Determination of creep behaviour of concrete made by brick chips in Bangladesh

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ABSTRACT

Concrete made of brick chips as coarse aggregate are extensively used in Bangladesh for construction of different types of structures from residential and commercial buildings to industrial complex. As creep is influenced among many factors including the constituents' materials, relative humidity and temperature, it is essential to examine the creep behavior for Bangladeshi brick chips made concrete in Bangladeshi environment. In this work, investigation on the behaviour of creep in concrete of same grade made with brick chips collected from various locations under single stage loading was done. With these investigations, a formula was derived to get theoretical creep values for 24 MPa brick chips made concrete in Bangladeshi environment.

KEYWORDS

Creep; Bangladesh; Concrete; Aggregate; Brick Chips.

INTRODUCTION

Concrete is a commonly used construction material for Bangladesh construction industry since centuries ago. One of the important behaviour of concrete is it undergoes volumetric changes throughout its service life. These changes are a result of creep and shrinkage, which are time-dependent deformation of concrete. According to Vincent, Townsend and Weyers (2004), creep is defined as the time-dependent deformation resulting from a sustained load. Creep without moisture loss is referred as basic creep whereas with moisture loss is referred as drying creep. Therefore, total creep strain comprises of basic creep and drying creep. In practice, local engineers predict the creep strains by using standard codes or other available prediction models which were developed in temperate country. These prediction models consist of Eurocode 2 (EC2), ACI 209 model (developed by American Concrete Institute), CEB-FIP 90 model (developed by Euro-International Concrete Committee and International Federation for Prestressing), B3 model (developed by Z. P. Bazant and S. Baweja 1994), GL2000 model (developed by N. J. Gardner and M. J. Lockman, 2001). These prediction models were derived by empirical approach, in which time functions were determined by curve fitting of test results. It is well documented that creep are influenced by various factors such as constituent materials, temperature and relative humidity of environment. Therefore, creep for Bangladeshi concrete made with brick chips is deemed to have different magnitude from the predicted values by those prediction models. However, local experimental works are scarcely available to study the effects of the influencing factors for Bangladeshi concrete made with brick chips. In addition, the degree of difference in creep value in brick chips made concrete and stone chips made concrete is never significantly verified. Hence, it is difficult for local design engineer to predict creep related behaviour such as deflection and prestress loss with confidence.

Based on the above factors the main objectives of this research are:
1. To investigate creep variation between brick chips made concrete in Bangladeshi environment.
2. To investigate creep variation for 24 MPa grade concrete made with brick chips collected from various locations.
3. To construct a formula for creep prediction for 24 MPa concrete made with brick chips for Bangladeshi environment.

CREEP PREDICTION MODEL

Four of the prediction models for creep are described in this section. The ACI 209 model is recommended by the American Concrete Institute. The CEB-FIP Mode Code 90 is used in Europe. Other models include the B3, which was developed by Bazant and Baweja (1995), and GL model, which was developed by Gardner and Lockman, (2001). The models look at free shrinkage, creep strain, and elastic deformation. The creep strain is the combination of the basic and drying creep. The elastic deformation is the instantaneous recoverable deformation of a concrete specimen during the loading process. The various creep models relate the creep strain to the loading conditions by using creep coefficient, specific creep, or creep compliance. The creep coefficient is the ratio of creep strain at given time to the initial elastic strain. Specific creep is the creep strain per unit stress. The creep compliance is the ratio of creep strain plus elastic strain per unit stress. The application of these prediction models are subjected to some limitations. The limitations were summarized by Vincent (2003) and it is presented in Table 1

Table 1. Limitations of Prediction Model (Vincent, 2003).

