Journal homepage www.jzs.univsul.edu.iq
Journal of Zankoy Sulaimani
Part-A- (Pure and Applied Sciences)

Crushed limestone from Pila Spi Formation as alternative for conventional aggregate, Qaradagh area, Kurdistan region - Iraq

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Article info
Original:06.10.2015
Accepted: 03.05.2016
Published online: 15.05.2016

Key Words:
Pila Spi Formation
Crushed limestone
Compressive strength.

Abstract

The late Eocene limestone rocks of Pila Spi Formation from Qaradagh area in Sulaimani Governorate, Kurdistan region (NE of Iraq) have been selected as alternative for conventional aggregate in concrete. The collected samples from the section are analyzed chemically and physically. Field investigations in the area were adopted. The laboratory tests including particle size analysis, los angeles abrasion, specific gravity, water absorption, soundness and gypsum content had been done for the crushed limestone aggregates. In addition, twelve concrete cubes in dimension 15cm^3 have been molded according to the Iraqi Standards and the compressive strength test was carried out on it. The aggregate mix design consists of 1.5: 2: 4 with 0.5 water/ cement ratio. The results of the aggregate are compared with the international standard tests; accordingly, the Limestone of Pila Spi Formation is acceptable as alternative for natural sand and gravel.

Introduction

Limestone which is composed from calcium carbonate $CaCO_3$ are common and widespread rocks that form most topographic features in Kurdistan region (NE of Iraq), It is also has chemical and physical properties that deliver exceptional performance and value in a broad range of applications. Aggregate is a collective term for the materials such as sand, gravel and crushed stone, which are used with a binding medium to form compound materials such as water, bitumen, Portland cement, lime, etc. Crushed Limestone aggregate used with Portland cement concrete for roads, buildings, other structures and in combination with bituminous materials for roads and similar constructions. They also used to make base courses for various types of pavements and to make water-bound macadam and unpaved roads [14], typically produced by mining and using crushers to produce different sizes of aggregates like sand and gravel. It is planned to use crushed aggregates instead of crushed boulders and natural mixture of aggregate which is nowadays used in Kurdistan region as their quantity is minimizing continuously. Therefore, crushed limestone aggregates and 12 concrete cubes in dimension 15cm^3 are prepared according to the Iraqi Standard [11]. Laboratory tests were carried out to assess the suitability of limestone in the Pila Spi Formation as alternative for conventional aggregates according to the results.

Studied area

Tlazait crusher is located 30 km South East of Sulaimani city, about 10 km North Qaradagh Town and near Tlazait village, in the middle of the Southwestern part of the Baranan Mountain in Kurdistan Region of Iraq. It is located in the intersection of longitude East 45º28′37″ and latitude North 35º21′26″ (Figure: 1). The studied area located at the boundary between High and Low Folded Zones [16], where extensive outcrop of the formation is found (Figure: 2).

