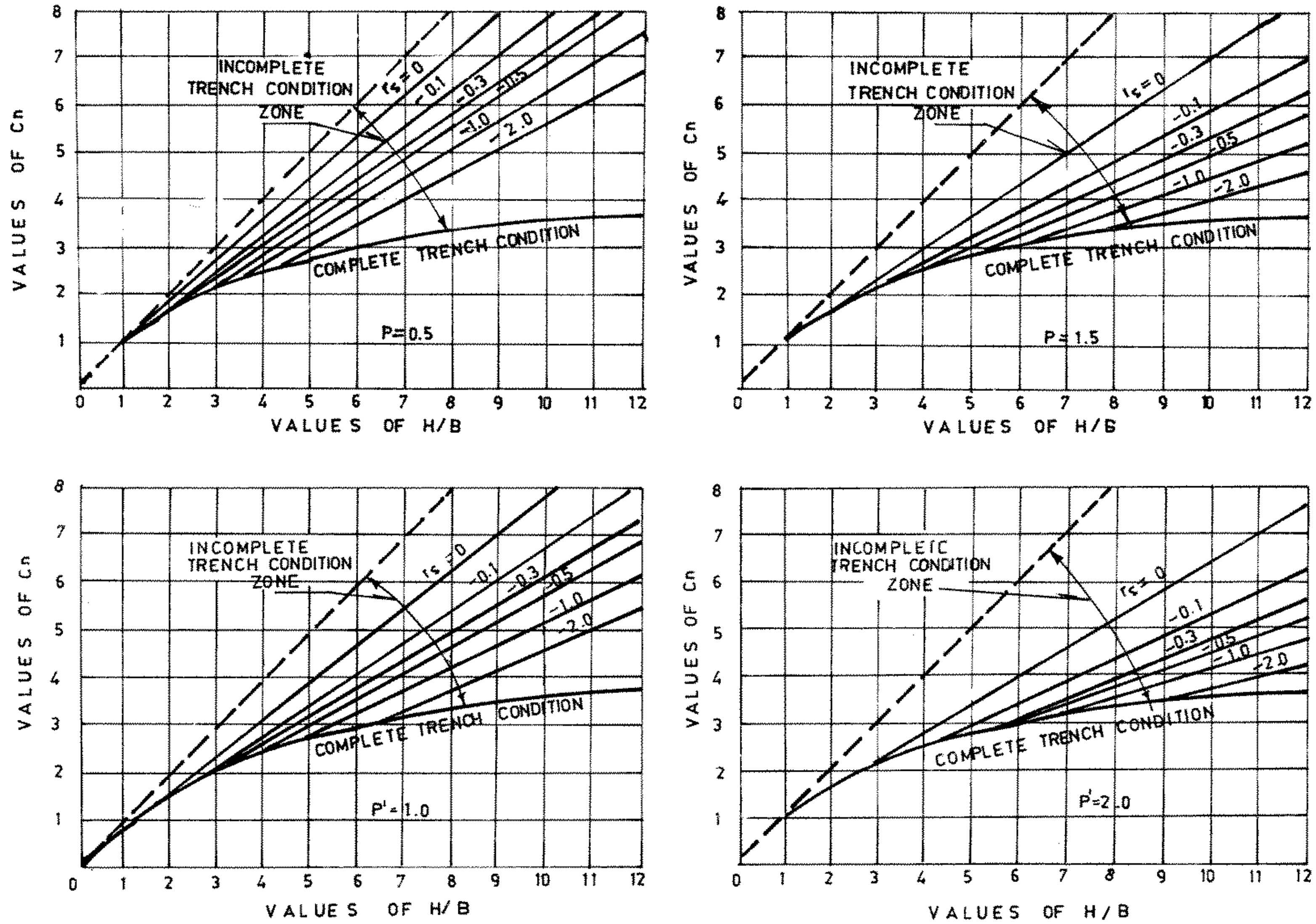

FIG. 6.5: COEFFICIENT Cn FOR NEGATIVE PROJECTING CONDUITS AND IMPERFECT TRENCH CONDITIONS

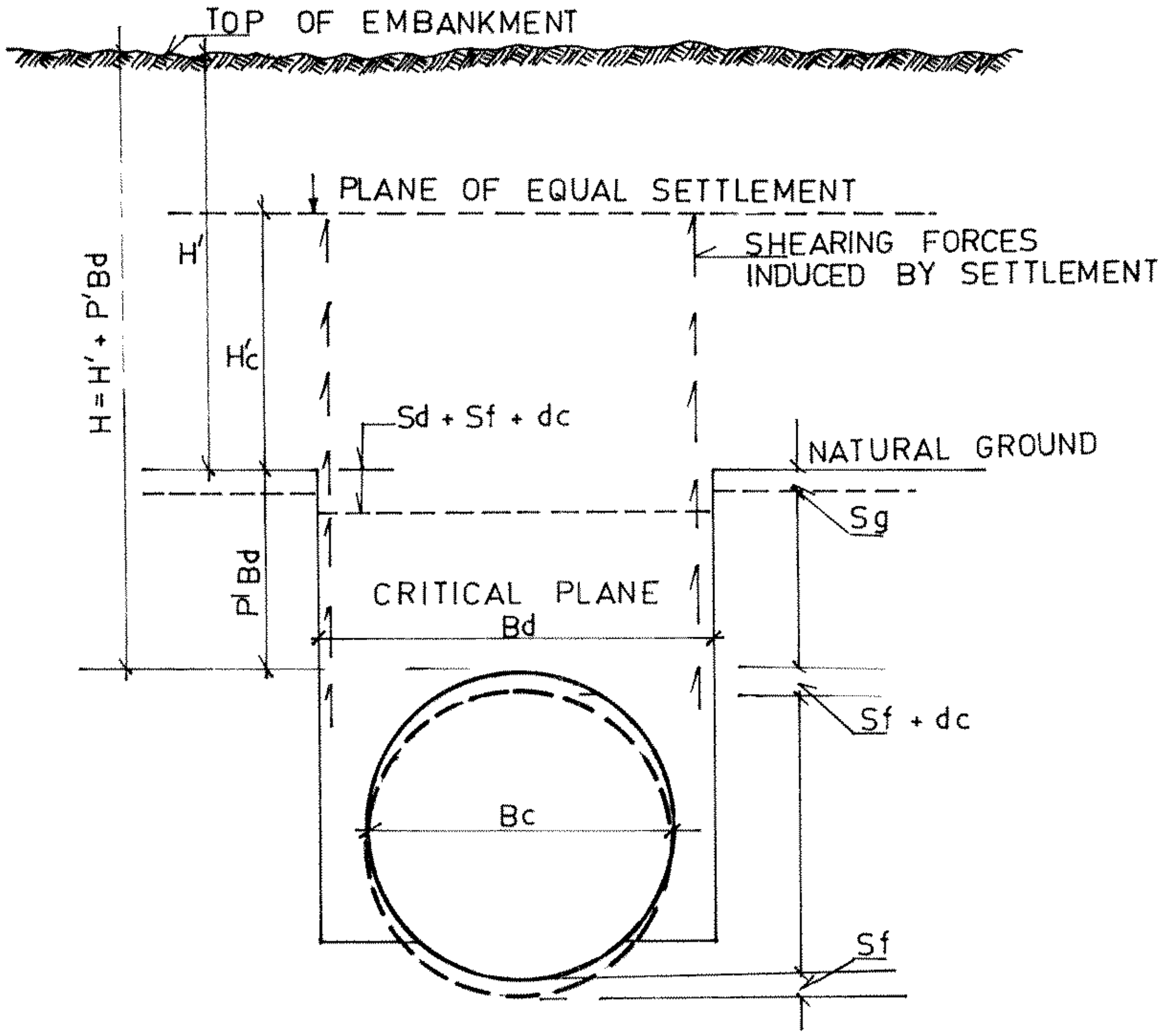

FIG. 6.6: SETTLEMENTS THAT INFLUENCE LOADS ON NEGATIVE PROJECTING CONDUITS

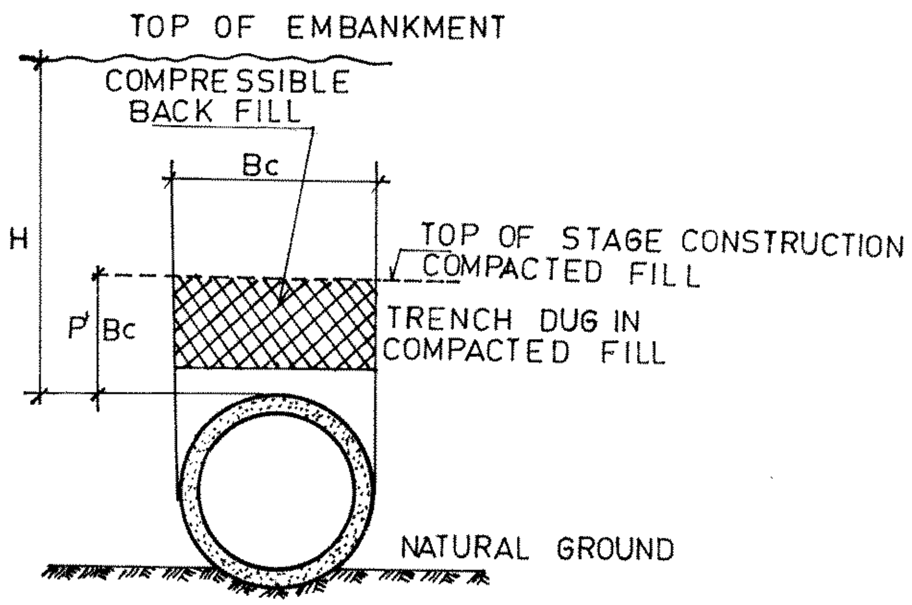

FIG. 6.7: IMPERFECT TRENCH CONDITIONS

The Marston's formula for this installation condition is again given by

$$W_c = C_n \; w \; B_c^2 \tag{6.5}$$

The values of C_n in this case also may be obtained from Fig.6.5 for negative projecting conduits taking $B_c = B_d$ on the assumption that the trench fill is no wider than the pipe.

6.3.2.2 TRENCH CONDITION

Generally sewers are laid in ditches or trenches by excavation in natural or undisturbed soil and then covered by refilling the trench to the original ground level.

