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Critical Evaluation for Grading and Fineness Modulus of Concrete Sands used in Sulaymaniyah City-Iraq

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ABSTRACT

Fine aggregates used for concrete works in Sulaymaniyah city frequently fail to meet the standard requirements for gradation and fineness modulus in cement concrete. This paper aims to critically evaluate gradation, fineness modulus, and clay contents of various natural sands produced and used for concrete work in the region. Sixteen field sand samples were collected from various sites in Darbandikhan (5 samples), Qalat Dizah (5 samples), Koysinjaq (5 samples), and Piramagroon (1 sample) confirming to ASTM D75. The field samples were parted into test specimens based on ASTM C702. Then, sieve analysis was carried out on the oven-dry test specimens in compliance with ASTM C136. The test results of fine aggregates were compared with American, British, and Iraqi specification standards using ASTM C33, BS 882, and IQS No. 45. It was revealed that only three sands satisfy the ASTM gradation limits while others do not comply and are on the coarser side. Also, eight samples meet the requirements recommended by BS 882, whereas five samples meet limits by IQS No. 45. It was found that only three sands have the fineness modulus within the ranges recommended by ACI 211.1 and ACI 211.4, while the others have high values. Furthermore, it was found that all sands include an allowable amount of finer particles passing sieve size 0.075 mm. In order to improve particle size distributions, it is recommended to use the blending method to obtain a suitable fine aggregate from two or more failed sands.

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Keywords: Fine Aggregate Gradation; Sieve Analysis; Fineness Modulus; Clay Content; Standard Specification Limits

التقييم النقدي لتصنيف ومعامل الصفاء للرمال الخرسانية المستخدمة في مدينة السليمانية – العراق

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الخلاصة

في كثير من الأحيان يفشل الركام الناعم في مدينة السليمانية بتلبية متطلبات المدونات القياسية للتدرج ومعامل النعومة للاستخدام في تنفيذ المشاريع الخرسانية. يهدف هذه البحث إلى إجراء تقييم عملي للتدرج ومعامل النعومة والمحتوى الطيني لمختلف انواع الرمال الطبيعية المنتجة والمستخدمة في ألاعمال الخرسانية في المنطقة. تم جمع ستة عشر عينة من الرمل الحقلي ومن اماكن مختلفة كدربنديخان (5 عينات) وقلعة دزة (5 عينات) وكويسنجق (5 عينات) وبيراماكرون (عينة واحدة) وذلك لفحصها ومعرفة مدى مطابقتها للمواصفة القياسية (ASTM D75). تم اخذ العينات الميدانية وفصلها في عينات اختبار وذلك وفق المواصفة (ASTM C702). كما وتم إجراء التحليل المنخلي على عينات الاختبار بعد التجفيف بالفرن وفق المواصفة (ASTM C136). تمت مقارنة نتائج الفحوصات للركام الناعم مع معايير المواصفات الأمريكية (ASTM C33) والبريطانية (BS 882) والعراقية (IQS NO.45). اظهرت النتائج أن ثلاثة انواع رمال فقط كانت تفي بمتطلبات المواصفة الامريكية للتدرج ASTM فيما لم يتوافق النماذج الاخرى مع المواصفة وكانت تميل لان تكون اكثر خشونة. أيضًا كانت هناك ثمان عينات تفي بمتطلبات المواصفة القياسية البريطانية (BS 882) ، اضافة الى خمس عينات كانت تفي بحدود متطلبات المواصفة العراقية (IQS NO.45). كما وقد وجد أن ثلاثة انواع رمال فقط كان لها معامل نعومة ضمن النطاقات الموصى بها من قبل (ACI 211.1 & ACI 211.4) ، في حين أن العينات الأخرى كانت ذات قيم عالية. علاوة على ذلك ، وجد أن جميع الرمال تحتوي على كمية مسموح بها من الجسيمات الدقيقة التي تمر من منخل قياس 0.075 مم. من أجل تحسين توزيع حجم الجسيمات ، يوصى باستخدام طريقة المزج للحصول على ركام ناعم مناسب من رملين فاشلين أو أكثر.

الكلمات الرئيسية: تدرج الركام الناعم ؛ التحليل المنخلي ؛ معامل النعومة ؛ محتوى الطين ؛ حدود المواصفات القياسية

1. INTRODUCTION

Aggregates occupy about three-quarters of concrete, and this high content emphasizes their influences on concrete behavior **(Muhammad et al., 2017; Abdullah et al., 2018; Muhammad et al., 2020; Abdullah et al., 2021)**. Fine aggregate is obtained naturally from wet sieving riverbeds or manufactured artificially from crushing large pieces of rocks into small particle sizes. The particle size of fine aggregate usually ranged from 4.75 mm to 75 µm, and this range is sometimes subcategorized into coarse sand, medium sand, and fine sand **(Neville and Brooks 2010)**. Fine aggregates improve the fresh mixture's cohesiveness and workability and help the mixture avoid segregation and bleeding **(Mindess et al., 2002)**. The influences of fine aggregate on concrete are primarily characterized by grain shape, surface texture, particle gradation, and fineness modulus **(Rangaraju and Kizhakommudom, 2013)**. The aggregate particle size distribution approach has become one of the most important characteristics regarding the utilization of aggregates in concrete **(Ukala, 2019)**. Well-graded aggregates generally lead to higher packing density, less cement paste, less permeability, higher abrasion resistance, and have a lower amount of bleeding, creep, and shrinkage (**Dobrowolski, 1998; Shilstone,1999**).

Recent studies revealed that aggregate gradation dramatically influences the physical, mechanical, and durability properties of concrete **(Abdel-Jawad and Abdullah, 2002; Yaşar et al., 2004; Sari and Pasamehmetoglu, 2005; Ashraf and Noor, 2011; Haque et al. 2012; Ekwulo and Eme, 2017)**.

