A Comparative Analysis of The Constructability and Reliability of Reinforced Concretegirder and Prestressed Concrete Girder of Caulaman Bridge in Floridablanca, Pampanga

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Abstract- Bridges hold a special position in the transportation system because of the connections to other locations. Because there are many variables to take into account when determining how well a bridge performs, such as geometry, span clearance, traffic flow, and the materials that are available, there are numerous options for bridges from which to choose. Thus, conducting a comparative analysis of Caulaman Bridge using Reinforced Concrete and Prestressed Concrete design will provide insights on what bridge is easier to construct and more reliable when subjected to various loads. This study was divided into three phases: Data Collection Phase, Data Analysis Phase, and Data interpretation Phase. Under the data collection phase, the researchers gathered data using DPWH's Bridge Inventory and PERTCPM. The bridge's As-built plan were also used. The data collected showed that in terms of manpower and duration of construction, it showed that Prestressed Concrete Deck Girder design needs fewer days and manpower to be constructed. For the data analysis phase, the researchers used Finite Element Analysis, specifically CsiBridge software to analyze the reliability of bridge when subjected to various loads. The analysis showed that the prestressed concrete girder is more reliable than reinforced concrete girder when subject to dead load and live load. Lastly, for the data interpretation phase, Microsoft Excel was used to compare the results of the analysis.

I. INTRODUCTION

Bridges are models for a nation's infrastructure. For connecting people, goods, and transportation, bridges are essential. Bridges allow for the easy completion of tasks that were once impractical. Merchandise and shipping supplies are moved between locations using bridges. The study of Dusicka (2013) said that bridge damage from an earthquake could significantly impact on a system of transportation. These setbacks can affect the post earthquake emergency response, delay repairs, and waste crucial time for commuters and freight. Older bridges, those built before an average service life lasts for 50 years, it should be upgraded with more substantial materials, especially in earthquake-prone locations, to avoid this catastrophe.

According to the List of National Bridges with Length, Type, and Condition per District Engineering Office of DPWH, the Caulaman Bridge in the 25th section of the table with a length of 134m, a permanent type of bridge is in poor condition as of November 17, 2022. DPWH decided to redesign and reconstruct the Caulaman Bridge and the new design will use prestressed concrete beams instead of reinforced concrete beams. Precast prestressed girders are a form of concrete girder that expedites bridge construction by utilizing manufactured off-site girders, transported to the construction site, and erected. Since these girders require little to no falsework, they are a preferred solution for projects that require rapid construction or minimal disruption to traffic. When lengthier beam lengths are necessary, prestressed girders are particularly economical. Prestressed girders are particularly cost-effective when longer beam lengths are required; specific variants are suitable for spans of up to 200 feet.

The bridge also has a history of repairs and strengthening for the past few years. Last 2016, the bridge was supported by reinforcing the substructure and prominent members. 10 This strengthening proved not effective when the superstructure of the bridge was severely damaged due to an earthquake last 2019.. With these, the researchers studied the bridge's constructability and reliability and simulated the data using finite element analysis.

Constructability does not seek to diminish the quality of the design, alter the project's objectives, or enhance or replace the designer's duties. Constructability is to gain a deeper understanding of the decision-making processes employed in design earlier. A statistical method is used in reliability analysis to evaluate whether a bridge will fail. Load and resistance variables are calibrated using a variety of approaches in structural reliability analysis. Proper calibration of the load and resistance factor is required to achieve the design confidence necessary to meet the design consistency requirements or to attain a desired reliability index. (Nims et. al., 2020) The researchers aim to analyze the two designs of the Caulaman Bridge.

