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16. Abstract

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The state Department of Transportation and Development, DOTD, has experienced bearing pad slippage at some of their prestressed concrete bridges. This project's objective is to determine the cause of the neoprene bearing pad slippage and to recommend to DOTD practical guidelines to correct the problem.

Investigative methods included measuring girder thermal movements and erecting video equipment to simultaneously monitor bearing pads and traffic. In addition, material testing was performed to determine the composition of problematic elastomeric bearing pads. By using time-lapse video equipment, bearing slippage was found to occur on a daily basis. Other findings include that a majority of bearing manufacturers adds wax to their neoprene bearings in order to satisfy the American Association of State Highway and Transportation Officials' specifications. As a result of this investigation, it was concluded that the primary cause of neoprene bearing pad slippage is due to wax materials that are added during pad manufacturing.

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Investigation of Elastomeric Bearing Pad Failures in Louisiana Bridges

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ABSTRACT

Elastomeric bearing pads provide a medium to transfer girder loads to the supporting substructure. Low cost and low maintenance in comparison with mechanical type bearings make elastomeric bearing pads attractive to use. However, some problems have developed. Failure modes for bearing pads include crushing, delamination, and slippage. The most notable of these failure modes is slippage or "walking" out of position.

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IMPLEMENTATION STATEMENT

Corrective measures for the prevention of bearing pad slippage at new bridges can be implemented through bearing pad material specifications. The problem of bearing pad slippage at existing bridges can be remedied through maintenance procedures during repositioning of faulty pads

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INTRODUCTION

Elastomeric bridge bearing pads act as a medium for load transfer transmitting dead and live loads imposed by the bridge superstructure as a compressive load to the substructure. In addition, the pads also accommodate translational and rotational movements between the bridge and its supporting structure. These movements include the effects of temperature, creep, shrinkage, and impact. Lateral forces developed from these effects are transmitted from the girder to the abutment through friction as shear forces. While providing a medium for the transfer of forces, elastomeric bearing pads protect the structure by preventing abrasion at the connection and absorbing any vibrations due to dynamic live loads.

Elastomeric bearing pads are commonly used because of their low cost, effectiveness, and low maintenance requirement *[1]*. Converse to the many advantages of bearing pads, various failure modes are associated with their use. These failure modes include delamination, crystallization, and slippage. This research project addresses the slippage failure mode.

The project research consisted of five focus areas. Initially, a literature search was conducted in order to gain extensive knowledge on the subject. Material pertinent to the study is included in the section of the report, "DISCUSSION OF RESULTS, Background". Secondly, surveys were conducted. These included other state departments of transportation (DOTs), bearing pad manufacturers, and researchers knowledgeable on the subject to gain further insight into the problem. Thirdly, a continuous field investigation was established to document the behavior of bearings in service. The fourth phase included laboratory investigation to determine the composition of neoprene bearings that experienced slippage. The fifth and final step summarized the previous phases and derived conclusions for the slippage problem.

OBJECTIVE

A clear understanding on the behavior of elastomeric bearing pads, in particular neoprene bearing pads, is needed to develop any type of corrective measure to the current problem of slippage. The project's objective was to investigate Louisiana DOTD's slippage problem of elastomeric bearing pads in order to:

- determine the cause of the problem and develop remedial procedures for existing bridges.

- determine bridge characteristics where bearing pad failure had developed and identify bridges that, although failure may not have occurred, may have the potential for bearing failure.

- recommend modifications to the current Louisiana Bridge Manual to avoid future bearing pad slippage problems.

SCOPE

The project was performed using existing field surveys conducted by the Louisiana Department of Transportation and Development to determine locations for extensive study and to monitor these sites for maximum bearing movement over the project study period. A field investigation is important to determine the possible variables that may affect bearing pad movement. Laboratory testing was conducted on the bearing pads to determine bearing pad composition. The two types of investigations, field and laboratory, provided an approach to analyze the behavior of elastomeric bearing pads and the cause of bearing pad failure.

METHODOLOGY

Literature Review

The initial phase of the project was to conduct a literature search on material relevant to the problem of elastomeric bearing pad failure. This allowed the researchers to become familiar with the characteristics of elastomeric bearing pads, also the problem of slippage, commonly referred to as walking.

