5.5 SECTION PROPERTIES OF GRILLAGE MEMBERS

This section summarizes the findings of the preceding section and demonstrates calculated examples of grillage section properties for three different decks. The notation for the dimensions of the cells, slabs and webs is defined in Fig. 5.14(a).

5.5.1 Grillage for three-span twin-cell box-girder deck

Figure 5.20 gives details of a three-span twin-cell box-girder with supports at 21° skew. The grillage mesh is chosen with three 'structural' longitudinal members 2, 3 and 4 coincident with the webs. Two 'nominal' members 1 and 5 are located along the edges of the cantilevers. Transverse members representing the top and bottom slabs are orthogonal to the longitudinal members. Along the spans their spacing is approximately one quarter of the distance between points of contraflexure, but over the intermediate supports the spacing is shorter to give greater detail near peaks in the bending moment diagrams. At

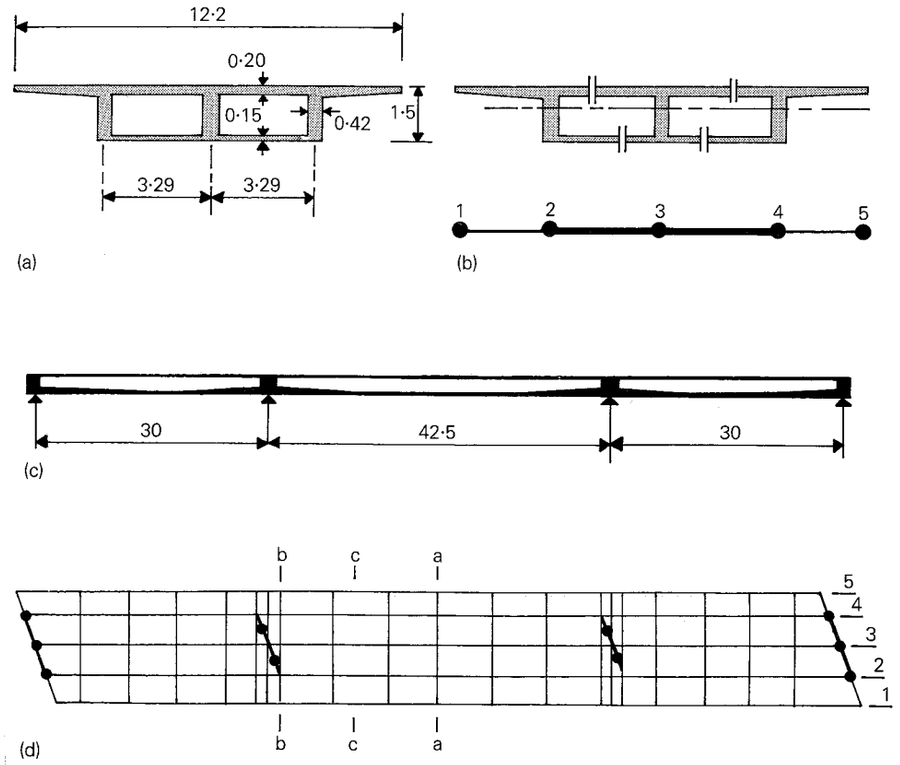

Fig. 5.20 Grillage for three span twin-cell concrete box-girder deck: (a) deck section; (b) grillage section; (c) deck longitudinal section; and (d) grillage mesh.

the ends the skew members represent the slabs and the diaphragm, while at the internal supports the skew member represents just the solid diaphragm without flanges.

The 'structural' longitudinal members 2, 3 and 4 have the moments of inertia of the 'I-beams' obtained by cutting the deck as in Fig. 5.20(b) so that the centroid of each 'I-beam' is on the principal axis of the deck. In this case each beam includes one third of the top slab and one third of the bottom slab. The moment of inertia of each is one third of the total moment of inertia of the deck

$$I_2 = I_3 = I_4 = \frac{1.54}{3} = 0.51\,\mathrm{m}^4.$$

The above calculation has ignored the reduction of effective flange widths of the sections due to shear lag. This is significant in this deck, particularly near the intermediate supports, and a simple correction described in Section 8.2 is strictly necessary.

The torsion constant per unit width is given by equation (5.5)

$$c = \frac{2h^2 d' d''}{(d' + d'')} \text{ per unit width}$$

$$c = \frac{2 \times 1.325^2 \times 0.2 \times 0.15}{(0.2 + 0.15)} = 0.30\,\mathrm{m}^4\,\mathrm{m}^{-1}.$$

The widths of cell in members 2, 3 and 4 are 3.29/2, 3.29 and 3.29/2, respectively. Hence their torsion constants are

$$C_2 = C_4 = \frac{3.29}{2} \times 0.30 = 0.49\,\mathrm{m}^4 \qquad C_3 = 3.29 \times 0.30 = 0.99\,\mathrm{m}^4.$$

The shear areas of members 2, 3 and 4 are equal to the areas of the webs:

$$A_{S2} = A_{S3} = A_{S4} = 0.42 \times 1.325 = 0.56\ \mathrm{m}^2.$$

Near each support the bottom slab of the deck is thickened. In these regions, the properties of each grillage member are calculated in the same manner as above for the section midway along its length.

