

## FEM ANALYSIS OF LAMINATED COMPOSITE PLATE WITH CUT-OUT

**Sumantra Mandyal**  
M.Tech Scholar  
Department of Mechanical Engineering  
Rayat Bahra University

**Er Harpreet Singh**  
Dr Neeru  
Assistant Professor  
Rayat Bahra University

### 1. Introduction

Laminated fiber-strengthened composites are a hybrid composite class that combines fibrous composites with lamination processes. Fiber-reinforced materials are used in the layer. Every fibres were arranged in such that they provide desired characteristics and stiffness. Therefore, the main favoured viewpoint with fibre reinforced composite materials seems to be that suitable lamination processes may provide quality and rigidity in a particular direction. Polaris missile shells, fibreglass boat hulls, aircraft wing panels & body sections, tennis rackets, or golf club shafts are all examples of laminated fiber-reinforced composites.

Plates are flat, non-curved surface structures having a thin thickness in comparison to their various measures. Large plates are subjected to loading that make transverse plate bending. These were geometrically connected via straight or bended lines. Plates contain boundary conditions that are either free, simply supported, or fixed. Plates typically carry static and dynamic loads that are perpendicular towards the plate surface.

Plates' load-carrying capability is similar with that of bars or links to some extent. Depending on the flexural rigidity of both the structures, plates can be simulated by either a rigid beams or a network of cables. Plates are widely used in the construction sector.

Composite materials were developed and implemented in response to the demands of the high-rise building & aircraft industries. Its usage of laminated composites has shifted form secondary to major structural components as a result of advancements in the production technology and process. In the aerospace, marine, transportation, electrical, or chemical industries, fibre reinforced composites are becoming more popular. These composites were exposed to dynamic loads in many of these applications. Distinct kinds of holes may well be given in composite constructions for the purpose of assembling components and units within the structure, passing cables, inspection, maintenance, or connection to those other units. Around certain cuts, severe gradient stresses & deformations are generated. At higher vibration modes, the thickness parameter has an inherent impact.

Because of their light weight and high particular strength and stiffness, laminated composite plates were extensively employed in aeronautical structures (aircraft/spacecraft), civil engineering structures (liquid retaining structures), maritime vehicles (ships), or nuclear structures (nuclear plants). Skew laminated composite plates are becoming more common with in current era in composites, including in aircraft wings. Cutouts are being used primarily for connecting or assembling parts and for lowering weight. It also must satisfy practical criteria “such as ventilation, electrical or fuel lines, and damage inspection, among others”. This dynamic behaviour of structural components is just an essential issue for structural designers to investigate.

## 2. LITERATURE SURVEY

**Elharfi(2021)**developed and investigated a comprehensive review of advanced composite materials based on thermoplastic polymers, elastomer polymers and thermosetting polymers. **Thionnet(2021)**Lithium-ion rechargeable batteries are becoming more prevalent in the daily lives. As a result, high-capacity secondary lithium batteries are becoming a focus for study. For its extraordinarily high specific capacity, silicon has already been widely explored as an anode material for Li-ion batteries during the last decade. **Omran(2021)**The huge demand of plastic and polymeric materials, that continues to rise year after year, makes these major sectors for whom sustainability is still a critical consideration. As a result, making it just a clean and renewable sector is becoming a must.

**Sultan (2019)**Anisotropic and inhomogeneous composite materials and components require a range of mechanical and physical testing, under a variety of environmental circumstances High-force tension (tensile), compression, impact, flexural, shear, rheology, and fatigue are now all recognised standardised mechanical tests on composite materials. **Tong(2019)**Composites are also employed in the manufacture of stealth aircraft as radar absorbent materials (RAMs). To reduce the reflection incoming electromagnetic waves back to a radar system, stealth technology (ST) employs a mix of RAMs and geometry. **Cherkas&Rimshin(2018)**Throughout the course of the twentieth century, the building sector has seen the greatest amount of changes. Today's construction industry has a vast array of scientific advancements and new solutions which, in many cases, improve the quality of work and work process reliability of construction.