Surveys

A survey of state DOTs was performed to identify the extent of the slippage problem and each of the state's corrective measures towards bearing pad movement. Bearing pad manufactures were then surveyed to investigate materials that manufacturers add during compounding, and to gauge their awareness of bearing pad slippage.

Field Investigation

Field investigation sites were determined based on the number of bearing failures occurring at each bridge, bridge characteristics, bearing pads' accessibility, and proximity to the LSU campus. These study sites aided in assessing if there were any bridge characteristics which was influential in causing bearing movement.

A survey conducted by the DOTD Bridge district offices helped determine these field locations. This survey by DOTD was conducted to identify bridges in the various parishes that have experienced elastomeric bearing pad failures. From the bridge survey and bridge inspection reports, three field study sites were monitored on a long-term basis. At two of the sites, bearing movements were measured in conjunction with girder thermal movements. At the third site, video cameras were utilized to monitor pad movement, ambient temperature, girder movement, and traffic on a continuous basis; its purpose was to monitor traffic patterns and possible corresponding bearing movement. The cameras were erected at each bearing level parallel to the roadway surface.

Laboratory Investigation

Bearing pads known to have failed due to slippage were evaluated to determine their material elements. Through lab testing, the material compositions of the bearing pads were determined

DISCUSSION OF RESULTS

Background

Although various failure modes have been found including bulging, cracking, splitting and pad slippage, the primary failure mode in Louisiana has been excessive "walking".

One cause of walking is due to horizontal forces applied to the bearing pad, which exceed the coefficient of friction at the bearing pad interface. For the boundary between an elastomeric bearing pad and concrete, the friction coefficient is a function of the applied vertical stress, shape factor of the bearing pad, and temperature *[2]*. Research showed as normal stress increases, the friction coefficient decreases. The minimum value for the friction coefficient was found to be:

$$f(\min) = 0.1 + \frac{0.2}{\sigma_v} \tag{1}$$

where σ_v is the average vertical stress in N/mm^2.

Elastomeric bearing pads have been used in the United States since the 1950's with neoprene bearing pads were first used in 1957 in Victoria, Texas as supports for prestressed concrete beams. Initially, a DuPont report, "Design of Neoprene Bridge Bearing Pads", served as guide for the bearing pads' design *[1]*. The DuPont report included standard procedures and relationships between compressive stress, shape factor, and compressive strain for durometer hardnesses of 50, 60, and 70. The report assumed a coefficient of friction equal to 0.20.

An early in depth study by Minor and Egen was conducted for AASHTO to revise existing specifications for elastomeric bearing pad design *[3]*; the study included examination of intrinsic properties of elastomeric bearing pads. The study, the authors found that cracking caused by ozone attack was confined to the pad surface and therefore, testing to establish criteria was deemed unnecessary.

Stanton and Roeder conducted later studies for AASHTO in the 1980's *[4], [5]*. This study was conducted under the National Cooperative Highway Research Program (NCHRP) 10-20A-research program and focused on the complex nature of elastomeric bearing pads. The material is nearly incompressible where the material's incompressibility is identified by its approximate 0.5 Poisson's ratio, the ratio of the lateral strain to the axial strain. Some of the material properties include a non-linear, time dependent stress-strain relationship. In addition, at high strains the material is thixotropic; the material becomes stronger at high strains. A characteristic of an elastomeric material is its creep, increasing deformation with constant loading, which approaches 20 to 40%. In the Stanton and Roeder studies, experimental work was conducted on elastomeric bearing pads to determine behavior as a function of low temperature, compression, rotation, shear, stability, fatigue, and shear. As a result of the work by Stanton and Roeder, two design methods were proposed and adopted by AASHTO *[6]*. These two major studies for AASHTO did not, however, directly address the problem of bearing pad slippage.

