A Geotechnical Investigation of the Effect of Grain Size and Texture of Calcareous Rocks on Their Engineering Behaviour

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Abstract

This paper examines the effect of the grain size and texture of calcareous rocks on their engineering behaviour with an emphasis on the texture of the rock. Aggregates are one of the most important construction materials in civil engineering, so their durability is critical to the long life of engineering works. The study of the effect of the size of aggregates leads to a new approach in the use of aggregates in order to achieve long life in engineering construction. Six different samples of calcareous rocks were selected from the regions of Hamedan province, Iran. The standard sulfate soundness test has been carried out on all samples and the weight loss of each sample was recorded. From the results, it was concluded that the grain size between 37.5 and 50 mm shows the best durability and quality of rocks and the grain size ranges between 4.5 to 12.5 mm shows the lowest durability and quality of calcareous rock samples in the sulfate soundness tests. Finally, the results show that there is a reasonable relationship between the texture of calcareous rocks and their durability, such that the rocks with a uniform and homogenous grain size and texture show a very good durability according to the sulfate soundness tests.

Keywords: *Aggregate, Engineering behaviour, Sulfate soundness test, Calcareous rocks, Grain size.*

Introduction

Sedimentary rocks form more than 80% of the crust of the earth references. In this regard, calcareous rocks are the most widely distributed sedimentary rocks through the earth. From an economic and engineering point of view, aggregates are very important and are one of the most widely used construction materials in civil engineering projects. Normally, aggregates and other borrow materials are used in high volumes in engineering construction. For this reason, the study of the engineering properties and geological factors affecting the behaviour of calcareous rocks is very important, Kazi and Almansour, (1980). Figure 1 shows a map of the study area.

Sampling has been undertaken based on Business, Transport and Housing Agency (1995), un-weathered and fresh samples were tested. From the thin section studies, it is clear that the texture of rocks can be used as the main factor in distinguishing calcareous rocks. Sulfate soundness tests have been carried out on different samples according to the ASTM C88 standard, American Society for Testing and Materials (1996).

Description of Textures of Calcareous Rocks

The study of the textures of different types of calcareous rocks has been carried out on the thin sections from different type of rocks. In order to recognize dolomites within the thin sections, they were painted with red alizarin liquid, Gupta and Seshgiri (2001). Figures 2, 3, 6, 7, 14 and 15 show the thin sections of six different samples of calcareous rocks from Hamedan province, Iran. The results of texture studies are presented in Table 1. Dunham, (1962) and Folk, (1962) have proposed some useful classifications for calcareous rocks. Dunham's classification is mainly based on texture and environmental deposition. Since, the main aim of this research was study of textures of calcareous rocks and their effects on the engineering behavior of calcareous rocks; therefore Dunham's classification has been used.

As is clear from Table 1, all six samples have different types of textures. The samples from Nahavand (No: 1) contain crushed micrite grains with sparry cement. The texture is that of a brecciated calcareous. The samples from the Malayer area (No: 2), show a texture type of crystalline calcareous containing some calcite, quartz, and also some opaque minerals (pyrite and chalcopyrite), and cherts.

Samples from the Hamehkasy area (No: 3) show a bioclastice packstone texture and contain reef and crinoid's pieces. Samples from the Ali-Sadr region (No: 4) show a dolostone texture and contain large crystal of dolomite and quartz.

The Abshineh samples (No: 5) show a bandstone reefy texture and contain reef pieces accompanied by micrite mud and cement. The samples from the Ekbatan Dam (No: 6) the texture is that of a calcareous conglomerate. The conglomerate contains pieces of calcareous which are slightly metamorphosed with spary cement. The results of the petrographic studies of the six different selected samples of calcareous rocks are shown in Table 1.

Results from Sulfate Soundness Tests

It should be noted that according to ASTM C88, the size of aggregates selected for the sulfate soundness test should be accordance with Table 2. In the sulfate soundness test, the sizes of aggregates are classified into seven groups. The biggest size (65 mm) is group one (G1) and the smallest size (4.75 mm) is group seven (G7).

A: Results for the Nahavand Samples

All samples selected from Hamadan province were prepared according to ASTM C88 standard, Ameraican Society for Testing and Materials (1996), into seven group sizes. The first groups of samples which have been tested were the Nahavand samples. Figures 2 and 3 shows the thin sections of Nahavad samples. The results of sulfate soundness test on the Nahavand samples (Brecciated calcareous) are presented in Figures 4 and 5. From Figures 4 and 5, the largest decrease of weight during the sulfate soundness test has been seen in the samples with 4.75 to 9.5 mm grain sizes (G7). This means that, from the seven groups of grain sizes, this group is most susceptible to weight loss in comparison with the other six sizes. On the other hands, the lowest decrease of weight has been recorded in samples with 37.5 to 50 mm grain sizes (G2).

