PGA STUDIES FOR THE SPECIFIC SITES OF BATHINDA REGION (PUNJAB)

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Abstract:

Estimation of Ground response analysis (GRA) is an important task in designing structures as sever conditions at the surface may occur due to the amplification of seismic design coefficient as compared to the value of bed rock level. very few studies have been carried out to characterize amplification of the Bathinda region soil and very limited attempts have been made to measure the dynamic properties for deeper depths. In the current study, one dimensional equivalent linear ground response analysis using DEEPSOIL has been conducted for 5 sites of Bathinda region using Uttarkashi (1991) earthquake motion. Input ground motion is taken from the worldwide-recorded database based on the seismicity of the region. Shear modulus was calculated using correlation between G and SPT –N Value. The peak ground acceleration was calculated using different ground motion and it has been detected that when Uttarkashi Earthquake motion is considered for the analysis, the PGA values at the ground surface for the sites are found less than the values mentioned in the relevant code.

1. INTRODUCTION

Natural tragedy is unpredictable and it is not possible to get full control over them. The history of human civilization reveals that man has been combating with natural disaster from its origin. but natural disaster like flood, cyclone, earthquake, effects property and life.

Earthquake can be explained as it is the process of rupture at the source which causes movement of seismic waves through underlying rock. seismic wave usually travels several kilometers of distance in rock but a few meters in soil, so the soil has a vital role in determining the characteristics of ground motion and its analysis. The local soil conditions have a reflective impact on the ground reaction at the time of earthquake. Earthquakes take place mostly along geologic faults and narrow zones. About 50,000 earthquakes are noticed without the aid of instruments which occur annually over the entire Earth. which of these, approximately 100 are of sufficient size to produce extensive destruction. Very great earthquakes occur on average about once per year. Over the centuries they have been responsible for millions of deaths and a huge amount of damage to property. Because of the moments of earthquake motion the bedrock motion is significantly modified at the ground surface. This happens due to the presence of local soil layers above the bedrock beneath the site of interest. Therefore, identification of soil layers susceptible to ground motion amplification is an important task for accurate assessment of seismic hazard in earthquake prone areas. This can only be achieved with the knowledge of a proper site response.

Ground response analysis (GRA) is considered as a one of the most important and commonly encountered problems in Civil Engineering. GRA can be done by using one dimensional, two dimensional and three dimensional methods. GRA is determined to study the effects of the soil deposit on the bed rock motion. It is used to forecast natural periods, evaluate ground amplification, provides, evaluate liquefaction potential, and to access the forces induced due to an earthquake which causes instability of structures supported on earth. The determination of amplifications in ground response due to the local region is very complex problem to the structural designers. It is so important that all structure such as super structure and sub structure should be designed for earthquake including rupture mechanics including nearest fault to the site of interest. The basic assumptions of GRA are that all the boundaries are considered horizontal, response of the soil deposit is caused by vertically propagating shear waves and the soil bedrock surface extends infinitely in horizontal direction. Over the year various seismologists, researchers and geotechnical engineers worked for the fulfill of requirements to develop quantitative methods for the estimation of ground response and thus developed one-dimensional, two-dimensional and three-dimensional ground response analysis methods. By performing the GRA of a given soil deposit, the geotechnical engineers are able to calculate the natural frequencies of the particular site, asses ground motion amplification and evaluate acceleration response. These details can further be used for any earthquake resistant structures considering the geotechnical parameters along with earthquake motions. Predicting the ground response and motion amplifications of a soil deposit in the regions where earthquake hazards exist is a challenging task to the geotechnical engineers and the problem becomes more important for a highly populated city. The literature available shows that the soil layers beneath the site play an important role in ground motion amplifications than the amplifications due to SH-waves (seismic waves) travelling through rocks from the zone of rupture to the site having large distances (say tens of kilometers of rock) (Kramer 2005). From the past many years' various researchers had carried out the GRA for several cities in India. For example, in India, Putti and Satyam (2018) carried out GRA and liquefaction hazard assessment for Vishakhapatnam city. They used one-dimensional equivalent linear ground response analysis for their study. The PGA values obtained have been used in liquefaction hazard assessment by adopting stress-based and energy-based methods. From the estimated values of PGA and factor of safety (FS) against liquefaction the hazard map was prepared. The surface PGA values obtained were higher than 0.1g and were in the range of 0.09–0.14 g. Bhutani and Naval (2018) carried out one-dimensional equivalent-linear ground response analysis for sites of Ludhiana City by using DEEPSOIL software. They characterized sites on the basis of Avg-N values as per the recommendations of NEHRP. The PGA for different sites has been calculated and found to vary between 0.173g to 0.254g. Puri et. al. (2017) estimated GRA for various locations in of Haryana by equivalent linear approach. They observed that PGA ranges from 0.702g to 2.339g. So till date no ground response studies are estimated for Bathinda region. A need is felt to estimate ground response studies for Bathinda region and considering its vulnerability.

