Step-III : Cantilever Slab.

i) Moment due to dead load

S.No.	Description	Load (KN)	Lever m	Moment KN·m
01	Handrails (approx.)	1.74	1.425	2.480
02	Kerb 0.475 × 0.275 × 25	3.27	1.340	4.380
03	Wearing course 1.1 × 0.075 × 25	2.06	0.55	1.133
04	Slab 1.575 × 0.1 × 25	3.94	0.79	3.113
	0.5 × 0.250 × 1.575 × 25	4.92	0.53	2.610
				13.72

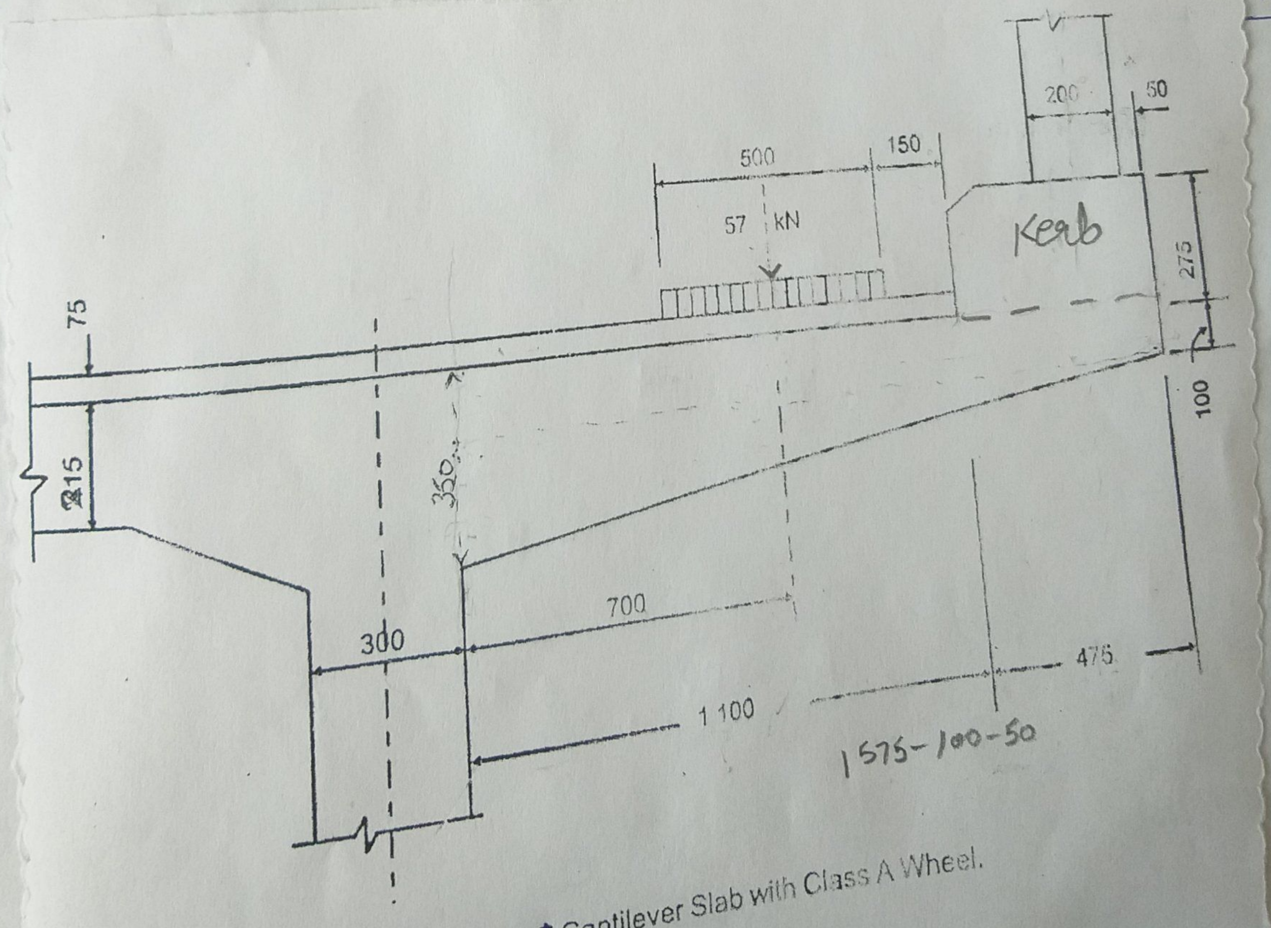


Figure 7A Cantilever Slab with Class A Wheel.