II. RESEARCH METHODOLOGY

To analyze and compare the constructability and reliability of the bridge, several data were required. The researchers gathered information on the Caulaman Bridge using Inventory Inspection provided by the Department of Public Works and Highways (DPWH) Bridge Engineering Department. The inventory consists of information such as the bridge's history, parameters, properties and history of repairs, and other technical data. The researchers also obtained the PERT CPM report by DPWH which consists of the duration of the construction, and the number of workers to finish the construction. With the use of PERT, the duration of a project was estimated. PERT is a well-known project management method that can be used when it is uncertain how long a project will take to complete. To compute for the manpower, aside from manual calculation, Microsoft Excel was also used.

Reliability analysis determines the probability that a bridge will fail. The researchers used the application of reliability methods using AASHTO(LRFD) bridge codes. The researchers used the Finite Element Method (CsiBridge Software) to simulate the Caulaman bridge. Finite Element Analysis is used for simulations to forecast and understand how an object will react under various physical conditions. With this, the researchers will use this method to simulate the data gathered and see how the structure will respond to a given load intervention. Additionally, CSiBridge v24.2.0 software is used to model the bridge. The steps involved in generating the model are Starting the model, Layout, Components, Loads, and Bridge Object.

III. RESULTS AND DISCUSSION

- Constructability

	Reinforced Concrete	Prestressed Concrete
Duration of Construction	747 Calendar Days	300 Calendar Days

Table 1: Duration of Construction

Table 1 shows the comparison of the duration of construction of Reinforced Concrete and Prestressed Concrete design. From the table shown above, the duration of construction of Reinforced Concrete design of Caulaman Bridge is 747 Calendar Days while 300 calendar days long for Prestressed Concrete design of Caulaman Bridge.

MANPOWER	REINFORCED CONCRETE				PRESTRESSED CONCRETE			
	QUARTER							
	1ST	2ND	3RD	4TH	1ST	2ND	3RD	4TH
PROJECT ENGINEER	1	1	1	1	1	1	1	1
MATERIALS ENGINEER	1	1	1	1	1	1	1	1
FOREMAN	1	1	1	1	1	1	1	1
SAFETY OFFICER	1	1	1	1	1	1	1	1
SKILLED LABORERS LABORERS	43	28	22	17	8	10	10	10
					16	18	18	17
TOTAL	47	32	26	21	28	32	32	31

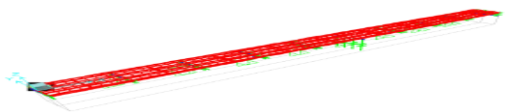
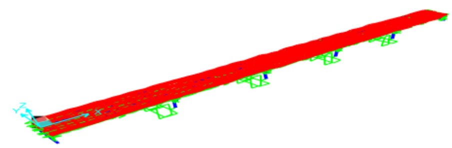
Table 2: Manpower

Table 2 shows the comparison of the Manpower during the construction phase of Reinforced Concrete and Prestressed Concrete design. From the table shown above, the total manpower for construction of Reinforced Concrete design for 1st, 2nd, 3rd, and 4th quarter is 47, 2532, 26, and 21 respectively.

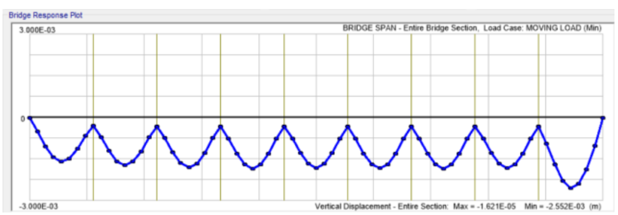
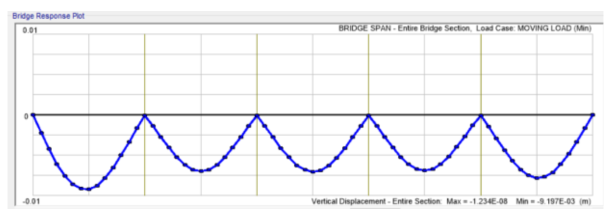
Meanwhile, for Prestressed Concrete design for 1st, 2nd, 3rd, and4thquarter is also 28, 32, 32, and 31 respectively.

