Pre - AGM Talk on " Analysis & Design of Prestressed Concrete Bridges "

by Ir. Lo Seng Ling

Ir. Lo Seng Ling is currently a Secretary/Treasurer in Civil and Structural Engineering Technical Division (CSETD).

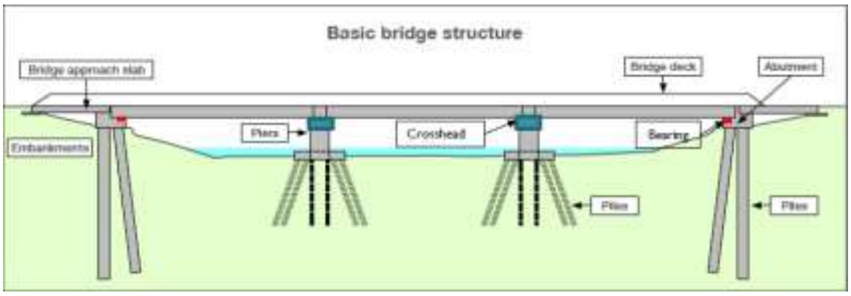
A Pre-AGM talk of "Analysis and Design of Prestressed Concrete Bridges" was organised by the Civil and Structural Engineering Technical Division (CSETD) of IEM on 13th July 2019. Total of 202 participants attended the talk.

The Pre-AGM talk was presented by Ir. Low Hin Foo. Ir Low graduated from University of Malaya with Honors degree in Civil Engineering. He has more than 18 years of experience in design and construction of various reinforced or post-tensioned bridges and buildings in Malaysia or oversea. He was Technical Manager for one of the prestressing contractor in Malaysia. Currently, he is the Principle Engineer for a design consultant firm.

Ir. Low has vast design experience in the design of prestressed structures for large commercial project and high-rise buildings. He specialized in handling the design of prestressed flat slab, flat plate system with irregular columns grids. He also involved in the design and construction of few long span prestressed bridges built by using balanced cantilever method and integral bridge with prestressed girder.

Ir. Low started the talk by introducing the basic components of the bridge, such as

- Super-Structure: precast beam, deck slab and diaphragm beam,
- Substructure: crosshead, pier or column,
- Foundation: pilecap, pile or footing,
- Abutment and approach slab.



Basic Bridge Components

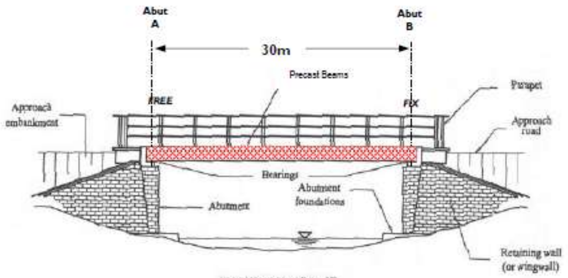
The structural interaction between the bridge beams and slabs depend on their relative stiffness and it requires a more rigorous analysis in 3-dimensional environment, such as grillage method of analysis, which is carried out by computer programme or software nowadays.

A grillage is a structure of rigidly connected longitudinal and transverse beams each with bending, shear and torsional stiffness. Three basic steps when analyzing a bridge using grillage approach are:

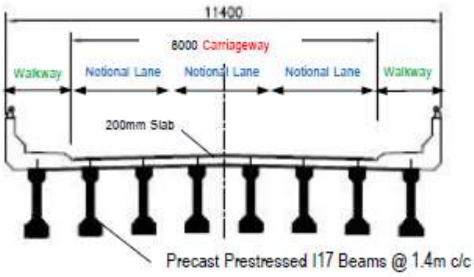
- Idealisation of physical deck into an equivalent grillage,
- Mathematical analysis of the grillage for various loadings,
- Interpretation of the results for the use in design of the deck.

Grillage method of analysis involves idealization of the bridge deck through its representation as a plane grillage of discrete inter-connected beams. The longitudinal member represents the bridge beams and the transverse member represents the deck slab. The section properties of each grillage member is calculated about the centroid of the section it represents. For longitudinal member, section properties of the precast beam and its deck slab flange (width taken as beam centroid spacing) are considered. For the transverse member, the deck slab width depends on the spacing of the transverse elements and the member depth is taken as the slab thickness. Additional transverse member shall be included to represent any bridge diaphragm. As a rule of thumb, the grillage mesh shall be as square as possible with the length to breath ration not exceeding 2:1 for a more well represented model. All the grillage members are modeled to be connected at their centroid with common nodes at all the junction for effective load distribution. Normally pinned support is chosen to represent the bridge end on bearings with dowel bars and roller support to represent free bridge end with just bearings.

An example of 30m length and 8m width simply supported bridge analyzed using grillage method was presented in the talk. The bridge has 8 nos of precast prestressed I17 beams spanning longitudinally between abutments with a 200mm thick cast in-situ deck slab spanning transversely across the beam top. One end of the precast beam is supported by bearing on abutment and dower bars with shear blocks are installed at the other end of the precast beam. Two RC end diaphragms are designed to tie the beams at abutment only with no intermediate diaphragm.

