First Semester Examination
Academic Session 2019/2020

December 2019/January 2020

EAS665 – Bridge Engineering

Duration : 2 hours

Please check that this examination paper consists of **NINE (9)** pages of printed material before you begin the examination.

Instructions : This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions

All questions must be answered in English.

Each question **MUST BE** answered on a new page.

(1). (a). Describe the characteristics of HA and HB loading types as specified in BS 5400.

[5 marks]

(b). Assume that you are being employed as a consultant of a company. The company is about to construct a dual-carriageway bridge deck in Batu 6, Gerik, Perak. You are required to analyse a bridge deck of the beam-slab type for design purpose. The cross sections of the proposed beam-slab bridge are shown in **Figure 1**. Basic data of the proposed bridge are listed in **Table 1**.

Your task as the consultant is to perform loading computation for the primary live loads acting on the proposed deck by considering combination of HA and HB highway loading types in accordance with BS 5400. Analyze the critical shear force and maximum bending moment in the beam. Assume that the maximum sagging moment occurs under the inner axle when the HB vehicle is positioned on the first notional lane and straddled in the second notional lane at the centre of the span.

Table 1: Design Data

Span	25.0 m
Skew	0^0
Width	17.98 m
Live loads	HA loading (UDL = $336\left(\frac{1}{L}\right)^{0.67}$) HB loading (30 units)
Inner Axle	Use inner axle spacing of 11.0 m

[20 marks]

