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LOAD-CARRYING GEOSYNTHETIC-REINFORCED SOIL BRIDGE ABUTMENTS

Jorge G. Zornberg[1] and Amr M. Morsy[2]

[1] Department of Civil, Architectural, and Environmental Engineering, The University of Texas at Austin, Austin, TX 78712, United States.
E-mail: zornberg@mail.utexas.edu, web page: https://sites.utexas.edu/zornberg/

[2] Department of Civil Engineering and Construction Engineering Management, California State University Long Beach, Long Beach, CA 90840, United States.
E-mail: amr.morsy@csulb.edu

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Abstract. *This paper presents the summary of a comprehensive survey conducted to synthesize global information on bridges supported by "Load-carrying Geosynthetic Reinforced" (LC-GR) abutments that have been constructed so far. An evaluation was conducted to assess the different abutment characteristics, geosynthetic types, and facing systems adopted worldwide in these systems. Evaluation of the over 500 structures incorporated into the database of worldwide LC-GR bridge abutments compiled as part of this study reveals that a particularly wide range of geosynthetic materials and facing types have been successfully used in LC-GR abutments for bridges with a wide range of heights, span lengths, and subsurface conditions.*

1 INTRODUCTION

Geosynthetic-reinforced (GR) soil walls have been adopted extensively in transportation infrastructure worldwide. In the specific case of bridge abutments, this technology has been generally used to support loads induced by approaching roads, while loads of the bridge superstructure have been typically transferred to competent soil strata through deep foundations. This technology has evolved into load-carrying geosynthetic-reinforced (LC-GR) bridge abutments, in which the geosynthetic-reinforced system acts not only as a retaining wall for the approaching road but also as a reinforced foundation to directly support the bridge superstructure loads. By omitting the use of deep foundations, LC-GR bridge abutments provide significant advantages, such as alleviating the differential settlements between approaching roads and bridge decks that often lead to the "bump at the end of the bridge." However, design approaches, materials, and construction guidelines for LC-GR bridge abutments have varied widely worldwide, which may have precluded a broad adoption of this system. Accordingly, a comprehensive survey was conducted as part of this study to synthesize global information on bridges supported by LC-GR abutments that have been constructed so far.

2 GEOGRAPHIC DISTRIBUTION OF LC-GR BRIDGE ABUTMENTS

The terminology adopted to refer to LC-GR bridge abutments has varied widely in the technical literature, which may have obscured understanding of the significance of different design approaches. For example, the terms "Geosynthetic Reinforced (GR)," "Geosynthetic Reinforced Soil (GRS)," "Mechanically Stabilized Earth (MSE)," and "Geosynthetic

Mechanically Stabilized Earth (GMSE)" have been used since the 1980s, often indistinctly in the technical literature, to refer to retaining structures that are reinforced with geosynthetics. While these various terms have often been used generically and irrespective of their reinforcement vertical spacing in most of the technical literature, the term "GRS" has been associated in some US Federal Highway Administration (FHWA) guidelines with structures designed using small reinforcement vertical spacing (Adams *et al.* 2011, 2018). Geosynthetic-reinforced walls constructed as part of a bridge system can be identified as "geosynthetic-reinforced (GR) bridge abutments," irrespective of whether they carry only the load of the approaching road (*i.e.*, the most common case) or the loads of both the approaching road and the bridge superstructure.

The specific term "Load-Carrying Geosynthetic-Reinforced (LC-GR) bridge abutment" is adopted herein to identify GR bridge abutments whose reinforced fill receive the full load of the bridge superstructure, rather than transferring such load directly to the foundation soils via deep foundation systems bypassing the reinforced soil structure. It should be noted, however, that other terms (*e.g.*, "true abutments") have been used to describe this type of systems. While the term "LC-GR bridge abutment" applies to any reinforcement vertical spacing, the term "Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) abutment" has been used for structures designed following FHWA guidelines that prescribe not only a comparatively small reinforcement vertical spacing but also rather specific requirements for construction and materials. Accordingly, GRS-IBS structures can be identified as a subset of the more generic "LC-GR bridge abutment" systems.

The term "integral" abutment has been used by bridge engineers to identify those abutments that have: (1) no thermal expansion joints between the bridge superstructure and approach road; and (2) no bearings or elastomeric pads isolating the superstructure from the substructure (Burke 2009). Some LC-GR bridge abutments, including many GRS-IBS structures, would classify as "integral" bridges according to this definition even though the GRS-IBS structures may not necessarily involve integration between the GR abutments, the bridge superstructure, and the approaching roads. Figure 1 summarizes the interrelationship among the geosynthetic-reinforced structures associated with the terms "GR walls," "GR bridge abutments," "LC-GR bridge abutments," "Integral GR bridge abutments," and "GRS-IBS."

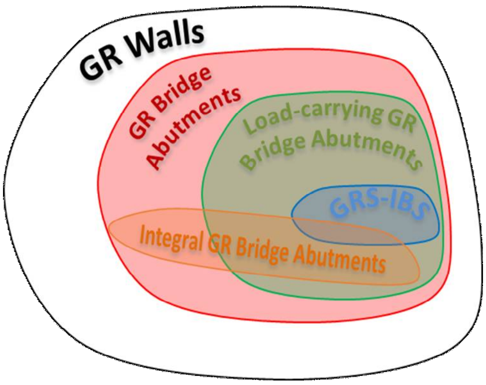

Figure 1. Interrelation among the different GR structures (after Zornberg *et al.* 2018).

