Design of Girder and Slab (T-Beam) Bridge

Components of a T-Beam Bridge

i) Deck Slab.
ii) Cantilever portion
iii) Footpaths : kerbs and handrails
iv) Longitudinal girders
v) Cross beams or diaphragms
vi) Wearing Course.

Width of Kerb :- 475 mm to 600 mm

Wearing course :- Asphaltic concrete of thickness 56 mm

Cement concrete (M30) of thickness 75 mm.

Footpaths of width = 1.5 m on either side of Bridges.

<u>Cross Beams</u> :- 1) to stiffen the girders and to reduce torsion in the exterior girders.

2) to equalize the deflections of the girders carrying heavy loading with those of the girders with less loading.

- When the spacing of the cross beams is less than about 1.8 times that of longitudinal girders, the deck slab can be designed as a two-way slab.
- the thickness of the cross-beams should not be less than the minimum thickness of the webs of the longitudinal girders.

Example :- Design a T- Beam bridge for a rural section of a State Highway. The bridge consists of five spans of 14.5m. Assume moderate exposure and cement concrete wearing course.

Solution :- Step I :- Preliminary Design :-

Clear road way = 7.5m

Assume three T-beams spaced at 2.5m interval.

Effective span of T-beam = 14.5m

Assume five cross beams at 3.625 m interval.

Use M25 grade of concrete and Fe 415 grade of HYSD steel.

Clear cover to reinforcement = 40 mm.

