

The primary objective of this study was to utilize the waste crushed concrete pavement as aggregate for base course.

Specific Objectives

The following were the specific objectives of this study:

- To process waste crushed concrete pavement into aggregate for base course;
- To determine the physical properties of the processed aggregate derived from waste crushed concrete pavement in terms of:
  - gradation,
  - abrasion loss,
  - Atterberg's Limits
  - Compaction Test,
  - California Bearing ratio,
  - Field Density test;
- To improve the physical properties of the processed aggregate through blending with natural aggregates of predetermined sources and properties using the following proportions:
  - 65% processed aggregate: 35% natural aggregate by weight,
  - 50% processed aggregate: 50% natural aggregate by weight,
- To compare the physical properties of the improved/blended aggregates to that of natural aggregates in terms of the aforementioned parameters;
- To conduct cost analysis

The need to reduce the consumption of the natural resources and the generation of waste is an urgent task for all who are engaged in the construction industry. If the country's progress is to be accompanied by the rapid deterioration of the environment, there will not be a sustainable development. One construction activity that has a very negative effect on the environment is quarrying, a form of open pit mining of coarse and fine aggregates. To limit quarrying to some extent, the study proposed to process concrete waste pavements as aggregates for base course materials. The processing of waste concrete pavement strikes at the very root of this quarrying problem because it allows for the conservation of mass. Figure 1 presents the schematic diagram of the development of processed aggregate derived from crushed waste concrete pavement.

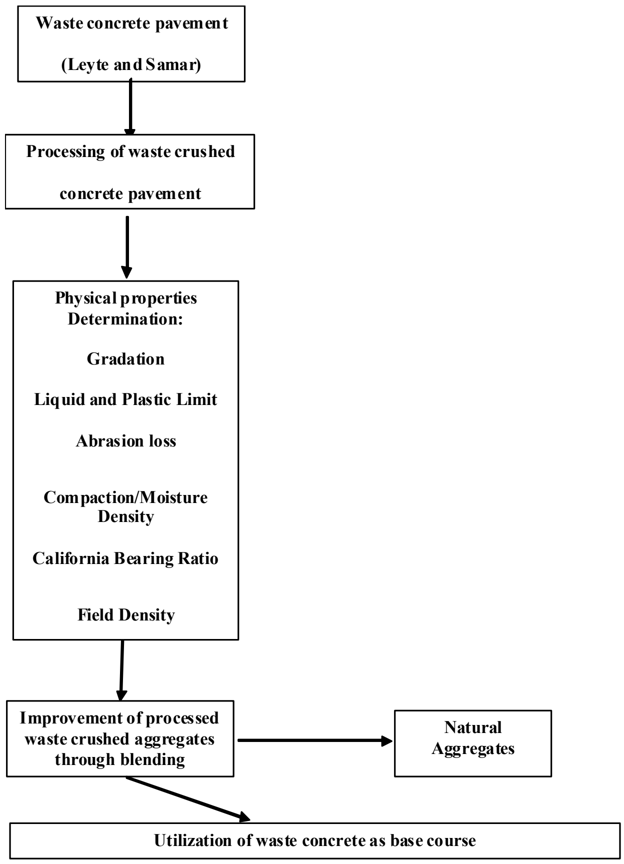

Figure 1.A Schema showing the conceptual framework of the study

Certain concepts, such as processing and re-using of waste concrete pavement, physical properties determination of the improved processed aggregate, comparison between the natural and the improved processed aggregate and the conservation of mass theory are cited in this framework, which served as guide in the development of the processed aggregate for base course use. The waste concrete pavement was obtained from among the waste concrete pavements resulting from the reblocking of Diamond street, barangay Tigawon, Tacloban City. The physical properties of the processed aggregates were determined by allowing them to undergo Sieve Analysis Test, Abrasion Test, Liquid Limit Test, Plastic Limit and Plasticity Index Test, Compaction Test, Moisture Density Relationship Test, California Bearing Ratio Test and Field density Test. Apparatus, instruments and other facilities for all laboratory test were limited to those available at the Department of Public Works and Highways, Region VIII, Government Center, Candahug, Palo, Leyte.

