

GEOTECHNICAL MAPPING PROPOSAL FOR FEDERAL HIGHWAY - BR 319

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ABSTRACT: The construction of the federal highway BR 319, has been in its construction phase since 2021, and the body responsible for the construction (National Department of Transport Infrastructure - DNIT) presented results of traditional technological characterization of soils that were removed from the piles along a stretch of BR 319, due to this fact, the present research proposes a geotechnical mapping study to present these values in image form.

KEYWORDS: Paving : Asphalt : Brazil : DNIT

INTRODUCTION

The construction of highways is essential for urban development with immeasurable benefits and whose construction techniques are specific and standardized nationally or/and internationally.

The sectoral policy of the Ministry of Transport for the performance of the National Department of Transport Infrastructure - DNIT aims, among its basic guidelines for the road sector: the implementation of new highways, paving of existing sections and the expansion of the capacity of various segments of the road network federal (DNIT, 2010).

In this context, it should be noted that BR 319 is the only federal highway that connects the capital of the State of Amazonas to other regions of Brazil. In a brief history, according to Fearnside *et al.*, such highway began its construction with 680 kilometers in mid-1972, and the 197 kilometers in 1973 that completed the popularly known Transamazônica highway.

It divided the Amazon region from east to west in half and currently has an extension of 885 km from north to south from Manaus to Porto Velho.

According to the general assessment of the conditions of federal highways, prepared by the CNT in 2021, Amazonas has 95.1% of the road network evaluated with some type of problem, being considered regular, bad to very bad, and only 4.9% estimated as excellent or good. This road, for most of its length, does not have a coating layer, and consequently, the stretches that do not have a surface layer coated with some type of asphalt mixture, may indicate a poor condition for vehicle traffic in the lane . scrolling, mainly during periods of high rainfall in the state.

In 2020, the preparation of studies, creation of a basic project and engineering executives of the BR-319 began, specifically along the kilometer 198.20 to 218.20. Such activities include the collection of soil samples *in loco* and the performance of tests, based on the guidelines established by government agencies and private entities in Brazil and abroad, for the purpose of building highways.

In another aspect, geotechnical mapping is a method to cartographically present geotechnical information for purposes of planning and use of the territory, as well as for the purposes of design, construction and maintenance of engineering works. Information on the characteristics and properties of the layers forming the subsoil profile of a given location may also be part of it, with a view to evaluating behavior and the probable geological-geotechnical problems resulting from its use in engineering projects (Vallejo et al, 2002) .

A GIS is defined as a manual or computational set of procedures used to store and manipulate georeferenced data, making it possible to obtain spatial information (Carr, 2003). It can also be understood as a technological information system similar to many others, however, it presents its database as a differential (Nuhcan Akçit , 2014) and therefore all stored knowledge which, on the other hand, must be linked to a geographical position, latitude and longitude (Lobo et al, 2015). It should be noted that the association of GIS with fuzzy logic has greatly increased its ability to operationalize information (Petry et al, 2003).

According to Fernandes (2009), geographic information systems allow storing not only vector or raster information , but also the alphanumeric attributes related to them in a georeferenced way. That is, the data alluding to a record that are linked to one or more points on the Earth's surface, thus allowing a more realistic analysis of the use of space.

The number of GIS software available on the market is very wide and the choice is very particular. Among these, there is the computational program developed by the North American company ESRIS, ArcGis , which shows the capacity to be a georeferenced database and, based on this storage, allows the creation of features objectifying the exposure of relevant data in image formats . Thus, for its implementation, the domain program (Arcgis 10.8 PRO) is necessary to create the maps and the auxiliary programs (Google Earth PRO, Autocad and Excell) to support the manufacture of the final products.

In this way, the creation of a geotechnical mapping with information on the

characteristics and behavior of the soil raises the development of research with these aspects, aiming at the use of this material in the construction of roads and highways through a geographic information system tool.

METHODOLOGY

In this chapter, the methodology used in the investigation in question is presented, as shown objectively in Figure 1. The predominant approach consisted of treating the data collected in the field, referring to a certain stretch of the federal highway BR 319, and showing them in form of geotechnical maps.

