

EVALUATION OF THE PROPERTIES OF RECYCLED CONCRETE AGGREGATE AND THEIR POTENTIAL USE IN ROAD PAVING

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Abstract

Concrete is one of the most widely used building materials due to its many advantages, which results in large amounts of concrete waste resulting from demolition. This study will be an attempt to produce an environmentally friendly road. In this research, recycled aggregates were used according to the class A and B, used in the Iraqi specifications for roads and bridges (SORB). Two methods were used, the first method was to use recycled aggregate of class A and B with different proportions of fine soil, as a binding material for the aggregate particles, and the second method was to use recycled aggregate of class A and B with different proportions of fly ash as a binding material for the aggregate particles. The physical and mechanical properties of the recycled aggregate were studied, the behaviour of road layers designed from recycled aggregate was also studied by determining the California bearing ratio in dry and wet conditions, as well as the unconfined compressive strength. The research showed that when using (5%, 10%, 14%) of fine soil with recycled aggregate, the California bearing ratio fit gave high and acceptable values. However, when increasing the ratio to 16%, the values decreased from 41.0% to 38.7% for class A in the soaking state, but in the unsoaking state, it decreased from 44.6% to 42.0% and Also the class B values decreased in the soaking state from 41.4% to 39.3%, and in the unsoaking state from 45.0% to 43.2%. Likewise The unconfined compressive strength decreased by 25% when the fine soil content increased to 16% while the values increased with increasing fly ash content. This study concluded that it is possible to use recycled aggregate in the design of road layers, especially since the values of the California bearing ratio of recycled aggregate are greater than the values of natural aggregate used in road works. Thus, this study achieved a major goal from an environmental and economic perspective.

Keywords:

mechanical properties
fine soil
California bearing ratio (CBR).
unconfined compressive strength
fly ash

1 Introduction

Although Iraq is relatively rich in natural aggregate stocks, this paper focuses on recycled concrete as a primary road material in order to dispose of this waste in a fruitful and safe manner. The waste materials from demolished building are crushed to produce a variety of particle sizes satisfying the gradations requirements of Iraqi specifications for sub base course. Road construction often involves the encountering of low-strength soil strata, which exert a substantial influence on multiple stages of construction design [1-3].

Recycling has become a policy adopted and insisted by many developed countries and is considered in New Zealand and Denmark is the leader in it [4]. As shown in Figure (1), and this process is summarized by The collection of demolition and construction waste, treatment and reuse of it again, that is. This method is as a landfill, and it contributes to preserving the original natural resources.

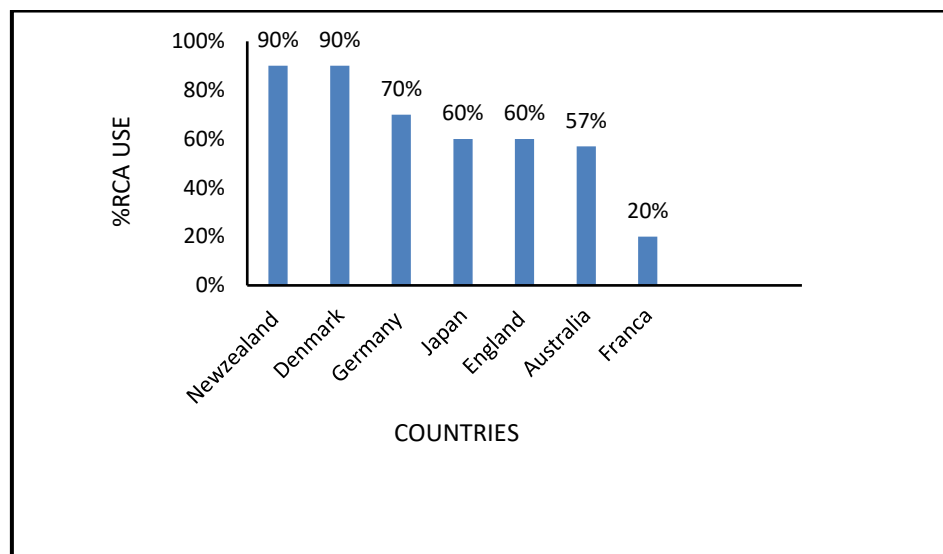


Fig. 1: the quantity of concrete debris recycled in certain places throughout the world [4]

