EXPERIMENTAL RESEARCH ON RESTORING FORCE CHARACTERISTICS OFLIGHT COMPOSITE STRUCTURE

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ABSTRACT: Pseudo dynamic test and pseudo static test were carried out on 1/2 scale model of light composite structure. By experimental research, hysteretic curves of base shear force and top displacement of the model structure were got, which come from various sections of pseudo dynamic test and pseudo static test, and through hysteretic curves of base shear force and top displacement of the model structure, skeleton curve of base shear force and top displacement of the model structure can be got. Outside line of all skeleton curves was skeleton curve of the light composite structure model. By analyzing and simplifying of the skeleton curve, finally restoring force model of the model structure was obtained, so reasonable dynamic analysis method of seismic design of the model structure can be offered. Research shows that as peak acceleration of inputting seismic wave continuously grows, especially when the peak acceleration reaching 800 gal, after the model structure reached plastic stage and in the stage of pseudo static test, the hysteretic curves become fuller and fuller, which shows that, with continuous emerging and propagation of crack, the structural rigidity losses gradually, and its energy dissipation capacity increases gradually. So earthquake fortification level of not collapse when hit by rarely occurred earthquake will achieve.

KEYWORDS: light composite structure, pseudo dynamic test, pseudo static test, skeleton curve, restoring force model

1. INTRODUCTION

Light composite structure[1] is a economic, light-weight, high-strength, energy-saving, seismic and complete new residential building structure. The main purposes of developing light composite structure are as follows: first, to diminish own weight of a building, promote its seismic behavior, protect the safety of individual life and property, secondly to reduce engineering cost and construction period, raise levels of building industrialization and thirdly, to fully utilize industry residual product, protect the environment, save the land, maintain the balance of nature.

Light composite structural system is developed in accordance with multistoried residential building that is widely used; it is developed based on various sandwich panels [2-6]. Developing light composite structural system is aimed at replacing masonry structure that is mainly used for multistoried buildings at present in China, and this structural system can be used for middle high-rise buildings in the future. Compared with masonry structure, light composite structure has following distinct advantages: ① Own weight of the structure is light and is about the half of brick-and-concrete composite construction(weight of brick-and-concrete composite construction is about 1,600kg/m^2, and weight of light composite structural system is about 800kg/m^2)[1], which largely makes seismic force bore by the structure small. ② Comprehensive economic index of the structure is

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better than that of brick-and-concrete composite construction[1]. ③ Thermal insulation effects of the external wall of the system are excellent. Compared with brick-and-concrete composite construction, thermal insulation effects can be raised by 200 percent or above [1] and can reach the building energy saving requirements put forward by the State. ④ Seven stories building 1/2 model test researching of light composite structural system shows that its load carrying and seismic behavior is much better than that of brick-and-concrete composite construction[7]. ⑤ The structure has achieved monolithic assembling of precast wall panels, that is, all connecting construction has achieved cast-in-place concrete connection, which has solved the historical problem of wind penetration and leakage of rain of horizontal connecting in assembled large panel structure and made assembled buildings greatly improved. ⑥ The structure can be designed simply, built into large bay, constructed conveniently and quickly, and is able to achieve building industrialization. From above, it is thus clear that, in developing of light composite structure, national policy of technology and economy, wall reformation, and thermal insulation and energy saving has been implemented, so prospects of replacing brick-and-concrete composite construction by light composite structure are very bright. If light composite structure is built into light composite short-leg shear wall structure, used as middle high-rise building, and compared with reinforced concrete frame structure, shear wall structure and light steel structure, it will bring more considerable economic benefit, so the structure has a very great developing future, and is suited to sustainable development strategy.

The structure is composed of light wall panels (including composite wall panel, perforated wall panel, and lightweight prestressed concrete wall panel) and light floor slab. Light composite structure uses the composite wall panels as external bearing walls, the perforated wall panels as internal bearing walls, the lightweight prestressed concrete wall panels as partition walls, large span prestressed concrete assembled monolithic perforated slab as floor slab (or cast-in-place reinforced concrete floor slab). Intersects between bearing wall panels put up embedded column, edges of doors and windows put up reinforcing rib, and intersects between bearing wall panel and floor slab put up embedded beam. Embedded column, beam and reinforcing rib are all reinforced by lightweight angle steel. Precast wall panels are connected and assembled to monolithic structure by embedded columns and beams; therefore, light composite shear wall structure with hidden frame is formed (or short-leg shear wall structure, used in middle high-rise buildings), as in Fig.1. Photograph of the model is as in Fig.2.

