Chapter Four

Modeling and analysis of case studied

4.1 Location of the Bridge:

The Bridge lies in Sudan in Southern KORDOFAN State of four simply supported spans each of length 15m making a total length of 60m and a total width of 12m, carriage way of 9m width and internal sidewalks of 1.5m per side, loading capacity of HA+HB 40, concrete deck. The bridge is designed according to the requirement of National Highway Authority.

4.2 Design notes:

The proposed bridge structure is a 15 m simply supported slab beam reinforced concrete deck construction with pre- cast reinforced concrete beams in composite action with in situ reinforced concrete slab supported by abutment/pier. The construction is in line with current trends in the industry and satisfies the National Highway Authority requirements [See Fig. (4.1)].

4.2.1Four span Bridge input Data:

• Deck Geometry:

= 250 mm

= 300 mm

= 250 mm

Parapet thickness

Inner curb width

Approach slab thickness



Fig. (4.1): Superstructure cross-section.

Deck span	= 15.00 m
Total Deck width	= 12.00 m
Width of carriageway	= 9.00 m
Width of walkway	= 1.50 m
Number of main girders	= 8 Nos.
Equivalent c/c spacing of girder	= 1.50 m
Length of overhang Deck-slab	= 0.61 m
Approach slab Length	= 6.500 m
Approach slab width	= 10.00 m
• Deck member sizes:	
Thickness of deck In-situ slab	= 200 mm
Thickness of pre cast slab	= 50 mm
Surfacing and overlay thickness	= 50 mm

Inner curb depth	=350 mm
Main beam width	= 320 mm
Main beam depth	= 900 mm
Diaphragm beam width	= 450 mm
Diaphragm beam depth	= 1000 mm

• Materials:

Unit weight of concrete	$= 25 \text{ kN/mm}^3$
Unit weight of Asphalt	$= 23 \text{ kN/mm}^3$
Strength of concrete (f_{cu})	=30N/mm ²
Reinforcing bars strength Steel, (fy)	$=460 \text{N/mm}^2$
Concrete cover	= 30 mm



Fig (4.2): Four span bridge elevation.

4.2.2 Design Considerations

The design of this bridge is based on the Bridge Standards BS 5400: Part 2 (1978) modified by BD 37/01 and Part 4 (1990) for Loads and design respectively.
 The bridge is designed for 40 units of HB abnormal vehicle and the associated HA loading. Three notional lanes are adopted as required by the codes for the carriageway width of 9 meters

4.2.3 Deck loading

1) Dead load:-	
Slab load = 25×0.20	$= 5.00 \text{ kN/m}^2$
Girders (Beams) = $25 \times 0.32 \times 0.90$	= 7.20 kN/m
2) Superimposed Dead load:-	
Surfacing = 23×0.05	$= 1.15 \text{ kN/m}^2$
Walkway = 25×0.40	$= 10.00 \text{ kN/m}^2$
Inner curb = 25×0.40	$= 10.00 \text{ kN/m}^2$
Parapet = 25×0.265	= 6.36 kN/m
Railings	= 1.00 kN/m

3) Live load:-

Deck loaded length under consideration= 15 mPedestrian (Walkway) $= 5 \text{ kN/m}^2$ (BD 37/01) clause 7.1.1HA loading considered: Include HA (UDL) and Nominal HA (KEL)HB loading:40 Units HB load $= 40 \times 10$ = 400 kN per Axle

Vehicular HA & HB live loads

Number of notional lanes = 3

(BD 37/01) clause 3.2.9.3.1

Table (4.1): Number of notional lanes.

Carriageway width (m)	Number of notional lanes
5.00 up to and including 7.50	2
Above 7.50 up to and including 10.95	3
Above 10.95 up to and including 14.60	4
Above 14.60 up to and including 18.25	5
Above 18.25 up to and including 21.90	6

* Notional lanes shall be taken to be not less than 2.50 m wide.

Notional lane width (bL) = $9 \div 3 = 3$ m

HA (UDL) per notional lane (for loaded length = 15.00 m)

(BD 37/01) clause 6.2.1

 $w = 336(1/L)^{0.67}$ = 54.75 kN/m

 $= 54.75 \div 3$ $= 18.25 \text{ kN/m}^2$

HA (KEL) per notional lane

= 120 kN

(BD 37/01) clause 6.2.2

$$= 120 \div 3$$
 $= 40 \text{ kN/m}$

HB load, (40 units)

(BD 37/01) clause 6.3.1

$= 40 \times 10 = 400$

Per wheel	$=400 \div 4$	= 100 kN

4) HA & HB loading application:

Lane 1 factor, $\beta 1$	= 0.822

Lane 2 factor, $\beta 2$ = 0.822

Lane 3 factor, β 3	= 0.600
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(BD 37/01) Table 14

Table (4.2): HA lane factors.