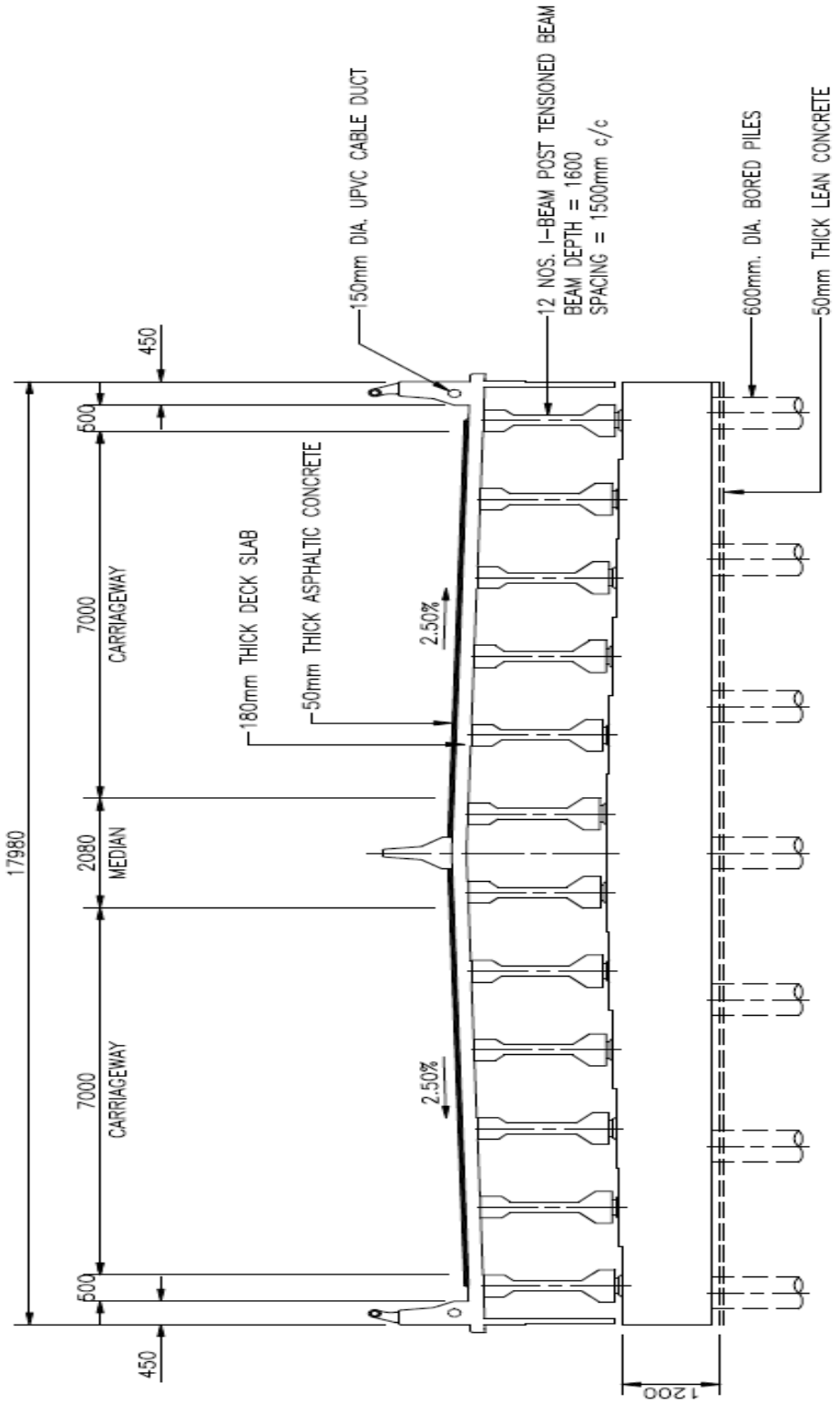


Figure 1: A bridge deck with the post-tensioned I-beam

(2) (a). The cross section of a 36 meter single span bridge is shown in **Figure 2**. The bridge is supported by six equally spaced rectangular post-tensioned beams. In addition, five diaphragms are provided for lateral stability. If the bridge is subjected to a Knife Edge Load (KEL), construct the equivalent grillage together with the notional lanes. Provide marking for all major elements and the properties of the corresponding critical sections. Take the carriageway with = 9.0 m. Disperse the KEL load to the appropriate nodes.

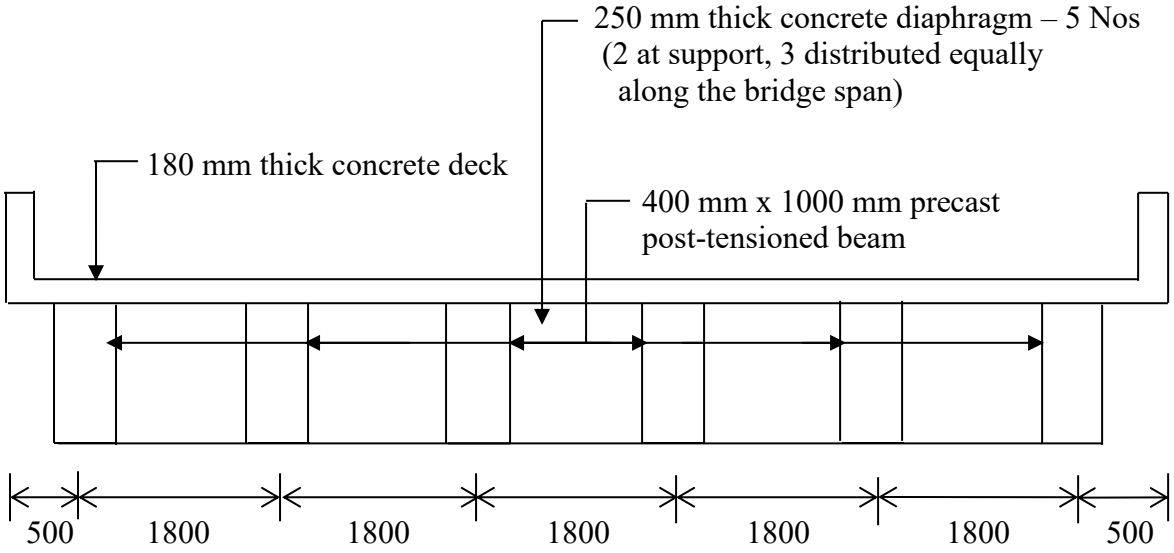


Figure 2 : Cross section of a bridge at midspan (all dimensions in mm)

[20 marks]

(b). The result of the support reactions may be extremely important in some design cases. Briefly discuss **TWO (2)** important criteria pertaining to the support when arranging the geometric layouts using grillage analysis.

[5 marks]

(3). (a). With the aid of sketches, differentiate the structural behaviour of pier bent and the conventional frame type pier.

[5 marks]

(b). A seat-type reinforced concrete abutment has been selected for a single span bridge project. The proposed abutment is supported by five vertical piles and five raked piles as shown in **Figure 3**. If the allowable axial pile capacity is calculated to be 800 kN, evaluate the pile arrangement. The overall forces and the corresponding lever arm are shown in **Table 2**. Take clockwise moment as positive.