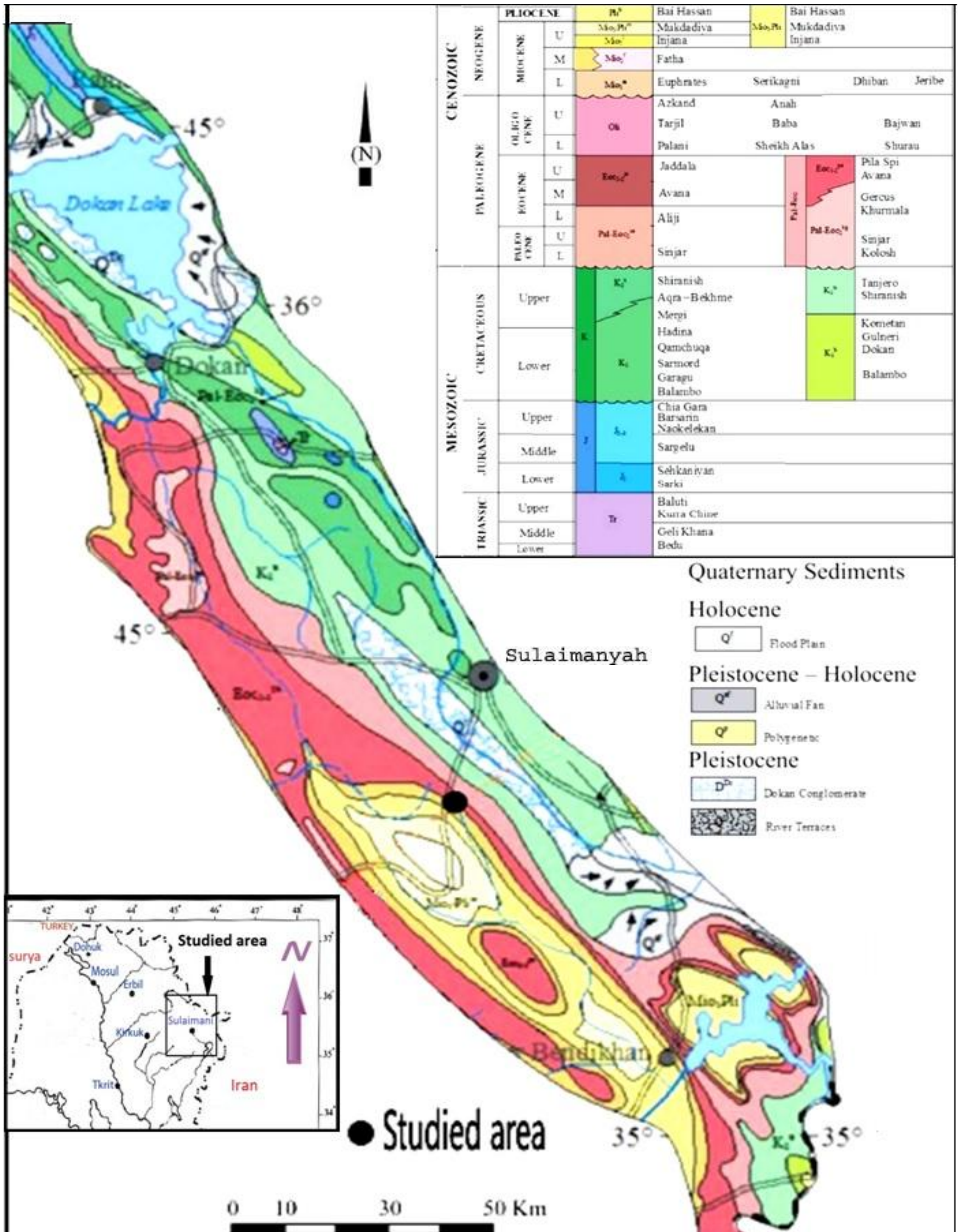

Figure-1: Geological map of the studied area after [15].

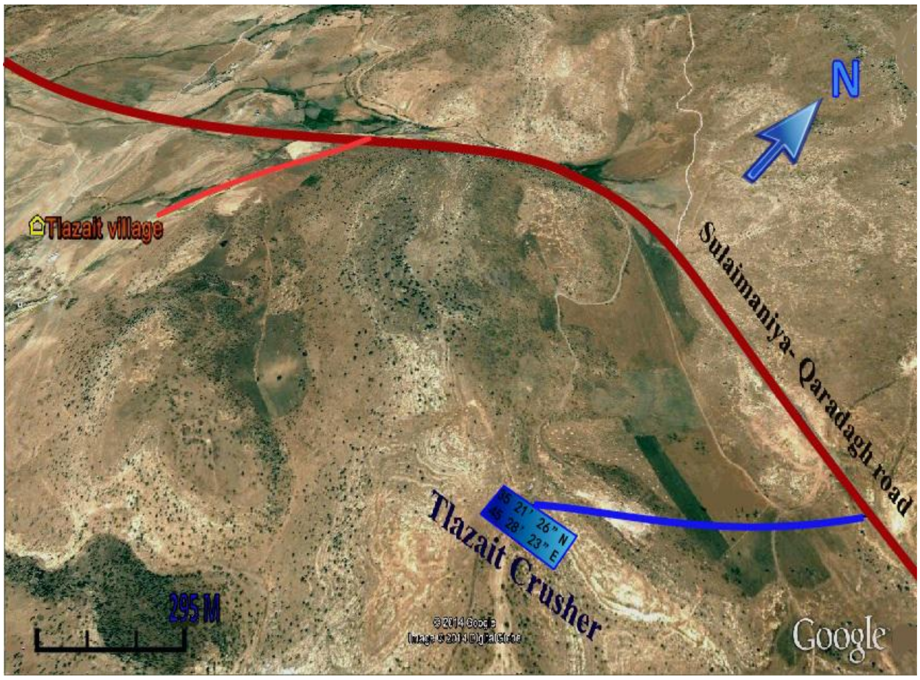

Figure- 2: Google image show the studied area.

Material and Methodology

Six samples are selected from Tlazait crusher. This aggregate is produced by crushing limestone from Pilaspi Formation. The samples are taken according to the location and geological conditions near to Tilazait crusher (Figure: 3), after mining via explosion. The cement used for the cubes is ordinary Portland cement (type 1) From United Cement Company at Sulaymaniyah (Tasluja- Bazian). Many tests have been conducted in Sulaimani Constructional Laboratory on limestone rocks for evaluating this rock for aggregate such as particle size analysis, los angeles abrasion, specific gravity, water absorption, soundness, and gypsum content and compressive strength**.**

Figure-3: Tlazait Crusher.

