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Case Study Contruction of Post Tensioned Bridge Deck Slab

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ABSTRACT

Pouring in-situ concrete on top of beams in rural bridge designs is a frequent design method that serves to both disperse weight and connect together all of the beams in the bridge. Pouring concrete on the job site, however, presents a greater danger, and most contractors try to avoid doing so. One such technique for securing beams is called transverse post tensioning. The purpose of this paper was to explore how transverse post-tensioning bars behave while providing load distribution between beams and, finally, to remark on how successful they are in comparison to in-situ poured decks. At this point in time, the industry has not conducted a comprehensive investigation into this subject in order to appropriately design post-tensioning. In today's business world, estimations that are on the conservative side are employed. The standard procedure, which is followed now, is to put fifty percent of the design load on the beam at the point where the load is applied in their design assumptions, which are rather high. The group used the grillage modeling technique to simulate concrete box girder bridges that included transverse post-tensioning. The length and breadth of the bridge, as well as its skew and the kind of beam, were all evaluated as potential contributors. The team came to the conclusion, based on the models, that raising the bridge span causes an increase in the load distribution, that the difference in load distribution between skew angles of 0 and 20 degrees is minimal, and that stronger shear actions are seen with increased skew and width. It was established that the worst-case total load that could be applied to the beam would be 40.5%, which is 9.5% less than what is considered standard practice. To get a more in-depth comprehension, it is strongly suggested that an examination identical to this one be carried out utilizing the finite element approach.

Keywords***: bridge deck; concrete box girders, Deck Slab***

INTRODUCTION

One of the most important aspects of urban growth is the construction of bridges. According to the American Association of State Highway and Transportation Officials (2017), there is a wide variety of bridge infrastructure types. In Australia, the box girder bridge, super T girder bridge, and segmental bridge are the most common types of bridges built. Significant changes in methodology have occurred in the building of bridges over the course of the last several decades. There is a large amount of variation in the types of structural components that support bridges as well as the types of decks that are used on bridges. On the other hand, it is plain to observe that the in-situ concreting of bridge decks in Australian bridges has not gone through a great deal of evolution. The framework is then tied together using an in-situ concrete deck that is poured over the supporting components. This creates a monolithic structure, which is depicted below along with some other popular techniques of building the construction of a bridge.

The process of modeling complex bridge structures is time-consuming for engineers working in the field. The load distribution of these transversely post-tensioned deck modules has not been properly analyzed in a research that adheres to Australian requirements and has not been subjected to a comprehensive inquiry. According to the Design Guide for Superstructures with Rectangular Planks published by the Tasmanian Government, each plank must be subjected to a load that constitutes fifty percent of the total design load (Li et al., 2020). This assumption is now being used whenever its bridge decks are being designed. Because of this assumption, the weight from the wheels that are resting on top of the beam is immediately transmitted to the beam that is below them. It is very clear that the design of the bridge does not take into consideration any kind of transverse distribution between the bridge deck elements. Therefore, the design is resilient in the sense that even if the transverse post-tensioning were to fail, it would not prevent the structure from complying with the requirements, and the danger of a catastrophic collapse would be tolerably low. At the moment, the pre-cast deck components are intended to withstand far greater forces than they actually go through in their lifetimes.

Project Significance

Bridge contractors would rather avoid pouring in-situ concrete on-site for the many new bridge constructions in order to lower the costs and dangers associated with the project. It is now best practice to manufacture as many of the bridge parts as possible in the precast yard, then transport those pieces to the construction site and build them there. The post-tensioning rods are often put transversely through the beams after the precast beams have been built in position side by side and grout has been poured into the shear keys. Finally, the beams are tensioned after the post-tensioning rods have been fitted. This method is frequently employed for the construction of smaller rural bridges around Australia. Because of this clamping action, the load distribution may be distributed evenly over all of the beams. A typical example of a transversely post-tensioned precast concrete beam unit seen in a bridge is shown in.

