THE FEASIBILITY OF USING SPECIALIZED SAND FOR MAKING MOSAIC OF READY MIXED MORTAR

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Abstract:

Studies show that mortar and concrete are used as the main materials in more than 80% of technologies. Therefore, pay attention how to increase workability and improve performance required of mortar and concrete. Mortar can be made in numerous ways, but studies have shown that the ready mixed mortar has many advantages compared to others, but without quality control and production monitoring, the customer confidence would be missed. The aim of this study is to investigate the possibility of using specialized sand in the factory for making mosaic mortar mix and controlling mortar properties. In this study, mortar specimens were created by specialized sand for making mosaic, and ordinary sand in different ratio of cement to sand. Also, specimens were produced by the ready mix mortar. The results of the compressive strength and water retention of mortar, the comparisons of fracture specimens and scanning electron microscope (SEM) images showed the possibility of using specialized sand mosaic in the production of dry mortar.

1 Introduction

In general, mortars are supplied to the job site in three ways. In the first method, the main raw materials are transported separately to the job sites and mixed together by hand at inaccurate ratios and in the traditional method. This method has many disadvantages including perth materials, human errors, slow performance, environmental pollution, depot maintenance problems, higher personnel costs, lower quality and durability of the mortar, lack of monitoring of the used materials, lack of special mortar for different parts of the building and restrictions in implementation of test samples [1]. The second method, which is known as fresh mortar procedure, mortar workshops are prepared by mixing raw materials. This method has some advantages including the reduction of the cost of raw materials, making mortar, reduction of human error, improvement of the quality and strength of the mortar. The method is cost-effective to use in high volume [1]. In this way, mixers are responsible to carry mortars. To maintain the properties of fresh mortar and standard mortar, the interval between the mixer being filled and used in the building should be short (about one hour), which is one of the disadvantages of this method. However, in large cities with high traffic and also rural areas that are located a long distance from job-site mortar, it takes long so that it would be practically impossible to use

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fresh mortar [2]. To increase the quality, execution speed and in some cases to reduce not only the dead load of the building, but also removing the deficiency of mentioned two methods, the dry-mix mortar technology was developed. For production of the dry-mix mortar, the ingredients of the mortars in the plants are mixed together in the appropriate ratio under quality control and are delivered to the consumer as bags or in silo containers. Then, in the job-site workshop, with a certain proportion of water, they are mixed and used [3].

Nowadays, because of the multiple advantages of dry-mix mortar, it is widely used around the world [4]. Ready mix mortar has increased the resistance of the structure due to the high and uniformity of the quality. In Europe, several companies engaged in the production of factory- mixed dry mortars so that the One Stone research group (2006), was reported the Europe's top 10 producers as shown in Table 1 [5]. The use of dry mortar in Europe is increasing dramatically, so that in Russia, using the dry mortar increased from 5% in 2002 to 50% in 2005 [6]. For this reason, despite 790 manufacturer companies of dry-mix mortar and plaster in Europe, with the annual output production capacity range from 20,000 ton to 200,000 ton, the workers in more than one shift work to meet the needs of consumers. [5].

Table 1. The top 10 dry-mix mortar manufacturers and suppliers in Europe [5]

Row	Company	Works	Capacity (Million Tons)	Market Share	Works Size
1	Maxit	72	6.5	12	90 000
2	saintGobain Weber	43	3.9	7	90 000
3	Knauf	27	3.1	6	115 000
4	BaumitBayisan	27	2.7	5	100 000
5	Hasit/Rofix	26	2.5	5	95 000
6	Quick-Mix	24	2.5	5	105 000
7	Sakret (Brand)	26	2.5	5	95 000
8	Cemex	17	2.0	4	115 000
9	Lafarge (ParexLanco)	16	2.0	4	125 000
10	Uniland	11	2.0	4	180 000
Total TOP10		289	29.7	56	100 000
Other		501	25.3	46	50 000
Total		790	55.0	100	

The properties of mortars are influenced by the mixing method of materials. In his study, Khalaf Rejeb examined the effect of a two-step mixing method upon the properties of concrete. He changed the arrangement of adding the materials of concrete, mixing time and the speed of mixing and also used a two-step mixing method. Based on the results obtained, by comparing the compressive strength of normally mixed concrete and that from two-step mixed concrete, the contact between cement particles and water increased in the two-step mixed method, it results in increased strength and improved cement properties. [7].

