THE INVESTIGATION OF PHYSICAL AND MECHANICAL PROPERTIES OF MORTARS USED IN HISTORICAL BUILDINGS IN HARRAN (SANLIURFA, TURKEY)

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ABSTRACT

In this study, a physical and mechanical property of mortar used in historical buildings in the region in Harran is investigated. The mortar samples were taken in accordance with the standards from Şanlıurfa Castle, Harran Mound, Harran University, Harran City Walls, Harran Castle and Harran Grand Mosque which are located in the Harran region. Mass and volume of water absorption rates, mass per unit volume, specific gravity and porosity had been found in order to specify the physical properties of mortar samples. In addition, grading of aggregates which is forming mortar is calculated. To specify the mechanical properties of mortar specimens also compressive strength had been found by 40x40x40 mm cube-shaped cut. The values that found in the tests carried out on mortar specimens was similar to results reported in the literature. It was observed that components of mortar samples were made according to a specific design. The values that found in the results of physical and mechanical analysis are very close to the specified value in TSE (Turkish Standard). The average value of water absorption of mortar samples is the rate of 16.66% by mass and 23.17% by volume.Mortar visible sample density values is equivalent to plaster and lime plaster mortar visible intensity value and the average of porosity is 25%. The largest grain size of aggregates that forming mortar had been found as 8 mm. According the mechanical analysis results average compressive strength of mortar samples had been found as 5.42 MPa. These values are closer to founded values in studies on Khorasan mortars.

Keywords: Harran; Historic Building; Mortar; Physical and Mechanical Properties.

INTRODUCTION

Although it is a new concept in our country the importance of the protection and repair of historical buildings which is the most important element of a country's historical and cultural heritage, particularly in Europe adopted many years ago and several principles are determined for restoration and conservation work in the historic buildings. The materials which will be used in the repair of historic buildings is one of the most important elements determining the quality of repairs carried out. Even the structure has not been reached with materials that the first made in its period, with interdisciplinary work to be done by analysing present materials of construction it is possible to use the most suitable materials. It is important that in the selection of material to be applied with the analysis, reaching also written historical documents also to benefit from these documents. The repair works to be

done based on both modern analysis and written documents that have still survive today will increase the quality of the work and the resistance [1].

In a structure mortars and plasters as in the new structure are one of the important elements in our cultural heritage in historic building during or after construction so that they assume the function [2]. Unconsciously and only made known on the basis of current methods protection - repair work on our cultural heritage monuments which are our cultural heritage without the scientific research may lead irretrievable damage. To prevent these types of applications and to choose the right application materials detailed scientific data should be obtained, conservation and restoration works must be performed in accordance with the general principles of restoration. In case of the material of the work which will be used in repair work to be carried out without specifying the content and quality have different chemical, physical and mechanical properties to artefact, various mechanical stresses will occur. The effect of these mechanical stress mostly will be on the weaker original material which had begun to lose its quality and as a result of that repair work to be done will bring more harm than good, will lead to accelerate the degradation process, irreversible damage [3].

Analysis of the mortar to be held within the scope of conservation efforts during the restoration of historical buildings is extremely necessary in the context of scientifically reviewed of these structures. Such that, in some cases analysis of the mortar makes section of dating and detection of the authenticity of the structure easier[4].Further, while preparing repair mortars, determination of the properties of the original mortar is necessary to investigation of production and application techniques, deterioration which had shown by mortar[5]. In this study, the original features of the mortar used in historical buildings in the area of Harran, Şanlıurfa Castle, Harran mound, Harran University, Harran City Walls, Harran Castle and Harran the Great Mosque are specified. Taking into account the properties of mortar which we have obtained in this work; provide advice about mortar will be used in the restoration of these structures.

MATERIAL

Şanlıurfa Castle

As a result of investigations conducted in Şanlıurfa Castle three points which are eligible to receive the mortar samples was determined. The most important factor for determining the point for eligible mortar sample, it has been noted the original structure of the mortar not to be intact. Received mortar samples are masonry mortar. Mortar samples was taken by help of hammer and chisel in convenient way to the standards (Figures1-3),

Figure 1. Mortar sample numbered SK H1 which was taken from Şanlıurfa Castle

Figure 2. Mortar sample numbered SK H2 which was taken from Şanlıurfa Castle

Figure 3. Mortar sample numbered SK H3 which was taken from Şanlıurfa Castle

Harran Mound

The binding material of The Harran Mound was mud mortar. As a result of investigations conducted three points which are eligible to receive the mortar samples was determined. The most important factor for determining the point for eligible mortar sample, it has been noted the original structure of the mortar not to be intact. Mortar samples were taken in convenient way to standards from the masonry mortar of the rooms located in the northwest of the mound (Figures 4-6).