METHODS

The researcher used the Descriptive-Experimental research method in this study. The descriptive method uses fact-finding activities coupled with adequate interpretation while the experimental research has to do with controlled observation of change and development.

There was a need for the researcher to use both methods because some experiments, laboratory analysis, field-testing, data gathering and data interpretation were concluded to determine if waste crushed concrete pavement could be utilized as aggregate for base course. The concrete waste pavement that were used for crushing and obtaining the processed aggregates were identified by the researcher with the aid of the Department of Public Works and Highways (DPWH) Materials Division Chief. The concrete pavement slabs were obtained from among the waste pavements resulting from the reblocking and repair of the Diamond road along the barrio Tigawon. (See Figure 5 for location of barrio Tigawon). Apparatus, instrument and other facilities for all laboratory tests were limited to those available at the Department of Public Works and Highways, Region VIII, Government Center, Candahug, Palo, Leyte. The concrete slabs used for the crushing and obtaining the processed aggregate were obtained from among the waste pavement slabs that resulted from the reblocking of Diamond Street along barrio Tigawon. Barrio Tigawon was chosen over the other reblocking sites because it was very near the residences of the researcher and his laborer/assistant. Hence, the accessibility of the site allowed for easier hauling and transporting to the laborer's residence where the processing of the crushed slabs was to be done. To facilitate the transfer of the waste concrete slab from the reblocking site to the laborer's residence, the bigger slabs were first broken down into smaller slabs with a use of a mace. Then, they were loaded on a tricycle and transported to the laborer's residence. The smaller concrete slab sample were placed on a hard flat surface and were manually crushed with the aid of a mace and a hammer.

The volume of crushed aggregate derived from the manual pulverization of the waste concrete slabs was approximately 1.5 cubic meters. The transportation of the crushed concrete sample to the processing site together with the manual pulverization of the slab sample to coarse and the fine sizes took three days to accomplish. After making the necessary arrangements with the DPWH Materials Laboratory officials, the crushed products, which included the coarse and fine materials, were placed inside clean empty cement or rice sacks and were then brought to the Department of Public Works and Highways (DPWH) Materials Laboratory for Testing. Initially, only about five (5) sacks of the crushed aggregate, or about 0.3 cubic meter, were brought to the DPWH laboratory as the need arose. Extra care was taken so as not to include natural aggregate or soil into the sample bags.

The methods (i.e., mechanical splitter, quartering and miniature sampling) cover the reduction of field samples to the appropriate size for testing employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the field sample. In the study, the quartering procedure was used to reduce the field sample to testing size. The physical properties of the processed aggregates were determined by allowing them to undergo Sieve Analysis Test, Abrasion Test, Liquid Limit Test, Plastic Limit and Plasticity Index Test, Compaction Test, Moisture Density Relationship Test, California Bearing Ratio Test and Field density Test. The procedures of these tests can readily be found in the American Standards for Testing of Materials (ASTM) so they do not have to be discussed in the Methods. Initially, the laboratory tests for Item 201 (Base Course) were conducted on the 100 percent processed aggregate derived from the manual pulverization of waste concrete pavement. The 100 percent processed aggregate passed the Sieve Analysis Test but failed the Abrasion Test so no further test were done on the said sample. The quality and the durability of the processed aggregate were improved by blending it with the natural Daguitan aggregate. Initially, a 65 percent processed aggregate/ 35 percent Daguitan natural aggregate blending proportion was used. This was achieved by mixing 65 percent by weight of processed aggregate that were retained on the 2 inch, 1 ½ inch, 1 inch, ¾ inch, ½ inch, 3/8 inch, #4, #10, #40, and #200 sieves with 35 percent by weight of the natural Daguitan aggregate that were retained on the same set of sieves. This blending proportion passed the Sieve Analysis Test, Abrasion Test, Liquid Limit Test, Plastic Limit and Plasticity Index Test, the Compaction Test and Moisture Density Relation Test but failed in the California Bearing Ratio Test.