ii) Moment due to ~~dead~~ live load :-

Class AA will not operate in the cantilever slab. Therefore Class A loading is to be considered

Effective width of dispersion be

$$b_e = 1.2x + b_w$$

Here $x = .70$ m

$b_w = D + 2H = 0.250 + 2 \times 0.075 = 0.40$ m

$\therefore b_e = 1.2 \times 0.70 + 0.40 = 1.24$ m

$\therefore$ Live load per m width including impact $= \frac{57 \times 1.5}{1.24}$

$= 68.95$ KN

Max moment due to live load $= 68.95 \times 0.7$

$= 48.26$ KNm

iii) Reinforcement

Design moment $= 13.72 + 48.26 = 61.98$ KNm

$= 62$ KNm

$\therefore$ Effective depth required $= \sqrt{\frac{62 \times 10^6}{1.1 \times 1000}} = 237.41$ mm

$\therefore$ Effective depth provided $= 350 - 40 - 8 = 302$ mm

Area of main reinforcement $= \frac{62 \times 1000 \times 1000}{200 \times 0.90 \times 302}$

$= 1140.32$ mm^2

Adopt 16 mm ϕ bars @ 220 mm c/c + 12 mm ϕ bars @ 220mm c/c with $A_{st\,total}$ 1428 mm^2.

~~Area of distribution steel =~~

Bending Moment for distributors $= 0.2 M_D + 0.3 M_L$

$= 0.2 \times 13.\cancel{42} + 0.3 \times 48.26$

$= 17.22$ KNm

Area of distribution steel

$$= \frac{17.22 \times 10^6}{200 \times 0.9 \times 289} = 331 \text{ mm}^2$$

$d = 350 - 40 - 16 - \frac{10}{2} = 289$ mm

Provide 10mm ϕ bars at 220mm c/c giving an area of 357 mm^2.

Step IV:- Intermediate Longitudinal Girders

i) Data.

Effective span = 14.5m

Slab thickness = 215 mm

Width of rib = 300mm

Spacing of main beams = 2500 mm

Overall depth of beam = 1575 mm

ii) B.M due to dead load.

S.No	Item	Details	Wt.
01	Wearing course	2.5 × 0.075 × 25	4.6875
02	Deck Slab	2.5 × 0.215 × 25	13.4375
03	T-rib	0.3 × 1.35 × 25	10.1250
04	Fillets	2 × 0.5 × 0.30 × 0.15 × 25	1.1250
05	Cross Beams (Total wt. divided by total length) ↓ (14.5+300+300 Fig. 7.3(b))	$\frac{5 \times 2.2 \times 1.06 \times 0.25 \times 25}{15.1}$	4.8261
		Total	34.2011

$$\text{Max. B.M} = \frac{34.20 \times 14.5 \times 14.5^2}{8} = 898.82 \text{ KNm}$$

iii) B.M. due to Live load

Max. Live load B.M would occur under class A two lane loading

Impact Factor Fraction $= \frac{4.5}{6+14.5} = 0.22$

The loading is arranged in the transverse direction, allowing the minimum clearance near the left Kerb.

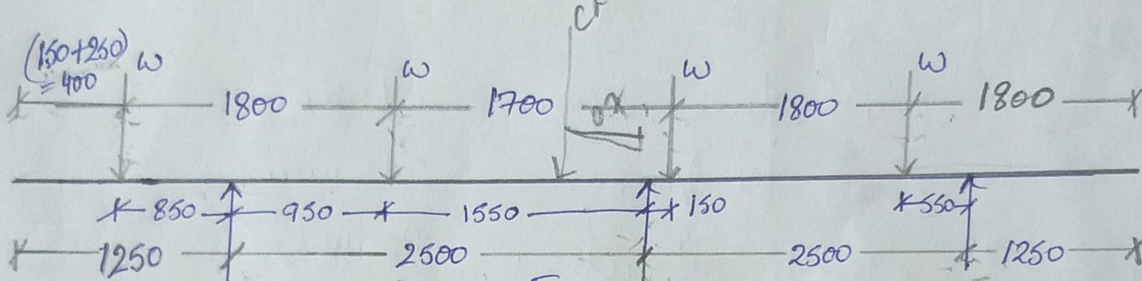


Fig. 7.5

Live load B.M. can be determined by using any one of the following methods:-

a) Courbon's Method.