Parameter	**ACI 209R-92**	**CEB MC90**	**B3**	**GL2000**
f_{cm} (psi)	-	2900-13000	2500-10000	2900-10000
a/c	-	-	2.5-13.5	-
c (lbs/ft^2)	-	-	10-45	-
w/c	-	-	0.30-0.85	-
H (%)	40-100	40-100	40-100	40-100
Cement Type	I or III	R, SL, RS	I, II or III	I, II or III
t_0 or t_s (moist cured)	$\geq$ 7 days	$t_s \leq$ 14 days	$t_s \leq t_0$	$\geq$ 2 days
t_0 or t_s (steam cured)	$\geq$ 1-3 days	$t_s \leq$ 14 days	$t_s \leq t_0$	$\geq$ 2 days
Model includes lightweight concretes?	Yes, normal lightweight sand & lightweight	No	No	No, but considers aggregate stiffness

Creep test for brick chips

Brick chips are widely used for concrete in Bangladesh. So it is very necessary to acquire knowledge of creep behaviour in brick chips. The bricks are gathered from brick kilns. These kilns are of various qualities. They produce wide variety of bricks. The main goal of this test was to test the creep behaviour of brick chips that are acquired from different locations. We have gathered bricks from three locations. The tests performed using them was laboratory creep test, sieve analysis, absorption capacity test, field moisture content test and compressive strength test. The bricks are named as following 1.EBS 2. NBM 3.MEB are used for testing purpose. This research also used Ordinary Portland Cement (OPC) and uncrushed fine aggregate. Coarse aggregate used in this study is a crushed type aggregate with ¾ inch maximum size. The properties of water that was used in the concrete work is being potable, free from oil and other organic impurities. Ordinary tap water was used as mixing water throughout the study. The creep and shrinkage tests were performed under the temperature of 27 ºC and 60-65 % of relative humidity to represent the Bangladeshi environmental conditions. Creep test was started by using 28 days specimen. ASTM C512 (1987) was mentioned that creep is proportional to stress from 0 to 40 % of concrete compressive strength but Neville et al. (1983) suggested that in terms of stress-strength ratio an upper limit between about 0.30 and 0.75 has been observed. Therefore, in this study 40 % stress-strength ratio was used as applied load for creep test.

Mix Design. The mix proportion in this study was designed for characteristic strength of 20.70 MPa. In this study, constant slump of 1 inch was designed for all mixes. The specimens were removed from the molds after 24 ± 8 hours (ASTM C192, 1990), moist cured at 23° ±1.7°C until the age of 7 days in accordance with ASTM C 512-87 (1987).

Compressive Strength Test. Cylinder specimens with 6 inch in diameter and 12 inch in height were prepared for compressive strength test. Thesp ecimens prepared were the same as specimens prepared for creep test and were tested at the age of 7 days. The compressive test was performed in accordance with ASTM C 39 (1993). The specimens were tested using a compression machine and with the rate of loading of 3.0 kN/sec. The load applied continuously and without shock until the specimen fails and the maximum load carrying by the specimen during the test was recorded.

Sieve Analysis. A sieve analysis consists of shaking the brick chips through a stack of wire screens with opening of known sizes. 5 kg sample was taken to perform this test. Sieve the brick chips through a nest of sieves by hand shacking, using a motion of horizontal motion or rotation. At least 10 minutes of hand shacking is needed to perform this test. Weigh the sample collected from each sieve and hand calculation have been done. After the completion of all data analysis need to draw the gradation curve.

*Absorption Test***.** To perform this test each brick has taken from each categories and divided each brick. Half of each brick kept in a plate full of water for 24 hours. Using oven water was removed from brick. Weigh each brick in dry condition and wet condition. Then calculate absorption of each brick in percentage.

*Moisture Content Test***.** To calculate moisture content of brick chip in field condition weigh the sample in field condition and in saturated condition. Dry the saturated sample using oven and weigh the oven dried sample. Then calculate the moisture content of brick chips in percentage. Moisture content = ((weight of saturated sample – weight of oven dried sample)/ weight of oven dried sample)*100%.

