Experimental Study Of Fly-Ash Brick Masonry Under subjected To Cyclic Loading

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Abstract

Fly ash bricks are new material and these bricks have certain advantages over clay bricks and no information regarding strength of these brick in masonry is available. Therefore goal of present work is to establish stress-strain curves for fly ash brick masonry having various H/T ratios under cyclic loadings. Also to establish envelope curve, common point curve and stability point curve. Since compressive strength of brick masonry depends upon various parameters viz. water absorption, mortar grade, slenderness ratio so these parameters are also taken into account. To achieve this above objective Fly ash brick masonry wall panel of size 800mm X 100 mm X 200 mm, 800mm X 100 mm X400 mm, 800mm X 100 mm X 600 mm and 800mm X 100mm X 800mm each constructed and cured for 28 days in 12 Nos., were tested for the study of stress-strain relationship of fly ash brick masonry under monotonic, cyclic, fatigue loadings. The effect of H/T ratio is also studied. In the experimental work 48 panels specimens were tested and compressive strength is calculated and stress-strain curve is plotted for each specimen and these curves are also normalized to each stress strain relationship. The results clearly indicate that the peak of the stress-strain curve obtained under cyclic compressive loading approximately coincides with the stress strain curve obtained under monotonic loading. Also cyclic load deformation history possesses locus of common points and locus of stability point Curves.
Keywords: Compressive Strength, Cyclic Loading, Cyclic Curve, Envelope Curve, H/T ratio, Stability Curve Stress-Strain Curve

I. INTRODUCTION

Housing is one of the basic requirements for human survival. For a normal citizen owning a house provides significant economic and social security and status in the society. In India 83% of the population live in villages and about 73% of the rural population reside in unreinforced masonry structures. Masonry is a composite material of brick units and mortar joints and interface between mortar and unit. The behavior of masonry is based on the properties of brick units and mortar joints [2]. The shear behaviour of masonry can be investigated at different levels [1]. At the micro level, the mortar and the bricks are considered separately. At the macro level the wall panels are considered. Brick masonry is the least understood in the aspect of strength and other performance related parameters because of its complex behavior and its non homogeneity even in deci-scale. As weaker the mortar used lower the masonry strength observed (due to the unit-mortar interaction, the masonry strength is always lower than the unit strength). Very few studies have been identified the effect of mortar type on the in-plane response of masonry walls [3]. Bridging this knowledge gap requires additional experimental research. The research review was classified into two different categories: first being the study of physical and mechanical behavior of brick masonry and its assemblages[6]; second the response of the in-plane shear behavior of the masonry wall elements[1,5]. In a developing country like India, there is a great need for a large number of residential units due to the rapid increase in population. This laborious task of building large number of building blocks can't be achieved unless efficient, fast and economic systems are utilized.

Load bearing masonry construction can be feasible solution to the problem of housing. It is previously reported that the load bearing masonry construction can save up to 30 % of the construction cost, when using framed type. Buildings can be safely raised up to 3 storeys with the usage of the ordinary bricks. It is claimed by the manufacturer that the Fly ash bricks can be safely used to raise the structure up to 4 floors without beams and columns.

The cement bricks or concrete blocks could be a good or bad choice depending on the manufacturer. However using cement would impose further strain on cement factories. As for the Sand lime bricks, it appears that its quality and durability depend on the quarry and the mix. The other option available is the Fly ash bricks. Therefore, presently most researchers directed their studies to eco friendly fly ash bricks.

Research has shown that the load carrying capacity of frame is increased many fold due to stiffening of the frame by the infilling material. In fact brick masonry imparts additional flexural strength due to its beneficial interaction with the supporting R.C.C. frames [5]. So the consideration of the behavior of the masonry leads to the rational design of beams and columns. This investigation involves an experimental study, conducted on 48 fly ash brick masonry panel specimens under uni-axial cyclic compressive loading. Then stress-strain Envelope curve, Common point curve and Stability point curves are developed. Also by the use of stability point curve permissible stress level under cyclic loads is recommended instead of monotonic curve.

