INVESTIGATING THE EFFECT OF USING RECYCLED MATERIALS IN HIGHWAY CCONSTRUCTIN

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Abstract-Recycled concrete and marble materials from construction and demolition operations are disposed in landfill sites. Concrete accounts for around 60% of waste in the U.S. in addition, landfill area and the guidelines govern their procedure becomes more serious. Environmental, it is important to recycle the landfill materials when it is possible as it sustain the natural resources to the coming generations. Moreover, the authorizing process for aggregate quarries has become a difficult task for contractors due to increased environmental regulations to sustain the natural resources. The aims of this paper are to evaluate the alternative usage of the recycled concrete and marble as well as marble dust for different road layers. The experimental program was carried out through different stages starting by evaluating the use of course aggregate in asphalt pavement mix (not in this research scope). The second stage was to develop different blends (S1 to S9) between dolomite stone, lime stone, recycled marble, and recycled concrete to be evaluated as a base and subbase layer. Finally marble dust was tried instead of lime dust in asphalt pavement mix. The outcomes of the second stage presented in this paper showed that all tried types of recycling material can be used as either a base course and or a subbase course. In addition it saves between 12.5 to 53.8% of the total cost. Furthermore, the marble dust enhanced the mix stability better than lime dust from 1680 lb to 1927 lb..

Index Terms— Recycled concrete, Marble, Lime, Nano Materials, and dolomite stone

1 Introduction

Roads networks worldwide costs milliards of dollars. Structural design of roads consists of asphalt layer, base layer, subbase layer on top of the sub grade layer. The production of demolition and construction waste has been increasing at a steady rate recently. The use of recycled materials as base course and or subbase in road construction has become common recently. The most widely used recycled materials are recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA). RAP is produced by removing and reprocessing existing asphalt pavement and RCA is the product of the demolition of concrete structures. The RAP and RCA produces a high quality aggregate.

Recycled aggregates are the materials that have been extracted from construction and demolition concrete, and asphalt pavement. Concrete is a construction material composed of cement, aggregate (coarse aggregate such as gravel, and limestone), water, and chemical additives. RCA is generated from road and bridge, building-related, airport, and waste new concrete.

Asphalt concrete consists of asphalt binder and mineral aggregate. Generally, recycled asphalt is entirely produced from roads. However, recycled concrete aggregate can be used in asphalt pavement construction. Recycled asphalt materials are reused at the same location which safes cost and time. It has been determined in some cities that recycled materials reduce the base course by 30%.

Table (1): Specifications of Sub base and base layer (ASTM C136):

Sieve size	Percent passing	Percent passing
	Sub base layer	Base layer
3in.(75mm)	100	
2.5in.(63mm)	90-100	
2in.(50mm)	35-70	
1.5in.(37.5mm)	0-15	100
1in.(25mm)		95-100
3/4in.(19mm)	0-5	
1/2in.(12.5mm)		25-60
No.4(4.75mm)		0-10
No.8(2.36mm)		0-5

2 PROBLEM DEFINITION AND OBJECTIVE

As there is a need to use recycled aggregate as a supplement to natural aggregates in order to conserve natural resources and preserve the environment. Therefore the main objectives of this paper are:

1. Develop a blend between recycled concrete and version lime to be used as a base and or subbase layer for asphalt pavement.

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2. Develop a blend between recycled concrete and version dolomite stone to be used as a base and or subbase layer for asphalt pavement.
3. Develop a blend between recycled concrete and Marble to be used as a base and or subbase layer for asphalt pavement.
4. Reduce the volume of recycled material disposals which require a huge space (landfill).
5. Sustain the current resources.

3 Background:

Large volumes of earthen materials are used in construction. In many cases, these materials could be replaced partially or totally with reclaimed highway paving materials, secondary materials, suitable waste materials and construction debris that are normally disposed in landfills, and can generate millions of pounds savings to financial budget.

Base Course layer and its components quality and performance are very important affects the road performance significantly in direct way. Generally, this layer consists of mix of different gradual sizes of crushed stone and gravel. This mix of materials should have specific properties and should pass several tests to be suitable for using as base course layer.