Geology of the studied area

Many geological formations are exposed within the studied area such as Kolosh, Sinjar, Gercus, Pila Spi, Lower Fars, Upper Fars, Lower Bakhtiari and Upper Bakhtiari Formations from northeastern limb to Southwestern limb of the Baranan anticline respectively. The Pila Spi Formation consists of two parts: "The upper part shows well-bedded bituminous limestone, weathering white, chalky and crystalline, with bands of pale green marl or chalky marl with buckled bedding planes; bands of buff chert nodules towards the top, traces of fossils; 57 m thick. The lower part shows well bedded limestone, hard though of chalky appearance, porous or vitreous, bituminous or white, poorly fossiliferous, algal and shell sections in calcite, 28 m thick" [6]. In the Qaradagh area the Pila Spi Formation is underlain by the Gercus Formation, and overlain uncomfortably by Lower-Fars Formation [16]. The formation was deposited in a shallow lagoon environment. Fossils are abundant and indicate a late Eocene age. In north Iraq the formation may be partly of middle Eocene age [12]. The Pila Spi Formation is very well exposed in the High Folded Zone; in form of outstanding scarps, which represent the contact between the High Folded and Low Folded Zones. It is exposed in Zakho, Dohuk, Zawita, Amadiya, Gara, Alqosh, Ain Sifni, Aqra, Peris, Shaqlawa, Salah Al-deen, Koi Sanjaq, Haibat Sultan, Qara Dagh, Darbandi Khan, Zimnako, Sharwaldir, and Bammu [16].

Crushed limestone properties

Crushed limestone aggregate is normally characterized by better surface texture and high angularity that obtains good bond which the cement and good particle interlock [8], both of them help in achieving good compressive strength properties. Concrete containing crushed rock will have higher strength than similar concrete made with rounded aggregate [4]. In addition to that low possibility of alkali-silica reaction which provide the aggregates reactive forms of silica, this reacts expansively with the alkalis contained in the cement paste, the expansion can cause cracking and also the decrease in drying shrinkage in concrete. The crushed limestone aggregate is more suitable than conventional aggregate because the conventional aggregates contain various forms of non- crystalline silica minerals, which have varying reactivity - a measure of the readiness of the silica to react with alkali [9]. Crushed Limestone for fine aggregate need to be washed because commonly that makes the aggregate dusty, it must be removed from the sand before combining with coarse aggregate and cement [13]. To improve workability of crush limestone aggregate as alternative to conventional aggregate these tests below will follow.

A. Particle Size Analysis

By observations during the sieve analysis the percent size passing of coarse gravel by weight into the sieve size 20mm is 83%, for sieve size 10mm is 2% and for 5mm is 0.1%. According to the Iraq specification fine gravel is required because 2% for sieve size 10mm less than 30 %, for this reason fine gravel add to the aggregate, for sieve size 10mm which passing 61 % and for sieve size 5mm is 0.9%. And the range size required for the sand is obtain which is between the sieve size 4.75mm to 75mc , the result of the sieve analysis according to the [10] reflect that crushed limestone aggregate of Pila Spi Formation are suitable for used in most types of concrete as shown in Tables 1, 2 and 3.

Table-1: Sieve analysis results of Tilazait crusher for coarse size Gravel.

		Stander specification for Gravel		
				Fine gravel
Sieve size	Gravel Percent passing by weight	(5 – 40) mm	(5 – 20) mm	(4 – 14)mm
37.5mm	100	95 - 100	100	-
20 mm	83	35 – 70	95 - 100	100
14 mm	-	-	-	90 – 100
10 mm	2	10 – 40	30 - 60	50 – 85
5 mm	0.1	2 – 10	1 – 10	0 – 10

Table -2: Sieve analysis results of Tilazait crusher for fine Gravel.

		Stander specification for Gravel		
				Fine gravel
Sieve size	Gravel Percent passing by weight	(5 – 40) mm	(5 – 20) mm	(4 – 14) mm
37.5 mm	100	95 - 100	100	-
20 mm	100	35 – 70	95 - 100	100
14 mm	100	-	-	90 – 100
10 mm	61	10 – 40	30 - 60	50 – 85
5 mm	0.9	0 – 5	0 - 10	0 – 10

Table-3: Sieve analysis results of Tlazait crusher for sand.

Sieve size	Percent passing by weight	Sand specification
10 mm	100	100
4.75 mm	93	90 – 100
2.36 mm	64	60 – 95
1.18 mm	37	30 – 70
600 mc	20	15 – 34
300 mc	10	5 – 20
150 mc	6	0 – 10
75 mc	3.4	0 – 5

B. Los Angeles Abrasion

As determined by ASTM Designation C 131 – 01 which indicates the resistance of the aggregate to degradation by impact in the Los Angeles Machine is 34%. Such result indicate the workability of the crushed limestone aggregate for type 2 along 500 round of rotation and 11 spheres, according to the [5] shall not exceed 35%.