- Reliability

Model Geometry

Reinforced Concrete Girder	Prestressed Concrete Girder
 *Figure 1: Finite Element Method*	 *Figure 1: Finite Element Method*

- Structure Results

Reinforced Concrete Girder (Vertical Displacement)	Prestressed Concrete Girder (Vertical Displacement)
 *Figure 2: Entire Bridge Section- Live Load* *Figure 2* Line graph illustrated the displacement along the entire vertical bridge section, which measures 135 m. It showed that the significant displacement is placed in span (1) one, in the starting point, having the 0 response after the current location and –1.621E-05 m response after the current location. The minimum envelope was -2.552E-03 m, located in span (9) nine, which has 126.795 m from the starting point.	 *Figure 9: Entire Bridge Section- Live Load* *Figure 9* Line graph illustrated the displacement along the entire vertical bridge section, which measures 135 m. It showed that the significant displacement is placed in span (1) one, in the starting point, having the -1.234E-08 m response after the current location and 0 m response after the current location. The minimum envelope was -9.197E-03 m, located in span (1) one, which has 13.5 m from the starting point.

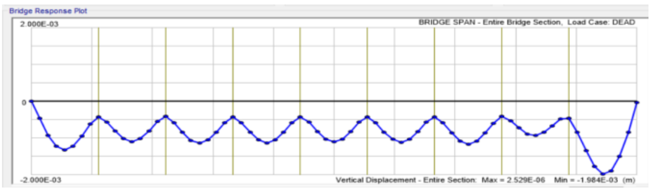


Figure 5: Entire Bridge Section- Dead Load

Figure 5 Line graph depicted the displacement in the left exterior girder. It illustrates the maximum displacement in span (1) nine, in the starting point, having the 0 response before the current location and 2.529E-06 response after the current location. The minimum envelope was -1.984E-03, located in span (9) nine, which has 126.795 m from the starting point.

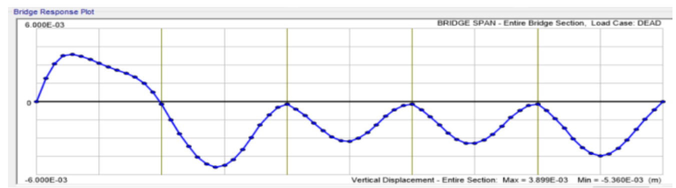
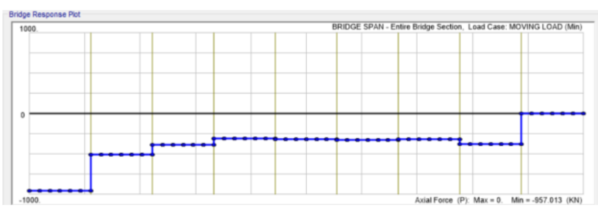
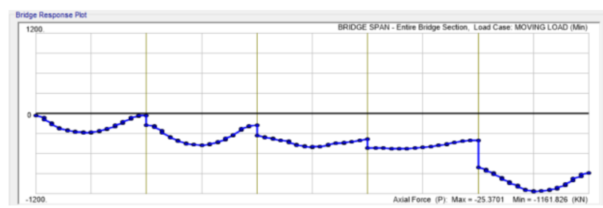
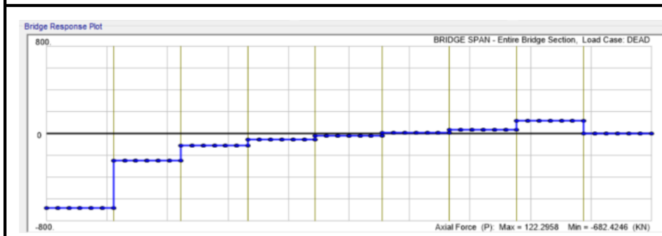
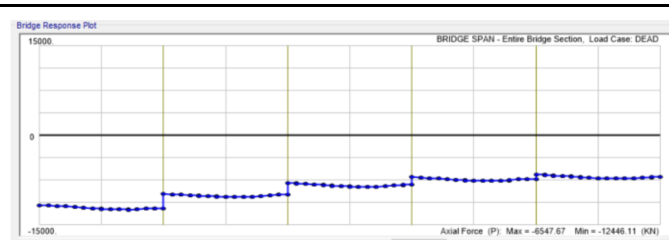