In order to reduce the cost of construction, to increase the performance of base course layer, many researches were carried out to investigate the effect of replacing or mixing these additives with base layer materials. These investigated different type of materials including slag, fly ash, and limestone, recycled concrete and recycled marble.

Lime stone could not be used separately as a solitary component in base course layer. Because of its properties, it could not achieve Egyptian Code (EC) limits. Therefore, this research investigates the effect of using west marble and recycled concrete (fine and coarse) with different percentages as a substitution of lime stone. Specifications tests for base course layer were carried out according to the Egyptian Code (EC). These tests include Sieve Analysis, Resistance of abrasion, Absorption, Atterberg Limits, Proctor and California Bearing Ratio.

In May 1997, RICHARD E.Y. YEO, KIERAN G. SHARP [1] uses recycled crushed concrete as a stabilized sub-base material which is placed in unbound or cement stabilized pavement layers and investigated available working time between mixing and compaction for four different cement binders, Unconfined Compressive Strength (UCS), permeability and UCS relative to a stabilized sub-base quality crushed rock. Found that significant gains in working time could be achieved through use of a blend of ground granulated blast furnace slag (slag) and lime as the binder. A slag/Portland cement binder was found to produce the highest UCS within a three hour working time.

The optimal binder which achieved the highest strength for recycled crushed concrete was the 50/50% slag/cement blend for working times up to 3 hours. For longer working times the 85/15 slag/lime blend produced the highest strength. The 100% GP cement binder generally produced the lowest strength of the four binders tested.

Taherkhani and Fazel, 2000 [2], uses different portions of natural aggregates of unbound base were replaced with recycled asphalt and cement concrete aggregate and some physical and mechanical properties of the mixtures were evaluated. The study concluded that the strength for the unbound aggregate containing recycled aggregate is lower than the pure natural aggregate base. Inclusion of any amount of recycled cement concrete in unbound aggregate which produced a mixture that satisfy the minimum required CBR, however, exceeding the inclusion of recycled asphalt concrete from a certain amount between 20 to 50% in the research, results in a mixture which cannot meet the requirements of specification for CBR.

Niekerk, M. and Houben, 2002 [3] the use recycled materials such as crushed concrete and masonry coming from demolishing buildings as a base and The gradation and the composition of the granular base (ratio crushed concrete to crushed masonry) certainly have an influence on its characteristics and pavement performance but are of secondary importance when compared to the influence of the stress conditions and the degree of compaction.

Cooley and Hornsby , 2012[4], use recycled materials such as crushed concrete and masonry coming from demolishing buildings as a base and sub-base courses for road and airfield pavements. Based upon the research approach undertaken for the ten selected materials for this project, the following conclusions are provided. RCA materials fabricated from controlled concrete sources and limestone materials resulted in higher resilient modulus values than RCA materials fabricated from construction debris. This was true for resilient modulus results from test samples fabricated using both a Standard and Modified compaction effort. California Bearing Ratio and resilient modulus values increased as the percent maximum dry density increased.

Smaller pieces of concrete are used as gravel for new construction projects. Sub-base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt poured over it. The US Federal Highway Administration may use techniques such as these to build new highways from the materials of old highways. Crushed recycled concrete can also be used as the dry aggregate for brand new concrete if it is free of contaminants. Also, concrete pavements can be broken in place and used as a base layer for an asphalt pavement through a process called rubblization. Larger pieces of crushed concrete, such as riprap, can be used for erosion control.

