CREEP OF WELDED TUFF AT 150 ºC

ABSTRACT: Creep experiments were performed on welded tuff specimens collected near Yucca Mountain, NV. The tests were performed at differential stresses of between 115 and 141 MPa, a confining pressure of 5.0 MPa, a pore pressure of 4.5 MPa, and a temperature of 150 ºC. All of the specimens tested showed primary and secondary stages of creep. The secondary creep strain increased as the differential stress was increased. The specimens that failed exhibited a tertiary creep stage. The specimens brought to failure were analyzed in terms of static fatigue. Tests were terminated for specimens that did not fail after 10^6 seconds.

INTRODUCTION

The applicability of laboratory data for engineering and modeling purposes is a prime concern for the design and licensing of the potential nuclear waste repository at Yucca Mountain, NV. Emplacement of containers containing radioactive waste will generate heat. The repository has a 10,000 year design life and may experience temperatures as high as 200 ºC. Performance assessment requires data on the long-term strength of the tuff at in situ conditions. To support these needs creep experiments on welded tuff were performed.

The welded tuff is composed of shards, pumice, and matrix. Pumice is the major constituent; it occurs as elongated fragments compacted and flattened during welding. The porosity of the specimens studied range between 8.7 and 11.5%.

EXPERIMENTAL PROCEDURE

The creep tests are conducted in a servo-hydraulic system with independent controls for the (1) axial force, (2) confining pressure, (3) pore pressure, and (4) temperature. The pressure vessel is divided into two chambers separated with a moveable piston (a schematic is shown). The specimen resides in the low-pressure chamber. This chamber exerts confining pressure on the specimen. The higher pressure, in the upper chamber, moves the piston in contact with the sample assembly to develop a differential stress.

The furnace consists of three independent band heaters positioned on the outside of the pressure vessel to produce a uniform temperature distribution in the specimen. A thermocouple inside the pressure vessel monitors the temperature at the midpoint of the specimen.

Axial strain is measured with an external displacement transducer (LVDT). The displacement of the piston is measured with respect to the closure plug for the high-pressure chamber of the pressure vessel. The strain resolution using the external LVDT is $4 \text{ x } 10^{-6}$.

The specimens are jacketed with two layers of 0.13 mm thick dead soft copper and Teflon. The sample assembly is inserted into the pressure vessel and the pressure and temperature conditions established. The differential stress on the sample assembly is rapidly increased to its pre-selected value. Loading of the specimen is completed in less then ten seconds. The output of each of the transducers is monitored continuously until the sample fails or the experiment is terminated.

RESULTS

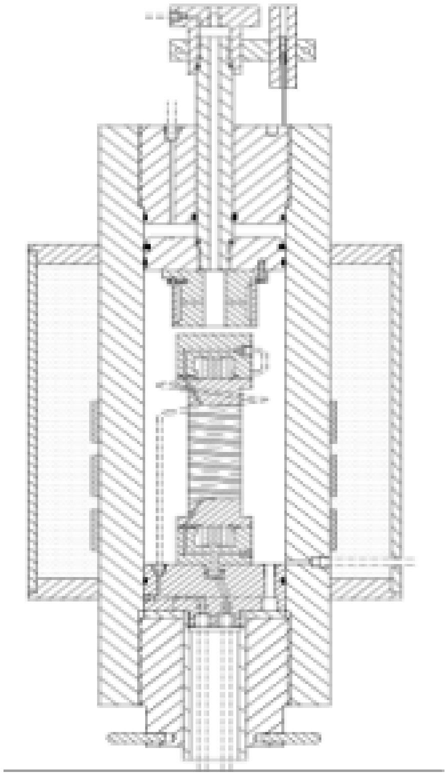
Typical data sets for the creep measurements are shown. All of the specimens tested showed a similar behavior. There is a pronounced transient primary creep followed by a continuous decrease in the rate of strain accumulation (secondary creep). For the specimens that failed, tertiary creep is observed. For the specimens that did not fail, the rate of strain accumulation during secondary creep was low.