To ensure that the blended aggregate sample would pass all the laboratory tests for Item 201 (Base Course), a 50 percent processed aggregate was blended with 50 percent natural Daguitan aggregate using the same procedure indicated in Step No. 2. The 50 percent processed aggregate blended with the 50 percent natural Daguitan aggregate finally passed all the Laboratory Tests for Item 201 (Base Course). The 50 percent processed aggregate that was blended with the 50 percent Daguitan natural aggregate was made to undergo the following tests three times: Particle size analysis test; Abrasion loss test; Liquid Limit test; Plastic Limit and Plasticity Index test; Compaction test; California Bearing Ratio test and the Field Density test. The results of the tests done on the improved blended aggregate were compared to the predetermined results of the tests done on the three natural aggregates namely, the Daguitan river aggregate from Dulag, Leyte, the Panilahan river aggregate from Ormoc, Leyte and the Subang Daku river aggregate from Maasin, Leyte (For the locations of the Leyte towns, refer to Figure 6). The Analysis of Variance (ANOVA) Two Way Classification test using α = 0.05 was used to determine if there was a significant difference between the Particle size distribution test results of the improved blended aggregate and the natural aggregates. For all the other laboratory tests, the Analysis of Variance (ANOVA) One Way Classification test using α = 0.05 was used to determine if there were significant differences between the laboratory test results of the improved blended aggregate and the natural aggregates (For the results and detailed computations using the ANOVA One Way and Two Way Classification tests, refer to Appendix B). The data used by the researcher in the cost analysis of the natural aggregate vis-à-vis the improved blended aggregate were from the Department of Public Works and Highways. In conducting the cost analysis of the two types of base courses, the cost per cubic meter of the natural base course material was compared to the cost incurred in obtaining one cubic meter of processed aggregate for base course use. The result of the cost analysis study are discussed in the next chapter.

RESULTS AND DISCUSSION

Table I presents all of the laboratory test results of the three natural aggregates (Daguitan, Panilahan and Subang Daku samples), the 100 percent processed aggregate, the 65 percent processed aggregate blended with the 35 percent natural Daguitan aggregate and the 50 percent processed aggregate blended with the 50 percent natural Daguitan aggregate.

Table 1. summary of laboratory tests results (natural and blended aggregates)

Test	Daguitan Aggregate	Panilahan Aggregate	Subang Daku Aggregate	100% Processed	65%/ 35% Blended	50/50 "A" Blended	50/50 "B" Blended	50/50 "C" Blended
Sieve Analysis								
1 ½"	95	100	100	100	100	100	100	100
1"	88	63	99	100	98	90	90	90
¾"	81	48	81	83	83	75	75	75
½"	74	42	64	30	76	69	69	69
3/8"	68	0	52	15	68	61	61	61
#4	62	35	29	8	51	44	44	44
#10	56	28	25	5	39	30	30	30
#40	41	20	21	3	21	11	11	11
#200	6	9	5	0.7	3	3	3	3
Atterberg's Limits								
Liquid Limit	-	25	-		-	-	-	-
Plasti-city Ind.	Non Plastic	Non Plastic	Non Plastic		Non Plastic	Non Plastic	Non Plastic	Non Plastic
Abrasion Loss, %	32.0	29.0	32.4	59 (Failed)	49.0	41.0	43.0	45.0
Compaction Test								
MDD Kg/cu.m.	2.10	1.91	1.96		1.84	1.93	1.95	1.931
OMC %	11.0	10.5	12.31		15.5	13.0	12.0	13.5
California Bearing Ratio								
CBR Value	90.0	81.0	83.0		63.0 (Failed)	81.0	85.0	84
Swell	0	2.58	0		0	0	0	0
Field Density	101	100	101			102.0	103.0	104.0
Remarks	Passed	Passed	Passed	Failed	Failed	Passed	Passed	Passed

As shown in Table 1, the 65 % processed waste crushed concrete pavement aggregate and 35 % Natural Aggregate blended aggregate as well as the 50%/50% proportioning of the blended aggregate satisfied the Item 201 governing requirement for the 1 ½ inch (100% passing), ¾ inch (83% passing), No. 4 (51% passing), No. 40 (21% passing), and the No. 200 (3% passing) sieves. With respect to the Atterberg's Limits, the 65 percent processed aggregate blended with 35% Daguitan Aggregate exhibited non-plastic properties. Since the Item 201 governing specification for the Liquid Limit test is from zero (0) to twenty-five (25) maximum and for the Plasticity Index test is from zero (0) to 6 maximum, the 65 percent processed aggregate blended with 35 percent Daguitan sample passed these two tests. It was expected that the sample would exhibit a non-plastic property.