Figure 10: Entire Bridge Section- Dead Load

Figure 10 Line graph depicted the displacement in the left exterior girder. It illustrates the maximum displacement in span (1) nine, which measures 7.7143 m from the starting point, having the 3.899E-03 response before the current location and –2E-03 response after the current location. The minimum envelope was -5.360E-03, located in span (2) two, which has 38.5714 m from the starting point.

Reinforced Concrete Girder (Axial Force)	Prestressed Concrete Girder (Axial Force)
 *Figure 3: Entire Bridge Section- Live Load* *Figure 3* Line graph showed the axial force in the entire bridge section. The maximum force is located in span (9) nine. The minimum force was -957.013KN in span (1) one at 14.85 m.	 *Figure 11: Entire Bridge Section- Live Load* *Figure 11* Line graph showed the axial force in the entire bridge section. The maximum force is located in span (1) one, which in the starting point, having the 0 response before the current location and -25.3701 KN response after the current location. The minimum force was -1161.826 KN in span (5) five at 121.5 m.
 *Figure 4: Entire Bridge Section- Dead Load* *Figure 4* Line graph showed the axial force in the entire bridge section. The maximum force is located in span (8) eight, which at the 119.27 from the starting point, having the	 *Figure 12: Entire Bridge Section- Dead Load* *Figure 12* Line graph showed the axial force in the entire bridge section. The maximum force is located in the 108 m from the starting point, having the -7282.34 KN response before the

122.2958 response before the current location and -2.771E-08 KN response after the current location. The minimum force was-682.4246 KN in span (1) one at 14.85 m.	current location and -6547.67 KN response after the current location. The minimum force was -12446.11 m in span (1) one located at 19.2857 m from starting point.

Reinforced Concrete Girder (Shear Forces Vertical)	Prestressed Concrete Girder (Shear Forces Vertical)

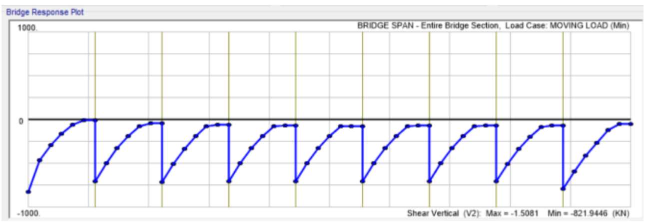


Figure 5: Entire Bridge Section- Live Load

Figure 5 Line graph depicted the shear forces in vertical. It illustrates the maximum forces in span (1) one, which measures 14.85 m from the starting point, having the -1.5081 KN response before the current location and –739.7424 KN response after the current location. The minimum force was -821.9446 KN, located in span (9) nine, with 119.27 m from the starting point.

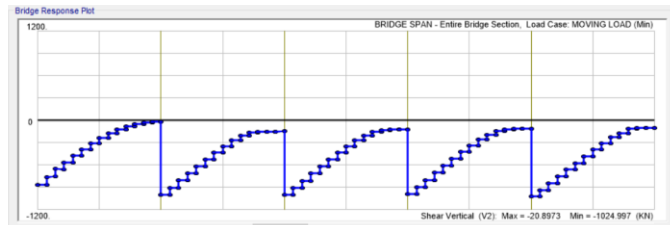


Figure 13: Entire Bridge Section- Live Load

Figure 13 Line graph depicted the shear forces in vertical. It illustrates the maximum forces in span (1) one, which measures 27 m from the starting point, having the -20.8973 KN response before the current location and –1001.313 KN response after the current location. The minimum force was -1027.997 KN, located in span (4) four, with 108 m from the starting point.