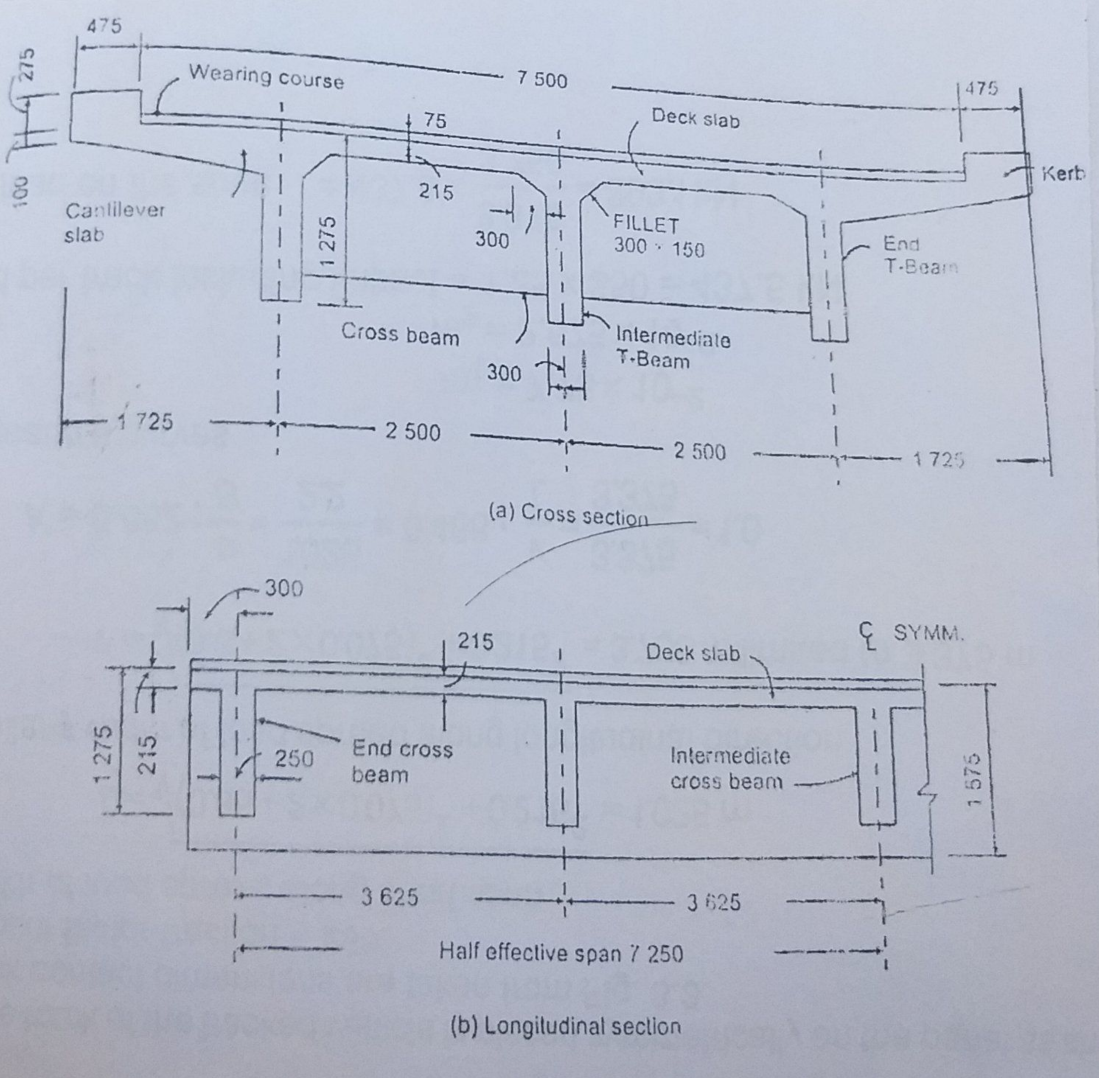


Figure 7.3 Preliminary Dimensions for T-beam Deck.

Step II :- Deck Slab

The slab is supported on four sides by beams.

Thickness of slab, H = 215 mm

Thickness of wearing course, D = 75 mm

Span in the transverse direction = 2.5 m

Effective span in transverse direction = 2.5 − 0.3 = 2.2 m

Span in the longitudinal direction = 3.625 m

Effective span in the longitudinal direction = 3.625 − 0.25 = 3.375 m

i) Max. B.M due to dead load

Wt. of deck slab = 0.215 × 25 = 5.375 KN/m²

Wt. of wearing course = 0.075 × 25 = 1.875 KN/m²

Total = 7.25 KN/m²

The spacing of cross beams (3.625 m) is less than 1.8 × 2.5 = 4.5 m, deck slab is designed as two-way slab using Pigeaud's curves.

$$\text{Ratio, } K = \frac{\text{Short span}}{\text{long span}} = \frac{2.2}{3.375} = 0.652$$

$$1/K = 1.53$$

Using Figure A.9, (slab completely loaded by udl).

