A Comparative Study of the Suitability of Dakuk, Kirkuk-Iraq and Tuz, Salahaddin-Iraq Coarse Aggregates for Construction Purposes

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Abstract: **This paper investigates the properties of some natural coarse aggregates in Dakuk and Tuz. Two gravel samples were obtained from different locations and transported to Civil Engineering Laboratory, Technical Institute of Kirkuk and Concrete Laboratory in Koya University. Tests conducted on the gravel samples include: specific gravity, bulk density, sieve analysis, abrasion, absorption, impact, crushing, elongation and flakiness. Test results revealed that the specific gravities of the gravels Dakuk and Tuz to be (2.641, 2.576) , compacted bulk densities to be (1657 Kg/m3, 1640 Kg/m3), loose bulk densities for both to be (1573 Kg/m3), abrasions to be (16.3%, 13.6%) , Gravel samples possessed low water absorption value (1% and 0.9%) and low effective porosity, elongation index to be 14% , 20% and flakiness (16.2% , 31%) , Aggregate impact values of samples were (9.18 and 7.33%) showing good soundness, crushing values of samples were (5.92% and 5.71%) , Los Angeles abrasion test also showed consistent hardness of each of the samples (16.3 and 13.6%) . The study results indicated that both samples satisfy the Iraqi standards, British standards and American Standards of Testing Material for concrete and road aggregates.**

***Keywords*—Absorption, Abrasion, Coarse Aggregate, Crushing Value, Elongation Index, Flakiness Index, Impact Value, Los Angeles Test, Sieving Analysis.**

I. INTRODUCTION

The importance of using the right type and quality of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger than 5 mm (0.2 in.) and generally between 9.5 mm and 37.5 mm (3⁄8 in. and 11⁄2 in.). Some natural aggregate deposits, called pit-run gravel, consist of gravel and sand that can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed.