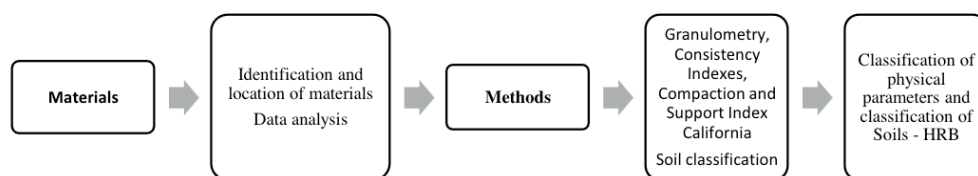


Figure 1 - Study methodology flowchart.

Materials

Regarding material data, DNIT makes available on its official federal government website all information regarding the characterization of materials.

The place where the soil samples were taken came from the subgrade, deposits and loan boxes. They were located in the stretch from kilometer 198.20 to 250.00 of the federal highway BR 319, in particular in the geographic coordinate system shown in Table 01.

excerpt	Latitude	Longitude
Kilometer 198.20 (Initial Station)	4°20'3.19"S	60°54'30.38"O
Kilometer 218.20 (Final Stakes)	4°27'28.71"S	61° 3'13.96"W

Table 01 – Coordinates of the sampled points. Source: Google Earth Pro

Data from samples extracted and analyzed in the laboratory were provided by the DNIT agency. In total 103 samples were collected, placed in plastic bags and identified by the numbering of the stakes from 00 to 1005, located every 0.02 km from one stake to the other, along the 20.00 km of the analyzed section of the BR 319 highway. The information was tabulated according to the following content: The) stake kilometer location; B) stake numbering; w) depth of sampling; c) granulometry; d) physical indices (liquidity limit, plasticity limit, plasticity index, group index); e) HRB classification; f) optimum humidity (w_{ot} %); h) California Support Index; i) expansion.

The texture and color of the materials were determined by percussion sounding,

whose execution procedure was carried out in accordance with the Brazilian Standard NBR 6484. In the case of the study of deposits, for use in the sub-base layer, it was obtained a purge volume of 1284.30 m³, usable volume of 38,529 m³ and incidence area of 12,843.00 m². Depending on the loan boxes, which are used to replace the soil layer for use in the body of the pavement, a total number of 07 (seven) were recorded, located in different locations along the stretch, and it is possible to identify relevant information in the Table 02.

loan box identification	incidence area	usable volume	purge volume	Local
Loan box 01	15,980.00 m ²	31,960.00 m ³	1,598.00 m ³	186.50 km
Loan box 02	33,136.00 m ²	66,272.00 m ³	3,313.60 m ³	186.50 km
Loan box 03	33,136.00 m ²	66,272.00 m ³	3,313.60 m ³	192.50 km
Loan Box 04	30,262.00 m ²	60,524.00 m ³	3,026.20 m ³	193.50 km
Loan box 05	62,024.00 m ²	189,072.00 m ³	6,202.40 m ³	194.50 km
Loan box 06	34,412.00 m ²	68,824.00 m ³	3,441.20 m ³	195.20 km
Loan box 07	4,872.00 m ²	9,744.00 m ³	487.20 m ³	EST. 654

Table 02 – Loan boxes, modified. Source: DNIT.

Methods

Analysis of geotechnical data

The data based on the geotechnical characterization, from laboratory tests, were granted to the work by the company Ardo Construtora e Pavimentação Ltda.

Texture and consistency tests followed the following procedures, respectively: DNIT ME 080/94 standard – Grain size analysis by sieving, Liquidity Limit, specified by DNIT ME 122/94 standard, and Plasticity Limit, according to DNIT ME 082 standard /94.

Following the guideline of the NBR 7182 standard, the compaction test was carried out at normal Proctor energy, determining the parameters optimal humidity and maximum dry apparent specific weight. The determination of the California Support Index, CBR, followed the NBR 9895 and DNIT 172/2016 - ME standards, and the soil expansion was also obtained.

Based on the results of granulometry and consistency tests, it was possible to typify the soils in accordance with the Jenkins classifications (Table 03) and the AASHTO recommendations. This methodology, according to DAS (2019), was developed in 1929. After several revisions, its current version is the result of a proposal by the Highway Research Board, following the guidelines of ASTM standard D-329-82 and AASHTO method M145 (Figure 03). It is noteworthy that, based on this classification, it is possible to evaluate the subgrade, for the purpose of building pavements.