Punjab is a state in North India. It is bounded by Jammu and Kashmir to the north, Himachal Pradesh to the east, Haryana to the south and Southeast, Rajasthan toward the southwest, and the Pakistani region of Punjab toward the west. Punjab lies in a fore-deep, a downwarp of the Himalayan foreland, of variable depth, converted into flat plains by long-vigorous sedimentation. This has shown considerable amounts of flexure and dislocation at the northern end and is bounded on the north by the Himalayan Frontal Thrust. Much of Punjab lies in the Punjab Shelf, bounded on the east by the Delhi-Haridwar Ridge and on the south by the Delhi-Lahore Ridge. Most earthquakes in this region are shallow though a few earthquake of intermediate depth have been recorded in Punjab. According to GSHAP data, the state of Punjab falls in a region of moderate to high seismic hazard and Bathinda falls in zone III (moderate risk zone) as shown in figure 1.

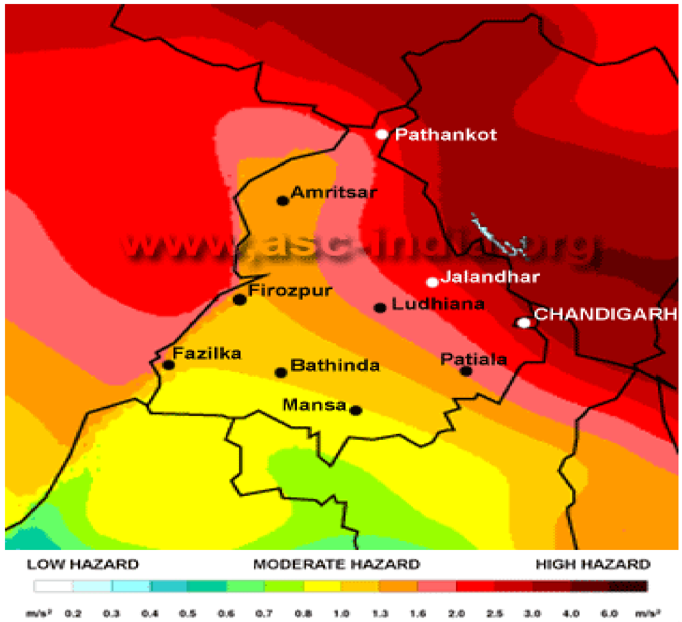

Figure 1: Earthquake Hazard Map of Punjab (www.asc.india.org)

The Indian tectonic plate's line is extremely close to the Punjab causing these cities to be more prone to earthquake than others. In order to help engineers and town planners, in designing earthquake resistant structures, it is necessary to carry out site specific seismic hazard analysis and evaluate liquefaction potential for the soils of this region.

2. EQUIEVALENT LINEAR GROUND RESPONSE ANALYSIS

In the present study, 1-D Equivalent Linear Ground response analysis for the sites of Bathinda region subjected to Uttarkashi earthquake motions have been carried out using DEEPSOIL Software. DEEPSOIL is a 1-D ground response analysis program which depends upon time domain as well as frequency domain methods. In DEEPSOIL we can perform 1-D non-linear analyses and 1-D equivalent linear analyses and features an easy graphical users interface. DEEPSOIL was created by Prof. Youssef M A Hashash in coordinated effort of different analysts and graduate and under graduate understudies. This software was developed under the supervision of Mr. Hashash including Duhee Park, Chi- Chin Tsai, David R., Groholski, Daniel Turner, Camilo Phillips, Michael Musgrove, Byungmin Kim and Joseph Harmon at the University of Illinois at Urbana-Champaign.

