# *Cost Effective and Fast Construction Method of the GRS-IBS Technology*

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***Abstract*** *— The Geosynthetic Reinforced Soil-Integrated Bridge System Technology (GRS-IBS) could reduce cost between twenty five to sixty percent and maybe more from conventional construction method. This report evaluated the cost and time between two bridge projects with comparable characteristics, one using GRS-IBS technology and the other using a conventional bridge construction method. Time and costs from each construction project was gather for analysis purposes. The time of construction using GRS-IBS technology represents a 14% of a total time spent for a conventional bridge construction method and the 21% of the total cost of a conventional construction method. Because this technology needs less equipment, different materials construction, less use of labor and can easily be constructed; provides more advantages than a conventional bridge construction method.*

***Key Terms*** *— Cost Reduction, Easily Fast Construction, Geosynthetic Reinforce Soil (GRS), Integrated Bridge System (IBS).*

## INTRODUCTION

For many years, the construction of bridges has been a long and expensive process. However; there are essential sections for the road design. Since 1970, the Geosynthetic Reinforced Soil (GRS) has been used to build walls for roads in steep mountain terrain. Since then, the technology has evolved into the GRS Integrated Bridge System (IBS). GRS-IBS, consists of three main components: the Reinforced Soil Foundation (RSF), the abutment, and the integrated approach. The system has several advantages. It can easily be design, economic constructed, built in variable conditions with readily available labor, materials, equipment and can easily be modified in the field. GRS-IBS technology could reduce cost from twenty five to sixty percent from conventional construction methods. [1]

As of 2010, 45 bridges utilizing abutments had been built in the United States; where the IBS had been employed on 28 bridges from the 45. All built over water crossings [1]. On October 2010, approximately 20 structures were constructed in two counties in two states. Since then, the Federal Highway Administration (FHWA), Every Day Count (EDC) initiative has resulted on over 150 new bridges in more than 35 states including bridges on the National Highway System (NHS) [2].

### Research Description

Recently on 2013, the Puerto Rico Highway and Transportation Authority (PRHTA) in partnership with the FHWA EDC, took advantage of this new initiative technology and replaced the PR-2 original bridges, BR-1121 and BR-1122 near Yauco, Puerto Rico [3]. The original bridges consisted of twin three span structures with a total length of 24.2 m which were replaced with twin single span structures of 11.1 m [2]. Fifty days and $738,560.63 were spent for the BR-1122 reconstruction using the GRS-IBS technology (Figure 1& 2) [4].

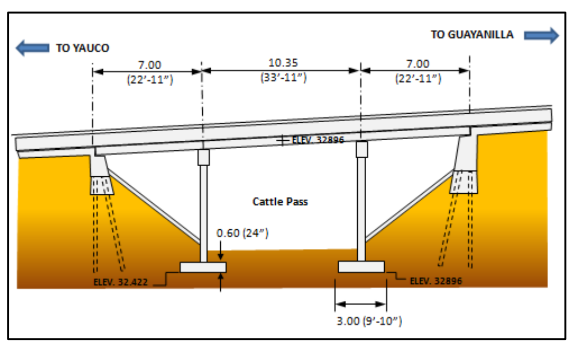


**Figure 1**
**C-Bridge - Bridge 1122**

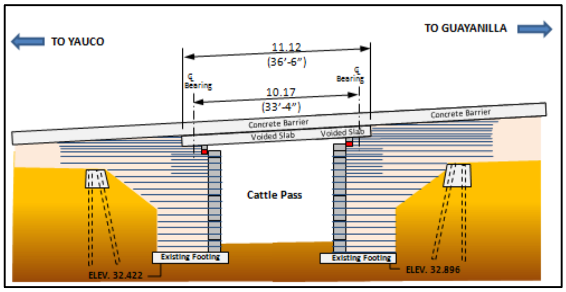


**Figure 2**
**Conventional Bridge Transform onto using GRS-IBS Technology**

To validate the cost and time that could be save using the GRS-IBS Technology on future bridge projects; a comparison was established on construction time and cost, between the replacement of BR-1122 and BR-1496.