*Specimen Preparation***.** For creep tests, vertically cast cylindrical specimens were prepared in accordance to the provisions of ASTM C 512 (1987). The size of specimens prepared is 6 inch in diameter and 12 inch in height. The numbers of two specimens were prepared for total creep (loaded specimens and unloaded specimens)**.** The concrete were placed in two approximately equal layers and each layer was compacted 25 times uniformly over the cross section of the mould. After consolidation, the top surfaces were finished by fitting the ends with Perspex plates normal to the axis of the cylinder to get the flat surfaces. Then the specimens were covered with wet gunnysack to protect water from evaporation and then the curing process was performed. For creep and shrinkage tests, DEMEC gauges were used to measure the deformation of the concrete. Before testing, four DEMEC measurements point (studs) were glued at 150 mm distant apart on four opposite sides of the concrete specimens. According to ASTM C 512-87 (1987), the loading frame used for creep test must be capable of applying and maintaining the required load on the specimens. The loading frame is consists of header plates bearing on the ends of the loaded specimens, a load-maintaining element either spring or a hydraulic capsule or ram, threaded rod to take the reaction of the loaded system.

*Testing Procedure for Creep Test***.** For this study, creep tests were carried out at age of loading of 28 days. Before loading the creep specimens, the compressive strength of the specimen was determined in accordance with Standard Test Method ASTM C 39 (1993). The average ultimate compressive strength of three specimens was used to determine a stress which was being applied to specimens for creep test. The manual loading system for creep test was subjected to a stress of 30% of average ultimate compressive strength as stress-strength ratio. The specimens were placed in the loading frame. The centre point of each plate was determined and the specimens were placed with caution to avoid eccentricity. The actual load applied was monitored using a load cell. The load was measured every time before each strain reading was taken to ensure the correct value of loading was applied. The strain reading was taken immediately before and after loading, two to six hours later, and then daily for 1 week, weekly until the end of one month and monthly until the end of the testing. Direct reading of the strain was obtained by multiplying the reading shown on the DEMEC gauge by a calibration of 0.002 mm.

Creep test for brick chips

*Total Creep***.** The total creep strain was obtained by subtracting the instantaneous elastic strain and from the total deformation strain as given in the following equation.

$C(t_1, t_o) = (\varepsilon_t(t_1) - \varepsilon_{ie}(t_o)) * M$

Where:

$C(t_1, t_o)$ = total creep at time t_1 due to a stress applied at t_o

$\varepsilon_t(t_1)$ = total deformation at t_1

$\varepsilon_{ie}(t_o)$ = instantaneous elastic strain at time t_o

M = coefficient of DEMEC gauge.

*Creep Coefficient***.** After the creep value obtained from above Equation the creep coefficient was obtained as a ratio of creep to the instantaneous elastic strain at any age.

$\Phi(t_1, t_o) = C(t_1, t_o) / \varepsilon_{ie}(t_o)$

Where:

$\Phi(t_1, t_o)$ = creep coefficient at t_1 due to a stress applied at t_0

$C(t_1, t_o)$ = total creep at time t_1 due to a stress applied at t_o

$\varepsilon_{ie}(t_o)$ = instantaneous elastic strain at time t_o.

RESULTS AND DISCUSSION

Figure-1 shows the creep strains of the brick samples with respect to time. It can be seen that creep strain varies with different brick chips. This is mainly because of their respective compressive strength. The basic knowledge is the higher the strength, the lower the creep strains. This is because of high resistance capability due to high strength.

From Figure-1 & Figure-2, it can be seen that, the sample “EBS” has the lowest compressive strength of 23.75 MPa. Because of its low strength, it has lower resistance to strain. That is why its creep strains are higher of the three samples. The sample “MEB” has the highest compressive strength of 24.55 MPa. That is why its creep strains are lower than the other two samples. Sample “NBM” has a mid value compressive strength of 24.22 MPa. That is why its creep strains value lies in between “EBS” and “MEB” samples.