Aggregates must conform to certain standards for optimum engineering use: they must be clean, hard, strong, durable particles free of absorbed chemicals, coatings of clay, and other fine materials in amounts that could affect hydration and bond of the cement paste. Aggregate particles that are friable or capable of being split are undesirable. Aggregates containing any appreciable amounts of shale or other shale rocks, soft and porous materials should be avoided, Normal-weight aggregates should meet the requirements of ASTM C 33.There are several reasons for specifying both grading limits and maximum aggregate size. Aggregates having a smooth grading curve and neither a deficiency nor excess of any one particle size will generally produce mixtures with fewer voids between particles. Since cement costs more than aggregate and the cement paste requirement for concrete increases with increasing void content of the combined aggregates, it is desirable to keep the void content as low as possible. If there is not enough sand to fill the voids between coarse aggregate particles, the space must be filled with cement paste. These under sanded mixes also tend to be harsh and difficult to finish. On the other hand, aggregate combinations with excessive amounts of sand or excessively fine sands may produce uneconomical concretes because of the larger surface area of finer particles. The maximum size of coarse aggregate used in concrete has a bearing on the economy of concrete. Usually more water and cement is required for small-size aggregates than for large sizes, due to an increase in total aggregate surface area, [1]. The specific gravity of an aggregate is used in mixture proportioning calculations to find the absolute volume that a given mass of material will occupy in the mixture. Absolute volume of an aggregate refers to the space occupied by the aggregate particles alone; that is the volume of solid matter and internal aggregate pores not including the voids between particles, [1]. The total water content of the concrete can be controlled and correct batch weights are determined. The internal structure of an aggregate particle is made up of solid matter and voids that may or may not contain water. The amount of water added to the concrete batch plant must be adjusted for the moisture conditions of the aggregates in order to accurately meet the water requirement of the mix design. If the water content of the concrete mixture is not kept constant, the water-cement ratio will vary from batch to batch causing other properties, such as the compressive strength and workability to vary from batch to batch, [2]. The amount of water added to the concrete batch plant must be adjusted for the moisture conditions of the aggregates in order to accurately meet the water requirement of the mix design. If the water content of the concrete mixture is not kept constant, the water cement ratio will vary from batch to batch causing other properties, such as the compressive strength and workability to vary from batch to batch, [1]. The bulk density is used in estimating quantities of materials and in some mixture proportioning calculations. If the moisture content of the aggregate varies, its bulk density will also vary for coarse aggregate. Increasing moisture content increases the bulk density. Other properties that affect the bulk density of an aggregate include grading, specific gravity, surface texture, shape and angularity of particles. Aggregates having neither a deficiency nor an excess of any one size will usually have a higher bulk density than those with a predominance of one size particles present. Higher specific gravity of the particle results in higher bulk density for a particular grading, and smooth rounded aggregates will generally have a higher bulk density than rough angular particles of the same mineralogical composition and grading. The rodded bulk density of aggregates used for normal-weight concrete generally ranges from 1200 to 1760 kg/m3 (75 to 110 lb./ft^3), [2]. The particle shape and surface texture of an aggregate influence the properties of freshly mixed concrete more than the properties of hardened concrete. Rough-textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, compact aggregates. Hence, aggregate particles that are angular require more cement to maintain the same water cement ratio. However, with satisfactory gradation, both crushed and not crushed aggregates (of the same rock types) generally give essentially the same strength for the same cement factor. Angular or poorly graded aggregates can also be more difficult to pump, [2]. Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. In general, excessively flaky aggregate makes very poor concrete, [3]. The abrasion resistance of an aggregate is often used as a general index of its quality. Abrasion resistance is essential when the aggregate is to be used in concrete subject to abrasion, as in heavy-duty floors or pavements. Low abrasion resistance of an aggregate may increase the quantity of fines in the concrete during mixing; consequently, this may increase the water requirement and require an adjustment in the water-cement ratio, [2]. Since concrete is an assemblage of individual pieces of aggregate bound together by cementing material, its properties are based primarily on the quality of the cement paste. This strength is dependent also on the bond between the cement paste and the aggregate. If either the strength of the paste or the bond between the paste and aggregate is low, a concrete of poor quality will be obtained irrespective of the strength of the rock or aggregate. But when cement paste of good quality is provided and its bond with the aggregate is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of concrete. From the above it can be concluded that while strong aggregates cannot make strong concrete, for making strong concrete, strong aggregates are an essential requirement. In other words, from a weak rock or aggregate strong concrete cannot be made. By large the naturally available mineral aggregates are strong enough for making normal strength concrete, [3].

II. METHODOLOGY

For the purpose of this work two natural coarse aggregates samples were obtained from areas currently in use for construction purposes in Dakuk, Kirkuk and Tuz, Salahaddin in Iraq as in Fig(1).