The University of Texas conducted an in-depth study for the Texas Department of Transportation. During the project, five reports were produced investigating the behavior of elastomeric bearing pads through field and laboratory studies and numerical simulation *[7], [8], [9], [10], [11]*. Slippage problem necessitated the study. Slippage was found to occur at elastomeric bearing pads made of natural rubber. It was concluded paraffin was added during the compounding process caused the slippage. During compounding, bearing pad manufactures add wax to meet required ozone degradation requirements established by AASHTO. The requirements are meant to prevent ozone attack of the carbon-carbon double bonds of the baring pad material that leads to surface cracking *[9]*. The problem was remedied by substituting natural rubber bearing pads with pads made with neoprene pads at problem sites. The explanation behind this solution was that neoprene doesn't require antiozonant protection and therefore wax bloom will not develop on neoprene bearing pad surfaces. Although this solution proved to be adequate for the Texas Department of Transportation, the Louisiana Department of Transportation and Development has had bearing pad slippage problems with neoprene bearing pads.

Field Investigation

To develop a field study program, a preliminary field investigation was performed at sites known to have experienced bearing slippage.

Seven Louisiana sites were investigated for bearing pad walking: US 190 railroad overpass in Pointe Coupee, US 90 Mermantau River Bridge in Mermantau, Hickory Avenue railroad overpass in New Orleans, I310 exit and entrance ramps near Luling Bridge, I310 near US 90, I310-LA3127 Interchange, and I55 near Pass Manchac. All of the bridges investigated use prestressed concrete beams and all of the sites except Hickory Avenue use continuous prestressed concrete beams. Following the preliminary survey, a more in-depth investigation was made using maintenance equipment to gain access underneath the bridges.

From the seven sites included in the preliminary study, four bridges were selected for the field investigation to monitor bearing pad slippage and girder thermal movements over an extended study period of approximately 18 months. All selected sites were at bridges using

Type III AASHTO continuous prestressed concrete girders. All bearing pads studied were rectangular, tapered, and made of neoprene. No adhesives or positive attachments were used at any of the sites selected except for the I310 eastbound entrance ramp from LA3127. All bridge sites selected for investigation were subjected to heavy truck traffic. A comparison of the bridges and bearing pads studied in the field investigation is given in the full report. In comparing bridge parameters at the field sites, no common bridge characteristic was found that would directly induce bearing pad slippage.

Girder Thermal Movements Monitoring

At three sites, US 190 in Pointe Coupee, I310-LA3127 Interchange, and I310 Westbound exit ramp to River Road, maximum girder thermal movements were measured at the girder flange and web levels. A frame was mounted to the abutment bridge seat and pointers attached to the bridge girder to monitor movements with respect to a fixed point, (Figure 1). Attachments of the frame to the abutment and girder pointers to the girder were made using a high strength epoxy. The initial position at the start of each study period, approximately two weeks, began with the frame markers butting against the girder pointer. During girder contraction or elongation, the girder pointer pushed the frame markers to locations of extreme girder thermal movement. These maximum values for contraction and elongation were then recorded over each study period of approximately two weeks to monitor any relationship between girder thermal movement and bearing pad slippage. A thermometer was attached to the frame to record maximum and minimum temperatures over the study period. Measurements from the field investigation are included in the final report *[12]*.

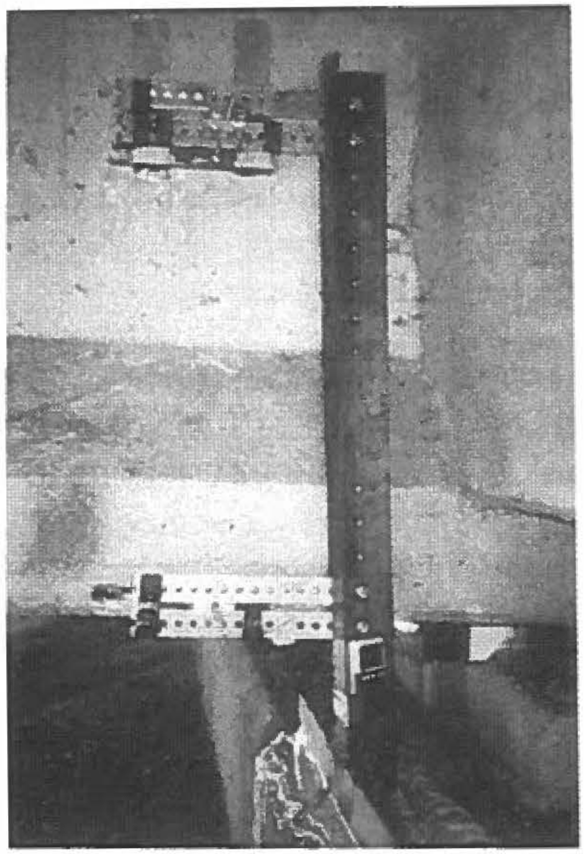

Figure 1
Frame to monitor girder thermal movements attached to the bridge abutment