Based on the Table 1, all the three improved blended samples with a 50 percent processed, 50 percent natural aggregate proportioning demonstrated non-plastic properties. The mean value of the three blended samples therefore, is also non-plastic. This is within the range of the base course specification. Again, it was mainly composed of mortar and fine and coarse aggregates. Unlike the 100 % processed aggregate which failed the Abrasion Test, the blended aggregate with a proportioning of 65 % processed waste crushed pavement aggregate and 35 % natural aggregate passed the crucial Abrasion Test. The blended sample lost 49.0 percent of its total mass so it is within the maximum Item 201 governing requirement for Abrasion loss at 50.0 percent. This laboratory test result indicated that the sample just barely passed the important Abrasion Loss test and could be considered as a borderline or marginal sample. Nevertheless, the base course sample with the 65 % processed and 35 % natural aggregate proportioning was made to undergo all tests required of the base course samples. The results show that the Abrasion Loss percentage of all the three 50 percent processed / 50 percent Daguitan blended aggregate are well below the Item 201 (Base Course) specification of 50.0 percent maximum loss. When subjected to the Abrasion Test, Sample A lost only 41 percent of its total mass, Sample B lost 43 percent of its total mass and Sample C lost 45 percent of its total mass. The mean value of 43.0 percent for all the three blended samples is also below the 50 percent maximum loss allowance for Abrasion Loss test. The test results also showed that there was an improvement in the structural strength of the processed aggregate when the natural aggregate was increased to 50 percent. Hence, there appears to be a direct relationship between the structural strength of the processed sample and the quantity of natural aggregate added into the sample.

The 65%/35% blended aggregate had a maximum density of 1.84 kg/ cu.m. while its Optimum Moisture Content (OMC) was observed to be 15.5 %. Although there are no Item 201 or base course specifications on the two tests, the Compaction Test can give the relative density of the base course sample and its ability to absorb water while undergoing compaction. These are two very important physical properties of soil samples that are to be used as base, subbase or subgrade material. The laboratory findings reveal that for the 50%/50% blended aggregate, the Maximum Dry Densities for Sample A, B, and C are 1.93 kg/m^3, 1.95 kg/m^3, 1.931 kg/m^3 respectively. The Optimum Moisture Content of the three blended samples are 13.0 percent (Sample A), 12.0 percent (Sample B) and 13.5 percent (Sample C). There is no Item 201 governing requirement as far as these results are concerned.

The laboratory findings also reveal that samples A, B and C of the 50%/50% proportioning had higher Maximum Dry Density values than the 65 percent processed/ 35 percent natural aggregate sample. As in the Abrasion Loss Test, there is a direct relationship between the amount of natural aggregate added into the processed aggregate and the Maximum Dry

Density attained by the sample after it underwent a compaction test. The test results of Table1 shows that while the 65 percent/ 35 percent proportioning of the processed waste crushed concrete pavement and Daguitan samples passed the crucial Abrasion Test, it failed in the equally important California Bearing Ratio Test. The California Bearing Ratio Test is also a critical test because it is an accurate indicator of the bearing capacity or the load bearing capacity of the soil. Since the sample failed in the California Bearing Test, it could not be utilized as a base course material. The table shows that for the 50%/50% blended aggregate, sample A (81.0 percent), Sample B (85 percent) and Sample C (84.0 percent) all passed the minimum Item 201 governing California Bearing Ratio requirement of 80.0 percent. The California Bearing Ratio mean value of the three blended aggregate (83.3 percent) also passed the minimum requirement.