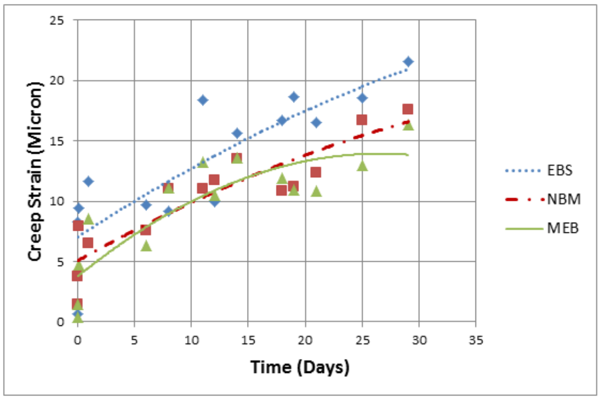

Figure 1: Creep Strain (Micron) vs. Time (Days) graph

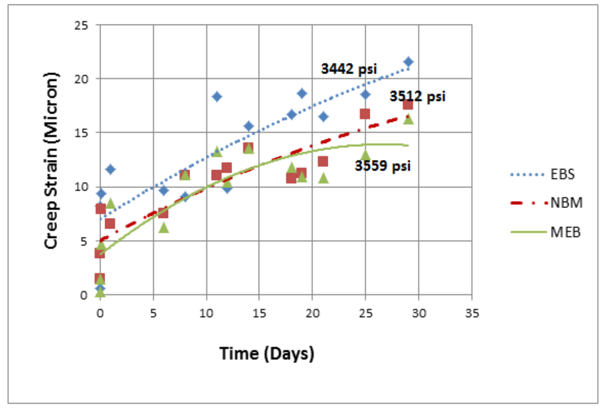

Figure 2: Effect of Compressive Strength

From the field moisture content test, it has been also seen that the higher the moisture content of the sample, the higher the creep strain of the sample. From above Figure-3, it is revealed that, “EBS” has the highest moisture content of 18.4% and it has the highest creep strains values. “MEB” has the lowest moisture content of 15.8% and has the lowest creep strain value. “NBM” lies in between them with moisture content of 17.5% and also has the creep strains laid in between “EBS” and “MEB”.

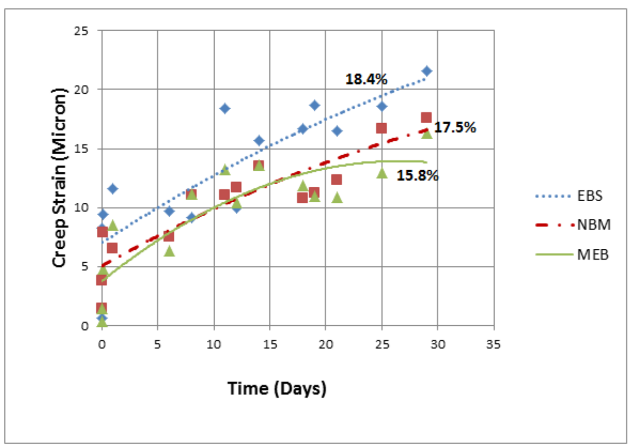

Figure 3: Effect of Moisture Content graph

Creep Expression

It is the interest of this study to predict the short term behaviour of creep in concrete made with brick chips. Therefore, in this section, the predictions of creep are determined based on the experimentally obtained result using hyperbolic expression. Hyperbolic expression is used in this study because it gives the best fit curve to the experimental result throughout the testing duration.