**Toor(2018)**examined Composites, in conjunction to nanotechnology, are an emerging area of research for developing multifunctional materials for space applications. For long-duration space

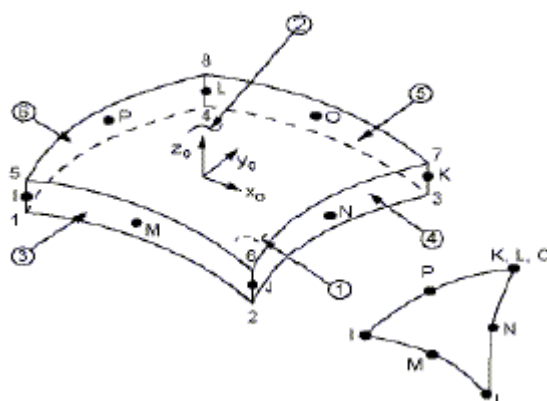
missions, weight reduction seems to be critical in order to increase payload accessories, that could only be accomplished besides replacing current metallic structures with composites.

**Mirji and Deshpande (2017)** The influence of cut out size and boundary condition here on fundamental natural frequency from both square plates cut-outs explored herein utilising various sizes of square mild steel plate and circular cut outs. ANSYS program has been used to analyse the plate's natural frequencies. **Vishnuchaitanya et. al. (2017)** The consequences of varying behaviour with various hole shapes while retaining the same length/height ratio & hole area ratio were investigated. One goal of this study is to perform the FEM analysis of plate with cut-out under different boundary conditions.

### 3. RESEARCH METHODOLOGY

#### *Finite Element Modelling*

The geometry of both the issue was blended in ANSYS using a generic composite laminate shell. The element type SHELL281 is being used for thin through moderately thick shell constructions. This is indeed a linear shell element containing eight vertices and six degrees of freedom at each node. These really are translation in the x, y, and z directions, as well as rotation around the x, y, and z axes. It's ideal for nonlinear linear, huge rotation, and/or large strain applications. It employs the very same theory and examines all of the aspects as SHELL181 does. Logarithmic strain and real stress metrics are used for the element formulation. The concept for the SHELL281 element is seen in Fig. 1.



**Fig. 1: A SHELL 281 Element**

### *Geometric Modelling*

The dimensions of the laminate (0°/90°/0°) considered for the present analysis is “l” and “b” are 500 mm. Length of minor axis (d) is = 100 mm.

### *Material Properties*

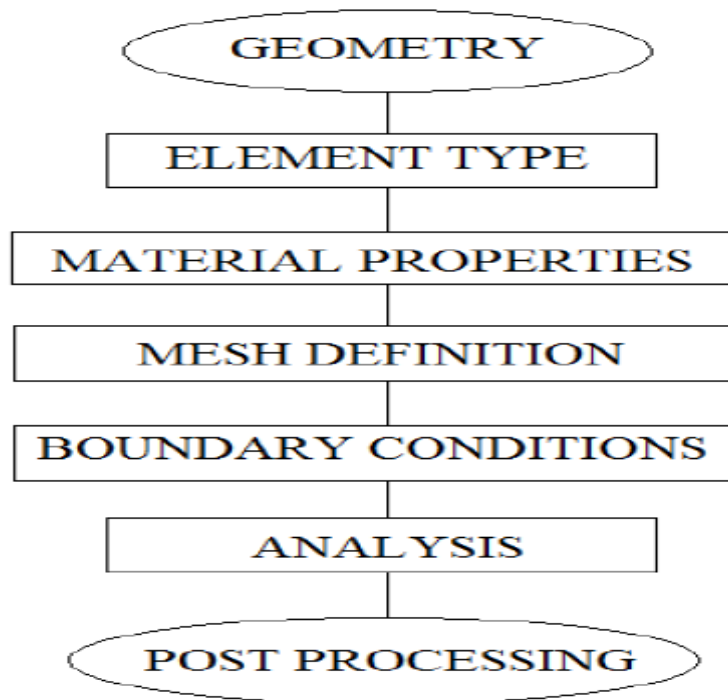
Those composite materials have been used in a wide range of technical and industrial applications. Because composite materials were rapidly being employed in a variety of industries, including civil, marine, aeronautical, and mechanical engineering applications, the prospect of economic development seems highly promising. The materials used to create the composite were carbon and epoxy.