$m_1 = 0.047$ for $K = 0.652$

$m_2 = 0.0175$ for $1/K = 1.53$

Total dead load = 7.25 × 2.2 × 3.375 = 53.83 KN

$(m_1 + \mu m_2) P$

Moment along short span $= (0.047 + 0.15 \times 0.0175)\, 53.83$

$= 2.67$ KNm

—— do —— long span $= (m_2 + \mu m_1) P$

$= (0.0175 \times 0.15 \times 0.047)\, 53.83$

$= 1.32$ KNm

ii) Live load B.M. due to IRC class AA tracked vehicle

Size of one panel of deck slab $= 2.5 \times 3.625$ m

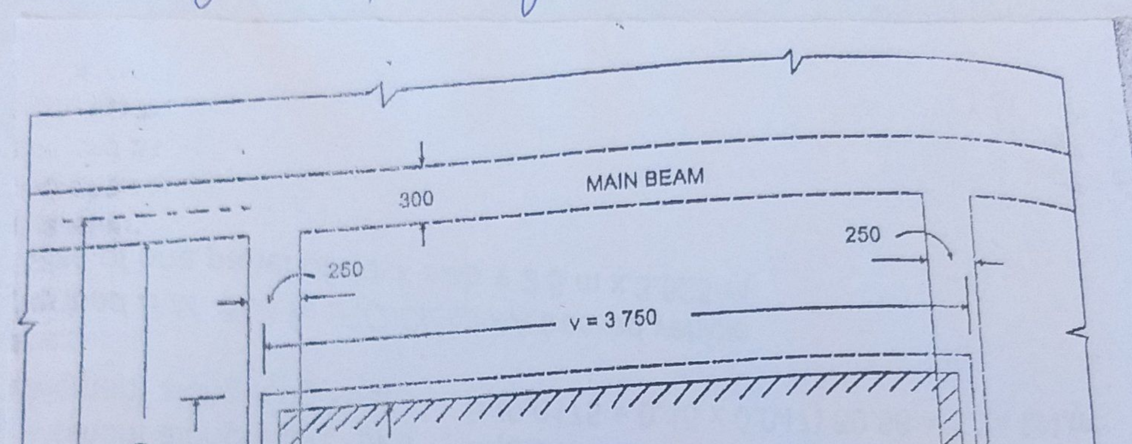
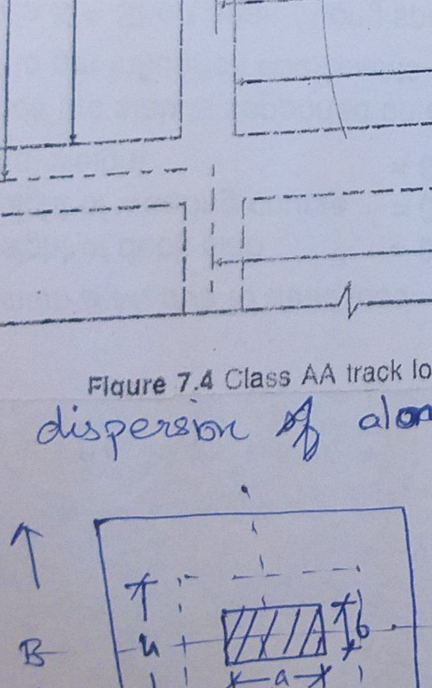
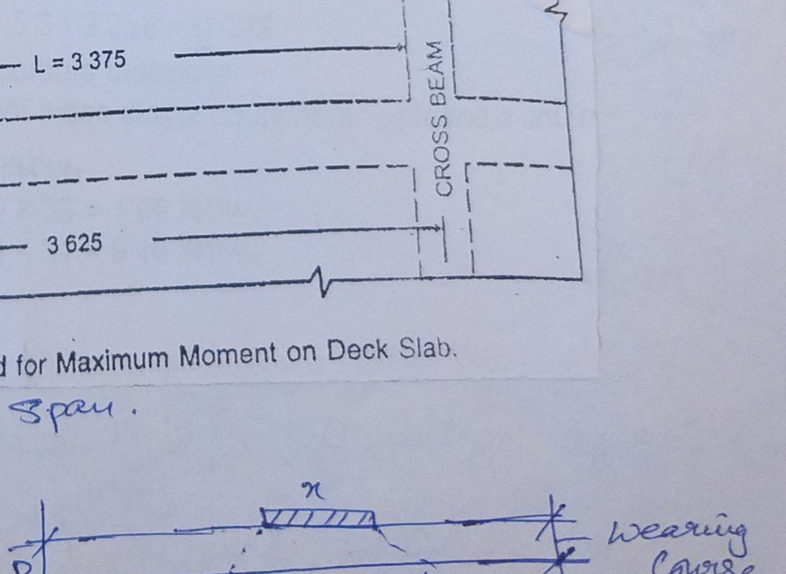


Figure 7.4 Class AA track located for Maximum Moment on Deck Slab.

Load dispersion of along span.





Width of load spread along short span

$$u = \sqrt{(0.85 + 2\times0.075)^2 + 0.215^2} = 1.025\ m$$

Width of load spread along long span

$$v = \sqrt{(3.6 + 2\times0.075)^2 + 0.215^2} = 3.756\ m \text{ limited to } 3.375\ m$$

$K = \frac{2.2}{3.375} = 0.652$; $\frac{u}{B} = \frac{1.025}{2.2} = 0.466$; $\frac{v}{L} = \frac{3.375}{3.375} = 1.0$

Using Pigeaud's curves for K = 0.6 & K = 0.7 and taking the avg. values.

$m_1 = 7.75\times10^{-2}$

$m_2 = 2.7\times10^{-2}$

Impacts factor fraction = 25%

Total load per track including impact = $1.25\times350 = 437.5$ KN

Effective load on the span = $437.5 \times \frac{3.375}{3.756} = 393.1$ KN.

Moment along shorter span = $(7.75 + 0.15\times2.7)\times10^{-2}\times393.1$

= 32.06 KNm

Moment along longer span = $(2.70 + 0.15\times7.75)\times10^{-2}\times393.1$

= 15.18 KNm.

(iii) Live load B.M. due to IRC class AA wheeled vehicle.

The class AA wheeld vehicle should be placed on the deck slab as shown for producing the severest moments