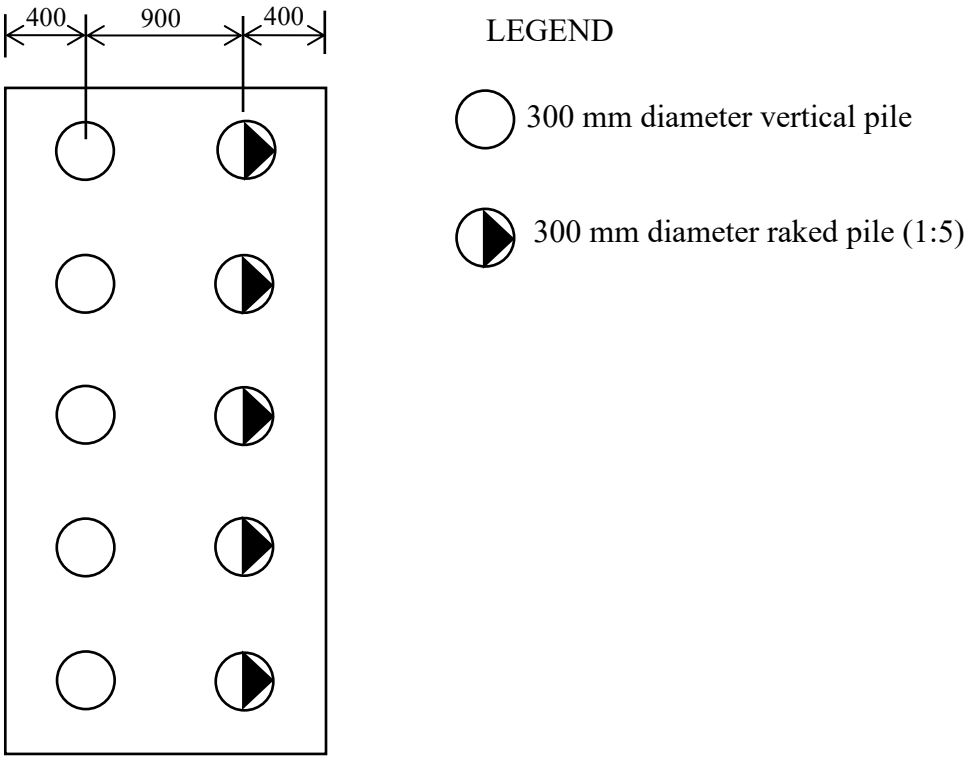


Figure 3 : Pile arrangement for a bridge abutment (all dimensions in mm)

Table 2: Forces acting on abutment

Item	Force (kN)	Lever Arm (m)
Horizontal Load		
Surcharge (active)	70	0.9
Surcharge (approach slab)	50	0.9
Soil (active)	120	0.6
Wind	30	1.1
Traction	300	1.1
Temperature	60	1.1
Shrinkage and Creep	80	1.1
Vertical Load		
Dead Load	1500	-0.15
HB Load	1600	-0.15
Curtain Wall	10	0.3
Abutment (seating)	350	0.03
Ballast Wall	60	-0.5
Approach Slab	80	-0.6
Wing Wall	30	-1.3

[20 marks]

(4). (a). The limiting factors in the construction of steel structures for bridges are identified as corrosion, salt exposure, aggressive environmental conditions, pitting, fatigue, in-service inspectability, shims and bearings, bolted connections, welding, alloy content of the steel, initial cleaning and painting, remedial cleaning and painting which lead to adverse deterioration of its life span. Beside all those deficiencies, describe the advantages of steel structures for the construction of bridges.

[15 marks]

(b). Bridge deck expansion joint should be able to provide smooth riding, durable and waterproof which are essential to the performance of the bridge superstructure. Discuss the consequences to the superstructure of the bridge if the joints fail to function properly.

[10 marks]

(5). The function of bearing is to carry the designed load and accommodate movement between superstructure and substructure components. With the aid of sketches, explain the function and mechanism of **FIVE (5)** types of bearing in accommodating and transferring the loads between the structures normally used for bridges.

[25 marks]

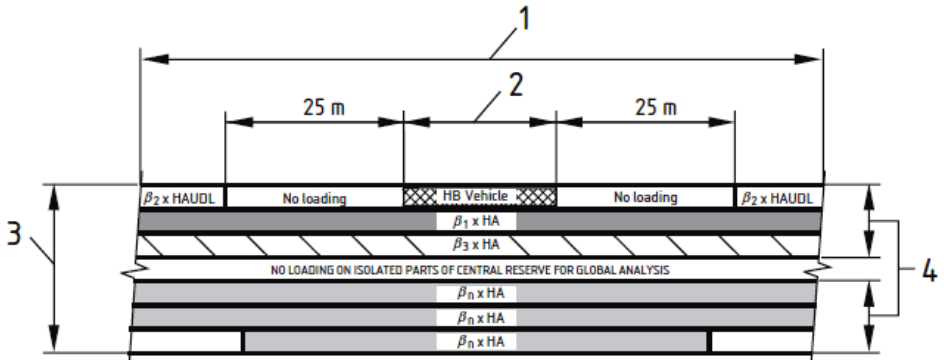
APPENDIX

Table A1

Carriageway width, b_L (m)	No. of notional lane
$5.00 \leq b_L \leq 7.50$	2
$7.50 \leq b_L \leq 10.95$	3
$10.95 \leq b_L \leq 14.60$	4
$14.60 \leq b_L \leq 18.25$	5
$18.25 \leq b_L \leq 21.90$	6
Lane no.	**Lane factor**
1	$\beta_1 = \alpha_2 = 0.0137[b_L(40 - L) + 3.65(L - 20)]$
2	$\beta_1 = \alpha_2 = 0.0137[b_L(40 - L) + 3.65(L - 20)]$
3	0.6
4 and above	$0.6\alpha_2$

