

EVALUATION OF USING A WHITE GRAVEL OF KERBALA QUARRIES IN ASPHALT MIXES ⁺

تقييم استخدام الحصى الابيض لمقالع كربلاء في الخلطات الاسفلتية

Abdul Hadi M. Al_Sa'adi *

Mohammed K. Abed Al-Kafaji **

Najah M.L. Al Maimuri *

ABSTRACT :

The basic purpose of this research is focused to assess the possibility of using a white gravel as a coarse aggregate in the asphaltic mixes which practically in turn reduce the eventual construction costs of the asphaltic roads in many cities at the middle of Iraq through evaluating their physical properties.

Three different local types of aggregates are selected from the middle and northern-west of Iraq and used in this laboratorial analysis; those are *White Crushed Gravel (WCG)*, *White Rounded Gravel (WRG)* and *Black Uncrushed (Rounded) Gravel (BRG)*.

Strength, extraction and stripping tests are conducted in evaluating the resulted physical properties of the produced asphaltic mixes.

The results of the laboratorial tests indicate that *White Crushed Gravel (WCG)* which is used as a coarse aggregate in the asphaltic mixes yields maximum Marshal Strength and minimum Marshal Flow of 8.3KN and 2.2mm respectively associated with an asphaltic mixing content of 5% of the total mixing weight, whereas BRG yields minimum Marshal Strength and maximum Marshal Flow of 6.8KN and 2.4mm respectively occurred with asphaltic mixing content of 4%.

White Crushed Gravel (WCG) gives an Index of Retained Strength of 94.7% with 5% asphaltic mixing content whereas *Black rounded Gravel (BRG)* yields 91.4% Index of Retained Strength occurred with 4% asphaltic mixing content.

المستخلص:

ان الهدف الاساسي لهذا البحث مركز لتقييم امكانية استخدام الحصى الابيض كركام خشن في الخلطات الاسفلتية والذي بدوره يقلل عمليا الكلف الانشائية النهائية للطرق الاسفلتية في عدة مدن في وسط العراق خلال تقييم خواصه الفيزيائية.

تم اختيار ثلاثة انواع من الحصى المحلي من وسط وشمال شرق العراق واستخدمت في التحليل المختبري، الحصى الابيض المكسر والحصى الابيض غير المكسر والحصى الاسود غير المكسر (المدور).

ان فحوص الثبات والاستخلاص والتعرية قد اجريت لتقييم الخواص الفيزيائية الناتجة من الخلطات الاسفلتية.

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* Lect .Technical College / Babil

** Assit . Lect .Technical College / Babil

ان نتائج الفحوص المختبرية تبين ان الحصى الابيض المكسر والمستخدم كركام خشن في الخلطات الاسفلتية قد اعطى اعلى قيمة للثبات واقل قيمة تعرية وهما 8.3 كيلونيوتن و 2.2 ملم على التوالي مصحوبا بمحتوى اسفلتي مقدار ه ٥% من وزن الخلط الكلي في حين ان الحصى الاسود قد اعطى اقل قيمة للثبات واعلى قيمة للاستطالة وهما ٦,٨ كيلونيوتن و ٢,٤ ملم على التوالي تحصل بمحتوى اسفلتي مقدار ه ٤% .
ان الحصى الابيض المكسر قد اعطى معامل ثبات ٩٤,٧ % بمحتوى اسفلتي مقدار ه ٥% في حين ان معامل الثبات للحصى الاسود المدور هو ٩١,٤ % بمحتوى اسفلتي مقدار ه ٤% .

Introduction:

In recent few years, the shortage for coarse aggregate of asphaltic and concrete mixes appears to be a major problem in the middle of Iraq. Such materials with a good quality are toughly requested for asphaltic pavement. Premature stripping can result from poor subsurface drainage (causing excessive moisture in the pavement structural layers), use of weak and friable aggregates (fracturing during construction and subsequently in service exposing uncoated surfaces), excessive dust coating around the aggregates, and very poor compaction of the hot mix asphalt (HMA) during construction.