The Bending moments are computed for individual wheel load

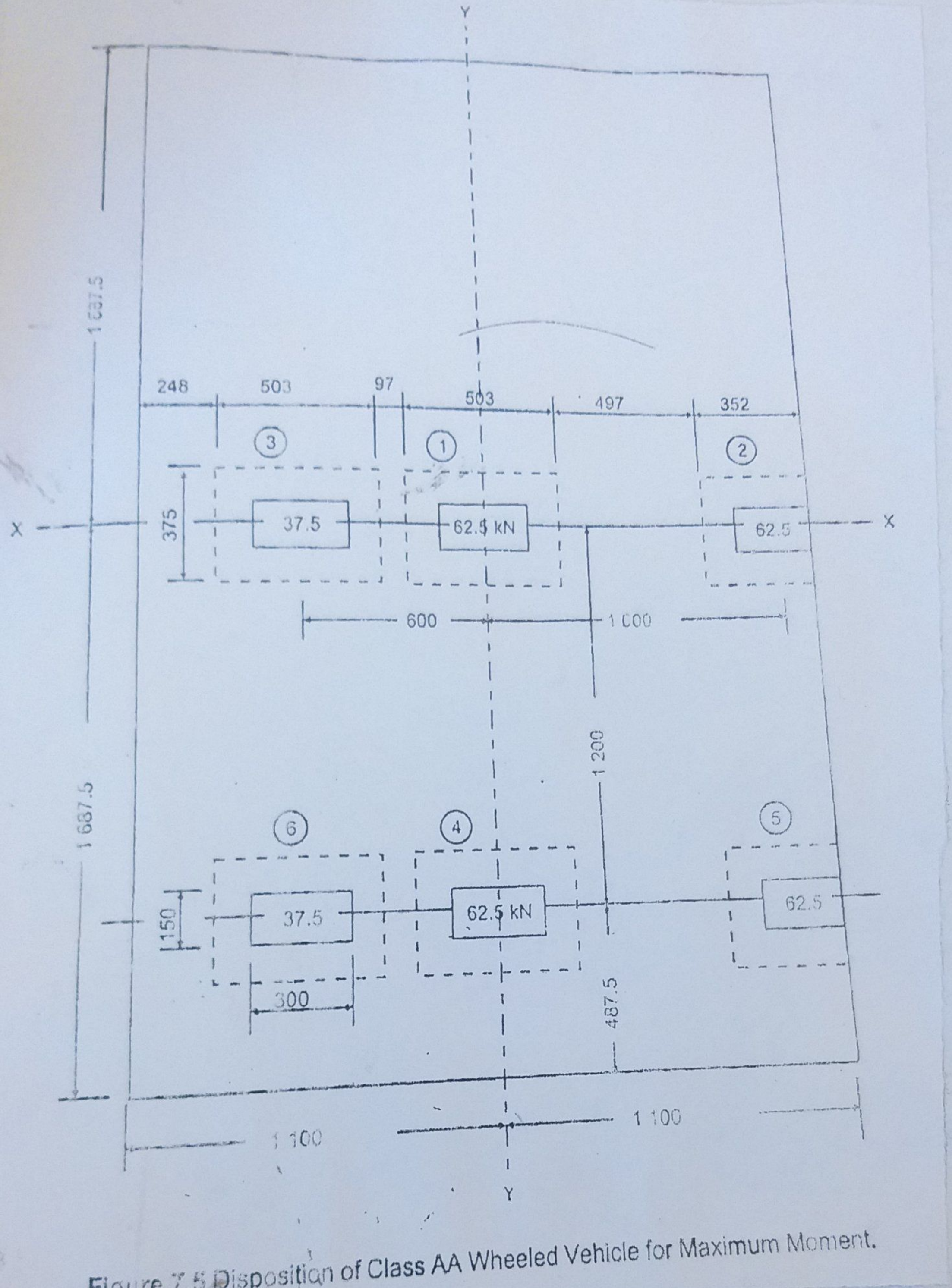


Figure 7.5 Disposition of Class AA Wheeled Vehicle for Maximum Moment.

a) B.M. due to wheel 1. (placed symmetrically at the centre).

Tyre contact dimensions are 300 x 150 mm

$$u = \sqrt{(0.3 + 2\times 0.075)^2 + 0.215^2} = 0.503\,m$$

$$v = \sqrt{(0.15 + 2\times 0.075)^2 + 0.215^2} = 0.370\,m$$

$$u/B = \frac{0.503}{2.2} = 0.227 \quad , \quad \frac{v}{\lambda} = \frac{0.370}{3.375} = 0.110 \quad , \quad K = 0.652$$

Using Pigeaud's curves.

$m_1 = 19.05 \times 10^{-2}$

$m_2 = 14.55 \times 10^{-2}$

Total load including impact 25% = ~~(19.05 + 0.15 × 14.55) × 10~~ = $62.5 \times 1.25 = 78.10$ KN

Moment along short span $= (19.05 + $ ~~2×~~ $0.15 \times 14.55) \times 10^{-2} \times 78.10$

$= 16.59$ KNm.

Moment along long span $= (14.05 + 0.15 \times 19.05) \times 10^{-2} \times 78.10$

$= 13.60$ KNm.

b) <u>B.M due to wheel 2 :—</u>

This load is unsymmetrically placed w.r.t. YY axis of the panel. The Pigeaud's curves are feasible only for symmetrical loading about the centre. Hence to analyse this load, dummy load is assumed acting with same value on the other side, making it symmetric along YY-axis. Hence the results can be computed, firstly considering the whole (strip) area to be loaded and then the central area beyond the loads, to be loaded. Subtracting the results ~~from~~ ~~second~~ of second from first and taking the half, gives the desired results.

