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# CREEP TESTS ON CLAY MASONRY PRISMS: APPARATUS AND SOME INITIAL RESULTS

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## ABSTRACT

The apparatus for a comprehensive set of creep tests on clay masonry prisms is described. The apparatus was designed to be self-sufficient should components fail in that the tests are intended to last for a minimum of fifteen years. Three series of tests have been begun examining the effect of the following variables on creep: unit, mortar, stress, moisture condition, and age at loading. The moisture condition of the unit when laid and the temperature during the test period were not investigated. Preliminary assessment of the data reveals that creep in clay masonry occurs for at least 2500 days: and creep varies with both moisture condition and age at loading. Analysis through the use of specific creep for a specific mortar/unit combination may not be possible.

## INTRODUCTION

Masonry construction has changed significantly during the twentieth century. Thick low-stressed walls have given way to other construction techniques. The changes in economics and the introduction of concrete blockwork have almost caused the demise of load-bearing brickwork. Brickwork is now mainly used for decorative purposes as veneer, or in low-rise housing: its load-bearing capabilities being heavily under-utilized or ignored.

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However, well-constructed brickwork can still form an economic load-bearing material especially when durability and the fact that brickwork is its own form-work and cladding are taken into consideration in the construction process. Indeed, construction costs and building life-cycle costs can be very competitive with other construction techniques. These facts, together with the recent innovations of fin and diaphragm walls (Curtin et al., 1982) and post-tensioning techniques [illegible] the potential for [illegible] These newer construction methods [illegible] with thick-walled construction. [illegible] compared to earlier construction. [illegible] will be compounded by the increase in cementitious material in clay [illegible] has also occurred in the last century.

Creep has two effects in structures [illegible] internal stresses and loads can be reduced [illegible] to the structure depending on the [illegible] increase. In composite construction [illegible] deformations be understood, calculated and [illegible] The deformations are not small: Lenczner (1986) observed [illegible] strain) of about 3 in a load-bearing wall in a tower block [illegible] years. The two effects of creep, either singly or together, can also cause strength reduction [illegible] failure of a structure. Shrive and Huizer (1991) postulated that creep was involved in the collapse of the medieval civic tower of Pavia. Binda et al. (1992) came to the same conclusion after a thorough assessment. Indeed subsequent tests by Papa et al. (1994) showed that loading masonry to 80% of the peak stress observed in a monotonic strength test, and holding that load, could lead to failure of the masonry in 3 hours or less.

While creep is clearly an important phenomenon, codes of practice provide little direction with respect to the magnitudes which may be expected. This is not surprising since there is a paucity of experimental data from which to draw conclusions. While creep appears to be a linear function of stress in light weight concrete blockwork within the stress range of 0.2-0.4 of ultimate strength examined (Ameny et al., 1980), a similar conclusion can not be drawn for brickwork. Tests have been performed on clay and calcium silicate brickwork specimens of various shapes and sizes subject to various stress levels (Lenczner et al., 1975, 1976, 1979; Warren and Lenczner, 1982; Brooks, 1986a; Brooks et al., 1986, 1990, 1994). Warren and Lenczner (1981) showed that the creep strain depends on whether the bricks are laid wet or dry. Predictions of creep based on specific creep appear variable in all reports.

Creep in concrete is known to depend on stress, temperature, humidity and age at loading (Ghali and Favre, 1994). The same factors can be expected to affect creep in masonry. Blockwork is mainly concrete, and mortars contain many of the same cementitious constituents as concrete. 10 mm joints in highly-stressed brickwork can be expected to give larger creep deformations than the thin lightly-stressed lime mortar joints in the stonework of old. However, there has been no systematic evaluation of the above