From the Figure-4, Figure-5 & Figure-6, three hyperbolic equations can be found for three test specimens. The equations will be,

EBS : $y = -0.004x^2 + 0.618x + 7.019$ ……………….(1)

NBM : $y = -0.004x^2 + 0.529x + 5.049$ ……………….(2)

MEB : $y = -0.014x^2 + 0.765x + 3.755$ ……………….(3)

Where, y = Creep Strain (Micron)

x = Time (Days)

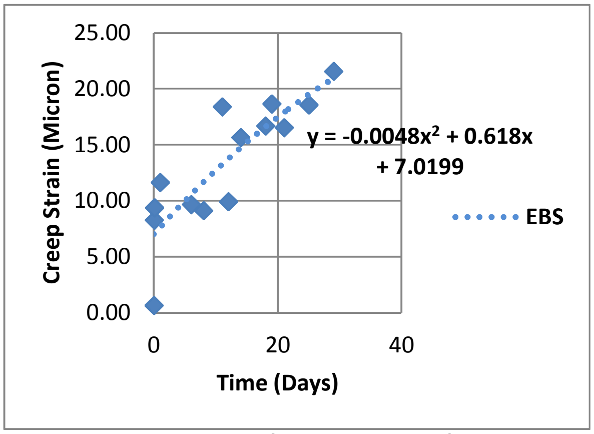

Figure 4: Equation of Creep Strain for Sample "EBS"

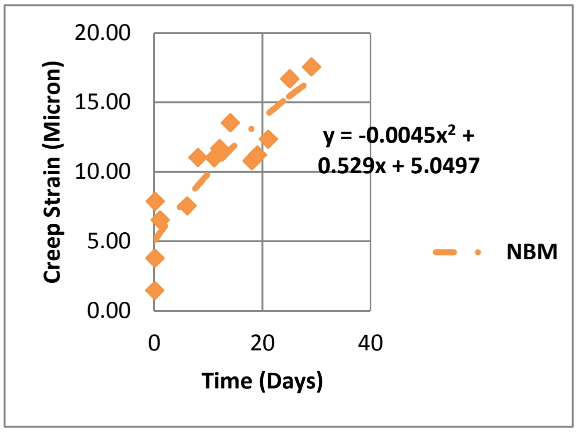

Figure 5: Equation of Creep Strain for Sample "NBM"

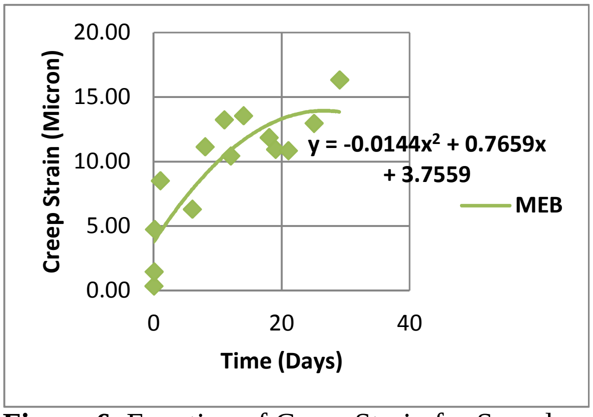

Figure 6: Equation of Creep Strain for Sample "MEB"

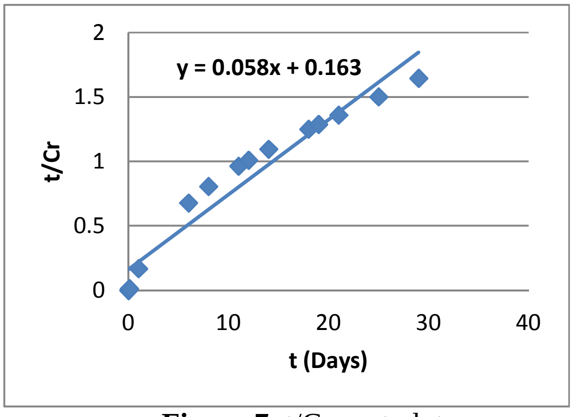

Figure 7: t/Cr vs. t plot

Using these three equations, a new equation will be constructed which will be valid for concrete made with brick chips with 28 days strength of 24 MPa with applied stress is 40% of ultimate strength. A hyperbolic relation between creep and time has been suggested by Ross (1937). The creep-time relationship as a hyperbolic function can be written as:

$$Cr = \frac{t}{A+Bt}$$

Where, t = Time (Days)
Cr = Creep Strain (Micron)
A,B = Constants

To achieve this equation, first combine Equation-1, Euation-2 & Equation-3 by averaging them. Their average gives us the following equation,

$$y = -0.0073x^2 + 0.6373x + 5.274 \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