a) ***Load Producing Forces***

The vertical dead load to which a conduit is subjected under trench conditions is the resultant of two major forces. The first component is the weight of the prism of soil within the trench and above the top of the pipe and the second is due to the friction or shearing forces generated between the prism of soil in the trench and the sides of the trench produced by settlement of backfill. The resultant load on the horizontal plane at the top of the pipe within the trench is equal to the weight of the backfill minus these upward shearing forces as shown in Fig.6.8.

b) ***Computation of Loads***

The load on rigid conduits in trench condition is given by the Marston's formula in the form

$$W_c = C_d \; w \; B^2_d \tag{6.6}$$

W_c = the load on the pipe in kg per linear metre

w = the unit weight of backfill soil in kg/m^3

B_d = the width of trench at the top of the pipe in m and

C_d = the load coefficient which is a function of a ratio of height of fill to width of trench (H/B_d) and of the friction coefficient between the backfill and the sides of the trench.

Weights of common filling materials (w) and values of C_d for common soil conditions encountered are given in Tables 6.2 and 6.3 respectively.

TABLE 6.2
WEIGHTS OF COMMON FILLING MATERIAL

Materials	Weight (Kg/m^3)
Dry Sand	1 600
Ordinary (Damp Sand)	1 840
Wet Sand	1 920
Damp Clay	1 920
Saturated Clay	2 080
Saturated Top Soil	1 840
Sand and Damp Soil	1 600