**Table 1: Material properties of carbon-epoxy**

Material Constant	E <sub>x</sub>	E <sub>y</sub>	E <sub>z</sub>	G <sub>xy</sub>	G <sub>yz</sub>	G <sub>xz</sub>	ν <sub>xy</sub>	ν <sub>yz</sub>	ν <sub>xz</sub>	ρ
Values	172.72 GPa	6.909 GPa	6.909 GPa	3.45 GPa	3.45 GPa	1.38 GPa	0.25	0.25	0.25	1500 Kg/m <sup>3</sup>

### *Modal Analysis*

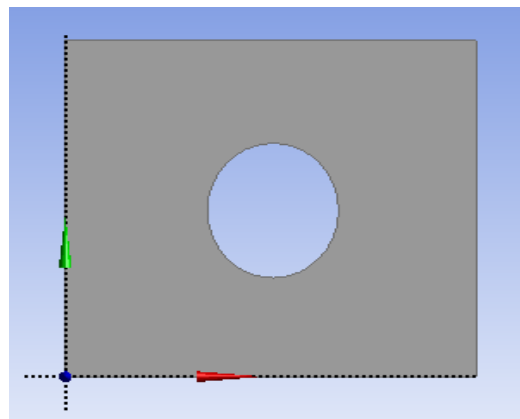
In ANSYS, a modal analysis is a linear analysis. There are indeed a variety of mode extraction algorithms available, including Block Lanczos, Supernode, PCG Lanczos, reduced, unsymmetric, damped, and QR damped. This present study employs the Lanczos Block. It's being used to solve symmetric eigenvalue problems with a lot of eigenvalues. The sparse matrix solver is used in the same technique. Similarly, each approach has its own set of constraints.



**Fig. 3** Layout of modeling procedure

#### *Modeling Of Square Laminate Plate*

The plate was modelled with the help of ANSYS and the ACP design modeller. The size of the plate has been used to make the model.