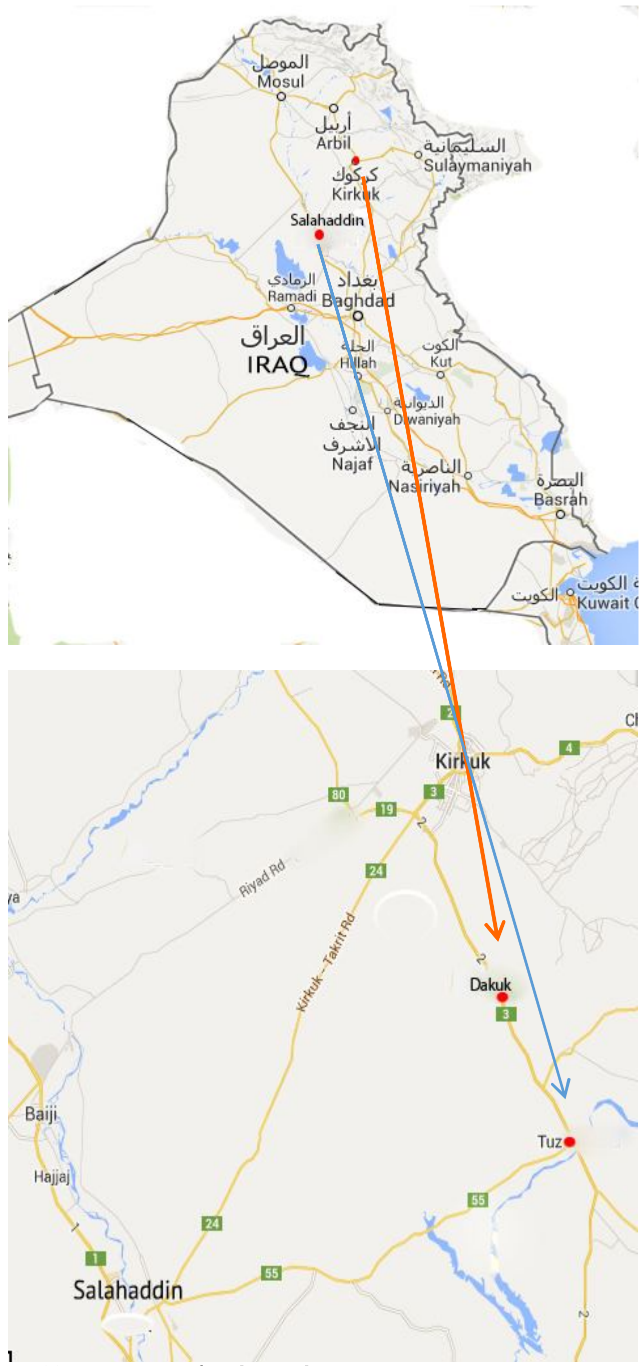


Fig (1) Location Map of Study Samples

The tests carried out were as below:

1—Grading

Grading refers to the distribution of particle sizes present in an aggregate. The coarse aggregate grading requirements of ASTM C 33 permit a wide range in grading and a variety of grading sizes, [1]. A sample of the aggregate is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom. After sieving, the mass of material retained on each sieve and on the pan is obtained using a balance accurate to 0.1% of the test-sample mass. Results are recorded in tabular form with some or all of the following quantities retained on each sieve, total percentage retained on each sieve, and total percentage passing each sieve. Grading charts are drawn to show the results of a sieve analysis graphically. The percentage passing is usually plotted on the vertical axis, while the sieve sizes are plotted on the horizontal axis. Upper and lower limits specified for the allowable percentage of material passing each sieve may also be included on the grading chart, [1].

2-Relative Density (Specific Gravity)

The relative density (specific gravity) of an aggregate is the ratio of its mass to the mass of an equal absolute volume of water. It is used in certain computations for mixture proportioning and control, such as the volume occupied by the aggregate in the absolute volume method of mix design, [2]. Test methods for determining relative densities for coarse and fine aggregates are described in ASTM C 127, [4].

3- Absorption and Surface Moisture

The absorption and surface moisture of aggregates should be determined according to ASTM C 127, [4], so that the total water content of the concrete can be controlled and correct batch weights determined. The internal structure of an aggregate particle is made up of solid matter and voids that may or may not contain water. The moisture conditions of aggregates are Oven dry, Air dry, saturated surface dry (SSD), Damp or wet, [2].

4-Bulk Density (Unit Weight) and Void

The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles, [2]. Methods of determining the bulk density of aggregates and void content are given in ASTM C 29, [5].

5 –Elongated Index and Flaky Index

Aggregate particles are classified as elongated when they have a length (greatest dimension) of more than 1.8 of their mean sieve size, this size being taken as the mean of the limiting sieve apertures used for determining the size fraction in which the particle occurs. The elongation index is found by separating the elongated particles and expressing their mass as a percentage of the mass of sample tested. Flaky index: Aggregate particles are classified as flaky when they have a thickness (least dimension) of less than 0.6 of their mean sieve size, [2]. Elongated index and flaky index were tested with BS 812:Section105.2, Section105.1 [6]

6- Crushing Value

Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load. This test is made on single sized aggregate Passing12.5 mm and retained on 10 mm sieve and in a saturated dry surface condition. The aggregate is placed in a cylindrical mould and

