Table 7.12
Standard Fire Hydrant Distribution

fire flow required (gpm)	minimum average area per hydrant (sq ft)
1000 or less	160,000
1500	150,000
2000	140,000
2500	130,000
3000	120,000
3500	110,000
4000	100,000
4500	95,000
5000	90,000
5500	85,000
6000	80,000
6500	75,000
7000	70,000
7500	65,000
8000	60,000
8500	57,500
9000	55,000
10,000	50,000
11,000	45,000
12,000	40,000

Table 7.13
Required Durations for Fire Fighting

required fire flow (gpm)	required duration (hr)
10,000 and greater	10
9500	9
9000	9
8500	8
8000	8
7500	7
7000	7
6500	6
6000	6
5500	5
5000	5
4500	4
4000	4
3500	3
3000	3
2500 or less	2

city. The high hydraulic head that results can be easily maintained for domestic and fire fighting mains.

Distribution by pumping with storage is the most desirable option if gravity distribution is not used. Excess water is pumped into elevated storage during periods of low consumption. During periods of high consumption, water is drawn from the storage to augment the pumped water. More uniform pumping rates result, and the pumps are able to run near their rated capacity most of the time.

Using pumps without storage to force water directly into mains is the least desirable option. Pumps must be able to maintain the flow during peak consumption, and pumps will not always run in their economical capacity ranges. In the event of a power outage, all water supply will be lost unless backup power is available.

Water mains in a distribution system should be at least 6 inches in diameter.

10 STORAGE OF WATER

Water is stored to equalize pumping rates, to equalize supply and demand over periods of high consumption, and to furnish extraordinary volumes during emergencies such as fires.

To equalize the pumping rate during the day will ordinarily require storage oı 15 to 30 percent of the maximum daily use. Storage for emergencies is more difficult to determine, and is dictated by economic benefits to the public. Fire insurance rates are generally lower the greater the emergency storage capacity is.

11 PIPE MATERIALS

Many types of pipe are available. Successful pipe materials used for distribution must have adequate strength to withstand external loads from backfill, traffic, and earth movement; high burst strength to withstand water pressure; smooth interior surfaces; corrosion resistant exteriors; and tight joints.

The types of pipes listed in table 7.14 are suitable for use in the water distribution system.

12 LOADS ON BURIED PIPES

If a pipe is buried (placed in an excavated trench and backfilled), it must support an external vertical load in addition to its internal pressure load. The magnitude of the load depends on the amount of backfill, type of soil, and type of pipe. For rigid pipes (concrete, cast iron, and clay) which cannot deform and which are placed in narrow trenches (2 or 3 diameters), the load in pounds per foot of pipe is given by equation 7.27.[10]

$$w = C\rho B^2 \qquad 7.27$$

[10] Equation 7.27 is known as *Marston's formula*.

Table 7.14
Water Pipe Materials

type	comments
ductile and gray cast iron	Long life, strong, impervious. High cost and heavy. May be coated to resist exterior and interior corrosion. Available in 4″ to 54″ standard sizes. 350 psi working pressure.
asbestos-cement	Immune to electrolysis and corrosion. Low flexural strength. Smooth interior surface. Available 4″ to 42″ diameter. Up to 200 psi working pressure.
concrete	Durable, watertight, low maintenance, smooth interior surface. Diameters 16″ to 144″, 50 psi (plain) and 250 psi (reinforced) working pressures.
steel	High strength, good yielding and shock resistance, but susceptible to corrosion. Exterior may be tarred, painted, or wrapped. Interior may have enamel or cement mortar lining. Smooth interior surface. 16″ to 120″ diameters, 250 psi pressures.
plastic	Chemically inert, corrosion resistant, smooth interior. PVC most popular. PVC available in rating to 315 psi, diameters 1/2″ to 16″.

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Typical values of C and ρ are given in table 7.15.[11] B is the trench width in feet at the top of the pipe. (A minimum trench width to allow working room is commonly estimated at 4/3 times the pipe diameter plus 8″.)

[11] There is considerable literature on the coefficients used in equations 7.27, 7.29, and 7.30. The values listed in this chapter are representative, but are not intended to cover every case. In most instances, other factors may be necessary to correctly select the coefficients.

