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Chapter 4

Enhancing seismic resilience of telecommunication tower using response spectrum analysis: A study with and without viscous dampers

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Abstract:

In regions with varying seismic activity, maintaining communication networks during earthquakes relies strictly on the seismic resilience of telecommunication towers. This study assesses the effectiveness of viscous dampers in enhancing seismic performance in telecommunication towers using response spectrum analysis. Different seismic zones like II, III, IV, and V along with different soil conditions viz., hard, medium, and soft soils are considered for the analysis. Its effects on some of the main structural parameters such as base shear, story displacement, and story drift are computed. Base shear is the total seismic force acting horizontally at the base of the tower. It is presented with and without viscous dampers. Results show a significant reduction in the base shear of the towers strengthened with dampers, though this reduction is more pronounced at higher seismic zones and softer soils due to the increased magnitudes of seismic force. This decrease is also most significant in greater seismic zones as well as softer soil conditions, wherein more significant movements are experienced by the tower. In addition, story drift, that refers to the relative displacement between adjacent floors, is significantly reduced with viscous dampers and thus, there is the possibility of fewer opportunities for non-structural damage along with the overall enhancement of the stability of the tower. The outcomes focus much on the need to include dampers in structures that could effectively control seismic forces, limit structural displacement and drift, and ensure operational reliability during earthquakes.

Keywords: Viscous Dampers, Base Shear, Lateral Story, Story Displacement, Story Drift, Seismic Zones.

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4.1 Introduction

Such infra elements provide communication networks and essential services in emergency communication, broadcasting, and data transmission (Amin, et al., 1971). Towers located in regions where earthquake activity has been reported or experienced are vulnerable to the destructive power of earthquakes (Gupta, 2017). which may interrupt communication services and render these towers structurally weak (Gupta, 2017). There is an increased number of seismic events all over the world (Kanazawa et al., 2000). Telecommunication towers are important in achieving connected networks (Kanazawa et al., 2000). As such, their seismic resilience has to be enhanced, whereby these towers remain functioning and safe during and post-earthquakes (Kaul, 1978). The viscous damper is one promising method of seismic performance (Kaul, 1978).: such dampers dissipate seismic energy and reduce the force transmitted to the structure (Kaul, 1978).

This paper compares the performance of structures with ad without viscous dampers in providing seismic resilience to telecommunication towers using response spectrum analysis (Gupta, 2017). Response Spectrum analysis is a commonly used tool to evaluate the dynamic responses of structures subjected to seismic loading (Kiureghian, A. D.1981). It is an efficient method to evaluate the maximum likely responses, such as base shear, story displacement, and story drift without necessitating complex time-history simulations (DER, 1981). Utilizing this methodology (DER, 1981), the study evaluates how viscous dampers impact the structural behavior of a telecommunication tower within differing seismic zones and in varied soil conditions (DER, 1981). Explainable Artificial Intelligence (XAI) frameworks contribute to the transparency and trustworthiness of AI models, which is crucial for high-stakes fields such as seismic analysis where understanding decision processes is essential (Patil et al., 2024; Rane et al., 2024a; Rane et al., 2024b; Rane & Paramesha, 2024; Rane & Shirke, 2024).

It represents the total horizontal force developed along a structure due to ground shaking and is considered one of the most important parameters in seismic design (Kiureghian et al.,1993). However, the magnitude of base shear depends not only on the seismic zone but also on the height and stiffness of the tower and soil conditions (Singh et al., 1983). Base shear tends to be higher in higher seismic zones (Singh et al., 1987), which present stronger expected ground motion and thus exercise greater demands on the structure. On the contrary (Singh et al., 1987), softer soils amplify the seismic forces while harder soils reduce base shear values (Singh et al., 1987). The viscous dampers have proved to reduce the base shear values by consuming and dissolving seismic energy (Da Silva et al., 2005), which reduces the total values the forces seek to develop in the tower (Da Silva et al., 2005).