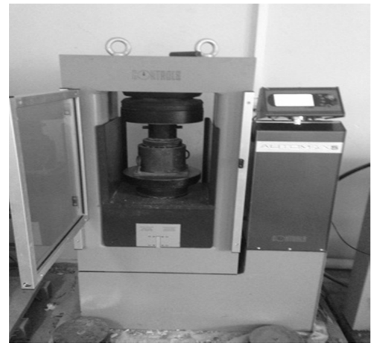


Fig (2) Aggregate Crushing Apparatus

a load of 40 ton is applied through a plunger, As shown in fig (2), the material crushed to finer than 2.36 mm is separated and expressed as a percentage of the original weight taken in the mould. The aggregate crushing value is calculated using the following formula (IQS NO.47):-

Aggregate crushing Value = (W2/W1)*100

Where: - W1=initial weight of sample

W2 = weight of aggregate passing through sieve 2.36mm

The crushing value of aggregate is restricted to 30 % for concrete used for roads and pavements and 45 % may be permitted for other structures. Therefore aggregate impact values of the samples studied lies within the IQS standards, [7].

7- Impact Value Test

Impact value is considered the measurement of aggregate toughness and basically is the percentage of fines produced from the aggregate after the aggregate sample subjected to fifteen blows of a metal hammer of weight 14 Kg falling from a height of 38 cm as shown in fig 3. The quantity of finer material (passing through 2.36 mm) resulting from pounding will indicate the toughness of the sample of aggregate. The ratio of the weight of the fines (finer than 2.36 mm size) formed, to the weight of the total sample taken is expressed as a percentage. This is known as aggregate impact value which is calculated using the following formula (IQS NO.47 &BSI:1992) (7,8):-

Aggregate Impact Value = (W2/W1)*100

Where: - W1=initial weight of sample

W2 = weight of aggregate passing through sieve 2.36mm.

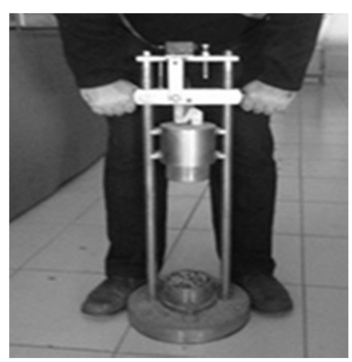


Fig (3) Impact Machine

C-Abrasion

Abrasion and impact resistance of an aggregate of 10% is regarded as strong and impact values above 35% would normally be regarded as too weak for using in concrete for wearing surfaces, such as run ways, roads and pavements due to BS:1992, [8]. Its ability to resist being worn away by rubbing and friction, or shattering upon impact is referred to as abrasion. It is a general measure of aggregate quality and resistance to degradation due to handling, stockpiling, or mixing. The most common test for abrasion resistance is the Los Angeles Abrasion test (rattler method) performed in accordance with ASTM C 131, [9]. In this test, a specified quantity of aggregate is placed in a steel drum containing steel balls as in fig (4). The drum is rotated, and the percentage of material worn away is measured, [1]. The abrasion value should not be more than 30 % for wearing surfaces and not more than 50 % for concrete other than wearing surface, [3].

Fig (4) Los Angeles machine

III. RESULTS & DISCUSSIONS

1-Sieve Analysis of Samples

The results for sieve analysis are shown in Table (1). The sample Dakuk satisfies the overall grading limit as in fig (5) except the percentage finer than 12.5mm sieve size which was 4.93% falling outside the range (10-40%). The soil is also fine grading. Soil sample Tuz satisfies the overall grading limit except the percentage finer than 12.5 mm sieve size which was 8.7 % falling outside the range (10-40%). The gravel samples agree reasonably well with [10] and are recommended for construction purposes.

Table 1: The Results of Sieve Analysis

Sieve Size (mm)	38	25	19	12.5	9.5	4.75	PAN
Sample	Percentage Finer (%)						
Dakuk	100	100	69	4.93	0.133	0	0
Tuz	100	100	70.6	8.7	1.7	0	0