The California Bearing Ratio Test is as significant as the Abrasion Loss Test because it gives a measure of the bearing capacity of load carrying of the base course sample. With the passing of this test, it can be said that the Samples A, B and C can be used as base course. With regards to the Field Density Test, the degree of Compaction values of Samples A, B and C are 102 percent, 103 percent and 104 percent respectively. These aforementioned values, together with the degree of compaction mean value of 103 percent, are greater than the 100 percent Item 201 minimum governing specification. In a capsule, the 100 percent processed waste crushed concrete pavement aggregate passed the Particle size analysis test but failed in the Abrasion test. The 65 percent processed waste crushed concrete pavement aggregate blended with the 35 percent natural Daguitan aggregate y weight passed all the tests except the California Bearing Ratio test. The 50 percent processed waste crushed pavement aggregate blended with the 50 percent natural Daguitan aggregate by weight passed all the laboratory tests required of Item 201 (Base Course) materials. The study made use of the Analysis of Variance (ANOVA) two way classification test to determine if there is a significant difference between the Percentage Passing test results of the three natural aggregates and the three improved processed aggregates with a 50/50 proportioning.

The laboratory test result showed that there is a significant difference between the two groups of samples as far as the gradation physical property is concerned even though all samples are within the Item 201 (Base Course) governing specifications. For instance, the allowable ranges of percentage passing for the ¾ inch, #4, #40, and #200 sieves are from 60 to 85, 30 to 35, 8 to 25 and 2 to 14 respectively. The varying Percentage Passing values obtained from the different soil samples, natural or blended, also illustrates the variable characteristics of soil. The study made use of the Analysis of Variance (ANOVA) one-way classification test to determine if there is a significant difference in the laboratory test results of all the other physical properties (See Tables 2 and 3). The conclusion drawn from the ANOVA one way classification test is that there is no significant difference between Liquid Limit and Plasticity Index test results of the three natural aggregates (i.e., Daguitan, Panilahan and Subang Daku samples) with the 50/50 improved blended processed aggregate. Both groups of samples exhibited non-plastic properties which is typical of river plain deposits. The 100 percent waste crushed pavement aggregate sample was not subjected to the Atterberg's Limits tests any more after it failed in the Abrasion test. It did not come as a surprise when the 100 percent waste crushed concrete pavement aggregate sample failed in the Abrasion test. Since most of the larger particles were still coated with mortar at the time the test was conducted, the 100 percent processed aggregate lost a lot of its mass when it was subjected to the Abrasion test. The 65 percent waste crushed concrete pavement aggregate blended with the 35 percent natural Daguitan aggregate sample just barely passed the Item 201 governing specification for the Abrasion Test. It lost 49 percent of its mass, just one percent short of the 50 percent maximum allowable abrasion loss for base course materials. The test result for the said sample indicated that it was not structurally strong since it was a borderline case.

The results of also show that as far as the Abrasion test is concerned, the strength of the blended aggregate increases when the amount of natural Daguitan aggregate is increased. Conversely, the amount of mass lost by the improved blended processed aggregate decreases when it is subjected to the Abrasion test as the amount of natural Daguitan aggregate is increased. One can therefore improve the strength of the blended aggregate by increasing the amount of natural aggregate that is to be added into the blended aggregate. The ANOVA one way classification test done on the Abrasion Loss test results showed that there is a significant difference between the three natural aggregate samples and the three 50/50 improved blended aggregate samples. While both group of samples were within the 50 percent maximum allowable abrasion loss, the 50/50 improved blended processed aggregates lost more mass than the natural aggregates. These underscore the fact that the natural aggregates are stronger than the processed aggregates. It can be observed from Table I that there is a direct relationship between the Maximum Dry Density (MDD) of the improved blended aggregate and the amount of natural Daguitan aggregate added into the improved blended base course material. That is, a greater degree of compaction, and hence a greater stability and a lesser chance of settlement, is attained by the improved blended aggregate as the proportioning of the natural aggregate is increased. For instance, the Maximum Dry Density value arrived at by the 65 percent processed/ 35 percent natural Daguitan blended aggregate is only 1.84 kg/cu. m. in contrast, the three samples with the 50 percent processed/ 50 percent natural Daguitan aggregate proportioning had 1.93 kg/cu. m., 1.95 kg/cu. m. and 1.931 kg/cu. m. Maximum Dry Density values.