Plasticity Index, IP	Description
1 < IP < 7	weakly plastic
7 < IP < 15	moderately plastic
IP > 15	highly plastic

Table 03 – Jenkins classification. Source: Caputo, 1987.

Classificação geral	Materiais granulares (35% ou menos da amostra total passante pela peneira nº 200)						
	A-1			A-2			
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7
Ensaio de peneiramento (porcentagem passante)							
nº 10	50 no máximo						
nº 40	30 no máximo	50 no máximo	51 no mínimo				
nº 200	15 no máximo	25 no máximo	10 no máximo	35 no máximo	35 no máximo	35 no máximo	35 no máximo
Características da fração passante nº 40							
Limite de liquidez				40 no máximo	41 no mínimo	40 no máximo	41 no mínimo
Índice de plasticidade	6 no máximo		NP	10 no máximo	10 no máximo	11 no mínimo	11 no mínimo
Tipos comuns de materiais constituintes significantes	Fragmentos de pedra, pedregulho e areia		Areia fina	Silte ou pedregulho argiloso e areia			
Avaliação geral como subleito	De excelente a bom						
Classificação geral	Materiais de silte-argila (mais de 35% da amostra total passante pela nº 200)						
Classificação de grupo	A-4	A-5	A-6	A-7 A-7-5 ^a A-7-6 ^a			
Ensaio de peneiramento (porcentagem passante)							
nº 10							
nº 40							
nº 200		36 no mínimo	36 no mínimo	36 no mínimo	36 no mínimo		
Características da fração passante nº 40							
Limite de liquidez		40 no máximo	41 no mínimo	40 no máximo	41 no mínimo		
Índice de plasticidade		10 no máximo	10 no máximo	11 no mínimo	11 no mínimo		
Tipos comuns de materiais constituintes significantes	Solos com silte		Solos argilosos				
Avaliação geral como subleito	De fraco a ruim						
^a Para A-7-5, IP ≤ LL - 30							
^a Para A-7-6, IP > LL - 30							

Figure 3 – HRB classification. Source: Caputo.

Arcgis Pro 10.8 Software

The program developed by the North American company ESRI, is conceptualized as a tool of the Geographic Information System. It is based on commands for data manipulation and its main feature is the creation of features to expose relevant data characteristic of a specific area, section or road. In compliance with the manufacturer (ESRI), this computational program has the capacity to store (Geodatabase), classify (Features) and cross data of different orders and magnitudes (Interpolation).

To create features in the computational program Arcgis PRO 10.8, it is fundamental that the connection between the geographic data (spatial) and the tabulated data (field) have a unique storage and identification relationship. For a better understanding of the program's functionality, the software has a wide range of functions, among which we explain below.

Shapefile , Attribute and Feature Set, and Arctoolbox

Shapefile is a command line software, with the function of storing vector data. With this domain of the program, it is possible to create a set of attributes and features.

The aforementioned set of georeferenced attributes can be inserted into the program by exporting tables, provided that the items under analysis are organized and described with the type of coordinate. To the set of non-georeferenced attributes, it is possible to import into the program with the help of Google Earth Pro tool or/and Autocad , being necessary to synchronize the measurement information with each item of the attribute and having a georeferenced starting point, it is possible to start from that point, if not, it is possible through empirical analysis by increasing the scale on the map, reconciling a location reference of the information obtained in the field with the image on the program screen.

Specific to the set of features, which constitute a grouping of a certain section, such as an area, land or a road, result in a layer, and in turn, is conceived through the representation of points, lines and polygons .

Arctoolbox consists of a set of geoprocessing tools, through which it is possible to: select a data and analysis conversion resource, import existing data into a geodatabase , permanently change the map, insert coordinate system parameters for a dataset, feature modification, interpolation of multivalued values and attributes for feature creation.

Google earth software for autocad and microsoft software excell

The process to georeference data that are not informed in the field analyzes is aided, as a rule, by the computer program Google Earth Pro. A tool that assists in exporting georeferenced items, via satellite image, to the ArcGis Pro 10.8 software format , thus contributing to better geographic accuracy in the design of features.

For assistance and support to the computational program sArcGis Pro 10.8, Autocad is also used . Program created and developed by the company Autodesk, whose function is to help export files to ArcGis Pro 10.8.