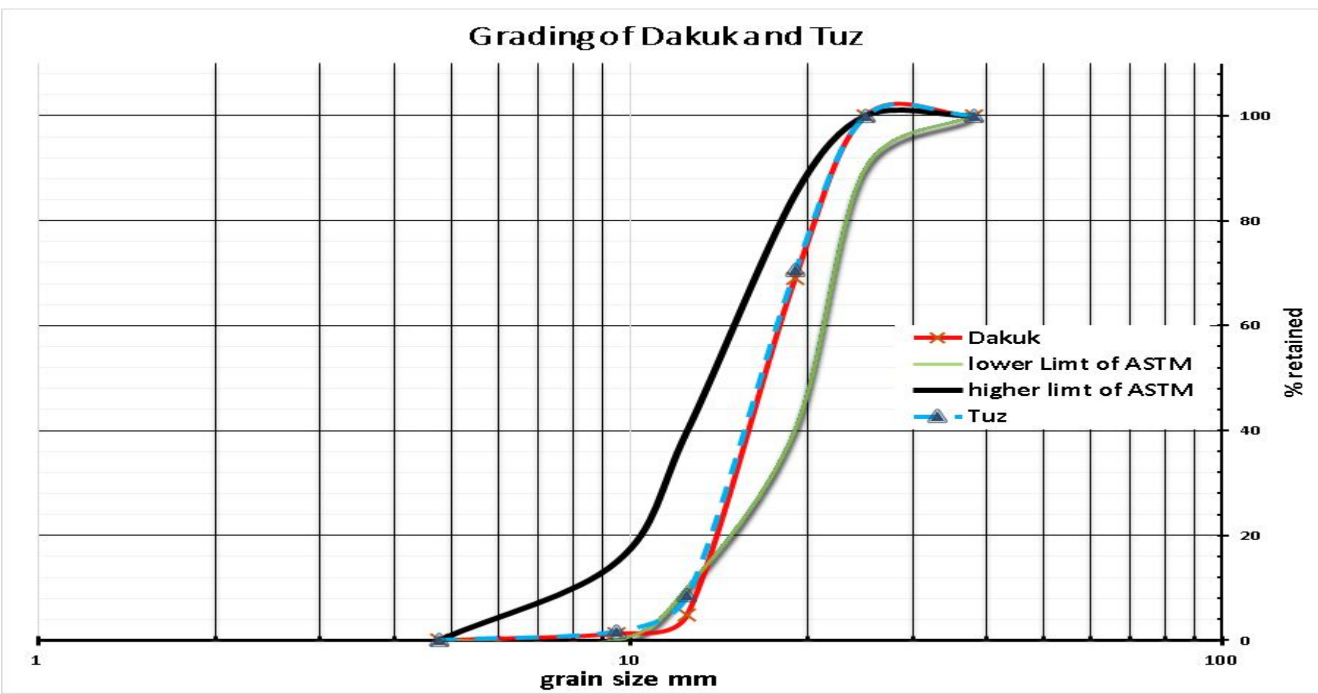


Fig (5) Graphical Representation of Samples Grading

2-Bulk Density

The results for the bulk densities of gravel samples are shown in Table 2. The compacted bulk densities of the aggregates were between 1636 Kg/m^3 to 1663 Kg/m^3 whereby the average were1640 and 1655 Kg/m^3 for Tuz and Dakuk samples. The loose bulk densities of the aggregates were between 1554 and 1598 Kg/m^3, averaging 1573 Kg/m^3 for both Tuz and Dakuk samples.

Table 2. Bulk Density of Gravel Samples

Loose		
Sample	Dakuk	Tuz
Test 1	1598	1591
Test 2	1564	1575
Test 3	1557	1554
Average Kg/m^3	1573	1573
Compacted		
Test 1	1642	1636
Test 2	1661	1637
Test 3	1663	1648
Average Kg/m^3	1655	1640

3-Specific Gravity

The results for the specific gravities of gravel samples are shown in Table 3.The average specific gravities were 2.576 for Tuz samples and 2.641 for Dakuk samples. The experimental results were in line with the standards.

Table (3) Specific Gravity of Samples

Samples	Dakuk	Tuz
Average Spec. Gravity	2.641	2.576

4-Absorption of gravel Samples

The results for the Absorption of gravel are presented in Table 4. According to [4], it is permitted for the absorption of gravel to have a maximum value of 2%. Gravel samples here have absorption which is lower than 2%.