b) Hendry-Jaeger method.

c) Morice-Little method.

a) Courbon's Method:- conditions for application

i) The ratio of span to width is greater than 2 but less than 4.

ii) The longitudinal beams are interconnected by symmetrically spaced cross girders of adequate stiffness.

iii) The cross girders extend to a depth of atleast 0.75 of the depth of the longitudinal girder.

Reaction, R_i of the cross beam on any girder i is given by:-

$$R_i = \frac{P I_i}{\Sigma I_i} + \left[\frac{P I_i}{\Sigma I_i} \cdot \frac{e d_i \Sigma I_i}{\Sigma I_i d_i^2}\right]$$

or $$R_i = \frac{P I_i}{\Sigma I_i}\left[1 + \frac{\Sigma I_i}{\Sigma I_i d_i^2} \cdot e d_i\right]$$

where P = total line load.

I_i = moment of inertia of longitudinal girder i

e = eccentricity of the line load

d_i = distance of girder i from the axis of bridge

Here

$P = 4W$

$n = 3$

$e = 0.7m$

$$R_A = \frac{4W.I}{3I}\left[1 + \frac{3I}{2(I \times 2.5^2)} \times 0.7 \times 2.5\right] = 1.89W$$

Similarly

$$R_B = \frac{4W}{3}(1+0) = 1.33W$$

$$R_C = 4W - 1.89W - 1.33W = 0.78W$$

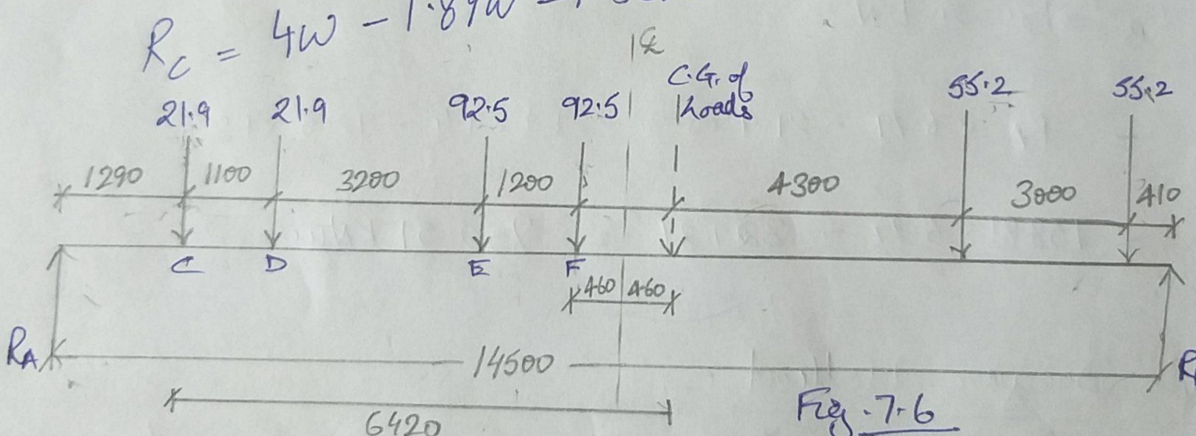


Fig. 7.6

Arrangement of Wheel loads in the longitudinal direction for Maximum moment.

First six loads of Class A loading are arranged, such that the maximum moment will occur under the fourth load from left. The loads are determined by multiplying by the reaction factor ($R_B = 1.33W$) for intermediate beam and then by impact factor i.e 1.22.

First load $= \frac{27}{2} \times 1.33 \times 1.22 = 21.9$ KN and so on.

