Design of Steel Flexural Members

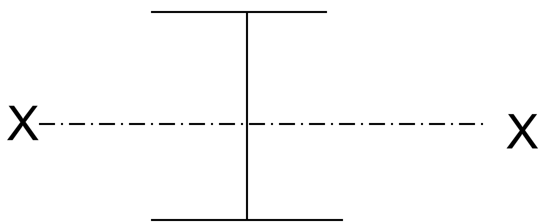
Design for :

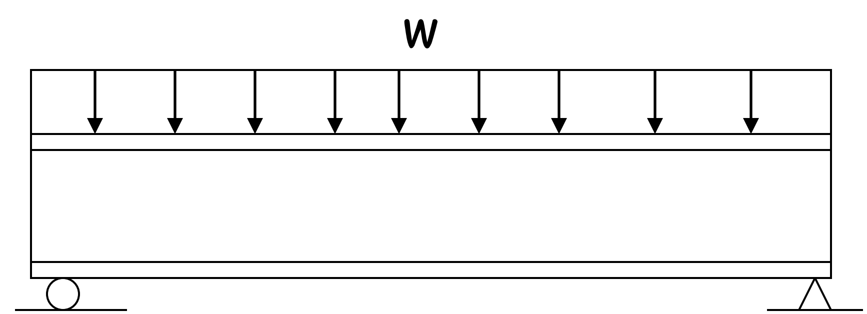
- Economy – choose lightest beam that can carry the load

- Serviceability – May need deeper beam to prevent serviceability problems such as deflection or vibrations

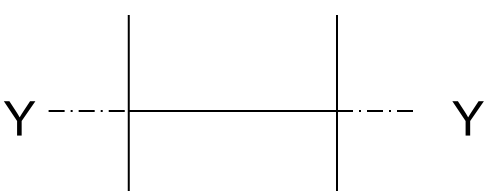
Design of Steel Flexural Members

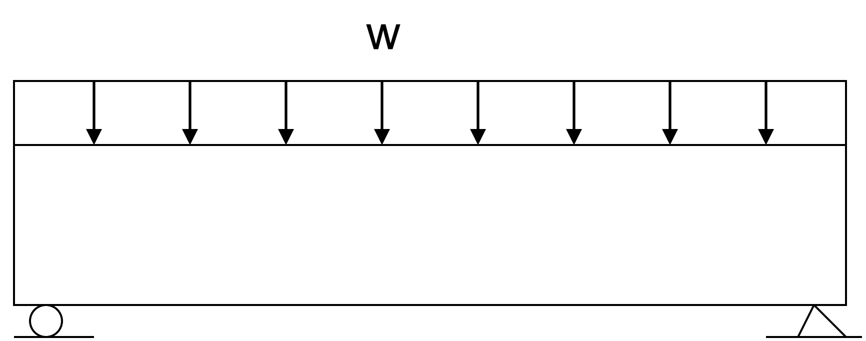
- Bending about strong axis (x-axis):