Story displacement is a lateral movement that can take place in one or more of the stories or segments of the tower during an earthquake (Bhosale et al., 2012). Such displacement beyond a certain limit may lead to damage from sources such as misalignment of antennae or other equipment (Rajasekharan et al., 2014). It also compromises the tower's functionality during and after seismic events (Bhosale et al., 2012). Seismic forces and tower stiffness vary with seismic zone and soil type, and thus story displacement is influenced by dynamic characteristics of the structure (Singh et al., 1987). Viscous dampers will help in reducing story displacement by damping the vibrational energy and that way the laterals are limited in movement of the tower preventing excessive displacement (Majeed Al AA, H. A. I. 2016). This should be highly accomplished in softer soils and higher seismic zones where movements of towers are pronounced (Pathrikar et al., 2017).

The other critical indicator of relative displacement between successive stories or structural members is story drift (Bhosale et al., 2012). High story drift usually occurs with potential damage to the structural elements, especially when the drift exceeds the permissible limits (Kaul, M. K. 1978). In this connection, high drift has the potential for causing inelastic deformation and may be detrimental to the long-term stability of the tower (Amin, M et al., 1971). In higher seismic regions with relatively soft soil conditions, the story drift would be more pronounced due to increased seismic forces and also because of the relative flexibility of the structure (Amin, M et al., 1971). The introduction of viscous dampers diminishes story drift (Gupta, A. K. 2017), manages the overall lateral movements of the tower (Gupta, A. K. 2017), and ensures better performance with only a minimal chance for the structure to suffer structural damage (Gupta, A. K. 2017).

The performance of telecommunication towers under seismic loading is very much affected by soil conditions (Kanazawa et al., 2000). Soils are divided into three categories depending on their stiffness: hard, medium (Singh et al., 1987), and soft soils. Hard soils typically result in lower seismic amplification and base shear (Singh et al., 1987) , displacement, and drift, whereas soft soils amplify the seismic waves (Kaul, M. K. 1978), resulting in higher forces and larger displacements (Singh et al., 1987). This paper examines the influence of viscous dampers on the performance of tower structures under different soil conditions (Kiureghian, A. D.1981). revealing how these dampers could be used in attempts to counteract the adverse influences of soft soils and help improve seismic resilience in towers (Kiureghian, A. D.1981).

4.2 Viscous Dampers

Viscous dampers are generally considered to be one of the best methods of suppressing dynamic vibrations in structures affected by the forces of earthquakes, wind loads, and even other dynamic excitations (DER, K. 1981). Generally, such devices work by dissipating the amount of energy introduced within a structure through external forces that may range from (Da Silva et al., 2005), but are not limited to, effects of earthquakes, wind forces (Da Silva et al., 2005), and traffic movements (Da Silva et al., 2005). Viscous dampers enhance general performance and strength of design requirements for buildings, bridges, and other civil engineering structures such as telecommunications towers (Bhosale et al., 2012), mainly through the reduction in vibration amplitudes and control of structural response (Bhosale et al., 2012).

Viscous dampers, therefore are supplementary elements in the seismic design process (Bhosale et al., 2012), enhancing a structure's capability to resist the dynamic load exerted by earthquakes (Kaul, M. K. 1978). Traditional methods include alterations made to increase structural stiffness, or adding reinforcement; however although they may be effective (Kanazawa et al., 2000), they tend to increase cost, or weight (Kanazawa et al., 2000). Viscous dampers, however, have inherent properties and tend to reduce seismic energy dissipation in the most cost-effective and efficient means of reducing mass without significant rises in the structure's mass (Pathrikar et al., 2017).. Thus, optimized designs well balanced in terms of performance, safety, and cost-effectiveness (Singh et al., 1987). Viscous dampers are proven technology in enhancing the seismic resistance of a structure through dissipating dynamic forces like earthquake. Such devices diminish the shear generated on the foundation (Pathrikar et al., 2017)., decrease story displacement, and control story drift (Pathrikar et al., 2017)., thus making telecommunication towers and important critical infrastructure survive seismic events in safety and functionality (Pathrikar et al., 2017).. The rising application of viscous dampers in contemporary seismic design has been an indicator of how these devices seriously contribute to improving the structural performance and the risk of failure in earthquake-prone regions (Pathrikar et al., 2017)..