Intensity of loading $= \dfrac{62.5 \times 1.25}{0.503 \times 0.375}$ = ~~41.42~~ 414.20 KN/m^2

(1) Considering whole area (strip) to be loaded = 2.2×0.375.

$m_1 = 8.25 \times 10^{-2}$, $m_2 = 8.0 \times 10^{-2}$

∴ Moment along short span $= (8.25 + 0.15 \times 8.0) \times 10^{-2} \times 2.2 \times 0.375 \times 414.20$

$= 32.29$ KNm

Long span $= (8.0 + 0.15 \times 8.25) \times 10^{-2} \times 2.2 \times 0.375 \times 414.20$

$= 31.56$ KNm.

ii) Considering area b/w real and dummy load

i.e. 1.496 m × 0.375 m
(2200 − 352 − 352)

For this $m_1 = 11.3 \times 10^{-2}$, $m_2 = 10.35 \times 10^{-2}$

Moment along short span $= (11.3 + 0.15 \times 10.35) \times 10^{-2} \times 1.496 \times 0.375 \times$ ~~41.42~~ 414.2

$= 27.89$ KNm

Moment along long span $= (10.35 + 0.15 \times 11.30) \times 10^{-2} \times 1.496 \times 0.375 \times$ ~~41.42~~ 414.20

$= 26.14$ KNm

∴ Net B.M along the short span $= \left(\dfrac{32.29 - 27.89}{2}\right) = 2.20$ KNm

Net B.M along the long span $= \left(\dfrac{31.56 - 26.14}{2}\right) = 2.71$ KNm.

c) B.M. due to wheel 3.:—

Intensity of loading $= \dfrac{37.5 \times 1.25}{0.503 \times 0.375} = 248.51$ KN/m²

Consider the loaded area of 2.2 × 0.375

For this area

$L/B = \dfrac{2.2}{2.2} = 1.0$, $\dfrac{v}{L} = \dfrac{0.375}{3.375} = 0.11$, $K = 0.652$

$m_1 = 8.5 \times 10^{-2}$, $m_2 = 7.8 \times 10^{-2}$

Moment along short span $= (8.5 + 0.15 \times 7.8) \times 10^{-2} \times 2.2 \times 0.375 \times 248$

$= 19.83$ KNm

long span $= (7.8 + 0.15 \times 8.5) \times 10^{-2} \times 2.2 \times 0.375 \times 24$

$= 18.61$ KNm

Now considering the non-loaded symmetrical area for imaginary loading.

loaded area $= (2.2 - 0.503 - 0.503) \times 0.375$

$= 1.194 \times 0.375$

For this area.

$u/B = \frac{1.194}{2.2} = 0.54 \quad \frac{v}{L} = \frac{0.375}{3.375} = 0.11 \quad , \quad K = 0.652$

$m_1 = 13 \times 10^{-2} \quad , \quad m_2 = 12 \times 10^{-2}$

Moment along short span $= (13 + 0.15 \times 12) \times 10^{-2} \times 1.194 \times 0.375 \times 248.51$

$= 16.47$ KNm

long span $= 15.52$ KNm.

Net B.M along short span $= \frac{19.83 - 16.47}{2} = 1.68$ KNm

long span $= \frac{18.61 - 15.52}{2} = 1.55$ KNm

d) B.M due to wheel 4

Similar as in case b) wheel 2 but the eccentricity is w.r.t XX axis and load area extended with respect to XX axis.

B.M. along short span = 3.11 KNm

B.M. along long span = 2.77 KNm

e) B.M due to wheel 5 ! eccentric to both XX & YY axis

Consider the case to be eccentric in XX direction and making the calculations

B.M along short span = 2.18 KNm

long span = 1.94 KNm

f) B.M due to wheel 6 :-

Net B.M along short span = 1.87 KNm

long span = 1.66 KNm

g) Total B.M. due to all wheels on the span

Total B.M along short span = 16.59 + 2.20 + 1.68 + 3.11 + 2.18 + 1.87

= 27.63 KNm

long span = 13.60 + 2.71 + 1.55 + 2.77 + 1.94 + 1.66

= 24.23 KNm.

iv) <u>Design B.M.</u>

Class AA tracked vehicle causes heavier moment, hence the design moments are :-

Design B.M along short span = (2.67 + 32.04) 0.8

= 27.77 KNm

Design B.M along long span = (1.32 + 26.34) 0.8

= 22.13 KNm.