B: Results for the Malayer Samples

The results of thin section studies on the Malayer samples are shown in Figures 6 and 7. This shows that these samples are crystalline calcareous sometimes with minor quartz grain. In addition, the results of five cycles of sulfate soundness test on the calcareous rock samples

from Malayer are shown in Figures 8 and 9. It can be concluded that the largest decrease of weight has occurred on samples of 4.75 to 9.50 mm grain sizes (G7) and the lowest decrease of weight has been seen in samples of 37.5 to 50 mm grain sizes (G2 in the magnesium sulfate test) and samples of 25 to 37.5 mm grain sizes (G3 in the sodium sulfate test).

It seems, sizes between 25 to 37.5 mm and 37.5 to 50 mm are most resistant to the sulfate soundness test and sizes below that and above these sizes have the lowest resistance to the sulfate soundness test. It means, the grain size is an important parameter affected to the durability of calcareous rocks.

C: Results for the Hamehkasy Samples

From thin-section study of the texture of calcareous rock samples from the Hamehkasy calcareous, it was found to be a bioclastic packstone texture. The Hamekasy calcareous is a white and porous calcareous with special engineering properties. Figures 10 and 11 showed the results of thin section studies on the Hamehkasy calcareous.

Figures 12 and 13 show the results of sulfate soundness test. As is clear from Figure 12, the Hamehkasy samples show the largest resistance to weight loss in grain sizes between 4.75 to 19 mm (Groups 5 to 7) and lowest resistance to weight loss in grain sizes between 37.5 to 65 mm (Groups 1 to 3) in magnesium sulfate soundness test. Figure 13 show the largest resistance to weight loss of calcareous samples from Hamehkasy in grain sizes between 4.75 to 19 mm (Groups 5 to 7) and lowest resistance to weight loss in grain sizes between 37.5 to 65 mm (Groups 1 to 3) in sodium sulfate soundness test.

D: Results for the Ali-Sadr Cave Samples

Thin section studies from the Ali-Sadr cave samples show that the texture of the Ali-Sadr samples is a type of Dolostone Zonotopic. Figures 14 and 15 show the results of thin section studies on the Ali-Sadr cave calcareous rock samples. From the engineering properties studies it was concluded that Ali-sadr calcareous is a very compact calcareous and shows very good engineering properties. Figures 16 and 17 show the results of these tests.

As is clear from Figures 16 and 17, the largest decrease of weight has occurred in grain sizes between 4.75 and 9.5 mm (G 7) for both tests and the lowest decrease of weight is recorded for grain sizes between 4.75 to 19 mm (Groups 1 to 3) in both tests respectively.

E: Results for the Abshineh Dam Samples

The results of thin section studies from the Abshineh Dam samples show that this type of calcareous rocks has a reefy boundstone texture. Figure 18 shows a photomicrograph of a thin section of the Abshineh dam sample. A part of a reef is in the centre of photomicrograph which is confined within the calcareous cement. Sodium and magnesium sulfate soundness tests were carried out on the Abshineh Dam samples in 5 cycles of wetting and drying. Figures 19 and 20 show the results of the sulfate soundness test.

F: Results for the Ekbatan Dam Samples

Dam is constructed near the boundary between the calcareous and metamorphic rocks and recently it has been raised (25m) in order to increase its storage capacity. The results from thin sections studies show that the texture of these samples is a calcareous conglomerate. Figures 21 and 22 show photomicrographs of calcareous rock samples from the Ekbatan Dam. Results from the sulfate soundness test show that the largest decrease in weight was in the size ranges between 9.5 to 12.5 mm and the smallest decrease in weight has occurred in size ranges between 25 to 37.5 mm in the magnesium sulfate soundness test (Figure 23). Also the

smallest decrease in weight was recorded in size ranges between 50 to 63 mm and the largest decrease in weight has occurred in size ranges between 9.5 to 12.5 mm in the sodium sulfate soundness test (Figure 24).

Conclusions

In this research, general tendencies of the sulfate soundness test results have decrease tendency. The uniformity of rocks caused the results tendency of Malayer and Ali-sadr samples are reversed manifest tendencies. This tendency is acceptable for Abshine Dam samples as well.