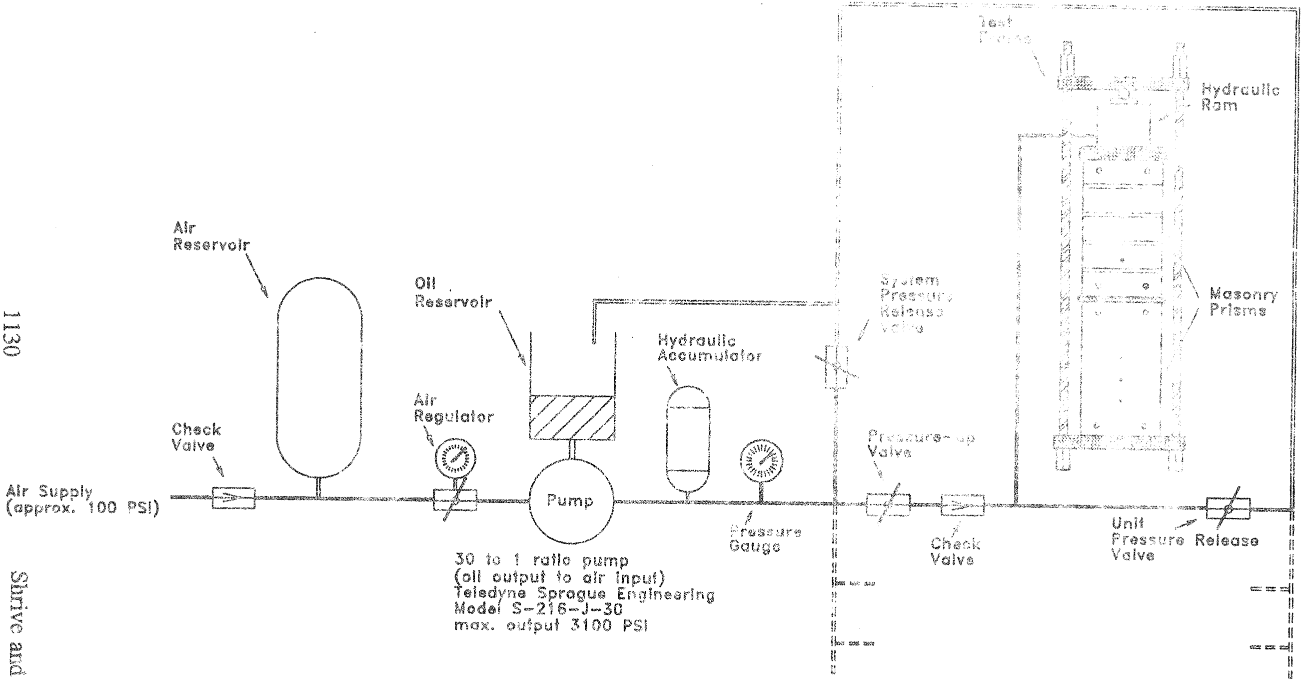

Fig. 1. Schematic of Loading Apparatus

environmental factors on the creep of brickwork. We have therefore begun tests to evaluate the effects of stress, moisture condition and age of loading. Since tests to date have typically been short-term (100-200 days with a few out to 400 days), the tests were aimed at the long term with the longest tests now being over 2500 days.

## APPARATUS

A schematic of the loading system is shown in Fig. 1. A major objective in the design was to be able to isolate individual test frames should any component fail or the frames need moving. The laboratory pressurized air supply is the primary source of energy for loading. This supply is used to pressure an air reservoir through a check valve. Should the laboratory air supply be shut down, the check valve will close and the reservoir can keep the system loaded temporarily. The air is used to pressurize a 30:1 pump through a regulator valve. The regulator is adjusted so that oil on the high pressure side of the pump is at 17.2 MPa (2500 psi). The accumulator reduces the cycling effect (pressure reduction) of the oil during the pump cycle.

The test frames are arranged in parallel, with only one being shown in Fig. 1. High pressure oil lines are shown in solid black, whilst return lines are open. Each frame can be pressurized by opening its pressure-up valve. Should the system oil pressure reduce, the check valve will maintain pressure in that frame. Each frame can be isolated by closing its pressure-up valve. Closing this valve and opening the pressure release valve means that individual frames can be unloaded should the need arise. Different loads are obtained in different frames by having different sized hydraulic rams in the test frames.

A schematic of a test frame is shown in Fig. 2. The prisms to be tested were five-high clay masonry prisms. Two prisms are held between steel plates with full contact between prism and plate being achieved through a thin layer of plaster of paris (not shown). The hydraulic loading ram lies between the upper "platen" and the frame: the ball joint accommodates small out-of-plane alignments, whilst also ensuring that load is applied axially. The tension side of the self contained frame is made up of four Dywidag bars.