II. EXPERIMENTAL PROGRAMME

A. Preparation of Panel Specimens:-

Fly ash brick masonry wall panel of size (800 mm X 100 mm X 200 mm), (800 mm X 100 mm 400 mm), (800 mm X 100 mm X 600 mm) & (800 mm X 100 mm X 800 mm) each constructed in 12 Nos. by joining bricks with mortar in the ratio of 1:3 (cement: sand) providing 10 mm thick bed joint. The specimens were constructed on plane ground and polythene sheets were used to prevent there direct contact with the ground. Uniform work man ship was maintained in the construction of test specimens. They were cured under damp condition for 28 days and then used on test study of stress-strain relationship of fly ash brick masonry under monotonic, cyclic & fatigue loading. (Refer Fig.1)

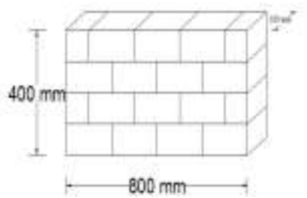

Fig. 1: Details of Panel Specimen

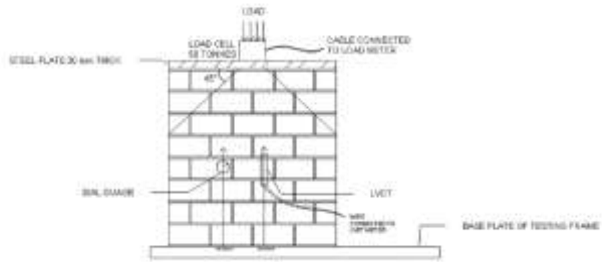

Fig. 2: Loading Arrangements

B. Loading arrangement

For specimens with variable H/T ratio load applied through 500KN capacity hydraulic jack connected to hand operated high pressure oil pump. A steel plate of 30 mm thick was placed over the top of the specimen to distribute the load uniformly over the entire cross section of the specimen.

C. Instrumentation

The panel and prism specimens were tested under axial compressive loading. A point load was applied at the centre. XY plotter was used to monitor displacement and applied load through linear variable displacement transformer (LVDT) and load cell, respectively. A sophisticated Dial gauge was also used for measuring the deflection. The instrumentation and loading arrangement is shown in Fig 2.

1) LVDT

Linear variable displacement transformer abbreviated as LVDT was used to measure the deflection of specimen. The LVDT was fixed below the specimen at the point where deflection was recorded. The LVDT was connected to XY plotter for obtaining the graph between load and deflection. The range of LVDT was ± 30mm.

2) Load Meter and Load Cell

Load cell is pressure transducers of capacity 500 KN is used to record the load applied. The load cell was connected to load meter and output of load meter was connected to X-Y plotter to get the load deflection plots.

3) X-Y Plotter

An XY plotter is a plotter which gives the plot between two variables connected to x and y axis. In the present study the output of load meter was connected to the Y-axis and the output of LVDT was connected to X-axis to obtain plot between load and deflection.

4) Dial Gauge

A dial gauge was also connected at the same level to the LVDT for recording the deflections. It gives the value of deflection on its dial. It operates on mechanical enhancement principle.

D. Test Procedure

All the tests conducted were stress controlled tests. A total of 48 panel specimens were tested to investigate the behaviour of fly ash brick masonry under uni-axial compressive loading. The whole experimental programmed can be divided in to three main phases. Three different types of loading were employed in this testing programmed.

1) In first phase of the work, fly ash brick masonry panels of varying H/T ratios, ranging from 2 to 8 were tested under uni-axial compressive loading. The monotonically increasing axial tests were conducted to obtain the ultimate strength of the specimens, and to determine the strains at various levels of stress. Two specimens were tested for each H/T ratios in all 12 specimens were tested in this phase under monotonic axial loading.
2) In the second phase of the experimental programmed, two specimens were tested for each H/T ratio under cyclic loading to establish common points and two specimens were tested for each H/T ratio to establish stability points under cyclic loading .From cycle to cycle the load was increased in regular intervals. The stress-strain curve obtained in this fashion possesses common points where reloading curve of any cycle crosses the unloading curve of previous cycle. Loci of all these common points are known as common point curve or shake down curve.
3) In the third phase, cyclic stability loading tests performed were the load was increased up to a pre- determined load level and then reduced to zero. Then stresses were increased up to the intersection of the loading curve with the previous unloading curve to obtain the common point. The load was again released down to zero and reloaded up to the intersection with the first unloading curve to obtain the second shakedown point. This was continued until the shakedown point was stabilized. It can be observed that during each stage the shakedown point was gradually pushed down. The magnitude of the reduction of the load level decreased with the number

of cycles until the intersection point stabilized at a certain load level. This point is termed as the stability point and the repeated cycles below this stress level resulted into the formation of a closed loop. Once this stabilization was achieved, the stress was increased up to another stress level and the procedure was repeated. The stress was increased in regular intervals from one cycle to the other.

