## 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 15 m making a total length of 60 m and a total width of 12 m , carriage way of 9 m width and internal sidewalks of 1.5 m per side, loading capacity of $\mathrm{HA}+\mathrm{HB} 40$, 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:



Fig. (4.1): Superstructure cross-section.

Deck span
Total Deck width
Width of carriageway
Width of walkway
Number of main girders
Equivalent $\mathrm{c} / \mathrm{c}$ spacing of girder
Length of overhang Deck-slab
Approach slab Length
Approach slab width

## - Deck member sizes:

Parapet thickness $\quad=250 \mathrm{~mm}$
Approach slab thickness $\quad=300 \mathrm{~mm}$

$$
=15.00 \mathrm{~m}
$$

$$
=12.00 \mathrm{~m}
$$

$$
=9.00 \mathrm{~m}
$$

$$
=1.50 \mathrm{~m}
$$

$=8$ Nos.
$=1.50 \mathrm{~m}$
$=0.61 \mathrm{~m}$
$=6.500 \mathrm{~m}$
$=10.00 \mathrm{~m}$

Thickness of deck In-situ slab
Thickness of pre cast slab
Surfacing and overlay thickness

Inner curb width
$=200 \mathrm{~mm}$
$=50 \mathrm{~mm}$
$=50 \mathrm{~mm}$
$=250 \mathrm{~mm}$

Inner curb depth
Main beam width
Main beam depth
Diaphragm beam width
Diaphragm beam depth

$$
=350 \mathrm{~mm}
$$

$$
=320 \mathrm{~mm}
$$

$$
=900 \mathrm{~mm}
$$

$$
=450 \mathrm{~mm}
$$

$$
=1000 \mathrm{~mm}
$$

## - Materials:

| Unit weight of concrete | $=25 \mathrm{kN} / \mathrm{mm}^{3}$ |
| :--- | :--- |
| Unit weight of Asphalt | $=23 \mathrm{kN} / \mathrm{mm}^{3}$ |
| Strength of concrete $\left(\mathrm{f}_{\mathrm{cu}}\right)$ | $=30 \mathrm{~N} / \mathrm{mm}^{2}$ |
| Reinforcing bars strength Steel, $\left(\mathrm{f}_{\mathrm{y}}\right)$ | $=460 \mathrm{~N} / \mathrm{mm}^{2}$ |
| Concrete cover | $=30 \mathrm{~mm}$ |



Fig (4.2): Four span bridge elevation.

### 4.2.2 Design Considerations

1) 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. 2) 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 $=25 \times 0.20 \quad=5.00 \mathrm{kN} / \mathrm{m}^{2}$
Girders (Beams) $=25 \times 0.32 \times 0.90 \quad=7.20 \mathrm{kN} / \mathrm{m}$
2) Superimposed Dead load:-

Surfacing $=23 \times 0.05$
Walkway $=25 \times 0.40$
Inner curb $=25 \times 0.40$
Parapet $=25 \times 0.265$
Railings
$=1.15 \mathrm{kN} / \mathrm{m}^{2}$
$=10.00 \mathrm{kN} / \mathrm{m}^{2}$
$=10.00 \mathrm{kN} / \mathrm{m}^{2}$
$=6.36 \mathrm{kN} / \mathrm{m}$
3) Live load:-

| Deck loaded length under consideration | $=15 \mathrm{~m}$ |
| :---: | :---: |
| Pedestrian (Walkway) | $=5 \mathrm{kN} / \mathrm{m}^{2}$ |
| (BD 37/01) clause 7.1.1 |  |
| HA loading considered: Include HA (UDL) and Nominal HA (KEL) |  |
| HB loading: 40 Units HB load $=40 \times 10$ | $=400 \mathrm{kN}$ 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 $\left(\mathrm{b}_{\mathrm{L}}\right)=9 \div 3=3 \mathrm{~m}$
HA (UDL) per notional lane (for loaded length $=15.00 \mathrm{~m}$ )
(BD 37/01) clause 6.2.1

$$
\begin{aligned}
\begin{aligned}
& \mathrm{w}=336(1 / \mathrm{L})^{0.67}=54.75 \mathrm{kN} / \mathrm{m} \\
&=54.75 \div 3 \\
& \text { HA (KEL) per notional lane }=18.25 \mathrm{kN} / \mathrm{m}^{2} \\
& \text { HN }
\end{aligned} \text { = } 120 \mathrm{kN}
\end{aligned}
$$

(BD 37/01) clause 6.2.2

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

HB load, (40 units)
(BD 37/01) clause 6.3.1

$$
\begin{array}{rlr} 
& =40 \times 10 & =400 \mathrm{kN} \\
\text { Per wheel } & =400 \div 4 & =100 \mathrm{kN}
\end{array}
$$

4) HA \& HB loading application:

Lane 1 factor, $\beta 1$

Lane 2 factor, $\beta 2$

Lane 3 factor, $\beta 3$
$=0.822$
$=0.822$
$=0.600$
(BD 37/01) Table 14

Table (4.2): HA lane factors.