And finally, the last tool that collaborates with Arcgis PRO 10.8 is the Excel program, belonging to the Microsoft office package. It is used to organize and identify geographic coordinates. Another advantage is that it allows changing coordinate systems, such as, for example, transforming coordinates based on degrees, minutes and seconds (geographical coordinates) to coordinates based on meters (UTM coordinates).

Geotechnical Mapping

The use of a Geographic Information System facilitates the manipulation and integration of georeferenced geotechnical data, in addition to providing the generation of thematic maps, a GIS tool, in addition to providing the opportunity for the associated database to be consulted, allowing its evaluation in a relation direct with location and spatial correlation with other data (Miranda, 2008).

ROSVELT *et al* (2022) mentions that a geotechnical map can be produced by crossing a series of information on morphology, geology, spatial distribution of soil types, mechanical properties and electrical properties of the soil.

It is emphasized that geotechnical mapping aimed at exposing data representative of the Brazilian context is not so contemporary. It is mentioned, for example, Valente (1999), who elaborated a geotechnical database inserted in the GIS tool for the city of Porto Alegre, in the State of Rio Grande do Sul.

Other authors investigated the use of geotechnics for road construction purposes and created a database through mapping. Higashi *et al* (2001) presented an analysis of the subsoil of the State of Santa Catarina with a view to the implementation of highways and, through the GIS environment, analyzed the geotechnical units with a view to the suitability of the soils for paving. Augusto *et al* (2002) discussed the advantages of using a GIS in the management of environmental liabilities, in the road network over the responsibility of the concessionaire responsible for the roads in the west of São Paulo. Using specific actions within a GIS, they created, through the programming language, an interface for easy access to geotechnical, road, and geological data, among others, and the interface obtained enabled public access to the data.

The result of making geotechnical maps, according to Davison Dias (1995), brings the advantage of a great reduction in the work of identifying and delimiting the area of the different types of soils present in a region.

Depending on the results obtained by geotechnical mapping techniques, Labib *et al* (2013), according to a customized GIS system methodology, obtained the provision of recovery processes, visualization and updating of large amounts of information associated with each soil sample and the combinations with its spatial location in a clear and organized way, being thus, it can be executed efficiently and with saving time.

rosvelt *et al* (2022), provide relevant information for assessing the stability of soils in an urban area, through the generation of laboratory data and, with such data, enabled the outlining of maps of soil units occurring in the researched region, resulting in exposure of the five types of soil found in each locality.

And in another investigation, EL MAY *et al* (2010) demonstrated the technical capacity of a GIS tool for the preparation of geotechnical zoning maps, regarding the suitability of a safe construction. They mention the potential of this resource portrayed by the ease,

handling, rapid analysis, treatment efficacy, and data updating.

RESULT

After cross-referencing the geotechnical data and preparing the maps, figures 4, figure 5, figure 6 and figure 7 were obtained.