Fineness modulus was offered as a method of representing the aggregate gradation curves, defined as an index number for all mean aggregate particle sizes in the mix, and calculated by the sum of the percent cumulative retained masses on the sieves divided by 100 **(Abrams, 1918)**. Several papers revealed that fineness modulus significantly influences both fresh and hardened concrete properties **(Donza et al. 2002; Salih et al. 2013; Ngugi et al. 2014; Haritha et al. 2015; Sabih et al. 2016; Ukala 2019)**. It was reported that the concrete strength rises with an increase in fineness modulus of fine aggregate **(ACI 211.4R, 2008)**. It was noted that aggregates with different gradation curves having the equal fineness modulus would need similar water content to make the mixtures with the same workability and strength **(Zhou et al. 1995)**.

This work aims to investigate the quality of the fine aggregates in terms of gradation and fineness modulus for those fine aggregates locally produced and used in Sulaymaniyah city, Iraq. Field samples from different sites are analyzed and evaluated based on international and Iraqi national specifications for particle size distributions.

2 SIGNIFICANCE OF RESEARCH

High strength concrete production needs to select an adequate fine aggregate with high fineness modulus and fewer particles passing through acceptable ranges on 300 µm sieves **(ACI 211.4R, 2008; Han et al., 2017)**. The procurement of suitable fine aggregate is one of the biggest challenges in most developing countries such as Iraq. Sulaymaniyah city is rich with natural sand resources and mainly most natural sands produced by wet riverbed sand washing processes on sieves. The raw materials (mixture of pebble, coarse, fine particles, and clay) are mined from the river by excavators. Then, in the wet screening, the sand is separated from the other ingredients. The washing process is done mainly to remove the clay and silt particles. Most manufacturers are likely to make high production rates using larger sieve sizes than usual adequate sizes, ignoring the specification requirements for their products. Due to the fact, most times, the fine aggregate for concrete works does not comply with the gradation specification limits. This issue needs to be revealed, and suitable solutions must be recommended to make the fine aggregate suitable high strength concrete production.

3. MATERIALS AND METHODS

3.1 Materials

Sand samples were collected from common sand supply sites consumed in the Sulaymaniyah Governorate and its surroundings in Iraq. Sixteen field sand samples were taken from ten different sites located in the municipalities: Darbandikhan (5 samples), Qalat Dizah (5 samples), Koysinjaq (5 samples), and Piramagroon (1 sample). The field locations on the map are shown in **Fig. 1**. The samples were given identification numbers from 1 to 16, as shown in **Table 1**. Also, They were labeled by three letters. For instance, the field samples from Koysinjaq are named KA1, KA2, KB1, KB2, and KG1. The first letter stands for the town where the sand is produced. The second letter represents the sand sites. The last one represents the sand sites where the field sample was taken. According to **ASTM D75 (2014)**, approximately 25 kg sand samples were obtained for gradation testing from each site.

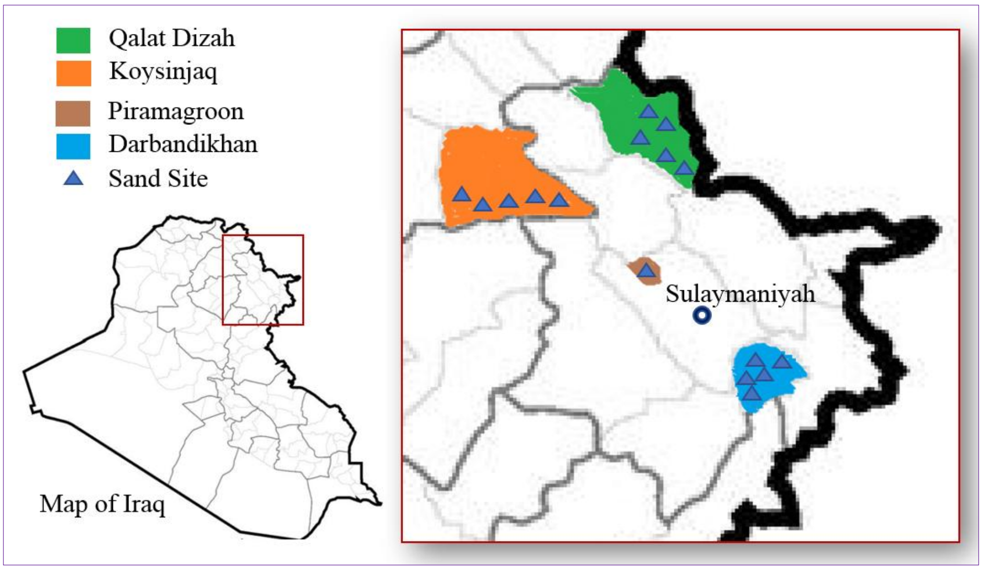


Figure 1. Site locations on the map.

3.2 Methods

The field samples were split to obtain a test sample using the quartering method conforming to **(ASTM C702, 2011)**. The wet samples were kept in the oven at 110 ^{0}C for 24 hours to make the sand dry. Then, the test sample was left at room temperature to cool down. Sieve analysis was carried out on the test sand samples conforming to **ASTM C136 (2014)**. The sieve opening sizes used for grading tests consisted of 9.5, 4.75, 2.36, 1.18, 0.6, 0.3, 0.15 and 0.075-mm. Percentages of sand passing on the sieves were calculated based on the test sample masses as given in **Table 1**. The fineness modulus for each test sample was determined according to **(ASTM C136, 2014)**. Fineness modulus was calculated based on the sum of cumulative percentages retained on the sieves (150-µm, 300-µm, 600-µm, 1.18-mm, 2.36-mm, and 4.75-mm) divided by 100.