4 INVESTAGATION PLAN

As shown in Figure 1; for the base and subbase stage; nine assumption were proposed to figure out the California Bearing Ratio (C.B.R.), that to figure out the effect of Crushed Plain Concrete as recycled material to the base or sub-base layer which chosen to be Crushed Stone #6. The chosen varieties of combinations between Crushed dolomite Stone & Crushed Plain Concrete -lime stone & crushed plain concrete and recycled marble &lime stone as shown in Table 1:

Table 1: Mixes between different types of recycled Material

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Specimen	Crushed Dolomite Stone	Crushed Lime stone	Marble	C.P.C
S1	100%	-		0%
S2	75%	-		25%
S3	50%	-		50%
S4	25%	-		75%
S5	0%	-		100%
S6	-	75%		25%
S7	-	25%		75%
S8	-	50%	50%	-
S9	-	0%	100%	-

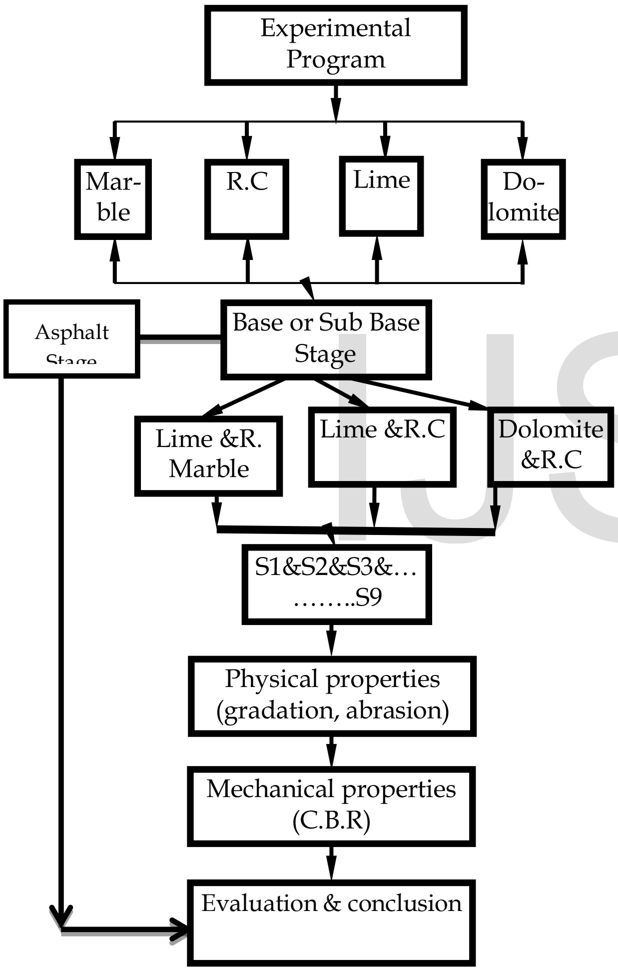

FIGURE 1: RESEARCH PLAN

4.1 Material Characteristics and Testing

The material characteristics where carried out for different materials such as virgin dolomite, recycled concrete aggregate, marble recycle. The testing process started by gradation, density, swelling, water content, and absorption. The dry density was carried out according to ASTM D2922, and the water content according to ASTM D 2216– after submerged in water. Figure 2 and 3 showing the acceptable specifications and the obtained gradation. Table 2 presents the obtained results for both virgin and recycles concrete.