Extensive research has been conducted on the mechanism of asphalt stripping [1]. It has been reported that "air voids in asphalt concrete may become saturated with water even from vapor condensation due to water in the subgrade or subbase. A temperature rise after this saturation can cause expansion of the water trapped in the mixture voids resulting in significant void pressure when the voids are saturated. It was found that void water pressure may develop to 137.91KN/M² under differential thermal expansion of the compacted asphalt mixture and could exceed the adhesive strength of the binder aggregate surface. If asphalt concrete is permeable, water could flow out of the void spaces under the pressure developed by the temperature rise and, in time, relieve the pressure developed. If not, then the tensile stress resulting from the pressure may break adhesive bonds and the water could flow around the aggregates causing stripping. The stripping damage due to void water pressure and external cyclic stress (by traffic) mechanism is internal in the specimens; the exterior sides of the specimens do not show stripping damage unless opened up for visual examination.

The water gets pressed down into the pavement in front of the tire and immediately sucked away from the pavement behind the tire. This compression-tension cycle contributes to the stripping of the asphalt film from the aggregate [2]. The aggregate used on that project had excessive amounts of a very fine dust coating. When the aggregate was washed in the quarry and used again the problem went away. Laboratory studies [3] have also shown improved adhesion characteristics of some dust contaminated coarse aggregates when washed.

Case Study and Social Problems:

Usually, Black Rounded Gravel (BRG) of Sammara Region is commonly used in most asphalt concrete mixes for road construction in the middle of Iraq in a few recent decades. Nowadays, under the circumstances of the current terroristic war in Iraq, most construction projects face constantly the problem of transportation of this material from the origin to destination considerably. This in turn, reflects a rapid increase in cost of roads construction. White Crushed Gravel (WCG) is selected as an alternative substance to solve this problem for the wide availability of this material in Kerbela Quarries Province.

Purpose of Study:

The purpose of this study is based on selecting an alternative material to substitute the discrepancy in Black Rounded Gravel (BRG) in most locations inside the country as a construction material for road pavement projects.

Methodology of the Work:

The work incorporates the following steps:-

- 1- Thirty six asphaltic concrete mixes are prepared. WCG, WRG and BRG are included in these mixes.
- 2- AASHTO Method [4] is used to standardize the physical properties of the mixes.
- 3- Stripping and extraction tests are carried out to obtain the strength index and degradation respectively, [4].

General Identification & Geologic Origination of Coarse Aggregate:

Several types of gravel are available in Iraq, among them WCG and WRG are shown photographically in Figs.(1a , 1b) respectively; they are characterized with whitely color, rough, irregular grains surfaces and the most common and favorable one is the Black Rounded Gravel (BRG) which is shown in Fig.(1c). This type is characterized with its blackly color and smooth grains surface. The part of Tigris Arm which passes through Samarra Area is the main origin of this type.



a) White Crushed Gravel (WCG)
(Origin: Samarra Quarries, Iraq)



b) White Unrushed Gravel (WRG)
(Origin: Kerbala Quarries, Iraq)



c) Black Rounded Gravel (BRG) (Origin: Samarra Quarries, Iraq)

Fig.(1) Common Types of Gravel in Iraq

The quarries of (WCG, WRG, and BRG) are found in Kerbala Province and on both sides of Tigris River Arm. [5] presents that thick sand, gravel and conglomerate terrace deposits occur on both banks of the Tigris. Three to five terrace levels can be differentiated. The thickness of these deposits does not exceed 19.25m.

Geologically, the interested coarse aggregate are made by the tectonic movements of the earth crust. In both quarries, the mixture of the sand, gravel, and conglomerate is obtained and then it is washed and classified according to the required sizes.

Materials Preparations:

1. Coarse Aggregate:

WCG, WRG, and BRG samples are prepared as a coarse aggregate as shown in table (1). The following tests have been conducted; Specific Gravity, Abrasion Resistance of Loss Angeles and Absorption tests [6] .The physical properties as obtained from the tests are indicated in Table (2).

Table (1) Grain Size Analysis of Aggregate

Sieve size		Allowable Limits (passing %)	Used (passing %)
Inch	mm		
1.5	37.5	100	100
1.0	25.0	70-95	83
3/4	19.0	65-86	75
1/2	12.5	46-70	58
3/8	9.5	38-65	52
No.4	4.75	25-50	38
No.8	2.36	15-40	28
No.50	0.30	5-18	12
No.200	0.075	2-8	5

Prepared by the Researchers, 2008

Table (2) : Laboratorial Analysis of Aggregates.