Test results were evaluated based on American, British, and Iraqi gradation limit requirements for fine aggregate, as shown in **Tables 2 to 4**. ASTM specification limit **(ASTM C33, 2016)** for concrete sands is as shown in **Table 2**. Only one limit is available, and it has a narrow range of percent particle passing. Sometimes it may be challenging to obtain sands to comply with the limits. Iraqi grading of the fine aggregate **(IQS No. 45, 1984)** is similar to those of **(BS 882:1973),** which defined the grading for four zones of fine aggregate as shown in **Table 3**. Zone 1 is more coarse than Zone 2 and so on. Zone 1, 2, and 3 are most likely to be used for concrete work, while Zone 4 indicates that the sand has very fine grains used for cement plastering and tiling works rather than concrete. **(BS 882, 1992)** classified fine aggregates with Coarse, Medium, and Fine gradings according to their particle size distributions broad in range for mix design purposes.

Table 1. Experimental results .

Sample ID	Field	Location	Particle passing on sieve sizes (%)								Fineness Modulus	Source
			9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm		
1	KA1	Koysinjaq	100	86	63	48	32	10	1	0	3.61	RWS
2	KA2	Koysinjaq *	100	100	99	85	57	16	3	1	2.41	RWS
3	KB1	Koysinjaq	100	81	60	47	35	15	4	1	3.58	RWS
4	KB2	Koysinjaq *	100	100	97	83	56	18	4	1	2.4	RWS
5	DC1	Darbandikhan	100	91	64	44	25	10	4	2	3.63	RWS
6	DC2	Darbandikhan	100	89	61	38	20	8	3	1	3.82	RWS
7	DD1	Darbandikhan	100	91	65	46	30	14	4	2	3.50	RWS
8	DE1	Darbandikhan	100	96	64	42	28	16	7	3	3.47	RWS
9	DF1	Darbandikhan	100	99	75	47	26	12	5	2	3.37	RWS
10	KG1	Koysinjaq *	100	92	82	73	59	25	8	3	2.60	RWS
11	PH1	Piramagroon	100	97	58	32	18	9	4	1	3.81	CWS
12	QI1	Qalat Dizah	100	91	76	60	37	10	3	1	3.24	RWS
13	QI2	Qalat Dizah	100	90	74	59	36	9	3	1	3.29	RWS
14	QI3	Qalat Dizah	100	96	81	62	38	14	4	1	3.07	RWS
15	QJ1	Qalat Dizah	100	85	65	46	22	8	3	1	3.72	RWS
16	QJ2	Qalat Dizah	100	82	62	43	20	7	3	1	3.83	RWS

(*) classified as fine sand used for cement plastering
RWS means produced from the river by wet washing
CWS means produced from crushing and wet washing

Table 2. American specification limits for percent passing of fine aggregate **(ASTM C33, 2016).**

Sieve size	Passing (%)
9.5mm	100
4.75mm	100 to 95
2.36mm	100 to 80
1.18mm	85 to 50
600µm	60 to 25
300µm	30 to 5
150µm	10 to 0
75µm	3 to 0

Table 3. Iraqi specification limits for percent passing of fine aggregate **(IQS No. 45, 1984).**

Sieve size	Passing (%)			
	Zone 1	Zone 2	Zone 3	Zone 4
9.5mm	100	100	100	100
4.75mm	100 to 90	100 to 90	100 to 90	100 to 95
2.36mm	95 to 60	100 to 75	100 to 85	100 to 95
1.18mm	70 to 30	90 to 55	100 to 75	100 to 90
600µm	34 to 15	59 to 35	79 to 60	100 to 80
300µm	20 to 5	30 to 8	40 to 12	50 to 15
150µm	10 to 0	10 to 0	10 to 0	15 to 0
75µm	N/A	N/A	N/A	N/A

Table 4. British specification limits for percent passing of fine aggregate **(BS 882, 1992).**

Sieve size	% passing for grading zones		
	C (Coarse)	M(medium)	F(Fine)
10 mm	100	100	100
5 mm	100 to 89	100 to 89	100 to 89
2.36mm	100 to 60	100 to 65	100 to 80
1.18mm	90 to 30	100 to 45	100 to 70
600µm	54 to 15	80 to 25	100 to 55
300µm	40 to 5	48 to 5	70 to 5
150µm	15 to 0	15 to 0	15 to 0
75µm	N/A	N/A	N/A