Another study examined the effect of dry mixture of cement and sand upon the changes of the properties of mortar and concrete. It was concluded that the strength of dry pre-mixed mortar didn't change or increased compared to ordinary cement. The premixed dry mortar prepared by improving chemical reactions occurring between the cement and other ingredients has more workability and increased cement cohesion [8]. Additives and spout-fluid bed mixer are used to combine materials, to increase flexural strength, reduce drying shrinkage and better flow as compared to conventional (normal) cement mortar [9].

A study was undertaken in New Zealand to investigate the feasibility of using recycled concrete aggregates (RCA). In this study, the samples were made by Natural Aggregate (NA) and recycled aggregates. Compressive strength, flexural strength and slump tests were performed on the samples and the results showed that there was the possibility of using recycled aggregates for the production of concrete [10]. To emend the structure stability, optimizing construction cost and quality have to be considered. Sustainable reasonable development in construction industry requires suitable experimental

analysis, methodology and technology [11]. Concrete mixture performance was investigated with SEM, which has been under researchers' consideration, for instance, K.B Park et al. have investigated the way of aggregates distribution with the aid of small scale images in an article [9]. Furthermore, in another research, Igarashi et al. have investigated behaviours of cement pastes and mortars with the aid of SEM-BSE image analysis. In the current research, these kinds of images were used to investigate the aggregate's distribution [12]. This research is focused on seeking a substitution of a ready mortar by a simpler and cheaper method. As a result, two different mortars have been compared with different preparation methods and materials. This research aims to determine the effect of using specialized sand for making mosaic of the compressive strength and at water absorption rate of the mortar and also compares the mortars made from specialized sand for making mosaic, ordinary sand and ready mix mortar. For this comparison, no additive was used in the manufacture of samples. Figure 1 shows the flowchart of research methodology

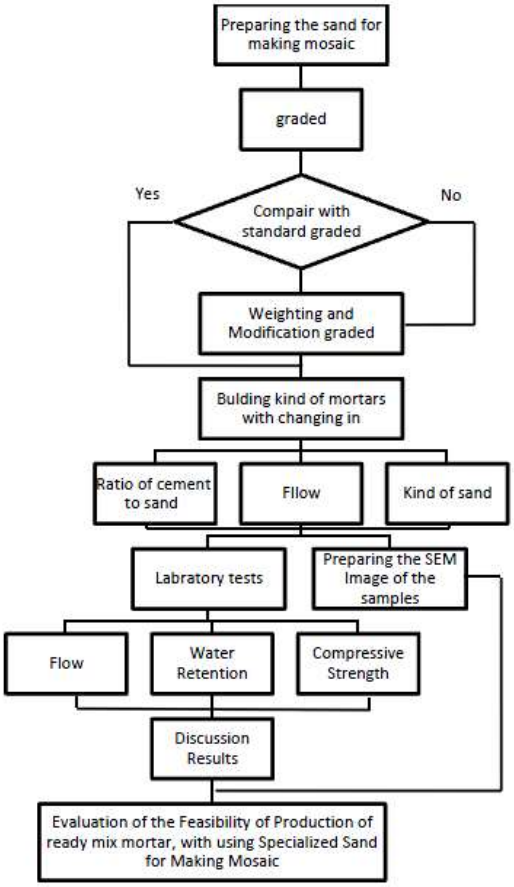

Figure 1. The flowchart of research methodology

2 Experimental process

2.1 The materials properties

2.1.1 Cement

The Ordinary Portland Cement (OPC) from Tejarat Mehriz Cement was used in all of the experiments. Table 2 indicates the properties of the Portland cement according to ASTM C1329 [13].

2.1.2 Aggregates

Sand used in this study was supplied from the mosaic plants around the Yazd city. One of the important characteristics of the sand used in the mortar is the grading or particle size distribution in terms of diameter in the mix. In accordance with ASTM-C-144, optimal graded standard sand used in the mortar should be about grading standard as shown in Fig. 2 [14, 15].

