Chapter 29

DESIGN II

29.1 Frames

29.1.1 Beam Column Connections

1 The connection between the beam and the column can be, Fig. 33.1:

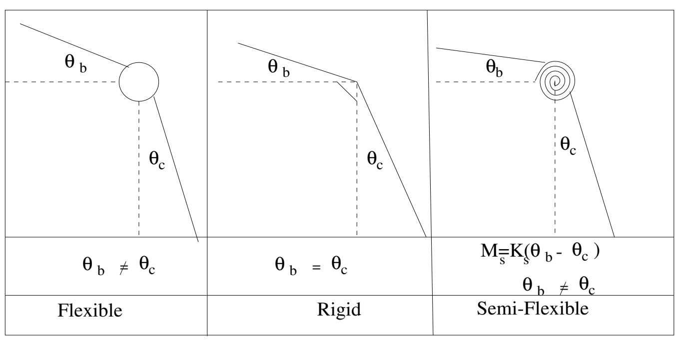

Figure 29.1: Flexible, Rigid, and Semi-Flexible Joints

Flexible that is a hinge which can transfer forces only. In this case we really have cantiliver action only. In a flexible connection the column and beam end moments are both equal to zero, $M_{\rm col} = M_{\rm beam} = 0$. The end rotation are not equal, $\theta_{\rm col} \neq \theta_{\rm beam}$.

Rigid: The connection is such that $\theta_{\rm beam} = \theta_{\rm col}$ and moment can be transmitted through the connection. In a rigid connection, the end moments and rotations are equal (unless there is an externally applied moment at the node), $M_{\rm col} = M_{\rm beam} \neq 0$, $\theta_{\rm col} = \theta_{\rm beam}$.

Semi-Rigid: The end moments are equal and not equal to zero, but the rotation are different. $\theta_{\rm beam} \neq \theta_{\rm col}$, $M_{\rm col} = M_{\rm beam} \neq 0$. Furthermore, the difference in rotation is resisted by the spring $M_{\rm spring} = K_{\rm spring}(\theta_{\rm col} - \theta_{\rm beam})$.

29.1.2 Behavior of Simple Frames

2 For vertical load across the beam rigid connection will reduce the maximum moment in the beam (at the expense of a negative moment at the ends which will in turn be transferred to