Strain is measured via the Demec system (Morice and Base, 1953). Two gauge lengths are employed, 250 mm and 50 mm. The 250 mm lengths provide measures of brickwork strain, covering four units and four joints. The 50 mm gauge lengths are used to measure strain on the central unit of the prism, and across the single joint and unit below. The intent was to estimate the relative contribution of the two components to the brickwork strain. Series of control (unloaded) prisms are used to account for strains induced by environmental changes in the laboratory (temperature, humidity). The laboratory temperature control keeps the temperature typically in the region 21 ∓ 2°C but humidity can vary with season. For most of the year, the relative humidity is about 20%.

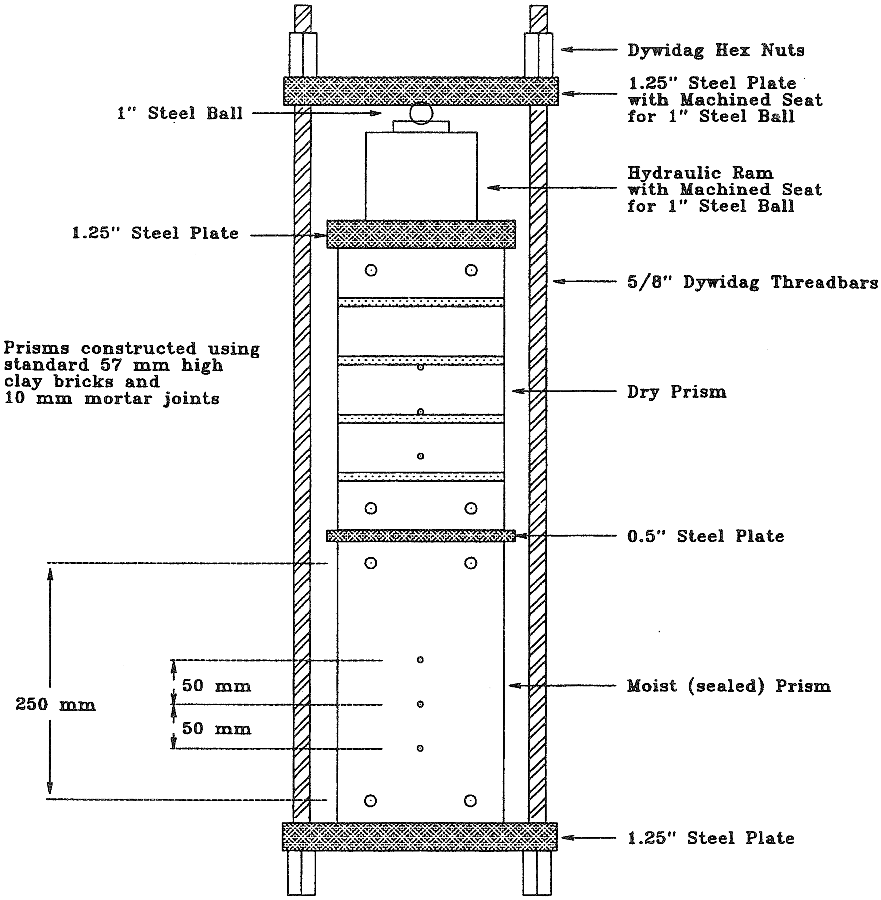

Fig. 2. Schematic of a Single Test Frame containing two Test Prisms

## MASONRY TEST SERIES

Three series of tests have been initiated. The variation of parameters in each series is shown in Table 1. The properties of the units are shown in Table 2. The cross-sections of the units are shown in Fig. 3, with the extrusion, cutting and firing processes not leaving the dimensions uniform. The corners of the square holes were slightly rounded. Series 2 and 3 units were 10-core extruded units.

