INTRODUCING INTEGRAL ABUTMENT BRIDGES TO PAPUA NEW GUINEAN NATIONAL HIGHWAYS

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1. INTRODUCTION

Currently, 80% of Papua New Guinea (PNG) national highway bridges are in a deteriorated state and there is a great need for all weathering bridge designs. High maintenance costs have resulted in a lack of budgeting for regular repairs.

According to Tabatabai et al (2017), 65% of all states in USA prefer to use integral abutment bridges over conventional bridges. Integral abutment bridges can be a viable alternative given the following advantages over conventional bridges highlighted by Shah (2007): i) simple, rapid, and more affordable construction; ii) no bearings at joint, no expansion joints so reduced construction costs and maintenance costs, reduced construction time; iii) improved seismic performance; iv) smooth, uninterrupted aesthetically pleasing deck giving improved vehicular riding quality and reducing hazards and hence liability; v) increased degree of redundancy, enhanced load capacity and distribution, resulting in higher resistance to overloads, catastrophic or extreme events and earthquakes (better performance under seismic loads); vi) ease of future widening or replacement, and vii) longer-lasting.

The critical areas of interest in its design philosophy covers the longitudinal expansion and contraction of superstructure under daily and annual cyclic thermal and vehicle loadings and the corresponding soil-structure interaction (abutment-soil and pile-soil). These areas are not specified in Papua New Guinea Bridge Design Specifications and Australian Code (AS5100).

Moreover, critical design parameters such as maximum permissible length, maximum skew angle, abutment earth pressure, pile types, orientation, embedment lengths, and design require definition as there are variations from state to state and country to country.

Therefore, the following objectives on integral abutment bridges are studied based on the locality of Papua New Guinea:

I. Investigate static design parameters by understanding the temperature-induced longitudinal movements and rotations and the corresponding geotechnical and soil-structure interaction between the abutment, pile, and the nearby soil.
II. Investigate seismic analysis and design considerations
III. Set guidelines for construction and maintenance methods of integral abutment bridges and present a simple cost comparison of conventional and integral bridges.

2. METHODOLOGY AND CASE STUDY

For objective (I), FEM models of existing three-span, double-span and single-span bridges will be formulated for parametric study. A first case study of a three-span bridge is currently undertaken and is presented.

Objectives (II) and (III) are yet to be carried out. The research will be limited to no more than three-span steel-concrete and concrete bridges. The superstructure will be confined to embedded and framed abutments, and with single steel H-piles and concrete piles.

In order to investigate the behavior of integral bridges under different dead and thermal loads according to Papua New Guinea conditions, and to understand the longitudinal displacement and rotation of the abutment and piles, the Bemis Road Bridge: F-4-20 in Fitchburg Massachusetts was selected as the first case study. It is a three-span steel girder composite bridge with a length of 45.7m and 16.5m in width.

Using the FEM software STAAD ProV22, the 3D model contains the following: i) 45.7x16.5x0.71m shell deck; ii) seven W36x135 steel girders modeled as beams and placed 2.7 apart; iii) seven transverse W36x135 steel beams modeled as beams; iv) two sets of simple supports modeling intermediate piers; 2.4x0.762x21m concrete abutment modeled as shell and each abutment supported by seven HP12x74piles, 8.8m long and spaced 2.7m apart allowing full moment transfer.

The model was subjected to Dead Load/self-weight (DL), and Thermal Loads (TL) of 5ºC, 10ºC, 15ºC, 20ºC increases were induced on the exposed substructure. A combination of the Dead Load with each Thermal Load was also introduced.

3. RESULTS AND DISCUSSION

The results of the model without modeling the abutment backfill and pile-soil interactions are presented. Fig. 2 shows the maximum deformation in z-axis for the abutment nodes at the top center and top-end nodes for different loads and combinations.

Other results such as the positive and negative bending moments, shear forces, axial forces, reactions and plate stresses for

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Keywords: integral abutment bridge, longitudinal movement, seismic analysis, soil-structure interaction

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the different loads and combinations, as given in Fig. 3, Fig. 4, Fig. 5 and Fig. 6, were also attained and will be compared with results obtained from analysis with soil-structure interaction. Although the results show anticipated behavior, the model will be subjected to checks to get improved values. A verification model is being carried out using the FEM Software ABAQUS.

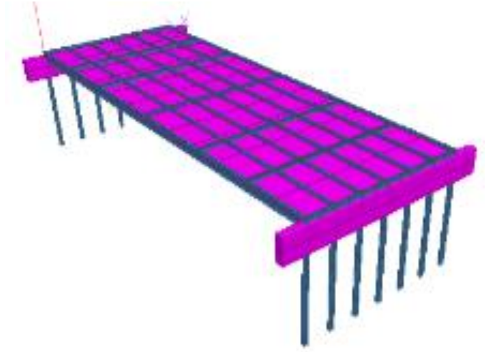

Fig. 1: Bridge Model

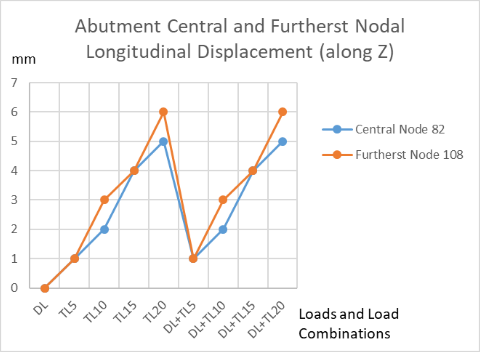

Fig. 2: Nodal Deformation of Abutment in longitudinal (z) direction

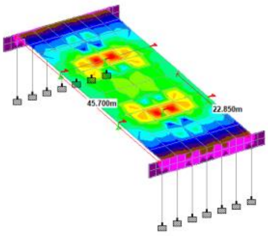

Fig. 3: The plate stress of deck under DL

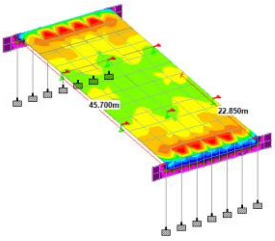

Fig. 4: The plate stress of deck under TL of 20ºC

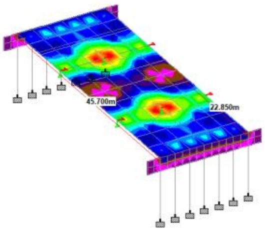

Fig. 5: The plate stress of deck under combination load of DL and TL 5ºC

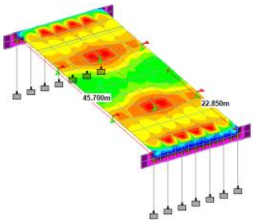

Fig. 6: The plate stress of deck under DL and TL 20ºC

4. CONCLUSION

To achieve objective (I) further analysis with the inclusion of soil-structure interaction for different soil types and compaction will be analyzed. Moreover, two other case study bridges of 2-span and single-span respectively will be studied to fully comprehend the behavior of integral abutment bridges and their implications on analysis and design.

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