	Max Allowable limits, [4],[6]	WCG	WRG	BRG
Specific Gravity Test	2.6 (Typical Value)	2.55	2.57	2.63
Loss Angles Test (%)	30%	25.50	22.83	16.26
Absorption Test (%)	5%	2.22	1.58	0.71

Tested by the Researchers, 2008

2. Fine Aggregate:

A sample of sand with a specific gravity of (2.51) and grading size of Table (2) is employed in the current analysis. The grading is chosen to meet the specification of base coarse material for road.

3. Filler:

Portland cement is used as fine grains (a filler material) in the mixes of the current research as recommended by [7]. A localizable type of Al Kufa Cement is used. The fine grain size laboratorial analysis is tabulated in Table.(3).

Table (3) : Laboratorial Analysis of Filler, [7]

Sieve size (mm)	Allowable limits (% passing)	Filler Used (% passing)
0.60	100	100
0.18	95-100	97
0.075	65-100	82

By the researchers, 2008

A filler/asphaltic mixing ratio of 2 is used to meet the required specification, [7], whereas the measured specific gravity is 3.09.

1. Asphalt:-

Asphalt of local type with shown specifications of Table (4) is used in this analysis.

Table (4) Asphalt Test analysis, [4]

	Test Type	Allowable limits	Results
1	Specific Gravity	-	1.045
2	Penetration	60-70	68
3	Ductility	> 100 cm	107 cm
4	Solubility in Tetrachloride Carbon	>99%	99.2%

By the researchers, 2008

Laboratorial Analytical Work & Mixing Equations Consideration:

Thirty six sample standard mixes of the preceding material is prepared and tested according to [4] and [8]. The specifications of Iraqi State Corporation of Road and Bridges (SORB/R9) for mixes of the base course are used to assign a suitable asphalt mixes contents in this study. In spite of the same gradation of Table (2) is specified for all aggregate mixes (WCG, WRG, and BRG), many asphalt contents are tried, searching for the optimum asphalt content; these contents are fallen between (3-5.5) percent of the total mixes weight according to the above specification.

But in this analysis, since three the different types of coarse aggregate with various physical properties are used (according to Table (1)), the asphalt content is slightly deviated to be (3, 4, 5, 6, and 7) percent of the total mixes weight to fit and workable to the resulted mixes. Accordingly laboratorial samples (with different coarse aggregate origins) have prepared and tested later on. It is found that the optimum asphalt contents for the above types of aggregate are 5.1%, 4.38%, and 4.17% respectively.

Laboratorial Results and Analytical Discussion:

I) Marshall Stability Test

The results of Stability Test Analysis of the suggested mixes with different asphaltic mixing contents are listed in Table. (5) and shown graphically in Fig.(2).

Table (5) Marshall Stability Test Results, [4]

Asphalt Content (%)	Marshall Stability, KN		
	WCG	WRG	BRG
3	5.8	4.3	4.9
4	7.2	5.6	6.8
5	8.3	5.9	6.6
6	8.0	4.5	5.1
7	6.8	3.8	4.2