Several research have looked into the usage of recycled concrete aggregate in road layer design. In a subsequent stage, twelve RCA batches from various suppliers were use in two concrete. Road pavement construction applications in which RCA replaced 20 to 40% of the coarse portion of limestone, above the current allowable replacement rate of 20% defined by S250. However, the outcomes showed that the recycled aggregates' characteristics fell within the specified bounds. In road pavements, these RCA might therefore be a suitable material for base or sub-base layers. Further studies validated these findings. According to Celeen (2007), approximately 85% of recycled aggregate is use in the United States for base or sub-base courses [5]. Similar quantities of virgin aggregates were utilize in both recycled and conventional pavements, and the results were equivalent [6]. According to the study, recycled mixes with suitable mechanical qualities can be used to make road sub-bases [7].

Numerous studies have determined that recycled concrete aggregate (RCA) varies from natural aggregate in a number of ways. The primary distinction is that RCA has a much higher absorption rate than natural aggregate and has been shown to negatively affect the thermal expansion behavior of concrete at 28 days of concrete age [8]. The sub base of highways is the ideal place for crushed concrete; layers above the sub base should not use it. Furthermore, crushed concrete may be used to build bike and pedestrian routes [9].

Because there is a lot of adhering mortar present, recycled concrete aggregates made using solely primary crushing have a much greater absorption rate than virgin coarse aggregates. [10]. Based on the findings of the CBR test, it can be concluded that recycled concrete has much greater CBR values than regular sub base. Thus, it is possible to draw the conclusion that recycled concrete might be utilized in high ways as a subbase material [11]. Combinations consisting of 40% and 50% waste aggregates and 60% and 50% laterite Due to their respective CBR values of 46 and 59, soils were deemed appropriate for use as sub base material [12]. Although its main usage has been in pavement sub base materials, RCA has also been applied in a variety of other contexts, including general fill, embankment material, concrete, and asphalt paving layers [13].

By enacting various laws and raising public awareness via various initiatives to lessen the effects on the environment, several nations throughout the world are attempting to reduce their building and demolition waste[14]. Fly ash falls into one of three categories: class C, class F, or class N (ash that does not fit the requirements for classes C or F). Using ASTM C 618 standards as a base [15].

Examined the strengthening of soil stabilization using fly-ash-based geopolymer an evaluation of fly ash, soil, water, and alkali activators. Eight molars of molarity was set, and the fly ash to soil ratios were 0.3, 0.6, 0.8, and 0.9. The findings show that strength rises with an increase in the fly ash/soil ratio [16]. In this investigation, hollow bricks were made using fly ash, cement, and sand. A maximum compressive strength of 13.15 MPa and an increased compressive strength of 64.3% were obtained by using fly ash [17]. In order to limit nearly distress, lower maintenance costs, and extend the service life of roads, the reinforcing pavement layer became a crucial element in the design and repair of pavement layers[18].

2 Methodology

2.1 fine soil used

Fine soil was used as a binding material for the recycled aggregate granules. The proportions (5%, 10%, 14%, and 16%) were use with the A and B grades. Many proportions were use and these proportions were the optimal proportions for the work. The soil was light reddish brown, and they were groups as (A-2-6) and According to unified soil classification.

2.2 Recycled Concrete Aggregate

Recycled concrete aggregate obtained from the debris of demolished buildings. Recycled concrete aggregate was used according to the Iraqi specification for roads and bridges, which stipulates four classes for designing the subbase layer of the road, namely (A, B, C, D), where work was done on class A and B.