The analysis covers the following areas:

- Cost for:
    - common items;
    - structural bridge construction major elements; and
    - the evaluation of the entire project
- Time spent for:
    - construction activities; and
    - the entire project

The conventional bridge BR-1496 from this point forward on this document refer as C-BRIDGE; has two spans, but for analysis purposes and comparable bridge projects; one bridge section is not been taken in consideration for cost and time construction (Figure 4) [5].

### Research Objectives

The objective of this project is the evaluation of the GRS-IBS Technology from the point of view of cost and time reduction.

## LITERATURE REVIEW

GRS-IBS is a fast, cost-effective method of bridge support that blends the roadway into the superstructure to create a jointless interface between the bridge and the approach (Figure 3) [1]. As mentioned above, GRS-IBS has three main components: The RSF, GRS abutment and the IBS approach.

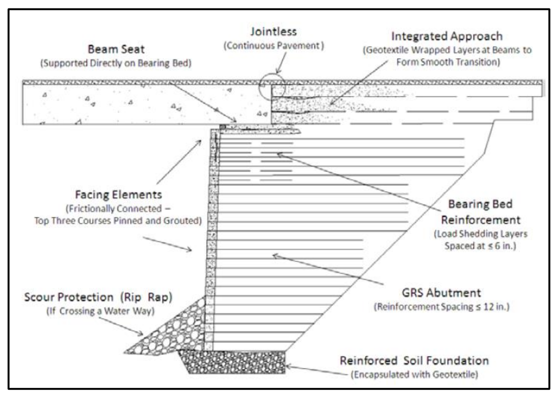


**Figure 3**
**GRS-IBS Cross Section**

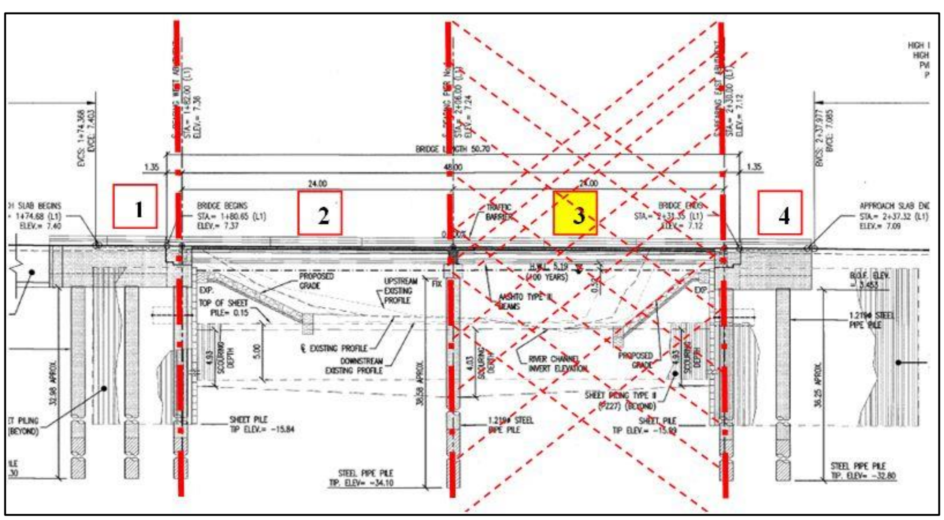


**Figure 4**
**C-Bridge Plan – Guayanilla Bridge 1496**

The RSF is composed of granular fill material that is compacted and encapsulated with a geotextile fabric (Figure 5). It provides embedment and increases the bearing width and capacity of the GRS abutment. It also prevents water from infiltrating underneath and into the GRS mass from a river or stream crossing. This method of using geosynthetic fabrics to reinforce foundations is a proven alternative to deep foundations on loose granular soils, soft fine-grained soils, and soft organic soils. The abutment uses alternating layers of compacted fill and closely spaced geosynthetic reinforcement to provide support for the bridge, which is placed directly on the GRS abutment without a joint and without cast-in-place (CIP) concrete (Figure 6). GRS is also used to construct the integrated approach to transition to the superstructure. This integrated bridge system therefore alleviates the "bump at the bridge" problem caused by differential settlement between bridge abutments and approach roadways. When integrated, into the construction of a bridge, the use of GRS makes bridge abutments that are easier and faster to build (Figure 7) [1].