From Fig. 7.6, the maximum bending moment occurring under the fourth load from left is found as.

$$R_A + R_B = 21.9 + 21.9 + 92.5 + 92.5 + 55.2 + 55.2 \quad \text{—} (1)$$

$$= 339.2 \text{ KN} \quad \text{—} (1)$$

$$\cancel{R_A \times 6.79 = 21.9 \times (1100+3200+1200) + 21.9 \times (3200+1200) + 92.5 \times 1200}$$

$$\cancel{554.508 + 1539.35 + 216.864}$$

$$\cancel{= 21.9 \times 5.5 + 21.9 \times 4.4 + 92.5 \times 1.2}$$

$$\cancel{R_A = \frac{327.81}{6.79} = 48.27}$$

$$R_A \times 14.5 = 21.9 \times 13.21 + 21.9 \times 12.11 + 92.5 \times 8.91 + 92.5 \times 7.71 + 55.2 \times 3.41$$

$$+ 55.2 \times 0.41$$

$$= 2302.722$$

$$R_A = 158.81 \text{ KN}$$

$$R_B = 180.39 \text{ KN}$$

$$M_{F(max)} = R_A \times 6.79 - 21.9 \times 5.5 - 21.9 \times 4.4 - 92.5 \times 1.2$$

$$= 158.81 \times 6.79 - 327.81 = \underline{750.51 \text{ KNm}}$$

b) Hendry - Jaegar Method :-

Cross beams can be replaced in the analysis by a uniform continuous transverse medium of equivalent stiffness.

$$A = \frac{12}{\pi^4}\left(\frac{\lambda}{h}\right)^3 \frac{n EI_T}{EI} \quad \text{———} (1)$$

$$F = \frac{\pi^2}{2n}\left(\frac{h}{\lambda}\right) \frac{CJ}{EI_T} \quad \text{———} (2)$$

$$C = \frac{EI_1}{EI_2} \quad \text{———} (3)$$

L — the span of the bridge

h — spacing of longitudinal girders

n — number of cross beams

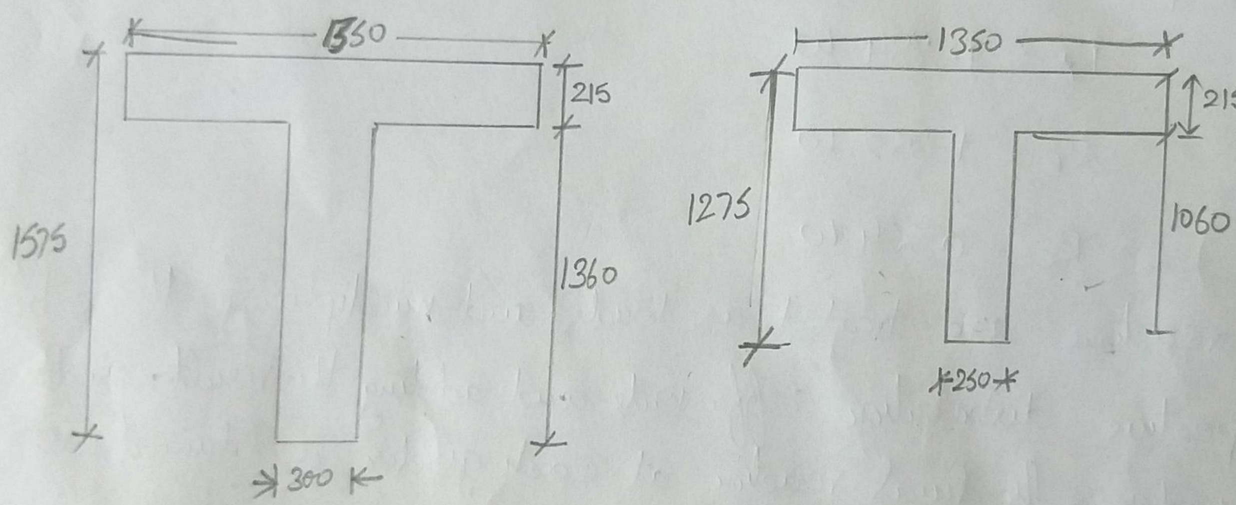
EI, CJ = Flexural & torsional rigidities, resp. of longitudinal girder

EI_1, EI_2 = Flexural rigidity of outer & inner longitudinal girder

EI_T = flexural rigidity of one cross beam.

