rib shortening, the live load being too small to materially change the stress ratios or increase the fibre stresses. Stresses were computed at the critical points along the ring and a tabulated comparison given in Table I.

A study of the table, together with the stress sheets of Fig. 1, will reveal the following significant facts:—

(1) Arch ring "B" contains about 21 per cent. more material than arch ring "A," thus increasing the cost for materials and for mixing and placing of concrete in about that ratio.

(2) Notwithstanding the above increase in material the average compression in arch ring "B" is about 11½ per cent. and the average tension about 90 per cent. in excess of the corresponding values in arch ring "A" for the same loadings.

(3) The deflection under dead load stress at the crown is .0468 in. for arch ring "A" and .037 in. for arch ring "B." Both these movements being comparatively small, the increased rigidity of arch ring "B" is but a small advantage.

(4) The abutment toe pressure for arch ring "B" is 14 per cent. in excess of that for arch ring "A" due to the greater value and less inclination of thrust at the springing lines.

$$\left[\int_0^{\frac{Z}{2}} Y \frac{ds}{I}\right] \div \left[\int_0^{\frac{Z}{2}} \frac{ds}{I}\right] \text{ where}$$

"ds" is an infinitesimal increment of axis length, "I" the moment of inertia at any point, and "y" the ordinate to the same measured from a straight horizontal line through the crown.

It is thus seen that the comparison, both as regards cost and stress condition, is favorable to arch ring "A" wherein the depth of section is not materially increased for the central half of the span. It will be noted that the equilibrium polygon for temperature is a straight horizontal line whose distance below the crown is a fixed quantity for a given arch.[1] Obviously, then, the temperature stress will decrease from crown towards spring line, passing through a zero value at the intersection of the equilibrium polygon with the arch axis and assuming its original or crown value (with opposite sign) at a point symmetrical with the crown with reference to the equilibrium polygon as an axis of symmetry. This latter point may be termed the "equivalent crown point for temperature stress." It is thus apparent that as a provision against temperature no increase in section is needed between the true and equivalent crown points.

Inasmuch as the equilibrium polygon can, by a proper selection of the central portion of the ring, be made to follow the arch axis between these two points, the dead load bending stress may be practically eliminated. The only remaining loading to be taken care of is the live and it can easily be shown that for highway loadings the increase in live load moments between the true and equivalent crown points is so small as to be negligible.

Based not only upon the example given herewith, but also upon the results of a large number of arch rings analyzed in the offices of the Iowa State Highway Commission, we are warranted in the conclusion that—

The economical section for short-span highway arch structures of which the span under discussion is typical is obtained when the axial curve is so chosen that the equilibrium polygon for dead loading is practically coincident therewith and when the depth of section between the true and equivalent temperature crown point as defined above is not materially increased.

[1]Note.—This distance, as can easily be shown mathematically, is dependent upon the elastic properties of the ring, and is measured by the quantity.

Table I.—Comparative Stress Values in Arch Rings A and B.

Section.	Loading.	Moment		Thrust		*Tension in reinforcing steel.		*Compression in concrete.	
		Ring A.	Ring B.	Ring A.	Ring B.	Ring A.	Ring B.	Ring A.	Ring B.
Crown	Dead load	— 2,826	— 2,416	24,000	25,370				
	Temperature rise	— 5,540	— 8,108	3,600	8,123				
	Rib shortening	+ 1,385	+ 1,824	— 900	— 1,828				
	Total	— 6,981	— 8,700	26,700	31,665	785	1,300	418	521
Section 10	Dead load	+ 2,436	+ 3,496	25,500	26,220				
	Temperature rise	+ 6,260	+ 9,292	3,400	7,900				
	Rib shortening	— 1,565	— 2,095	— 850	— 1,782				
	Total	+ 7,125	+ 10,693	28,050	32,338	112	401	373	371
Section A.A. and Section B. B. (see Fig. 1)	Dead load	+ 560	+ 2,796	25,500	26,200				
	Temperature drop	— 7,710	—12,616	— 3,340	— 7,820				
	Rib shortening	— 1,927	— 2,840	— 835	— 1,760				
	Total	— 9,078	—12,660	21,325	16,640	2,750	6,070	396	386
Point 11	Dead load	— 4,711	— 2,476	27,750	27,650				
	Temperature drop	—13,080	—29,292	— 3,270	— 7,560				
	Rib shortening	— 3,270	— 6,590	— 818	— 1,700				
	Total	—21,061	—38,358	23,662	18,390	9,050	23,000	506	655
Spring line	Dead load	—23,961	—30,454	29,500	30,900				
	Temperature drop	—21,060	—49,172	— 3,240	— 7,460				
	Rib shortening	— 5,265	—11,080	— 810	— 1,680				
	Total	—50,286	—90,706	25,450	21,760	19,860	31,000	603	631

*The stresses in the material were figured on the basis of a "cracked section"—that is, the steel assumed to take the entire tensile stress. In reality such a cracked condition would alter the position of the neutral axis and therefore the pressure curve. However, for our present purpose this method gives a very good indication of the actual comparative stress conditions.