Using the ANOVA one way classification test done on Compaction laboratory test results of the three natural samples and the three improved blended samples with a 50/50 proportioning, it was determined that there is no significant difference between the compaction physical properties of the two groups. There is, however, no Item 201 (Base course) specification on the said physical property. The California Bearing test is an indicator of the bearing capacity or the load carrying capacity of the soil. While the 100 percent processed waste crushed concrete pavement aggregate failed in the Abrasion test, the improved blended aggregate with a 65 percent processed/35 percent natural Daguitan aggregate proportioning passed the Abrasion test but failed in the California Bearing Ratio test. The 65/35 improved blended aggregate only had a California Bearing Ratio (CBR) value of 63 percent. This is way below the Item 201 (Base Course) governing specification of 80 percent. In contrast, the three improved blended aggregate with 50/50 proportioning of the processed and natural aggregates had CBR values of 81.0 percent, 85.0 percent, and 84.0 percent.

The aforementioned CBR values again show that the quality of the blended aggregate can be improved by increasing the amount of natural aggregate present in the soil mixture. The ANOVA one way classification test done on the California Bearing Ratio test results showed that there is no significant difference between the three natural aggregate samples and the three 50/50 improved blended aggregates samples. The Field Density Test compares the degree of compaction between aggregates. Comparing the degree of compaction values of the three natural aggregates and the three improved blended aggregates with 50/50 proportioning, it can be observed that the latter had higher degree of compaction values. One possible explanation to these test results is that since the improved blended aggregates had weaker coarse grain materials than the natural aggregates, it was easier to compact the improved blended aggregates.

Again, the ANOVA one way classification test done on the Field Density test results showed that there is no significant difference between the three natural aggregate samples and the three 50/50 improved blended aggregate samples. With respect to the cost analysis, it took the laborer three days to pulverize and process 1.5 cubic meter of waste concrete pavement as aggregate for base course use. Since the laborer was paid P200.00/day, the total cost of obtaining the 1.5 cubic meters of processed aggregate is P200.00 times three days or P600.00. On a per cubic meter basis, the cost therefore of obtaining one cubic meter of processed aggregate is P600.00/1.5 cubic meters or P400.00/cubic meter. It should be noted that there are no stockpiling costs, material costs, hauling costs, etc. in obtaining the processed aggregate because it is presumed that the waste concrete pavement material will be obtained at the job site. The cost of obtaining one cubic meter of natural base course material is P850.00/cubic meter which is obviously more expensive than the processed aggregate.

Conclusion

Based on the results obtained from the study conducted, the following conclusions are drawn:The waste concrete pavement can be processed as aggregate for base course use by manually pulverizing the waste material with the aid of a hammer and a mace; The 100 percent processed aggregate cannot be used as base course; The 65 percent processed aggregate blended with the 35 percent natural Daguitan sample likewise cannot be used as base course; The 50 percent processed aggregate blended with the 50 percent natural aggregate can be used as base course; There is no significant difference between the 50 percent processed aggregate blended with the 50 percent natural Daguitan sample and the natural aggregate as far as Atterberg's Limits (Liquid Limit, Plastic Limit and Plasticity Index), Maximum Dry Density, California Bearing Ratio and the Field Density physical properties. There is a significant difference, however, in the gradation and abrasion loss properties between the improved blended aggregate and the natural Daguitan sample. The strength and durability of the processed aggregate can be improved by blending the processed aggregtate with natural aggregate; The use of processed aggregate in lieu of the natural aggregate should be encouraged in areas which are well beyond the 25 kilometer radius of the traditional sources in Leyte of base course materials (i.e., Dulag, Ormoc, Maasin, etc.).

The use of processed aggregate in lieu of the natural aggregate should particularly be encouraged in the whole Samar province because good quality river aggregate is not available in the said province; Whenever feasible, the use of processed aggregate in lieu of the natural aggregate improves the construction methods and procedures because there is no need for the contractor to haul sand and gravel from- flung areas. The contractor only needs to pulverize the waste concrete pavement to obtain his aggregate; And, the blended improved processed atural aggregates can be used in areas or towns where good quality aggregates are not available. They can also be use in countries such as Japan where their aggregate resources are about to be exhausted from over-consumption.