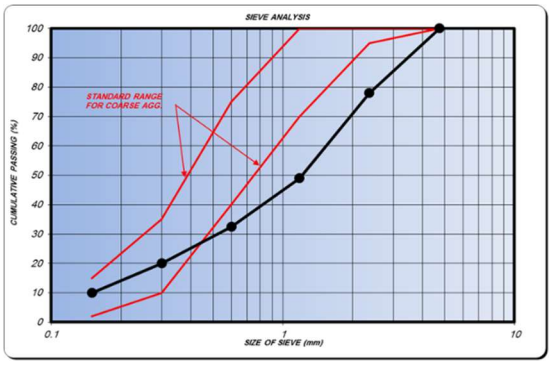

Figure 2. Graded sand chart used in making mosaic and the portion of graded standard sand used in mortar

Figure 3 shows that the specialized sand for making mosaic was coarser than the standard reference materials.

Figure 3. The grading of specialized sand for making mosaic used in the manufacture of samples

Therefore, the grading of the sand should be based on the standards. At this stage, 22% of sand retained on the sieve No. 8, is considered as waste so that it should be taken into account as cost for the production of laboratory samples, the specialized sand for making mosaic was prepared in a way that was consistent with the average of graded standard sand. Table 3 shows the characteristics of the graded sand used for making mosaics and the ordinary sand. As can be seen, there is not a single significant difference in the sand density, but the water absorption of specialized sand of the mosaic is 0.4 % higher than the ordinary sand.

Table 2. The properties of the portland cement used in the mortars

Specification / Cement	Air content, volume (%)		Autoclave Expansion (%)	Setting Time (hr)		Compressive Strength (Mpa)	
	Min	Max		Initial	Final	7 Days	28 Days
ASTM C 1329	8	17	< 1.0	≥ 2	≤ 24	≥ 3.4	≥ 6.2

Table 3. The characteristics of the graded sand used for making mosaics and the ordinary sand in laboratory specimens

Experiment / Sand Type	Percent passing through the sieve (75mm)	Relative density oven dry	Relative density in a saturated surface-dry	Apparent relative density	Relative density oven dry (kg/m^3)	Relative density in a saturated surface-dry (kg/m^3)	Apparent relative density (kg/m^3)	Water retentivity (%)
Ordinary Sand	-	2.64	2.69	2.77	2630	2679	2764	1.88
Specialized Sand of the Mosaic (Passing Through the Sieve No. 8)	7.3	2.65	2.70	2.73	2647	2696	2727	0.66

2.2 Laboratory production of mortar

In this study, a sample was made from the ready mix mortars. Fig. 4 shows the graph of ready mix mortars and the graded sand. The ready mix mortar was composed of the aggregate, cement, lime and chemical additives. Following a new grading system for ready mixed mortars, it was observed that 18% of mortar had passed sieve No. 200. In other words, it can be concluded that 18% of mortar was composed of cement, lime and chemical additives. E.g., weight ratio mixing of cement, lime and additives to sand in ready mix mortars were about 1:4.5 Among other characteristics of ready mix mortars provided by the manufacturer at 10 to 35°C was considered as the best mixing temperature, 1 cm as the proper thickness for performance and 11.4 Mpa as the minimum compressive strength for mortar.

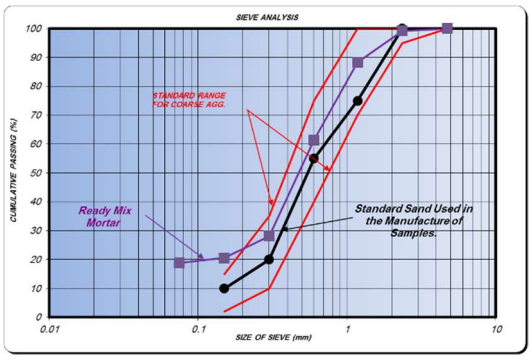

Figure 4. Grading of ready mix mortar and standard sand used in the manufacture of samples