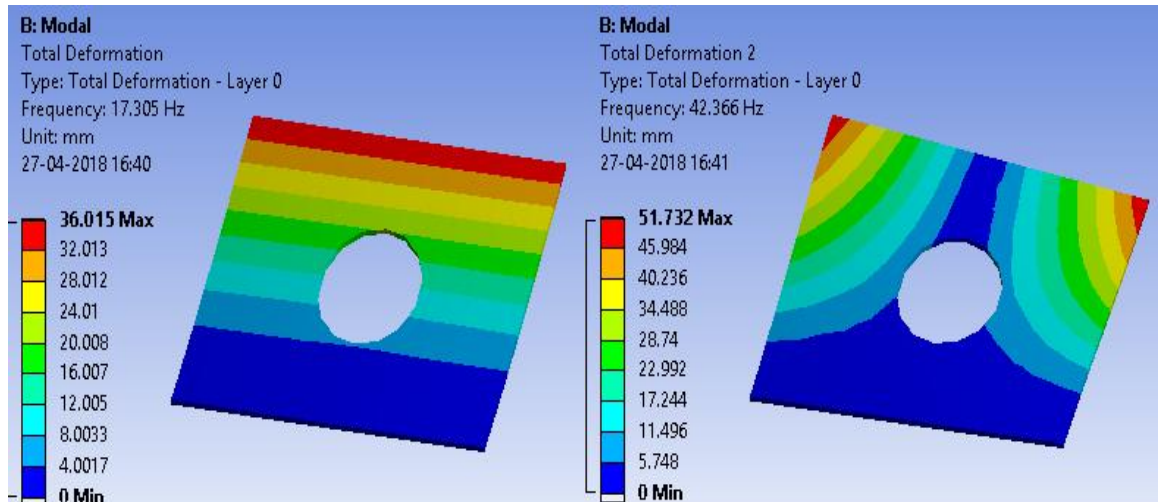


**Fig. 3** Square laminate plate in design modeller

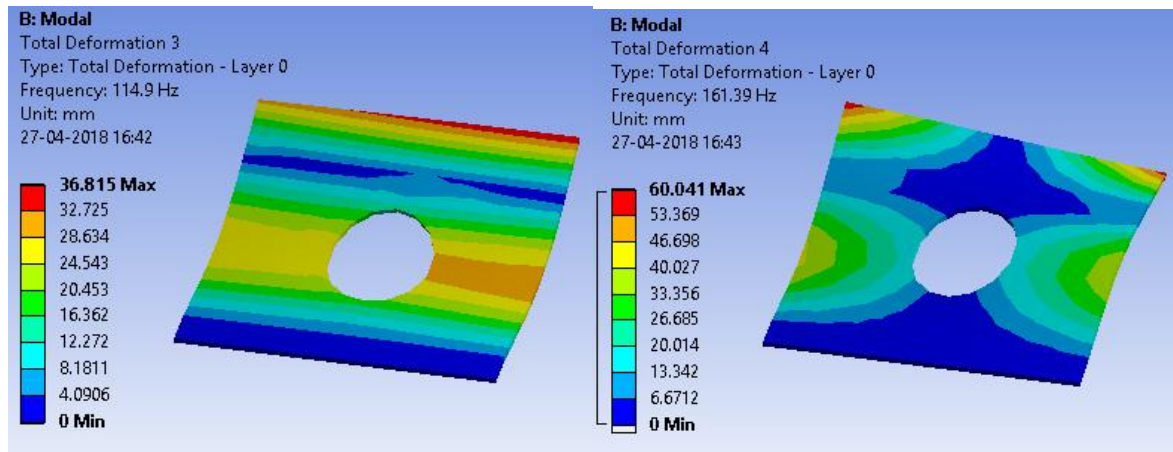
## **4. Results and Discussions**

### *Effect Of Boundary Conditions*

Figure depicts the mode forms corresponding towards the frequency for the various boundary conditions mentioned previously.

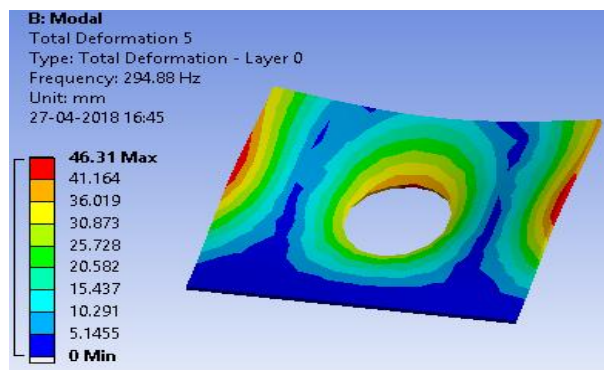


**Mode 1 Mode 2**



**Mode 3**

**Mode 4**



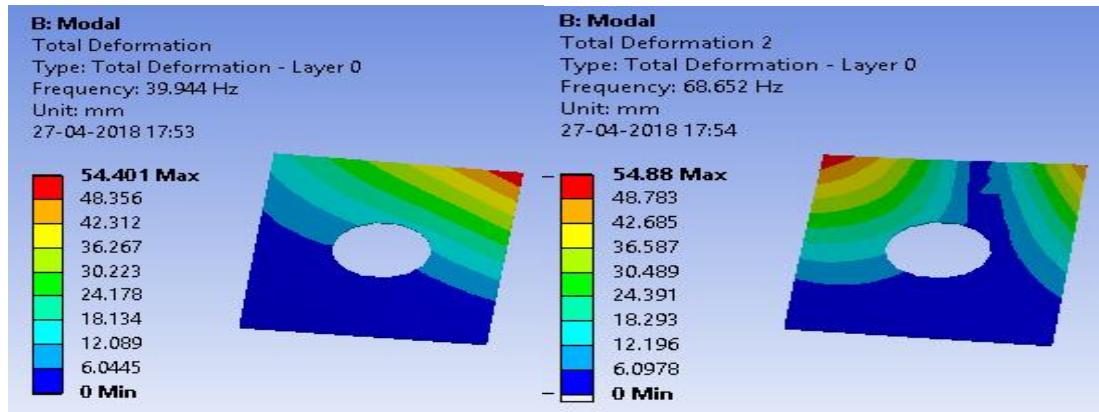
**Mode 5**

**Fig 4: Mode shapes for a square cross-ply ( $0^{\circ}/90^{\circ}/0^{\circ}$ ) plate with a central elliptical hole for the boundary condition CFFF**