4. RESULTS AND DISCUSSIONS

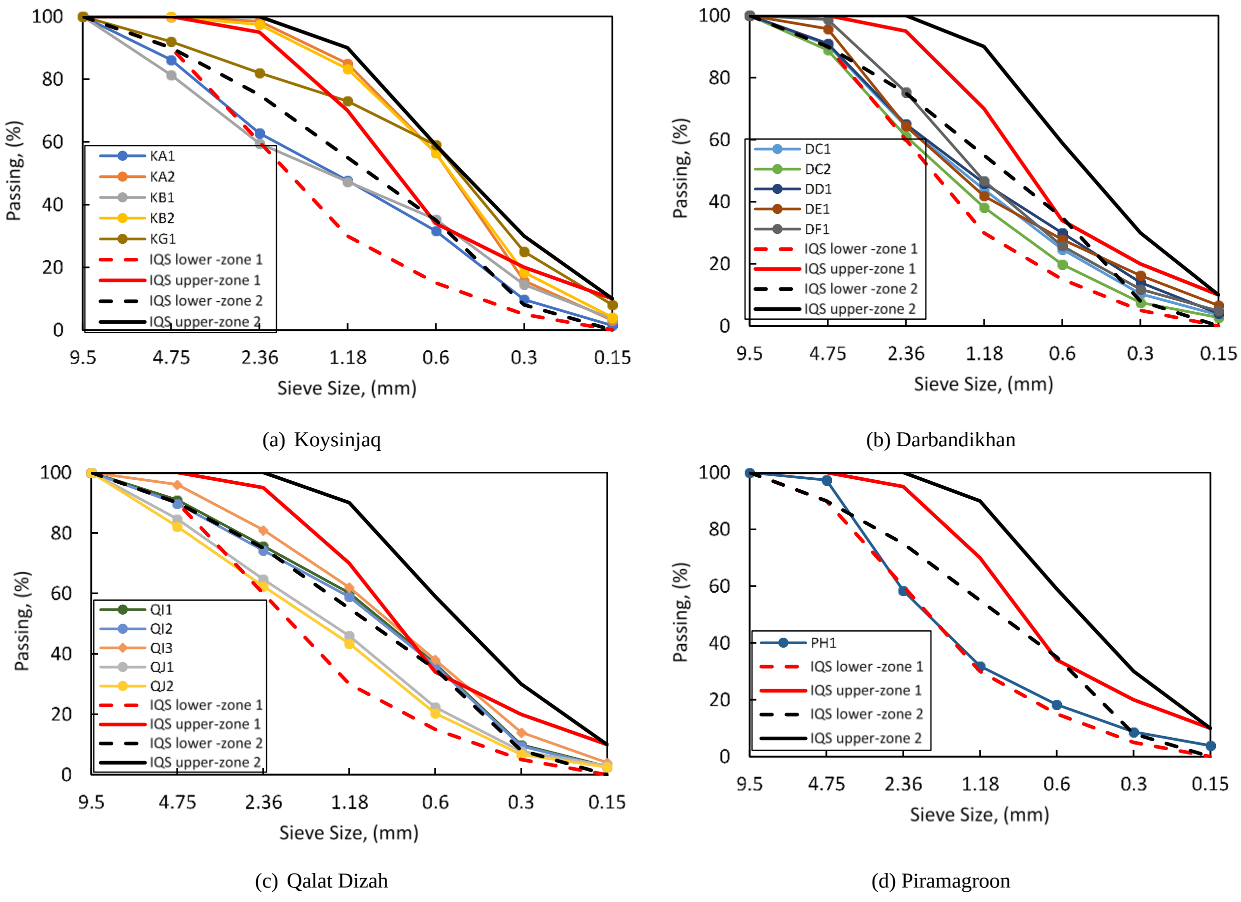
4.1 Particle Size Gradation

Fig. 2 shows the gradation curves of the fine aggregates compared with the standard gradation zone curves of fine aggregate recommended by the IQS standard. Both Zone 1 and 2 are considered for gradation evaluation of samples. Most of the sands fall partially outside the standard gradation Zone 1, especially on sieve 4.57 mm and 2.36 mm. The samples comparing with gradation Zone 2 limits were out of the range on most of the sieves. However, the samples can be ranged in the marginal of both Zone 1 and 2. These curves indicate that the sands brought from Sulaymaniyah city contain coarser particles than the amounts allowed by the IQS standard. Understanding the site work has revealed that very fine sands or very coarse sands are intolerable. The former is uneconomical due to the low production rate, making the concrete mix severely unworkable.

Fig. 3 presents the percent passing sample curves with the ASTM limits. None of the sample curves went beyond upper limit curves, while most samples were out of the range from lower limit sides. The percent passing of the most samples failed on the sieve sizes of 4.75, 2.36, 1.18, and 0.6 mm. However, the samples were within the range at sieve sizes 0.3 and 0.15 mm. The results showed that the sands are significantly coarser than the allowable quantities. This issue could lead to the poor dense packing of the aggregate volume in concrete.

Fig. 4 illustrates the percent passing samples with the BS zone limits. None of the sample curves went beyond the BS medium sand upper limit curve, while some samples failed outside the BS Coarse sand lower limit at sieve size 4.75mm. The percent passing of the most sample curves was within BS coarse zone limits than BS medium zone limits. Most samples failed to be out of BS-C ranges due to the failure on the sieve sizes of 4.75 mm. However, the samples were within the range at sieve sizes 1.18, 0.3- and 0.15-mm. Considering BS-M limits, most of the percent passing was out of range, especially at the lower limit through sieve size 4.75 till 0.3 mm. The results showed that the sands contain a higher rate of particles coarser than 4.75.

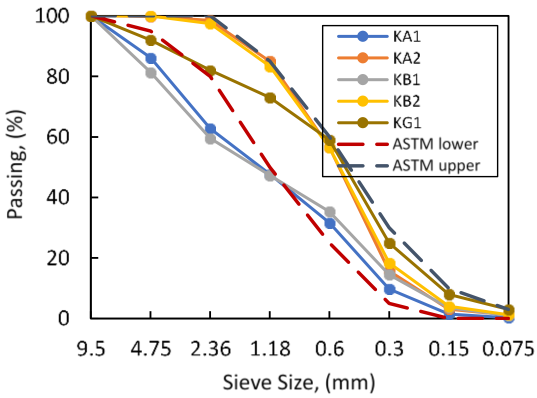
Table 1 previously shows the percent passing on each sieve for each field sample. Percent passing and fineness modulus were reported per field location. **Table 5** presents the total results for each sample compared with the specification limits for all sand samples collected in four main towns around Sulaymaniyah city. When the sample had percent passing on all sieves located in the limited ranges, it was classified as passing sample (Y) and otherwise classified as failing sample (N). According to ASTM limits, only three samples (nearly 19%) were acceptable, while eight samples (50%) were adequate and classified as coarse and medium sand for BS limits. The sample IDs 2, 4, and 10 commercially manufactured for plastering were fine sand and complied with BS-F limits. As a result, BS limits are extensive ranges rather than those limits given in the ASTM standard. Following IQS limits, four samples (25%) were satisfactory in Zone 1, while five samples (31%) were acceptable in Zone 2. None of the samples were located in the range of Zone 3 and 4.



