

ARCADIA
LABORATORY TEST REPORT

ASTM C39
UNCONFINED COMPRESSIVE STRENGTH TEST



August 14th, 2020
DOC-2008-01 Rev. 00

0. Summary

The purpose of this Test is to show that sand treated with Arcadia can withstand a compressive pressure of more than 20 MPa.

The compressive strength test was conducted through ASTM C39 on cylindrical samples with a size of (L 150 × dia.7.5)mm of sand (available in the deserts or the sea bottom) treated with Arcadia.

1. Test Procedure

Test Date: August 4th, 2020

Test Equipment:

- ❖ N.1 Compressive Press
- ❖ N.1 Cylindrical Glass Container

Test Materials:

- ❖ To produce the Cylindrical Sample with Arcadia:
 - Geomaterial (Sands): 1350 g
 - Urea Concentration: ≥ 0.03 M
 - Protein Source: ≤ 20 g/l
 - Indigenous Ureolytic Bacteria (natural indigenous population)

Test Phases:

- i. Feed the bacteria of the Cylindrical Sample for 14 days in a Cylindrical Glass Container at a temperature of 25°C to 30°C
- ii. Dry the Cylindrical Sample for 28 days at a temperature of 45°C
- iii. Insert the Sample into the Compressive Press
- iv. Test the Compressive Strength according to ASTM C39

Geomaterial Characteristics:

Test	Unit	Sand	Fine Sand
pH		7.9 – 8.2	7.9 – 9.6
Ca ²⁺	ppm	100 – 180	120 – 380
Clay	%	2% - 4%	6% - 11%
Silt	%	12% - 18%	10% - 14%
Sand	%	80% - 86%	80% - 86%
Particle Size	mm	0.08	0.002
EC	m mho/cm	0.76 – 0.79	0.86 – 0.92

Tab. 1: Geomaterial composition



Fig. 1: Geomaterial (Sand and Fine Sand)



Fig. 2: Arcadia Culture in Laboratory



Fig. 3: Autoclave



Fig. 4: Incubator



Fig. 5: Centrifuge

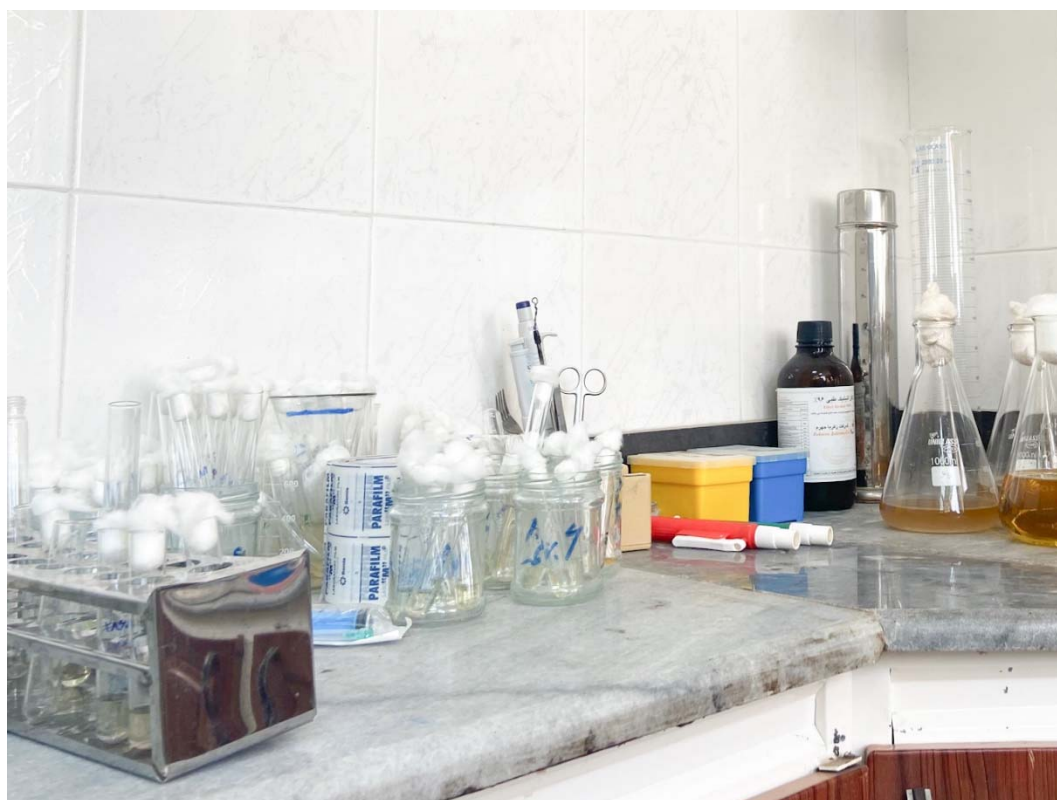


Fig. 6: Glassware



Fig. 7: Laboratory Substances used for Arcadia

2. Test Execution

The test, as described in the previous chapter was conducted for N.7 Samples using the same bacteria type but in different concentration.

Note that all the bacteria were indigenous and already naturally living in the Sand soil.

For the geomaterial necessary to produce of each Sample, we mixed Sand with Fine Sand.