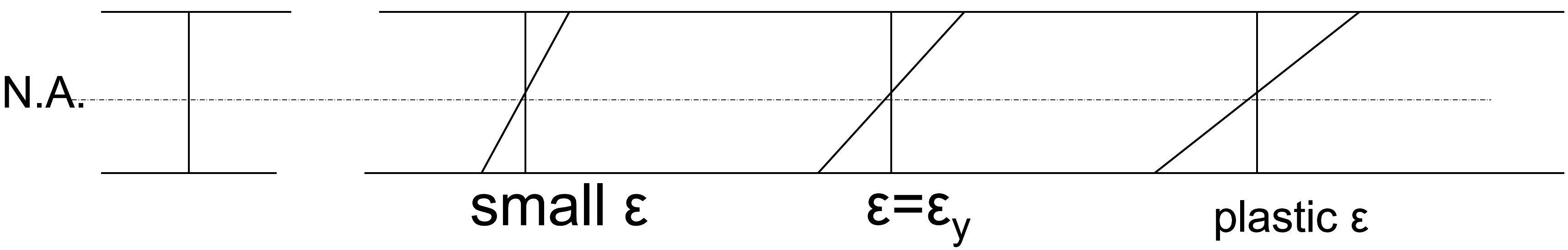
- Bending about weak axis





Stress and Strain in the Cross-section

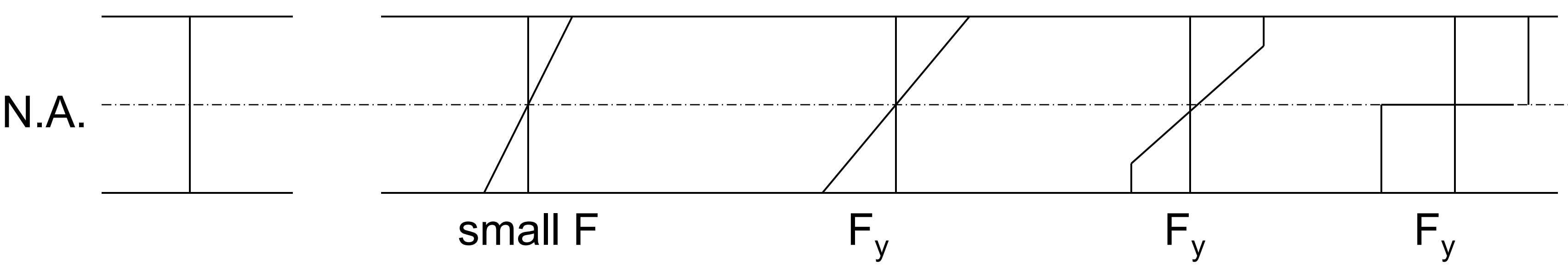
Strain



Stress

$E = F/\varepsilon$

$E \neq F/\varepsilon$



LRFD Equation

$$\sum \gamma_i Q_i \leq \phi R_n$$

Load Effect ≤ Factored Resistance

$$M_u \leq \phi M_n$$

Specification for Flexural Members

p. 16.1-207

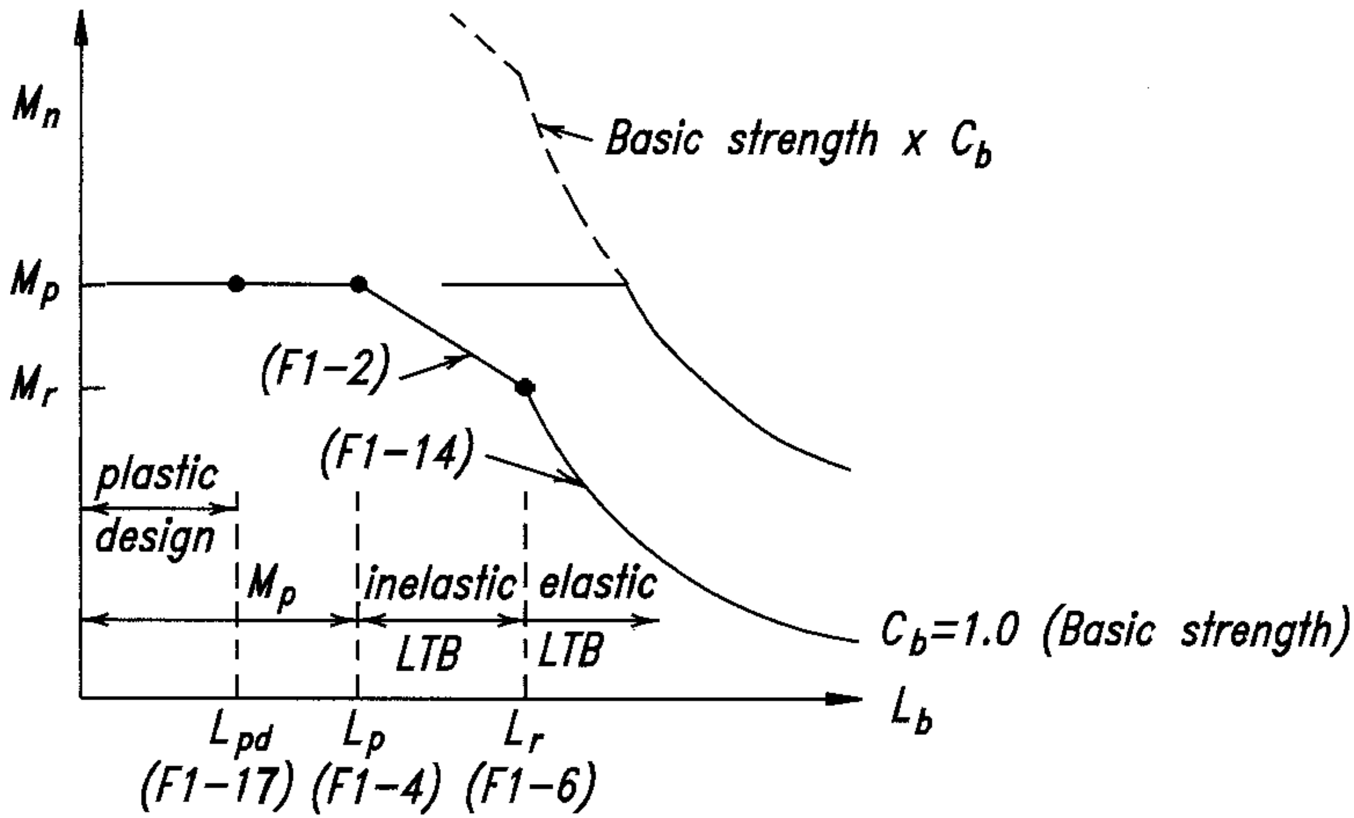


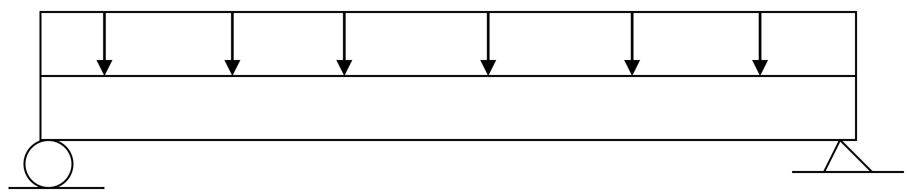
Fig. C-F1.1. Nominal moment as a function of unbraced length and moment gradient.