## The GRS-IBS Activities

The following figures are the three main activities of the GRS-IBS taken at the Yauco bridge construction process.

**Figure 5**
**Reinforced Soil Foundation**

**Figure 6**
**Abutment and Wing Walls (CMU) GRS**

**Figure 7**
**Integrated Approach Zone (IBS)**

The construction is much simpler with GRS-IBS since it has fewer parts, involves basic earthwork methods and practice. A GRS bridge resist earthquake forces if it is constructed properly with closely spaced reinforcement. One of the benefits of construction GRS-IBS can be built in variable weather conditions and can be adapted very easily in the case of unforeseen site conditions.

GRS-IBS Quick Facts [1]:

- Bridges constructed with the GRS-IBS cost 27 percent less than bridges built with traditional methods, depending on the standard of construction and the method of contracting (local forces versus a private contractor).
- Compared with a Department of Transportation standard bridge, a GRS-IBS can potentially save up to 60 percent in cost.
- Construction is much faster than traditional construction methods. A bridge can be completed in weeks, not months.
- Eliminates the "bump at the end of the bridge" problem caused by differential settlement between the bridge abutment and the approaching roadway.

## Yauco GRS-IBS Guidelines

The design of Yauco's GRS bridges were made in accordance with the nine design steps of the GRS-IBS Guidelines [4]:

- Establish Project Requirement (Geometry, Loading Conditions & Performance Criteria).
- Perform Site Evaluation (Topographic, Soil Conditions, H-H & Existing Structures).
- Evaluate Project Feasibility (Cost, Logistics, Technical Requirements and Performance Objectives).

- Determine Layout of GRS-IBS (Geometry and Excavations).
- Calculate Loads (Live, Dead, Impact and Earthquake Loads).
- Conduct External Stability Analysis (Direct Slide, Bearing Capacity & Global Stability).
- Conduct Internal Stability Analysis (Vertical Capacity, Deformations and Reinforcement Strength).
- Implement Design Details (Reinforced Soil Foundation, Guardrails, Drainage & Utilities).
- Finalize GRS-IBS (Reinforcement and facing block layout & fill).

Fifty seven days to complete the BR-1122 using the GRS-IBS Technology; it had a big reduction on materials, labor and equipment. The longest activities on the GRS-IBS construction were the GRS abutment and wing wall (Table 1) [4].

**Table 1**
**Time of Each Activity**

| ACTIVITIES | CONSTRUCTION DAYS |
| --- | --- |
| Demolition | 12 |
| Foundation RSF | 10 |
| GRS Abutments and Wing Walls (CMU) | 18 |
| Prestressed Voided Slabs | 2 |
| Integrated Approach Zone (IBS) | 5 |
| Concrete Parapets | 8 |
| Waterproof Membrane | 1 |
| Asphalt Pavement | 1 |
| **TOTAL** | **57** |

This technology has its advantages; however it has certain requirements on the geometry, loading conditions and performance criteria as part of the first of the design criteria of the GRS-IBS Guidelines [1].

## METHODOLOGY

For the comparison of costs and construction time, two bridge replacement projects were selected. Table 2, provides a general description of their superstructure and substructure. BR-1122 bridge with GRS-IBS technology and the BR-1496 using the conventional method. The total project costs in common and the time of construction phases will be compared. It is important to understand that the process of construction of the GRS-IBS is different in almost all its phases because the equipment, type of materials and also the amount of labor needed for its construction.

**Table 2**
**Bridge General Description**

| ITEM | C-BRIDGE - 1496 | GRS-IBS - 1122 |
| --- | --- | --- |
| Bridge Total Width | 9.9 m | 12.44 m |
| Bridge Lanes | 2 | 2 |
| Foundation | Deep Foundation | RSF & Deep Foundation |
| Abutment | Sheet Piles | Geosynthetic Reinforced Soil |
| Types of Beam | AASHTO Type III Beam Reinforcement | Prestressed Structural Concrete Member Voided Slab |

Figure 4, shows the bridge division, where the section three was neglected as part of the cost and the Guayanilla River related construction items. The comparison will be based on a bridge with one span configuration (Figure 8) [5].