Table 4. Absorption % 0f Samples

Samples	Dakuk	Tuz
Absorption (%)	1	0.9

5-Abrasion of gravel Samples

The results for the abrasion of gravel are presented in Table 5. According to [11], the permitted abrasion of gravel must be less than %40. Since both gravel samples have lower values than that, we can use them for heavy duty floors or pavements.

Table (5) Abrasion % of Samples

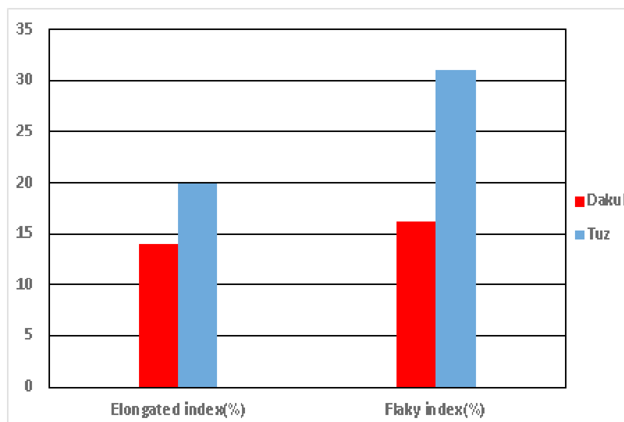
Samples	Dakuk	Tuz
Abrasion (%)	16.3	13.6

6- Elongated, Flakiness index

Here we observe considerably lower Elongated index for the Dakuk and Tuz samples. According to [6], it is permitted to have maximum elongated index of 25% , and maximum flakiness index of 25%. In chart (1), Elongation & Flakiness Indices seem to be relatively different. The flakiness index is considerably higher, (above the range), for Tuz samples compared with Dakuk samples, but both samples are within the range as long as the elongated index is concerned.

Table (6) Elongated & Flaky index %

Samples	Dakuk	Tuz
Elongated index(%)	14	20
Flaky index(%)	16.2	31



Chart(1) Elongated & Flaky index %

7-Aggregate Crushing values:

From the test results illustrated in table (7) and chart (2), it is shown that the coarse aggregate of Tuz zone has better resistance to crushing force than the coarse aggregate of Dakuk zone.

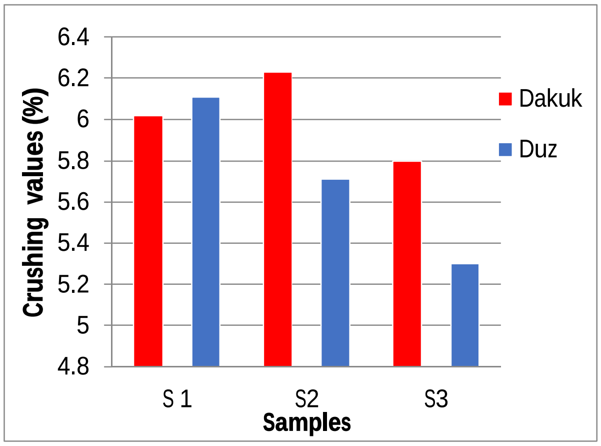


Chart (2) Aggregate crushing values

TABLE (7) CRUSHING VALUES AS PERCENTAGE OF SAMPLES

No.	Crushing value (%)	
	Dakuk	Tuz
S1	6.02	6.11
S2	6.23	5.71
S3	5.8	5.3
Ave.	5.92	5.71

8- Aggregate Impact value

From the test results illustrated in table (8) and chart (3) we see that the coarse aggregate of Tuz zone has better resistance to impact force than coarse aggregate of the Dakuk zone.