The 'nominal' edge members have the section properties of half the cantilever

$$I_1 = I_5 = \frac{bd'^3}{12} = \frac{2.81}{2} \times \frac{0.2^3}{12} = 0.000\,94\,\mathrm{m}^4$$

$$C_1 = C_5 = \frac{bd'^3}{6} = \frac{2.81}{2} \times \frac{0.2^3}{6} = 0.0019\,\mathrm{m}^4$$

$$A_{S1} = A_{S5} = bd' = \frac{2.81}{2} \times 0.2 = 0.28\,\mathrm{m}^2.$$

The transverse members representing cells have section properties given by equations (5.4), (5.5) and (5.8):

$$i_{23} = \frac{h^2 d' d''}{(d' + d'')} \text{ per unit width}$$

$$= \frac{1.325^2 \times 0.2 \times 0.15}{(0.2 + 0.15)} = 0.15\,\text{m}^4\,\text{m}^{-1} \quad \text{From equation (5.4)}$$

$$c_{23} = \frac{2h^2 d' d''}{(d' + d'')} \text{ per unit width}$$

$$= 2 \times 0.15 = 0.30\,\text{m}^4\,\text{m}^{-1} \quad \text{From equation (5.5)}$$

$$a_{S23} = \frac{(d'^3 + d''^3)}{l^2}\left[\frac{d_w^3 l}{d_w^3 l + (d'^3 + d''^3)h}\right]\frac{E}{G} \text{ per unit width}$$

$$= \frac{(0.2^3 + 0.15^3)}{3.29^2}\left[\frac{0.42^3 \times 3.29}{0.42^3 \times 3.29 + (0.2^3 + 0.15^3)1.325}\right]2.3$$

$$= 0.0024\,\text{m}^2\,\text{m}^{-1}.$$

Transverse members on the cantilever have the properties of the top slab

$$i_{12} = \frac{d^3}{12} \text{ per unit width} = \frac{0.2^3}{12} = 0.000\,67\,\text{m}^4\,\text{m}^{-1}$$

$$c_{12} = \frac{d^3}{6} \text{ per unit width} = \frac{0.2^3}{6} = 0.001\,34\,\text{m}^4\,\text{m}^{-1}$$

$$a_{S12} = d \text{ per unit width} = 0.2\,\text{m}^2\,\text{m}^{-1}.$$

The skew members representing the internal diaphragm (here 1.5 m wide) have the properties of the solid section. For derivation of the torsion constant see Section 2.4.2.

$$I = \frac{1.5 \times 1.325^3}{12} = 0.29\,\text{m}^4$$

$$C = \frac{3 \times 1.5^3 \times 1.325^3}{10(1.5^2 + 1.325^2)} = 0.59\,\text{m}^4$$

$$A_S = 1.5 \times 1.325 = 2.0\,\text{m}^2.$$

5.5.2 Grillage for wide multicellular deck

Figure 5.21 gives details of a three-span multicellular deck at high skew angle. The section properties of the grillage members are derived as in the preceding example except that it is inconvenient to split the deck up into beams with individual centroids precisely on the principal axis of the deck. Consequently, the deck is notionally cut midway between webs as shown in (b). The centroids of internal 'structural' members 3, 4, etc. are virtually coincident with the principal axis of the deck. Edge 'structural' member 2 has its centroid at a higher level but, like the other members, its grillage moment of inertia is calculated about the principal axis of the deck.

5.5.3 Grillage for cellular deck with inclined webs

Figure 5.22 gives details of part of a multispan four-cell deck with inclined edge webs and haunches at the supports. It is impracticable to split up the deck into longitudinal members with centroids on the principal axis of the deck, hence the deck is notionally cut as in (a) into five 'structural' members with inertias calculated about the principal axis of the deck. There are no 'nominal' edge members in order to permit economy in the size of the grillage.

There is no clear-cut equivalence of grillage torsion stiffness for the non-rectangular cells. However, sensible results are obtained if equation (5.6) is used with h equal to the average height of the cell.

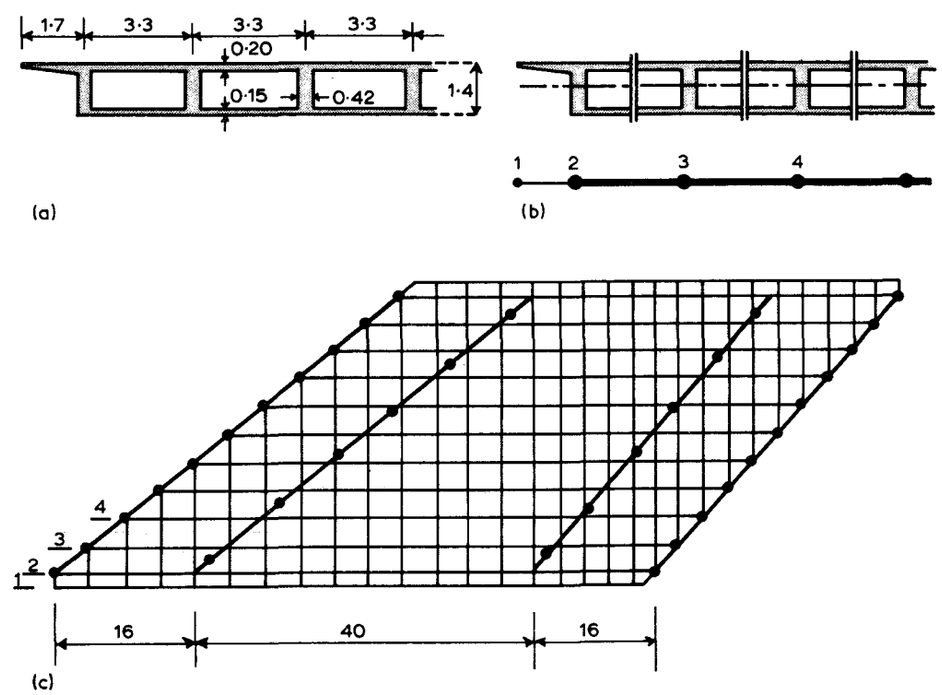

Fig. 5.21 Grillage for three-span high-skew multicell concrete deck: (a) part deck section; (b) grillage section; and (c) grillage mesh.