Fig. 2: Shows the recycled aggregate and the used clay soil

2.3 Fly Ash

One byproduct of burning coal in an industrial environment is fly ash, a leftover material. It is made up of tiny particles that are taken away by exhaust fumes; base ashes are the ones that do not climb. Fly ash has a heterogeneous composition; its usual constituents are silicon dioxide (SiO_2), magnesium oxide (MgO), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), and calcium oxide (CaO). Fly ash was used as a binder for the recycled aggregate granules at rates of (5%, 10%, 14%, and 16%) for class A and B.



Fig. 3: Shows the recycled aggregate and the fly ash

2.4 Natural materials

The natural materials used primarily in road layers in Iraq, especially the sub-base layer, are a diverse mixture of sand, gravel, crushed rocks and clay in different proportions. The materials that pass through the sieve with a size of 0.075 mm, ranging from 5-20%, are use in the sub-base of roads.



Fig. 4: Shows the natural materials used in the road layers.

3 Sample Preparation:

This study covered 34 California bearing capacity test samples including 16 recycled aggregate mixed with fine soil of classes A and B, 16 recycled aggregate mixed with fly ash of classes A and B, and 2 natural material samples.

4 Test

Class A and B for sub base are use according to the following approved tests:

- 1 - Maximum dry density & Optimum moisture content according to AASHTO T-180 & ASTM.D1557-2004.
- 2 - California Bearing Test (CBR) according to AASHTO T-193, ASTM D 1883-05.
- 3- Gradation test (-particles size distribution) According to Iraqi specifications for roads and bridges and amendments for 1999 - 2003- (SROP/R6) .
- 4- Unconfined compressive strength (UCS) test for cylinder BS -1881-110, BS EN - 12390 - 3.
- 5- Compaction test ASTM D -698.

4.1 Proctor Compaction

This test was perform on samples to calculate the dry density and optimum moisture content using the Modified compaction method, Four attempts were made for each sample and the points of the values of these attempts were plotted on a graph and these points were connected by a graph curve, and the dry density was calculated from the highest point on the curve.

4.2 Gradation Test

The test was carried out in accordance with 1999 - 2003- (SROP/R6) in this test, Representative samples of approximately (5Kg) for type B and (5 Kg) for type A, were used for the test, An automated shaker was used to do the sifting, and a series of sieves arranged in decreasing order of sieve size was used. The proportion of material passing through each sieve was calculated using the weights retained, and the resulting semi-logarithmic graph was used to create the particle distribution curve.

4.3 California Bearing Ratio (CBR) test

All design mixes are taste in accordance with ASTM D 1883-05 and AASHTO T-193 California Bearing Ratio Test that is the standard test for measuring the strength of road layers. test for measuring the strength of road layers. The test was conducted on 34 samples according to the specification i.e. the sample was placed in the test mold in the form of five layers with compaction with 56 blows each layer, 17 samples in the soaked state and 17 samples in the unsoaked state.

4.4 Unconfined compressive strength

One of the durability tests is unconfined compressive strength for cylinder, According to ASTM D2166. The test was conducted on 34 cylindrical models.

5 Results And Discussion

5.1 Recycled Concrete Aggregate

The Data	Value	Specification
"Constant Head Permeability"	1.617×10^{-4}	"ASTM D -2434"
"Plastic Limit"	NON	"ASTM D-4318"
"Liquid Limit"	NON	"ASTM D -4218"
"Shrinkage Limit"	NON	"ASTM D- 4943"
"Specific Gravity Of Fin Aggregate (RCA) "	2.67	"ASTM, C127- C 128"
"Specific Gravity Of Coarse Aggregate(RCA)"	2.48	"ASTM, C127- C 128"
"Absorption Of Fine Aggregate(RCA)"	5.41 %	"ASTM - C 127"
"Absorption Of Coarse Aggregate(RCA)"	1.80 %	"ASTM - C 128"
Soundness Of Fine Aggregate (RCA)In Sodium "Sulphate"	2.65 %	"ASTM C88/C88M – 18"
Soundness Of Coarse Aggregate (RCA)In Sodium "Sulphate"	0.85 %	"ASTM C88/C88M -18"
Soundness Of Fine Aggregate (RCA)In Magnesium "Sulphate"	2.7%	"ASTM C88/C88M – 18"
Soundness Of Coarse Aggregate(RCA) In Magnesium "Sulphate"	0.83 %	"ASTM C88/C88M – 18"

In this study, the physical and mechanical properties of recycled aggregate were identified through the tests that were conducted, and Table 1 shows that.

