4.15 and 4.16 using a 180,000 pound dual tandem wheel assembly, 190 pounds per square inch tire pressure, 26-inch spacing between dual tires, 66-inch spacing between tandem axles, k value of 300 pounds per cubic inch, 12-inch, thick concrete pavement and an R_s, value of 37.44 inches. Subgrade and subbase support for a rigid pavement is evaluated in terms of k, the modulus of subgrade reaction. A k value of 300 pounds per cubic inch was used, since this value represents a desirable subgrade or subbase material. In addition, because of the interaction between the pavement and subgrade, a lower value of k (representing reduced subgrade support) results in less load on the pipe.

Although Tables 53 through 55 are for specific values of aircraft weights and landing gear configuration, the tables can be used with sufficient accuracy for all heavy commercial aircraft currently in operation. Investigation of the design loads of future jets indicates that although the total loads will greatly exceed present aircraft loads, the distribution of such loads over a greater number of landing gears and wheels will not impose loads on underground conduits greater than by commercial aircraft currently in operation. For lighter aircrafts and/or different rigid pavement thicknesses, it is necessary to calculate loads as illustrated in Example 4.10.

Flexible Pavement. AASHTO considers flexible pavement as an unpaved surface and therefore live load distributions may be calculated as if the load were bearing on soil. Cover depths are measured from the top of the flexible pavement.

Railroads. In determining the live load transmitted to a pipe installed under railroad tracks, the weight on the locomotive driver axles plus the weight of the track structure, including ballast, is considered to be uniformly distributed over an area equal to the length occupied by the drivers multiplied by the length of ties.

The American Railway Engineering and Maintenance of Way Association (AREMA) recommends a Cooper E80 loading with axle loads and axle spacing as shown in Illustration 4.19. Based on a uniform load distribution at the bottom of the ties and through the soil mass, the live load transmitted to a pipe underground is computed by the equation:

$$W_L = Cp_oB_cI_f \tag{4.17}$$

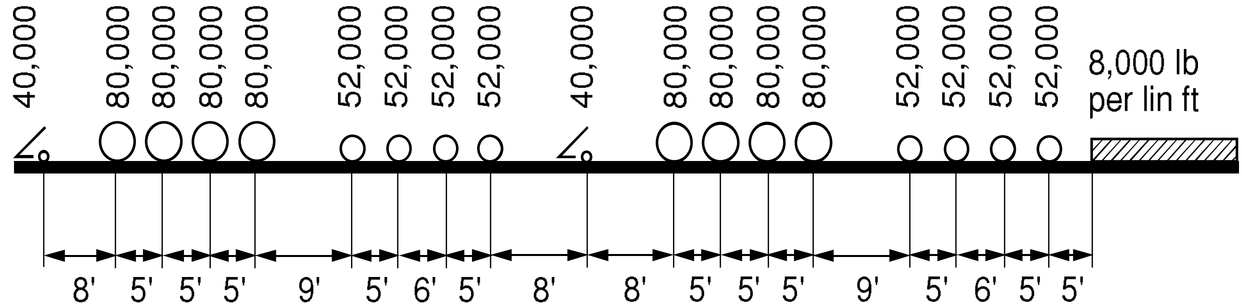
where:

C = load coefficient
p_o = tire pressure, pounds per square foot
B_c = outside span of the pipe, feet
I_f = impact factor

Tables 56 through 58 present live loads in pounds per linear foot based on equation (4.17) with a Cooper E80 design loading, track structure weighing 200 pounds per linear foot and the locomotive load uniformly distributed over an area 8 feet X 20 feet yielding a uniform live load of 2025 pounds per square foot. In accordance with the AREMA “Manual of Recommended Practice” an impact factor of 1.4 at zero cover decreasing to 1.0 at ten feet of cover is included in the Tables.

Illustration 4.20 Cooper E 80 Wheel Loads and Axel Spacing

Based on a uniform load distribution at the bottom of the ties and through the



3 Op. cit., p. 28

4 Equation (21) is recommended by WPCF-ASCE Manual, The Design and Construction of Sanitary Storm Sewers.

soil mass, the design track unit load, W_L, in pounds per square foot, is determined from the AREMA graph presented in Figure 215. To obtain the live load transmitted to the pipe in pounds per linear foot, it is necessary to multiply the unit load, W_L, from Figure 215, by the outside span, B_c, of the pipe in feet.

Loadings on a pipe within a casing pipe shall be taken as the full dead load, plus live load, plus impact load without consideration of the presence of the casing pipe, unless the casing pipe is fully protected from corrosion.

Culvert or sewer pipe within the railway right-of-way, but not under the track structure, should be analyzed for the effect of live loads because of the possibility of train derailment.

Construction Loads. During grading operations it may be necessary for heavy construction equipment to travel over an installed pipe. Unless adequate protection is provided, the pipe may be subjected to load concentrations in excess of the design loads. Before heavy construction equipment is permitted to cross over a pipe, a temporary earth fill should be constructed to an elevation at least 3 feet over the top of the pipe. The fill should be of sufficient width to prevent possible lateral displacement of the pipe.