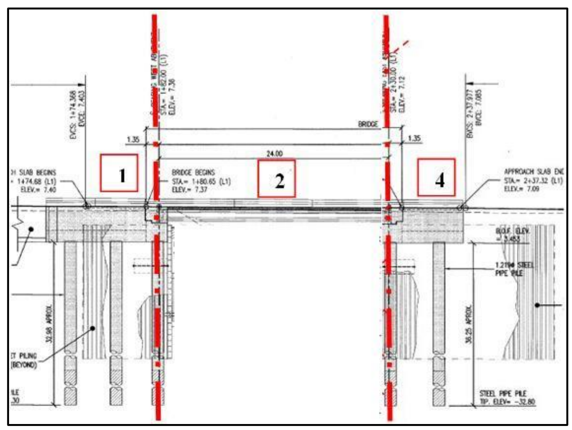


**Figure 8**
**C-BRIDGE**

The higher percentage of cost for BR-1496 relies on the West and East Side of the bridge. In terms of cost analysis, a twenty five percent was reduced of the total cost for those items related on section three to obtain comparable samples (e.g., Reinforcing Steel, AASHTO Prestressed Beam Type III, others). Therefore, the percentages and numbers obtained from the analysis are reliable data.

## RESULTS AND DISCUSSION

The cost and time analysis for the project, is as follows:

- The total cost of the C-Bridge is $4,040,125.00; this amount is taking in consideration the entire bridge system. After applying the twenty five percent of reduction, the C-Bridge total cost is now $3,562,976.10, having a $2,824,415.47 more money spent for a bridge construction. However, only $738,560.63 was spent for the GRS-IBS project, which represents a 21% of the total C-Bridge cost. Therefore, 79% of more money was utilized to complete a C-Bridge project. The 79% represent an approximate three more bridges that could be built using the GRS-IBS Technology (Figure 9).

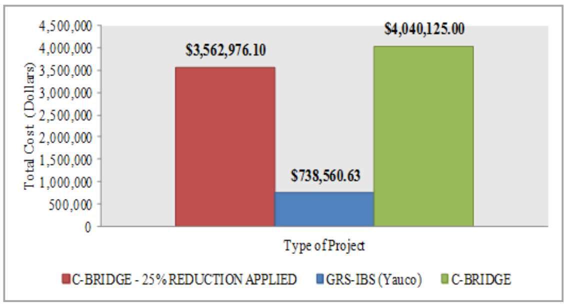


**Figure 9**
**Project Total Cost**

- The activities with major differences were on mobilization and reinforced steel (Figure 10). Other activities were evaluated as the unclassified excavation, unclassified excavation for structures, trench excavation unclassified and others.
- The C-Bridge project spent $185,000 more money for mobilization and $165,521.22 for reinforced steel.
- Approximate 52% and 99% more costs for mobilization and reinforced steel activities.

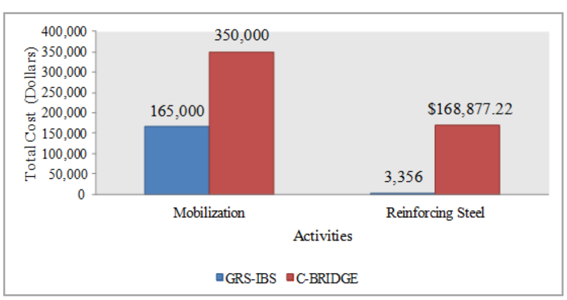


**Figure 10**
**GRS-IBS & C-BRIDGE Common Schedule**

- Comparing the structure costs, the C-Bridge is 85% higher on cost than a Bridge construction using the GRS-IBS technology (Figure 11).

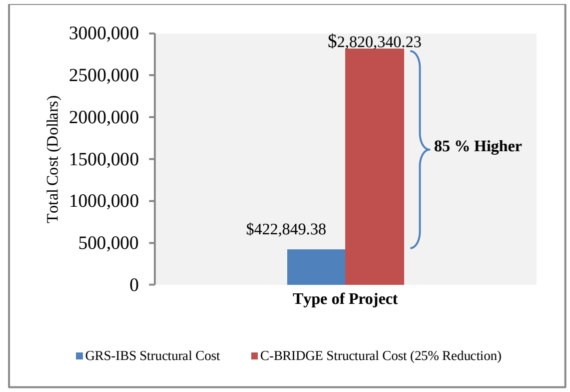


**Figure 11**
**Structural Total Cost per Project**

- The C-Bridge spent 343 more days on construction than the GRS-IBS bridge construction (Figure 12).
- Almost 7 bridges could be build using the GRS-IBS Technology meanwhile takes approximates 400 days to build one conventional bridge project.
- The time spent for the GRS-IBS bridge construction only represents a 14% of the total time spent for the C-Bridge Construction.