The dead load pressure is simply the experienced load divided by the trench width.

$$p_{DL} = \frac{w}{B} \qquad 7.28$$

Flexible pipes (steel, plastic, copper) are sufficiently flexible to develop horizontal restraining pressures equal to the vertical pressures if the backfill is well compacted.

$$w = C\rho BD \qquad 7.29$$

Table 7.15
Approximate Pipe Load Correction Coefficients

backfill material	cohesionless granular material	sand & gravel	saturated topsoil	clay	saturated clay
density	100	100	100	120	130
h/B			values of C		
1	0.82	0.84	0.86	0.88	0.90
2	1.40	1.45	1.50	1.55	1.62
3	1.80	1.90	2.00	2.10	2.20
4	2.05	2.22	2.33	2.49	2.65
5	2.20	2.45	2.60	2.80	3.03
6	2.35	2.60	2.78	3.04	3.33
7	2.45	2.75	2.95	3.23	3.57
8	2.50	2.80	3.03	3.37	3.76
10	2.55	2.92	3.17	3.56	4.04
12	2.60	2.97	3.24	3.68	4.22
∞	2.60	3.00	3.25	3.80	4.60

If a pipe is placed on undisturbed ground and covered with fill (***broad fill*** or ***embankment fill***) the load is

$$w = C_p \rho D^2 \quad 7.30$$

Table 7.16
Representative Values of C_p

h/D	rigid pipe, rigid surface, noncohesive backfill	flexible pipe, average conditions
1	1.2	1.1
2	2.8	2.6
3	4.7	4.0
4	6.7	5.4
6	11.0	8.2
8	16.0	11.0

Equation 7.27 shows that the trench width is an important parameter in determining whether or not the pipe is overloaded. There is a depth for each conduit size beyond which no additional load is transmitted to the conduit, regardless of trench width. This limiting value is known as the ***transition width.*** Specifically, the load on a rigid pipe (e.g., cast iron, concrete, ductile iron) can never exceed the value calculated from equation 7.30. The transition width can be calculated by equating equations 7.27 and 7.30.

$$B_{\text{transition}} = D\sqrt{\frac{C_p}{C}} \quad 7.31$$

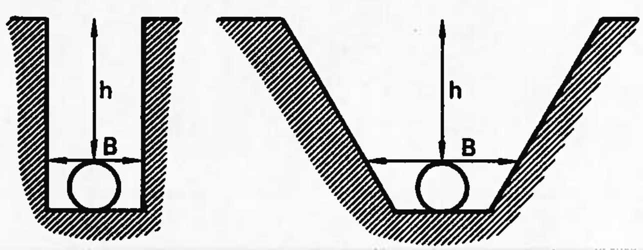

Figure 7.2 Backfilled Trenches

Boussinesq's equation should be used to calculate the load on a pipe due to a superimposed line load, P, at the surface. This load should be added to the loadings calculated from equations 7.27, 7.29, and 7.30.

$$p = \frac{3h^3 P}{2\pi z^5} \quad 7.32$$

$$w = Dp \quad 7.33$$

If the pipe has less than 3 feet of cover, a multiplicative impact factor should also be used.

$$w = F_I D p \quad 7.34$$

Table 7.17
Impact Factors

BY DEPTH (general use)	
less than 1 foot	1.3
1 to 2 feet	1.2
2 to 3 feet	1.1
more than 3 feet	1.00
BY USE	
highway	1.50
railway	1.75
airfield runway	1.00
airfield taxiway, apron	1.50

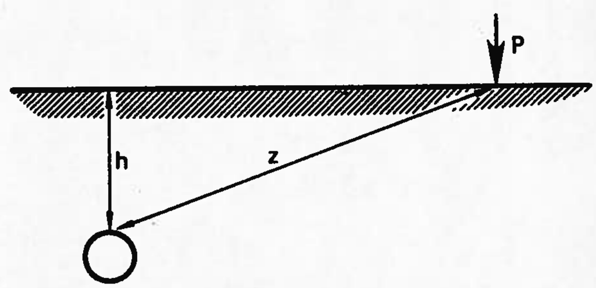

Figure 7.3 External Loads on Buried Pipes

Concrete pipes are tested in a 3-edge bearing mechanism, as shown in figure 7.4, to determine the ***crushing strength.*** Crushing strength (taken as the load which produces a 0.01″ crack) is given in pounds per foot of pipe per foot of inside diameter. Therefore, crushing strength (in pounds per linear foot of pipe) is

$$\text{crushing strength} = (\text{load per unit diameter})(\text{diameter}) \quad 7.35$$

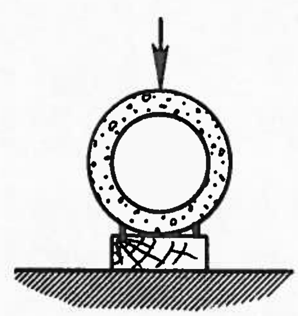

Figure 7.4 Three-Edge Bearing Test

The load on the pipe can be decreased below the crushing strength by proper bedding. Different bedding methods and their load factors are given in figure 7.5. The allowable load per foot of pipe is given by equation 7.36. The factor of safety varies from 1.25 for flexible pipe to 1.50 for rigid pipe. For reinforced concrete, the factor of safety is 1.0.

$$\text{allowable load per foot of pipe} = \frac{(\text{crushing strength})(\text{load factor, LF})}{\text{factor of safety}} \qquad 7.36$$

13 WATER SUPPLY TREATMENT METHODS

A. AERATION

Aeration can be used where there is a high concentration of carbon dioxide, where tastes and odors are objectionable, and where iron and manganese are present in amounts above 0.3 ppm.