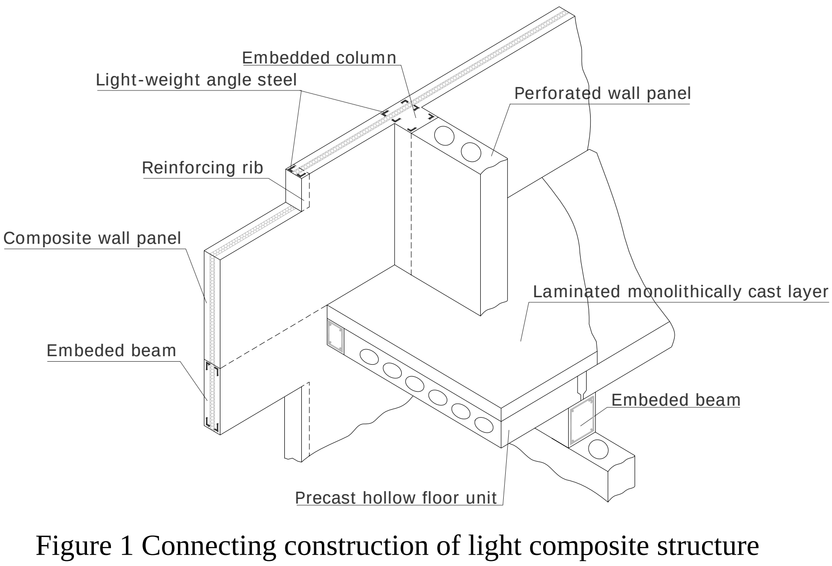

Figure 1 Connecting construction of light composite structure

Figure 2 Test model

As the cores in the structure, light composite wall panels are a new kind of bearing shear walls (or short-leg shear walls, used in middle high-rise buildings), which has good thermal and sound insulation effects. In these wall panels, two layer steel wire mesh which is connected by horizontal oblique tie bars is taken as the skeleton, in the middle, polystyrene foam plate put, and on each side of the polystyrene foam plate, concrete poured, therefore the wall panel is formed, as in Fig.3. As light composite structure is a complete new residential building structure, it is very important to study its seismic behavior. In order to study seismic behavior of the light composite structure, in the first place, restoring force characteristics of it should be studied

2. DESIGNING AND MAKING OF THE MODEL

2.1. Designing of the Model

Prototype of the light composite structure is 18.9 meter high, 7 stories, and 2.7 meter every story. Site classification is second kind. 1/2 scale model of two bays of prototype of the light composite structure was chosen to do experimental study, and load area of the model is three bays. Plan and elevation drawing of the model is as in Fig.4 and 5.