4.1.1 Sieve analysis (Samples S1 to S6-S5).

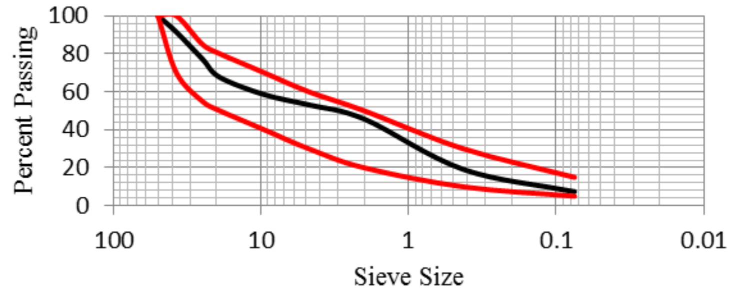

Figure 2: Sieve Analysis for Dolomite Stone

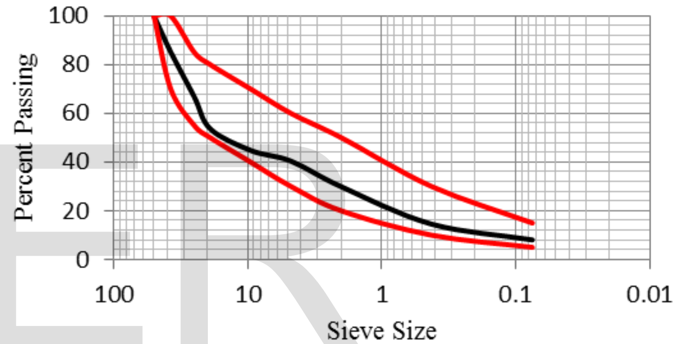

Figure 3: Sieve Analysis for Crushed Plain Concrete

Table 2: Specifications

	Dolomite	Crushed Plain	Re-
Maximum dry	2.268	2.14	
Water Content	6.25%	8.75%	
C.B.R.	+100	60	≥80%
Swelling	Zero	Zero	≤3%
Degradation	31.8	46.2	≤50%

4.1.2 Los Angeles (L.A.)

The standard L.A. abrasion test subjects a coarse aggregate sample (retained on the No. 4 sieve) to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres.

After being subjected to the rotating drum, the weight of aggregate that is retained on a No. 12 sieve is subtracted from the original weight to obtain a percentage of the total aggregate weight that has broken down and passed through the No. 12 sieve.

Table 3: Abrasion test Results

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Spec. N	S1	S2	S3	S4	S5	S6	S7	S8	S9
Ab. %	31.8	35.2	38.7	42.9	46.2	56.8	53.2	41.1	49.0

Replacing specific sizes of lime stone with marble or recycled concrete improved its resistance of abrasion in Los Anglos test. However, waste marble improved the lime stone resistance more than recycled concrete as results illustrated in the Table 3. The testing process is shown in Figure 4.

FIGURE 4: LOS ANGELES TEST

4.1.3 Proctor compaction test

Laboratory procedures known as the modified Proctor test (ASTM D 1557/AASHTO T 180) have been carried out to estimate the greater densities available from the compaction efforts of modern construction equipment. For the same soil, the optimum moisture content (OMC) for a modified Proctor test is usually less than OMC for a standard Proctor test while maximum dry density is higher. Figure 5 showing the testing machine during compaction.

Figure 5: Proctor test

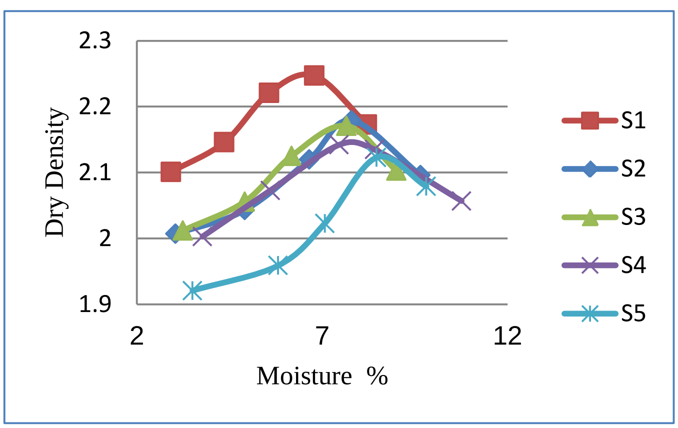

Figure 6: Water Content and Dray Density

The observations can be obtained from the figure 6 are:

1 The maximum dry density is deceased with increase of percentage of crushed plain concrete in specimen.
2 The moisture content increase with the increase of percentage of crushed plain concrete in specimen
3 The OMC is changing depending on the mix blending and for the first six mixes was ranged from 6.5 to 8.5%.

4.1.4 California Bearing Ratio (C.B.R) tests (ASTM D1883-14)

Normally 3 specimens each of about 7 kg must be compacted so that their compacted densities range from 95% to 100% generally with 10, 30 and 65 blows. Weigh of empty mould and Add water to the first specimen (compact it according to modified proctor procedure). After compaction, remove the collar and level the surface then take sample for determination of moisture content. Place the mold in the soaking tank for four days (ignore this step in case of unsoaked CBR). After four days, measure the swell reading and find % age swell. Remove the mould from the tank and allow water to drain and then place the specimen under the penetration piston and place surcharge load of 10lb.