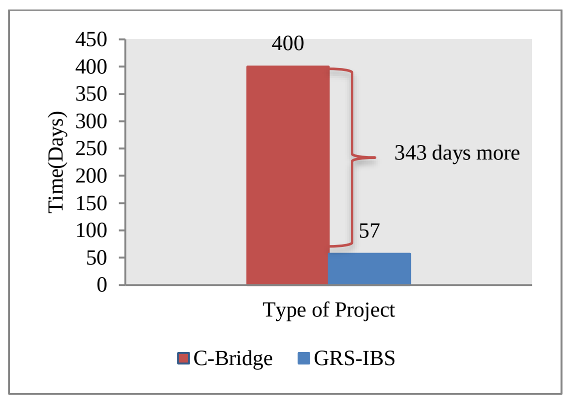


**Figure 12**
**Time Project Construction**

- Eighteen days were the longest time spent on one construction activity on the GRS-IBS from a total of fifty seven days. (Figure 13).
- One hundred thirty five days were spent just for the Westside bridge construction on the C-Bridge (Figure 14). However, the GRS-IBS only took thirty two days to complete the abutment and wing walls, the integrated approach zone and the RSF construction. A lot of progress on a short timeframe (Figure 13).

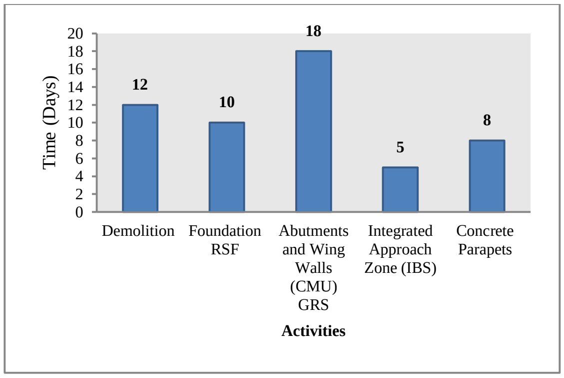


**Figure 13**
**Time of Construction per Activity**

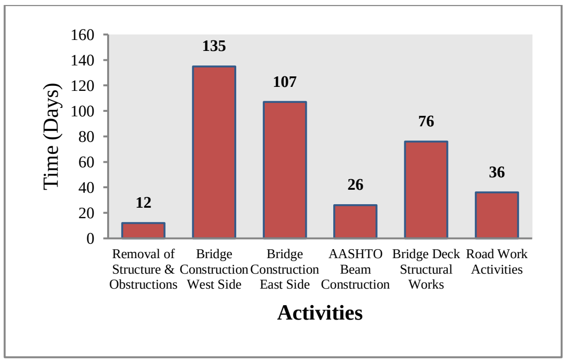


**Figure 14**
**Time of Construction per Activity**

## CONCLUSION

The objective of this project was to evaluate the GRS-IBS Technology from the point of view of cost and time reduction. After analyzing the two projects, we can conclude that an 86% of time and 79% of cost could be saved; if the GRS-IBS Technology had been implemented. Until now, there are some minimum requirements to use this technology [1], but the FHWA EDC keeps working toward its development, implementation and research [6], which leads this technology to a viable option.

## RECOMMENDATIONS

Following the minimum requirements (the geometry, loading conditions and performance criteria) [1] and in accordance, with the nine design steps for the GRS-IBS Guidelines mentioned above [4]. This bridge construction method should be taken in consideration, as a possibility for Puerto Rico Bridge System (PRBS). All those bridges that require to be replaced on the PRBS should be evaluated for GRS-IBS construction method and be integrated on the Puerto Rico Bridge Asset Management Plan.

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