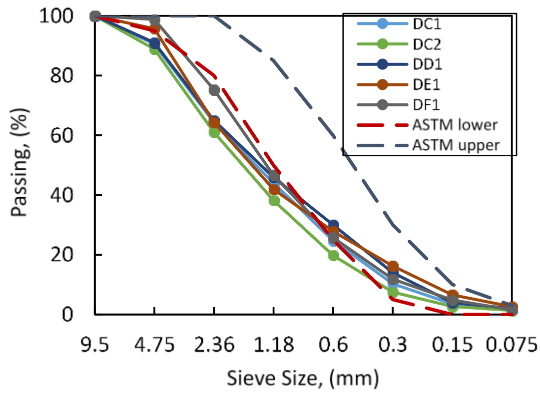
(a) Koysinjaq (b) Darbandikhan

(c) Qalat Dizah (d) Piramagroon

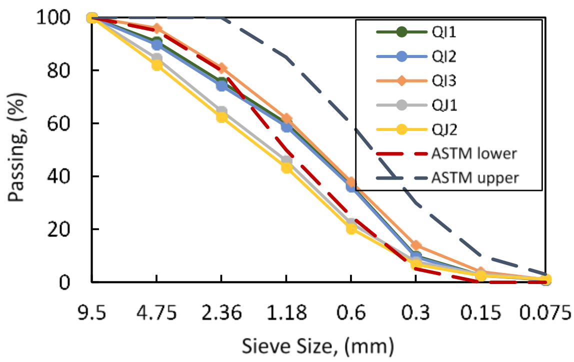
Figure 2. Sample Gradation curves with IQS limits.



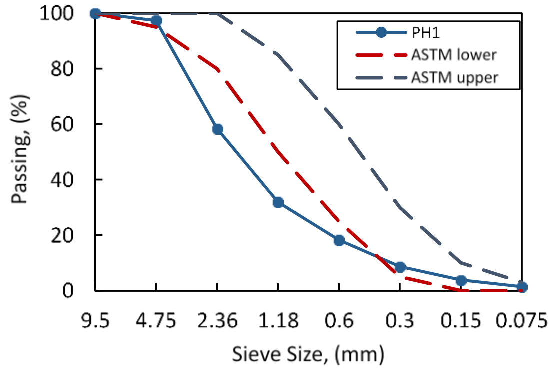
(a) Koysinjaq



(b) Darbandikhan

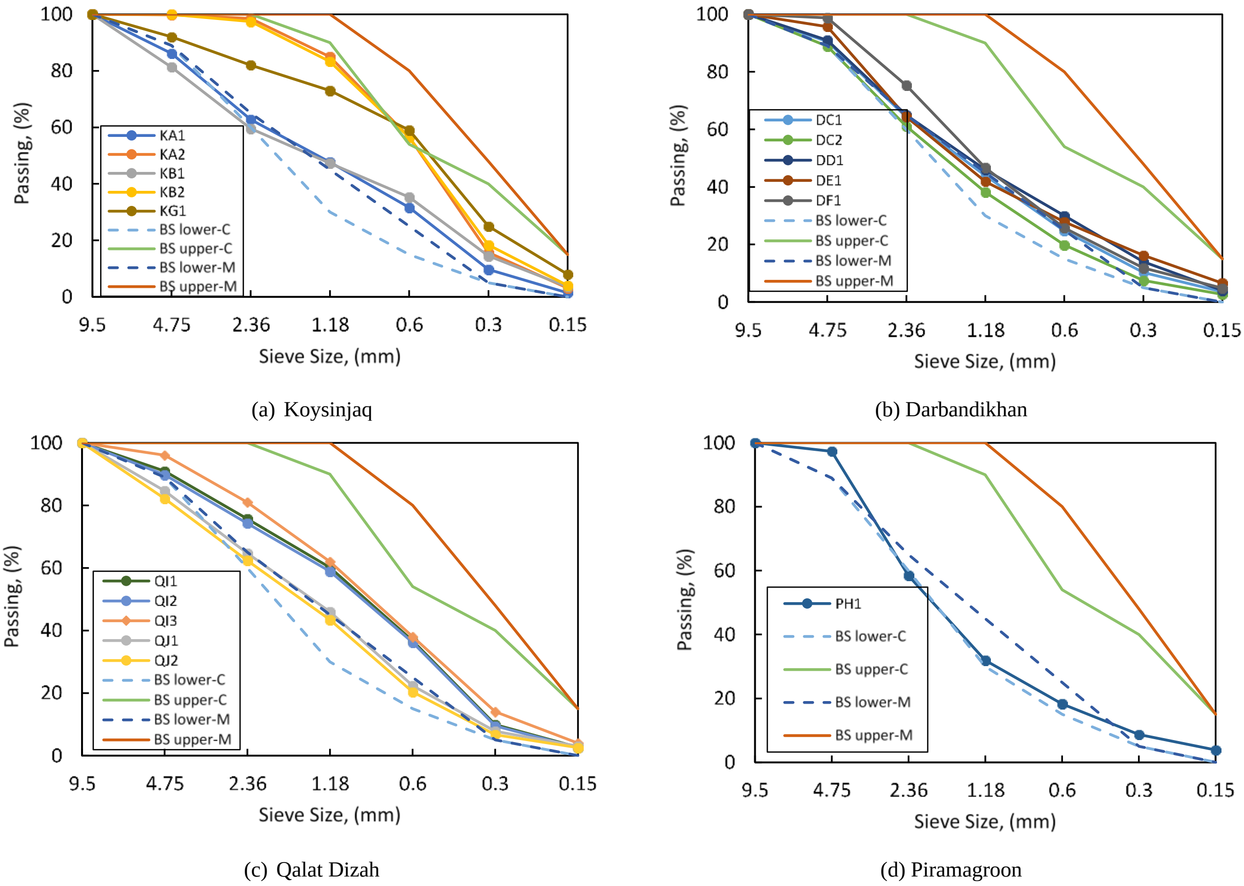


(c) Qalat Dizah



(d) Piramagroon

Figure 3. Sample Gradation curves with ASTM limits.