Video Monitoring

A procedure was adopted to be able to monitor pad movements continually at a site that had previously experienced pad movement. In addition to pad movements, temperature and traffic flows were continually monitored. Traffic flows were desired in order to determine if any relationship existed between traffic and pad movement. It was determined that these type of measurements could be best attained by using a time-lapse VCR and video cameras placed at the bearing pad and superstructure levels. Simultaneous coverage of traffic, temperature, and pad location were taken at three-second intervals; at this time interval, two-hour videotapes required changing within 15-day periods.

The Mermantau site was selected. The bridge is 619 m (2031ft.) long and was built in 1981. The site was selected due to its pad slippage record, availability of electricity, and secluded location to protect against vandalism. At this bridge, Bent Five, Span Five was selected because of pad slippage record cited in inspection reports. To gain accessibility to the bent, the DOTD constructed a catwalk adjacent to the pier that ran the length of the bent. On site visits, access to the pier was made using a temporary ladder on the side of the bridge, which was then removed after measurements were taken. Two video cameras and two time-lapse video recorders were used. The video equipment was found invaluable in understanding the type of movements that occurred on a daily basis and to rule out any relationship between traffic and pad movement. Figure 2 shows the camera setup on the bridge pier where the camera was focused on the bearing pad. The pad was marked to easily identify any bearing pad movement. The camera was encased in a PVC tube to protect against ambient conditions and attached to a 10" pedestal. Figure 3 is a typical snap shot taken from the superstructure camera, which recorded traffic movements at 3-second intervals.