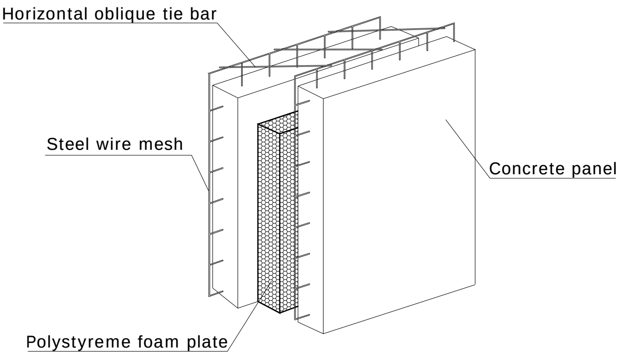

Figure 3 Construction of composite wall panel

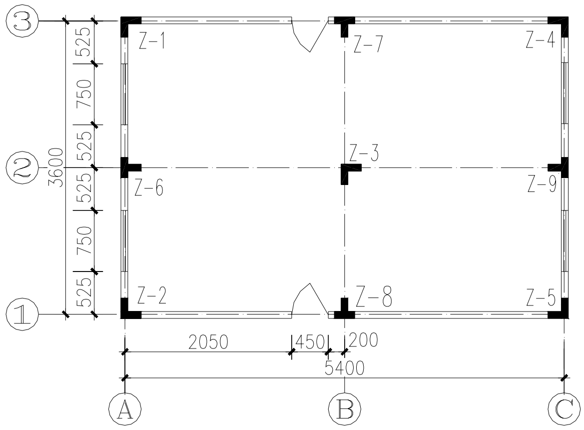

Figure 4 Plan drawing of the model

2.2. Making of the Model

Three floors from bottom of the model were constructed by cast-in-place construction, and four floors up of the model were constructed by cast in place and precast construction, i.e. the walls were prefabricated, and then the walls were connected to monolithic one by cast-in-place beams, columns and floor slabs(this test model use cast-in-place floor slabs). Bottom of the wall and the beam were connected by pin keys. Arrangement of pin keys and placing of steel bars are as in Fig.6 and 7.

3. LOADING METHOD

3.1. Vertical Load

Vertical load was applied by uniformly distributed sandbag on every floor, and it was applied at a time before test. According to the principle that axial compression ratio of the model is equal to that of the prototype, and moreover, considering influence of vertical seismic actions, vertical load was applied only 70 percent.

3.2. Horizontal Load

Through reinforced concrete reaction wall, horizontal load was applied on the test model at the third, fifth and seventh floor by three electro-fluid servo loader, in each floor, the horizontal load was distributed to the floor by transverse distribution girder, and the load was applied to the whole model structure by two embedded bolt 40mm in diameter. According to the seismic action calculation principle of "Code for seismic design of buildings (GB50011-2001)", using inverted triangular load distribution, in the light of equivalence principle of the bending moment and shearing force, the seismic action distribution was calculated by equivalent base shear method, and loading proportion of the third, fifth and seventh floor is 0.625:0.875:1.000.

