Fourth Panel

The load on the fourth panel, l_4, is similar to that on the second and third panels. Let these loads be P_4 and P_4'. Then

$$M_4 = \tfrac{1}{8}P_4l_4+0.128P_4'l_4 \quad \ldots\ldots (19)$$

in which

$$P_4 = \tfrac{1}{12}\times 0.434h_3l_4p$$

and

$$P_4' = \tfrac{1}{2}[(0.434h_3/12)+(0.434h_4/12)]l_4p$$

in which $h_4 = h_3+l_4\cos\alpha = 228+l_4\cos\alpha$.

Substituting the values of h_3 and h_4, we get

$$P_4 = \tfrac{1}{12}\times 0.434\times 228l_4p = 8.23l_4p \quad \ldots\ldots (20)$$

$$P_4' = \tfrac{1}{2}[(\tfrac{1}{12}\times 0.434\times 228)+(\tfrac{1}{12}\times 0.434)(228+l_4\cos\alpha)]l_4p$$
$$= \tfrac{1}{2}[8.23+0.0362(228+l_4\cos\alpha)]l_4p \quad \ldots\ldots (21)$$

The resisting moment, as before, is

$$M_{r4} = 4{,}170bd^2 \quad \ldots\ldots (22)$$

Substituting values of (20) and (21) in equation (19), we get

$$M_4 = (\tfrac{1}{8}\times 8.23l_4^2p)+(\tfrac{1}{2}\times 0.128l_4^2p)(8.23+8.23+0.0314l_4)$$

Reducing and substituting for p, we get

$$M_4 = 1.29l_4^2+1.317l_4^2+0.00252l_4^3$$
$$= 2.607l_4^2+0.00252l_4^3 \quad \ldots\ldots (23)$$

Equating (22) and (23), we get

$$2.607l_4^2+0.00252l_4^3 = 4{,}170bd^2 = 6{,}660.$$

Solving for l_4 by trial, we get

$$l_4 = 49 \text{ ins.}$$

and

$$h_4 = h_3+l_4\cos\alpha$$
$$= 228+(49\times 0.866) = 270.5 \text{ ins.}$$

In this way the length of panels between supports can be determined for any spacing of bars and any size bar. The accompaning Table No. 1, gives these lengths for bars ¼ in. by 2 ins. to ¼ in. by 4 ins. and spacing of 1¼ ins. to 3 ins. inclusive.

If it be desired to use a bar thicker than ¼ in., the length of first panel can be obtained from the table as follows:—

Cube the length, l, corresponding to a bar of the same height, d, and spacing p, and multiply by the width of bar to be used. Then divide by the width of bar in table (¼ in.). Extract the cube root of this result, and this will be the desired length, l_1. See equation (8).

By examining equation (13a), it will be seen that the second term of the left hand member is of small value, and the first term is the controlling factor, and we can therefore say that the length varies as the square root and not as the cube root, with no appreciable error. We can therefore say that the length of all panels after the first vary as the square root of the resisting moment of the bar. As this moment is directly proportional to the thickness of the bar, the values of l_2, l_3, etc., can likewise be taken from the table by squaring the length given in table for a bar of the same height and spacing, and multiplying this result by the desired thickness, and dividing by the thickness used in the table (¼ in.), then extracting the square root and using the values of l_2, l_3, etc., so obtained.

For example, say it is desired to use a bar ⅜ in. by 3½ ins. instead of ¼ in. by 3½ ins., and a spacing of 2 ins. Then l_1 from table = 147 ins. Let l_1' = the desired length for ⅜ in. by 3½ ins. bar. Then

$$l_1' = (l_1^3\times 0.375/0.25)^{1/3}$$
$$= l_1(0.375/0.25)^{1/3}$$
$$= 147\times 1.145 = 168 \text{ ins.}$$

Let l_2' = second panel length. From table, l_2 = 69 ins. Therefore

$$l_2' = (l_2^2 0.375/0.25)^{1/2}$$
$$= l_2(0.375/0.25)^{1/2}$$
$$= 69\times 1.225 = 84.5 \text{ ins.}$$

Let l_3' = third panel length. From table, l_3 = 57.5 ins. Therefore

$$l_3' = (l_3^2\times 0.375/0.25)^{1/2}$$
$$= l_3(0.375/0.25)^{1/2}$$
$$= 57.5\times 1.225 = 70 \text{ ins.}$$

Let l_4' = fourth panel length. From table, l_4 = 51.5 ins. Therefore

$$l_4' = (l_4^2\times 0.375/0.25)^{1/2}$$
$$= l_4(0.375/0.25)^{1/2}$$
$$= 51.5\times 1.225 = 63 \text{ ins.}$$

Of course this is only true when the angle of the rack bar is 30 degs. from the perpendicular. For any other angle, the panel lengths should be determined from the foregoing equations by substituting the proper value for $\cos\alpha$.