Moment of Inertia of longitudinal girder, $I = 0.2012\ m^4$

Cross Beams $I_t = 0.1610\ m^4$



2. From Equation – 1

$$A = \frac{12}{\pi^4}\left(\frac{L}{h}\right)^3 \cdot \frac{5EI_T}{EI} = \frac{12}{\pi^4}\left(\frac{14.5}{2.5}\right)^3 \cdot \frac{5 \times E \times \cancel{0.1610}\ 0.08211}{E \times 0.2012}$$

$$= 48.68 \simeq 50.$$

As per the method, for T Beam having 3 or 4 Longitudinal girders it is permissible to employ distribution coefficients with no. of cross-beams, it is permissible to employ distribution coefficients for $F = \infty$. Using curves B.3 & B.4, the distribution coefficients corresponding to $A = 50$ are:–

Distribution Coefficient (D.C)

Unit load on girder	D.C for Girder A	Girder B	Girder C
A	0.40 m_{11}	0.32 m_{12}	0.28 m_{13}
B	0.28 m_{21}	0.34 m_{22}	0.38 m_{23}
C	0.32 m_{31}	0.34 m_{32}	0.34 m_{33}

Solving Fig. 7.5 using Moment Distribution Method, we get the moments at A, B and C as $-0.85W$, $-0.19W$ and 0 resp. and hence reactions at the supports

$$R_A = 1.884\ W$$

$$R_B = 1.352\ W$$

$$R_C = 0.764\ W$$

These reactions are treated as loads and multiplying these by the respective distribution coefficients and adding the results under each girder, the final reaction at each girder is obtained as:-

	Load	Reactions: Girder A	Girder B	Girder C
1.	1.884 W	$0.40 \times 1.884W = 0.754W$	$0.32 \times 1.884W \doteq 0.602W$	$0.28 \times 1.884W = 0.528W$
2.	1.352 W	$0.28 \times 1.352W = 0.378W$	$0.34 \times 1.352W = 0.460W$	$0.38 \times 1.352W = 0.514W$
3	0.764W	$0.32 \times 0.764W = 0.244W$	$0.34 \times 0.764W = 0.260W$	$0.34 \times 0.764W = 0.260W$
	Net reaction	1.38 W	1.322 W	1.302 W

Design max. B.M.

$$= \frac{750.51}{1.33} \times 1.322 = 746 \text{ KNm.}$$

Comparing the moments from the 3 methods.

Live load moment = 750 KNm

Hence Total design B.M = 898.82 + 750

= ~~1648.82~~ KNm. ≃ 1650 KNm

Design of Section :-

Effective flange width = thickness of web + 0.2 × 0.7 × effective span

= 0.3 + 0.14 × 14.5

= 2.33 m

Effective depth = 1575 − 120 − 120 [allowing a distance of 120mm from the bottom of T-beam & 120mm as the centre of compression below the top of T-beam]

= 1335

$$\therefore A_{st} = \frac{1650 \times 10^6}{180 \times 1335}$$

$(\sigma_{st} \times 0.9)$

$\sigma_{st} = 200$ MPa

= 6866.99 ≃ 6870 mm²

Provide 12 bars of 28 mm ϕ in 03 rows of 04 each.

∴ Ast provided = 7389 mm²

For shear, 4 legged stirrups @ 10 mm ϕ are provided @ 120 mm c/c.

Step V :- End Longitudinal Girder:-

The procedure is same as for the intermediate longitudinal girder.

B.M due to D.L = 898.82 KNm

Reaction Factor for end beam according to Hendry-Jaeger method = 1.38.

$\therefore$ B.M due to L.L $= \frac{750.51}{1.33} \times 1.38 \simeq 790$ KNm

Additional moments taken @ 10% = 1.1 × 790 = 869 KNm

Total design B.M = 898.82 + 869 = 1767.82 KNm

$\therefore$ Provide 14 bars @ 28 mm ϕ with an area of 8620 mm^2.