Table(8) Impact values as percentage of samples

No	Impact value (%)	
	Dakuk	Tuz
S1	8.77	6.87
S1	9.59	7.25
S1	9.18	7.86
Ave	9.18	7.33

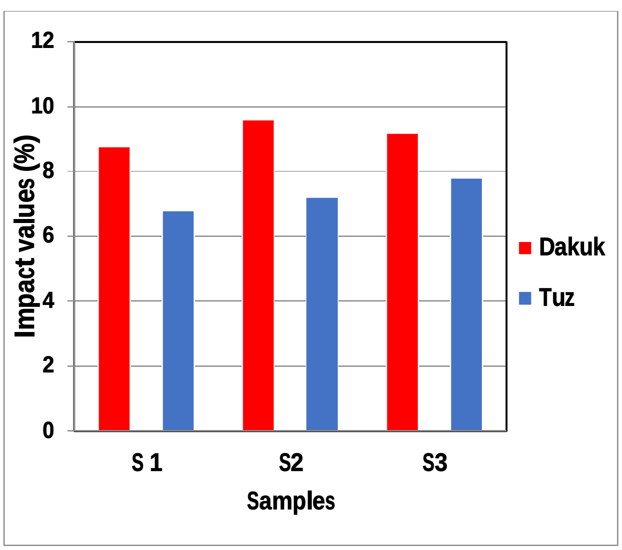


Chart (3) Aggregate impact values

IV. CONCLUSIONS

The following conclusions can be drawn from this study:-

1- The specific gravity tests revealed average values for Dakuk as (2.641) being slightly higher than that of Tuz (2.576). Both samples belong to the normal weight aggregate.

2- The compacted bulk density revealed average values for Dakuk as (1655 kg/m^3) being slightly higher than that of Tuz (1640 kg/m^3), while both samples show the same loose density as (1573 kg/m^3).

3- The absorption tests revealed average values for Dakuk as (1%) being slightly higher than that of Tuz (0.9%).

4- The Los Angeles abrasion test revealed average values for Dakuk as (16.3%) being considerably higher than that of Tuz (13.6%). Which reflects that the erosion of Tuz aggregates is less than that of Dakuk samples.

5- The impact value test revealed average values for Dakuk as (9.18 %) being considerably higher than that of Tuz (7.33 %), which indicates that the toughness of Tuz aggregates is higher than that of Dakuk samples.

6- The crushing value test revealed average values for Dakuk as (5.92%) being slightly higher than that of Tuz (5.71%), which gives indication that the strength of Tuz aggregates is higher than that of Dakuk aggregates.

7- The flakiness and elongation test revealed average values for Dakuk as (14 and 16.2%) being considerably lower than that of Tuz (20 and 31%).

8- Both samples satisfy the overall grading limits for natural coarse aggregate and are suitable for construction purposes.

All tests results show that the physical and mechanical properties of Dakuk and Tuz aggregates satisfy the standards.

Recommendations

It is recommended to do further tests to the two samples such as:

1-Sulphate resistance, freezing and thawing.

2- Further investigation on the occurrence history of aggregate samples, their structural behaviour and morphology.

References

[1] ACI Education Bulletin E1-99, AGGREGATES FOR CONCRETE Developed by Committee E-701

[2] Design and Control of Concrete Mixtures (13th Edition), (EB- 001), Kosmatka, Steven H.& Panarese,William C.1988-02

[3] Materials for Concrete Construction Charles K. Nmai, Chairman David M. Suchorski, Patrick L. McDowell Secretary Chairman.

[4] ASTM, Book of American Standard Specification, Standard Specification for Concrete Aggregates C33, 2001.

[5] ASTM C127, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate. Book of American Standard of Testing Materials Standards, 1978.

[6] Properties of Some Natural Fine Aggregates in Minna, Nigeria and Environs, M. ABDULLAHI Civil Engineering Department, Federal University of Technology, Minna, Niger State, Nigeria.

[7] ASTM, Book of American Standard of Testing Materials Standards, Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate C 29, 2009.

[8] BS 812: Section105.2: 1990UDC [625.07+691.22]:620168.36 Testing aggregates Part 105. Methods for determination of particle shape Section 105.2 Elongation index of 6- coarse aggregate.

[9] Iraqi specification No.47, "Aggregate tests from natural source for concrete and building construction", 1980.

[10] BSI, Specification for aggregate from natural sources of concrete, BS 882, British Standard Institution (BSI) London, 1992.

[11] ASTM, Book of American Standard of Testing Materials Standards, Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine C131, 2006.