4.3 Material property and modelling

This chapter develops and validates the structural model at both linear and non-linear static tools for the evaluation of chosen mathematical models. To assure the accuracy and practicality of this research, it did require basic assumptions with relevant geometric considerations as seen in this dissertation with the necessary material parameters. This extremely mathematical model captures the non-linear behavior of the parts in the structure. In this work, the elastic flexural hinges do contain the elements of plasticity to model the frame parts just to realistically display the material's behavior under stress. This chapter briefly describes the process of non-linear modeling of framed structures including techniques that have been applied to realistically represent inelastic reactions.

The object of this research work is to explore actual life service and the performance of structures for telecommunication towers under seismic loading. A simple design approach is utilized here with minimal complications to the model in order to have a realistic response from the structure. The paper aimed at comparing seismic behavior between two models of the telecommunication tower: one model without a damper and one model with a damper, to determine differences in seismic behavior between them by making use of the effect of earthquake loading using SAP 2000 version 18.2.4.

Height is set at 56 meters, tapering design, with the base at 10 x 10 meters and tapering down to 2 x 2 on top. Models are prepared structurally; dampers were placed in one instance in order to furnish the real comparison of seismic performance and realistic response characteristics of the tower with and without damping.

Indian standard rolled steel angle section for tower construction Here ISA-200x200x25mm column leg and bracing of tower is done using ISA 100x100x12mm. The stress stain relationship that has been used as per IS:800:2007; Basic material properties for the tower structure: As shown in Table.

Table 4.1 Shows the modal description for telecommunication tower

Sl.No	Parameters Used For Modelling	Description Of Tower Model
1.	Plan dimension of model in m	10X10m
2.	Top plan dimension of model in m	2X2m
3.	Height of tower	56m
4.	**Material Property**	
5.	Leg member	ISA-200X200X25mm
6.	Bracing member	ISA-100X100X12mm
7.	Bracing type	Concentric and eccentric
8.	Types of soil	Hard, medium & soft soil
9.	Seismic zones	II, III, IV & V

10.	Response spectrum (R)	4
11.	Importance factor (I)	1
12.	Grade of steel	Fe-345 Hot ruled steel section
13.	Plat form load on tower (kN/m^2)	1
14.	Stiffness of damper (kN/m)	1645

Antennas Loading On Towers

Sl. no	Item	Quantity	Diameter (m)	Weight (kg)
1.	CDMA	8	0.26X2.5	20
2.	Microwave	2	1.2	77
3.	Microwave	3	0.6	45
4.	Microwave	4	0.3	25

Total joint load consisted on telecommunication tower is 50kN

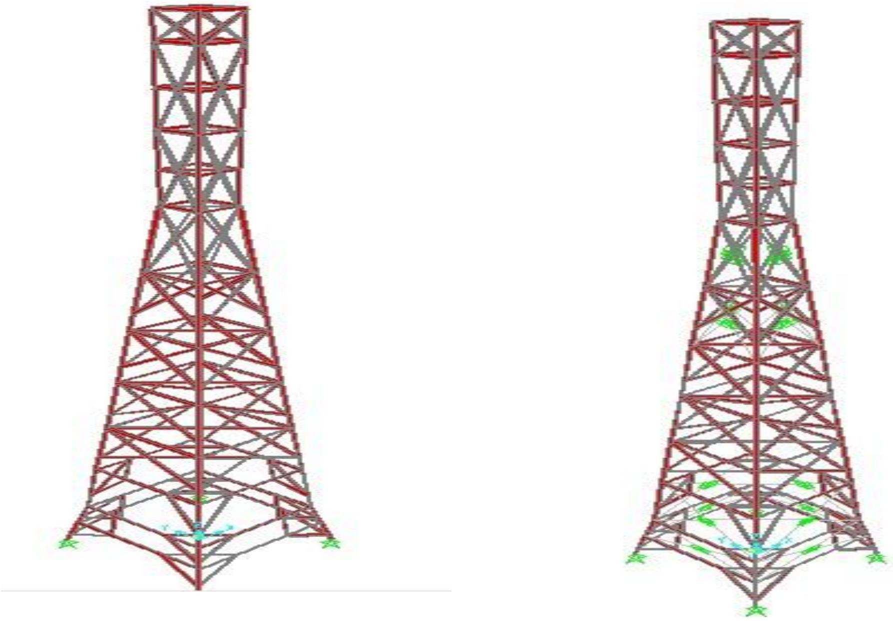


Fig. 4.1 Telecommunication Tower with and without Dampers

4.4 Response Spectrum Analysis

Total design seismic force is determined along any principle direction is given in terms of horizontal seismic coefficient and seismic weight of the structures IS 1893: 2002 (Part 1).. The design horizontal seismic coefficient is calculated by using expression as per IS1893-2002. Ah= (Z/2)*(I/R)*(Sa/g) IS 1893: 2002 (Part 1). Where Z= seismic zones, zone-II, zone-III, zone-IV & zone-V.