2.1 STUDY REGION

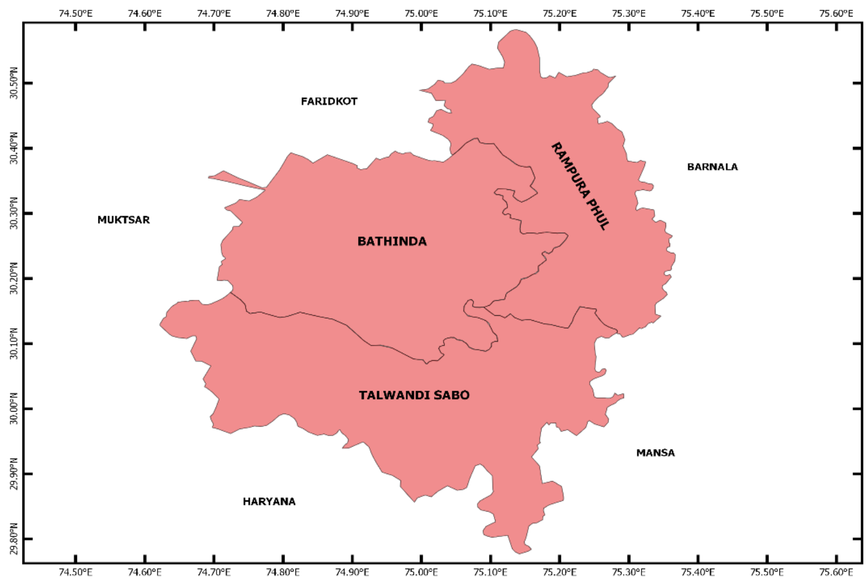

Figure 2: Bathinda Region Map

Majha, Malwa and Doaba divide Punjab into three regions. This division is due to the rivers Sutlej and Beas. Bathinda district is in north western India in Malwa region (Punjab), 227 km west of the capital city of Chandigarh and is the fifth largest city of Punjab. It is one of the oldest city in Punjab and covers an area of 3,344 square kilometers. It is surrounded by Faridkot, Moga, Mukatsar, Barnala, Mansa and the state of Haryana to the south as shown in figure 2. Bathinda is a part of the Indo-Gangetic alluvial plains. The exact cartographic co-ordinates of Bathinda are 30.20°N 74.95°E. The slope of the area is from north-east to south-west as indicated by the direction of the flow of canals and spot heights. The highest point in the area is Ratta Khera in north-eastern part with a height of 205 meters. It has an average elevation of 201 meters. As per reports of Census India the population of Bathinda city is 285,813 (male) and 151,782 (female) and 134,031 respectively. Though there were major developments in real estate in the district in recent past, yet the industrial sector also witnessed some investments in large sector. Over the year's investment in large scale sector was observed in the field of Plastic and food products. There was a growth of 447 persons in employment, Rs. 2748.06 lakhs in production and Rs. 2239.99 lakhs increase in investment.

2.2 SITE CHARACTERIZATION

In the current study, one dimensional (equivalent linear) ground response analysis of 5 sites of Bathinda region is carried out. The borehole data of the sites were collected from the different department & private organizations to access the soil properties (thickness of subsoil strata, SPT values, index properties) and ground water conditions. The location detail of selected sites has been shown in Table 1 & Figure 3.

Table 1: Location detail of selected sites of Bathinda Region for Ground response analysis

Site code	Area	Latitude	Longitude
BAT-1	gagan society colony	30.22859	74.9503
BAT-2	model town phase-1	30.1949	74.96441
BAT-3	maur kalan	30.069072	75.243544
BAT-4	Behman Jasa Singh	29.923418	75.113825
BAT-5	Mandi Kalan	30.213321	75.25566

The SPT-N values are obtained at 1.5m to 2m intervals. The geologic strata comprise mostly sand, sandy-silt, silty-sand and small pockets of clay having low compressibility at shallow depths. The water table was found in 2 sites of Bathinda region at a depth of 9.5m & 8.5m for BAT-1 & BAT-2 site.

