# INFLUENCE OF UNIT WATER ABSORPTION ON DEFORMATION OF MASONRY

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**ABSTRACT**

Water absorption and initial rate of suction tests for each type of unit were carried out and several tests were conducted with 5-stack units: clay, calcium silicate bricks and concrete block, to study the effect of unit water absorption. The 5-stack units were built in the controlled environment room and cured under polythene sheet for 14 days before loading. Creep and shrinkage were measured for 100 days after loading. It was found that the unit water absorption causes a reduction of the water/cement which lead to poor quality of mortar thus effecting deformation of masonry. In addition, the amount of water present in the mortar joint at the time of loading is an important influence on the creep potential in the masonry as well as the degree of hydration.

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## INTRODUCTION

Bricks often absorb water from the fresh mortar when they are laid dry. If the rate of water absorption is high, it may effect the hydration of mortar and result in poor bonding between bricks and mortar. The suction exerted by the units is an important factor affecting the fresh mortar, and consequently the properties of mortar joint. The suction depends upon the unit water absorption and the ability of unit to remove water from mortar which is measured by initial rate of absorption test. Apart from affecting hydration of mortar due to capillary action of the units, strength of mortar is reduced and possibly contains more unhydrated cement. In the effect of deformation, it could be expected that creep and shrinkage might be less due to less water in the mortar absorbed by the unit, and unhydrated cement which restrains the hydrated paste movement. Moreover, the water absorbed by the units would not appreciably affect the shrinkage of the unit because it is in the form of free water which merely affects reversible shrinkage; this type of reversible shrinkage is small compared to the irreversible shrinkage caused by the loss of absorbed water. On the other hand, elastic strain of the mortar and hence masonry could be greater because the cement gel structure is more porous and can be more easily compressed under the applied load. Tapsir [1] found that the prediction of long-term deformation of masonry using composite models [2] were rather poor estimates, particularly for the calcium silicate and concrete block masonry; these units had high water absorptions. In conclusion, the composite model is only valid if the units are docked first before laying. For masonry laid dry, the shrinkage of the unbonded mortar prism used for predicting the shrinkage of the masonry, has to be reduced, and the amount of that reduction can be as much as 80% for units with high water absorption characteristics. This situation also applies to creep. It should be noted that BS 5628: Part 3 (1985) recommends that masonry units having initial suction rate greater than 1.5 Kg/(mm$^2$.min) should be docked first before laying. Forth[3] observed the influence of unit water absorption on deformation of masonry wall constructed with Armitage class 'B' brick units. He compared the movement of mortar joint in the masonry deduced from measurement with the unbonded mortar prisms and found that shrinkage of mortar was 25% less than the shrinkage exhibited by an unbonded mortar prism at 160 days. This phenomenon was thought attributed to a reduction in water content of the mortar joint caused by the unit water absorption. Moreover, the effect of the unit water absorption was to reduce creep of the mortar joint by 5%. It was suggested that the reduction factors could be made to the unbonded mortar prism deformations which could then be incorporated in the composite models.

## EFFECTS OF UNIT WATER ABSORPTION

Generally, the unit unit water absorption causes a reduction of the water/cement ratio which can lead to a poor quality of mortar. Since masonry consists of brick and mortar, the behavior resulting from the transfer of water from the mortar to the brick can be likened to that caused by absorption of water by the aggregate in concrete. Therefore, the modulus of elasticity is not only dependent on the properties of the mortar and the masonry unit but probably also on the effect of unit water absorption through an equivalent transition zone. The composite model [2] does not take this effect into account.

In order to understand the occurrence of water absorption in masonry, the absorption properties of aggregate in concrete may be useful to explain this phenomenon. The water absorption of aggregate affects the bond between the aggregate and the cement paste, consequently could influence the deformation of concrete. Much work has been carried out into the mechanism of the bond between masonry units and mortar. It was found under laboratory conditions that, when clay bricks are being used, the strength of the bond varies according to their water absorption properties. Thus for clay bricks, BS 5628 provides characteristic flexural strength values for various ranges of water absorption. This paper discusses on the deformation of small scale masonry structures caused by unit water absorption and consequently affecting the modulus of elasticity, creep and moisture movement.