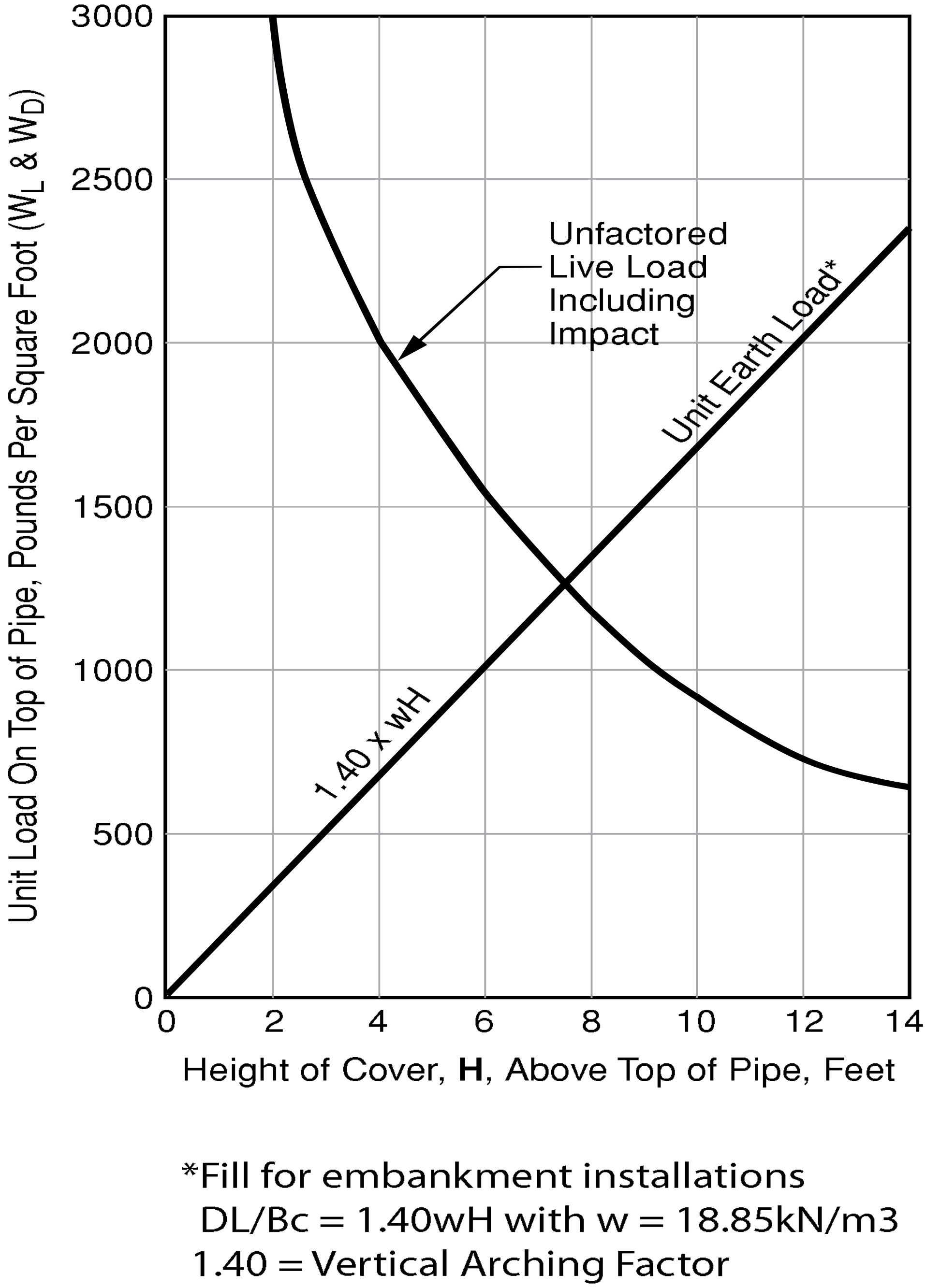
SELECTION OF BEDDING

A bedding is provided to distribute the vertical reaction around the lower exterior surface of the pipe and reduce stress concentrations within the pipe wall. The load that a concrete pipe will support depends on the width of the bedding contact area and the quality of the contact between the pipe and bedding. An important consideration in selecting a material for bedding is to be sure that positive contact can be obtained between the bed and the pipe. Since most granular materials will shift to attain positive contact as the pipe settles, an ideal load distribution can be attained through the use of clean coarse sand, well-rounded pea gravel or well-graded crushed rock.

BEDDING FACTORS

Under installed conditions the vertical load on a pipe is distributed over its width and the reaction is distributed in accordance with the type of bedding. When the pipe strength used in design has been determined by plant testing, bedding

Figure 215 Loads on Concrete Pipe Installed Under Railways



* Fill for embankment installations DL/B_c = 1.40wH with w = 120pcf 1.40 = Vertical Arching Factor

"Part 10 Reinforced Concrete Culvert Pipe, Chapter 8, Concrete Structures and Foundations, AREMA Manual of Railway Engineering", American Railway Engineering and Maintenance-of-Way Association, 1999.