Table 1. Variation of Parameters in the three Series of Tests

| Series | Mortar Type | Gross (Net) Area Stress Levels (MPa) | Moisture Conditions | Ages at Loading (days) |
|---|---|---|---|---|
| 1 | N | 2.43(3.0), 4.86(6.0) | wet and dry | 7, 14, 28 |
| 2 | N<br>N<br>S | 2.43(3.0), 4.86(6.0)<br>2.43(3.0)<br>2.43(3.0) | wet and dry<br>wet and dry<br>wet and dry | 7, 14<br>28<br>7, 14, 28 |
| 3 | N and S | 1.21(1.5), 3.64(4.5), 4.86(6.0) | wet and dry | 28 |

Table 2. Properties of Units (mean ∓ std. dev. with n = 5 for all groups)

| Series | Absorption (%) | IRA (ASTM C 67 1990) (grm/30 $\text{in}^2$/ min) | Net Area ($\text{m}^2$) | Net area single unit strength (MPa) |
|---|---|---|---|---|
| 1 | 9.10∓0.13 | 34.5∓3.1 | 0.0133 | 79∓12 |
| 2 | 7.06∓0.19 | 21.8∓0.6 | 0.0140 | 95∓6 |
| 3 | 6.35∓0.67 | 5.6∓1.6 | 0.0140 | 109∓4 |

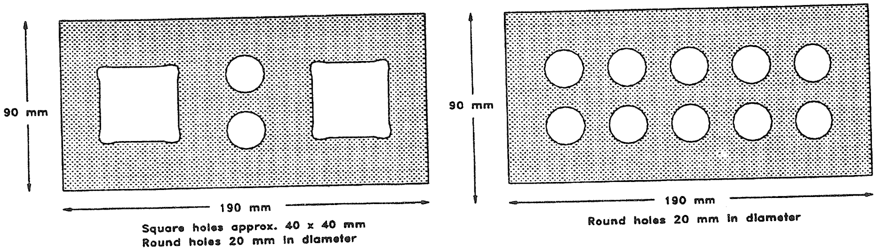

Fig. 3. Cross-section of Series 1 (left) and Series 2 and 3 Units (right)