Figure 2 shows a world map with the distribution of bridges supported by LC-GR abutments by country. Note that the number of bridges in each country may not necessarily represent the total number of bridges that have been constructed so far. Instead, it represents the number of bridges identified by the authors following an extensive search of published and unpublished sources. Overall, a total of 507 bridges constructed with LC-GR abutments were identified worldwide. In North America, the United States tops the world's list, with 205 identified bridges. Many LC-GR abutments that have been constructed in the continental US were instrumented as part of various research studies undertaken to understand their behavior. However, the structures considered in this study did not consider experimental structures unless they involved operational bridges. A total of 241 bridges were identified in North America, with a majority in the US. A significant increase in the number of bridges supported using LC-GR abutments occurred after the introduction of the GRS-IBS approach as part of a program under the FHWA's "Every Day Counts" initiative. Because of this initiative, the great majority of LC-GR bridge abutments can be characterized as GRS-IBS and were designed following guidelines described by Adams *et al.* (2011, 2018). The older abutments, however, were designed and constructed as geosynthetic-reinforced soil walls with distributed loads equivalent to their respective bridge superstructure loads.

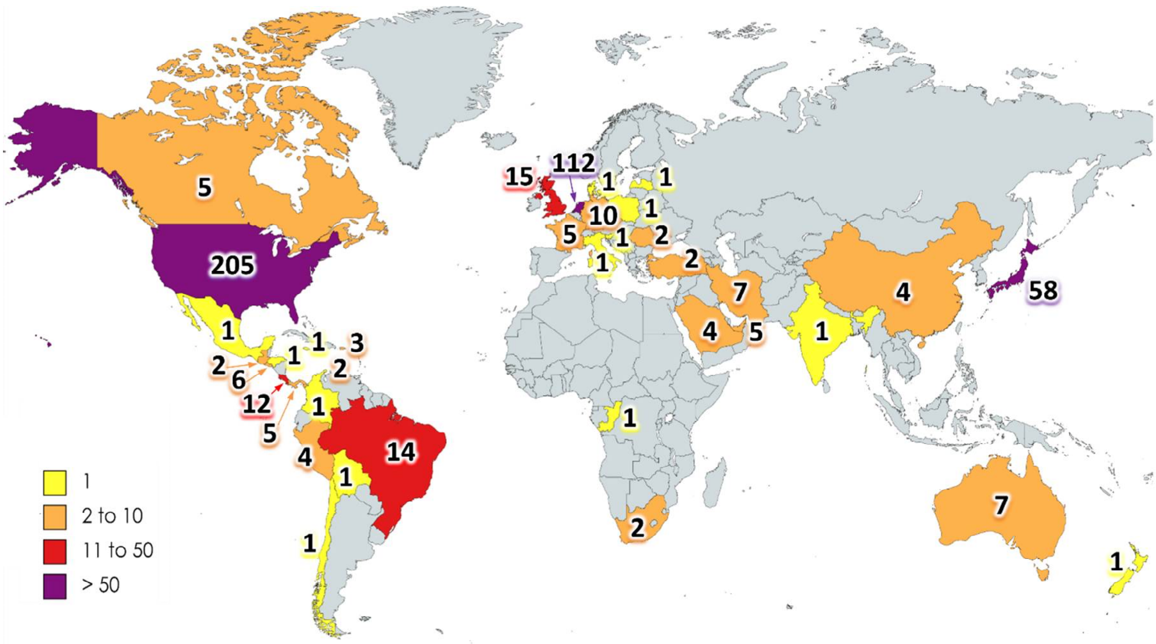

Figure 2. Worldwide distribution of LC-GR bridge abutments by country.

A total of 23 bridges were identified in South America, with a majority in Brazil. Most of the bridges in Brazil were designed considering the approach outlined by Ehrlich and Mitchell (1994) and considered LC-GR abutments as geosynthetic-reinforced soil walls with distributed bridge loads.

A total of 154 bridges were identified in Europe, with most of them in the Netherlands, the United Kingdom, and Germany. The majority of the structures constructed in Europe followed the EBGEO or BSI specifications for reinforced soil walls with distributed bridge loads.

A total of 78 bridges were identified in Asia, with the majority of them having been constructed in Japan. Tatsuoka *et al.* (1997) reported that 17 bridges were constructed in Japan through April 1997, after which the design of LC-GR abutments was modified so that the bridge superstructure would rest on the wall's full-height rigid facing rather than on the geosynthetic-reinforced soil mass; 34 bridges were identified as having adopted this design. Despite its distinct load transfer approach, these structures are also considered in this article since the bridge load is still transferred primarily to the reinforced soil mass (through a rigid facing rather than through a bridge footing) and does not involve deep foundations. Overall, the structures in Japan have been characterized by their unique facing designs, which were developed to improve their seismic performance.

A total of 8 bridges were identified in Oceania. Notably, one of the oldest major LC-GR abutments identified in this study was constructed in Australia to support a nine-span bridge. Finally, a total of 3 bridges were identified in Africa.

3 CONCLUDING REMARKS

An important outcome of the survey conducted in this study is that the range of reinforcement vertical spacings, geosynthetic types, facing types and even fill materials is very wide. Also, while the most common geosynthetic type has been geogrids, the majority of the structures in the US have been constructed using woven geotextiles. In addition, while the types of facing in LC-GR bridge abutments vary widely worldwide, the use of modular block facing systems has prevailed in the US. A common characteristic between the structures designed in the US and designed abroad has been the stringent requirements regarding the selection of fill materials.

The motivation for the selection of LC-GR bridge abutments has been their anticipated good performance in providing adequate bearing capacity to support bridge loads and the flexibility required to reduce the bumps at the ends of bridges with acceptable deformations. Additional common reasons for their selection have been the shorter construction time as compared to conventional abutment alternatives, and their comparatively lower cost in relation to conventional abutments, as they do not require special equipment or a highly skilled workforce.

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