SUGGESTED METHOD FOR PROGRESSIVE SATURATION OF ROCK SAMPLES

1. Scope and Background

1.1 This recommended method outlines procedures for the process of progressive saturation of rock core and other specimens to promote the filling of interconnected pore spaces in the rock fabric structure. Where "saturated" is used herein to indicate the condition of samples after the progressive saturation process, the term appears in quotes so that it may not be construed to indicate a complete saturation (filling of all voids), although that may have been achieved.

1.2 The validity of the method described below was demonstrated in the rock testing program of the Corps' Dredging Research Program (DRP) 1988-1994. The method was subsequently used with expected results at Ohio River Division (ORD) Laboratory, where a variation of this method will become part of their standard procedures.

1.3 As a part of the rock dredging research of the DRP, a comparative testing program was conducted to develop the use of the point load test for weak/saturated rock typical of many dredging applications. The Point Load and Unconfined Compressive Strength (PLUCS) Database System (Smith, 1994) was developed to obtain point load to unconfined compressive strength comparisons, and wet to dry rock strength ratios for a given rock description and/or site. The PLUCS contains results from 334 "saturated" rock specimens of various sedimentary rock types which were destructively tested. All these samples were progressively "saturated" using the proposed method and none showed evidence of nonuniform saturation along the exposed planes of failure. However, in a comparison of saturation methods, rock cores taken from the same uniform blocks of Berea sandstone and Indiana limestone were "saturated" using the emersion method. Oven-dried core was covered with a minimum of ten inches of water for three weeks and then broken. Visual examination clearly implied an incomplete saturation as it showed nonuniform wetting as evidenced by a lighter coloration of the rock toward the inside of the core.

2. Need for Saturation Method

2.1 With few exceptions, in situ rock is fully saturated or at least has a high water content (Broch, 1974). In spite of this natural condition, laboratory testing is often done on either oven-dried or ambient humidity dry specimens. Strengths of rock decrease with increasing moisture content. Most of this change occurs between the oven-dried condition and a stabilized water content at 50% relative humidity. Rock strengths at 98% relative humidity and a stabilized water content closely approximate the "submerged in water" condition. An important application of this observation is that materials that change, if emersed, may be tested with consistent saturated condition results (Colback and Wild, 1965). A study of 35 sandstones (Hawkins and McConnell, 1992) indicated that most rocks in their natural state will have a moisture content of more than 1%, and that there is a negligible loss of strength as moisture content is increased to saturation. Therefore, rocks should be tested in the saturated condition as standard procedure—assuming the intent of testing is to assess in situ conditions. Strength changes induced by moisture changes vary with the rock under observation. Based on oven drying, the PLUCS database indicates a loss of strength as great as 36% when

Encl 1

"saturated" (for Dardanelle sandstone), but greater changes can be expected for other rocks such as some shales and siltstones.

2.2 Uniformity of water content is important and especially so if regions of low moisture content can be present in a sample, as in the case of the emersion method where a volume of air can become trapped in the center of the sample. Several other methods are used, each requiring more elaborate equipment. Most of these involve oven drying, cooling under controlled conditions, evacuation of air using a special cell followed by adding water slowly under low pressure. For some tests, such an operation can be done in the triaxial cell prior to testing of the sample, or a special saturation apparatus is sometimes available. Even though such procedures are time consuming and expensive, at times nonuniform saturation results.

3. Outline of Saturation Method

3.1 **Apparatus** - Flat bottomed container(s) of sufficient depth to cover samples with water. If samples have ground flat bottom surfaces, the container should have an irregular bottom surface. A coarse wire mesh under the samples can serve this purpose.

3.2 **Procedure** - Samples should be oven dried (50° to 75°C) and allowed to cool to room temperature. In very humid regions, humidity should be controlled to be less than 50%; humidity control as provided by air conditioning for human comfort is usually sufficient. Saturation should begin as soon as cooling is accomplished, unless special means for storage are used such as a desiccator. Samples should be placed in containers in a stable position and water added to wet bottom of the samples to less than 1-cm depth. Samples may initially absorb enough water, through wicking or capillary action, that additional water should be added to maintain a wetted bottom surface. Depth of water added should not exceed the original water depth. With passage of time the outside wetted surface of the sample will extend upward. At the end of a chosen time cycle, add water to cover no more than half the increased wetted surface, at its lowest point. Although the time cycle is usually one day, the cycle chosen may vary; for example, a shorter time may be used if samples are very porous as indicated by rapid wicking of water and a large stabilized wetted surface area. At the end of each of the next successive time cycles repeat this process until the meniscus reaches the top edge of the sample and the top surface is wetted by capillary action. After an additional time cycle, the sample can be inundated and kept in that condition until just before testing.

3.3 The speed at which the rock is wetted varies with rock fabric and porosity. Therefore, a time based progressive saturation, such as adding a predetermined amount of water each day to achieve inundation within a given time, is not recommended. However, the time reasonably required should be indicated by the wetting of the outer surface.

4. Special Observations, Monitoring

4.1 Planes of bedding that are not evident by examination of dry or wet samples can sometimes be observed during progressive saturation; this and other nonuniformities evidenced by differences in capillary action should be carefully noted. Immediately after destructive testing, samples "saturated" by this method, as well as by other methods, should be monitored for evidence of nonuniform wetting by examination of the exposed planes of failure. If nonuniformity is observed, resaturation of untested samples using a longer time cycle should be done, or other methods of saturation should be tried.

5. Points for Consideration

5.1 Oven drying allows all samples to start saturation from a uniform condition and may in the case of this method enhance capillary action. However, no scientific demonstration or analysis has been performed to prove the necessity of oven drying. Rather, the instruction outlined above is based on the common practice of drying before saturation and the practices used in the comparative testing program of the DRP which resulted in several hundred successfully "saturated" samples, as indicated above.

5.2 Similarly, humidity control may not be required. However, the benefits of oven drying could be partially lost if samples are cooled at high relative humidity.

5.3 Under most conditions, beddings and fractures should be oriented nonparallel to the water surface, as air in cracks and voids would more likely become trapped in a horizontal geometry. To date, no special study has been done to show the relative benefits of orientation.

5.4 Further testing and observations designed for the purpose of addressing these issues are needed for their resolution.

6. References

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6.3 Hawkins, A. B. and McConnell, B. J. 1992. "Sensitivity of Sandstone Strength and Deformability to Changes in Moisture Content," Quarterly Journal of Engineering Geology, Vol. 25, p. 115-130. The Geological Society.

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