Figure 4. Mortar sample numbered HH H1 which was taken from Harran Mound

Figure 5. Mortar sample numbered HH H2 which was taken from Harran Mound

Figure 6. Mortar sample numbered HH H3 which was taken from Harran Mound

Harran University

Harran University is located in the north east of Harran Grand Mosque as location. When we examine the current status of Harran University structure parts which surviving until today; 1- 1.5 meters in height walls of rooms which are forming the Harran University. Eligible to receive mortar sample points were specified on masonry mortar of these walls. To get the original mortar samples removing one or two stone of these walls, mortar samples was taken in convenient way to standards. (Figures 7-9),

Figure 7. Mortar sample numbered HU H1 which was taken from Harran University

Figure 8. Mortar sample numbered HU H2 which was taken from Harran University

Figure 9. Mortar sample numbered HU H3 which was taken from Harran University

Harran City Walls

After examining the current status of Harran City Walls three points which are eligible for mortar specimens were determined. The determined points are on mesh mortar of the rear wall of Aleppo door which is extant. Mortar samples were taken in convenient way to the standards from this masonry mortar. (Figures 10-12).

Figure 10. Mortar sample numbered HSS H1 which was taken from Harran City Walls

Figure 11. Mortar sample numbered HSS H2 which was taken from Harran City Walls

Figure 12. Mortar sample numbered HSS H3 which was taken from Harran City Walls

Harran Castle

After examining the current state of the building three different points which are eligible for mortar specimens were identified. The first of these specified points: was masonry mortar of bottom wall of the north-west corner of the castle, the second point: was masonry mortar of the bricks forming the arch at the top of the castle and the third point was plaster mortar of top wall of the eastern facade of the castle. Mortar samples was taken in convenient way to the standards from this decided three points (Figures13-15).

Figure 13. Mortar sample numbered HK H1 which was taken from Harran Castle

Figure 14. Mortar sample numbered HK H2 which was taken from Harran Castle

Figure 15. Mortar sample numbered HK H3 which was taken from Harran Castle

Harran Grand Mosque

Harran Grand Mosque, is located at the north of the Harran Mound. After examining the current state of the building three different points which are eligible for mortar specimens were identified. These points were on the bottom of the wall on the eastern front. Mortar samples were taken in convenient way to the standards from these decided three points. (Figures 16-18.).

Figure 16. Mortar sample numbered HUC H1 which was taken from Harran City Walls

Figure 17. Mortar sample numbered HUC H2 which was taken from Harran City Walls

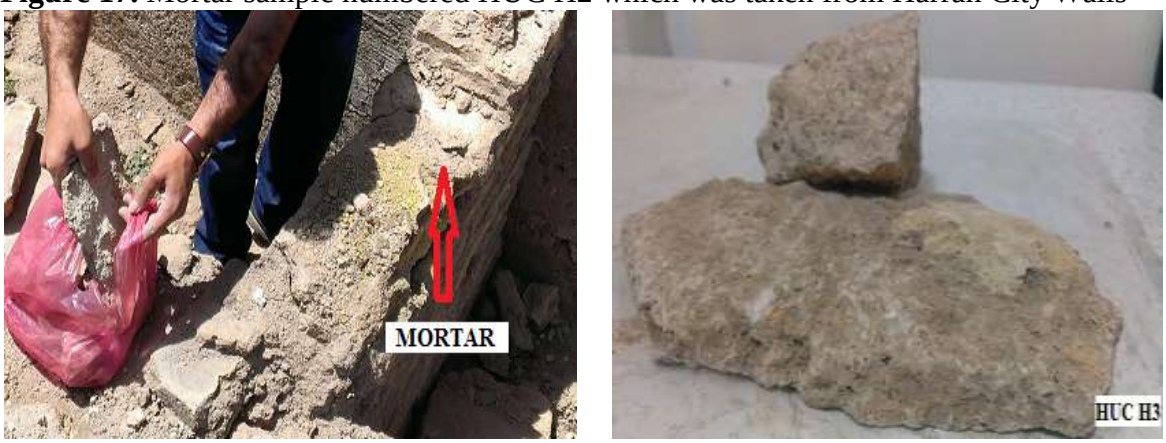

Figure 18. Mortar sample numbered HUC H3 which was taken from Harran City Walls

EXPERIMENTAL WORKS

Water Absorption Rate of Mass and Volume

In order to determine water absorption of mass and volume of mortar samples water absorption tests were performed. WS initial value of the example between 20-50 g which was dried for 48 hours at 60 C by weighing was recorded after cooled in adesiccators.After standing for 48 hours by placing a bowl of water weight saturated with water and weight in water was recorded [6-8].