The use of an in-situ deck as the technique of construction is not without its drawbacks. Residents who depend on this infrastructure will have a more difficult time since waiting for an in-situ concrete deck to attain suitable strength takes time and is an inconvenience. It is an annoyance, yes, but it also puts employees in danger on the job site, which leads to an increase in expenses for the project, and it is an inconvenience. Precast concrete deck unit bridges that are transversely post-tensioned are an excellent choice for contractors in terms of speed and ease of construction, as well as aesthetics, risk, and cost. However, in comparison to "traditional in-situ deck bridges," it is unclear whether or whether transversely post-tensioned precast concrete deck units are successful in providing load distribution between beams. According to research by Fu et al. (2011), transverse post-tensioning applies a normal force to the contact, which then develops a clamping mechanism via friction in order to withstand shear stress. This will result in an increase in the shear strength, as well as an improvement in the performance of the transverse connection. By adopting cautious assumptions about the load distribution, the majority of the bridge design companies in Australia have been developing transversely post-tensioned precast concrete deck unit bridges. This analysis will tell them if the assumptions that they are making about the lateral load distribution are cautious or not, and it will help them moving ahead with their future design of precast concrete deck unit bridges. When it comes to building bridges utilizing this technique of construction, this has the potential to cut down on both the expenses and the amount of materials needed. In the course of this project, a numerical investigation will be carried out, during which the bridge decks will be modeled using analytical software. The research that has been provided on the subject will be used to guide the selection of an appropriate modeling strategy and program. The Australian Standards AS5100:2017 Bridge Design, as well as studies from earlier authors and government authorities, will serve as the foundation for the deck analysis of the bridge.

The testing program included both static and dynamic load testing using a variety of vehicle types, as well as long-term monitoring of the behavior of a representative bridge when subjected to natural traffic conditions. According to the findings of this program, the live load distribution is comparable to that of a flat slab, and the stiff kerb units draw the bulk of the load (Ngo et al., 2015). These findings were published in the journal Civil Engineering. The performance of the bridge was able to exceed what was predicted by the theoretical model. They came to the conclusion that more research is required to fully comprehend the process behind how relative motions between deck components effect the transmission of transverse load. In 2019, the Queensland Department of Transport carried out a performance assessment of transversely stressed deck unit bridges. Additionally, in Queensland, Main Load testing was carried out on a decommissioned deck unit bridge span in order to investigate the effects of damaged stressing bars on the performance of the bridge. Both of these tests were carried out in order to determine whether or not the bridge was safe to use. According to Ngo et al., for this particular kind of bridge, the weight transfer process that takes place between the deck components has neither been completely understood nor correctly calculated. In addition to this, he explains that it is difficult to provide an exact estimate of the capacity of the bridge.

For the purpose of this investigation, the transverse stressing bars on the bridge deck were intentionally severed in a number of different places throughout its surface. This resulted in the bars suffering varying degrees of damage. Based on the findings of this investigation, they came to the conclusion that gradually causing damage to the transverse stressing bars decreased the overall capacity of the structure as well as the lateral load distribution. This research led to a significant discovery as a result of its findings. The amount of transverse stressing bar damage is not related to the changes in the load transmission between the deck units; rather, the changes are proportional to the decrease in the areas of mortar joints. The lateral load transmission mechanism of the bridge deck relies heavily on the mortar joints' ability to retain their integrity, and the stressing bars' contribution to the mortar joints' integrity maintenance under lateral pressure is essential. This is a significant finding since the mortar joints are the mechanism that facilitates the transmission of lateral loads from one deck unit to another.

When a deck unit bridge is overloaded above its ultimate limit state load, the likelihood of damage to the mortar joints occurring increases significantly. This is especially true for a bridge that already has damaged transverse stressing bars. In the event that the mortar joints sustain significant damage, the deck units will bear the weight individually, and there will be no transverse load distribution between adjacent). This discovery is backed by the works of Annamalai, who carried out an experimental program to explore the impact of transverse post-tensioning on tiny deck assemblies. Their findings lend credence to the aforementioned observation. They came to the conclusion that post-tensioning had a substantial positive impact on the shear strength of grouted shear key connections. Under the influence of service loads, post-tensioned grouted shear key connections demonstrate a high degree of monolithic behavior. modelled a multi-beam bridge deck using a grillage analysis approach developed by, as demonstrated in the previous sentence. The complete span of the bridge is stretched by a longitudinal shear key that is built into the bridge. states that longitudinal shear key joints have bending stiffness, and that's why shear keys can be represented by a short transverse member that replicates the size and stiffness of the longitudinal shear key joint. shear keys can be represented by a short transverse member. The research is based on the hypothesis that the grouted joint has very low transverse torsional stiffness.