Apply the load and note the penetration load values and draw the graphs between the penetration (in) and penetration load (in) and find the value of CBR.

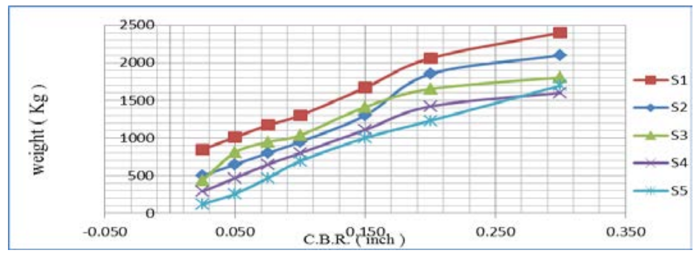

FIGURE 7: COMPACTION MOISTURE CONTENT

The observations can be obtained from the Figure 7:

1 The CBR values are decrease when the percentage of crushed plain concrete increased.
2 The combination between crushed stone and crushed plain concrete in specimen (S2, S3 & S4) show some non-linear or proportional relation between weight and CBR.
3 The results of CBR calculations are presented in Table 4.

Table 4: California Bearing Ration (C.B.R) of samples

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
100.98	90.69	80.88	69.6	60.29	60.29	52.87	57.29	53.21	44.32

1- Mixes from S1 to and S2 are accepted for the base course based on the obtained CBR.
2- Mixes from S3 to S9 have accepted CBR value to be used as subbase.

5 THE OUTCOMES OF ASPHALT STAGE

The application of building rubble collected from damaged and demolished structures is an important issue. Aggregate reclaimed from demolition concrete with fully hydrated cement can contain a significant amount of adhered mortar. After crushing and screening, this material can serve as recycled aggregate in road construction. A series of experiments using recycled aggregate of various compositions from building rubble is conducted. The test results show that the building rubble can be transformed into useful recycled aggregate through proper processing. Using unwashed recycled aggregate in HMA will affect its stability. The effect will be more obvious at higher asphalt content. When the recycled aggregate is washed, these

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negative effects are greatly improved. This study evaluated the effects of replacing virgin aggregates (VA) by recycled concrete aggregates (RCA) on local HMA binder (3B). One source of RCA were procured and used in this study. The evaluation consisted of three aspects: effects of RCA on mix design, effects of RCA on performance of HMA binder (3B), and effects of hydrated lime on the performance of HMA binder (3B) with RCA. Based on the experimental evaluation, the following conclusions could be observed (Abdel latif Jamal, Master thesis, 2013 and Haifang Wen, 2011, Nyoung Rak Choi, and Yoon - Hocho, Taeyoung 2010):

- Blending of RCA with VA can lead to combined aggregates which pass the Egyptian standard specifications gradation.
- Different percentages of RCA from 15% to 100% were blended with VA in HMA binder (3B) but the OAC was changed.
- The increase of use RCA percentage in HMA leads to an increase in the (OAC), due to the high absorption of RCA.
- Stability of the HMA binder (3B) decreased but still within the Egyptian standard specifications by replacement of percentage of VA up to 80% by weight with coarse RCA in HMA binder (3B).
- Replacement up to 2% of powder passed sieve No. 200 by hydrated lime in HMA- binder (3B), leads to an increase in coarse RCA up to 100% and the Marshall Stability value increased.

6 Marble Powder

In this section marble dust was tried as an alternative to lime dust using. The powder percentage in the designed mix was 5% which was used as a lime for the control mix. Table 5 shows the blending between marble dust and lime dust and their effect on mix stability

Table 5: Effect of adding Marble Dust

Lime	Marble	Asphalt	Density	Stability	Flow	% of
5	0	5.5	2.256	1680	13.30	Zero
4	1	5.5	2.260	1700	13.63	1.20
3	2	5.5	2.260	1743	13.58	3.75
2	3	5.5	2.261	1817	13.40	8.15
1	4	5.5	2.261	1870	13.17	11.30
0	5	5.5	2.262	1926	12.73	14.64

As shown in Table 5, adding marble dust increased stability up to 14.64% and achieved even surface layer stability without compromising any other properties of asphalt mix. It can be concluded that marble dust is better than lime dust as well as it has an economic and environmental benefits.