Based on geotechnical data collected, sites have been categorized using N30 values as per the NEHRP (national earthquake hazard reduction program) recommendations. The current NEHRP provisions categorize soils into the classes A, B, C, D, E and F based on average N-value of the profile. Average-N value (N30) for the soil profile can be calculated from the following equation:

$$N_{30} = \frac{\sum_{i=1}^{n} di}{\sum_{i=1}^{n} \frac{di}{Ni}}$$

Where, N30 = Average SPT N-value for 30 m depth, Ni = SPT N-value of any layer, Di = thickness of any layer. It has been observed that all the 5 selected sites of Bathinda Region come under class D with the Avg-N value for the profiles ranging from 16.99 to 26.67. The minimum and maximum Avg-N values were observed at BAT-1 and BAT-5 sites respectively. The engineering bedrock is generally assumed to be the uppermost layer, having a shear wave velocity (Vs) ≥ 760 m/s of the soil column in accordance with NEHRP provisions.

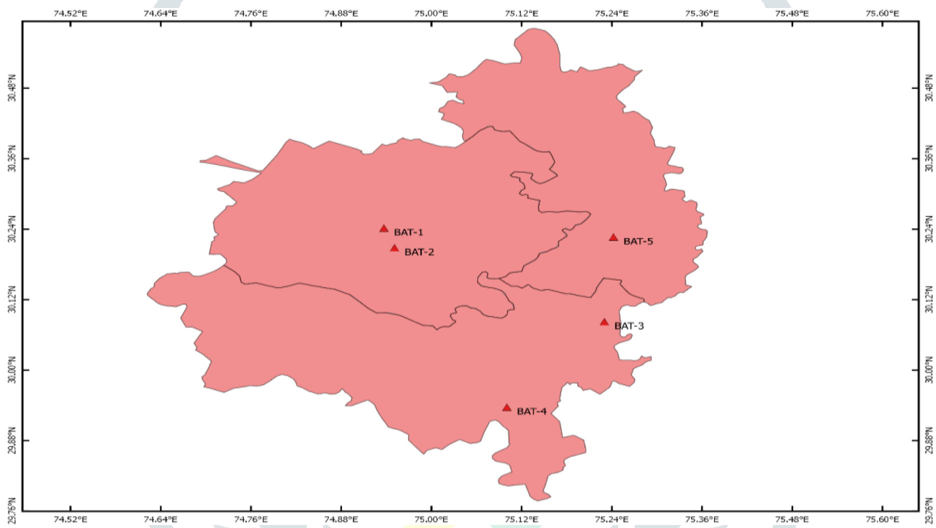

Figure 3: Location of Borehole in Bathinda Region

Therefore, in this study, engineering bedrock has been assumed at refusal, i.e. for N > 50 for 15 cm penetration or N > 100 for 30cm penetration of SPT split-spoon sampler. Hence, the boreholes drilled up to refusal have been considered for the analysis. Bedrock has been modeled as an elastic half space with 2% damping, density of 2.5 g/cc and shear wave velocity (Vs) of 760 m/s. The site class detail of selected sites of Bathinda region have been presented in Table 2 and shown in Fig 4.

Table 2: Site Class as per BSSC (2003) NEHRP

Site code	Area	Avg. N-Value (N_{30})	Site class as per NEHRP
BAT-1	gagan society colony	26.67	class D
BAT-2	model town phase-1	23.00	class D
BAT-3	maur kalan	20.84	class D
BAT-4	Behman Jasa Singh	19.67	class D
BAT-5	Mandi Kalan	16.99	class D