Regarding to heterogeneity of the Nahavand, Ekbatan Dam and Hamekasi samples, the sulfate soundness test results haven't reversed manifest tendencies. Also, the lowest weight decrease of Hamekasi samples during soundness tests has been seen with finer grain sizes (G5 and G7). It could be described that the durability strength of fossil particles is more than the welded particles from the same fossils. For all samples (except Hamekasi samples) the lowest weight decrease during soundness tests has been seen with G2 grain size (37.5 to 50 mm) that could be optimized size against corrosion. Consequently it can be concluded that, before using calcareous rocks as aggregates or as borrow materials, their texture and grain size should be studied carefully.

References

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Table 1: The results of thin section and texture studies for carbonaceous rocks.

Sample No:	Name of the study Area	Description of Rock	Texture of the rock (Dunham, 1962)	Texture of the rock (Folk, 1962)
1	Nahavand	crushed micritic limestone pieces with spary cement	brecciate limestone	
2	Malayer	calcite crystals, quartz, opaque minerals, chert and muscovite	crystalline limestone	
3	Hamehkasy	reef pieces with crinoids and algae	bioclastic packestone	
4	Ali-Sadr Cave	large crystals of dolomites and quartz	dolostone	
5	Abshineh Dam	reef pieces and muddy micrites with micritic cement	reefy bandstone	
6	Ekbatan Dam	metamorphosed pieces of limestone with spary cement	conglomerate with limestone cement	

Table 2: The percentages of particles within the each sample

Name of the study Area	Sample No:	Opaque (%)	Fossil (%)	Alluvial Particles (%)	Porosity (%)
Nahavand	NA-1	1-2	-	5	2
	NA-2	1	-	11	1-2
Malayer	MA-1	-	-	3	3
	MA-2	1	-	10	1-2
Hamehkasy	HA-1	-	50	-	35
	HA-2	-	70	-	25
Ali-Sadr Cave	AL-1	1	-	3	<0.5
	AL-2	1	-	1-2	<0.5
Abshineh Dam	AB-1	-	>95*	-	8
	AB-2	-	>95*	-	4
Ekbatan Dam	EK-1	-	-	-	5
	EK-2	-	-	-	3

*Corral Boundstone

Table 3: Description of sizes used in Sulfate Soundness Test.

Group	G1	G2	G3	G4	G5	G6	G7
Size (mm)	50 – 65	37.5 – 50	25 – 37.5	19 - 25	12.5 - 19	9.5 – 12.5	4.75 – 9.5

1 Location of the study area within the circle on the map. (from website:www.iranmap.biz)

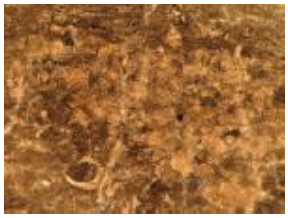

Figure 2. Photomicrogarph of a thin section of the breciated limestone from Nahavand.

Figure 3. Photomicrogarph of a thin section of the the breciated limestone from Nahavand

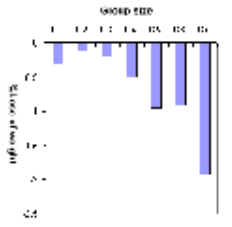

Figure 4. Results of magnesium sulfate soundness test for the Nahavand samples.

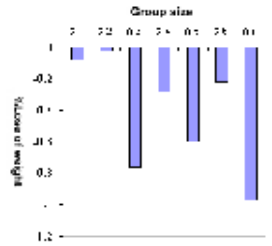

Figure 5. Results of the sodium sulfate soundness test for the Nahavand samples.

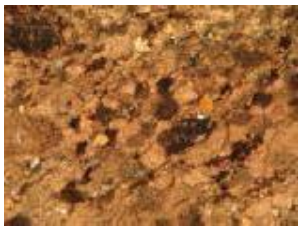

Figure 6. Photomicrograph of a thin section of a Malayer sample.

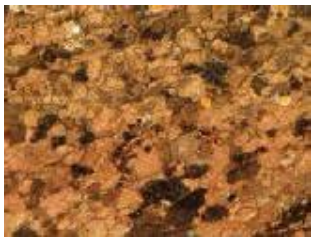

Figure 7. Photomicrograph of a thin section of a Malayer sample.

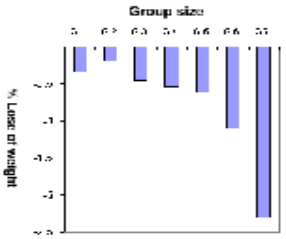

Figure 8. Results of magnesium sulfate soundness test for theMalayer samples

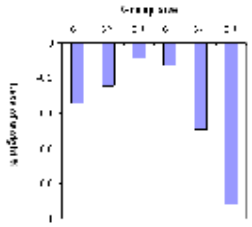

Figure 9. Results of the sodium soundness test for the Malayer samples sulfate

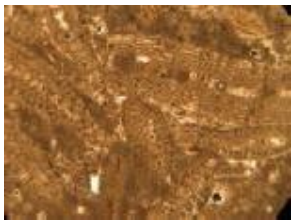

Figure 10. Photomicrogarph of a thin section of the Hamehkasy carbonaceous sample. Note the Alokoms within the limestone.