The computed moments are multiplied by a factor 0.8 to allow for continuity.

v) <u>Reinforcements</u> :-

$\sigma_{cb} = 8.3 MPa$, $\sigma_{st} = 200 MPa$, $j = 0.90$

$R = 1.10$.

Effective depth reqd $= \sqrt{\frac{27.77 \times 10^6}{1.10 \times 1000}} = 158.88 \simeq 160 mm$

Effective depth provided assuming $\phi = 12 mm$ = $215 - 40 - 6 = 169 mm$

Hence safe depth of 215 mm.

$A_{st} = \frac{27.77 \times 10^6}{200 \times 0.90 \times 169} = 913.27 mm^2$

Adopt 12 mm ϕ bars @ 110 mm c/c, A_{st} provided = $1028 mm^2$

Area of longitudinal reinforcement

$$= \frac{22.13 \times 10^6}{200 \times 0.90 \times 157} = 783.12\ mm^2$$

effective depth = $215 - 40 - 12 - 6 = 157$ mm.

Provide 12 mm ϕ bars @ 140 mm c/c , A_{st} provided = $808\ mm^2$

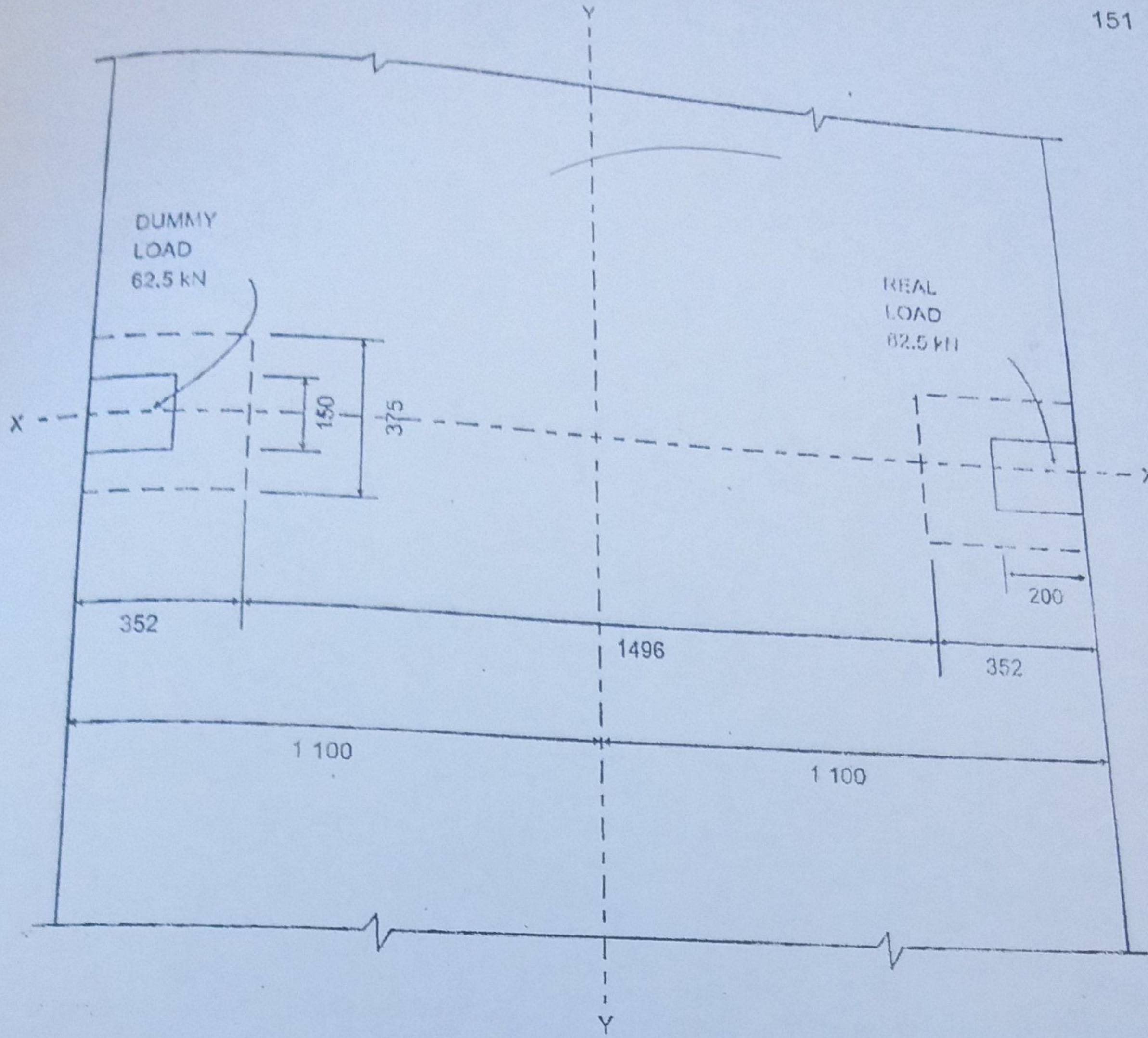


Figure 7.6 Details of Disposition of Wheel 2.