Part 5 – Design of Flexural Members

- Beam Tables – Table 5-3, p. 5-42 – 5-48
- Beam Charts – Table 5-5, p. 5-71 – 5-102
- Beam Diagrams – Table 5-17, p. 5-162 – 5-177

Flexural Design Example p. 27 notes

You are to select the lightest A992 steel beam that can carry a live load of 1.9 k/ft and a dead load of 1.4 k/ft for a span of 33 feet. Assume first continuous lateral support, and then lateral support 10 ft from each end only.



Flexural Design Example p. 27 notes

Select an A36 channel to carry a 500 lb/ft live load and a 300 lb/ft dead load for a simply supported span of 15 ft. Lateral support will be continuous for both flanges.

Deflections

- Serviceability (not strength) – Chapter L
- Calculated for service live load only
- KBC:
  - Δ_{max} = L/360 floor members
  - Δ_{max} = L/240 roof members

where Δ_{max} = maximum deflection

L = span length

Deflections

p.5-11 LRFD

$$\Delta = \frac{ML^2}{C_1 I_x}$$

Can also be written

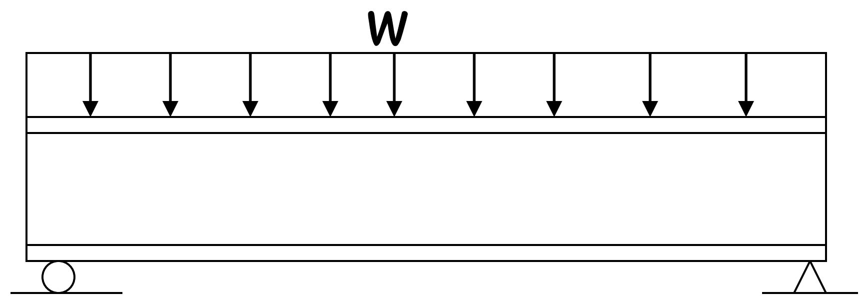
$$\frac{\Delta}{L} = \frac{ML}{12C_1 I_x}$$

Check deflection of beams chosen in previous examples

Beam Shear

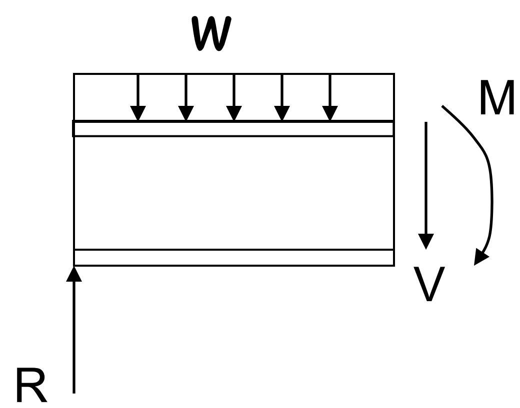
Maximum moment:

$$M_{\max} = \frac{wL^2}{8}$$

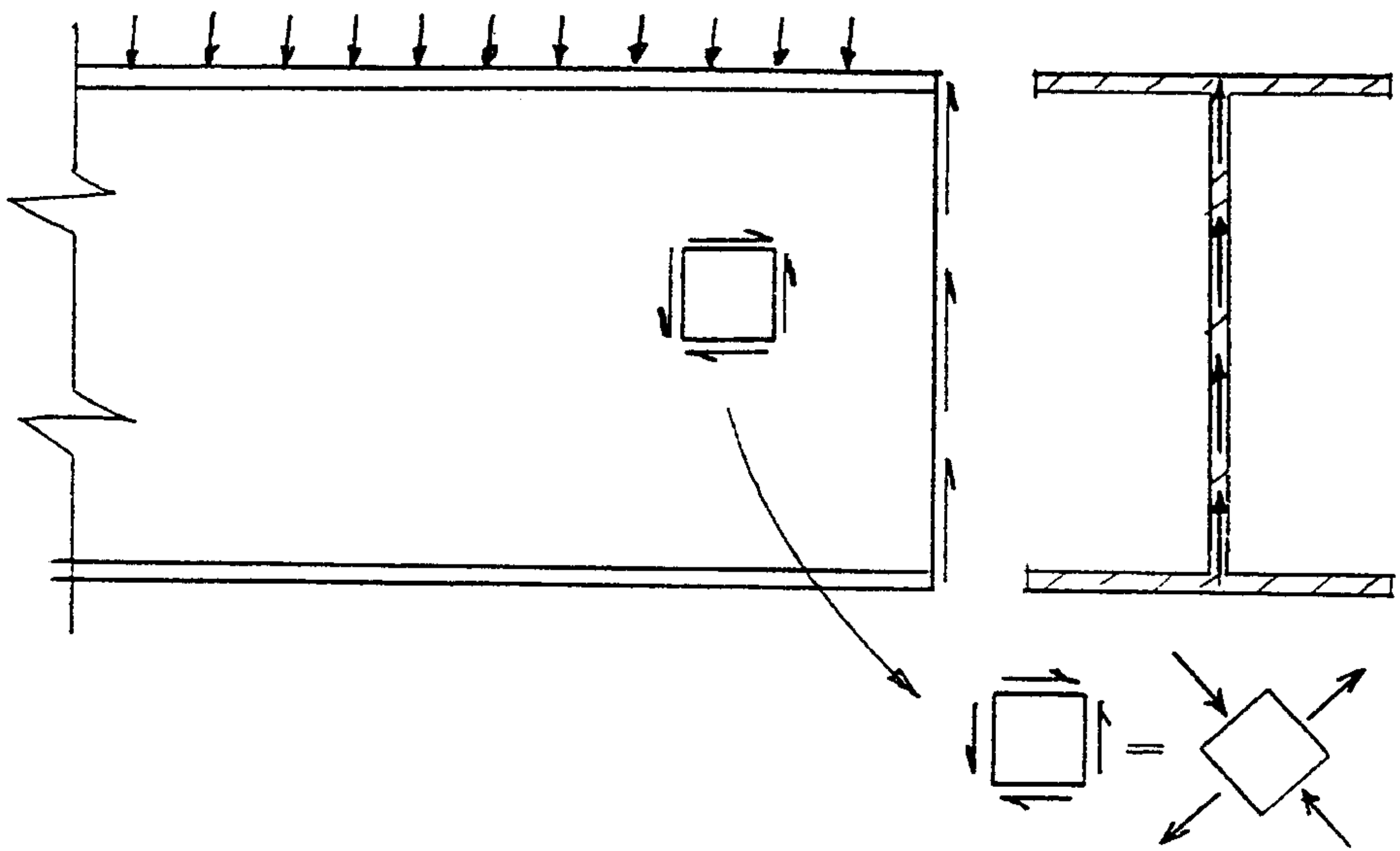


Also an internal shear:

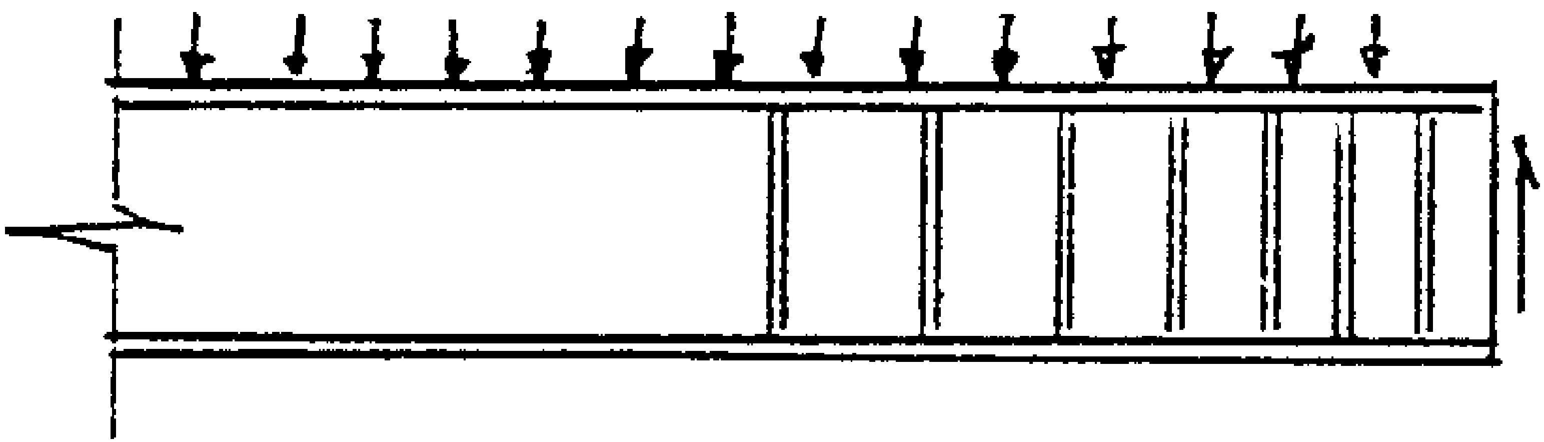
$$V_{\max} = \frac{wL}{2}$$



Beam Shear



Beam Shear



Shear Strength of Beams

p. 16.1-35 LRFD (with no holes in web)

$$\phi_v V_n = 0.9(0.6) F_{yw} A_w \qquad \text{if,} \quad \frac{h}{t_w} \leq 2.45\sqrt{\frac{E}{F_{yw}}}$$

true for steel shapes

where,

F_{yw} = yield strength web = F_y for steel shapes

A_w = area of web = d x t_w

p. 16.1 – 67 At connection where holes are in web:

$$\phi V_n = \phi R_n = 0.75(0.6) F_u A_{nv}$$

Check Shear Strength of beams previously designed

Floor Systems for Steel Frame Structures

Typical floor systems consist of steel decking filled with concrete

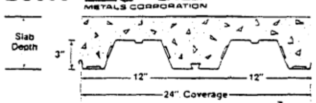
Figures of steel decking p. 16.1- 223

(Commentary to chapter I)