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APPENDICES OF TABLES

Table 3. Anova one way classification Computation of means (particle size analysis)

No. of Blows	Natural Aggregate	50/50 Processed Aggregate	
	25	0	
	0	0	
	0	0	
Total	25	0	25
Mean	8.33	0	4.17

Table 4. Particle size distribution of 100 percent processed waste crushed pavement aggregate

Sieve Size	100 Percent Processed Aggregate % Passing	Item 201 Governing Specification % Passing	Remarks
1 ½ "	100	100	Passed
1 "	100		
¾ "	83	60-85	Passed
½ "	30		
3/8 "	15		
#4	8	30-55	Failed
#10	5		
#40	3	8-25	Failed
#200	0.7	2-14	Failed

Table 5. Percentage abrasion loss of 100 percent processed waste crushed pavement aggregate

Type of Test	100 Percent Processed Waste Crushed Aggregate	Item 201 Governing Specification	Remarks
Abrasion Loss (%)	59 %	50 max.	Failed

Table 6. Particle size distribution of 65% processed waste crushed pavement, 35% daguitan aggregate

Sieve Size	65% Processed, 35% Daguitan Blended Aggregate	Item 201 (Base Course) Governing Specification	Remarks
1 ½ "	100	100	Passed
1 "	98		
¾ "	83	60-85	Passed
½ "	76		
3/8 "	68		
#4	51	30-55	Passed
#10	39		
#40	21	8-25	Passed
#200	3	2-14	Passed

Table 7. Liquid limit and plasticity index of 65% processed blended with 35% daguitan aggregate (atterberg's limits)

Sieve Size	65% Processed Blended w/ 35% Natural Daguitan Aggregate	Item 201 (Base Course) Governing Specification	Remarks
Liquid Limit	-	25.0 max.	Passed
Plasticity Index	Non Plastic	6.0 max.	Passed

Table 8. Percentage abrasion loss of 65% processed blended with 35% daguitan sample

Type of Test	65% Processed Blended w/ 35% Natural Daguitan Sample	Item 201 (Base Course) Governing Specification	Remarks
Abrasion Loss (%)	49.0	50.0 max.	Passed

Table 9. Moisture density relationships of 65% processed and 35% daguitan blended aggregate

Type of Test	65% Processed Blended w/ 35% Daguitan Aggregate	Item 201 (Base Course) Governing Specifications	Remarks
Moisture Density			
1. Max Density (kg/m^3)	1.84	None	None
2. Optimum Moisture Content (OMC)	15.5	None	None

Table 10. california bearing ratio of 65% processed and 35% daguitan blended aggregate

Type of Test	65% Processed Blended w/ 35% Daguitan Aggregate	Item 201 (Base Course) Governing Specifications	Remarks
California Bearing Ratio (CBR)			
1. CBR Value (%)	63.0	80.0 min.	Failed
2. Swell	0	None	None

Table 11. Particle size distributionof 50% processed and 50% daguitan blended aggregate

Sieve Size	Sample A % Passing	Sample B % Passing	Sample C % Passing	Mean or Average % Passing	Item 201 Governing Specification % Passing	Remarks
1 ½”	100	100	100	100	100	Passed
1 “	90	90	90	90		
¾”	75	75	75	75	60-85	Passed
½”	69	69	69	69		
3/8”	61	61	61	61		
#4	44	44	44	44	30-55	Passed
#10	30	30	30	30		
#40	11	11	11	11	8-25	Passed
#200	3	3	3	3	2-14	Passed

Table 12. Liquid limit and plasticity indexof 50% processed and 50% daguitan aggregate (atterberg’s limits)

Test of Test	Sample A	Sample B	Sample C	Mean Value	Item 201 Governing Specification	Remarks
Liquid Limit	-	-	-	-	25.0 max.	Passed
Plasticity Index	Non-plastic	Non-plastic	Non-plastic	Non-plastic	6.0 max.	