C. Specific Gravity

Specific gravity is the ratio of the mass of a given volume of aggregate to the mass of an equal volume of water [1]. The result of the Bulk specific Gravity is 2.44, Bulk Saturated Surface Dry (SSD) Specific Gravity is 2.52 and Apparent Specific Gravity is 2.67, which found according to [1].

D. Water Absorption

Water absorption is increase in mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles [1]. However the water absorption test of aggregate is not required in the Iraqi specification for concrete, but this test had been done so the result is 3.5 %**,** the water absorption should not exceed 5% according to specification [1]. Water absorption of aggregate is very important. These properties affect aggregate qualities such as the bond between aggregate and cement, also affecting concrete strength and freezing [13].

E. Soundness

It is the durability or resistance to weathering [2] by use of Magnesium Sulfates, soundness test of aggregate had been done. The results show durability of the crushed limestone of Pila Spi Formation is 1.43% and the maximum range of soundness is 18% according to AASHTO, Designation [2].

F. Gypsum Content

The Gypsum content was determined for aggregate; the result shows the applicability of crushed limestone of Pila Spi Formation which is 0.047%. The Gypsum content of aggregate in concrete shall not exceed the 5% according to [7].

Mixing and molding

The standard cubes mold (15*15*15) cm^3 are used for production of concrete samples according to [11]. Cubical specimens are used to test the compressive strength of concrete. Twelve cubes are prepared for each operation. After mixing cement, sand and gravel respectively on this proportion 1.5: 2: 4 with 0.5 water/ cement ratio, the concrete cubes were leaved in the molds for one day. After that by using air pressure the moulds were took off and started curing for 7-28 days, was achieved as shown in (Figure: 4). The purpose of the mix design is to group the aggregates in different proportions to achieve the desired strength. Eventually the aggregate mixed to make reinforced concrete this type of concrete is needs compressive strength more than 25 MPa and the suitable design to reaching this durability is 0.5: 1.5: 2: 4 for water/cement ratio, cement, sand and gravel respectively according to [3], shown in Table 4. The compressive test was done according to Iraqi Standards [11] by uniaxial compressive strength.

Figure - 4: Concrete component and cubes.

Table - 4: Mix design.

	Gravel	Sand	Cement(C)	Water(w)	w/c ratio
Mix ratios	45%	2%	1.5%	-	0.5
Mix weight(kg)	64	32	24	12 (liter)	0.5

Compressive strength of concrete cubes

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, it can be measured by plotting applied force against deformation in a uniaxial compressive strength testing machine according to [10] (Figure: 5). From laboratory work after concrete casting, the cubes submerged in water for two periods 7 and 28 days. The applied rate of compressive load for studied prepared cubes ranges between 632 KN – 1025 KN according to the time of cubes failure. Clearly the average compressive strength for concrete cubes of 7 days lower than 28 days along the curing time, the strength of concrete increase gradually as time increased [4], which is compressive strength for 7 days are 24.5 Mpa and for 28 days are 37.4 Mpa. The average weight of the concrete cubes at 7 days is 7.8 kg and the average weight for 28 days is 7.9 kg. By observing the weight of the concrete cubes it can be inferred that the concrete cubes with crushed limestone aggregate is lighter weight than concrete cubes with conventional aggregate due to low specific gravity of the aggregate which is the bulk specific gravity 2.44, never the less indicate high compressive strength which is 37.4, that is a good advantage when lighter weight concrete is required, also the result shows in Tables 5 and 6.

Figure-5: laboratory test (compressive strength for concrete cubes).

Table-5: Laboratory test result for cubes after 7 day.

Cubes Number	Weight (Kg)	Maximum load at failure (KN)	Compressive strength (Mpa)
1	7.677	546	22.7
2	7.548	632	26.3
3	7.602	591	24.5
Average	7.6	590	24.5

Table-6: Laboratory test result for cubes after 28 day.

Cubes number	Weight (Kg)	Maximum load at Failure (KN)	Compressive Strength (Mpa)
1	7.836	807	35.5
2	7.902	829	36.5
3	7.958	756	33.3
4	7.94	890	39.2
5	7.976	856	37.7
6	7.949	901	39.6
7	8.072	1025	45.1
8	7.87	778	34.2
9	7.87	800	35.2
Average	7.9	849	37.4

Conclusion

1- The crushed limestone of Pilaspi Formation from Qaradagh area within required limits of the standard specification is considered as a good alternative of conventional aggregate.

2- The results lead to applicability of crushed limestone aggregate as lighter weight concrete than conventional concrete due to low specific gravity of crushed limestone aggregate which is the bulk specific gravity 2.44.

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