OBJECTIVE

1. The Study Construction Of Post Tensioned Bridge Deck Slab
2. Thes study team modelled concrete box girder bridges with transverse post-tensioning

RESEARCH METHODOLOGY

To study the influence that post-tensioning has on the distribution of lateral loads, a three-dimensional non-linear finite element model was created using commercially available software. He used four-node tetrahedral elements to simulate the concrete, grout, and steel components of the structure. Brick pieces are used to create the bridge deck in which may be found here. Because it is possible to do an exact analysis of the elastic behavior of any structure using the finite element technique, it is now the most powerful and adaptable analytical tool that is accessible.

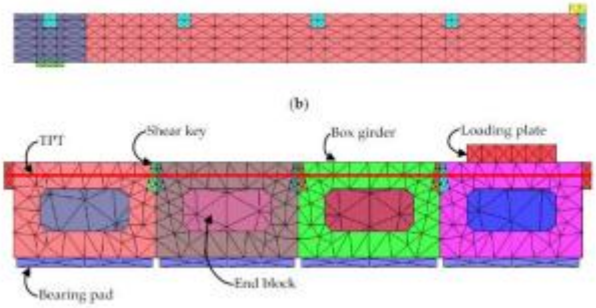

Figure 1: Bridge deck modelled using brick elements

The geometric entities that made up the concrete and the grout each received a fracture-plastic constitutive model as their assignment. For the purpose of simulating unbonded TPT, the internal TPT reinforcement cable was modeled using truss elements that were embedded in the solid components. The coefficient of friction was also set to 0 for this simulation. For the modeling of the girder-to-girder interaction, a Mohr-Columb failure criteria was used.

The use of a grillage analysis, which was created in the past, is the most prevalent analytical approach that is used to evaluate bridge decks. For the purpose of modeling bridge constructions, the grillage analogy has developed into a typical approach. The grillage technique conceptualizes the bridge deck as an assembly of longitudinal and transverse components that are firmly coupled at nodes that are situated on the same plane. The Hambly's Grillage model for bridge deck analysis is seen in Figure 1.

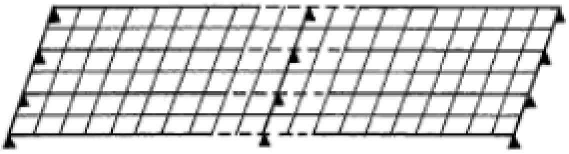

Figure 2: Hamby's Grillage Method

was able to demonstrate that the outcomes of a grillage analysis performed on a box girder are equivalent to the outcomes of a space frame analysis performed on the same box girder He emphasizes the need of giving careful consideration to the relevance of the approximations that were used in the grillage model and provides further information on the grillage study.

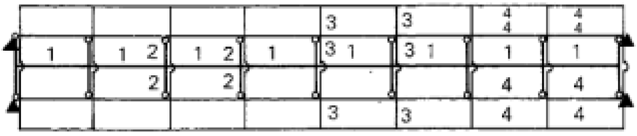

Figure 3. Grillage Analysis Of A Box Girder

The longitudinal spine serves as a representation of the box girder. The spine beam is the sole member of the box girder that represents the stiffness of the box girder in bending, torsion, and distortion. The transverse members, which go across the spine beam, and the longitudinal members, which run parallel to it, together make up the slab. In this grillage, the relative movement of the webs is represented by the twist rotation of the box longitudinal members, and the slope of the transverse members reflects the slope of the slab. Both of these elements are reflected in the grillage. In this work, an adaptation of Hambly's grillage modeling approach was used for the bridge. Our group's goal was to develop a model that was as simple as possible, one in which it would not be difficult to test the findings, and one that would be something that bridge design engineers could use. Utilizing complicated FEM software does not come without its share of downsides. Because of the complexity of the program, the engineer has to undergo training in order to make effective use of it; otherwise, it might be challenging to comprehend or validate whether or not the element stiffnesses are acceptable. When compared to grillage models, it is a substantially more difficult task to extract member activities. Although finite element modeling (FEM) may address the amount of transverse post-tensioning and shear transfer of the bridge deck, this method requires a lot of resources and is thus not essential for the regular examination of deck unit bridges. Because engineers understand beam behavior better using the grillage approach than they do using other methods (Badwan and Liang, For the sake of our project, we judged that a grillage model would be the most suitable way of study.

DATA ANALYSIS

The live load moment distribution, also known as LLMD, will be provided for a variety of beam types, bridge widths, bridge skews, and bridge spans. In the appendix, you can find tables that depict the live load moment distribution.