Table 1: shows the test results for recycled concrete aggregate.

5.2 Particle Size Distribution

The gradation (particle size distribution) was tested according to the Iraqi specifications for roads and bridges and their amendments for the years 1999-2003 (SROP/R6). Which stipulates the four classes for designing road layers (A,B,C,D) and according to the gradation the type of category is class.

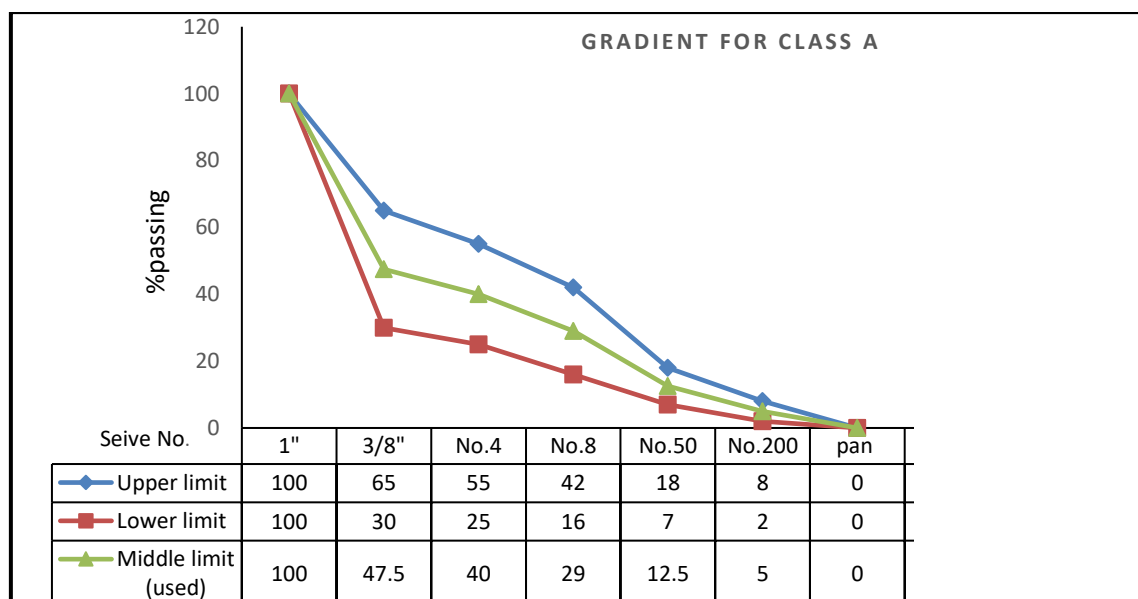


Fig. 5: Graph showing the distribution of aggregate particles for class A.