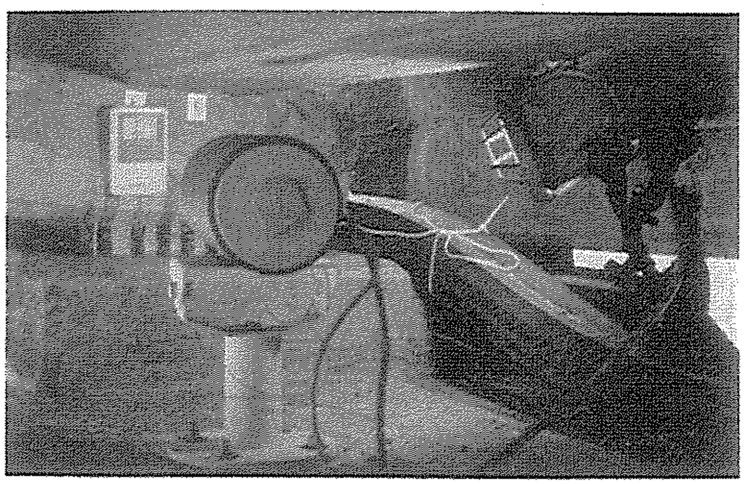

Figure 2
Camera setup on substructure

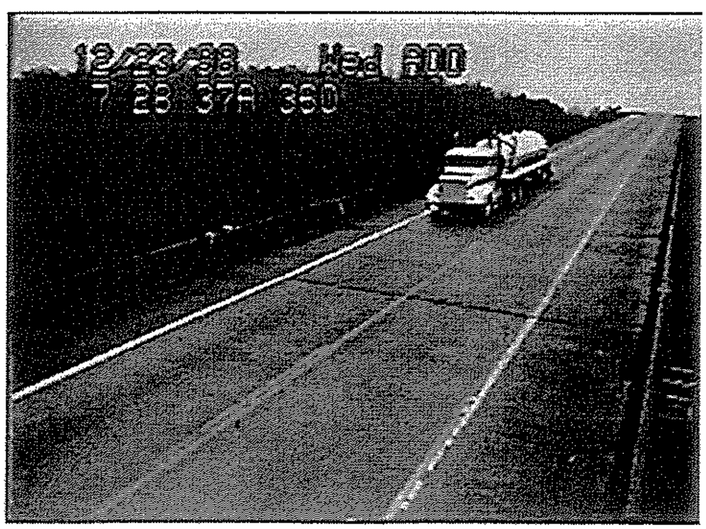

Figure 3
Snap-shot from superstructure camera

By reviewing the videotapes, it was found that the bridge girder slides over the bearing pad on a daily basis due to temperature fluctuations, Figures 4 and 5. Continuous black lines were drawn on the bearing pad, girder, and riser to easily determine any relative movement along the contact surfaces. The variation from a vertical position of the black lines on the pad, Figure 4, indicates that the pad deflects only slightly in shear before the coefficient of friction at the contact surface is overcome.

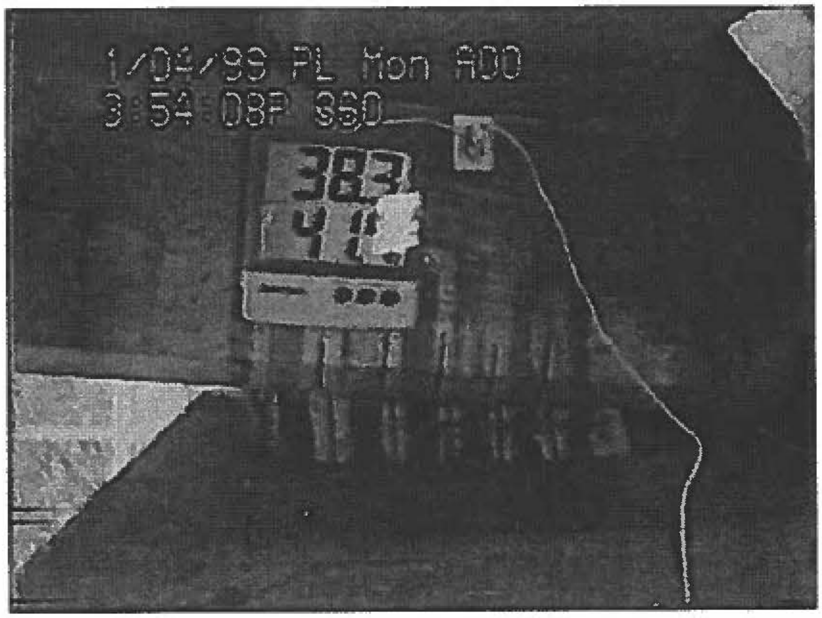

Figure 4
Girder position afternoon of 1/4/99 (T=38°F)

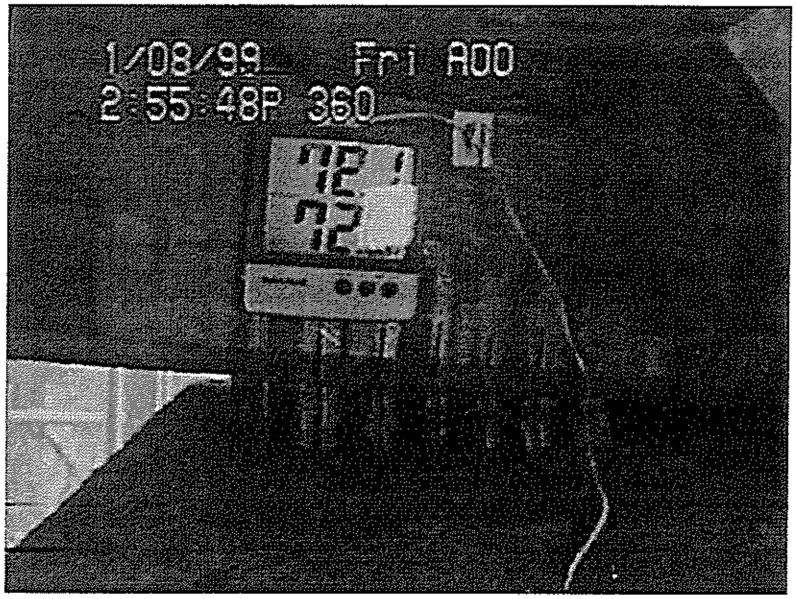

Figure 5
Girder position afternoon of 1/8/99 (T=72°F)

No relationship was found that would directly relate girder thermal movements with the initiation of pad walking.