Visible Density

Due to mortar samples have amorphous form, visible density detecting was performed by taking advantage of the water absorption test. The examples dried until it reaches the invariant mass, visible density was calculated by using weight saturated with water and weight in water [9,10].

Real Density

To determine the actual density of mortar samples pycnometer experiment is performed. A certain amount of ground mortar samples were weighed by sieving in 0.063 mm mesh aperture sieve separately and m_e value was recorded. Pyknometer was charged with deionized water until half. Then weighed mortar sample (me) was added to pyknometer and was shaken to distribute solids in fluid. Vacuum was applied to pyknometer until completion of output of air bubbles, then pycnometer was filled approximately to the brim and was expected the

water on the solid to collapse until it becomes clear. Then pycnometer was completely filled carefully with deionized water, sealed with a shaven cap and pycnometer was dried with a dry cloth. Afterwards pycnometer was weighed and m1 values were recorded. After pyknometer was drained and washed, was filled with just deionized water was closed with the shaven caps and after pycnometer was dried with a dry cloth was weighed and m2 value was recorded [11].

Porosity

In order to calculate the porosity of mortar samples first composite values was calculated by using the value of visible density and real density. Using Composite values of mortar samples porosity has been identified [12-13].

Sieve Analysis

To indicate granulometer of aggregate in mortar components sieve analysis was performed. Received mortar samples were stored in 10% HCl solution until reaction is complete. Afterwards dried aggregates which were separated from clay, and fibrous materials by filtering with filter paper, has been passed in set of the sieve which is formed by 8 mm., 4 mm., 2 mm., 1 mm., 500 µ, 250 µ, 125 µ and 63 µ opening sieves[14].

Mechanical Properties

It is usually hard to take examples from historical structure of sizes mentioned in the current test standards to determine mechanical properties of newly manufactured samples. Moreover, it would be more accurate that dealing masonry structures which are composite systems and not show homogeneity as a whole in order to assess mechanical precision. In contrast, determination of mechanical properties of the original mortar is required In terms of design of the repair mortar [15].

RESULTS AND DISCUSSION

Physical Features

According to the results of physical tests of mortar samples which were taken from the structure; mass water absorption rate varies between 9.52% and 27.90%. Volume water absorption rate of mortar samples varies between the values of 13.68% and 35.88 %(Table 1). The sample which has highest water absorption rate is HUC H2 numbered mortar samples. The sample which has lowest water absorption rate is HSS H2 numbered mortar samples. The water absorption rate of mortar samples has direct proportion with clay rate and the porosity of the components of mortar. The water absorption rate of mortar samples are close to the water absorption ratios which are found in studies on historical mortar [16-17]. The water absorption rate of mortar samples which are taken from the Harran Mound (HH H1, HH H2, HH H3) could not be determined because they are dispersed in water. The reason of water dispersion of mortar samples which are taken from the Harran Mound is that they are mud mortar.

Table 1. Water Absorption Rate of Mass and Volume of Mortar Sample

SAMPLE	WATER ABSORPTION RATE MASS (%)	WATER ABSORPTION RATE OF VOLUME (%)
SK H1	13,03	17,83
SK H2	14,65	20.86
SK H3	17.46	27.25
HU H1	15.64	22.33
HU H2	18.83	26.42
HU H3	16.88	23.42
HSS H1	13.46	18.04
HSS H2	9.52	13.68
HSS H3	10.02	14.30
HK H1	18.14	24.09
HK H2	13.95	19.06
HK H3	17.17	23.08
HUC H1	24.72	30.98
HUC H2	27.90	35.88
HUC H3	18.52	30.33

The visible density (mass per unit volume) of mortar samples varies between the values of 1.25 to 1.64 g / cm3 (table 2). These values are equivalent to the apparent density of the plaster mortar and lime plaster mortar. The real density of mortar samples varies between the values of 1.51 to 2.29 g / cm3 (Table 2). Porosity of mortar specimens varies between the values of 4.94% and 42.06%. Real density and porosity values of mortar specimens are closer to values of the mortar used in historic structures (18-19-20).