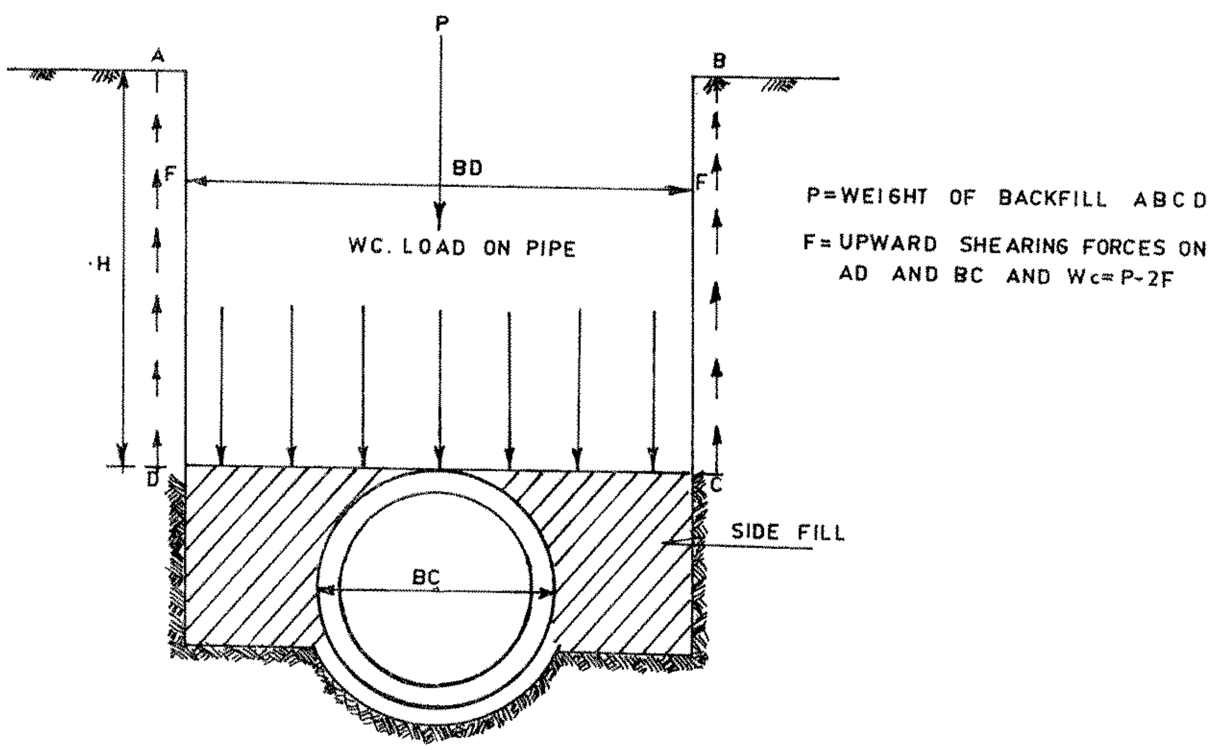

FIG. 6.8: LOAD PRODUCING FORCES

Equation (6.6) gives the total vertical load due to backfill in the horizontal plane at the top of the conduit as shown in Figure 6.8 if the pipe is rigid. For flexible conduits, the formula may be modified as

$$W_c = C_d \, w \, B_c \, B_d \qquad (6.7)$$

Where B_c is the outside width of the conduit in m.

c) *Influence of Width of Trench*

It has been experimentally seen that when the width of trench excavated is not more than twice the external width of the conduit, the assumption made in the trench condition of loading holds good. If the width of the trench goes beyond three times the outside dimension of the conduit, it is necessary to apply the embankment condition of loading. In the transition width from $B_d = 2B_c$ to $B_d = 3B_c$ computation of load by both the procedures will give the same results.

TABLE 6.3

VALUES OF C_d, FOR CALCULATING LOADS ON PIPES IN TRENCHES ($W_c = C_d \cdot WB^2d$)

Ratio H/B$_d$	Safe working Values of C_d				
	Minimum Possible without cohesion	Maximum for Ordinary Sand	Completely Saturated Top Soil	Ordinary maximum for clay	Extreme maximum for clay
0.5	0.455	0.461	0.464	0.469	0.474
1.0	0.830	0.852	0.864	0.881	0.898
1.5	1.140	1.183	1.208	1.242	1.278
2.0	1.395	1.464	1.504	1.560	1.618
2.5	1.606	1.702	1.764	1.838	1.923
3.0	1.780	1.904	1.978	2.083	2.196
3.5	1.923	2.075	2.167	2.298	2.441
4.0	2.041	2.221	2.329	2.487	2.660
4.5	2.136	2.344	2.469	2.650	2.856
5.0	2.219	2.448	2.590	2.798	3.032
5.5	2.286	2.537	2.693	2.926	3.190
6.0	2.340	2.612	2.782	3.038	3.331
6.5	2.386	2.675	2.859	3.137	3.458
7.0	2.423	2.729	2.925	3.223	3.571
7.5	2.454	2.775	2.982	3.299	3.673
8.0	2.479	2.814	3.031	3.366	3.764
8.5	2.500	2.847	3.073	3.424	3.845
9.0	2.518	2.875	3.109	3.476	3.918
9.5	2.532	2.898	3.141	3.521	3.983
10.0	2.543	2.918	3.167	3.560	4.042
11.0	2.561	2.950	3.210	3.626	4.141
12.0	2.573	2.972	3.242	3.676	4.221
13.0	2.581	2.989	3.266	3.715	4.285
14.0	2.587	3.000	3.283	3.745	4.336
15.0	2.591	3.009	3.296	3.768	4.378
Very Great	2.599	3.030	3.333	3.846	4.548

W_c = load on pipe in kg per linear metre
C_d = Coefficient
w = Weight of trench filling material in kg/m^3
B_d = Width of trench a little below the top of the pipe in metres.
* Ratio of height of fill above top of pipe to width of trench a little below the top of the pipe.
** These values give the loads generally imposed by granular filling materials before tamping or settling.
*** Use these values as safe for all ordinary cases of sand filling.
**** Thoroughly wet. Use these values as safe for all ordinary cases of clay filling.
***** Completely saturated. Use these values only for extremely unfavourable conditions.