Figure 5 Elevation drawing of the model

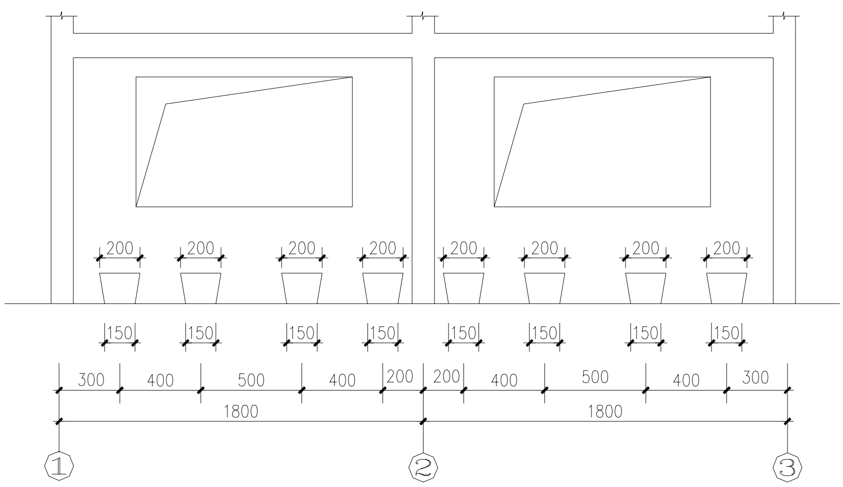

Figure 6 Arrangement of pin keys in the east wall

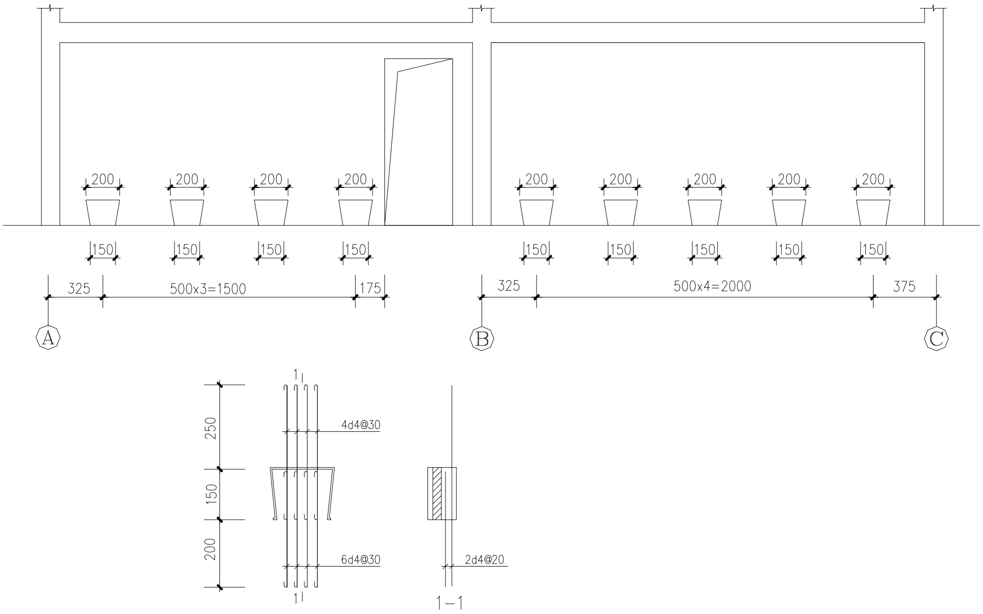

Figure 7 Arrangement of pin keys in the south wall

In different experimental stages, different loading control methods were used. First experimental stage was non-periodic repetitive loading, that is pseudo dynamic loading. In pseudo dynamic test, mass of the model structure was still inputted by 100 percent, and using EL-centro earthquake wave (N-S), it was inputted by maximum acceleration value of 50gal, 100gal, 200gal, 400gal and 800gal respectively until yielding of the model structure. The duration of seismic action was ten second, among them eight second being forced vibration and two second being free vibration, and step length was 0.01 second, which was calculated to the model respectively by similarity theory, earthquake wave acceleration value do not change, the duration of seismic action was 7.07 second, and test time expand to 100 to 200 times as much as that of actual earthquake wave acting. From yielding of the model structure, second experimental stage began, this stage was low cycle repetitive loading, that is pseudo static test. Pseudo static test was controlled by displacement, which was circulated in one times yielding displacement, two times yielding displacement, three times yielding displacement and so on, and each displacement was circulated three times until cyclic load peak value dropped down to 85 percent of ultimate load.

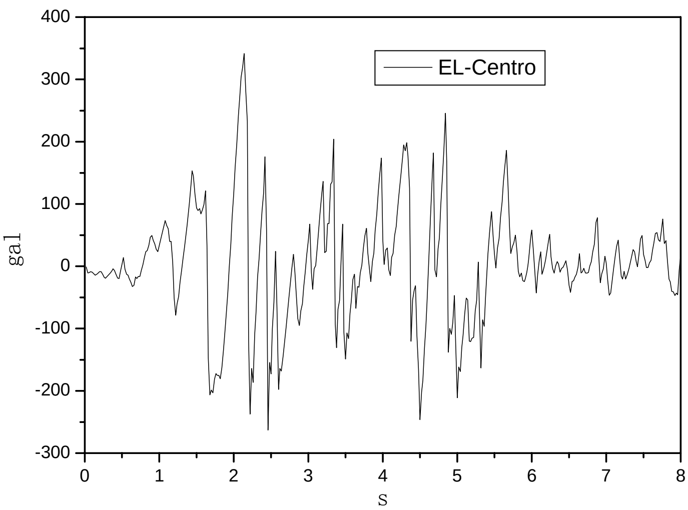

Figure 8 Source record of EL-centro earthquake wave

For comparative analysis of every kind of seismic response of the model structure, EL-centro earthquake wave (N-S) curve is given as Fig.8. As input earthquake wave in various test sections was adjusted only according to maximum acceleration value, EL-centro earthquake wave (N-S) in Fig.8 is only source record, and form of actual input earthquake wave was the same as the one in Fig.8, only the amplitude to change.