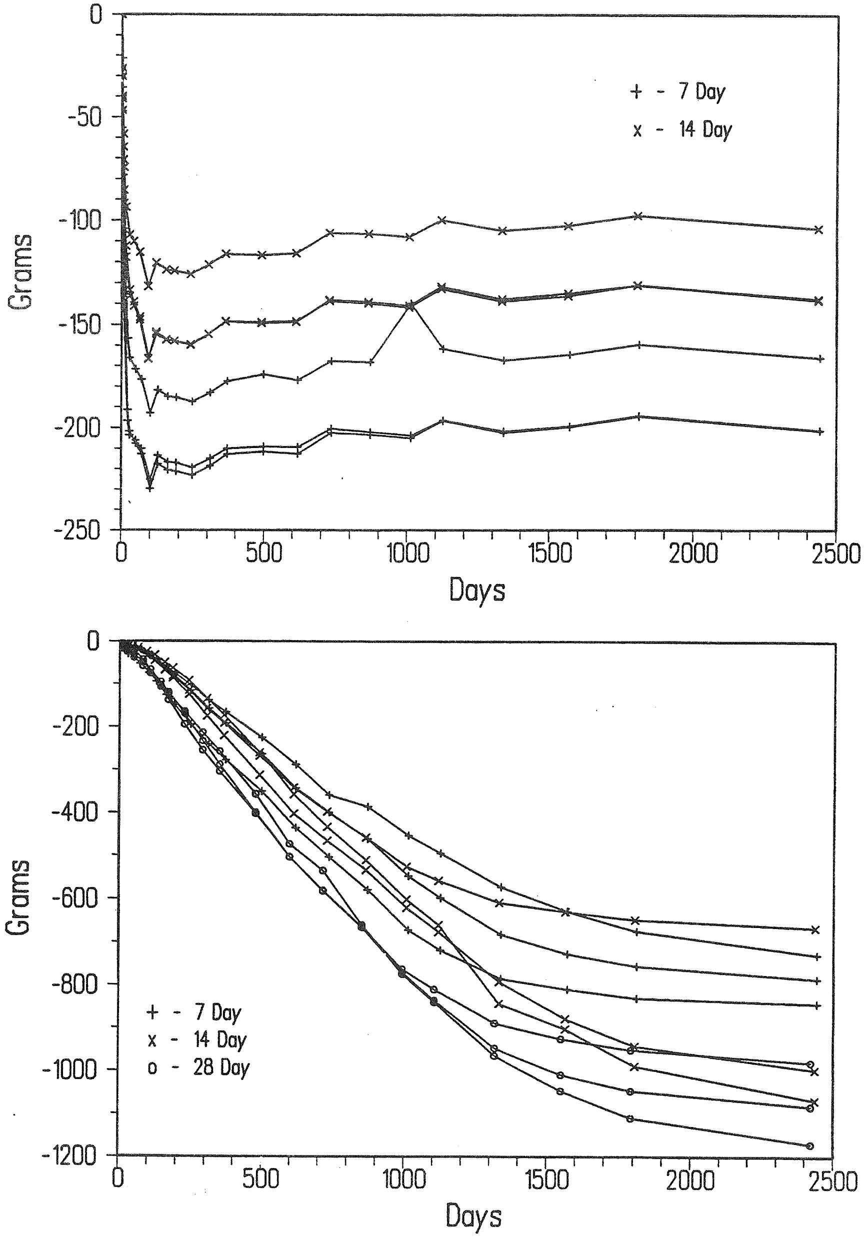

Fig. 4. Weight Loss in Series 1 Control Specimens: Dry above, wet below

In Series 1, pre-bagged Type N mortar (1:1:6 PC:lime:sand) was used, unfortunately batched by weight rather than by volume, while in Series 2 and 3 both Type N and Type S (1:½:4½ PC:lime:sand) were used, again pre-bagged with proportions by weight rather than volume. Hence, mortar cube strengths were a little below those required of laboratory prepared mortars (5.0 MPa) in CSA 179-94 but above the values for site prepared mortars (3.5 MPa). For the twelve batches of mortar used in Series 1, the strengths were 4.4∓0.7 MPa, n=36, for cubes kept in laboratory air: and 3.5∓0.5 MPa, n=72, for cubes kept in the fog room.

The major comparisons in Series 1 are moisture condition and age at loading. The two stress levels were expected to give some indication of the potential of specific creep (creep strain per unit stress) being applicable to masonry. Gross area stresses of 2.43 and 4.86 MPa correspond to the 3.0 and 6.0 MPa net area stresses respectively. The 28 day gross area compressive strengths of 5-high prisms were 11.0∓1.7 MPa (n=5) for laboratory air prisms and 8.6∓1.6 MPa (n=5) for prisms kept in the fog room. Series 2 compares to Series 1 through similar tests but with a different unit. In Series 2 some Type S mortar prisms were introduced to begin assessment of mortar type. In Series 3, mortar type and stress level were the prime variables but again at stress levels and a loading age which would allow comparison of the effect of the third unit with the other two.

Three creep replicates were tested in each condition, with three control specimens.

## EXPERIMENTAL PROCEDURES AND DIFFICULTIES

The "wet" specimens were placed in the fog room (21°C with 100% RH) immediately after construction. In the Series 1 tests, just before loading, specimens were removed, surrounded in bituthene and then had Demec points glued on. The prisms were then placed on the platens on a thin layer of plaster, and sealed to the platens with a silicone sealant. The holes created for access to the Demec points were also sealed with the sealant. Specimens were placed with their dry counterparts in the test frames, Demec readings taken, the load applied and readings taken again. Readings have been taken at various times subsequently.

Control specimens were not only measured for strain variation, but were also weighed at each measuring time. This revealed a steady weight loss in the wet specimens, indicating loss of moisture (Fig. 4). The dry specimens which had been exposed to laboratory air showed weight losses ranging between 100 and 200 grams, substantially less loss than the wet specimens. In Series 2 and 3 therefore, attempts have been made to supply water to the wet specimens to maintain a saturated condition. Initially a constant head was supplied through a plastic tube, but continual problems with leakage rendered this method impractical. Water is now supplied on an intermittent basis - the plastic tubes are filled at regular intervals and then sealed. This avoids continuous pressure on the seals around Demec points and at the bituthene/platen interface. Thus,