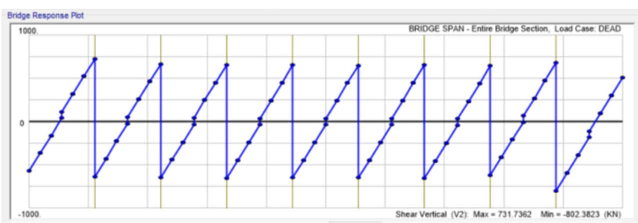


Figure 6: Entire Bridge Section- Dead Load

Figure 6 Line graph depicted the shear forces in vertical. It illustrates the maximum forces in span (1) one, which measures 27 m from the starting point, having the -731.7362 KN response before the current location and –670.5983 KN response after the current location. The minimum force was -835.7633 KN, located in span (9) nine, with 119.27 m from the starting point.

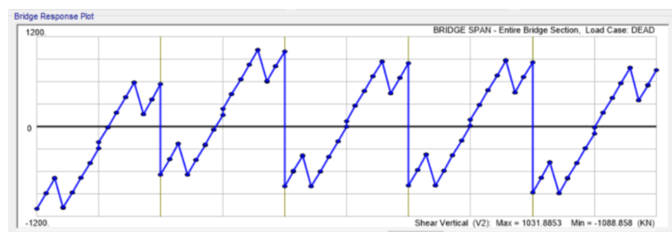


Figure 14: Entire Bridge Section- Dead Load

Figure 14 Line graph depicted the shear forces in vertical. It illustrates the maximum forces in span (1) one, which measures 27 m from the starting point, having the -20.8973 KN response before the current location and –1001.313 KN response after the current location. The minimum force was -1027.997 m, located in span (4) four, with 108 KN from the starting point.

Reinforced Concrete Girder (Deformed Shape)	Prestressed Concrete Girder (Deformed Shape)

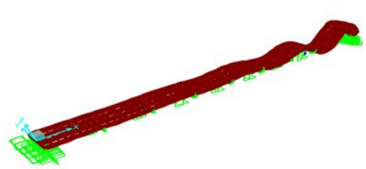


Figure 7: Deformed Shape

Figure 7 was the best presentation of the deformed bridge after being subjected to dead load.

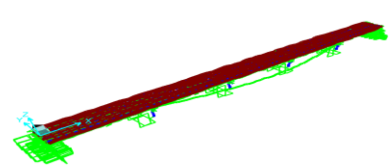


Figure 17: Deformed Shape

Figure 17 was the best presentation of the deformed bridge after being subjected to dead load.

CONCLUSION

This study aimed to analyze the two approaches of bridge design of the Caulaman Bridge, which is the Reinforced Concrete and Prestressed Concrete design. Using the analysis done and the data gathered, the researchers compared the constructability and reliability of the bridge.

For constructability, the results showed that Reinforced Concrete Deck Girder's construction lasts for about 747 calendar days while for Prestressed Concrete Deck Girder, the construction lasts for about 300 days only. Meanwhile, for the manpower, the Reinforced Concrete Deck Girder utilized 43, 28, 22, and 17 total workers for 1st, 2nd, 3rd, and 4th quarter respectively while for Prestressed Concrete DeckGirder, there were 28, 32, 32, and 31 for 1st, 2nd, 3rd, and 4th quarter respectively. Therefore, there is more ease in the construction of the Prestressed Concrete Deck Girder than Reinforced Concrete Deck Girder in terms of duration of construction and manpower.

In terms of reliability, when subjected to dead loads, the analysis showed that Prestressed Concrete Bridge can sustain dead loads better than the Reinforced Concrete Bridge. Also, Prestressed Concrete Bridge can carry live loads better than Reinforced Concrete Bridge. In terms of displacement, the respond of the reinforced concrete girder is greater than prestressed concrete girder.

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