(a) Koysinjaq

(b) Darbandikhan

(c) Qalat Dizah

(d) Piramagroon

Figure 4. Sample Gradation curves with BS limits.

Table 5. Results of the samples according to the specifications.

Sample ID	Field	Locations	ASTM	BS-C	BS-M	BS -F	IQS, Zone 1	IQS, Zone 2	IQS, Zone 3	IQS, Zone 4
1	KA1	Koysinjaq	N	Y	N	N	N	N	N	N
2	KA2	Koysinjaq *	Y	N	Y	Y	N	Y	N	N
3	KB1	Koysinjaq	N	N	N	N	N	N	N	N
4	KB2	Koysinjaq *	Y	N	Y	Y	N	Y	N	N
5	DC1	Darbandikhan	N	Y	N	N	Y	N	N	N
6	DC2	Darbandikhan	N	N	N	N	N	N	N	N
7	DD1	Darbandikhan	N	Y	Y	N	Y	N	N	N
8	DE1	Darbandikhan	N	Y	N	N	Y	N	N	N
9	DF1	Darbandikhan	N	Y	Y	N	Y	N	N	N
10	KG1	Koysinjaq *	N	N	Y	Y	Y	Y	N	N
11	PH1	Piramagroon	N	N	N	N	N	N	N	N
12	QI1	Qalat Dizah	N	Y	Y	N	N	Y	N	N
13	QI2	Qalat Dizah	N	Y	Y	N	N	N	N	N
14	QI3	Qalat Dizah	Y	Y	Y	N	N	Y	N	N
15	QJ1	Qalat Dizah	N	N	N	N	N	N	N	N
16	QJ2	Qalat Dizah	N	N	N	N	N	N	N	N
Total Y			3	8	8	3	4	5	0	0
Total N			13	8	8	12	12	11	16	16

Note:
Y means the sample passed according to the corresponding specification limits
N means the sample failed according to the corresponding specification limits

4.2 Fineness modulus

Fineness Modulus is a term used as an index number representing the mean size of particle sizes in aggregates. It is the summation of the cumulative percentage of aggregates retained on the required sieves divided by 100. The ACI 211.1 code has specified that the fineness modulus of sand shall not be less than 2.4 and not more than 3.0. **ASTM C33 (2016)** notes that the fineness modulus for fine aggregate ranges from 2.3 to 3.1. For high-strength concrete, the high fineness modulus is recommended to be within 2.5 to 3.2 **(ACI 211.4, 2008)**.

Furthermore, when fine aggregates have the exact percent passing of upper and lower limits (**Table 1**), the fineness modulus calculated based on the percent passing will be 2.5 for ASTM upper limit and 3.45 for the ASTM lower limit. **Fig. 5** shows the fineness modulus for the samples compared to the specification limitations. Three samples (18.75%) were in the ranges given by ACI 211.1, whereas most of the fineness modulus results were higher than 3. Regarding the application of the fine aggregates for high-strength concrete, due to higher coarseness, only two samples (12.5%) were adequate with the recommendation of **(ACI 211.4)**. Comparing the results with the ASTM lower and upper fineness modulus, only five samples (31.25%) were within the range.

(BS 882, 1992) deals with specifications for coarse and fine aggregates from natural sources for concrete. The specification does not specify any limitation for fineness modulus to be used in concrete since the samples were much closer to the limitations for coarse and medium sands. Fineness modulus was calculated for upper- and lower-percent passing limits (**Table 4**) recommended by **(BS 882)**. The fineness modulus for BS upper and lower limits were 2.54 and 4.01 for coarse sand and 2.1 and 3.71 for medium sand. **Fig. 6** shows the results of fineness modulus compared with those computed according to BS limits. Most fineness modulus values reached the ranges of BS-C limits rather than those of BS-M.

(IQS No. 45, 1984) does not mention the ranges for fineness modulus more than the fine aggregate should meet the percent passing zone limits (**Table 3**). However, fineness modulus was computed for the fine aggregates to meet the upper and lower limit requirements. According to IQS upper and lower limitations, the fineness modulus was 3.06 and 4 for Zone 1, 2.46, and 3.37 for Zone 2, respectively. **Figure 7** presents the fineness modulus values of samples compared with those calculated according to IQS limits. Most fineness modulus values reached the ranges of Zone 1 limits similar to those obtained by BS-C limits. Due to the presence of a higher range of coarse particles and falling the samples to be in the specification limitations, it can be concluded that most fine aggregates are not suitable to be used in concrete to do dense packing in terms of particle size distribution.