III. FAILURE MODES

It is known that when masonry is tested in axial compression it fails in lateral tension, with the formation of vertical cracks. This failure pattern has been observed in the present study also. However, a difference in comparison to ordinary brick masonry is observed that, at failure bricks were broken into two pieces also, a distinct plane characterized by a vertical crack and no crushing of bricks was occurred [2, 15]. In case of the specimens subjected to Monotonic axial loading, the failure was characterized by a vertical crack in the middle of the specimen, in a plane parallel to the plane of loading. In some cases the cracks were observed on one face only and in some cases the crack appeared on more than one face of the specimen. In some of the cases, the crack was found to be extended over the entire length and in some other cases it was confined to the parts close to top and bottom bricks, which indicates the poor quality of bricks [10, 14]. In all the types of cyclic loading, the failure of the specimen was due to the accumulation of strains and the mode of failure is similar to that observed in case of monotonic loading. Failure of the specimen under fatigue tests was also defined in similar pattern**.**

A. Stresses-Strain Curves

For plotting envelope point curve, common point curve and stability point curve the stress and strain coordinates are normalized. The stress co-ordinate is normalized with respect to the failure stress (peak stress) of each specimen and the strain coordinate is normalized with respect to the axial strain, when the peak stress is reached.

1) Monotonic Loading

Under Monotonically increasing load, specimens with varying H/T ratio ranging from 1 to 4 are tested to obtain unit-axial compressive strengths. Stress V/S Strain curves showing the parabolic relationship are presented in Figure 3.

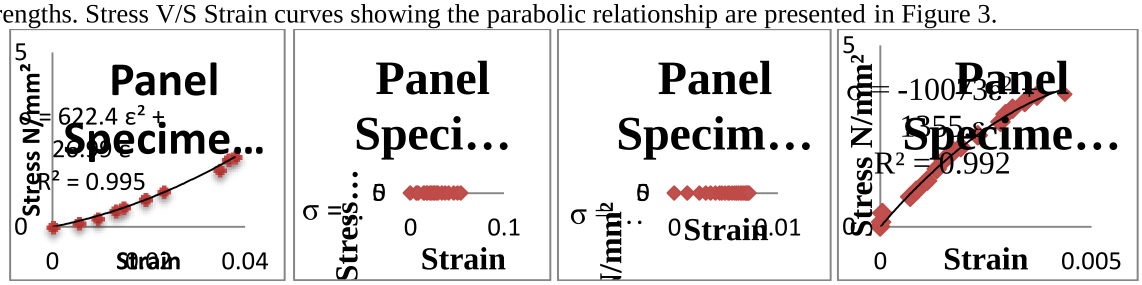

Fig. 3: Stress-Strain Curve under Monotonic Loading for Panel Specimen

2) Cyclic Loading

Results of Cyclic loading for common points are presented in the Figure 4. Behavior of the common point is investigated by establishing stability point for which cyclic stability loading was applied.

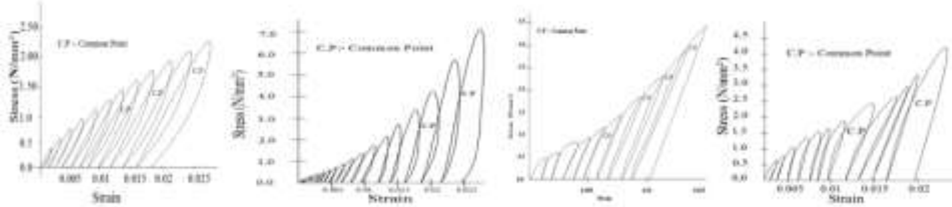

Fig. 4: Stress-Strains Curve under Cyclic Loading For Panel Specimen

3) Stability Loading

The load was applied as in the cases of cyclic loading except that in each cycle, loading and unloading were repeated several times, each time unloading being done when reloading cure intersected with initial unloading curve. These points of intersection descended and stabilized at lower bound and further cycling led to formation of a closed hysteresis loop. Such lower bound points are known as stability points. Stress- strain curves plotted for establishment of stability points are shown in Figures 5.