Table 2. Visible density, real density and porosity of mortar samples

SAMPLE	VISIBLE DENSITY (g/cm^3)	REAL DENSITY (g/cm^3)	POROSITY (%)
SK H1	1.40	1.53	8.70
SK H2	1.42	1.63	12.88
SK H3	1.44	1.60	10.14
HH H1	They dispersed in water	1.49	They dispersed in water
HH H2		1.53	
HH H3		1.51	
HU H1	1.43	1.71	16.64

HU H2	1.40	1.74	19.24
HU H3	1.39	1.71	18.94
HSS H1	1.34	1.52	11.71
HSS H2	1.44	1.53	6.33
HSS H3	1.43	1.56	8.64
HK H1	1.33	2.29	42.06
HK H2	1.37	1.90	28,18
HK H3	1.34	2.10	35.89
HUC H1	1.25	1.81	30.79
HUC H2	1.29	1.70	24.41
HUC H3	1.64	1.72	4.94

The aggregate gradation of components of mortar samples was calculated by performing a sieve analysis. The aggregate gradation of component of mortar samples which are taken from Şanlıurfa Castle(ŞK H1, ŞK H2, ŞK H3) was determined by TS 13 515 and it is observed that the grading curve which is Dmax 8 mm remains in the suitability region(Figure 19). The aggregate gradation of components of other mortar samples was evaluated according to TS 802 (figures 20-24). The granulometry of this mortar samples has not fully in compliance of the grading curve of Dmax 8 mm of TS 802 but it is seen remains near the border [21-22].

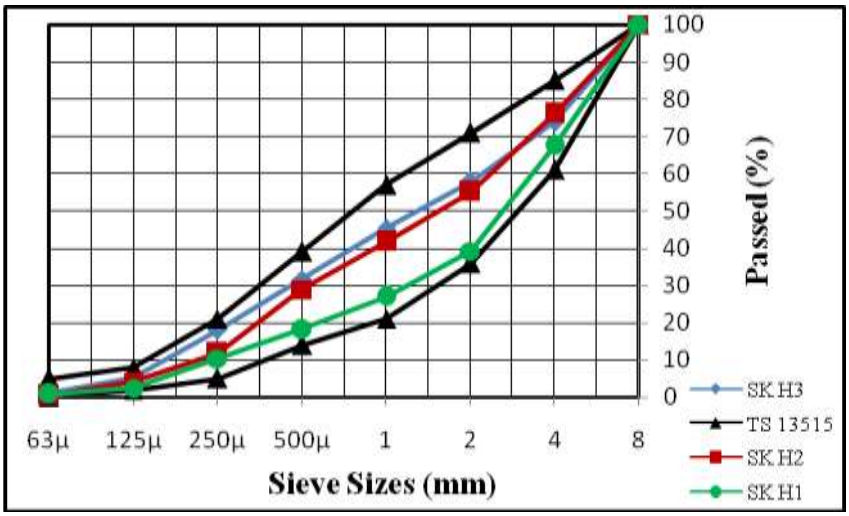

Figure 19. Aggregate grading curve of mortar samples which are taken from Şanlıurfa Castle

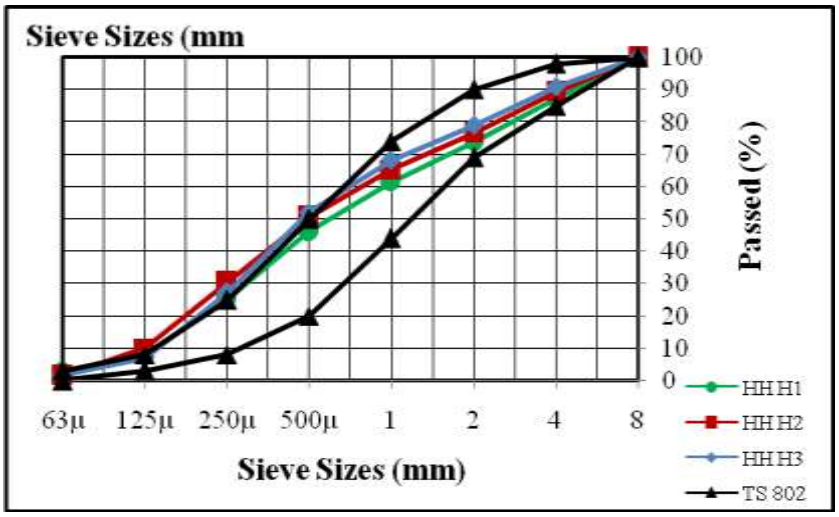

Figure 20. Aggregate grading curve of mortar samples which are taken from Harran Mound