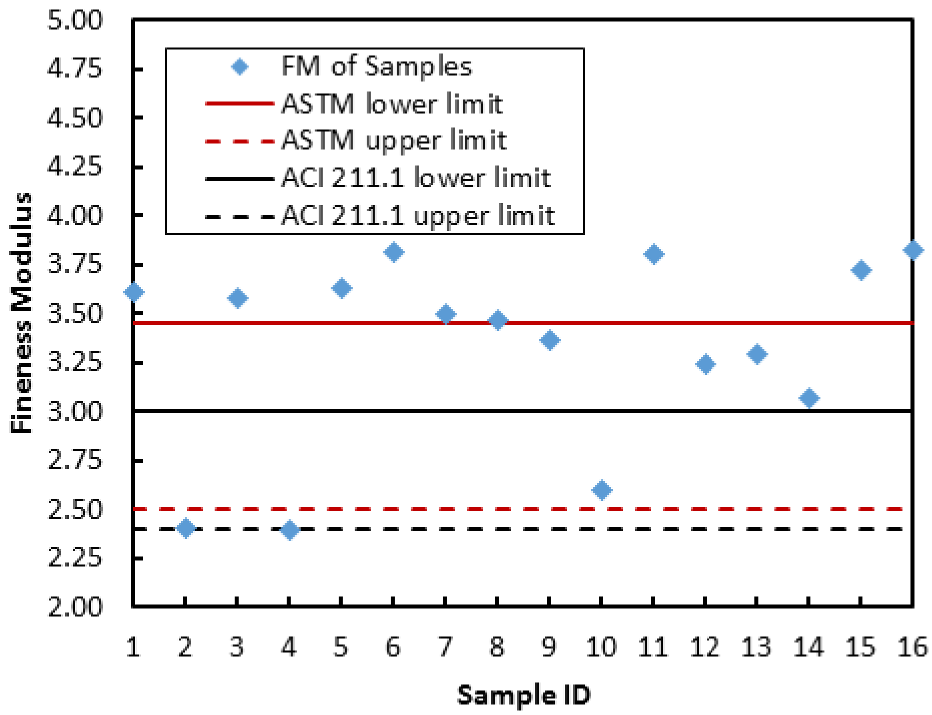


Figure 5. Fineness modulus versus ASTM C33 and ACI 211.1 limits.

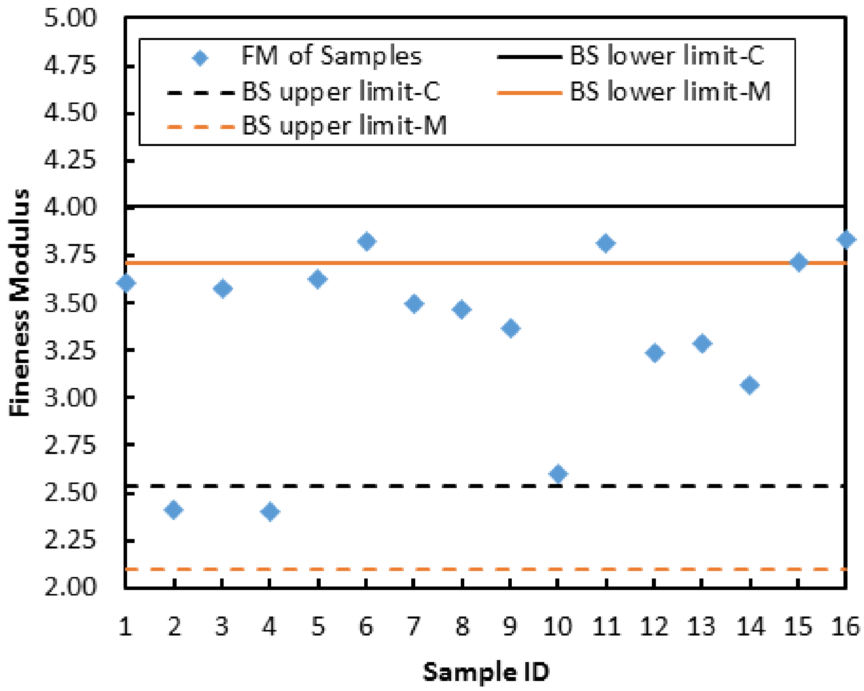


Figure 6. Fineness modulus versus BS limits.

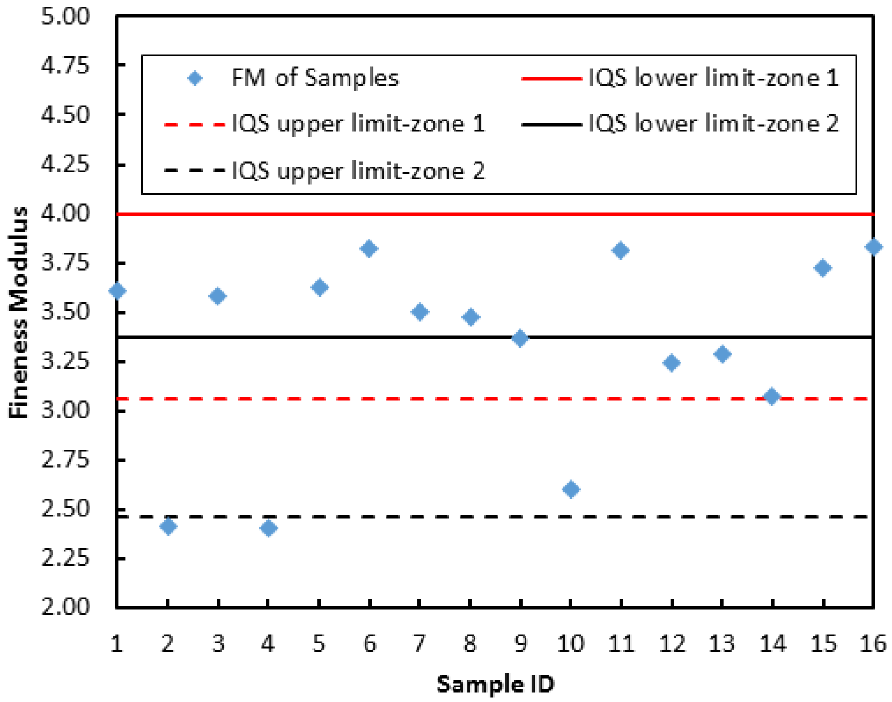


Figure 7. Fineness modulus versus IQS limits.