In Figure-7, a straight line of $\frac{t}{Cr}$ vs. t has been plotted using equation-4. From that plot the values for constants A & B can be found.

A = 0.163
B = 0.058

So, the desired equation becomes,

$$\mathbf{Cr} = \frac{\boldsymbol{t}}{\mathbf{0.163+0.058}\boldsymbol{t}}$$

Where, Cr = Creep Strain (Micron)
t = Time (Days)

Using the above formula, theoretical creep strain values can be found which is plotted in Figure-8. The comparison of strains calculated from the formula with the experimental values is given in the Figure-9.

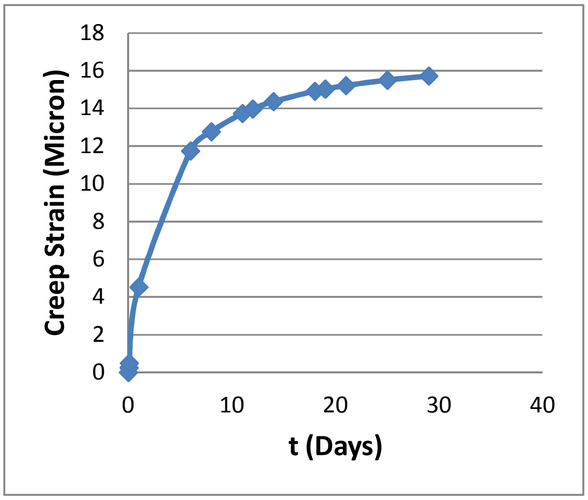

Figure 8: Theoretical values of creep strain.

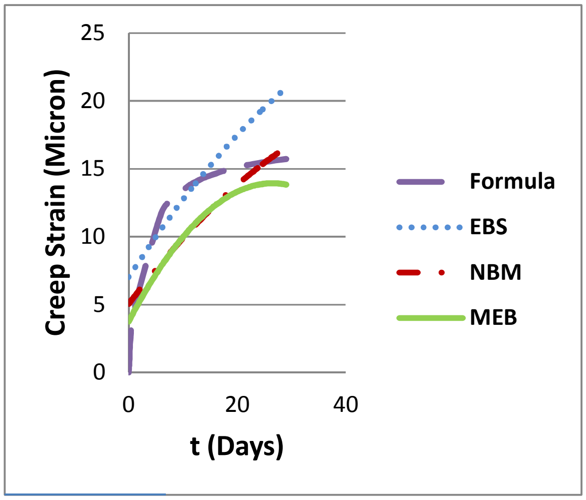

Figure 9: Comparison of creep strain.

Figure-9 shows that, the theoretical values lies near all the experimental values. This proves that the formula is sufficient. This formula can only be used for brick chips made concrete with strength 24 MPa. For different strength, the formula needs to be modified.

CONCLUSIONS

In this study, several concrete specimens made of brick chips as course aggregate of 24 MPa compressive strength in the environment of Bangladesh are prepared and tested for creep behavior as per ASTM C512. Creep strain is measured for up to 100 days. The focus of the experiment was to construct a formula for creep prediction for 24 MPa concrete made with brick chips for Bangladeshi environment. Using the experimental data, a formula has been made which provides theoretical values for creep strain which lies near experimental values. The constructed formula is valid only for 24 MPa concrete of brick chips. For other type of concrete, the formula needs to be modified accordingly.

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