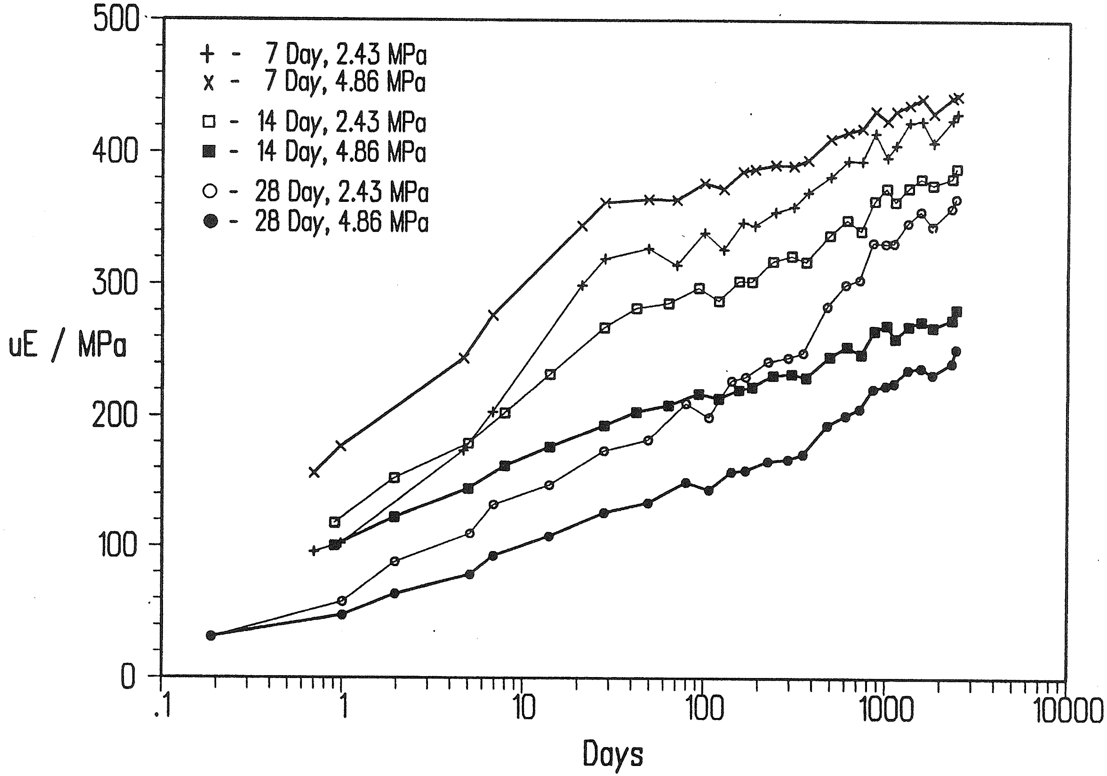

Fig. 5. Specific Creep (creep strain per unit stress) in Series 1 Dry Prisms (averages of 3 specimens in each set)

while Series 1 wet specimens have been slowly drying out, Series 2 and 3 specimens have been kept in a substantially more moist condition.

The repeated weighing has had its toll in handling, in that some specimens have cracked, and thus become non-functional for strain measuring purposes.

## INITIAL RESULTS

A typical set of results to date is shown in Fig. 5. Here specific creep is plotted against time for the Series 1 dry specimens loaded at three different ages. Three points are clear from these data:

(i) Prisms loaded 7 days after construction creep more than those left 14 days which in turn creep more than those loaded 28 days after construction.

(ii) Specific creep may not be a viable method of defining creep in that the specific creep results for the two stress levels show some differences (up to 40%).

(iii) Creep has occurred over the whole 2500 days, although there is a hint that creep may now be levelling off.

Comparisons with results from other sets of data (not presented here) indicate that, as with concrete, dry specimens creep more than wet ones, and that brick and mortar types do affect the amount of creep. These factors all need further evaluation before mechanisms can be proposed.

## CONCLUSIONS

Creep in clay masonry occurs over a considerable time period, for much longer than previous tests have been run. Preliminary assessment of the results indicates that creep in clay masonry is affected by moisture condition, mortar type, unit properties, age at loading and stress. It may be possible to model creep as a linear function of stress, as suggested by Wyatt et al. (1975) and Brooks (1986 b). The effects of temperature and moisture content of the brick at time of laying were not investigated.

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