I= importance factor.

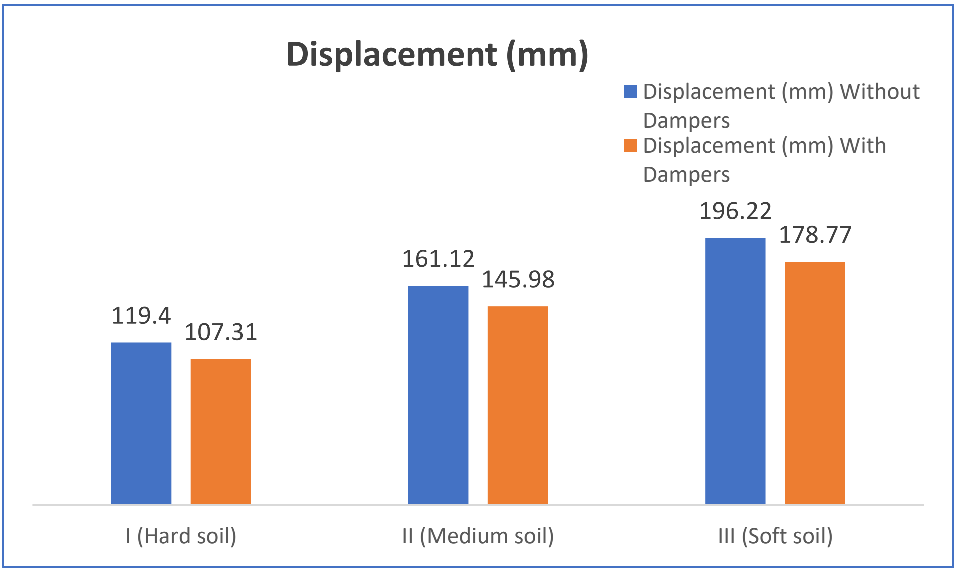
R= response reduction factor based on lateral load resisting system.

Sa/g= depends on nature of foundation soil like hard soil, soft soil & medium soil. Time period is calculated for steel structure is T_a=0.085*h^0.75 IS 1893: 2002 (Part 1).

4.5 Results and Discussion

Table 4.2 Displacement values for different types of soil

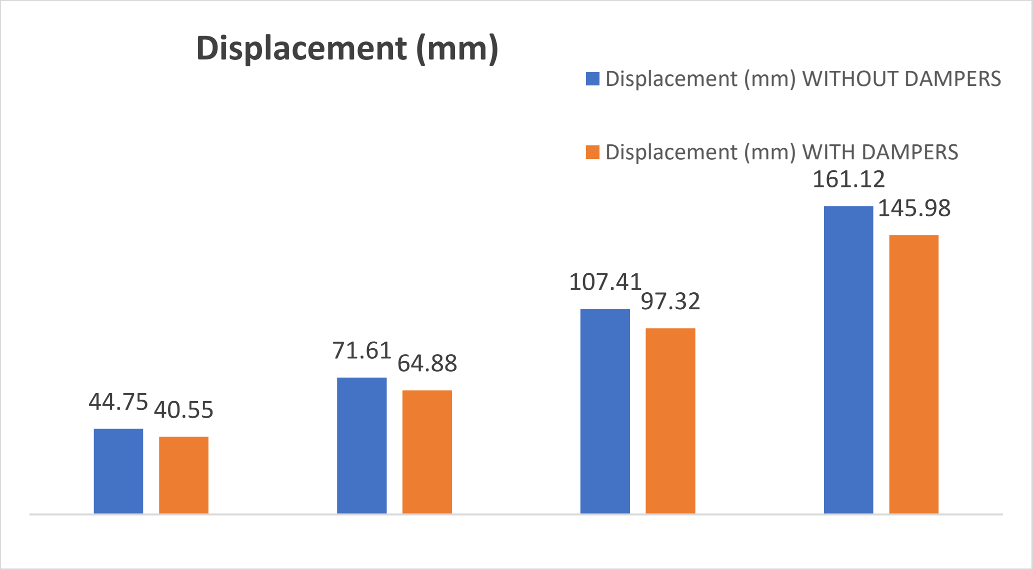
	Displacement (mm)	
Soil Type	**Without Dampers**	**With Dampers**
I (Hard soil)	119.40	107.31
II (Medium soil)	161.12	145.98
III (Soft soil)	196.22	178.77