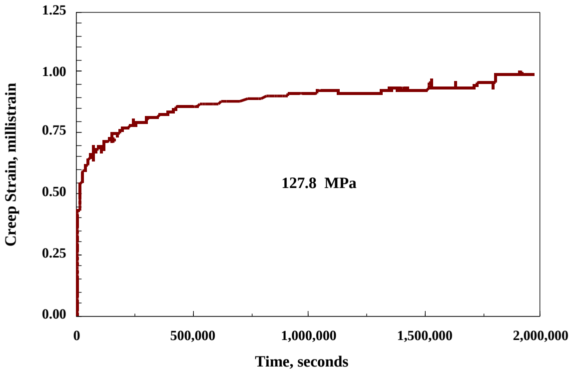
For the tuff, the strain at failure is extremely small (typically less than 0.5%) and varies by as much as a factor of two on nearly identical specimens. Furthermore, the creep strain accumulation is not linear with time. This makes estimation of the time to failure difficult to predict from strain rate data. For this reason, time dependent failure of brittle rocks is often treated in terms of static fatigue. That is, the time to failure is considered a function of the applied stress. In this way, an estimate of the long-term strength of the rocks and a measure of its uncertainty can be achieved without specific reference to the associated strain.

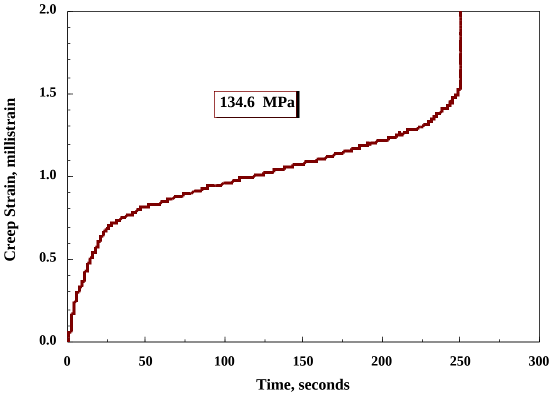
The time to failure for each specimen is plotted as a function of differential stress (solid symbols). The specimens that did not fail are also included (open symbols). Small decreases in differential stress produce large increases in the time to failure. For example, a specimen tested at 134 MPa failed in several hundred seconds. At a differential stress of 128.7, the time to failure exceeded several million seconds. A curve was fitted for specimens that failed in creep. The time to failure, t, is given by:

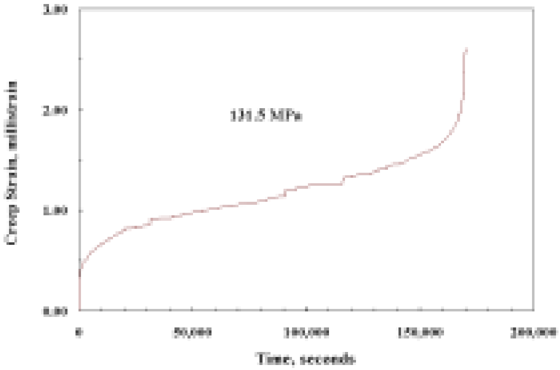
$$t = 9 \text{ x } 10^{58} e^{-0.958}$$

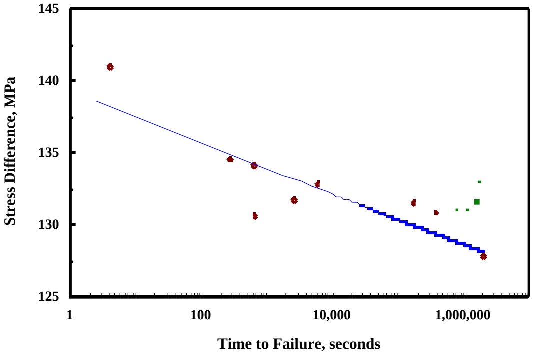
where, σ is the differential stress.




Creep Strain, millistrain
1.25
1.00
0.75
0.50
0.25
0.00
127.8 MPa
0
500,000
1,000,000
1,500,000
2,000,000
Time, seconds


Creep Strain, millistrain
2.0
1.5
1.0
0.5
0.0
134.6 MPa
0
50
100
150
200
250
300
Time, seconds


Creep Strain, millistrain
3.00
2.00
1.00
0.00
131.5 MPa
0
50,000
100,000
150,000
200,000
Time, seconds


Stress Difference, MPa
145
140
135
130
125
1
100
10,000
1,000,000
Time to Failure, seconds