Example Data Sheet for Steel Decking

- 31 -

EC366 EPIC METALS CORPORATION



Note: Vol. of concr. in 3" form ht. ≈ .125 ft³/ft²

Suggested Temperature and Shrinkage Reinforcement — 6 x 6 Welded Wire Fabric

Slab Depth in.	Wire Size: Spans to 10'	Wire Size: 10' & up
5½ - 6¼	10/10	8/8
6½ - 7½	8/8	6/6

Section Properties

Design Thickness in.	Weight psf	I in.⁴	S_p in.³	S_n in.³
.0295	1.8	.799	.450	.497
.0358	2.2	.984	.571	.599
.0474	2.9	1.307	.806	.802
.0600	3.6	1.633	1.004	1.004

Total Allowable Superimposed Loads (psf) Working Stress Design. f_y = 40 ksi. f'_c = 3 ksi.

Table 1
Regular Weight Concrete: N = 9 (145 pcf)

Span ft.-in.*	Slab Depth in.*	Design Thickness (in.) .0295	.0358	.0474	.0600
9-0	5½	200	254	290	290
	6	226	287	328	328
9-6	5½	189	241	268	268
	6	214	272	302	302
10-0	5½	180	227	250	250
	6	203	256	282	282
10-6	5½	171	207	231	231
	6	194	234	261	261
	6½	216	261	292	292
11-0	5½	162	193	210	210
	6	182	218	238	238
	6½	203	244	265	265
	7	224	269	293	293
12-0	5½	131	170	183	183
	6	148	187	207	207
	6½	166	209	231	231
	7	184	232	256	256
	7½	202	[illegible]	280	280
13-0	5½	104	127	161	161
	6	118	151	182	182
	6½	132	169	203	203
	7	146	187	[illegible]	221
	7½	[illegible]	205	245	242
14-0	5½	82	102	143	143
	6	94	122	[illegible]	159
	6½	105	137	[illegible]	177
	7	117	152	[illegible]	196
	7½	128	167	[illegible]	216
15-0	6	[illegible]	99	120	145
	6½	83	111	148	162
	7	92	123	[illegible]	179
	7½	102	135	198	198
16-0	6	58	80	99	109
	6½	65	90	122	135
	7	73	100	148	160
	7½	80	110	167	175

Table 2
Lightweight Concrete: N = 14 (110 pcf)

Span ft.-in.*	Slab Depth in.*	Design Thickness (in.) .0295	.0358	.0474	.0600
9-0	5½	185	235	268	268
	6	209	266	303	303
9-6	5½	176	223	247	247
	6	198	252	279	279
10-0	5½	167	210	230	230
	6	188	237	261	261
10-6	5½	159	191	214	214
	6	179	216	242	242
	6½	200	242	270	270
11-0	5½	150	179	194	194
	6	169	202	220	220
	6½	189	226	245	245
	7	208	249	271	271
12-0	5½	133	157	169	169
	6	151	177	192	192
	6½	168	198	214	214
	7	186	219	236	236
	7½	203	239	259	259
13-0	5½	112	138	148	148
	6	127	156	168	168
	6½	142	174	187	187
	7	157	193	207	207
	7½	172	211	227	227
14-0	5½	91	113	131	131
	6	103	131	149	149
	6½	115	146	166	166
	7	128	162	184	181
	7½	141	178	201	198
15-0	6	84	108	136	134
	6½	94	121	152	149
	7	105	135	168	164
	7½	115	147	184	181
16-0	6	68	89	113	119
	6½	76	100	136	133
	7	86	112	150	150
	7½	94	122	164	164

The following applies to both Regular Weight and Lightweight Concrete Load Tables.