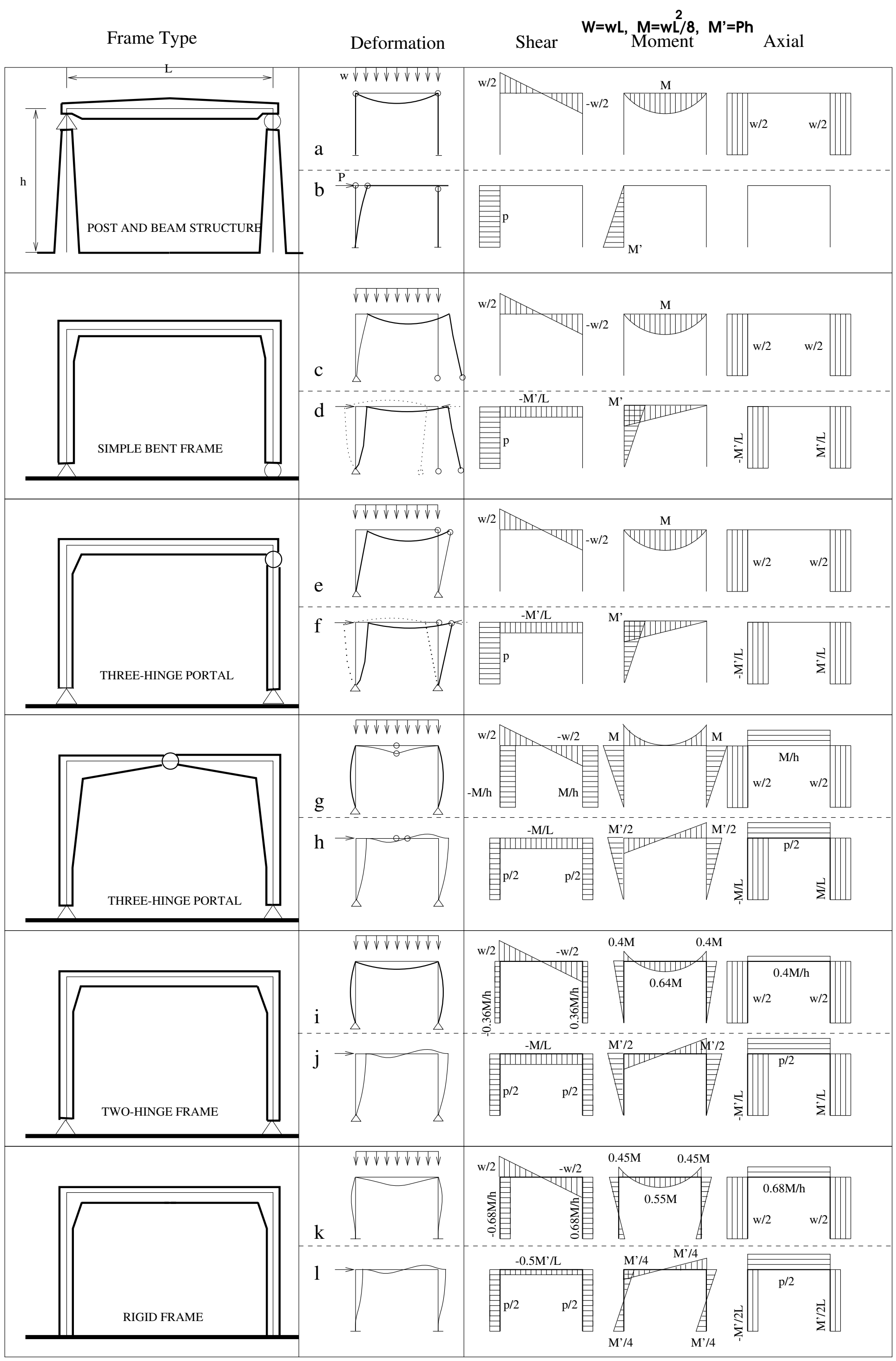

Figure 29.3: Deformation, Shear, Moment, and Axial Diagrams for Various Types of Portal Frames Subjected to Vertical and Horizontal Loads

29.1.4 Design of a Statically Indeterminate Arch

`Adapted from (Kinney 1957)`

Design a two-hinged, solid welded-steel arch rib for a hangar. The moment of inertia of the rib is to vary as necessary. The span, center to center of hinges, is to be 200 ft. Ribs are to be placed 35 ft center to center, with a rise of 35 ft. Roof deck, purlins and rib will be assumed to weight 25 lb/ft^2 on roof surface, and snow will be assumed at 40 lb/ft^2 of this surface. Twenty purlins will be equally spaced around the rib.

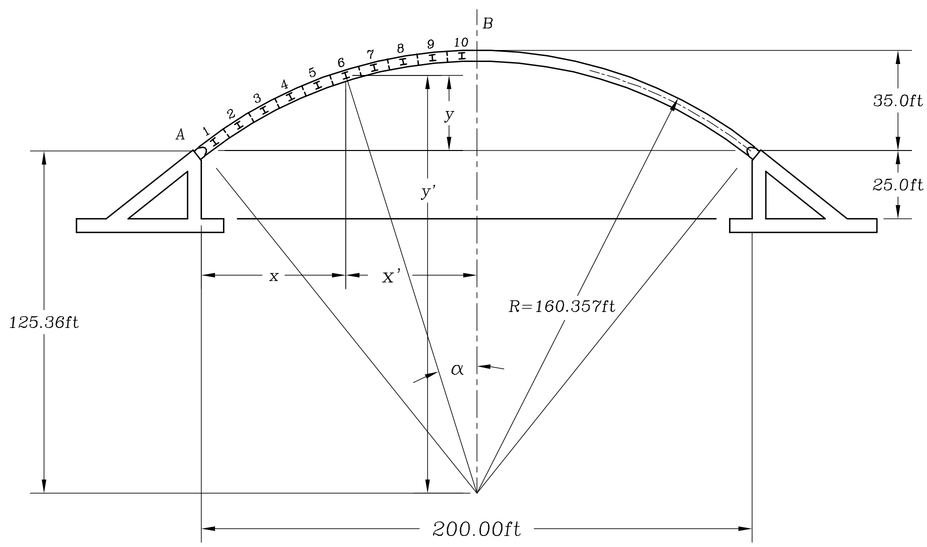

Figure 29.5: Design of a Statically Indeterminate Arch

1. The center line of the rib will be taken as the segment of a circle. By computation the radius of this circle is found to be 160.357 ft, and the length of the *arc AB* to be 107.984 ft.

2. For the analysis the arc AB will be considered to be divided into ten segments, each with a length of 10.798 ft. Thus a concentrated load is applied to the rib by the purlins framing at the center of each segment. (The numbered segments are indicated in Fig. **??**.

3. Since the total dead and snow load is 65 lb/ft^2 of roof surface, the value of each concentrated force will be

$$P = 10.798 \times 35 \times 65 = 24.565 \text{ k} \tag{29.8}$$

4. The computations necessary to evaluate the coodinates of the centers of the various segments, referred to the hinge at A, are shown in Table 29.1. Also shown are the values of Δx, the horizontal projection of the distance between the centers of the several segments.