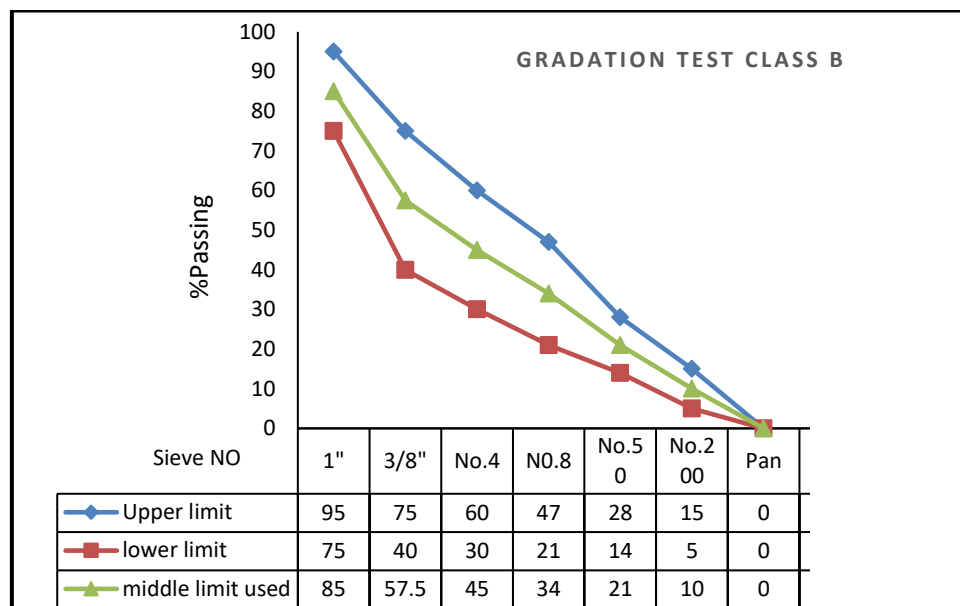


Fig.6: Graph showing the distribution of aggregate particles for class B.

5.3 Proctor Compaction

Compaction tests were performed in accordance with ASTM D-698. Specimens were prepared for this test to obtain maximum dry density and optimum moisture content for Class A, B in accordance with AASHTO T-180 and ASTM.D1557-2004.

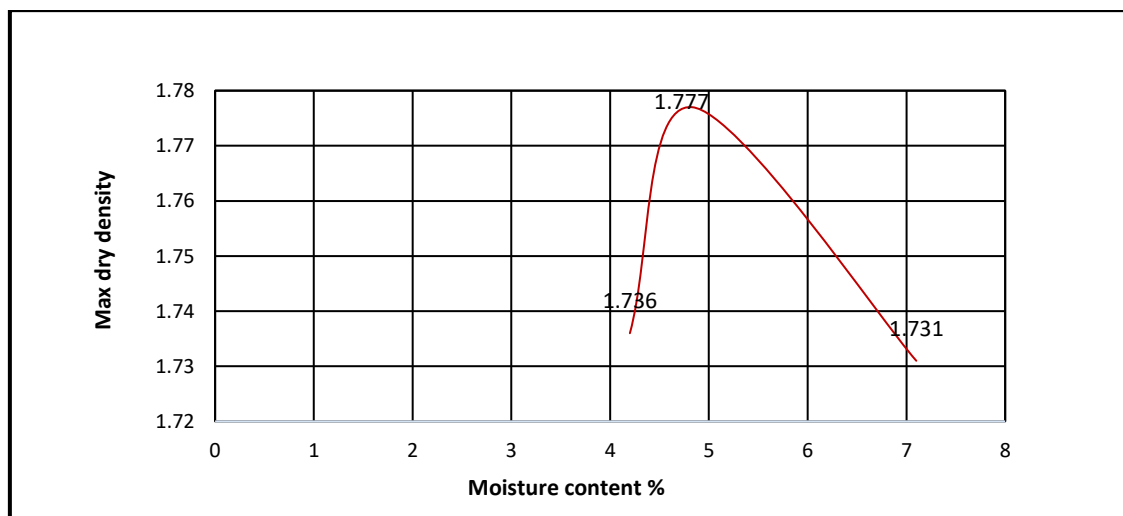


Fig. 7: Shows the relationship between dry density and optimum moisture content (class A)