☐ No shoring ☐ 1 line of shoring

Concrete Volume in Cubic Yards per 100 Square Feet

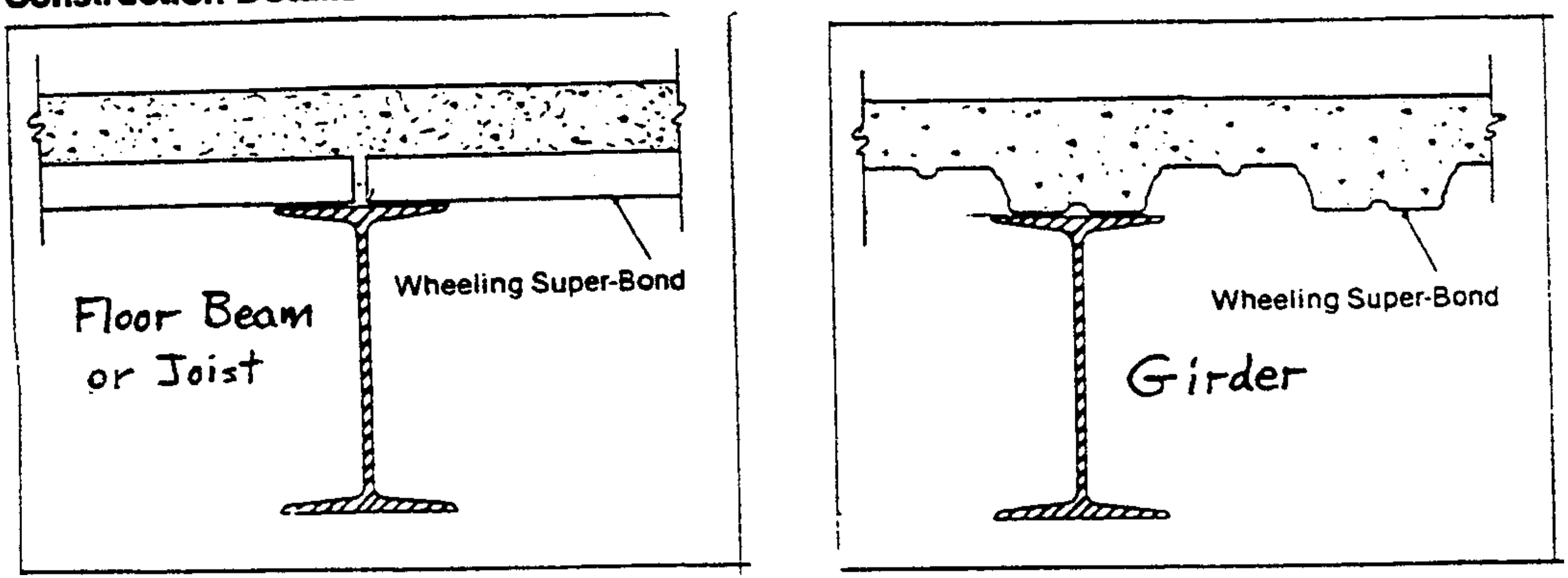
Fully Shored Condition	Concrete Cover above Deck Ribs (in.) 2	3	4	5
EC366	1.08	1.39	1.69	2.00
wt/ft², Reg. Conc. + deck	*46*	*58*	*70*	*82*

Notes:

1. All loads are assumed to be statically applied. For dynamically applied loads, consult Epic.
2. Superimposed loads for unshored spans (loads in white areas) are based on the use of floor units on 3 or more spans. *For single spans use approx. 90% of tab. load.*
3. Composite slab design is based on simple span analysis.
4. Deflection limit of the composite slab is ℓ/360 under the superimposed load.
5. Load tables are in accordance with SDI Recommendations.