Table 13. Percentage abrasion loss of 50% processed and 50% daguitan aggregate

Test of Test	Sample A	Sample B	Sample C	Mean Value	Item 201 Governing Specification	Remarks
Abrasion Loss (%)	41.0	43.0	45.0	43.0	50.0 max.	Passed

Table 14. Moisture density relationships of 50% processed and 50% daguitan blended aggregate

Type of Test	Sample A	Sample B	Sample C	Mean Value	Item 201 Governing Specification	Remarks
Moisture Density Test						
a. Max. Dry Density	1.93	1.95	1.931	1.937	None	None
b. Optimum Moisture Content	13.0 %	12.0 %	13.5 %		None	None

Table 15. California bearing ratio (cbr) test on 50% processed and 50% daguitan blended aggregate

Type of Test	Sample A	Sample B	Sample C	Mean Value	Item 201 Governing Specification	Remarks
California Bearing Ratio (CBR)						
a. CBR (%)	81.0	85.0	84.0	83.33%	80 min.	Passed
b. Swell	0	0	0	0	None	None

Table 16. Field density test on 50% processed and 50% Daguitan blended aggregate

Type of Test	Sample A	Sample B	Sample C	Mean Value	Item 201 Governing Specification	Remarks
Field Density Test						
Degree of Compaction %	102.0	103.0	104.0	103.0	100	Passed

Table 17. Anova two way classification computation of means (particle size analysis)

Sieve Analysis	Panilahan Sample	Daguitan Sample	SubangSample	50-50 Processed Sample (average)	Total	Mean
1 ½”	100	95	100	100	395	98.75
1”	63	88	99	90	340	85
¾”	48	81	81	75	285	71.25
½”	42	74	64	69	249	62.25
3/8”	40	68	52	61	221	55.25
#4	35	62	29	44	170	42.5
#10	28	56	25	30	139	34.75
#40	20	41	21	10.67	92.67	23.17
#200	9	6	5	3	23	5.75
Total	385	571	476	482.67	1914.67	
Mean	42.78	63.44	52.89	53.63		53.19

Table 18. Anova one way classification computation of means (abrasion loss)

	Natural Aggregate	50/50 Processed Aggregate	
	29.0	41.0	
	32.0	43.0	
	32.4	45.0	
Total	93.4	129	222.4
Mean	31.13	43	37.07

Table 19. Anova one way classification computation of means (particle size analysis)

No. of Blows	Natural Aggregate	50/50 Processed Aggregate	
	25	0	
	0	0	
	0	0	
Total	25	0	25
Mean	8.33	0	4.17

Table 20. Anova for the data in table xix (liquid limit)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	Computed f
Column Means	104.17	1	104.17	1.0
Errors	416.66	4	104.17	
Total	520.83	5		

Table 21. Anova for the data in table xix (abrasion loss)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	Computed f
Column Means	211.23	1	211.23	56.6
Errors	14.9	4	3.73	
Total	226.13	5		

Table 22. Anova one way classification computation of means (maximum dry density)

	Natural Aggregate	50/50 Processed Aggregate	
	1.91	1.93	
	2.10	1.95	
	1.96	1.931	
Total	5.97	5.811	11.781
Mean	1.99	1.937	1.9635

Table 23. Anova for the data in table xxiii (maximum dry density)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	Computed f
Column Means	4.21×10^{-3}	1	4.21×10^{-3}	0.842
Errors	0.02	4	5×10^{-3}	
Total	0.02421	5		

Table 24. Anova one way classification computation of means (california bearing ratio value)

	Natural Aggregate	50/50 Processed Aggregate	
	81.0	81.0	
	90.0	85.0	
	83.0	84.0	
Total	254	250	504
Mean	84.67	83.33	84.0

Table 25. Anova for the data in table xxv (california bearing ratio)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	Computed f
Column Means	2.67	1	2.67	0.20
Errors	53.33	4	13.33	
Total	56	5		

Table 26. Anova one way classification computation of means (degree of compaction)

	Natural Aggregate	50/50 Processed Aggregate	
	101	102	
	100	103	
	101	104	
Total	302	309	611
Mean	100.67	103	101.83

Table 27. Anova for The Data in table Xix (Abrasion Loss)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	Computed f
Column Means	8.16	1	8.16	3.06
Errors	2.67	4	2.67	
Total	10.83	5		

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