In-Situ Deck vs Post Tensioned Deck Units

A grillage model was developed for a single-lane bridge that was 20 meters long and had no skew at all. This model was constructed for both an in-situ deck and a deck unit bridge with TPT. The comparison of the live load moment distribution in in-situ and transverse post-tensioned deck components for a 20 m 4 beam bridge is shown in.

Single Lane Bridge

The effects of skewing the bridge at 20 degrees on the lateral moment distribution were explored for each of the distinct bridge configurations. An M1600 live load was placed in the centre of a single-lane bridge as well as at the edge of the bridge in order to evaluate the consequences of skewing the bridge at an angle of 20 degrees. illustrate how the skewness of the bridge affects the LLMD of the 20-meter and 12-meter 4-beam bridges, respectively.

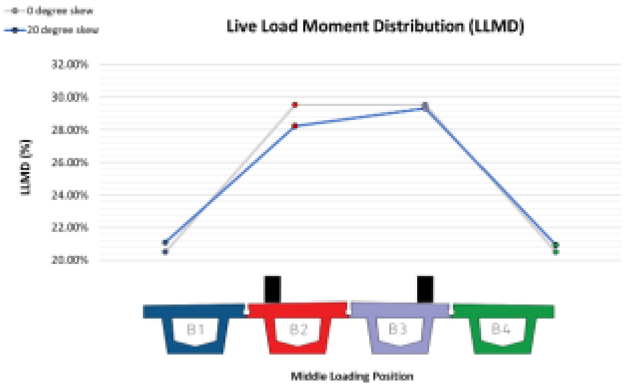

Figure 4. Middle Loading Position

Double Lane Bridge

On a bridge with two lanes, four different loading scenarios were analyzed for their potential effects. shows a model of a double-lane bridge that is 20 meters long and has six beams. The stations for loading cargo moved from the center of the bridge to the sides. The skew angle went from 0 degrees to 20 degrees as a result of the adjustment. On these, the load distribution (LLMD) was compared to the standard, cautious strategy that is currently employed in the industry, which is the p&s approach.

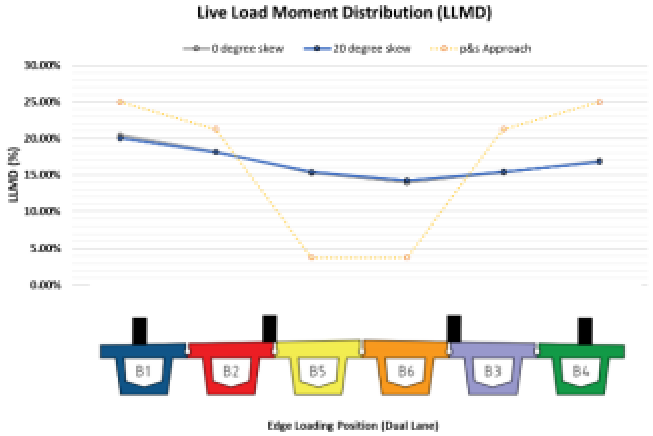

Figure 5: Effect Of Skew On Load Distribution For 20m, 6-Beam Bridge

From what has been shown so far, it is very evident that the industrial technique was unable to accurately predict the LLMD on the beams. When the load is distributed more evenly throughout the beams, such as when it is more centrally located, the load on the outside beams is overestimated by roughly 10%, while the weight on the center beams is underestimated by around 5%. When the stress is closer to the margins of the beam, and beams 3 and 4 are predicted to be around 5% stronger than they really are. are understated by about ten percent on average. There is just one loading position specified in this section of the 20-meter, 6-beam bridge. This model makes use of the same bridge as the previous one; however, rather of two loads, this model just has one. Tests were performed using the same placements and skew.

The findings are able to demonstrate how the live load moment distribution (LLMD) is affected when the span of the bridge is altered, the beam type is changed, the deck is skewed, and the width of the bridge is changed. The findings indicate that there is not a discernible change in the LLMD as a consequence of tilting the bridge deck by 20 degrees. When the skew of the bridge is less than 20 degrees, grillage models do not need to be angled for the sake of design going forward. By increasing the span, the load distribution between the longitudinal components may be improved. When the width of the bridge is raised, the exact same effect may be seen. The LLMD % is dispersed throughout the precast components in a manner that is more equitable. It was also discovered that bridge decks with a greater width experienced a greater amount of shear force. According to this, the post tensioning force ought to be greater for bridge decks that are wider; yet, the standard practice in the industry is to specify the same tension value—354 kN—for all of their different bridge designs. Due to the varying lengths of the beams, it is impossible to achieve any data that might be considered illuminating by comparing the bridge decks with the various beam kinds. Because it determines the moment action that the precast prestressed beams need to be constructed for, engineers are needed to complete the LLMD. This is the reason why the LLMD is necessary.

