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Density, porosity, water absorption, saturation
coefficient, compressive strength and acid immersion
on samples of Cementstone Group (Lower Carboniferous)
from the Swinton Quarry, near Greenlaw, Borders

By D C Entwisle and M A Allen

British Geological Survey, Keyworth, Nottingham NG12 5GG, June 2000

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COASTAL AND ENGINEERING GEOLOGY LABORATORY REPORT No 2000/

Density, porosity, water absorption, saturation coefficient, compressive strength and acid immersion determinations on samples prepared from blocks the Cementstone Group the Lower Carboniferous from the Swinton Quarry, near Greenlaw, Borders, Scotland.

1. Introduction

This is a factual report on the density, porosity, saturation coefficient, water absorption, soaked compressive strength and acid immersion determinations carried out on samples of Lower Carboniferous Sandstone from the Swinton Quarry (NT 853 484), near the Greenlaw, Borders, Scotland. The work was requested by Mr Wallace Glendinning of Oakbank Ltd. Oakbank, Livingston, West Lothian. The blocks were received on 17 May 2000. Sample preparation was carried out at the British Geological Survey, Keyworth, on 19 and 20 May. and the testing was carried out between the 22 and 26 May 2000. The results are listed in Tables 1 and 2.

2. Sample Description

The three blocks provided were similar to each other. They were moderately strong, very pale orange (10YR 8/2), medium SANDSTONE with some mica speckles. Bedding was difficult to discern from the blocks.

3. Methods**3.1 Density and Porosity**

Scope

The test is intended to measure the porosity, dry density, saturated density and grain density of a rock sample as regular geometry or irregular lumps.

Procedure

Saturated moisture content, effective porosity, dry density, saturated density and grain density were determined using the standard buoyancy method described in Anon. (1981) and Ross and Butlin (1989). The sample used were cylinders with a nominal diameter of 50 mm and length of approximately 39 to 54 mm. The samples were saturated under a vacuum of 6 Torr or better with de-aired, distilled water for at least 1 hour. The samples were allowed to equilibrate to room temperature, about 20°C. The saturated samples, were weighed, in turn, under distilled water at 20°C, that is, the saturated/submerged weight (W_{sub}) and then surface dried with a damp cloth and weighed in air (W_{sat}). They were then placed into a fan oven at 105-110°C for 24 hours and allowed to cool to room temperature

in a desiccator containing dry self indicating silica gel and weighed (W_{dry}). The mass was determined on a digital balance having an accuracy of 0.01 g. The calculations are as follows:

$$\text{Dry density, } Y_d = W_{dry} / (W_{sat} - W_{sub}) \quad \text{Mg/m}^3 \quad (1)$$

$$\text{Saturated density, } Y_{sat} = W_{sat} / (W_{sat} - W_{sub}) \quad \text{Mg/m}^3 \quad (2)$$

$$\text{Grain density, } Y_g = W_{dry} / (W_{dry} - W_{sub}) \quad \text{Mg/m}^3 \quad (3)$$

$$\text{Effective porosity.} = 100 * (Y_{sat} - Y_d) \quad \% \quad (4)$$

The results are presented in Table 1.

3.2 Water absorption and saturation coefficient

Water absorption was carried out before the density and porosity tests and saturation coefficient after.

Water absorption (ASTM C97-90)

The samples were placed in an oven at $60^\circ\text{C} + 2^\circ\text{C}$ for 48 hours and then allowed to cool in a desiccator and then weighed. They were then soaked in distilled water for forty eight hours at room temperature ($2^\circ\text{C} \pm 2^\circ\text{C}$) for forty eight hours, surface dried with a damp cloth and reweighed.

Calculation

$$\text{Water Absorption } \% = [(B-A)/A] \quad (5)$$

Where: A is the weight of the dried sample

B is the weight of the soaked sample

Saturation coefficient

After the density and porosity test the cooled and weighed (W_{dry}) the sample is soaked in distilled wafer for 24 hours, surface dried and reweighed (W_{soaked}). The saturation coefficient was determined following the procedures described by the Building Research Establishment (Ross and Butlin. 1989).

Results

$$\text{Saturation coefficient } S = (W_{\text{soaked}} - W_{\text{dry}}) / (W_{\text{sat}} - W_{\text{dry}}) \quad (6)$$

The results are presented in Table 1.

3.3 Compressive strength

Method

The test technique was based on that described in Anon. (1995b), test C 170-90. A cylindrical core sample, of nominal diameter of 54 mm, was drilled from the block sample. A sub-sample was cut and the ends surface ground so they were flat and parallel to within 20 am. The test sample length was nominally the same as the diameter. The samples were weighed and measured and then placed in distilled water for forty-eight hours. A 2000-kN compression machine was set up for the size of the specimen used. Both platens had a Rockwell hardness of not less than HRC58. The lower platen included a spherical seat. The spherical seat was lubricated with oil. The specimen, platens and spherical seating were accurately centred. The loading rate during the test did not exceed 690 kPa/sec.