| Loaded Length (m) | First Lane <br> Factor $\beta 1$ | Second Lane <br> Factor $\beta 2$ | Third Lane <br> Factor $\beta 3$ | Fourth \& subsequent Lane Factor $\beta \mathrm{n}$ |
| :---: | :---: | :---: | :---: | :---: |
| $0<\mathrm{L} \leq 20$ | $\alpha 1$ | $\alpha 1$ | 0.6 | $0.6 \alpha 1$ |
| $20<\mathrm{L} \leq 40$ | $\alpha 2$ | $\alpha 2$ | 0.6 | $0.6 \alpha 2$ |
| $40<\mathrm{L} \leq 50$ | 1.0 | 1.0 | 0.6 | 0.6 |
| $\begin{aligned} 50<\mathrm{L} & \leq 112 \\ \mathrm{~N} & <6 \end{aligned}$ | 1.0 | $7.1 \sqrt{ }$ L | 0.6 | 0.6 |
| $\begin{gathered} 50<\mathrm{L} \leq 112 \\ \mathrm{~N} \geq 6 \end{gathered}$ | 1.0 | 1.0 | 0.6 | 0.6 |
| $\begin{array}{r} \mathrm{L}<112 \\ \mathrm{~N}<6 \end{array}$ | 1.0 | 0.67 | 0.6 | 0.6 |
| $\begin{array}{r} \mathrm{L}>112 \\ \mathrm{~N} \geq 6 \end{array}$ | 1.0 | 1.0 | 0.6 | 0.6 |

NOTE: $\quad \alpha 1=0.274 \mathrm{bL}$ and cannot exceed 1.0

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

Where bL is the notional lane width (m)

For $\mathrm{L}<20 \quad \beta 1=\beta 2=\alpha 2, \beta 3=0.6$

$$
\alpha 1=0.274 \mathrm{bL}=0.274 \times 3=0.822<1.0
$$

Load on lane (i) equals: $\beta \mathrm{i}$ (UDL KEL)

For (lane $1 \&$ lane 2):-

| HA (UDL) $\times \beta 1=18.25 \times 0.822$ |  | $=15.00 \mathrm{kN} / \mathrm{m}^{2}$ |  |
| ---: | :--- | ---: | :--- |
| HA (UDL) $\times \beta 2=18.25 \times 0.822$ |  | $=15.00 \mathrm{kN} / \mathrm{m}^{2}$ |  |
| HA (KEL) $\times \beta 1$ | $=40 \times 0.822$ |  | $=32.88 \mathrm{kN} / \mathrm{m}$ |
| HA (KEL) $\times \beta 2$ | $=40 \times 0.822$ |  | $=32.88 \mathrm{kN} / \mathrm{m}$ |

For lane 3:-

| HA $(\mathrm{UDL}) \times \beta 3=18.25 \times 0.600$ | $=10.95 \mathrm{kN} / \mathrm{m}^{2}$ |
| :--- | :--- |
| $\mathrm{HA}(\mathrm{KEL}) \times \beta 3=40 \times 0.600$ | $=24.00 \mathrm{kN} / \mathrm{m}$ |

### 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:

Table (4.4): Load combinations.

| Combinations | Self- <br> weight | Surfacing | Railing | Walkway <br> (Footway) | HA alone | HA + <br> 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 |

* 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:

$$
(0.2 * 0.59+0.32 * 0.9) * 25=10.15 \mathrm{kN} / \mathrm{m}
$$

Superimposed load:
$0.05 * .59 * 23=0.68 \mathrm{kN} / \mathrm{m}$

## Sidewalk:

$0.4 * 1.5 * 25=15 \mathrm{kN} / \mathrm{m}$

## Railing:

$1 \mathrm{kN} / \mathrm{m}$

## HA loading:

$\mathrm{UDL}=15^{*} 0.59=8.9 \mathrm{kN} / \mathrm{m}$
$\mathrm{KEL}=32.88^{*} 0.59=19.4 \mathrm{kN}$

## Moment and shear force:

## Self weight:

B. $\mathrm{M}=\mathrm{w} * \mathrm{~L}^{2 /} 8=10.15 * 15^{2} / 8=285.5 \mathrm{kN} . \mathrm{m}$

$\mathrm{S} . \mathrm{F}=\mathrm{w} * \mathrm{~L} / 2=10.15 * 15 / 2=76.1 \mathrm{kN}$

## Superimposed load:

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

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

## Walkway:

B. $\mathrm{M}=15 * 15^{2} / 8=421.9 \mathrm{kN} . \mathrm{m}$
S. F $=15 * 15 / 2=112.5 \mathrm{kN}$

## Railing:

B. $\mathrm{M}=\mathrm{w} * \mathrm{~L} / 4=1 * 15 / 4=3.75 \mathrm{kN} . \mathrm{m}$
S. $F=1 \mathrm{kN}$

## H A loading:


B. $\mathrm{M}=\mathrm{w} * \mathrm{~L}^{2} / 8+\mathrm{w} * \mathrm{~L} / 4=\left(8.9 * 15^{2} / 8\right)+(19.4 * 15 / 4)=323.05 \mathrm{kN} . \mathrm{m}$
S. $\mathrm{F}=\mathrm{w}^{*} \mathrm{~L} / 2+\mathrm{w}=19.4+(8.9 * 15 / 2)=86.2 \mathrm{kN}$


Table (4.5): Factored moment and Shear force

| Load | $\boldsymbol{\gamma} \mathbf{F}$ | $\mathbf{B . M}$ <br> $\mathbf{k N . m}$ | $\mathbf{B . M} \mathbf{} \mathbf{*} \mathbf{\gamma} \mathbf{F}$ <br> $\mathbf{k N . m}$ | $\mathbf{S . F}$ <br> $\mathbf{k N}$ | $\mathbf{S . F} \mathbf{F}^{*} \mathbf{F}$ <br> $\mathbf{k N}$ |
| :--- | :---: | :---: | :---: | :---: | :---: |
| 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 |