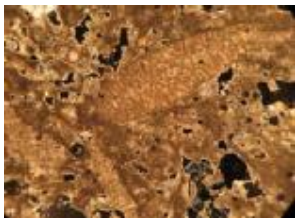

Figure 11. Photomicrogarph of a thin section of the Hamehkasy carbonaceous sample. The Alokoms are very clear within this sample

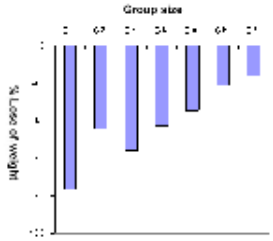

Figure 12. Results of magnesium sulfate soundness test for Hamehkasy samples.

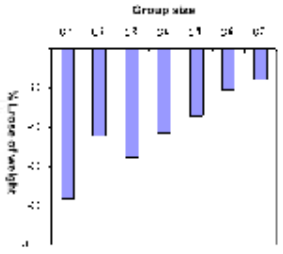

Figure 13. Results of sodium sulfate soundness test for Hamehkasy samples

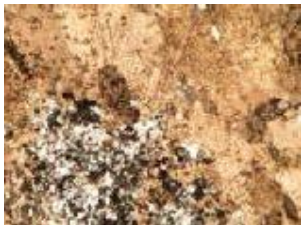

Figure 14. Photomicrogarph of a thin section of the Ali-Sadr Cave carbonaceous samples. On the right hand side there are dolomite crystals and on the left hand side there are quartz crystal within the limestone

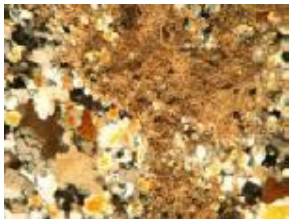

Figure 15. Photomicrogarph of a thin section of the Ali-Sadr Cave carbonaceous samples. The upper right part of figure shows dolomite crystals and the lower left part of the figure shows quartz crystals within the limestone.

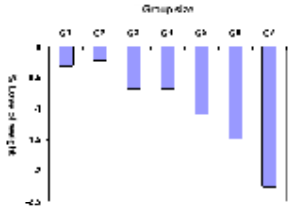

Figure 16. Results of magnesium sulfate soundness test for the samples from the Ekbatan Dam area.

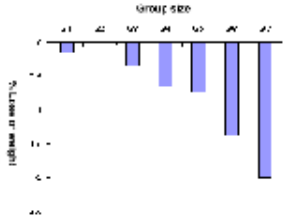

Figure 17. Results of sodium sulfate soundness test for the samples from the Ekbatan Dam area.

Figure 18. Photomicrograph of a thin section of the Abshineh Dam carbonaceous samples.

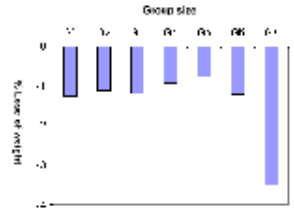

Figure 19. Results of magnesium sulfate soundness test for Abshineh Dam samples.

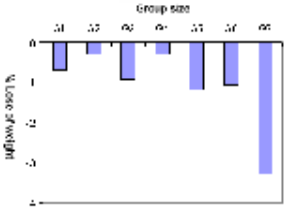

Figure 20. Results of sodium sulfate soundness test for Abshineh Dam samples.

Figure 21. Photomicrograph of a thin section of the Ekbatan Dam samples.

Figure 22. Photomicrograph of a thin section of theEkbatan Dam samples.

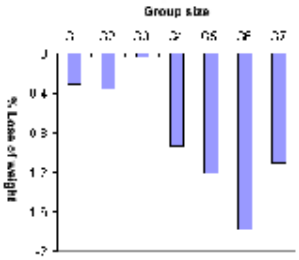

Figure 23. Results of magnesium sulfate soundness test for the Ekbatan Dam samples.

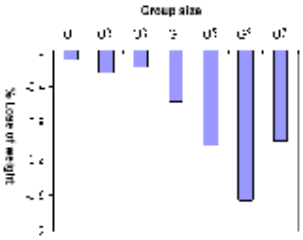

Figure 24. Results of sodium sulfate soundness test for the Ekbatan Dam samples.