Step VI :- Intermediate Cross Beam :-

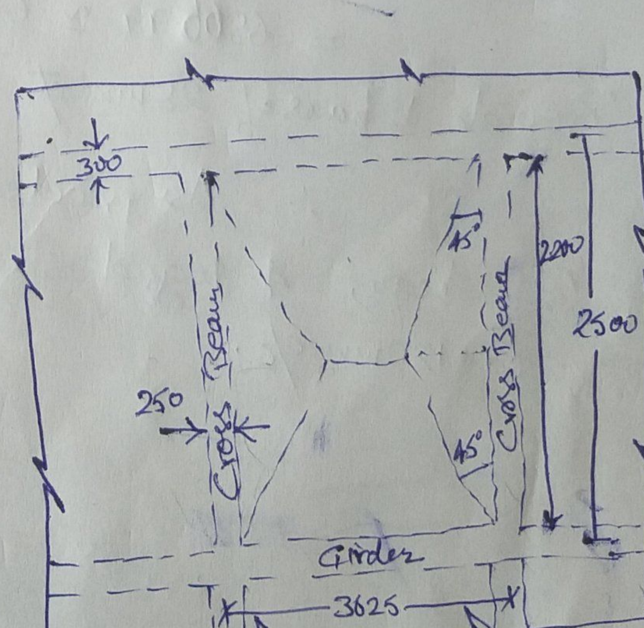
a) Data : Spacing of cross beam :- 3.625 m

Effective span = 2.5 − 0.3 = 2.2 m

b) Bending moment due to dead load.

Weight of deck slab & wearing course per m^2 = 0.215 × 25 + 0.075 × 25

= 7.25 KN/m^2



Total load on cross beam due to trapezoidal distribution $= 2 \times 0.5 \times 2.2 \times \frac{2.2}{2} \times 7.25$

= 17.55 KN

Self wt. of crossbeam and wt. of wearing course over the cross beam

= 2.2 × 0.25 × 1.275 × 25 + 2.2 × 0.25 × 0.075 × 25

= 18.56 KN.