## EXPERIMENTAL DETAILS

In this investigation, each type of masonry unit i.e. clay, calcium silicate and concrete block was used to built 5-stack masonry walls with a 1:1½:4½ mortar and tested in the controlled environment room for 100 days. The walls were built in pair i.e. one wall being subjected to load and the other being used as control wall and both were built with docked and undocked units. The walls were built in 3 days according to their type of unit i.e. one day for clay and the other days for calcium silicate and concrete block. For concrete block, it has been cut into the same size as the other type of brick to suit with same volume/surface ratio. After building, they were cured under the polythene sheet for 14 days and then loaded at 14 days. Before loaded, all walls were capped on the top surfaces with steel plates which were bedded and levelled using a 1:1 (cement:sand) mortar. For the controlled walls, the top surfaces were sealed with bitumastic paint and a water proof adhesive tape. The idea is to obtain the same volume/surface ratio between loaded and unloaded walls. Several days after building the walls, Demec gauge points were attached using Demec bar (150 mm) to the walls for measurement purposes as shown in Figure 1. The first strain reading of the walls was taken as a zero reading before applying the load at the age of 14 days. For the loaded walls, a stress of 1.5 $N/mm^2$ was applied at the same age by tensioning the four calibrated 18 mm diameter steel tie rods of the creep rigs. The time taken for applying the load was 1-10 min and the immediate movement was considered as a elastic movement. After that the subsequent movement was considered as the start of creep. Since relaxation of the load occurred due to creep and shrinkage of the masonry, the tie rods had to be re-tensioned frequently, particularly at the early stage of loading. The strain readings were taken for 100 days and creep was defined in usual manner, that is total time-dependent load strain less the initial elastic strain, and minus shrinkage or plus expansion as measured on the clay controlled walls. The compressive strength of mortar was obtained by testing 100 x100 x 100 mm cubes from each set of walls at the age of 7 and 14 days.

## MASONRY DEFORMATION

Table 1 shows Initial suction rate and standard water absorption which was tested according to BS 3921 (1985). It showed that concrete blocks exhibit the highest suction rate compared with the clay and calcium silicate units. In practice, the initial suction rate is used to measure surface porosity of the unit and that causes transportation of water from mortar to the unit by capillary action. Thus affecting the bond between the unit and the mortar. Table 2 shows the effect of docking the unit before building the masonry. For clay masonry with low unit water absorption, there is a little change in modulus of elasticity. However, for the calcium silicate masonry, which had high unit water absorption, there was a large increase in modulus for the docked unit. Creep of masonry may be not only dependent on the properties of the unbonded unit and the mortar but also on the effect of unit water absorption. In the previous investigations [1,4,5] it was found that the higher the water absorption of the unit the lower the creep potential of the mortar. However, in this investigation, there is a contradiction of creep of masonry built with the docked clay, calcium silicate and concrete units. For the docked clay brick as shown in Fig.2, the creep of masonry is lower than the creep of undocked unit after 14 days curing. The same behaviour occurs for the calcium silicate wall, but the docked concrete unit produces a greater creep of concrete masonry as shown in Figs. 3 and 4.

Comparison has been made on the shrinkage of the masonry built with and without docked units. Shrinkage of the clay wall occurred at an early ages followed by slow long-term moisture expansion at a later ages, there being little difference between the masonry built with docked and undocked units and cured for 14 days. For the calcium silicate and concrete of 5-stack units, shrinkage with the docked units was higher than for the 5-stack units built with undocked units. This phenomenon can be attributed to a reduction in the shrinkage potential of the mortar due to pre-shrinkage caused by water absorption of the dry units.