Loaded Length (m)	First Lane Factor β1	Second Lane Factor β2	Third Lane Factor β3	Fourth & subsequent Lane Factor βn
$0 < L \le 20$	α1	α1	0.6	0.6 α1
$20 < L \le 40$	α2	α2	0.6	0.6 α2
$40 < L \le 50$	1.0	1.0	0.6	0.6
$50 < L \le 112$ N < 6	1.0	7.1√L	0.6	0.6
$50 < L \le 112$ $N \ge 6$	1.0	1.0	0.6	0.6
L < 112 N < 6	1.0	0.67	0.6	0.6
$L > 112$ $N \ge 6$	1.0	1.0	0.6	0.6

NOTE: $\alpha 1 = 0.274$ bL and cannot exceed 1.0

 $\alpha 2 = 0.0137 [bL (40-L) + 3.65(L-20)]$

Where bL is the notional lane width (m)

For L < 20 $\beta 1 = \beta 2 = \alpha 2$, $\beta 3 = 0.6$ $\alpha 1=0.274$ bL = 0.274 $\times 3 = 0.822 < 1.0$ Load on lane (i) equals: βi (UDL KEL)

For (lane 1 & lane 2):- $= 15.00 \text{ kN/m}^2$ HA (UDL) $\times \beta 1$ = 18.25 × 0.822 $= 15.00 \text{ kN/m}^2$ HA (UDL) \times = 18.25 \times 0.822 β2 = 32.88 kN/m HA (KEL) \times β1 $= 40 \times 0.822$ $= 40 \times 0.822$ = 32.88 kN/mHA (KEL) $\times \beta 2$ For lane 3:- $= 10.95 \text{ kN/m}^2$ = 18.25 × 0.600 HA (UDL) \times β3 HA (KEL) $\times \beta 3 =$ 40×0.600 = 24.00 kN/m

4.2.4 Load cases and load combination

1) The load cases have been used in accordance with BS 5400 as follow:-

Table (4.3): Load cases.

	Load case	Group
1	Self-weight	DEAD
2	Surfacing	SUPERIMPOSED DEAD
3	Railing	SUPERIMPOSED DEAD
4	Walkway (Footway)	LIVE
5	HA alone	LIVE
6	HA + HB	LIVE

2) Load combinations using strength design factor in the BS5400 as critical combinations were considered as follow:

Combinations	Self- weight	Surfacing	Railing	Walkway (Footway)	HA alone	HA + HB
ULS C1	1.05	1.75	1.2	1.5	1.5	-
ULS C2	1.05	1.75	1.2	1.5	-	1.3
SLS C2	1	1	1	1.2	-	1.1
ULS C3	1.05	1.75	1.2	1.5	1.5	-
ULS C4	1.05	1.75	1.2	1.5	-	1.3

Table (4.4): Load combinations.

* ULS C1 & ULS C2: The (KEL) applied parallel to the bearing, but it is still has a length equal to the lane width.

* ULS C3 & ULS C4: The (KEL) applied perpendicular to notional lane.

4.3 Manual Calculation:

By using 1 m strip width

Edge girder:



Fig (4.3): Section of edge beam

Loading:

Self weight:

(0.2 *0.59 + 0.32 *0.9)*25 = 10.15 kN/m

Superimposed load:

0.05*.59*23 = 0.68 kN/m

Sidewalk:

0.4*1.5*25 = 15 kN/m

Railing:

1kN/m

HA loading:

UDL = 15*0.59 = 8.9 kN/m

KEL = 32.88*0.59 = 19.4kN

Moment and shear force:

Self weight:

B.M = w *
$$L^{2/8}$$
 = 10.15 * 15²/8 = 285.5 kN.m



S .F = w * L /2 =10.15 * 15 / 2 = 76.1 kN

Superimposed load:

B. $M = 0.68 \times 15^2 / 8 = 19 \text{ kN.m}$

S
$$.F = 0.68 * 15 / 2 = 5.1 \text{ kN}$$

Walkway:

B.
$$M = 15 * 15^2 / 8 = 421.9 \text{ kN.m}$$

S. F = 15 * 15 / 2 = 112.5 kN

Railing:

- B. M = w * L / 4 = 1*15 / 4 = 3.75 kN .m
- S. F = 1 kN

H A loading:



B. M = w * L²/8 + w * L/4 = (8.9 * 15²/8) + (19.4 * 15/4) = 323.05 kN .m

S. $F = w^* L / 2 + w = 19.4 + (8.9 * 15 / 2) = 86.2 \text{ kN}$



Load	γF	B.M kN.m	B.M*γF kN.m	S.F kN	S.F*γF kN
Self weight	1.05	285.5	299.8	76.1	79.9
Surfacing	1.75	19	33.25	5.1	8.5
Railing	1.2	3.75	4.5	1	1.2
Walkway	1.5	421.9	632.9	112.5	168.8
HA alone	1.5	323.05	484.6	86.2	129.3
Total			1455		388.1

Table (4.5)	: Factored	moment and	Shear	force
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