At first stage, the samples were created using 1:5, 1:7, and 1:9 ratio of cement to sand by the specialized sand for making mosaic. Also, the samples were made using 1:6 ratios by the ordinary sand. Then, the cube specimens were produced by using 1:4.5 and 1:5 ratio of cement to sand by specialized sand for making mosaic and factory mixed mortar with the standard flow (100-115). The reason for choosing these ratios is to compare it with factory mixed mortar, because as mentioned before, the ratio of sand to other ingredients in this mortar is 1:4.5 The flow of mortar by flow table was tested in accordance with ASTM C1437 [16]. Primary flow of the mortar used in the construction of building according to the international and Iranian standard should be between 100-115 percent [17]. For the compressive strength tests, about 2000 g mortar was required to build six cube mortars (50 mm). The samples were coded as shown in Table 4.

Table 4. Coding and the properties of the samples

Name	Ratio of cement to sand (by weight)	Ratio of cement to sand (by volume)*	Water (g)	Kind of sand
SSM 5	1:5	1:6	258	Sand for making mosaic
SSM 7	1:7	1:8	260	Sand for making mosaic
SSM 9	1:9	1:10	262	Sand for making mosaic
NSM 6	1:6	1:7	265	Normal sand
ready mix mortar***	1:4.5**	-	-	-
SSM 4.5****	1:4.5	1:5	400	Sand for making mosaic
SSM 5 ****	1:5	1:6	440	Sand for making mosaic

* Specific weight of dry cement = 3150 kg/m^3
** The ratio of cement, lime and chemical additives
*** Added water in accordance with the manufacturer factory instructions of this kind of mortar.
****With standard flow

3 The method of tests and results

3.1 Compressive strength of mortars

The compressive strength of mortar samples was determined by ASTM C1314 for this purpose, a number of samples on the 7th and the 28th day were placed into Compressive Strength Testing Equipment. Therefore, the compressive strength was determined by loading and recording the load at the moment of fracture [18].
In this study, 5 samples of all mortar types were prepared. Two samples for determining the compressive strength on the 28th day, three samples on the7th day and two samples were tested as control samples. Fig. 5 shows the ratio of compressive strength of samples produced by specialized sand for making mosaic on the 7th and 28th day. As this ratio becomes smaller than 1, the mortars have gained more amount of strength between the 7-day and the 28-day tests. From Fig. 5, it can be seen that the samples produced by ordinary sand had less strength whereas an increasing trend between the 7th to 28th day compared to the samples were produced by the specialized sand for making mosaic.

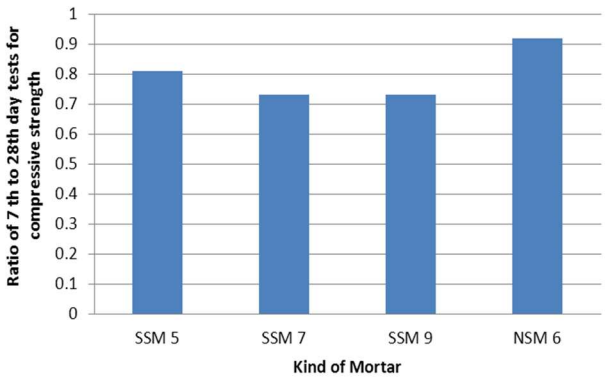

Figure 5. The ratio of 7th to 28th day tests for compressive strength of the specimens mixed by specialized sand for making mosaic

Table 5 shows the average compressive strength of the 28th day with the standard flow. As shown, the

factory dry mortar had lower compressive strength when compared to the mortar which mixes by specialized sand for mosaic. Fig. 6 shows the failure of two factory samples of dry mortar and SSM 6.

