THE DESIGN OF A REINFORCED CONCRETE ABUTMENT.

Application of Theoretical Formulæ to Practical Design.

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THE general dimensions for the abutment shown in detail in Fig. 1, as designed for general use, are from the set of standard abutments of the Board of Highway Commissioners for the Province of Saskatchewan. The distance from bottom of footing to grade level is taken as 24 feet. The spans allowed for are truss spans up to and including 175 feet. The bottom chords of the standard Petit truss bridges are 17 feet 6 inches centre to centre. The width and depth of bridge seat are constant and the wing wall of the abutments slope back at an angle of 30 degrees with the face wall and decrease in height at a 1½ to 1 slope.

The dead load for a 175-foot Petit truss span consists of steel, 1,250 lbs. per lineal foot, while the live load is assumed as 100 lbs. per square foot of floor, (16 feet wide), and a 25-ton traction engine, with two-thirds of its weight assumed to act on rear wheels, which are 30 inches wide and 8 feet centres; axles being 10 feet centres.

This abutment was designed by the aid of general usages and empirical formulæ, and it is the purpose of this article to investigate the design from the standpoint of theoretical formulæ.

Foundations.—When rock foundations are unattainable on account of the great depth of soil, piles are driven to increase the bearing capacity of the foundations. If the nature of the soil is accurately known, the number of piles required can usually be determined before the excavations are made. As a guide in determining the necessary increase in bearing capacity of a certain soil, or the allowable stress on foundations of other materials, Baker's and Rankine's tables of crushing strengths for various materials likely to be used as foundation beds for abutments are of great service.

It is the custom of the Board of Highway Commissioners for the Province of Saskatchewan to carry the excavation to such a depth that the top of the piles shall be below low-water level. This condition is not required in the case of concrete piles, but the equipment required in driving is more elaborate, and is usually not included in the plant of contractors doing this class of work, hence wooden piles of 25 feet in length with a minimum diameter at the tip of 6 inches, are always used under normal conditions. These piles are placed principally under the main buttresses, centre of wing walls, and toe of footings, and vary from three feet to five feet centres, according to the requirements of the specific case considered. Spacing is left largely to the judgment of the resident engineer.

Design.—The base is approximately one-half the height. Two buttresses support the bridge seat, and are placed directly beneath the centres of bearing of the bottom chords of the truss. A face wall connects these buttresses, which resists the lateral earth pressures transmitted through the earth. The face wall is continued forming the wing walls. The buttresses and the face wall rest on a continuous base which resists the earth pressures. At the back of the bridge seat is a parapet wall supported by the bridge seat, which runs into the wing walls and simply serves as a retaining wall to protect the bridge seat.

Parapet Wall.—This wall is designed as a cantilever beam connected by continuous reinforcement to the bridge seat. Its height is 2 feet 6 inches. We shall consider a strip one foot wide, assuming that the line of cleavage of material behind the wall is at a slope of 30 degrees to the horizontal, or that ϕ equals 30 degrees. Hence Rankine's formula for resultant earth pressure becomes,

$$P = \frac{w.\ h.^2}{6}, \text{ where } h = 2.5, \text{ and } w = 100 \text{ lbs.; and}$$

therefore, P = 104 lbs.

For live load pressure we will assume the worst possible case of loading, i.e., when rear wheels of 25-ton traction engine are just off the bridge. This live load of 33,000 lbs. we shall assume to be distributed on 6 linear feet of roadway. Therefore, the load per lin. foot of

$$\text{roadway equals } \frac{33,000}{6} \text{ equals } 5,500 \text{ lbs.}$$

This live load of 5,500 lbs. per lin. foot of roadway is assumed to be distributed over a distance equal to the out to out dimension of the rear wheels which is 10.5 feet, therefore, the vertical pressure due to live load equals

$$\frac{5,500}{10.5} \text{ equals } 525 \text{ lbs. per square foot.}$$

$$\text{Horizontal pressure equals } \frac{525}{3} \text{ equals } 175 \text{ lbs. per}$$

square foot. Bending moment of resultant earth pressure assumed to act at lower third equals

$$w.\ l. = 104 \times 10 = 1,040 \text{ in. pds.}$$

Bending moment of uniformly distributed live load of 175 lbs. per square inch equals

$$\frac{w.\ l.}{2} = \frac{175 \times 2.5 \times 30}{2} = 6,575 \text{ in. pds.}$$

Total moment = 1,040 + 6,575 = 7,615 in. pds.
Hence, from theory of beam, 108 b. $d.^2$ = 7,615; and d = 2.4 inches.

In order to secure against impact, and to protect the steel, this beam is made 6 inches thick.

Amount of steel required = 12 × 2.4 × .008 = .22 square inches per foot of wall. Use ¾-in. rods, (area = .44 sq. ins.) spaced 2 feet centre to centre. Also to resist cross bending, horizontal rods ¾-in. diameter and 15-in. centres are used.

Face Wall.—The face wall is designed as a horizontal beam supported by the buttresses. As buttresses are 17 ft. 6 in. centres, and assumed 4 feet wide, we have a clear span of 13 ft. 6 in. Consider a strip one foot wide at base of face wall, assuming the thickness of footing to be 1 ft. 6 in., the depth of fill at centre of strip equals

$$22 \text{ feet. Hence, } p = \frac{w.\ h.}{3} = \frac{100 \times 22}{3} = 733 \text{ lbs per}$$

square foot.

The live load stresses are assumed to have become dissipated in the embankment before reaching this depth. Hence bending moment equals

$$\frac{w.\ l.}{10} = \frac{(733 \times 13.5) \times (13.5 \times 12)}{10} = 160,000 \text{ in. pds.}$$

Therefore, 108 b. $d.^2$ = 160,000, from which d = 11.2 ins. Similarly we shall examine a strip one foot wide at depth

$$\text{of } 15 \text{ feet. } p = \frac{w.\ h.}{3} = \frac{100 \times 15}{3} = 500 \text{ lbs. per sq. ft.}$$