By the researchers, 2008

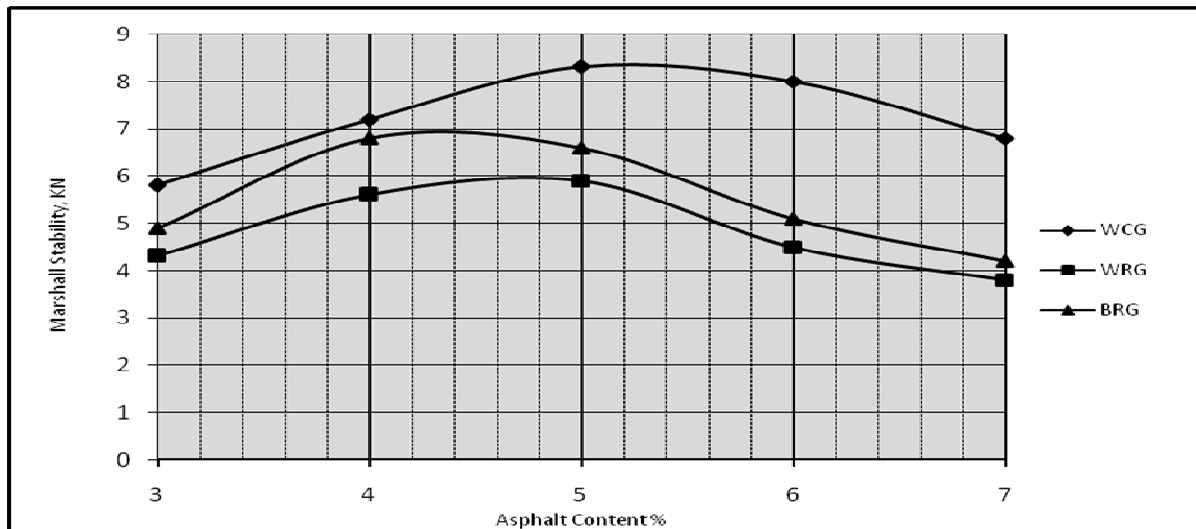


Fig.(2) Marshall Stability Values for Gravel Types Under Various Asphaltic Percentage Content

In general, Marshall Stability testing results as shown in Table.(5) and Fig.(2) indicate that strength values are increased gradually with the increase of asphaltic percentage content until the peak Stability value is met and then it is reduced with further increasing of Asphaltic content percentage as indicated in the figure. Table (5) indicates that a maximum strength of 8.3KN, 5.9KN, and 6.8KN are associated with asphaltic content 5%, 5%, and 4% for WCG, WRG, and BRG is obtained respectively. Specifically, if WCG has been used, the maximum strength of asphalt mixes is increased by 25.7% of similar mixes used BRG.

In this analysis, WCG gives a higher Marshall Stability value than others occurred with 5% asphalt mixing content of the total weight; nevertheless BRG is characterized with better

physical properties as presented in Table. (1). Whereas, WRG gives a lower Marshall Stability values.

Comment No1: The preponderance and superiority of WCG with respect to BRG returns to the nongranularity, roughness and irregularity of WCG external grain surfaces and not to its chemical properties. A microscopic inspection to a single grain surface shows that it is covered with small holes dispersed overall the outer surface. The asphaltic mortar penetrates these infinitesimal holes to contribute additional bonds to the body of asphaltic layer.

II) Flow Test Analysis

Marshall Flow Test [9] is also carried out for the previous mixes, the results are presented in Table.(6) with a graphical representation of Fig.(3).

Table (6) Marshall Flow Test Results

Asphalt Content (%)	Marshall Flow, mm		
	WCG	WRG	BRG
3	1.5	1.8	2.0
4	1.8	2.1	2.4
5	2.2	2.7	3.0
6	2.6	3.1	3.4
7	3.0	3.7	3.9

By the researchers, 2008

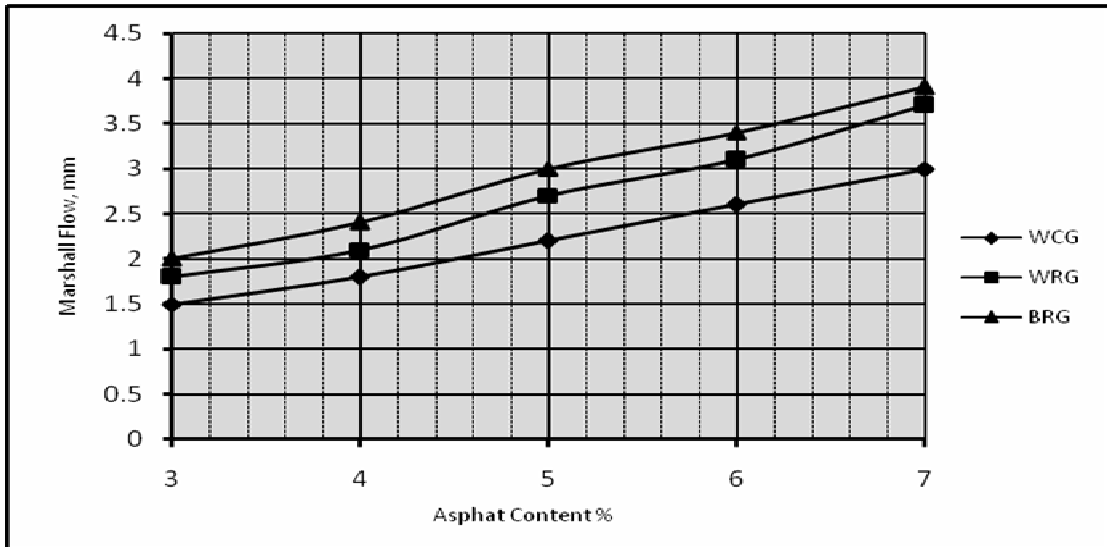


Fig.(3) Marshall Flow Test Values for Gravel Types Under Various Asphalt Content

Comment No2: Marshall Flow test results indicate that WRG and BRG yield an marshal flow values of 3mm and 2.7mm respectively higher than 2.2mm of WCG with 5% asphalt mixing content, Table (6); this is attributed also to the angular and rough nature of grains which in turn increase friction forces between the adjacent grains from one side and increases the adhesive forces between the bitumen and grain surface from other side which already reduces the Marshal Flow values.