Construction Details

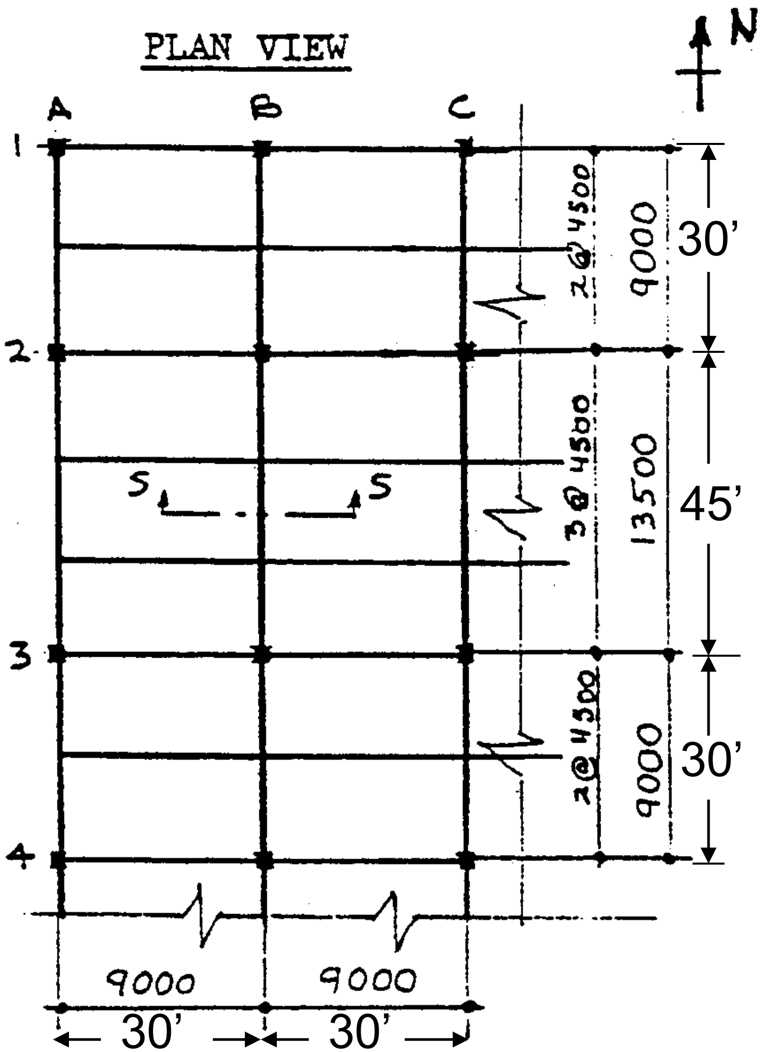
Construction Details

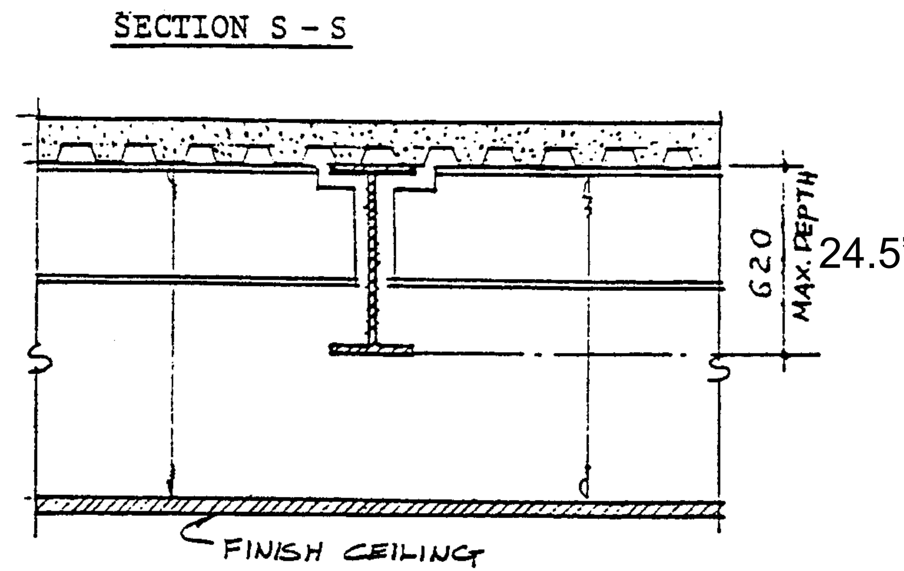


Design Example with Floor System

p. 33 notes

Design the floor system for an office building using the KBC minimum distributed live load for corridors (to allow flexibility of office space). The depth of the floor beams is limited to 24.5” to allow space for mechanical systems. Use EC366 steel decking and lightweight concrete without shoring.


PLAN VIEW
N
A
B
C
1
2
3
4
2@4500
9000
30'
3@4500
13500
45'
2@4500
9000
30'
S
S
9000
9000
30'
30'


SECTION S - S
620
MAX. DEPTH
24.5"
FINISH CEILING

KBC Minimum Distributed Live Loads

Table 1106
MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS

Occupancy or use	Live load (psf)[a]
Office buildings:	
Offices	50
Lobbies	100
Corridors, above first floor	80
File and computer rooms require heavier loads based upon anticipated occupancy	

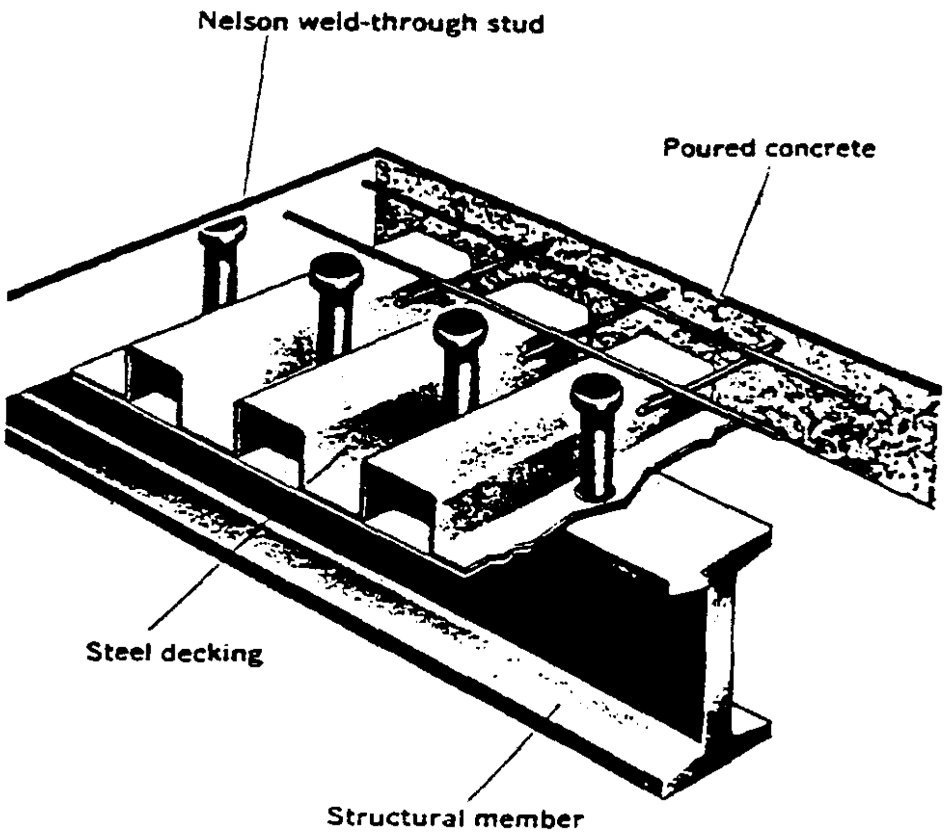
KBC Minimum Concentrated Load

Table 1107
MINIMUM CONCENTRATED LOADS ON 2½' × 2½'