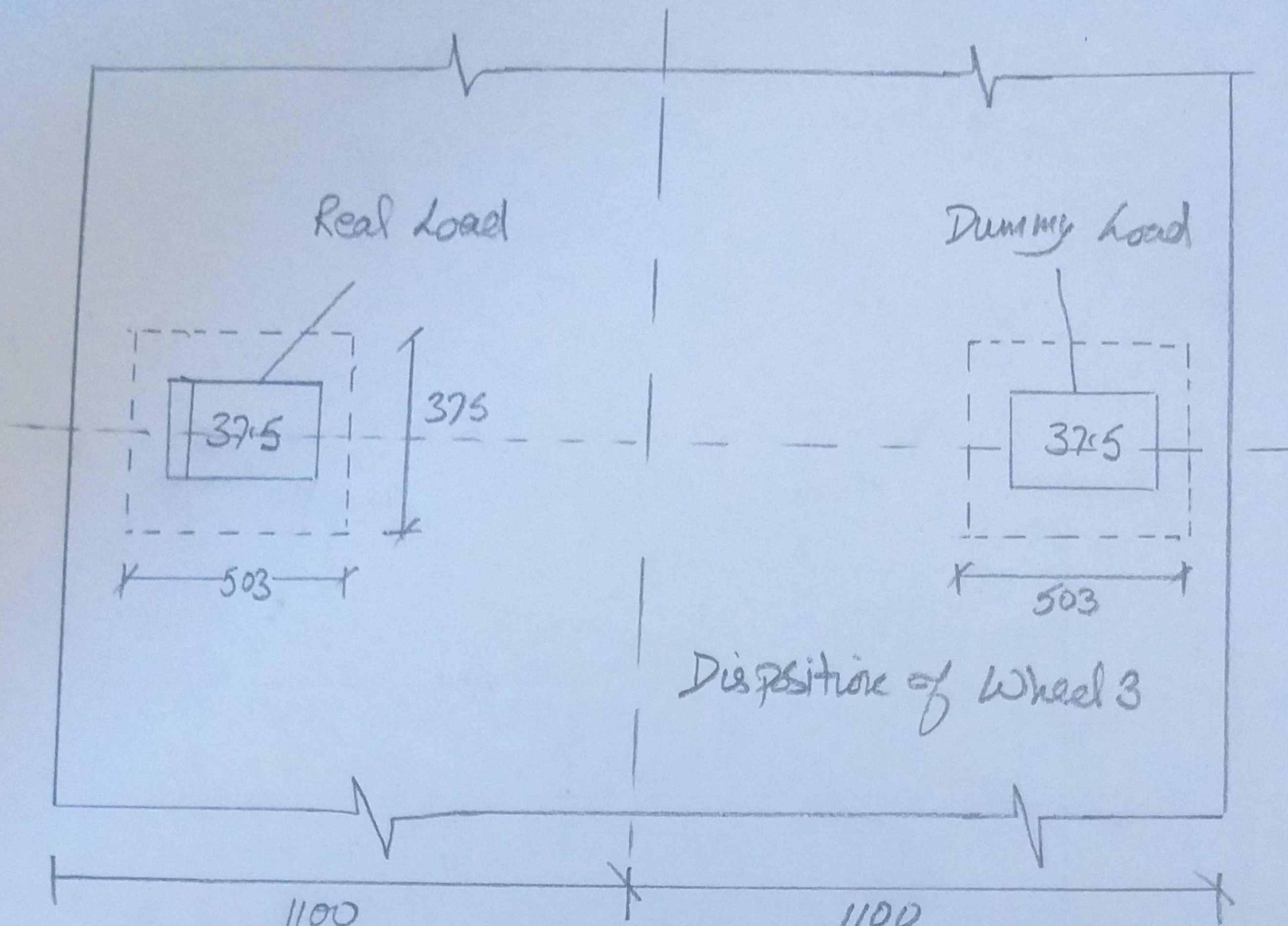
Moment along long span = 26.14 kN.m
Net B.M. along short span = 1/2 (32.29 – 27.89) = 2.20 kN.m
Net B.M. along long span = 1/2 (31.56 – 26.14) = 2.71 kN.m