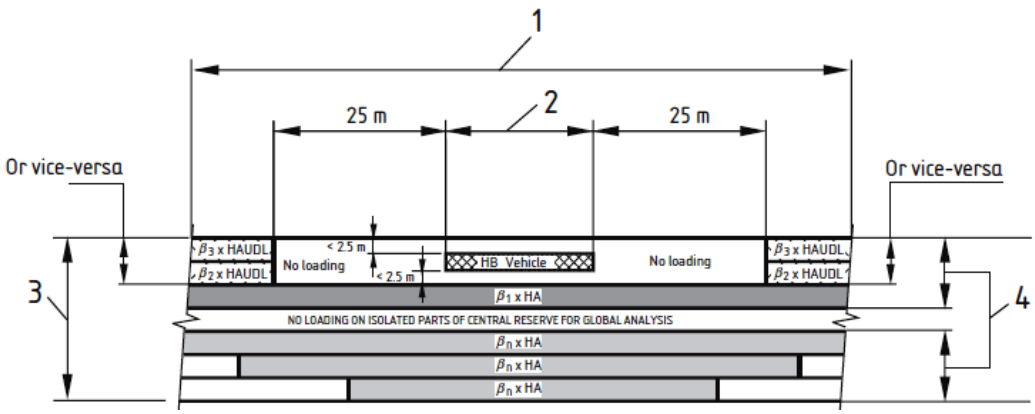
Table A2

1) HB vehicle within one notional lane



2) HB vehicle straddling two notional lanes

(a)



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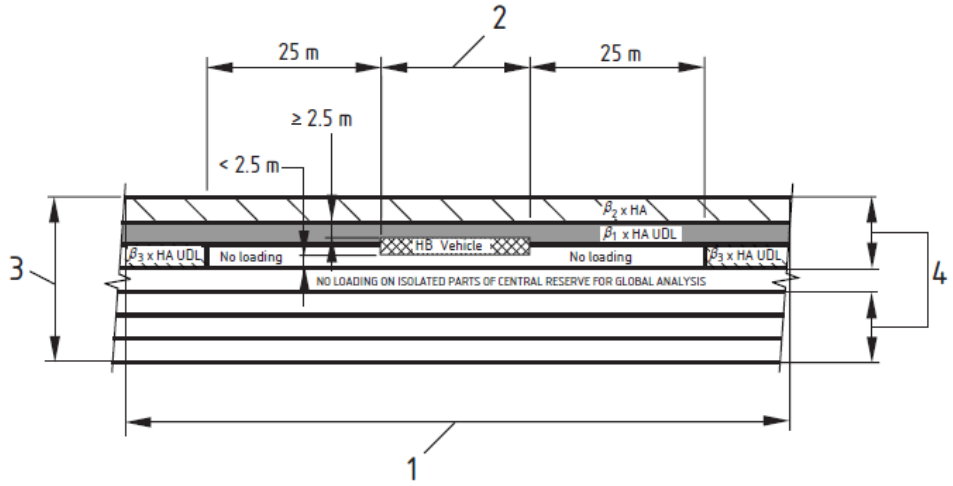
(b)



Key

1 Loaded length for intensity of HA UDl in lane containing HB vehicle
2 Overall vehicle length for axle spacing having most severe effect
3 Lane loadings are interchangeable for most severe effect
4 Notional lanes in each carriageway

NOTE 1 See **6.4.1.1** for the value of the HA lane factor (β) to be taken for each lane.
NOTE 2 The overall length and width of the HB vehicle shall be as specified in **6.3.1**.
NOTE 3 Unless otherwise stated, type HA loading includes both uniformly distributed loading (UDL) and knife edge loading (KEL).
NOTE 4 See **6.4.1** for loaded length to be taken in each lane.

Table A3

Carriageway width (m)	Number of notional lanes
4.6 up to and including 7.6	2
above 7.6 up to and including 11.4	3
above 11.4 up to and including 15.2	4

Table A4

Condition	k_1
$\frac{b_{max}}{b} < 2.0$	$\frac{1}{3}\left(1 - 0.63\frac{b}{b_{max}}\left(1 - \frac{b^4}{12{b_{max}}^4}\right)\right)$
$\frac{b_{max}}{b} \geq 2.0$	$\frac{1}{3}\left(1 - 0.63\frac{b}{b_{max}}\right)$

Torsional Constant = $k_1(b)^3(b_{max})$

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