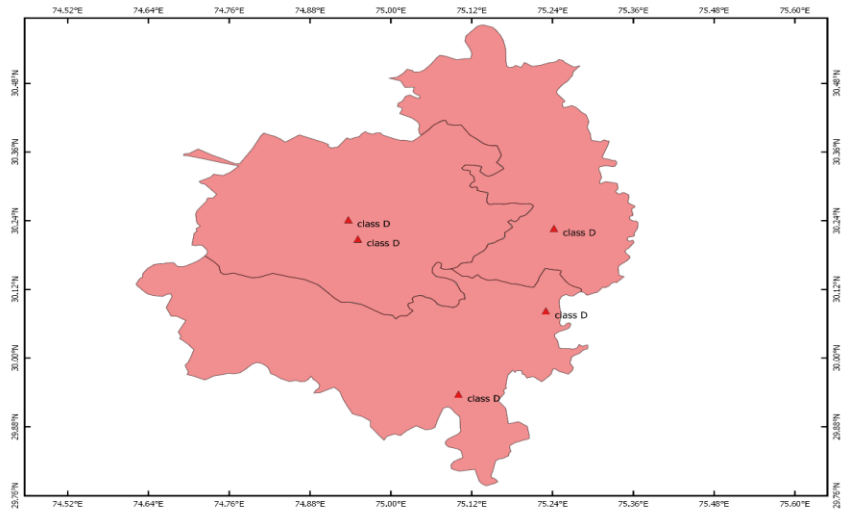

Figure 4: Site Class for selected sites of Bathinda Region as per NEHRP

2.3 DYNAMIC PROPERTIES OF SOIL

Shear modulus (G) plays an important role in the estimation of the seismic response parameters in seismic microzonation studies. The ground motion parameters at the surface are generally obtained by conducting 1-D ground response analysis considering only the upward propagation of shear wave. using available correlations for different soil types shear modulus for study region has been calculated. Correlations can be selected based on soil type and value of correlation coefficient (R). In the present study, correlations have been selected as per the recommendations of Anbazhagan et al. and are given in Table 3.

Table 3: Correlations for Calculation of Shear Modulus (G)

Correlations	Soil Profile	Author(s) Name
$G=1220N^{0.62}$	Clay	Ohba and Toriunmi
G=650	Sand	Ohsaki and Iwasaki
G=1182	Other Soils	Ohsaki and Iwasaki
G=82.5	Gravel	Imai and Tonouchi

2.4 INPUT MOTION

The final step in ground response analysis is getting an acceleration time history, which is compatible with the maximum dynamic loading expected at the site of interest. Suitable acceleration time histories can be selected based on PGA value, the magnitude of controlling earthquake, source to site distance and site class. For present analysis, PGA values for rock sites given in IS: 1893-2016 are used for the selection of acceleration time histories. Uttarkashi earthquake motion (1991) have been applied at the bedrock level to study the soil effects. The time history of 1991 Uttarkashi earthquake motion considered in the study is shown in Figure 5. The earthquake characteristics of Uttarkashi motion (1991) like date of occurrence, recoding station, source distance, Magnitude, Maximum horizontal acceleration is shown in Table 4.

Table 4: Strong Motion Characteristics considered in this study

S. No.	Strong Motion Parameter	Uttarkashi Earthquake
1	Date of Occurrence	19-10-1991
2	Magnitude, Mw	7.0
3	Location of Epicenter	30.837 N 78.984 E
4	Distance from Source	34 km
5	Recording Station	Uttarkashi
6	PGA (g)	0.253

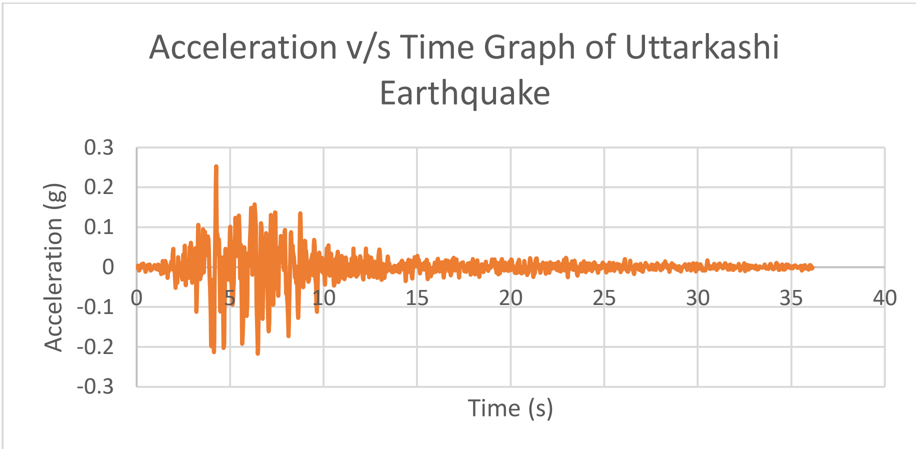

Figure 5: Acceleration v/s Time Graph of Uttarkashi (1991) Earthquake

3 RESULTS & DISCUSSION

Ground response analysis (equivalent linear) have been carried out to study the effect of local ground conditions for the sites of Bathinda region using DEEPSOIL (v6.1) software. The ground surface acceleration with time history were computed at all 5 locations of Bathinda region in response to the 1991 Uttarkashi applied at the bedrock and the result is shown in Table 5.