Table 5. The average compressive strength of the specimens on the 28th day with standard flow

Kind of mortar	The average compressive strength of the specimens (Mpa) 28th day		
Ready mix mortar	No.1	5.32	5.46
	No.2	5.60	
SSM 4.5	No.1	11.88	11.76
	No.2	11.64	
SSM 5	No.1	10.12	10.10
	No.2	10.08	

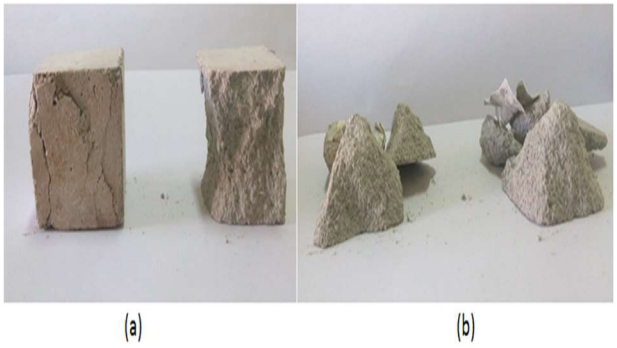

Figure 6. The fracture of two samples in compressive strength test: (a) SSM 6 (b) ready mix mortar

Gonçalves et al. showed as a result of their research that unclassified impact crusher aggregates had highest packing density, and mortars produced from it had comparatively low porosity and low absorptivity but the highest unconfined compressive strength that does match the results of this research [19].

3.2 Water retention of materials

Since most of the materials used in the wall of the Iran constructions (brick, block, etc.) have a relatively high water absorption values, the water retention test is required. The test was performed in accordance with standard ASTM C 91 which should be at least 75% [20, 21].

Figure 7 and Table 6 shows the values of water retention of samples

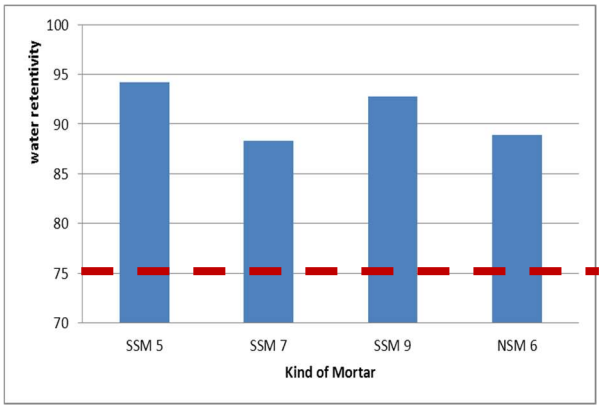

Figure 7. The values of water retention of samples mixed by specialized sand for making mosaic and compared to the standards

Table 6. The result of water retention SSM, NSM and ready mix mortar

Kind of mortar	Percent of water retention		average
SSM	No.1	88.37	88.3
	No.2	88.14	
NSM	No.1	87.72	88.08
	No.2	88.45	
Ready mix mortar	No.1	87.27	87.68
	No.2	88.08	

Since no additives were used for making this mortar, and as it can be seen, compared with other mortars, there isn't much difference in their water retention.

3.3 SEM image of the samples

In the past decade, the use of a scanning electron microscope (SEM) and growth of digital image measurement has been applied to deformation measurement and formation of material of samples test, the images visible show the formation of material test. With a scanning electron microscope (SEM) the sample structures of various material types can be determined [22]. Figures 8 to 11 show the SEM images of two samples made from the ready mix mortar and SSM 5 in two sizes: 10μm and 20μm.

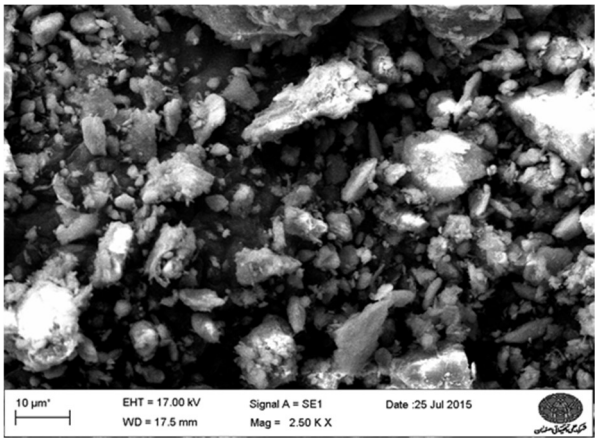

Figure 8. SEM Image of the samples ready mix mortar (10µm)