4. HYSTERETIC CURVES OF THE MODEL STRUCTURE

Hysteretic curves of base shear force and top displacement of the model structure were as in Fig.9, which come from input maximum acceleration value of 50gal, 100gal, 200gal, 400gal and 800gal in the pseudo dynamic test and pseudo static test. It can be seen from load-displacement curve in various test sections:

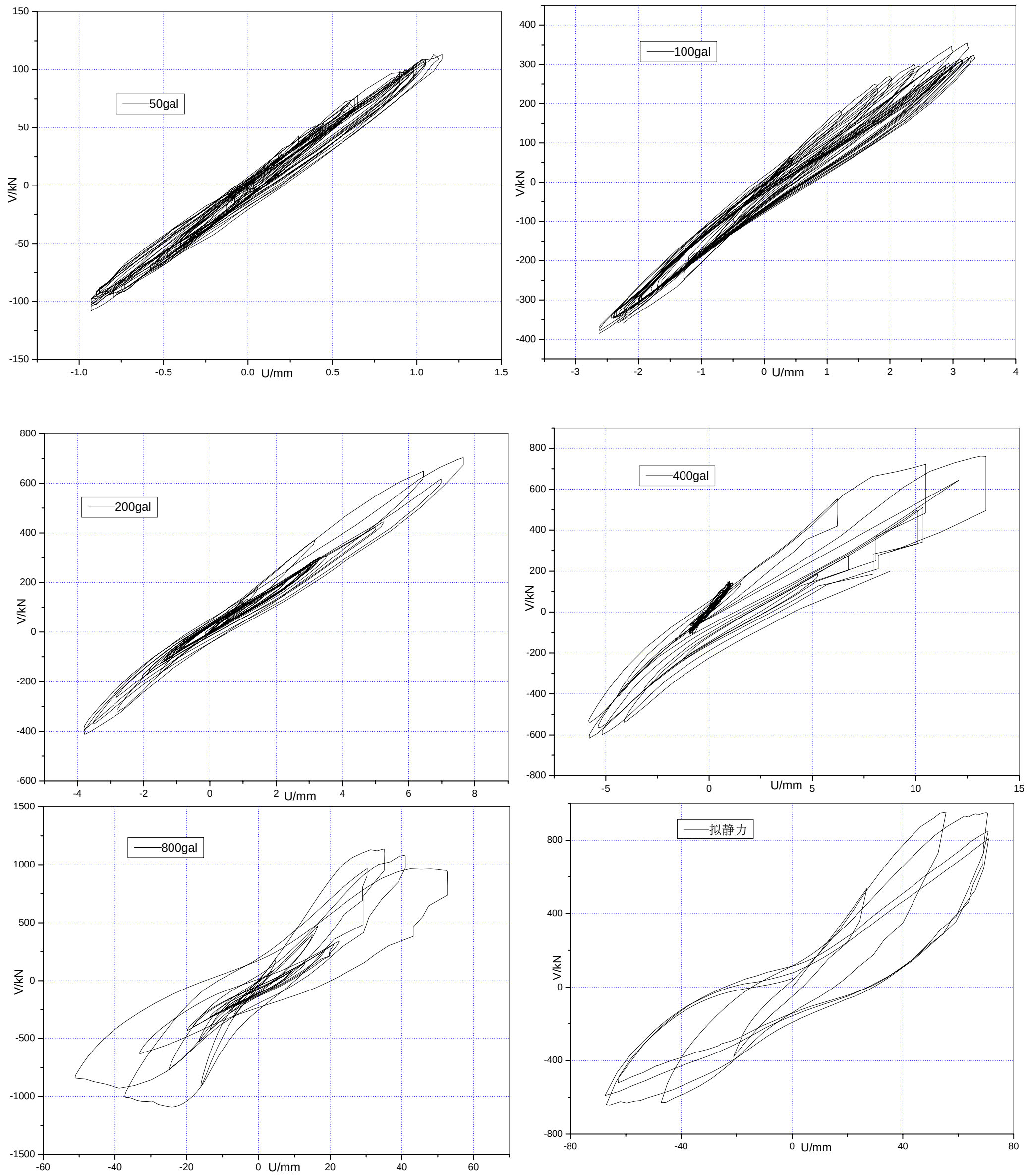

Figure 9 Hysteretic curves of base shear force and top displacement of the model structure

a. When earthquake wave of maximum acceleration value of 50gal, 100gal, 200gal was inputted, curves of base shear force and top displacement of the model structure is linear, which indicate the model structure is in elastic stage. When earthquake wave of maximum acceleration value of 400gal was inputted, the model structure is basically still in elastic stage, and the hysteretic curve is fusiform, showing a certain energy dissipation ability.

b. When earthquake wave of maximum acceleration value of 800gal was inputted, the model structure yielded and went into plastic stage, area of hysteresis loop enlarged markedly, and energy dissipation ability of the model structure greatly increased.

c. In pseudo static test stage, the hysteretic curve of the model structure is comparatively full, which shows a certain energy dissipation ability of the model structure in late plastic stage.