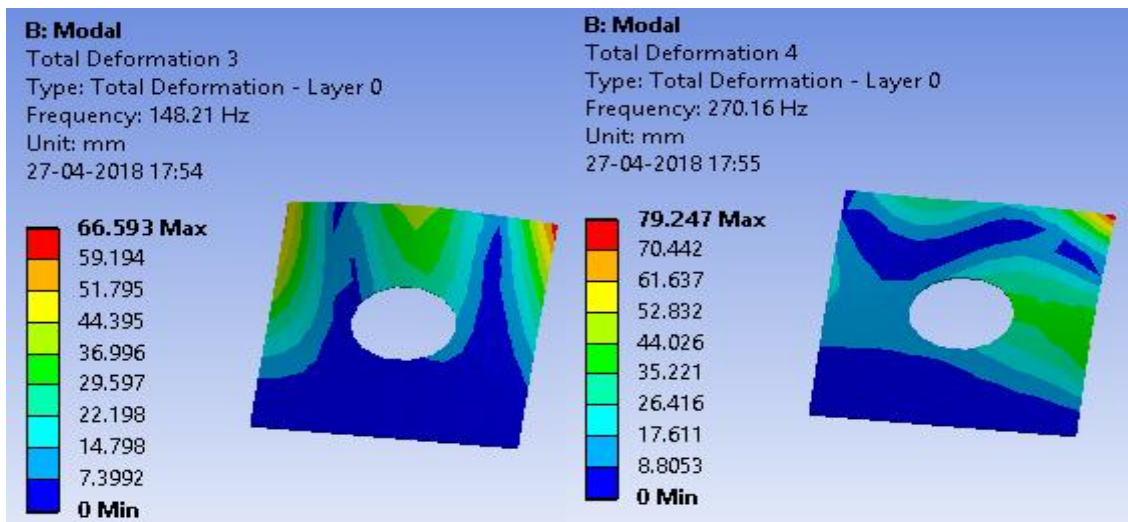


**Effect Of Fiber Orientation**

In just this section, the first five natural frequencies are calculated using various fibre orientations, ranging from (15°/-15°/-15°/15°) to (60°/-60°/-60°/60°). Below are the natural frequency values for the very first five modes.

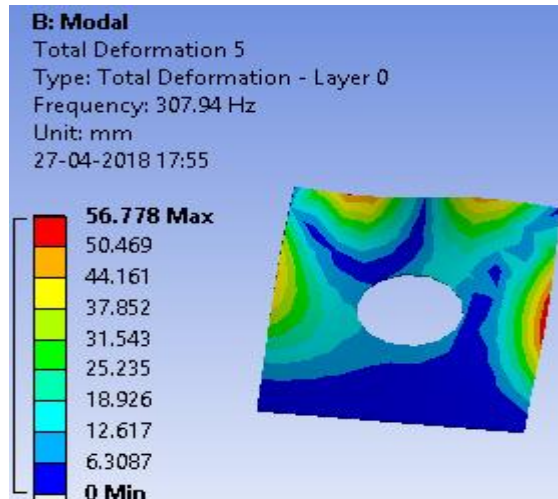


**Mode 1 Mode 2**



**Mode 3**

**Mode 4**

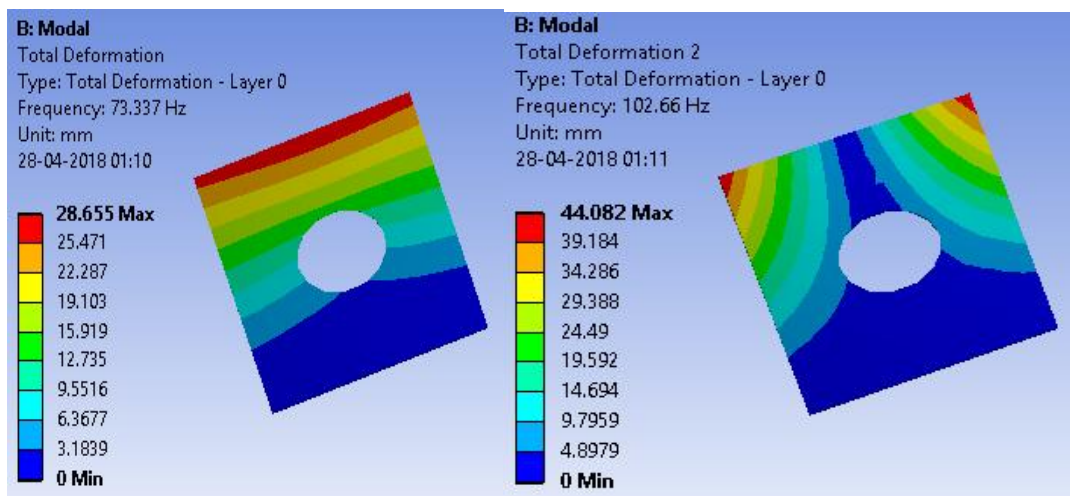


**Mode 5**

**Fig.5: Mode shapes for a square cross-ply (15°/15°/15°) plate with a central elliptical hole for the boundary condition CFFF**