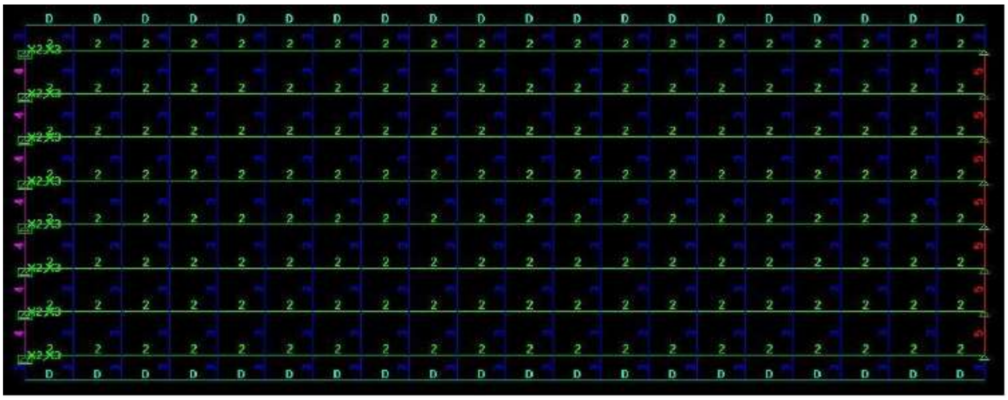


SINGLE SPAN BRIDGE

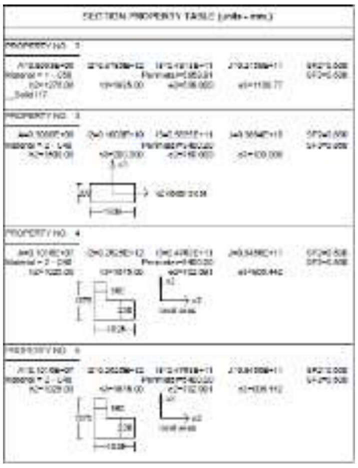


BRIDGE MIDSPAN SECTION

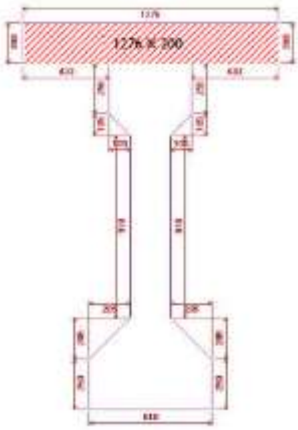
Longitudinal grillage members (in green in the figure below) with the spacing of 1.4m representing precast beams while transverse grillage members (in blue in the figure below) representing deck slab. The spacing of the transverse members was set at 1.5m c/c so that the grillage mesh length to breath ratio is kept around 1:1.



Plan View of Grillage Analysis



Section Properties for Each Members



Section of I-beam with Deck Slab

Deck Slab width of 1276mm was used in the computation of longitudinal member section properties instead of the actual beam spacing (1400mm) because the concrete cube strength of the deck slab was designed as G40 (f_{cu}=40MPa) while the concrete strength for the precast beam was designed as G50 (f_{cu}=50MPa). For compatibility, transformed section based on modular ratio calculated from concrete elasticity was used.

Uniformed Distributed Load (UDL) such as 100mm thick road surfacing (premix), parapet wall, pedestrian load (5kN/m^2) and traffic loads (HA and HB) according to BS5400:Part 2 were imposed on the bridge model. After imposed all the required loads, the bridge model can be analyzed.

From the analysis results, the beams at center of the bridge are subjected to higher bending moment compared to the beams at the edge of the bridge. This is because the carriageway is located at the center of the bridge and the both edges of the bridge are subjected to walkway load only. It was also found that HB45 vehicle created the highest bending moment to the beams when moving at the extreme lane of the bridge. Maximum beam shear force diagram was found when HB45 vehicle is close to bridge support. Maximum bridge deflection from the analysis results was compared to the allowable deflection limit of L/1000 or L/500 for HB45 (abnormal load).

The most critical deck slab elements is found to be located at bridge midspan. Deck slab bending moment can be averaged at the intersection point for design purpose. However, traffic loads due to HA or HB are applied in the bridge model through numerous nodes located at the intersection of the longitudinal members (beams) and transverse members (slab). Therefore, the loads are not applied directly on the slab whereby the local bending effect due to the vehicle wheel load has not been considered. The bending moment and shear force of the slab due to the local wheel effect and the influence of the adjacent wheel can be computed using Westergaard Method. The moment and shear of the local effect shall be added to those forces from the grillage analysis (global effect) to obtain the total slab forces for design.

Then, Ir. Low proceed the talk with the design of the prestressed precast beam based on the analysis results. The critical conditions for the prestressed structure are:

- During transfer - when the load is minimum and prestress force is largest,
- At service - when the load is maximum and the prestress force is minimum (after losses).

In design stage, the top fiber and bottom fiber stresses of the prestressed beams (in tensile or compression) at transfer stage and service stage were computed. All the stresses shall not exceed the allowable stresses stated in BS5400: Part 4 either designed as Class 1 member or Class 2 member. Shear capacity of the prestressed beam shall be taken as the smaller between uncracked (web) shear resistance or flexural shear resistance (section cracked in flexural) stated in BS5400: Part 4.

Before the talk ended, a Q&A session was carried and a token of appreciation was presented to Ir. Low by Ir. Chong Chee Meng as the Chairman of IEM Civil and Structure Engineering Technical Division.

Ir. Chong Chee Meng presented a token of appreciation to Ir. Low Hin Foo