Table 1 Initial suction rate and standard water absorption

| Type of masonry unit | Initial suction rate test ($Kg/m^2/min$) | Standard water absorption test (% increase in mass) |
|---|---|---|
| Clay unit | 0.95 (0.13) | 3.52 (1.15) |
| Calcium silicate unit | 0.75 (0.05) | 14.18 (1.22) |
| Concrete block | 5.13 (1.06) | 9.08 (0.63) |

Table 2 Modulus of elasticity of masonry as affected by unit water absorption

| Type of masonry | Unit water absorption (%) | Modulus of elasticity (GPa) | |
|---|---|---|---|
| | | Undocked | Docked |
| Clay | 3.52 | 14.2 | 14.1 |
| Calcium silicate | 14.18 | 6.7 | 10.6 |
| Concrete | 9.08 | 13.0 | 13.5 |

## CONCLUSION

An investigation into the influence of unit water absorption of masonry built with theree different types of unit have led to the following conclusions:

i. The modulus of elasticity of 5-stack masonry built with docked and undocked unit was generally insignificant except for calcium silicate. However, further research is need to be carried out to verify the effect unit water absorption with different types of units.
ii. There was no consistent change in 100-day creep for the undocked unit of clay and calcium silicate 5-stack masonry except for concrete.
iii. As a result of using undocked unit, shrinkage was reduced compared to the docked unit.
iv. According to the above investigation, it is confirmed that there is an effect of unit water absorption on the overall deformation of masonry.
v. Other effects of unit water absorption should be investigated and quantified because this appear to be important factors in shrinkage and creep of masonry.

## REFERENCES

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Fig.1 Creep frame for 5-stack brick