It is standard procedure for designers to start their work on the beam that would experience the most stress and then proceed to design the rest of the beams using the same amount of prestress and reinforcement. This was in accordance with the findings of his research, since the largest LLMDF was seen in the outside girder when the load was applied at the position that was the farthest practicable from the center of the bridge's breadth. Because of the findings, bridge design engineers will be able to apply the LLMD factors to the process of designing the precast deck parts that will be used in future bridge projects. This is a significant development for bridge design engineers. The results of this study will be presented in the form of tables, and those tables will include the various LLMD percentages. According to the team's ten different bridge models, the configuration of the bridge with 16 meters in length, four beams, and no skew resulted in the exterior beam being subjected to the greatest proportion of the live load. When the M1600 load was situated in the exact center of the external beam, an LLMD factor of 40.46 percent was recorded. The more cautious design method that is currently being used involves just applying half of the design load to each individual plank. They have included some kind of redundancy in the bridge system in order to ensure that even in the event that the post-tensioning bars fail, the bridges will still be able to handle the ultimate limit state design loads in an acceptable manner.

When it comes to load transmission, maintaining the integrity of the PT bars is very crucial. Without the clamping force, the shear key will likely get broken when it is overloaded. Because these remote bridges will not undergo routine inspections, the designers should take into account the fact that they cannot depend on the structural soundness of the PT bars to provide load transmission. This is a factor that should be taken into account. The in-situ deck and a TPT deck unit construction were both subjected to an examination and comparison. Because of a few different factors, the lateral moment distribution produced by the in-situ deck is preferable. The reduction factors to the sectional characteristics and the alterations to the joint connection were modified as a result of the modifications that were made to the grillage model. As was said before in the showing TPT deck modules perform better than what the theoretical models indicated when load testing was carried out, the torsional stiffness and the bending stiffness were lowered.

The theoretical models were constructed using the modeling instructions provided by the department of This proposal served as the basis for the team's decision to implement a decrease in the component's transverse stiffness. Because of this, the findings of this study don't amount to much in the way of research, but they do provide useful direction for the manufacturing sector of the bridge business. The Queensland Government Department of Transport has not updated the annexure (TMR) on modeling deck units. It would be interesting to see whether they make any changes to the modeling suggestions in light of the load tests and performance analyses that they have recently carried out. According to the results of the parametric analysis, the sectional characteristics of the grillage members have an effect on the distribution of the load over the deck units. It is essential that load testing be carried out on bridges of this kind in order to get an exhaustive comprehension of the behavior of the deck.

The Queensland Government has carried out load testing on deck unit planks; however, load testing still has to be carried out on this form of deck unit, which is characterized by deep beams and shear keys. To further advise designers on how to construct these structures using grillage models and estimating a hypothetical stiffness of the transversely post tensioned deck, more information has to be generated and published. These grillage models do not accurately describe the behavior of these bridge decks; rather, they provide a depiction that is close to the behavior of the deck. The team is able to demonstrate, using conservative sectional values for the transverse and longitudinal members of the grillage model, that the bridge deck is capable of exhibiting moment dispersion across deck units. This is something that the team is able to do. However, the grillage model did not provide for this distribution to be appropriate, therefore the team was unable to assess the lateral shear distribution of the bridge decks. The grillage members' shear forces are very sensitive to the manner in which the wheel loads are delivered to the grillage. This is a natural result of representing a continuum as a succession of discrete line components in an approximation. ensuring that the peak shears are achieved in the essential locations by using transverse elements that have tighter spacing and are located near supports.

CONCLUSION

The purpose of this research was to examine the load distribution of transversely post-tensioned precast concrete deck unit bridges with varying numbers of beams. After that, the load distribution of an in-situ deck system with the same number of beams as the post-tensioned system with four beams was compared to the post-tensioned system with four beams. After that, a six-beam transversely post-tensioned system with varying width, length, and skew was modeled, and the live load moment distribution was explored once again. In order to find the most effective strategy for modeling those bridges, the team did a considerable amount of study. The approach used a grillage structure as its basis.

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