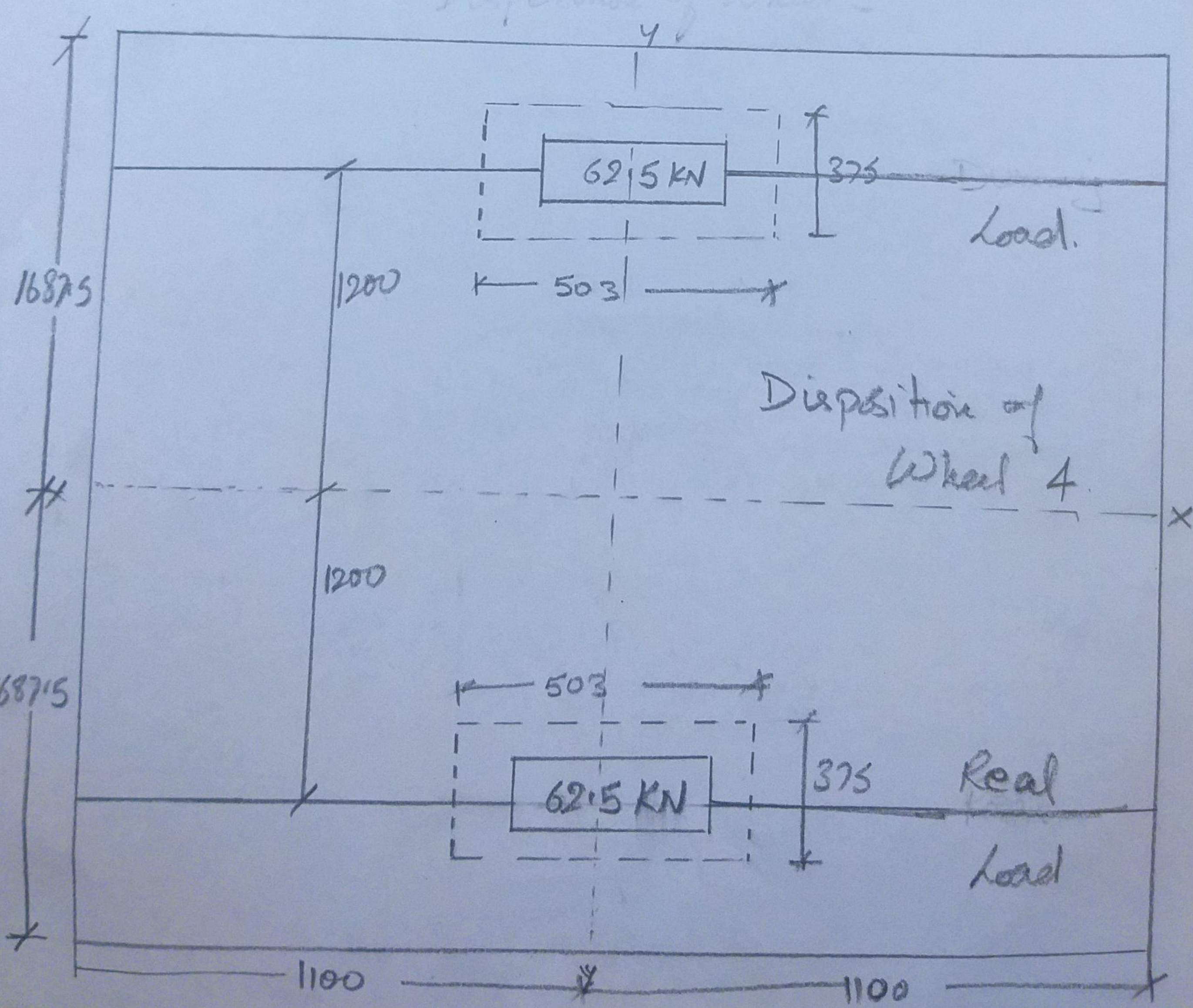
(c) *B.M. due to wheel 3*

By similar procedure as for case (b), we get
B.M. along short span = 2.98 kN.m
B.M. along long span = 3.66 kN.m

(d) *B.M. due to wheel 4*

Here the load is eccentric with respect to XX axis. By similar procedure as for case but with the load area extended with respect to XX axis, we get
B.M. along short span = 3.11 kN.m
B.M. along long span = 2.77 kN.m


Real Load
Dummy Load
37.5
37.5
375
503
503
Disposition of Wheel 3
1100
1100


y
62.5 KN
375
Load.
503
1200
1687.5
Disposition of Wheel 4
x
1200
1687.5
503
62.5 KN
375
Real Load
1100
y
1100