III) Degradation Test Analysis

Table (7) and Fig.(4) present the results obtained from degradation test for the considered types of aggregate. BRG yields minimum degradation whereas WCG yields higher values. Nevertheless, the difference in the results is few and acceptable

Comments: Table (7) presents the Degradation Test Results which reveals that Black Rounded Gravel (BRG) is characterized with a better stiffness than the other interested Aggregate types.

Table (7) Degradation Results for Different types of Aggregate

Sieve Size, mm	Used Grading (%passing)	Degradation Results, (%passing)		
		WCG	WRG	BRG
37.5	100	100	100	100
25.0	83	84.6	83.4	83.2
19.0	75	77.2	76.1	75.8
12.5	58	61.5	59.1	58.5
9.5	52	56.0	53.9	53.0
4.75	38	40.9	39.1	38.8
2.36	28	30.2	28.9	28.5
0.30	12	14.1	13.0	12.4
0.075	5	5.8	5.5	5.3

Tested by the authors, 2008

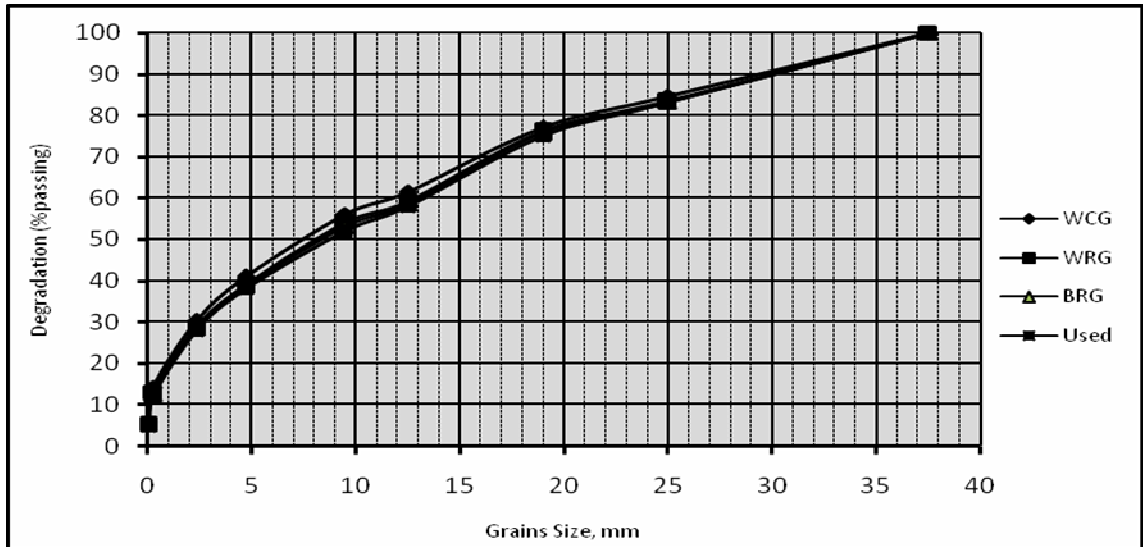


Fig.(4) Degradation Test Analysis Results

IV) Retained Strength Test

Table(8) and Fig.(5) present the variation of the *index of retained strength* of the three types of aggregates with the variation of different percentage of asphaltic contents. Retained Strength test shows a less variation in the index of retained strength occurred with WCG. This is may be also attributed to the angularity and irregularity of WCG surfaces which is in turn allowing the bitumen to be penetrated into the pores in between aggregate grains. The results of Table (8) show that WCG gives a rise in the average index of retained strength in asphaltic mixes by 3% than BRG with 5% asphalt mixing content.