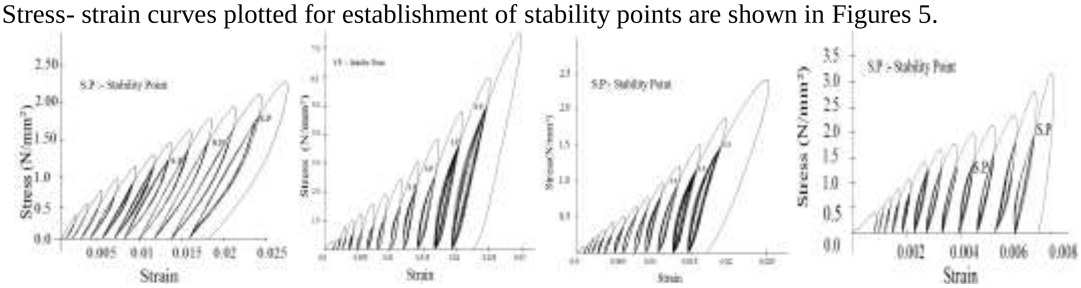

Fig. 5: Stress-Strain Curve under Stability Loading For Panel Specimen

4) Normalized Curve

Envelope, Common point and Stability point curves are plotted on normalized stress – strain coordinate system. The peak points of stress-strain curve under cyclic loading curve and stability curve are plotted for obtaining envelope curve. The common points extracted from the graphs of cyclic loading and stability points from stability point curve respectively. All three are jointly presented in Figure 6.

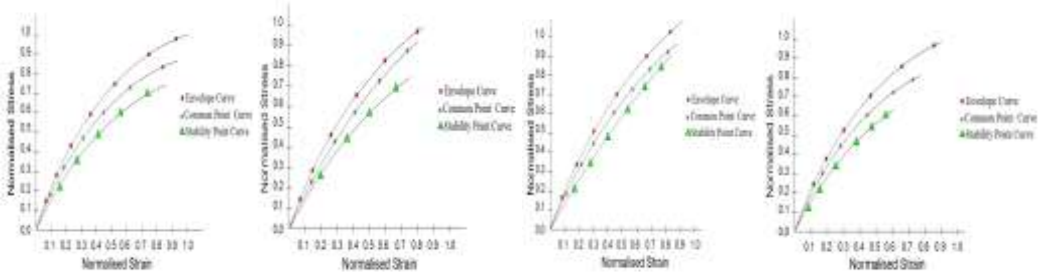

Fig. 6: Normalized Stress-Strain Curve For Panel Specimen

5) Plastic Deflection Curve

Plastic deflection may be considered as an index of detritions and is related to permissible load level [15]. Therefore, it is important to relate the elastic deflection with the envelope, common point and stability point deflections. For the sake of comparison the normalized plastic deflection corresponding to normalized envelope point deflection, common point deflection and stability point deflection are jointly plotted in Figure 7.

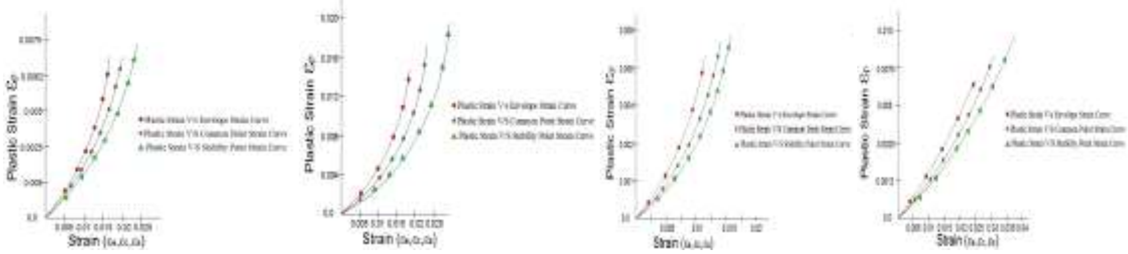

Fig. 7: Plastic Deformation Stress-Strain Curve For Panel Specimen

6) Permissible Stress level

If the common point corresponding to a given load history is unique, i.e. intersection of the loading curve with the previous unloading curve is unique , cycles in which the stresses are below this limit will not result in higher strains than the strains obtained at the same stress level in the previous unloading.