The values here given in Table 1 will be safe for the worst conditions imaginable, because the stress used is inside the elastic limit of steel. If the designer wishes to use a different stress, he need only multiply l_1, from the table, by the cube root of the quotient, stress (S) divided by 25,000; that is, multiply l_1, from the table, by $(S/25{,}000)^{1/3}$ for the first panel length, and by $(S/25{,}000)^{1/2}$ for l_2, l_3, etc.

TABLE 1

Back Bar (Inches)	Resisting Moment*	Spacing of Bars (Inches)	l_1	l_2	l_3	l_4	h_1	h_2	h_3	h_4
¼x2	4,170	1¼	118	58	48	42	102	152.5	194	230
¼x2½	6,660	1¼	135.5	67	56	49	117.4	174	228	270
¼x3	9,350	1¼	155	77	64	56	134	201	256	304
¼x3½	12,750	1¼	172	86	71	62	149	247	308	361
¼x4	16,650	1¼	188	94	78	68	163	245	312	371
¼x2	4,170	1½	111.5	55	45	39.5	96.5	144	183	217
¼x2½	6,660	1½	130	65	54	47	113	169	216	257
¼x3	9,350	1½	146	73	60.5	53	127	190	242	288
¼x3½	12,750	1½	161.5	81	67	59	140	210	268	319
¼x4	16,650	1½	176.5	88	73	64	153	229	292	347
¼x2	4,170	1¾	106	52	43	37	92	137	174	206
¼x2½	6,660	1¾	123	61	51	45	107	160	204	243
¼x3	9,350	1¾	138.5	69	57.5	50	120	180	230	273
¼x3½	12,750	1¾	153.5	76	63.5	55	133	199	254	301
¼x4	16,650	1¾	168	83	69	60	145.5	217	277	329
¼x2	4,170	2	103	48	40	36	89	131	166	197
¼x2½	6,660	2	118	56	47	43	102	150	191	228
¼x3	9,350	2	133	62.5	52	47	115	169	214	255
¼x3½	12,750	2	147	69	57.5	51.5	127	187	237	282
¼x4	16,650	2	160	75	62.5	56	139	204	258	306
¼x2	4,170	2¼	97.5	46	39	35	84	124	158	188
¼x2½	6,660	2¼	114	54	46	41	99	146	186	221
¼x3	9,350	2¼	127	60	51	46	111	163	207	247
¼x3½	12,750	2¼	141	66.5	56	50	122	179	227	270
¼x4	16,650	2¼	154.5	73	62	55	134	197	250	297
¼x2	4,170	2½	94	44.5	38	34	81.5	120	153	182
¼x2½	6,660	2½	110	52	44	39	95.5	140.5	178.5	212
¼x3	9,350	2½	123	58	49.5	44	106.5	156.5	199.5	237
¼x3½	12,750	2½	136	64.5	55	49	118	174	221.5	264
¼x4	16,650	2½	149	70.5	60	53.5	129	190	242	288
¼x2	4,170	2¾	91	43	37	33	79	116	148	177
¼x2½	6,660	2¾	106	50	43	38	92	135	172	205
¼x3	9,350	2¾	119	56	48	43	103	151.5	193	230
¼x3½	12,750	2¾	133	63	54	48	115	169.5	216	257
¼x4	16,650	2¾	144	68	58.5	52	125	184	234.5	279
¼x2	4,170	3	88.5	42	36	32	76.5	113	144	172
¼x2½	6,660	3	104	49.5	42.5	38	90	133	170	203
¼x3	9,350	3	116	55	47	42	100.5	148	188.5	225
¼x3½	12,750	3	128.5	61	52	46	111	164	209	249
¼x4	16,650	3	140	66.5	57	50	121	178.5	228	271

$^*M = \tfrac{1}{6}\times bd^2\times 25{,}000.$

Construction of Panels

The bars are usually held together by through bolts, with sections of wrought-iron pipe of proper length strung between the bars, as shown in Fig. 3. The through bolt is placed back of the centre line of the bar so that the cleaning rake will not catch so readily.

The nuts on the bolts should not project outside the panel but should be guarded by a bar which is riveted at both ends. If this is done, the rack panels can be easily withdrawn and replaced.

The lower end of the rack bars can rest in an angle iron embedded in the concrete, and the upper end should be anchored by means of a hook engaging the spacing bars.

Supporting Structure

There are various methods for supporting the bars, depending on the construction of the adjacent building. If dividing walls can be placed at frequent intervals so as not to make too great a spacing, then I-beams can be embedded in these to support the racks. Such an arrangement is