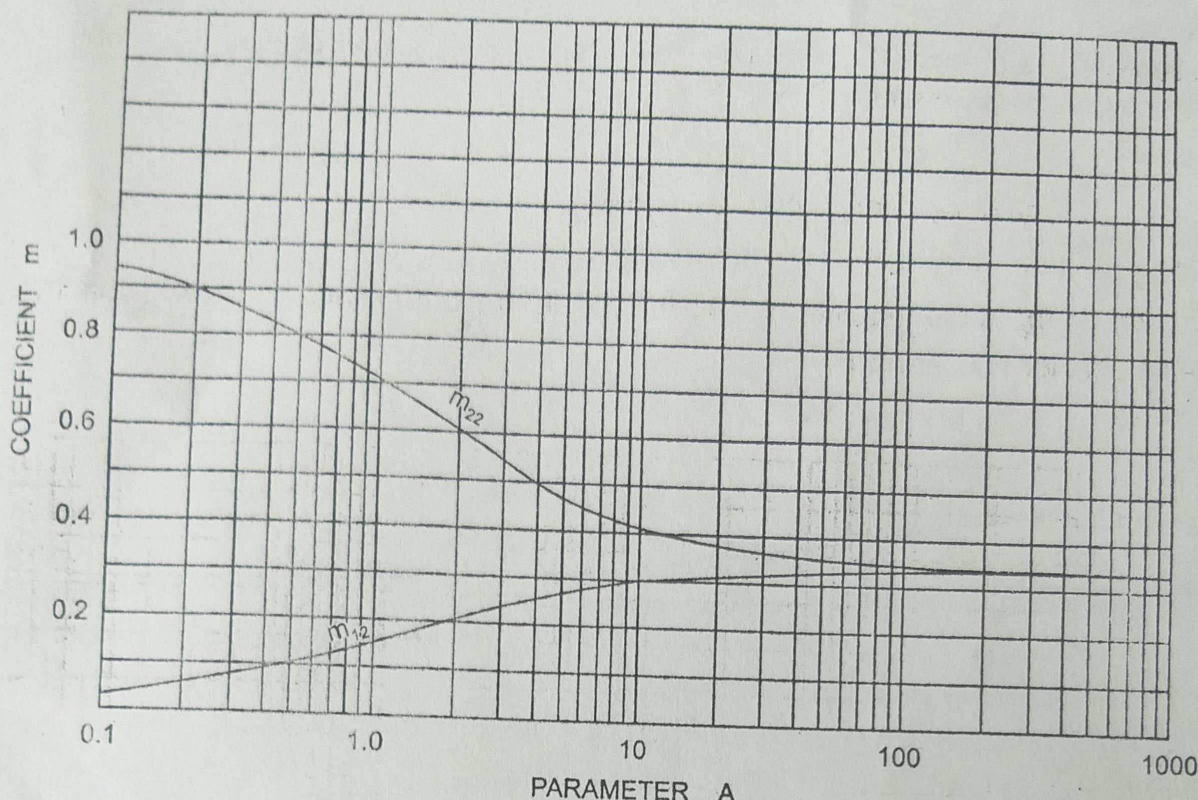


Figure B.2 Distribution Coefficients for Three-girder Bridge with Load on Girder No. 2, $F = 0$

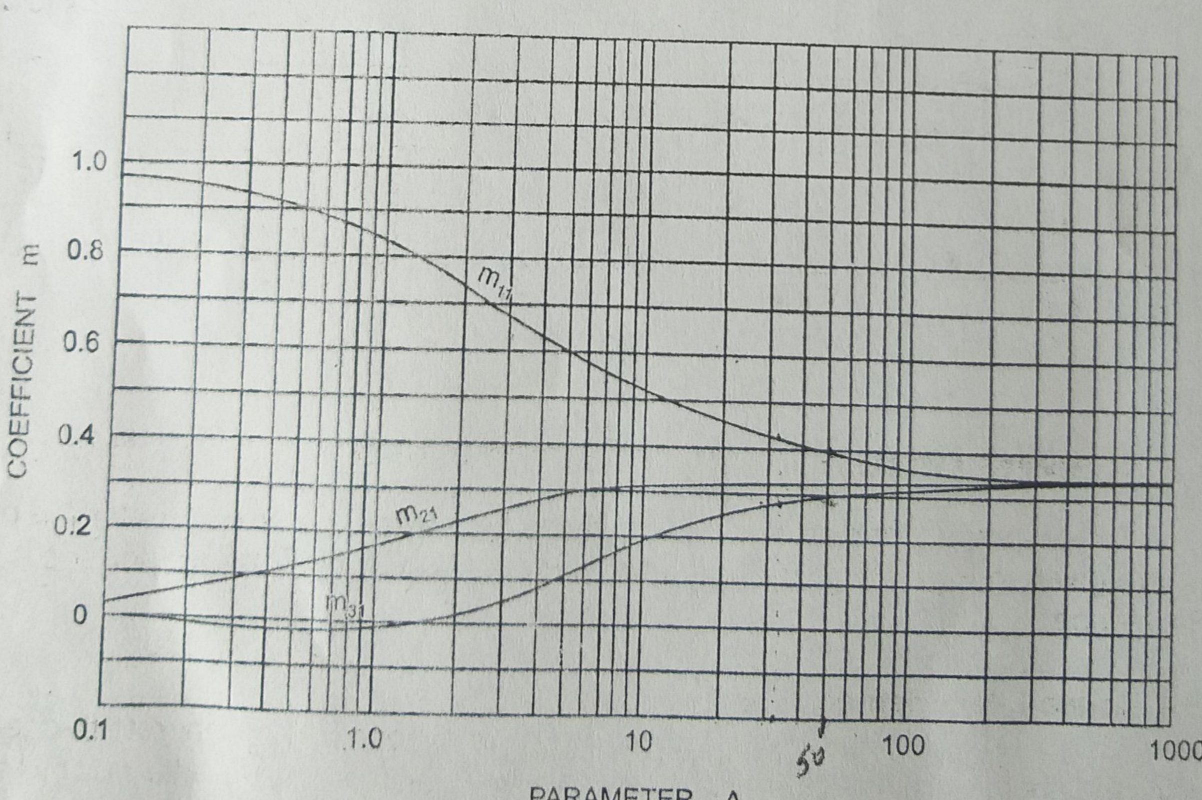


Figure B.3 Distribution Coefficients for Three-girder Bridge with Load on Girder No. 1, $F = \infty$