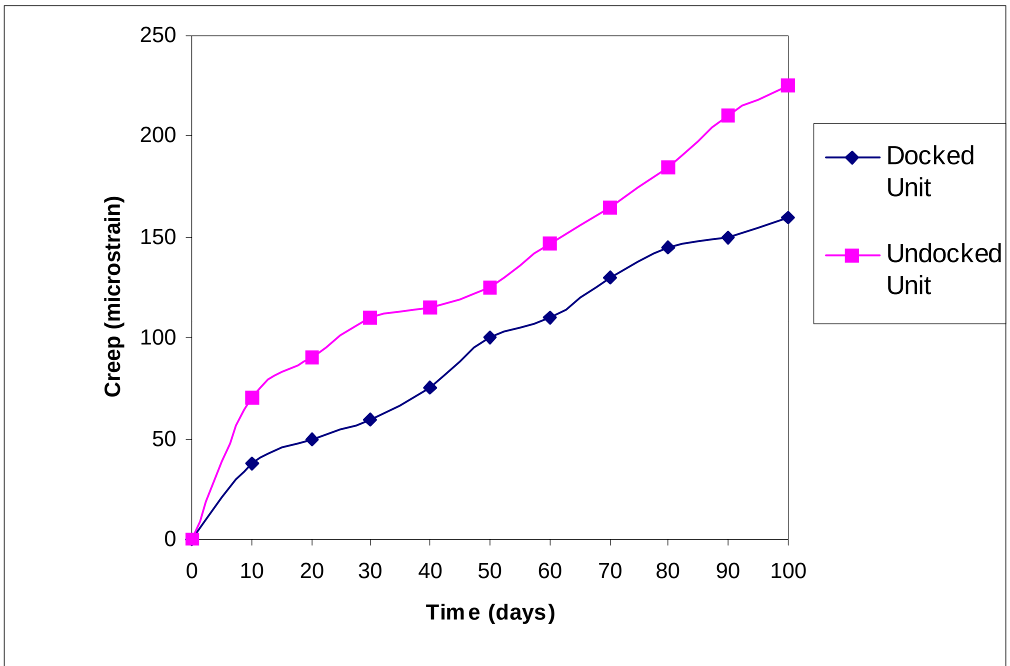


**Fig.2 Creep-time curves of 5-stack clay brickwork**

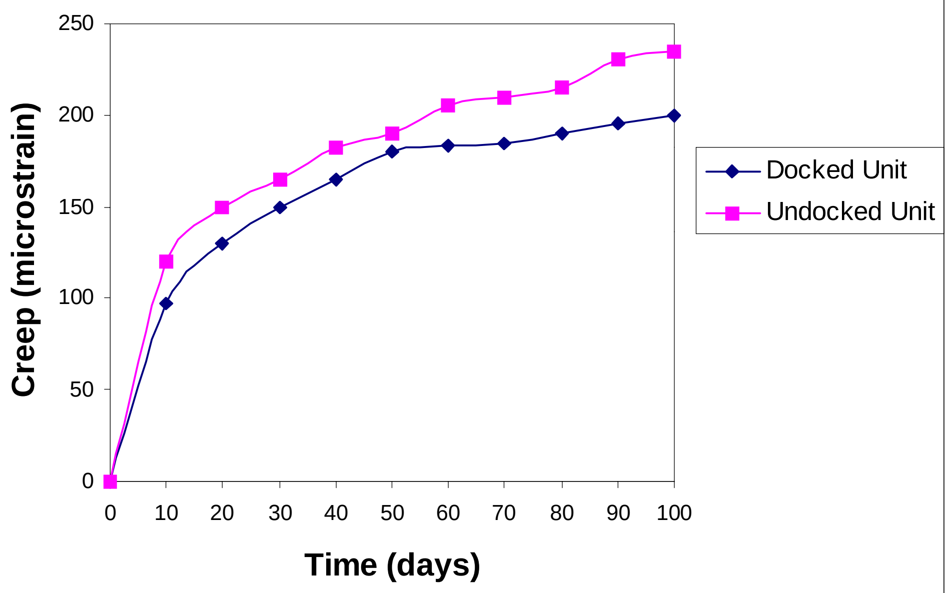


**Fig.3 Creep-time curves of 5-stack calcium silicate brickwork**

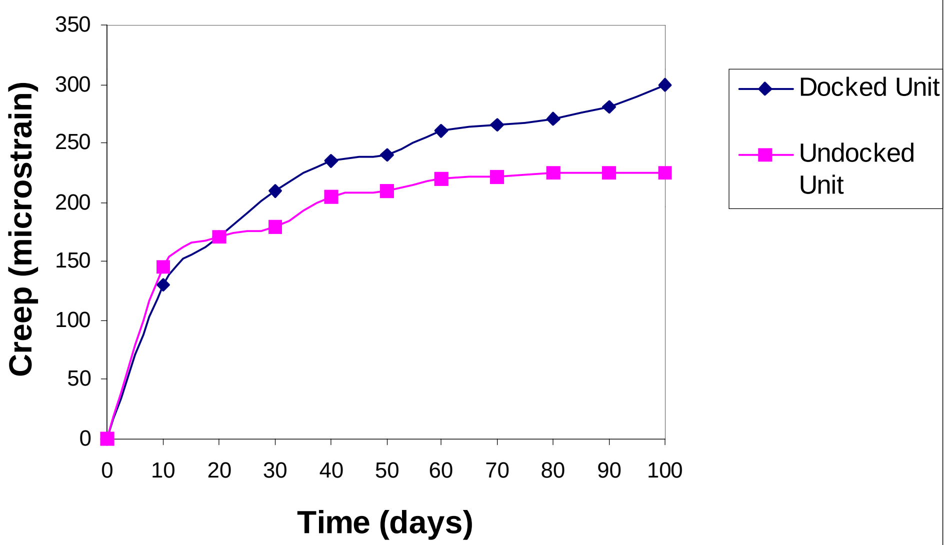


**Fig.4 Creep-time curves of 5-stack concrete blockwork**