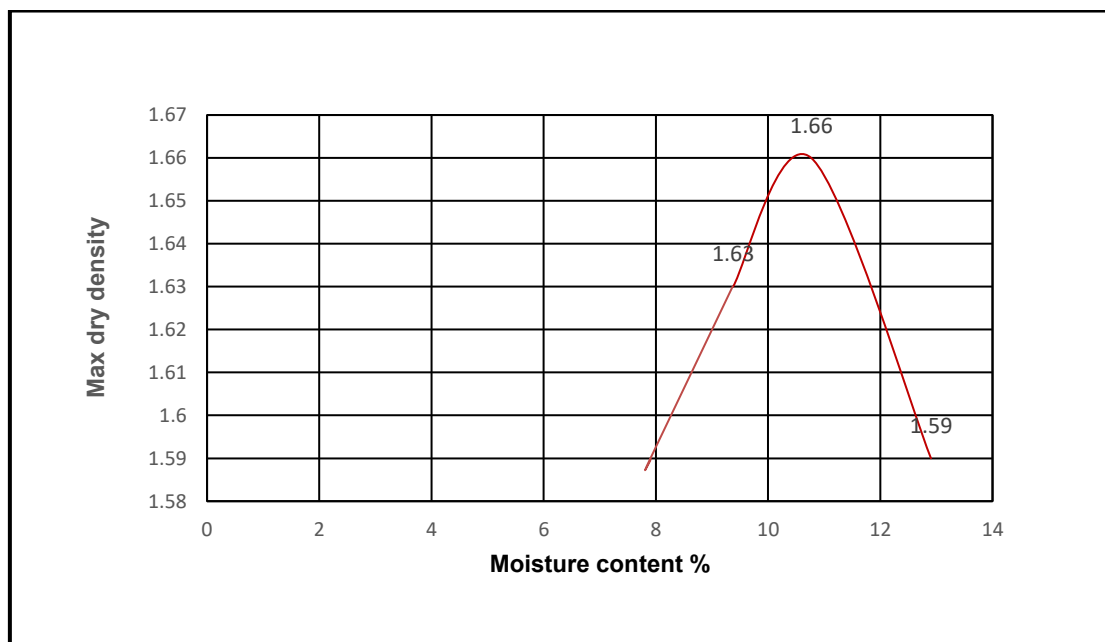


Fig. 8: Shows the relationship between dry density and optimum moisture content (class B)

5.4 California Bearing Ratio (CBR) test:

After obtaining the optimum water content from the compaction test, the CBR test was performed for all the design mixes according to AASHTO T-193 and ASTM D 1883-05. The CBR results for class A and B mixed with fine soil and fly ash are shown in Tables below, as well as the values of the natural materials.

Table 2: Shows CBR values for class A mixed with fine soil.

The data		Added fine soil (5%)	Added fine soil (10%)	Added fine soil (14%)	Added fine soil (16%)
CBR class A	Soaking	39.0 %	40.3 %	41.0%	38.7%
	Un soaking	41.8%	43.5%	44.6%	42.0%

Table 3: Shows CBR values for class B mixed with fine soil.

The data		Added fine soil (5%)	Added fine soil (10%)	Added fine soil (14%)	Added fine soil (16%)
CBR class B	Soaking	40.1%	40.8%	41.4%	39.3%
	Un soaking	42%	43.7 %	45%	43.2%

From the values obtained from the California Bearing Ratio for soaked and unsoaked samples, it was shown that the higher the percentage of fine soil, the lower the bearing strength of the samples.

Table 4: Shows CBR values for class A mixed with fly ash

The data		Added fly ash(5%)	Added fly ash(10%)	Added fly ash (14%)	Added fly ash(16%)
CBR class A	Soaking	41.8%	42.5%	44.4%	47.3%
	Un soaking	43%	45.3 %	47%	50.2%

Table 5: Shows CBR values for class B mixed with fly ash

The data		Added fly ash(5%)	Added fly ash(10%)	Added fly ash (14%)	Added fly ash(16%)
CBR class B	Soaking	42%	43.5%	45.1%	48.4%
	Un soaking	44.6%	45.3 %	46.8%	51%

As for the values obtained from the California bearing ratio test for soaked and unsoaked samples, it was shown that the higher the percentage of fly ash, the higher the bearing strength of the samples.

Table 6: Shows CBR values for Natural materials.