Location	Pounds[a]
Elevator machine room grating (on area of 4 sq. in.)	300
Finish light floor plate construction (on area of 1 sq. in.)	200
Garages Varies by use	See Section 1107.1.1
Greenhouse roof bars, purlins and rafters	100
Hospitals and ward rooms	1,000
Libraries	1,000
Manufacturing and storage buildings	2,000
Mercantile areas	2,000
Office	2,000
Schools	1,000
Scuttles, skylight ribs and accessible ceilings	200
Sidewalks or vehicular driveways subject to trucking	8,000
Stair treads (on area of 4 sq. in. at center of tread)	300

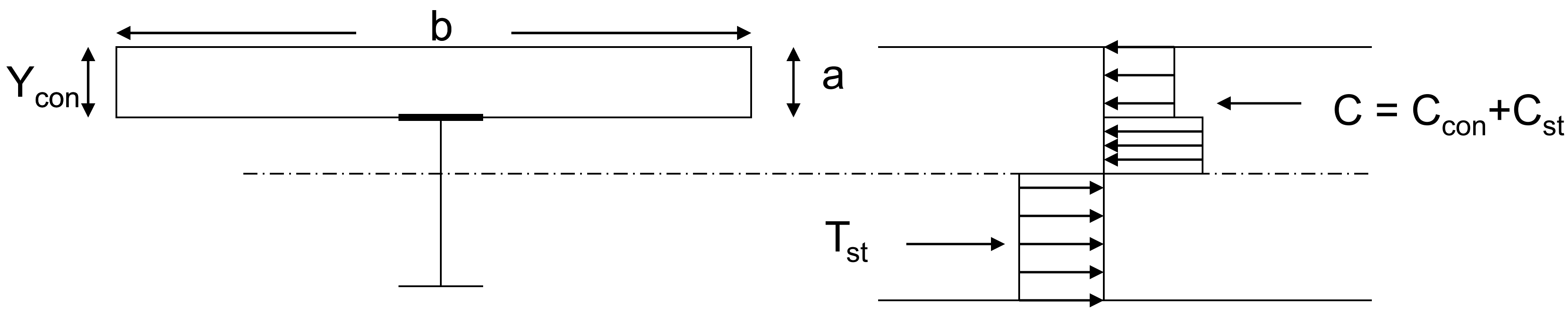
Composite Construction

- Detail of shear connectors



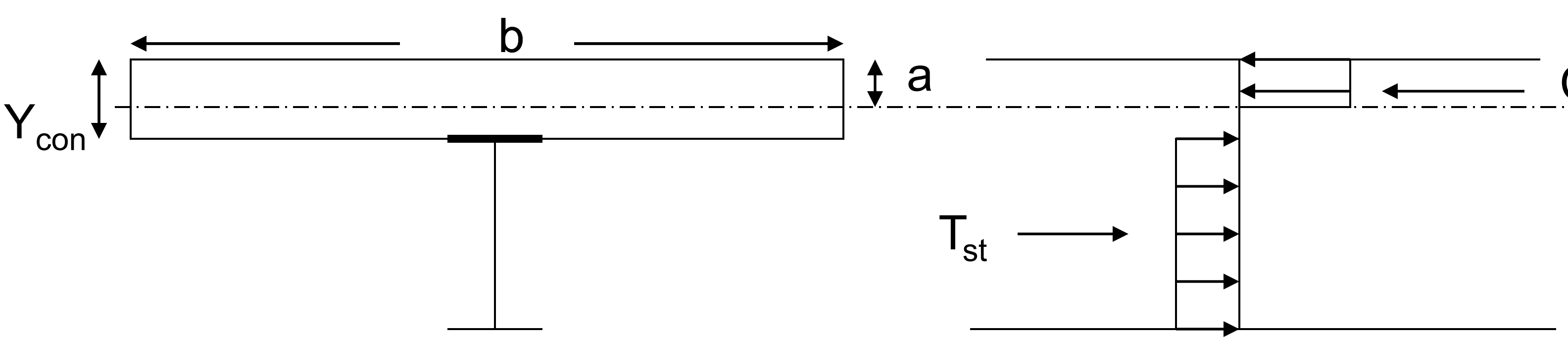
Composite Construction

PNA in steel



C=T

PNA in concrete



Composite Construction

$$C_{con} = 0.85f'_c ba$$

$$T = F_y A_s$$

C and T can not exceed force carried by studs, $\sum Q_n$

$$\sum Q_n = 0.85\, f'_c ba$$

$$a = \frac{\Sigma Q_n}{0.85 f'_c b}$$

Depth of compression block

Composite Construction p.5-33

- Y1 – Distance from PNA to beam top flange
- Y2 – Distance from concrete flange force to beam top flange
- b – effective width of concrete slab flange
- a – effective concrete flange thickness