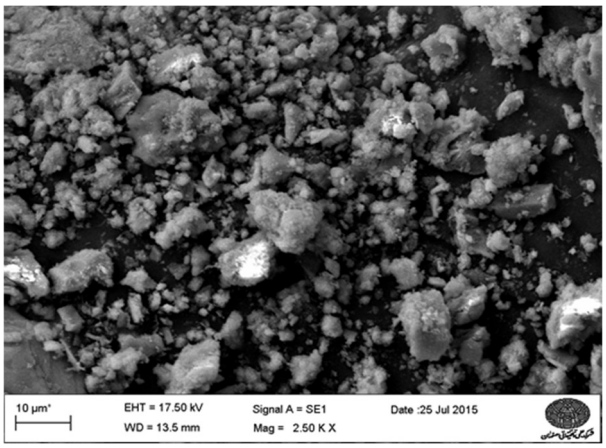

Figure 9. SEM Image of the samples SSM5 (10µm)

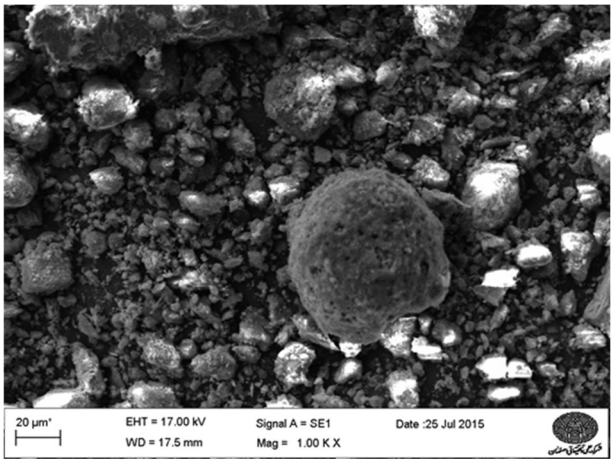

Figure 10. SEM Image of the samples ready mix mortar (20µm)

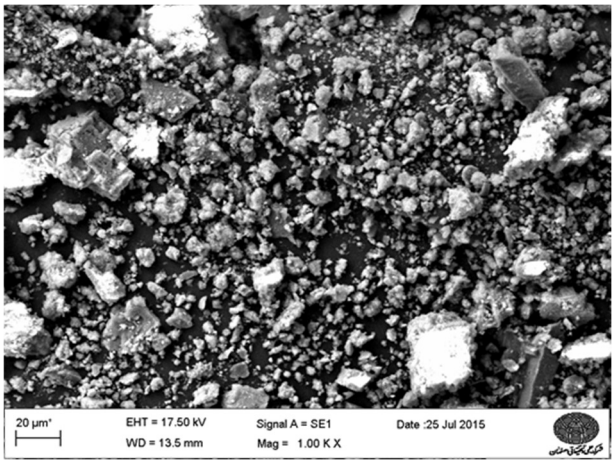

Figure 11. SEM Image of the samples SSM5 (20µm)

By comparing the SEM images of two samples, we can conclude that the particles of mortars made from the specialized sand for making mosaic were regularly scattered and the size of the particles were the same, but the particle size of ready mix mortar was more heterogeneous. So, this can be one of the reasons of fragmentation of ready mix mortar under compressive strength test.

4 Conclusion

According to test results, the mortars made from specialized sand for mosaic are more economical than mortars made from the ordinary sand due to their higher strength. Therefore, we can reach proper specifications for ready mix mortar just by grading adjustment of natural and abundant materials and by using that in production of this mortar. Also, the comparison of specimens' strength, SEM image and fracture showed that mortars for making mosaic made from the specialized sand exhibited more workability than the ones made from ready mix mortar. An increase in mortar flow according to the Standard test method caused strength reduction, but the strength of the specimens made from the specialized sand for making mosaic on the 28th day and the standard flow would be 2.5 times the strength of ready mix mortars. In all samples, the water retention values of mortar were higher than those from the standard tests.

Due to the difference in strength value reported by the manufacturer and the amount achieved in the laboratory tests, it was suggested that dry mortar manufacturers should pay more attention to the

process of making the mortar and control the quality so as they could attract the consumer trust. It was suggested that in further research into the properties of mortars researchers should not only use specialized sand for making mosaic, but also add chemical additives.