4.3 Clay and silt contents

Clay and finer particles in fine aggregate cover the surface of coarse aggregate particles and result in aggregate paste transition zone weakness. Therefore, a high amount of clay and silt contents causes a significant reduction in the compressive strength of the concrete **(Olanitori, 2006)**. Several building collapses were reported due to the poor quality of fine aggregate and high clay contents **(Oloyede et al., 2010)**. Generally, the specifications restrict the presence of finer particles in fine aggregates. It is difficult to produce fine aggregate without very fine particles from either crushing stone or the natural river process. There are various ranges for the classification of clay and silt particles. **(Nevil, 2010)** mentioned that materials with a size ranging from 0.06 to 0.02 mm are defined as silt, whereas those with a size less than 0.02 mm were categorized as clay.
(ASTM C33, 2016) allowed particles finer than 0.075 mm to be less than 3% for fine natural aggregates. This limitation was confirmed by IQS standards as well. On the other hand, BS 882 states that finer particles on sieve 0.075 mm must not exceed 4% by weight for sand for concrete production. According to **Table 1**, it can be seen that most samples have less than 3% finer particles on 0.075 mm. Fine aggregates containing more than the allowable percentages of clay contents must be washed to make clay content within allowable limits. **(ACI 363, 2017)** reported that fine aggregate gradation plays a vital role in fresh and hardened concrete properties. It clarified that while fine aggregate has high particle contents retained on sieve sizes (300 and 150 µm), resulting in the loss of compressive strength.
Fig. 8 shows the percentage of particles passing 0.3, 0.15- and 0.075-mm sieve sizes. According to the upper percent passing of 15% on sieve size 150 µm, all samples were less than 10% confirmed with adequate fine particles. Furthermore, particles were finer than the 30% upper limit for sieve size 0.3 mm. Regarding clay and silt contents, it can be concluded that it is a positive key point towards fine aggregate production in Sulaymaniyah province.

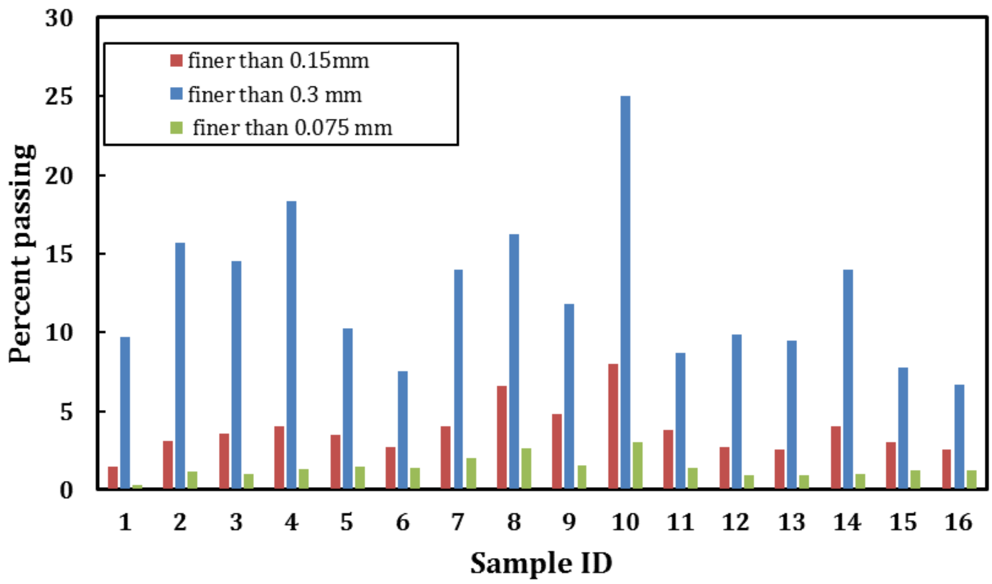


Figure 8. Amount of particles finer than 0.3, 0.15, and 0.075 mm.

5. CONCLUSIONS

The conclusions drawn from the current research can be summarized as follows.

1. Particle size distributions of most fine aggregates taken from several locations in Sulaymaniyah have been out of standard graduation limits. Nearly 81% of fine aggregates do not comply with the ASTM standard. In addition, nearly 50% and 75% fine aggregates do not meet the specification limits given by both BS and IQS standards, respectively. Therefore, they might be unsuitable for concrete works.
2. The failure of fine aggregates in gradations mainly results in retaining many coarser particles on 4.75 sieve size. It is due to the manufacturing process that uses larger sieve sizes of more than 4.75 mm to increase production.
3. Three samples of fine aggregates containing a high amount of very fine particles with a lower fineness modulus (locally used for cement mortar plastering) meet the BS requirement for fine sands. However, they do not comply with both ASTM and IQS standards.
4. Due to a lack of suitable gradation, most fine aggregates have a high value of fineness modulus greater than 3. The fineness modulus of approximately 19% fine aggregates is within ACI 211.1 recommendation (2.3-3.1) for normal concrete. Furthermore, 12.5% of fine aggerates have fineness modulus between (2.5-3.2), which can be used for high-strength concrete, according to the guide ACI 211.4.
5. All fine aggregates contain an acceptable amount of clay and silt contents. The clay contents in the fine aggregates were less than 3%. The quantity of fine grains passing sieve size 0.15 mm and 0.3 mm was adequate considering the specification upper limits.
6. Quality control is needed to monitor the manufacturers to follow the specifications. Alternatively, it can be recommended to make suitable fine aggregate gradation following blending methods from two or more fine aggregates on the job site.

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