7 Analyses of Results and Discussions

Table 5: Results of Applied Tests

Test	Abrasion	Density	O.W.C	C.B.R
S1	31.8	2.260	6.24	100.98
S2	35.2	2.208	7.24	90.69
S3	38.7	2.191	7.55	80.88
S4	42.9	2.149	7.78	69.60
S5	46.2	2.124	8.84	60.29
S6	53.18	2.11	14.3	52.87
S7	56.82	2.05	10.2	57.29
S8	41.10	2.10	10	53.21
S9	45.2	2.03	12	44.32

The general results are presented in Table 5; density results showed that:

- For samples (S1-S5) density increases with the increase of dolomite percent.
- For sample (S6-S7) density decrease with the increase of R.C percent.
- For sample (S8-S9) density decrease with the increase of marble percent.
- All densities are above 2 kg/cm3

The OMC results can be categorized as follows:

- For samples (S1-S5) O.M.C increases with the decrease of dolomite percent.
- For sample (S6-S7) O.M.C decrease with the increase of R.C percent.
- For sample (S8-S9) O.M.C increase with the increase of marble percent.

The abrasion results:

- For samples (S1-S5) % abrasion increases with the decrease of dolomite percent.
- For sample (S6-S7) % abrasion increase with the increase of R.C percent.
- For sample (S8-S9) % abrasion increase with the increase of marble percent.

As shown in Figure 8 for CBR Values:

- For S1To S5 the % C.B.R decreases with the decrease of dolomite percent. Only S1, S2, and S3 are accepted as a base course with CBR value 80% and above.
- For S6-S7 the % C.B.R increase with the increase of R.C percent (CBR% = 53 to 56)
- For S8-S9 the % C.B.R decrease with the increase of marble percent.

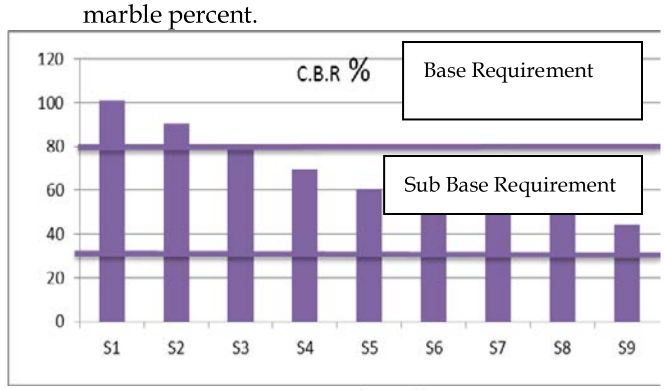

Figure 8: CBR Values for different mixes

7 Economic Evaluation

Analysis the market cost for each type of the used material

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showed that the unite cost for dolomite stone stands at 80 L.E. Including 30 L.E. material, 20 highway toll cost, 20 transportation cost and adding 10 Egyptian bound for construction for 20 cm thickness. On the other hand lime will cost around 65 L.E. for same and the only difference would be in Material cost. For Marble and recycled concrete the unite cost would be 30 L.E. which include the transportation and gradation only. It seems that the minimum cost reduction for the base course as shown in Table 7 is 12.5% while the maximum could be 31.25%. On the other hand the cost reduction for the subbase is ranged from, 23% to 53.8%. The cost reduction is not the only benefit of using the recycled material bout there are more benefit such as cleaning the landfills and environment as well as reserving the virgin materials to the coming generations.