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References

[1] Zarei, S.E., Karimi, N.: *Technology for Producing Dry Mortar*, International Journal of Civil Engineering, 2014, Vol. 68, 30-39.

[2] *Lahti Precision, Plaster and Mortar Plants and Product technology catalog*, Lahti, Finland, 2016, Dealers in Iran, 1-8.

[3] Rais Ghasemi, A., Kalantari M.: *Ready -To-Use Factory Dry Mortar and The Necessity for Its Application*, Iran Concrete Institute Quarterly, 2012, 47, 74-81.

[4] Wan, I. R.: *Advanced Dry Mortar Technology for Construction Industry*, Professional Services Development Assistance Scheme, 2002, Hong Kong, 1-19.

[5] ParsRabin, *Trading with grout and mortar dry*, 2016, Iran - South Khorasan, 1-4.

[6] Bayer, R., Lutz H.: *Dry Mortar Ullmann's Encyclopedia of Industrial Chemistry*, Sixth Edition, 2003 Electronic Release, Wiley-VCH, Wenham, 2003, 1-17.

[7] Rejeb, S.K.: *Improving Compressive Strength of Concrete by a Two-Step Mixing Method*, Cement and Concrete Research, 26 1996, 4, 585-592.

[8] Plawsky, J.L., Jovanovic, S., Littman, H., Hover, K.C., Gerolimatos, S., Douglas, K.: *Exploring the effect of dry premixing of sand and cement on the mechanical properties of mortar*, Cement and Concrete Research, 2003, 33, 255–264.

[9] Park, K.B., Plawsky, J. L., Littman, H., Paccione, J. D.: *Mortar properties obtained by dry premixing of cementitious materials and sand in a spout-fluid bed mixer*, Cement and Concrete Research, 2006, 36, 728–734.

[10] Zhang, W., Ingham, J.: *Using Recycled Concrete Aggregates in New Zealand Ready-Mix Concrete Production*, Journal of Materials in Civil Engineering, 2010, 5, 443-450.

[11] Namdar, A., Feng, X.: *Economic Considerations in the Development of Construction Materials – A Review*, Engineering Review, 2015, 35, 3, 291-297.

[12] Igarashi, Shin-ichi, M. Kawamura, A. Watanabe: *Analysis of cement pastes and mortars by a combination of backscatter-based SEM image analysis and calculations based on the Powers model,* Cement and Concrete Composites, 2004, 26, 8, 977-985.

[13] ASTM C1329 / C1329M, *Standard Specification for Mortar Cement*, ASTM International, West Conshohocken, PA, 2016

[14] Rahimi, H.: *Building Materials*, Institute of Tehran University Press, Tehran, 2009.

[15] ASTM C144, *Standard Specification for Aggregate for Masonry Mortar, STM C144-11, Standard Specification for Aggregate for Masonry Mortar*, ASTM International, West Conshohocken, PA, 2011.

[16] ASTM C1437-15, *Standard Test Method for Flow of Hydraulic Cement Mortar*, ASTM International, West Conshohocken, PA, 2015,

[17] Sarmadanhari, A., Kardan, S. M.: *Full Reference of Building Materials*; 2012; Tehran, 137.

[18] ASTM C1314, *Standard Test Method for Compressive Strength of Masonry Prisms*, ASTM International, West Conshohocken, PA, 2016

[19] Gonçalves, J. P., Tavares, L. M., Toledo Filho, R. D., Fairbairn, E. M. R., & Cunha, E. R.: *Comparison of natural and manufactured fine aggregates in cement mortars*, Cement and Concrete Research, 2007, 37, 6, 924-932.

[20] Raisghasemi, A. M., Parhizgar, T.: *Dry mortar ready - Introduce and apply*, Research Center Building and Housing, 2015, Tehran, 7.

[21] ASTM C91 / C91M-12, *Standard Specification for Masonry Cement*, ASTM International, West Conshohocken, PA, 2012,

[22] Dong, J., Shoal.: *Experimental Study on Deformation Properties of Unsaturated Compacted Soil Based on Digital Image Measurement*, Engineering Review, 2014, Vol. 34, Issue 3, 217-222.