Table (8) Index of Retained Strength Variations

Asphalt content (%)	Index of Retained Strength (%)		
	WCG	WRG	BRG
3	92.1	89.5	90.8
4	93.8	90.5	91.4
5	94.7	91.4	92.0
6	95.7	92.6	92.7
7	96.5	94.0	94.2

By the researchers, 2008

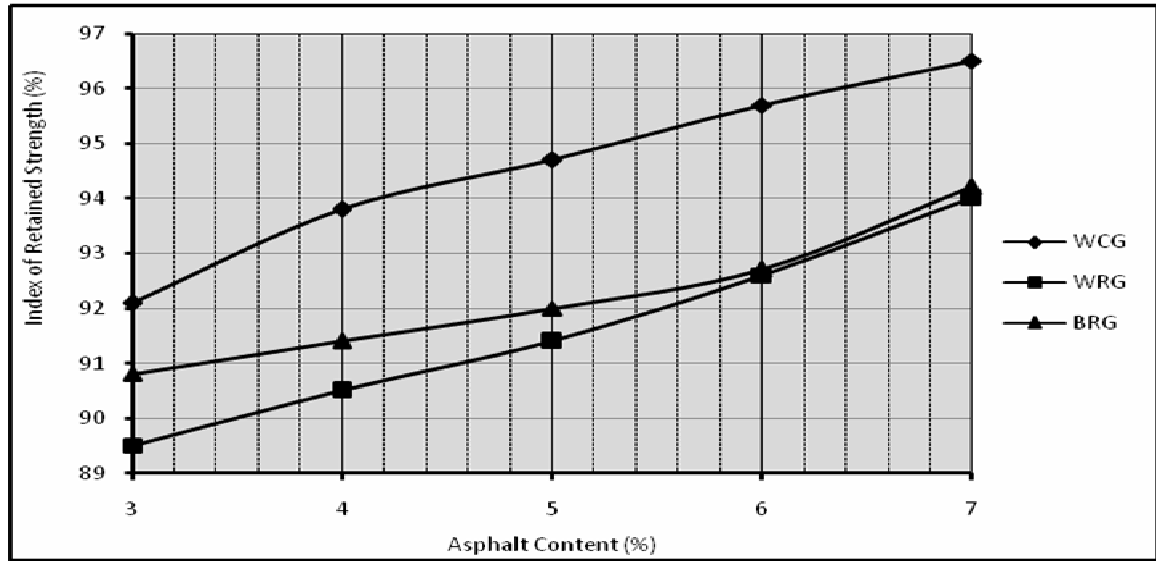


Fig.(5) Index of Retained Stability Variation Versus Asphalts Content Percentage

Conclusions:

The following conclusions are obtained from the current analysis:-

The laboratorial results show some variations in asphaltic mixes characteristics. Many of these variations indicate that WCG of Kerbala Area enhances the quality of asphalt mixes; they are:

- 1- The optimum asphaltic mixing content is occurred with 5% by weight of the total mixing weight for both WCG and WRG.
- 2- WCG gives a rise of 25.7% in maximum *Marshall Stability* of asphaltic mixes (with 5% asphaltic mixing content) in comparison with mixes of similar characteristics made of BRG as coarse aggregate. Specifically WCG mixes offer 8.3KN maximum *Marshall Stability*, whereas BRG mixes fulfill 6.6KN
- 3- WCG yields a *Marshall Flow* of 2.2mm less than 2.7mm and 3mm for WRG and BRG respectively (with 5% asphaltic mixing content). The roughness and irregular surface nature of grains cause the reduction in *Marshall Flow* results.
- 4- WCG mixes yield Index of Retained Strength of 94.7 higher than 92.0 of similar mixes of BRG (with 5% asphaltic mixing content).
- 5- Maximum *Marshall Stability* of WCG and WRG is occurred (with 5% asphaltic mixing content) which is higher than the maximum *Marshall stability* of BRG of samara which is reached with asphaltic content of 4%. This means that there is an 1% increment of asphaltic content whenever and wherever WCG and WRG have been used. This increment in asphaltic content may be taken into account in the cost balance consideration in most sensitive projects.
- 6- Kerbala County represents the main origin of both WCG and WRG, therefore the two types are better to be used for road construction with low costs.

Recommendations:

The following points are recommended:-

- 1- It is recommended to use WCG as another option for its acceptable physical properties and easiness if obtaining from its origin for projects especially located in the middle of Iraq.
- 2- It is recommended to perform an extensive study to investigate the physical effects of such gravel type in the design of High Strength Concrete Mixes (HSC)
- 3- An extensive chemical study for WCG is recommended.

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