Typical aerating devices are listed in table 7.18. Greatest efficiencies can be achieved by designing for increased water surface exposed to air, rapid change of air in contact with the water, and increased aeration periods.

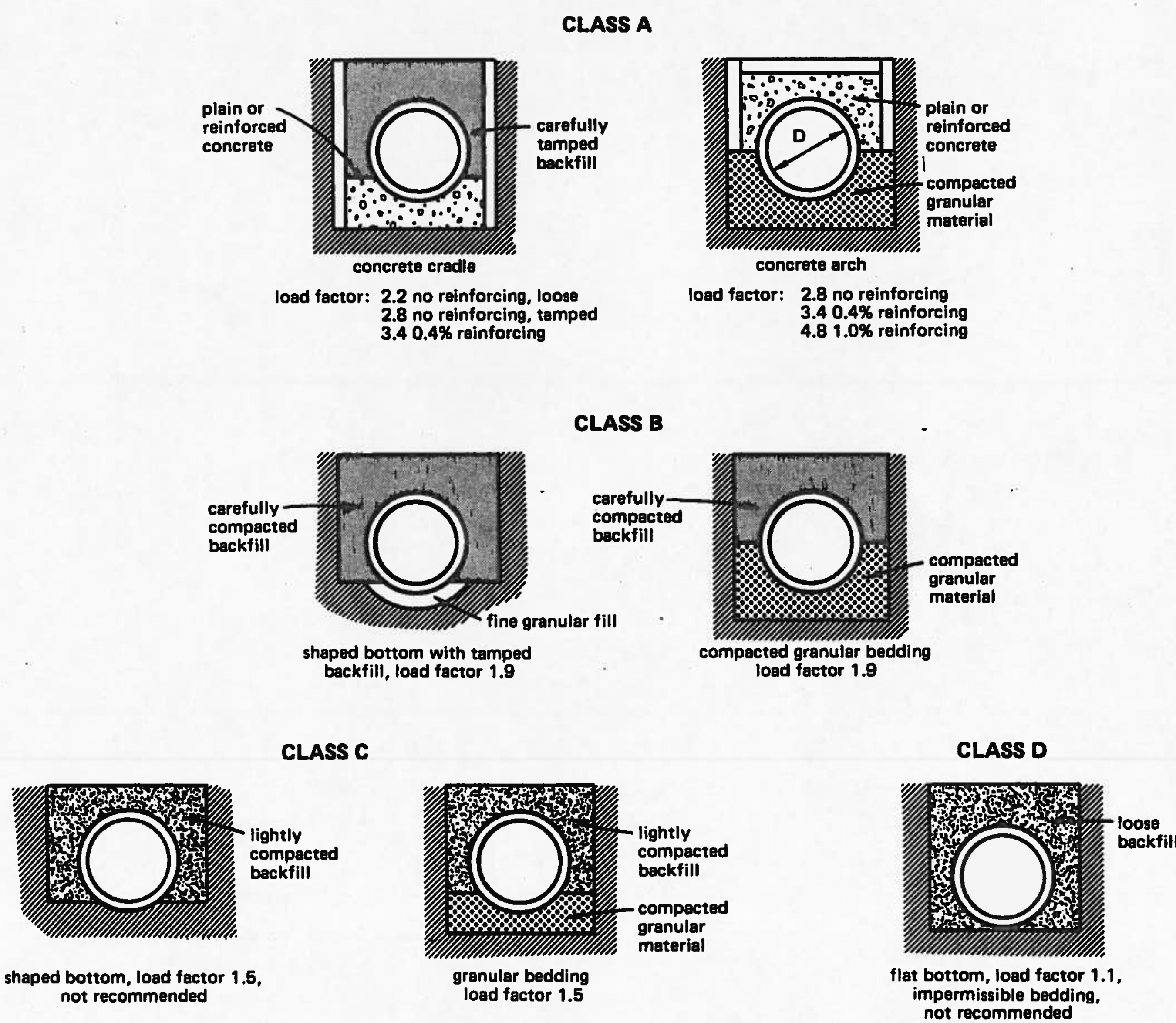

Figure 7.5 Bedding Classes and Load Factors