5. If experience is lacking and the designing engineer is therefore at a loss as to the initial assumptions regarding the sectional variation along the rib, it is recommended that the

Segment	(2) x (ft)	(3) $y=\delta\overline{M}$ (ft · k)	(4) Shear to right (k)	(5) Δx (ft)	(6) M increment (ft · k)	(7) M simple beam (ft· k)	(8) $M\delta\overline{M}$	(9) $\delta\overline{M}M$
A	0.0	0.0	245.650					
1	4.275	3.29	221.085	4.275	1,050	1,050	3,500	10.9
2	13.149	9.44	196.520	8.874	1,962	3,010	28,400	89.2
3	22.416	14.98	171.955	9.267	1,821	4,830	72,400	224.4
4	32.034	19.88	147.390	9.618	1,654	6,490	129,100	395.4
5	41.960	24.13	122.825	9.926	1,463	7,950	191,800	582.2
6	52.149	27.69	98.260	10.189	1,251	9,200	254,800	767.0
7	62.557	30.57	73.695	10.408	1,023	10,220	312,400	934.4
8	73.134	32.73	49.130	10.577	779	11,000	360,000	1,071.4
9	83.831	34.18	24.565	10.697	526	11,530	394,100	1,168.4
10	94.601	34.91	0.000	10.770	265	11,790	411,600	1,218.6
Crown	100.00	35.00	____	5.399	0	11,790		
$\sum$							2,158,100	6,461.9

Table 29.2: Calculation of Horizontal Force

Segment	y (ft)	M simple beam (ft · k)	H_Ay (ft · k)	Total M at segment (ft · k)
A	0			
1	3.29	1,050	–1,100	–50
2	9.44	3,010	–3,150	–140
3	14.98	4,830	–5,000	–170
4	19.88	6,490	–6,640	–150
5	24.13	7,950	–8,060	–110
6	27.69	9,200	–9,250	–50
7	30.57	10,220	–10,210	+10
8	32.73	11,000	–10,930	+70
9	34.18	11,530	–11,420	+110
10	34.19	11,790	–11,660	+130
Crown	35.00	11,790	–11,690	+100

Table 29.3: Moment at the Centers of the Ribs

Segment	V (k)	V cos α	$-H$ sin α	$=$ S (k)	V sin α	$+H$ cos α	$=$ N (k)
A	245.6	192	-208	= -16	153	+ 261	= 414
1	221.1	177	-199	= -22	132	+268	= 400
2	196.5	165	-181	= -16	106	+281	= 387
3	172.0	150	-162	= -12	83	+292	= 375
4	147.4	133	-142	= -9	62	+303	= 365
5	122.8	114	-121	= -7	44	+311	= 355
6	98.3	94	-100	= -6	29	+319	= 348
7	73.7	72	-78	= -6	17	+325	= 342
8	49.1	48	-56	= -8	8	+329	= 337
9	24.6	244	-34	= -10	2	+332	= 334
10	0.0	0	-11	= -11	0	+334	= 334
Crown						+334	= 334

Table 29.4: Values of Normal and Shear Forces

3 to the crown is made to vary linerarly. The adequacies of the sections thus determined for the centers of the several segments are checked in Table 29.5.

17. It is necessary to recompute the value of H_A because the rib now has a varying moment of inertia. Equation 29.11 must be altered to include the I of each segment and is now written as

$$H_A = -\frac{\sum M\delta\overline{M}/I}{\sum \delta\overline{M}\overline{M}/I} \tag{29.14}$$

18. The revised value for H_A is easily determined as shown in Table 29.6. Note that the values in column (2) are found by dividing the values of $M\delta\overline{M}$ for the corresponding segments in column (8) of Table 29.2 by the total I for each segment as shown in Table 29.5. The values in column (3) of Table 29.6 are found in a similar manner from the values in column (9) of Table 29.2. The simple beam moments in column (5) of Table 29.6 are taken directly from column (7) of Table 29.2.

19. Thus the revised H_A is

$$H_A = -\frac{2\sum M\delta\overline{M}/I}{2\sum \delta\overline{M}\overline{M}/I} = -frac2 \times 1,010.852 \times 3.0192 = -334.81k \tag{29.15}$$

20. The revised values for the axial thrust N at the centers of the various segments are computed in Table 29.7.

21. The sections previously designed at the centers of the segments are checked for adequacy in Table 29.8. From this table it appears that all sections of the rib are satisfactory. This cannot be definitely concluded, however, until the secondary stresses caused by the deflection of the rib are investigated.

29.1.5 Temperature Changes in an Arch

`Adapted from (Kinney 1957)`

Determine the effects of rib shortening and temperature changes in the arch rib of Fig. 29.5. Consider a temperature drop of 100°F.