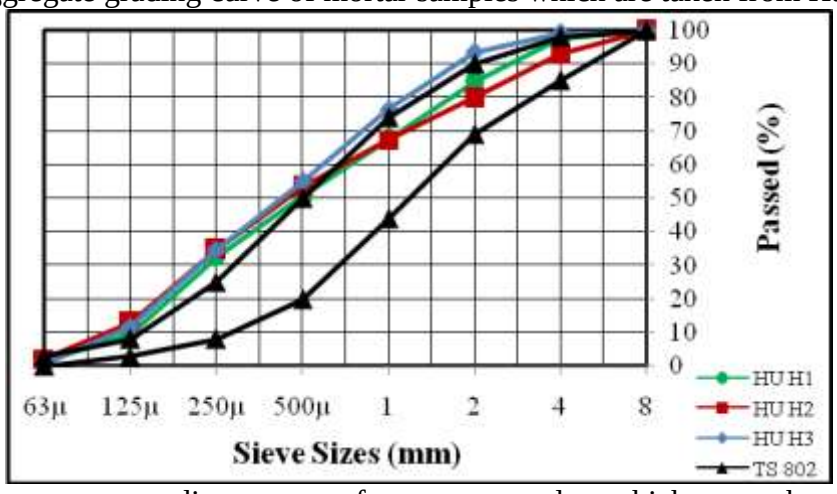

Figure 21. Aggregate grading curve of mortar samples which are taken from Harran University

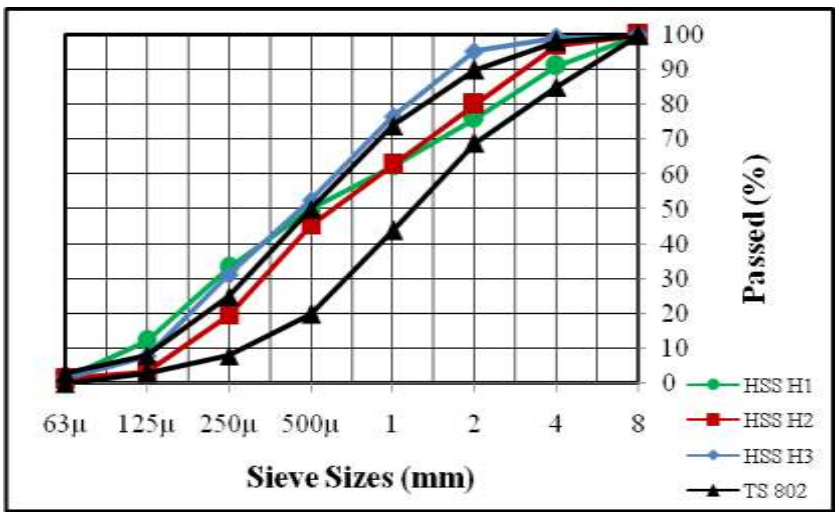

Figure 22. Aggregate grading curve of mortar samples which are taken from Harran City Walls

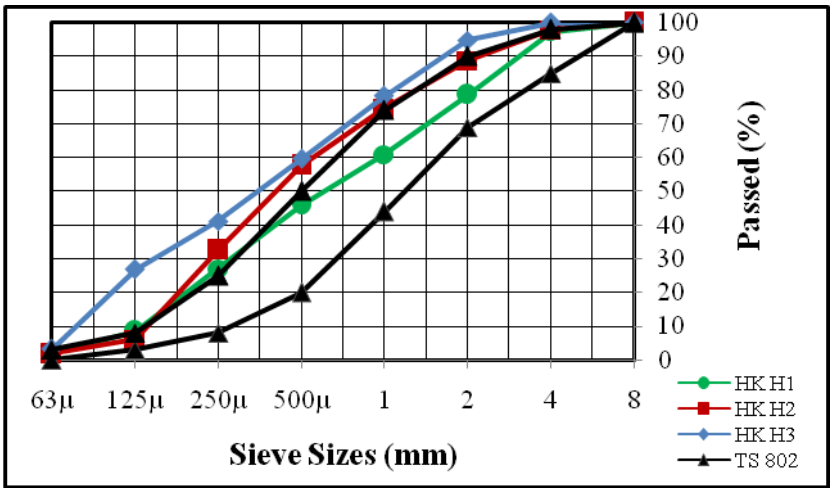

Figure 23. Aggregate grading curve of mortar samples which are taken from Harran University