As depicted in the above table, it is seen that displacement value increases from hard to soft soil in the case of both with and without a damper. The percentage variation for displacement value from hard to soft soil is 40 percent for without a damper as well as for with damper analysis. Therefore, it can be concluded that the types of soil cause a major role for the variation in displacements in the analysis. Above figure plotted displacement vs type soils along vertical and horizontal direction respectively, displacement values varies lineally for different types of soil and maximum % of reduction in displacement from medium to hard soil is 40% for both with and without damper. Displacement values decease for without damper compared to with damper & it varies 10% for hard soil.

Table 4.3 Displacement values for different types of zones

	Displacement (mm)	
Types Of Zones	**Without Dampers**	**With Dampers**
II	44.75	40.55
III	71.61	64.88
IV	107.41	97.32
V	161.12	145.98



From the table above, for both without and with damper, displacement versus types of zones shows that the variation of displacement from zone II to zone III region is 38% while from zone III to zone IV is 33% and maximum reduction of displacement from zone II to zone V is 72.22% for both without and with damper tower model. The variation of displacement for all zones is 9.4% for without and with damper. As shown in the above plot that, displacement result variation with respect to different types of zones varies parabolic. The maximum % of reduction in displacement is 72.22% from zone-II to zone-V and for all zones without and with damper values varies up to 9.4%.