It is essential to soak the walls of the soil with a thin layer of mineral oil to prevent the adhesion of sand samples after stabilization.

The compressive strength of each sample was determined in the Compressive Press at a given time based on division of maximum recorded force by cross-section area.



Fig. 8: Sample N.1 before Compressive Test



Fig. 9: Sample N.1 after Compressive Test



Fig. 10: Sample N.2 before Compressive Test



Fig. 11: Sample N.2 after Compressive Test



Fig. 12: Sample N.3 before Compressive Test



Fig. 13: Sample N.3 after Compressive Test



Fig. 14: Sample N.4 before Compressive Test



Fig. 15: Sample N.4 after Compressive Test



Fig. 16: Sample N.5 before Compressive Test



Fig. 17: Sample N.5 after Compressive Test



Fig. 18: Sample N.6 before Compressive Test



Fig. 19: Sample N.6 after Compressive Test



Fig. 20: Sample N.7 before Compressive Test



Fig. 21: Sample N.7 after Compressive Test



Fig. 22: Sample N.1 during Compressive Test



Fig. 23: Sample N.2 during Compressive Test



Fig. 24: Sample N.4 during Compressive Test

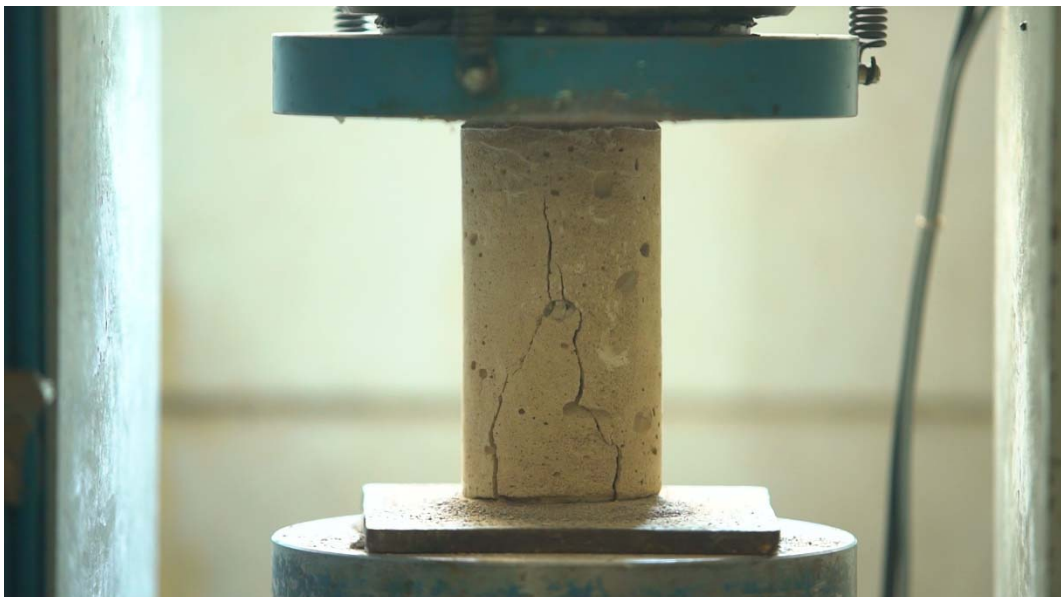


Fig.25: Sample N. 7 during Compressive Test



Fig.26: All Samples after Compressive Test

3. Conclusions

The Test was successful: we proved that Sand treated with Arcadia method can withstand a Compressive Pressure greater than 20 MPa.

Under laboratory conditions, unconfined compressive strength (UCS) ranging from 300 kPa up to 30 MPa were attained.

The results are summarized for the N.7 Samples in Tab.2:

- ❖ In four cases, we reached a Compressive Pressure of more than 20 MPa
- ❖ In two cases, the Compressive Pressure was between 10 MPa and 20 MPa
- ❖ In one case, the Compressive Pressure was 1.66 MPa (Sample N.1)

The Sand mix in Sample N.1 was 20% Fine Sand and 80% Sand.

We decided to include also this Sample in the analysis to show that the size of the geomaterial is important to obtain high compression strength.

In any case, as it can be note from Tab.2, the geomaterial size is not the only important parameter. Also, for example, the density of bacteria is extremely important.

It must be noted that in most real cases applications, low strength up to 1.5 MPa will be much more enough.

In fact, for example, in case of stabilizing sand dunes, only a Compressive Strength of 0.15 MPa

is sufficient to prevent sand from flowing.

Sample Number	Production Time	Sample dimensions [cm]		Sand %	Fine Sand %	Pressure Resistance [kg/cm ²]	Pressure Resistance [MPa]
		Height	Diameter				
1	28 days	14.8	7.5	80	20	16.6	1.66
2	28 days	15.3	7.5	20	80	302.9	30.29
3	28 days	14.4	7.4	40	60	247.0	24.70
4	28 days	15.4	7.4	0	100	165.7	16.57
5	28 days	14.4	7.4	40	60	210.6	21.06
6	28 days	15.1	7.4	40	60	227.5	22.75
7	28 days	12.3	7.4	50	50	117.0	11.70

Tab. 2: Test Results

4. Attachments

A1 – Compressive Test Certificate (original copy and English translation)