Results

$$\text{Compressive strength } \sigma_c = W / (1000 \times A) \quad \text{MPa} \quad (6)$$

where W is the maximum load (kN).

A is the area of the load bearing surface of the sample (m²).

The results are presented in Table 2 with units of MPa.

3.4 Acid Immersion

The acid immersion test as described by BRE (see Ross and Butlin, 1989) was carried out on approximately 50 mm x 50 mm x 15 mm tiles, in 20% sulphuric acid at 22 to 25°C for 10 days; four test specimens per block. After 10 days any changes in the integrity of the cubes was described. The results are in Appendix 1.

4. Results

The results are presented in Tables 1 and 2.

5. Reference

Anon. 198 1a. Rock characterisation, testing and monitoring. I.S.R.M. suggested methods. Editor E.T. Brown. Pergamon Press, Oxford.

Anon. 1995b. Annual Book of ASTM Standards, section 4: Construction, volume 04.08 Soil and Rock; Building Stones. American Society for Testing and Material, Philadelphia, USA.

Ross, K.D. and Butlin, R.N. (1989). Durability tests for building stone. Building Research Establishment Report number 141. Building Research Establishment, Garston, Watford.

Appendix 1. Acid Immersion Results

All specimens passed the test with no significant surface degradation. Samples 3A –D exhibited very slight surface reactivity causing blurring of the sample number not see on samples 1A-D or 2 A-D, however, no surface damage could be seen.

Acid Immersion Testing : Swinton Stone

Methodology

Testing was undertaken in accordance with the method described in Building Research Establishment publication 'Durability tests for building stone' 1989. Twelve test specimens measuring 50 mm x 50 mm x 15 mm were prepared and air dried for 24 hours to ensure complete dryness prior to testing. Each specimen was then immersed in a 20% solution of sulphuric acid (at $22^{\circ}\text{C} \pm 2^{\circ}\text{C}$) for 10 days \pm 30 min.

Results

All specimens were found to have passed the test with no significant surface degradation (Samples 1A to 1D and samples 2A to 2D). Samples labelled 3A to 3D did exhibit **very** slight reactivity causing blurring of sample numbers, however visually the surface was undamaged.

Mark A. Allen.

BGS Sample Preparation and Testing Facility Supervisor

7 June 2000

Table 1. Density, porosity and saturation coefficient results

| Sample | Weight, g | | | | | | Densities, Mg/m ³ | | | Effective porosity % | Water Absorption % | Saturation Coefficient |
|------------|------------------|-------------|-------------------------|-----------------|-------------------|----------------|------------------------------|-----------|-------|----------------------|--------------------|------------------------|
| | Oven Dry 105 C A | Saturated B | Saturated under water C | Oven dry 60 C D | Soaked 48 hours E | Soaked 24hrs F | Dry | Saturated | Grain | | | |
| EGLLJ45/1E | 261.36 | 288.18 | 162.37 | 261.63 | 279.36 | 278.44 | 2.077 | 2.291 | 2.640 | 21.3 | 6.8 | 0.64 |
| EGLLJ45/2E | 263.81 | 290.93 | 163.95 | 264.00 | 281.98 | 281.55 | 2.078 | 2.291 | 2.642 | 21.4 | 6.8 | 0.65 |
| EGLLJ45/3E | 256.74 | 284.80 | 159.58 | 256.95 | 275.00 | 274.89 | 2.050 | 2.274 | 2.642 | 22.4 | 7.0 | 0.65 |

Calculations

Dry density = A/(B-C) Saturated density = B/(B-C) Grain density = A/(A-C)

Effective porosity = 100% x (Saturated density - Dry Density)

ASTM Water absorption = 100% x (E - D) / D

BRE Saturation coefficient = (F - A)/(B - A)

Table 2. Compressive strength results

| Sample | Dimensions, mm | | | | Compressive Strength MPa | Approximate test moisture content % |
|------------|----------------|----------|--------------------|----------------------|--------------------------|-------------------------------------|
| | Length | Diameter | Load at Failure kN | Time to Failure secs | | |
| EGLLJ45/1E | 54.13 | 54.77 | 82.64 | 61 | 35.1 | 6.9 |
| EGLLJ45/2E | 54.14 | 54.77 | 83.12 | 60 | 35.3 | 6.9 |
| EGLLJ45/3E | 54.18 | 54.77 | 74.68 | 52 | 31.7 | 7.1 |

Compressive strength samples were soaked for 48 hours in distilled water before testing.