The stability point curve can be a useful aid in defining the permissible stress levels of brickwork structures where reductions of compressive strength due to the effect of repeated load cycles have to be taken into account [19]. When the peak stress of the repeated load is higher than peak of the stability point curve, then the repeated cycles of load will cause accumulation of plastic strains in each cycle of loading, and hence, resulting in ultimate failure. If the peak stress of the repeated loading is less than the peak stress of stability point curve, then the repeated cycles of load will result in accumulation of plastic strain till it coincides with the stability point curve, at the stability point, thereafter, it follows same cyclic path and plastic strain stabilizes at this point. Therefore, the level of plastic strain present in the material has to be considered in defining the permissible stress level. If the plastic (residual) strain present in the material is more than the plastic strain corresponding to peak stress of stability point curve, then the stability point stress at the level of stability point may be adopted as the permissible stress level [19].

IV. DISCUSSION

A. Compressive Strength of Bricks

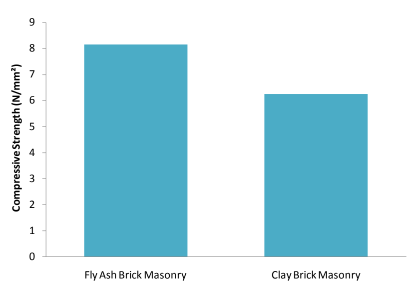

Fig. 8: Comparison Of Compressive Strength Of Fly Ash Brick Masonry And Clay Brick Masonry

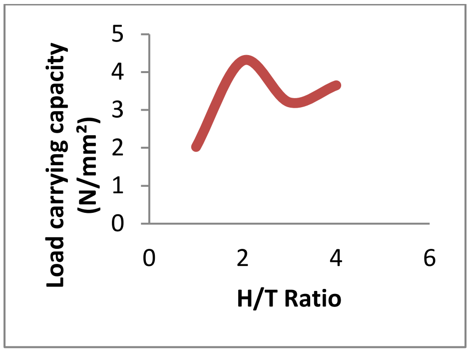

Fig. 9: Wall Panel Load Carrying Capacity V/S H/T Ratio Plot

The strength of fly ash bricks in compression varied from a minimum of 9 N/mm^2 to maximum of 11.5 N/mm^2, averaging about 10.25 N/mm^2. It is noted that the discrepancy between the maximum value and the minimum value is large, which implies that the variation of compressive strength is more. From the result it is concluded that the bricks are of non uniform strength. The compressive strength of ordinary bricks is found to vary in the range of 3.25 to 5.5 N/mm^2. [2,17] Upon comparison the strength of fly ash bricks, in compression, with that of ordinary bricks it is perceived that the fly ash bricks are about 2 times stronger than the ordinary bricks. (Refer Figure 8)

B. Compressive Strength of Brick Masonry Panels

The compressive strengths of the entire Fly ash Brick masonry prism with H/T ratios; 2, 4, 6 and 8 are presented in **Figure 9**. For each H/T ratio two specimens were tested. There is a significant variation in compressive strength from specimen to specimen, although they belong to same H/T ratio group. This can be related to the variation in compressive strength of brick units. The nature of the curve is hyperbolic with its peak observed at an H/T ratio is equal to 4. In the zone of low H/T ratio i.e. up to 4, the stress versus H/T ratio curve showed an upward trend, while it descended in the zone of H/T ratio between 4 and 8.This pattern of variation is in contrast to the pattern of variation observed in case of the ordinary brick masonry, which shows down ward trend with the increasing H/T ratios [3].

C. Stress- Strain Curves

1) Monotonic Loading

Stress –Strain curves, for all the specimens with different H/T Ratios, followed a parabolic relationship up to failure. Actually, in case of monotonic axial loading to failure, the stress-strain relationship beyond ultimate is taken as a straight line. But keen observation of Figures, reveal that, in the present study also stress-strain curves have taken parabolic path up to the peak and one or two points beyond the ultimate have shown down ward trend. Significant consideration has been given to establish the stress-strain curve for monotonically increasing load, beyond the ultimate load. The variation of stress, with the varying H/T ratio, is also presented in the Figure 9.