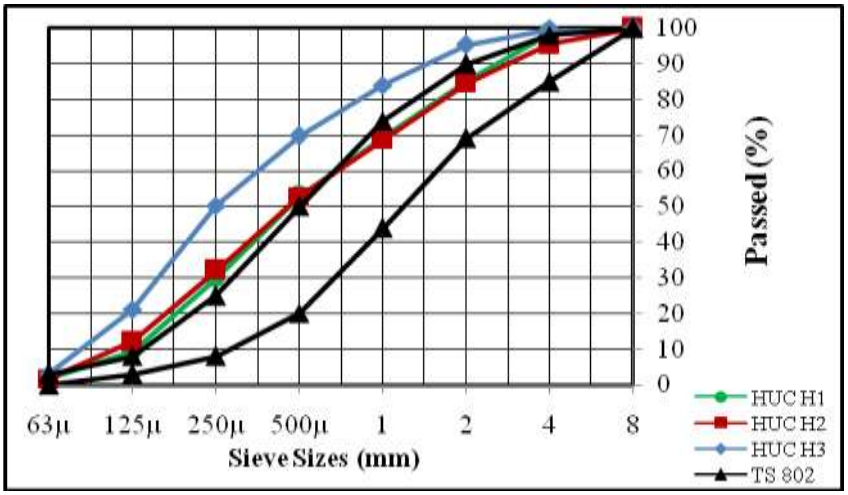

Figure 24. Aggregate grading curve of mortar samples which are taken from Harran Grand Mosque

Mechanical Properties

To indicate mechanical properties of mortar samples which are taken from the structure uniaxial compressive strength test was performed. It is observed that compressive strength of mortar samples varies between the values of 4.56 and 6.40 MPa (Table 3). These values are closer to founded values in studies on khorasanmortars [17].

Table 3. Compressive strength of mortar specimens

BUILDING WHICH MORTARS SAMPLE WERE TAKEN	SAMPLE NO	COMPRESSIVE STRENGTH (MPa)
ŞANLIURFA CASTLE	SK H1	5.33
ŞANLIURFA CASTLE	SK H2	5.87
ŞANLIURFA CASTLE	SK H3	5.09
HARRAN UNIVERSITY	HU H1	6.22
HARRAN UNIVERSITY	HU H2	5.27
HARRAN UNIVERSITY	HU H3	6.40
HARRAN CITY WALLS	HSS H1	5.28

HARRAN CITY WALLS	HSS H2	4.92
HARRAN CITY WALLS	HSS H3	5.91
HARRAN CASTLE	HK H1	5.18
HARRAN CASTLE	HK H2	5.49
HARRAN CASTLE	HK H3	5.29
HARRAN GRAND MOSQUE	HUC H1	5.07
HARRAN GRAND MOSQUE	HUC H2	4.56
HARRAN GRAND MOSQUE	HUC H3	5.44

CONCLUSION

The following conclusions were drawn from the present study:

1. The average value of water absorption of mortar samples was found the rate of 16.66% by mass and 23.17% by volume. Because of the clay material usually found in components of mortars water absorption rate in component varies proportionally with the amount of clay.
2. When we look at density values of mortar samples it is seen that the mortars are gypsum slurry or lime plaster mortar. When we examine work done on the history of mortar it is seen that historical mortars are gypsum mortar or lime plaster mortar.
3. The biggest factor affecting durability of mortar samples is porosity. Increasing percentage porosity makes penetration of harmful substances easier and it destroys the original structure of the mortars. Further increasing percentage porosity leads the water will penetrate the structure of mortar becomes resistless to frost. The average the rate of the porosity values which we found from results of physical analyses is 25%. When we consider the work done on the historical mortar, it is seen that this value is ideal value.
4. It is observed that curve of granulometry of aggregates forming the mortar samples mostly in compliance boundaries which are stated in TS 13515 and TS 802. The largest grain size of aggregates that forming mortar had been found as (Dmax) 8 mm. This value is suitable for mason with rubble, freestone and clay brick.
5. It is seen that the value of compressive strength which was obtained from results of mechanical analysis of mortar samples closer to found values in studies on khorasanmortars.

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