Table 5: Results of GRA for the sites of Bathinda Region with Uttarkashi Earthquake (1991) Input Motion

Site code	Area	PGA Rock (g) as per IS:1893	PGA Soil (g)	AF
BAT-1	gagan society colony	0.25	0.090	0.360
BAT-2	model town phase-1	0.25	0.091	0.364
BAT-3	maur kalan	0.25	0.082	0.328
BAT-4	Behman Jasa Singh	0.25	0.059	0.236
BAT-5	Mandi Kalan	0.25	0.063	0.252

The effect of local soil conditions in amplifying earthquake ground motion has been estimated at all the sites of Bathinda region as amplification factor (AF) varies from 0.236 to 0.364 using Uttarkashi earthquake (1991) motion. It has been observed that under the influence of Uttarkashi (1999) Earthquake, PGA values for the sites of Bathinda region varies from 0.059g to 0.091g with minimum & maximum observed PGA value at BAT-2 and BAT-3. The amplification factor profile map of selected sites of Bathinda region using Uttarkashi (1991) motion is shown in figure 6.

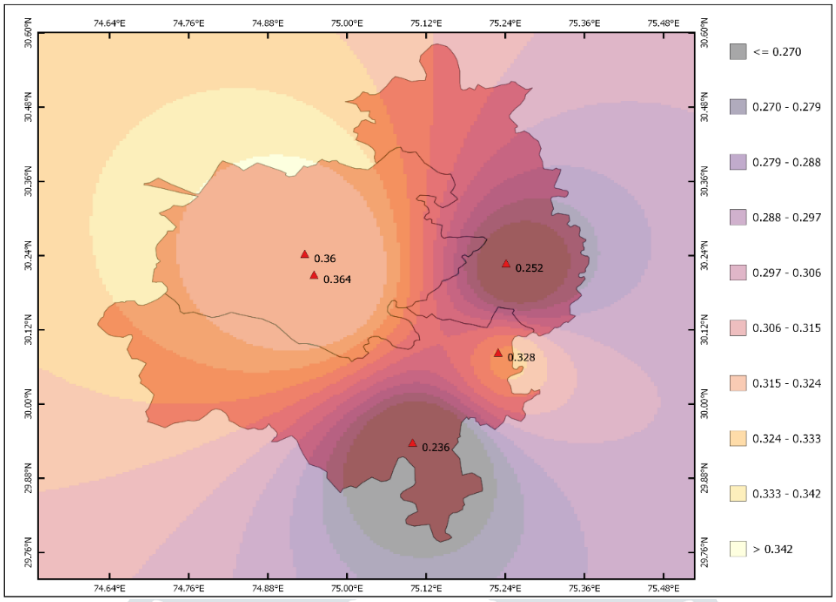

Figure 6: Amplification factor profile map of selected sites of Bathinda region using Uttarkashi (1991) motion

4 CONCLUSION

One dimensional Equivalent-linear ground response analysis for five sites of Bathinda region (Punjab) is carried out with DEEPSOIL Software using Uttarkashi earthquake motion (1991). On the basis of the results obtained, the following conclusions have been drawn:

- For the Estimation of Ground Response Analysis (GRA) for the sites of Bathinda Region (Punjab), the SPT data of 5 locations has been collected.
- The data of Bathinda Region (Punjab) region is collected by excavating the borehole up to different depths. The depth of borehole for the 5 locations varies from 1.5m to 30m respectively.
- The borehole data of all the sites were collected and characterized on the basis of Avg. N-value (N30). It has been detected that all sites of Bathinda region fall under the category of Class D as per the NEHRP (2003) provisions.
- The PGA for all the 5 sites of Bathinda region varies from 0.059g to 0.091g with minimum & maximum observed PGA value at BAT-2 and BAT-3 using Uttarkashi earthquake motion (1991).
- PGA values at surface for all the 5 sites are found to be less than the expected value of PGA based on Zone factors mentioned in IS: 1893 (Part 1): 2016.
- The amplification factor for all the 5 sites of Bathinda region varies from 0.236 to 0.364 using Uttarkashi earthquake (1991) motion.

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