2) Cyclic Loading

In the cyclic loading, common points, which are defined by the investigators as the points, where reloading portion of any cycle crosses the unloading portion of previous cycle, are established. Stress above this limit will lead to additional strains, while the stresses below this limit will give no strain increments and the stress- strain curves will go into a closed hysteresis loop. The investigation, for the behavior of common point under various load histories, yields the stability point. It represents the stabilized lower bound common point. As cycles with lower stress levels are introduced, in the cyclic loading for common points, the common points are reduced to a lower limit where accumulation strains finally stabilize. Therefore it is reasonable to define a series of common point curves instead of defining a single common point curve. This enables one to perceive the things, related to the behavior of common point, more easily and quickly. An analysis of the test results obtained reveals that a definite relation between the maximum value of the applied stress and the location of the related common point, which in turn governs the location of the stability point.

If the common point for a given loading history is unique, cycles in which the stresses are below the limit of common point curve will not result in higher strains than the strains obtained at the same stress level in the previous unloading. All the tests in which the common point was investigated showed a definite relationship between stress & strain at the peak of loading cycle and location of the common point. If the stress and the strain at the peak of the cycle are above the common point limit, the shakedown limit is very near to the upper bound. If the peak stress of the load cycle is higher than the maximum stress of the stability point, repeated cycles will gradually produce failure as the accumulated strains approach the envelope curve. It the peak of the load cycles is less than the maximum stress of the stability point limit, repeated load cycles will not to lead accumulation of strains instead the strains will stabilize resulting in a closed hysteresis loop for subsequent load cycles.

3) Envelope, Common Point and Stability Point Curves

All these curves are plotted on a non-dimensionalised stress- strain co-ordinate system [3, 16]. The envelope, common point and stability point curves show an exponential variation. Theoretically, these curves possess positive slope in the zone up to the attainment of peak and then gradually decrease i.e., the curve will have negative slope after attaining the peak. In the present study the curves were obtained up to the peak level omitting the descending portion of the curve. The presented curves are following exponential variation. The peak stresses and the peak strains corresponding to the common point curve are about 80 % of the corresponding stresses and strains of the envelope curve while those corresponding to the stability point curve are about 60% of the values.

V. CONCLUSIONS

- It can be concluded that Fly ash brick masonry has average comparative strength is about 8.13 N/mm², which is approximately 1.3 times the strength of conventional brick masonry and these bricks are environmentally friendly alternative to burnt clay bricks which are generally used for construction in India. Therefore, use of this masonry system is strongly recommended over conventional burnt clay and other brick masonry. **(**Refer Table 1)
- It can also be inferred that the strength of masonry is about 40 to 45 % of the strength of brick units.
- Stress-strain curves for all the specimens with different H/T ratios followed a parabolic relationship up to failure.
- Very little variation is observed in compressive strength of various piers indicate that brick used were of uniform strength hence lower factor of safety may used.
- The peak of the stress-strain curve obtained under cyclic compressive loading approximately coincides with the stress strain curve obtained under monotonic loading.
- The cyclic load deformation history posses' locus of common points and locus of stability point.
- The Stress versus H/T ratio curve shows an increase in stress taken by the pier specimen, with increasing H/T ratio, attaining a peak value at the H/T ratio 3. Later on stress falls gradually with the increasing H/T ratio. This behaviour is found to be peculiar when compared to the ordinary brick masonry.
- The common point of Fly-Ash brick masonry is mainly dependent on the magnitude of the maximum stress and strain value of the previous cycle.
- The stress-strain envelope, common point, and stability point curves can be represented by a mathematical polynomial formulation. The correlation index of these equations with corresponding test data ranges from 0.94 to 0.986, which is indicative of good agreement.
- Stresses above the common point limit will lead to additional strains, while the stresses below this limit will give no strain increments.
- The peak stresses corresponding to the common point curve are about 80% of that corresponding to envelope curve.
- The peak stress corresponding to the stability point curve are about 60 % of that corresponding to envelope curve.
- Failure of masonry in compressive stress is mainly governed by failure of bond. Therefore, strength may be increased by improving bond strength either by mixing some adhesive material in mortar or by making corrugation on brick surfaces.

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