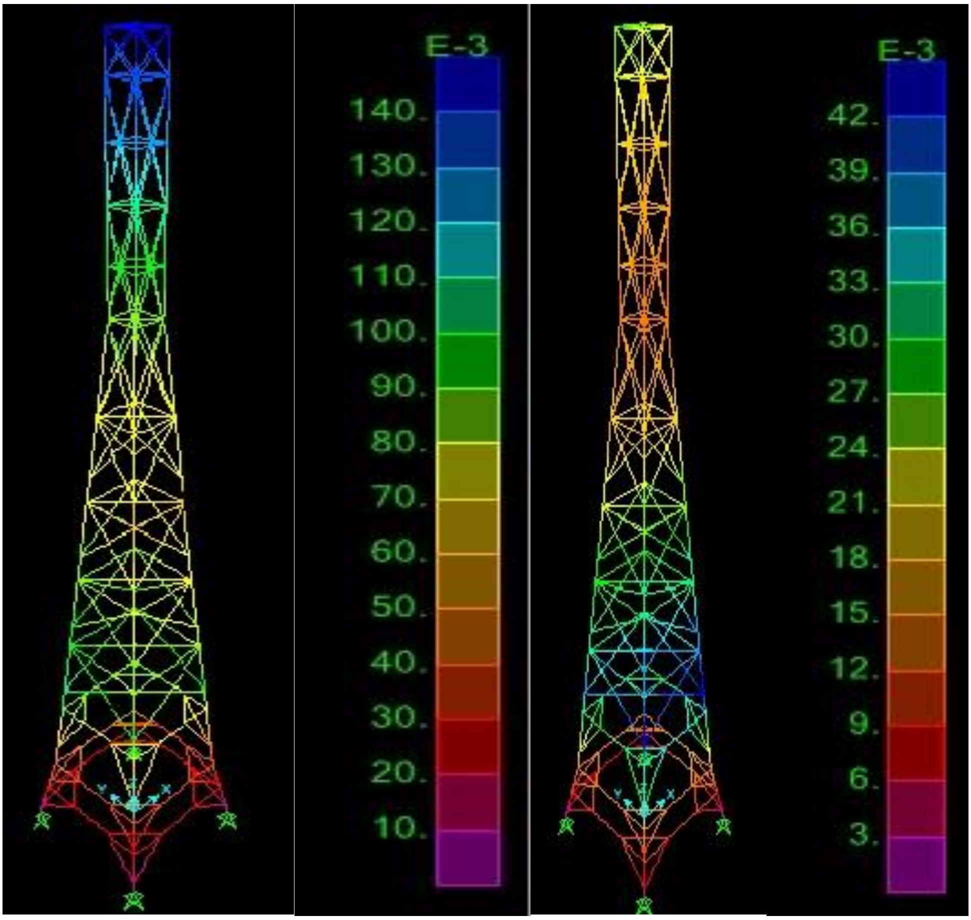


Fig 4.2 Deformed shapes for tower without damper for SPECX & SPECY

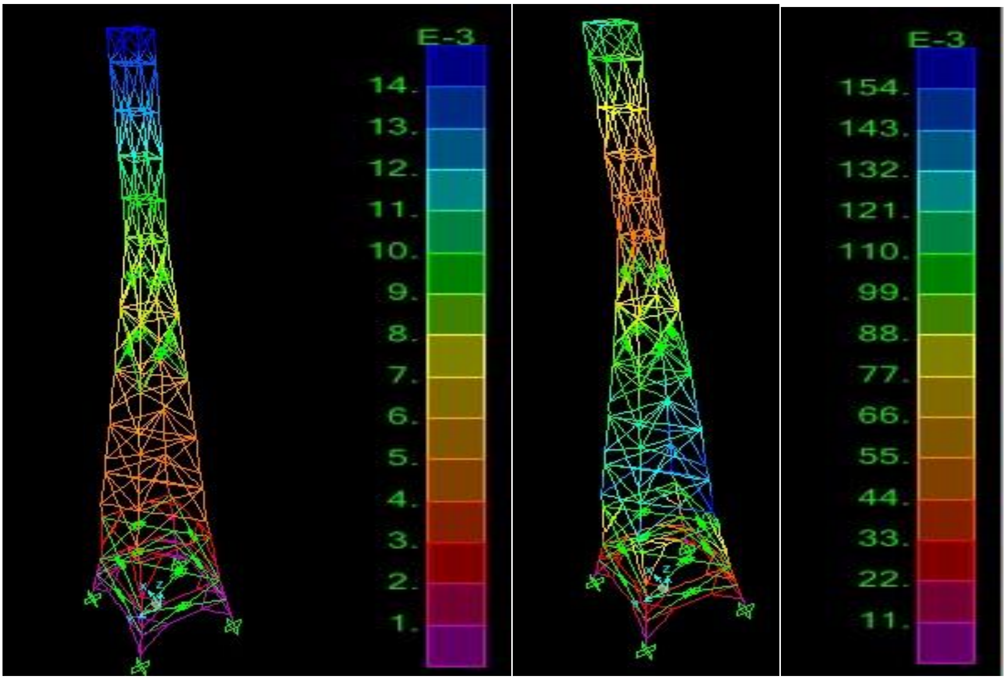


Fig 4.3 Deformed shapes for towers with damper SPECX & SPECY

4.6 Conclusions

The response spectrum analysis to be applied to the telecommunication tower is reflected in the inclusion of viscous dampers. The soil structure displacement significantly reduced with all types of soils. For example, under hard soil, Type I, the displacement would be 119.40 mm, and such would reduce to 107.31 mm, showing a reduction of about 10%. It reduces to 161.12 mm in medium soils (Type II) and to 178.77 mm in soft soils (Type III). These reductions indicate that viscous dampers are efficient in the mitigation of seismic-induced displacements of the tower, enhancing stability and making it more resilient towards seismic episodes, particularly within the softer condition, where the effects of seismic forces are more pronounced in the softer soils. The analysis of the response spectrum for the telecommunication tower is such that the inclusion of viscous dampers reduces the displacement considerably at various seismic zones. The displacement in Zone II comes down from 44.75 mm to 40.55 mm, whereas in Zone III, it comes down from 71.61 mm to 64.88 mm. For Zone IV, displacement comes down from 107.41 mm to 97.32 mm and in Zone V, the displacement comes down from 161.12 mm to 145.98 mm. These results prove that viscous dampers are highly efficient in smoothing seismic displacements and increase the structural stability and resilience of the tower for different seismic intensities.

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