Laboratory Investigation

The primary goal of the laboratory investigation was to determine the bearing pad composition of the pads that had experienced walking. Ozone cracks develop at the edge of the bearing where the pad is in tension. To insure that pads satisfy AASHTO requirements to prevent ozone degradation, bearing pad manufacturers add wax during compounding so that the nominal wax solubility to prevent ozone degradation is exceeded throughout the life of the bearing pad. At high temperatures, which occur during compounding, a bearing pad is supersaturated with wax and as the pad cools excess wax crystallizes out of the pad onto the surface *[9]*. Although the addition of wax protects against ozone degradation, the addition of wax to elastomeric bearing pads reduces the pad's coefficient of friction.

In this investigation, laboratory tests were conducted on bearing pads that had experienced walking. The purpose of these tests was to determine the material composition of bearing pads that slipped. The laboratory tests included:

- A neoprene material verification test to confirm that the bearing pads were made of neoprene
- Fourier Transform Infrared Spectrometer (FTIR) tests to determine the pad's composition

Ten bearing pads that had experienced walking while in service were obtained from the DOTD Bridge City district. A neoprene material verification test was conducted and the pads were confirmed to be neoprene *[13]*. In addition, samples from the five field sites, which were included in this project, were tested along with a sample from a bearing manufacturer, which was used as a reference.

No bearing pads supported combustion, indicating that all were made of neoprene. An infrared spectrum of each pad sample is provided in the project final report *[12]*. Most of the bearing pads were found to contain some kind of wax, however none of the wax appeared to be pure paraffin, but rather a wax blend. 12 of the 14 pads that slipped out of position contained some form of wax.

CONCLUSIONS

With the use of time-lapse video equipment, slippage was found to occur daily along the boundary between the pad-girder interface during girder thermal movements. This behavior is contrary to the design assumption that bearing pads deflect in shear with girder thermal movements. In comparing bridges in which bearing pads had experienced slippage, no obvious similarities were found except in the material content of the bearing pad. A laboratory investigation conducted on ten bearing pads that had experienced walking revealed that a majority of these pads contained some form of wax. In some cases wax bloom was clearly noticeable on the surface of the pad. Although wax bloom provides for ozone protection, it adversely affects the coefficient of friction of the pad.

In order to remedy this condition, the amount of wax materials added by bearing pad manufacturers for ozone protection should be limited. For existing cases in which bearing pad slippage has occurred, pads and contact surfaces need to be cleaned with a degreasing agent to thoroughly remove any wax residual.

RECOMMENDATIONS

- AASHTO should remove ozone requirements on neoprene bearing pads. These requirements are unwarranted since only a thin outer layer is affected by ozone attack. Waxes added by manufactures to satisfy these requirements migrate to the surfaces of the bearing pad and substantially reduce the coefficient of friction.

- If wax is required, AASHTO should prohibit the use of paraffin wax in neoprene bearing pads.

- AASHTO anchorage specifications use a limiting coefficient of friction of 0.2 for bearing pads. Because of wax bloom, a lower coefficient of friction should be used to determine the need for positive pad anchorage.

- Neoprene bearing pads should only be ordered from those bearing manufacturers that do not add wax to their product.

- A random bearing pad from each order should undergo rigorous testing to ensure quality of the product.

- For repositioning of pads that have experienced walking, the contact surfaces and bearing pad surfaces must be scrubbed with a degreasing agent to remove any wax. The pad should be soaked with chlorobenzene to soften the pad and allow a greater contact bond between the pad and contact surfaces.

- Pads of lower hardness should be used to better absorb any slope mismatch and ensure desirable shear deflection. Therefore, pads using 50-durometer hardness should be used.

- 70-durometer bearings are too stiff in shear and should be prohibited. Harder bearings are stiffer in shear and more prone to slip *[11]*. Since neoprene bearings have a tendency to stiffen after a decade of service, 50 durometer neoprene-bearing pads are recommended.

- The texture of the concrete surfaces that will be in contact with the bearing pad should be roughened to increase contact area.

- Plain bearings should be prohibited at expansion joints.

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