Table 7: Economic Evaluation

Mix	Unite Cost for Base m3	Unite Cost for Sub	% of Reduction	Original Cost	Comments
S1	80.0		Zero	80	No change
S2	67.5		12.50%	80	Reduction of 5 LE form material and 5 LE from transportation
S3	55.0		31.25%	80	Reduction of 15 LE form material and 10 LE from transportation
S4		42.5	34.50%	65 (as lime)	Reduction of 12.5 LE form material and 10 LE from transportation
S5		30.0	53.80%	65 (as lime)	Reduction of 20 LE form material and 15 LE from transportation
S6		50.0	23.00%	65 (as lime)	Reduction of 5 LE form material and 10 LE from transportation
S7		40.0	38.50%	65 (as lime)	Reduction of 10 LE form material and 15 LE from transportation
S8		50.0	23.00%	65 (as lime)	Reduction of 5 LE form material and 10 LE from transportation
S9		40.0	38.50%	65 (as lime)	Reduction of 10 LE form material and 15 LE from transportation

8 CONCULSIONs

From the technical studies of using recycled materials (crushed plain concrete) and to mixed with the base & sub-base layer (crushed stone # 6), it can be concluded that:

4 Using Crushed Plain Concrete in mix with the crushed stone in the base and sub-base is decrease the CBR and increase the optimum moisture content.
5 Increasing the crushed plain concrete percentage over 50% makes the base layer out of specification range of CBR
6 The obtained results from Los Angeles tests showed the mixing between limestone aggregate 75% and recycling concrete 25% are more than the Egyptian code (40%) and also the mixing between limestone aggregate 25% and recycling concrete 75% show the same result.
7 In the California Bearing Ratio test (CBR) the results from mixing between limestone aggregate 75% and recycling concrete 25% are less than the Egyptian code (80%) and also the mixing between limestone aggregate 25% and recycling concrete 75%
8 For S1To S5 the % C.B.R decreases with the decrease of dolomite percent. Only S1, S2, and S3 are accepted as a base course with CBR value 80% and above.
9 For S6-S7 the % C.B.R increase with the increase of R.C percent (CBR% = 53 to 56)
10 For S8-S9 the % C.B.R decrease with the increase of marble percent.
11 From the economic point of view using recycled materials (crushed plain concrete) and to mixed with the base & sub-base layer (crushed stone # 6) can be more economic than pure crushed stone and helps in decrease the waste material in environment. Also, it reduces the cost from 12.5% to 53.8%.
12 Marble dust can be used instead of lime dust of asphalt pavement mix.

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9 REFERENCES

13 Haifang Wen, Sushanta Bhusal (2011), “Evaluated Recycled Concrete as Hot Mix Asphalt Aaggregates,” Dept. of civil & Environmental Engineering Washington State University.
14 Nyoung Rak Choi, Yoon - Hocho, Taeyoung, In Tai Kim, (2010), “The application of RCA for HMA”.
15 R. E. Yeo and K. G. Sharp, "Recycled Crushed Concrete Stabilised With Cementitious Binders".
16 F. P. H. Taherkhani, "Investigating the Viability of using Recycled Aggregates in Unbound Base layer".
17 v. Niekerk, A. Molenaar and L. Houben, "Effect of Material Quality and Compaction on the Mechanical Behaviour of Base Course Materials and Pavement Performance".
18 L. A. Cooley and H. Hornsby, "Evaluation of Crushed Concrete Base Strength".
19 Roadway construction using Industrial Materials (2014), US EPA and Federal Highway Administration Resources.
20 Concrete recycling from Wikipedia, the free encyclopedia 29-

ISSN 2229-5518
12-2013.
21 Crushed Edwards Limestone Road Base, from Wikipedia the free encyclopedia (2013).
22 Cement concrete and Aggregates Australia use of Recycled Aggregates in construction May 2008 pp.1-22.
23 Recycled concrete aggregate Federal Highway Administration national review, United States Department of Transportation (FHWA).
24 Sevil Kofteci, Niyazi Ugu rKockal (2014) "Using Marble Wastes as Fıne Aggregate in Hot Mix Asphalt Production" Proc. of the Intl. Conf. on Advances In Civil, Structural And Construction Engineering; p 117-121
25 Rajan Choudhary and Satish Chandra " Granite and Marble Dusts as filler in Asphalt Concrete" Department of Civil Engineering, Indian Institute of Technology Roorkee, India 247667