The data		Class A	Class B
Natural materials (natural aggregate)	Soaking	37%	39%
	Un soaking	42%	44%

5.5 Durability test

This test was conduct on samples consisting of recycled aggregate mixed with fine soil of classes A and B, as well as samples consisting of recycled aggregate with fly ash of classes A and B.

Table 7: Shows the values of the unconfined compressive strength (UCS) of class A containing fine soil for 7 days.

The data	Added fine soil (5%)	Added fine soil (10%)	Added fine soil (14%)	Added fine soil (16%)
Unconfined compressive strength	0.215N/mm ²	0.210N/mm ²	0.186N/mm ²	0.166N/mm ²

Table 8: Shows the values of the unconfined compressive strength (UCS) of class B containing fine soil for 7 days.

The data	Added fine soil (5%)	Added fine soil (10%)	Added fine soil (14%)	Added fine soil (16%)
Unconfined compressive strength	0.221 N/mm ²	0.219 N/mm ²	0.211 N/mm ²	0.207 N/mm ²

The recycled aggregate samples mixed with fine soil decreased in unconfined compressive strength test values when the percentage of fine soil of class A and B increased.

Table9: Shows the values of unconfined compressive strength (UCS) of class A containing fly ash for 7 days.

The data	Added fly ash (5%)	Added fly ash (10%)	Added fly ash (14%)	Added fly ash (16%)
Unconfined compressive strength	0.225 N/mm ²	0.228 N/mm ²	0.23 N/mm ²	0.232 N/mm ²

Table10: Shows the values of unconfined compressive strength (UCS) of class B containing fly ash for 7 days.

The data	Added fly ash (5%)	Added fly ash (10%)	Added fly ash (14%)	Added fly ash (16%)
Unconfined compressive strength	0.227 N/mm ²	0.229 N/mm ²	0.233 N/mm ²	0.237 N/mm ²

As for the samples of recycled aggregate mixed with fly ash, the unconfined compressive strength test values increased with the increase in the percentage of fly ash of class A and B.

6 Conclusion

In this study, the properties of recycled concrete aggregate and its potential use in the design of road layers were evaluated, as well as the effect of California load ratio and unconfined compressive strength tests on the recycled aggregate granules. In addition, special attention was paid to the physical and mechanical properties of the recycled aggregate granules. Some of the following conclusions can be drawn:

- 1) The results obtained from the maximum dry density test indicated that recycle concrete aggregate could be well compacted to reach a reasonable density.
- 2) The California bearing ratio (CBR) values of aggregates used from recycled concrete mixed with fine soils of classes (A) and (B) in soaked and unsoaked condition as well as recycled aggregates mixed with fly ash were higher than the CBR values of natural materials normally used in pavement layers.
- 3) In this study, it was shown that the values of California bearing ratio and unconfined compressive strength of samples composed of recycled aggregate with fly ash increased with increasing fly ash percentage, unlike samples composed of recycled aggregate with fine soil, where the values decreased with increasing fine soil percentage.
- 4) Through the work, it was found that the samples of class B showed higher values than class A. The reason for this is that class B contains more fine materials than class A. This is clear in the graph that shows the distribution of aggregate particles.
- 5) When conducting tests (Permeability, Specific Gravity, Absorption, Soundness) on recycled aggregate, all results were found to be good and within the applicable specifications.
- 6) This study dealt with several percentages of fine soil added to recycled aggregate and showed that at a percentage of 14% it gave satisfactory results and was the best percentage for grades A and B in the CBR test and the unconfined compressive strength (UCS) test.
- 7) The above result shows that recycled concrete aggregate can be used in pavement design, which reduces the requirement of natural resources and can be useful in controlling environmental pollution.
- 8) Once the waste materials have been processes at the recycling plant and the destroyed concrete blocks can be returned to the market as recycled building materials, their use in paving layers is no different from using natural materials. The construction steps are the same and the same machines can be used to deliver, place, and grade and compact the layers.

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