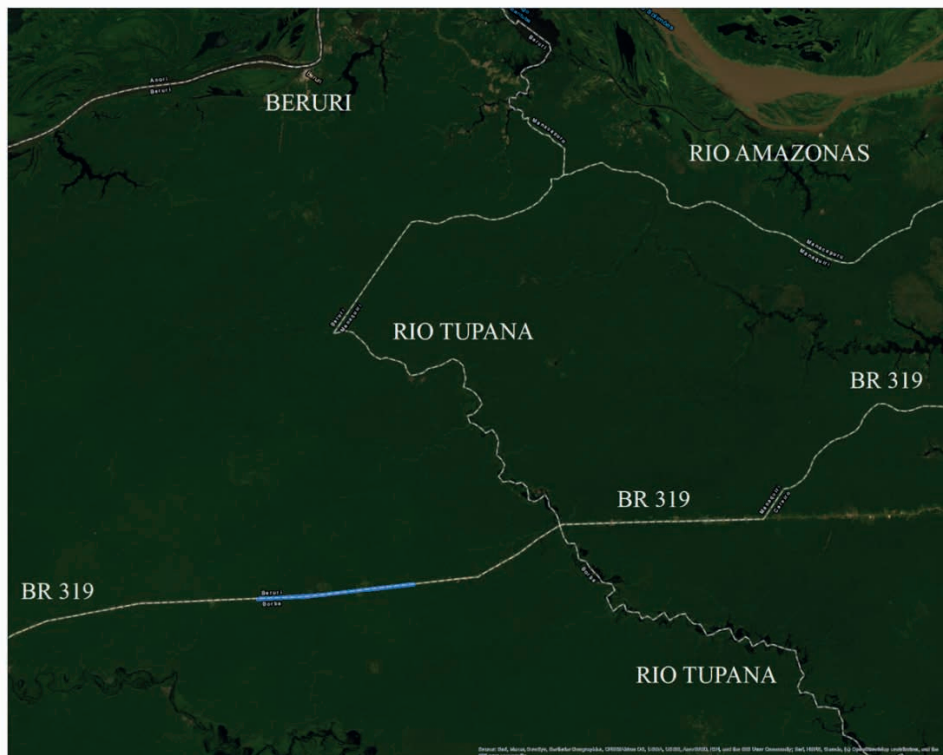


Figure 4 – Location of the stretch along BR 319. Source: Own

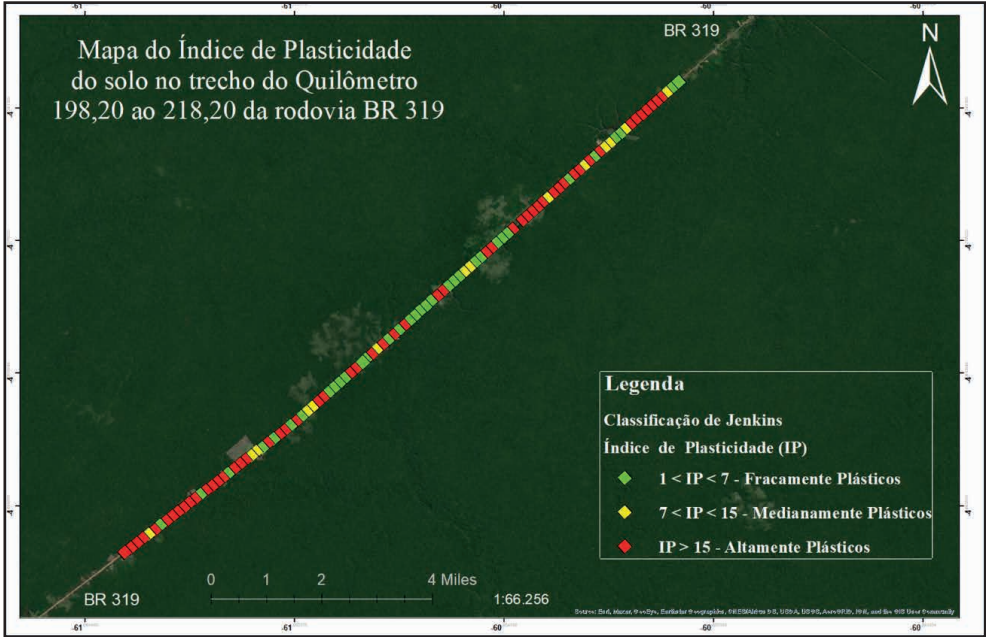


Figure 5 – Plasticity Indexes. Source: Own

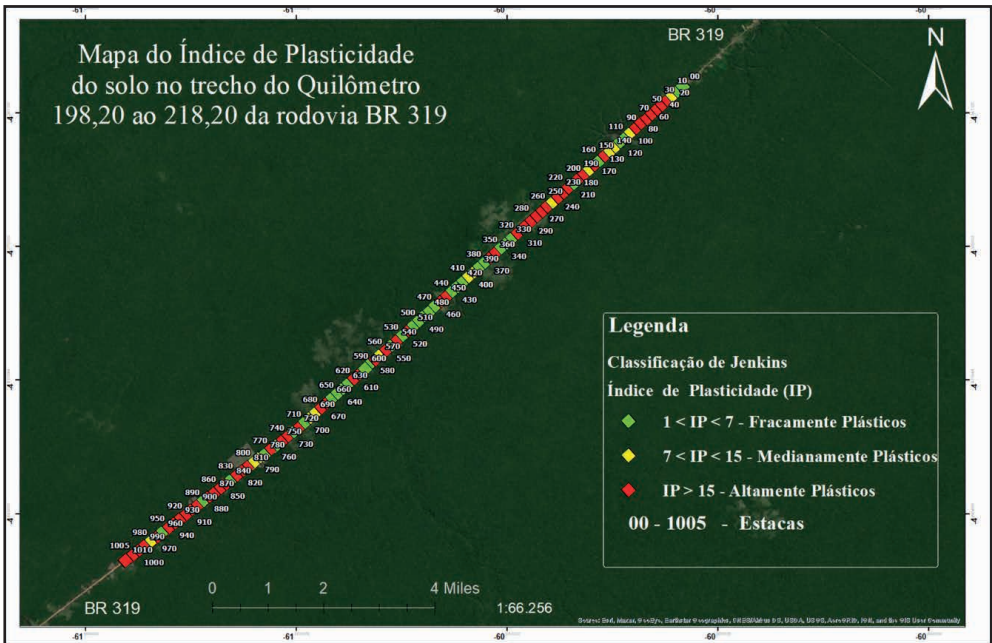


Figure 6 – Plasticity Indexes according to the location of the piles Source: Own

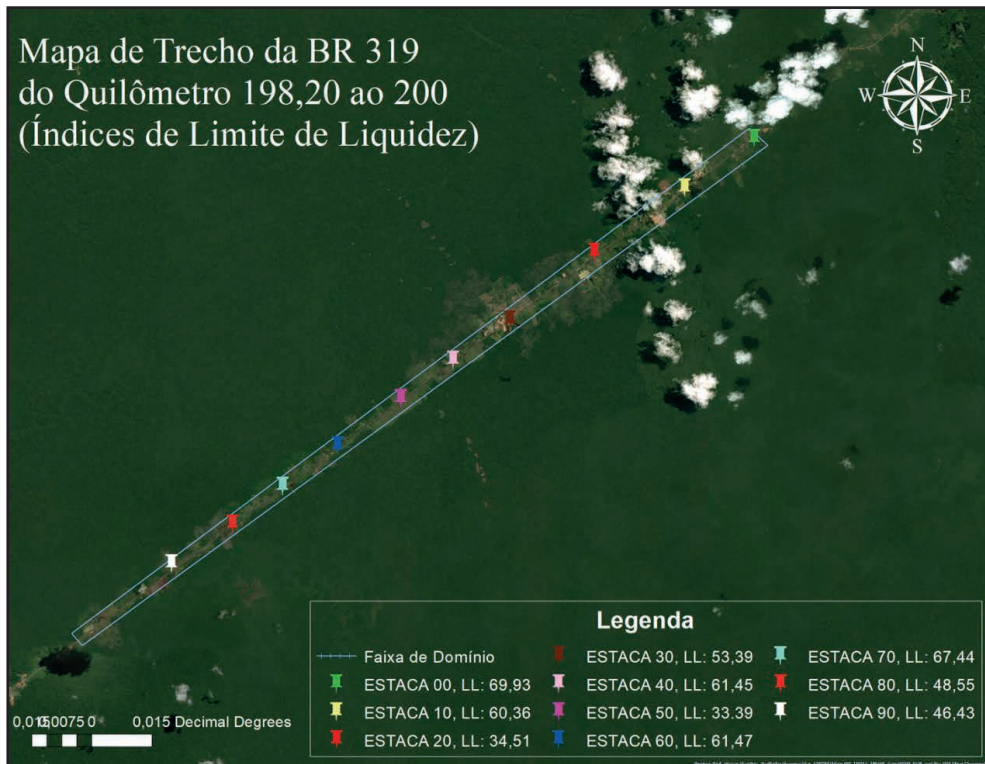


Figure 7 – Position of stakes. Source: Own

CONCLUSION

With the results presented in the figures, and due to the fact that the city of Manaus and the sites around the capital of Amazonas are located in a sedimentary basin, the type of soil that contemplates the road is a highly clayey soil, and this results in a type of natural material not very satisfactory for road and pavement construction, therefore, with the present maps indicating the plasticity indexes and liquidity limit, they will be able to collaborate with a future study to indicate possible points that present a fast and physical wear of the future pavements. As the classification of the indices are based on each stake, the collaboration will georeference with the future researcher to identify the type of problem based on the map.

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