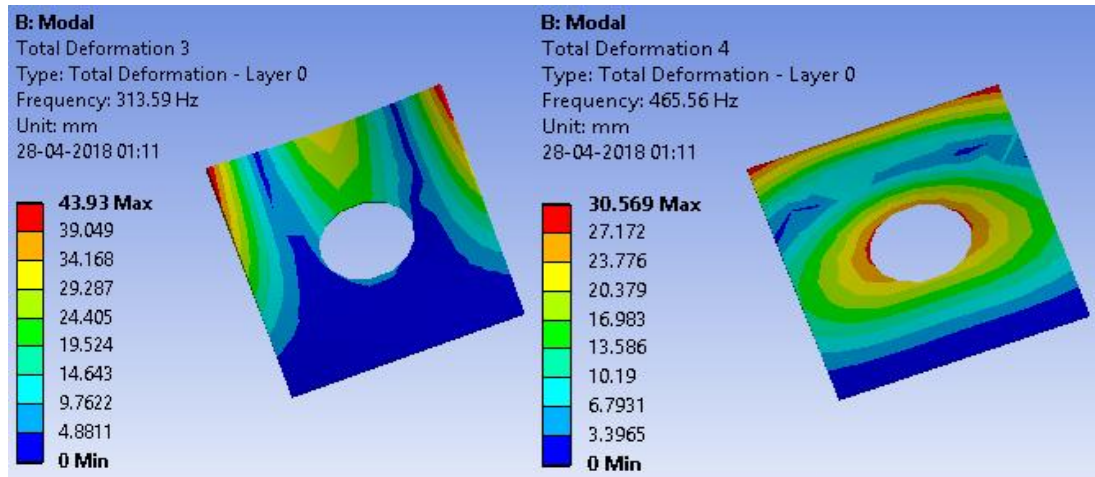
*Effect Of No. Of Layers*

The aforementioned findings were achieved with the three-layer cross-ply plate that was symmetric. The fluctuation in natural frequencies the with number of layers of laminates were investigated in this section for four-layer or eight-layer cross-ply plate, while keeping thickness of the square plate constant.



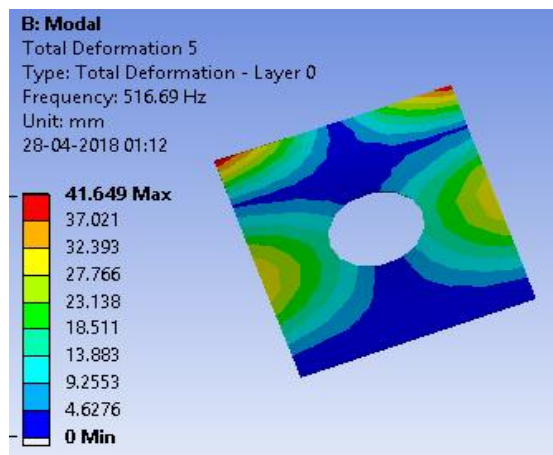
**Mode 1 Mode 2**





**Mode 3**

**Mode 4**



**Mode 5**

**Fig. 6: First five natural frequencies (Hz) for a CFFF square laminate with 5 layers**

#### 4. CONCLUSIONS

As a result, the free vibration of such a laminated composite plate is investigated for various boundary conditions, layer counts, various fibre orientations. The cutout plate has discovered to be responsive to imposed boundary conditions. The natural vibration for CCCC plate is higher with fiber orientation ranged from  $(15^\circ/-15^\circ/-15^\circ/15^\circ)$  to  $(60^\circ/-60^\circ/60^\circ/-60^\circ)$ . The fundamental frequencies of fibres was found to increase with the angle of orientation of the fibres. Regardless of boundary conditions used, the frequencies of the laminated composite plate increase with the number of layers increased.

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