5. SKELETON CURVES OF THE MODEL STRUCTURE

Linking peak point of the hysteretic curve, skeleton curves of base shear force and top displacement of the model structure were got, which come from every section of pseudo dynamic test and pseudo static test. Outside line of all skeleton curves was skeleton curve of the model structure, as Fig.10. From skeleton curve of the model structure in various test sections, it can be very clearly seen:

a. When earthquake wave of maximum acceleration value of 200gal, 400gal was inputted, the model structure is still in elastic stage.

b. When earthquake wave of maximum acceleration value of 800gal was inputted, the model structure reached ultimate load and went into yielding stage.

c. When the model structure was in elastic stage, its horizontal bearing capacity was symmetrical on the whole in positive and negative direction. After the model structure reached plastic stage, its horizontal bearing capacity was no longer symmetrical in positive and negative direction, and its horizontal bearing capacity in negative direction somewhat reduced relative to that in positive direction, which was caused by heavy damaged beam over the door resulting in the left and right wall of the door not coactions well, after the model structure reached plastic stage.

6. RESTORING FORCE MODEL OF THE MODEL STRUCTURE

There are two constituent in restoring force model, skeleton curve and hysteretic model. In practical application, to simplify skeleton curve, making it use mathematical formula to express, that is called restoring force model. The restoring force model should express load point at first diagonal crack of the wall, yielding of the model structure and ultimate load. The restoring force model in this paper takes secant stiffness at first diagonal crack of the wall as initial elastic stiffness, secant stiffness from first diagonal crack of the wall till yielding of the model structure as post cracking stiffness, and secant stiffness from yielding of the model structure till reaching ultimate bearing capacity as post yielding stiffness. The story restoring force model can be deteriorative trilinear, as in Fig.11

7. CONCLUSIONS

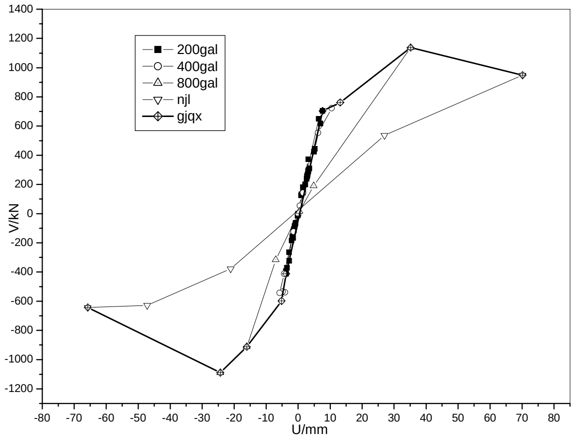

Figure 10 Skeleton curves of the model structure

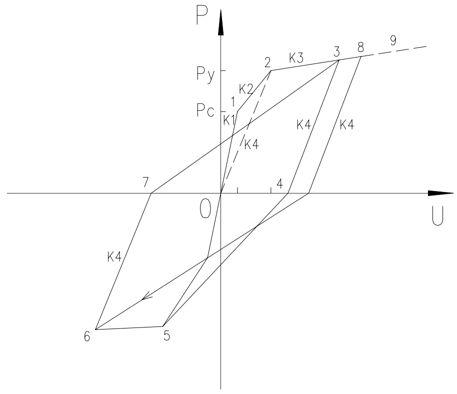

Figure 11 The story restoring force model of the model

1) From above analyzing, obtained the story restoring force model of light composite structural model can offer reasonable dynamic analysis method of seismic design of the model structure.

2) As peak acceleration of input seismic wave continuously grows, especially when the peak acceleration reaching 800 gal, after the model structure reached plastic stage and in the stage of pseudo static test, the hysteretic curves become fuller and fuller, which shows that, with continuous emerging and propagation of crack, the structural rigidity losses gradually, and its energy dissipation capacity increases gradually. So earthquake fortification level of not collapse when hit by rarely occurred earthquake will achieve.

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