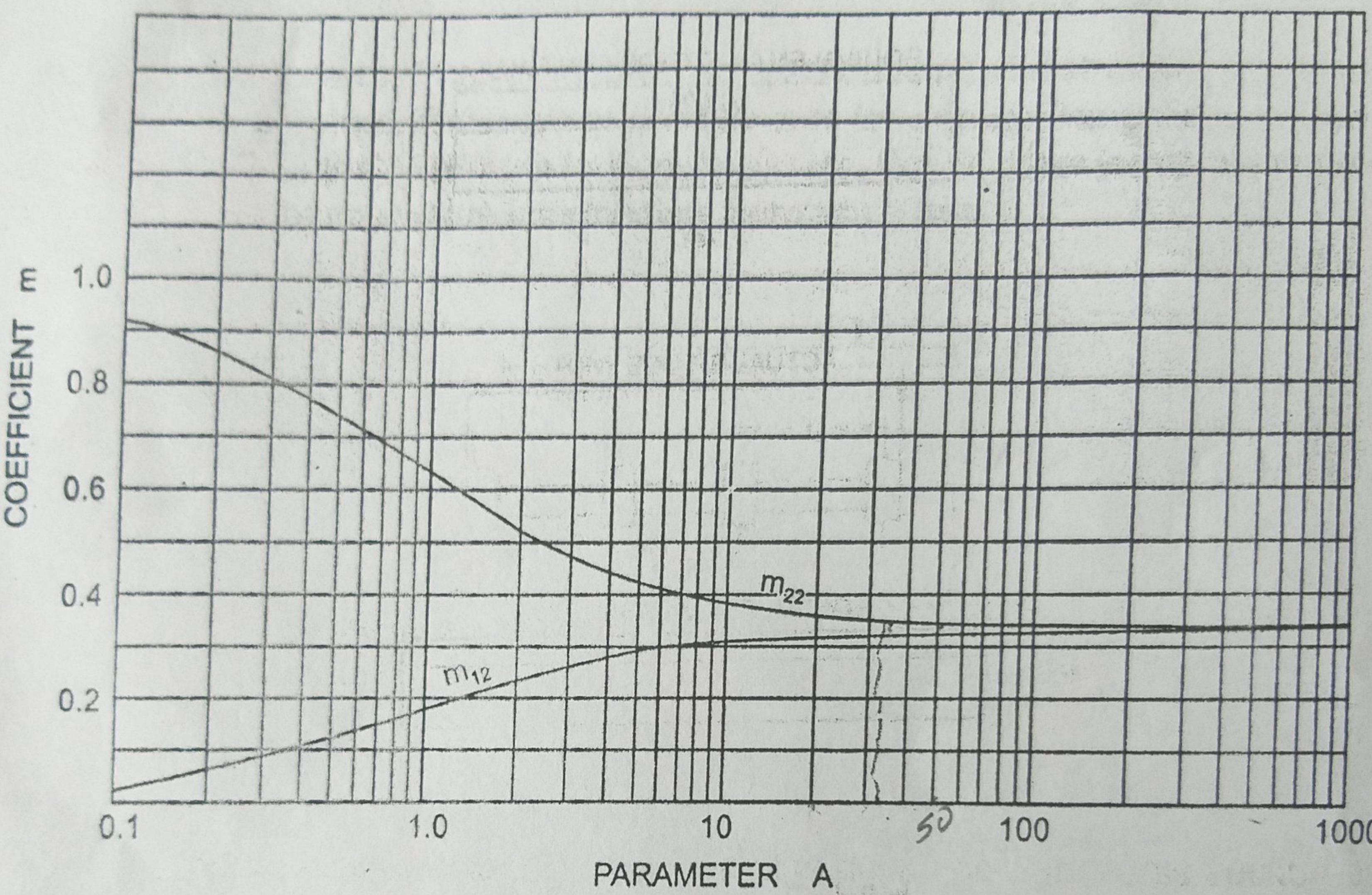


Figure B.4 Distribution Coefficients for Three-girder Bridge with Load on Girder No. 2, $F = \infty$