In case of excavations with sloping sides (possible in undeveloped areas), the provision of a sub-trench (Fig.6.9) minimises the load on the pipe by reducing the value of B_d.

6.3.2.3 TUNNEL CONDITION

When the conduit is laid more than 9 to 12 meters deep or when the surface obstructions are such that it is difficult to construct the pipeline by the conventional procedure of excavation and backfilling, it may be more economical to place the conduit by means of tunnelling. The general method in this case is to excavate the tunnel, to support the earth by suitable means and then to lay the conduit. The space between the conduit and the tunnel is finally filled up with compacted earth or concrete grout as indicated in Fig.6.10. If the length of tunnel is short say 6 - 10 meters the entire circular section can be constructed as one unit. For longer tunnels construction may be in segments with refilling proceeding simultaneously.

a) ***Load Producing Forces***

The vertical load acting on the tunnel supports and eventually the pipe in the tunnel is the resultant of two major forces viz. the weight of the overhead prism of soil within the width of the tunnel excavation and the shearing forces generated between the interior prisms and the adjacent material due to friction and cohesion of the soil.

b) ***Load Computations***

Marston's formula to be used in this case of installation of conduit is given by:

$$W_t = C_t\ B_t\ (wB_t - 2C) \qquad (6.8)$$

Where

W_t = load on the pipe or tunnel support in Kg/m

w = unit weight of soil above the tunnel in kg/m^3

B_t = maximum width of the tunnel excavation in m

C = coefficient of cohesion in kg/m^2 and

C_t = load coefficient which is a function of the ratio (H/B_t) of the distance from the ground surface to the top of the tunnel to the maximum width of tunnel excavation and of the coefficient of internal friction of the material of the tunnel.

When the coefficient of cohesion is zero, the formula reduces to the same form as in trench condition Eq.(6.6).

Value of C_t for various values of H/B_t and different soil conditions are to be obtained from Fig.6.11.

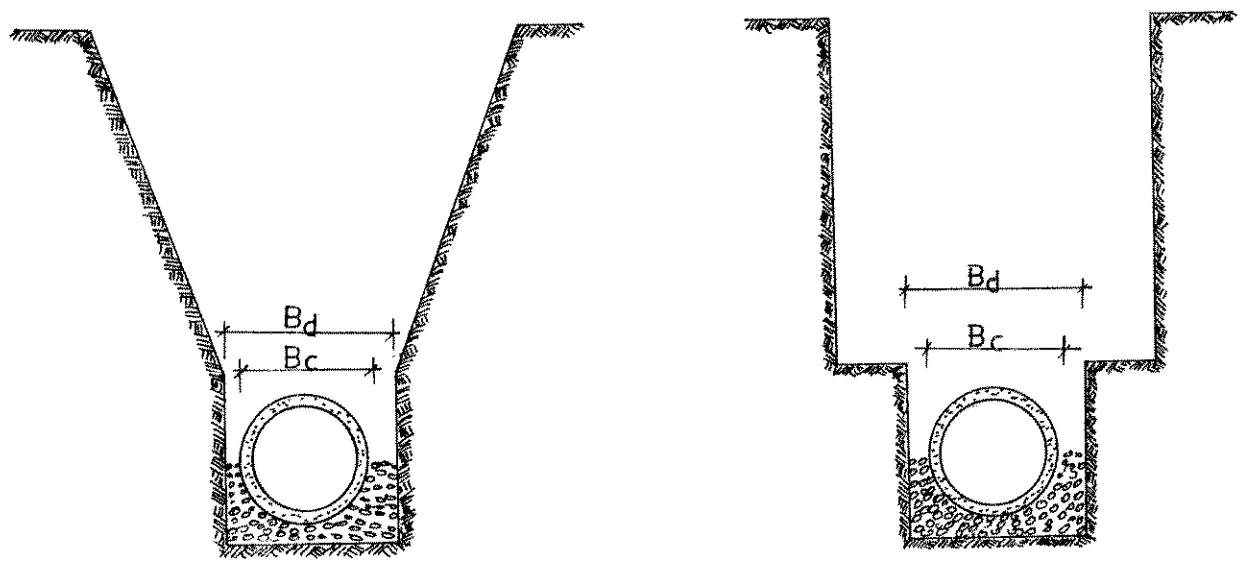

FIG. 6.9: EXAMPLES OF SUBTRENCH

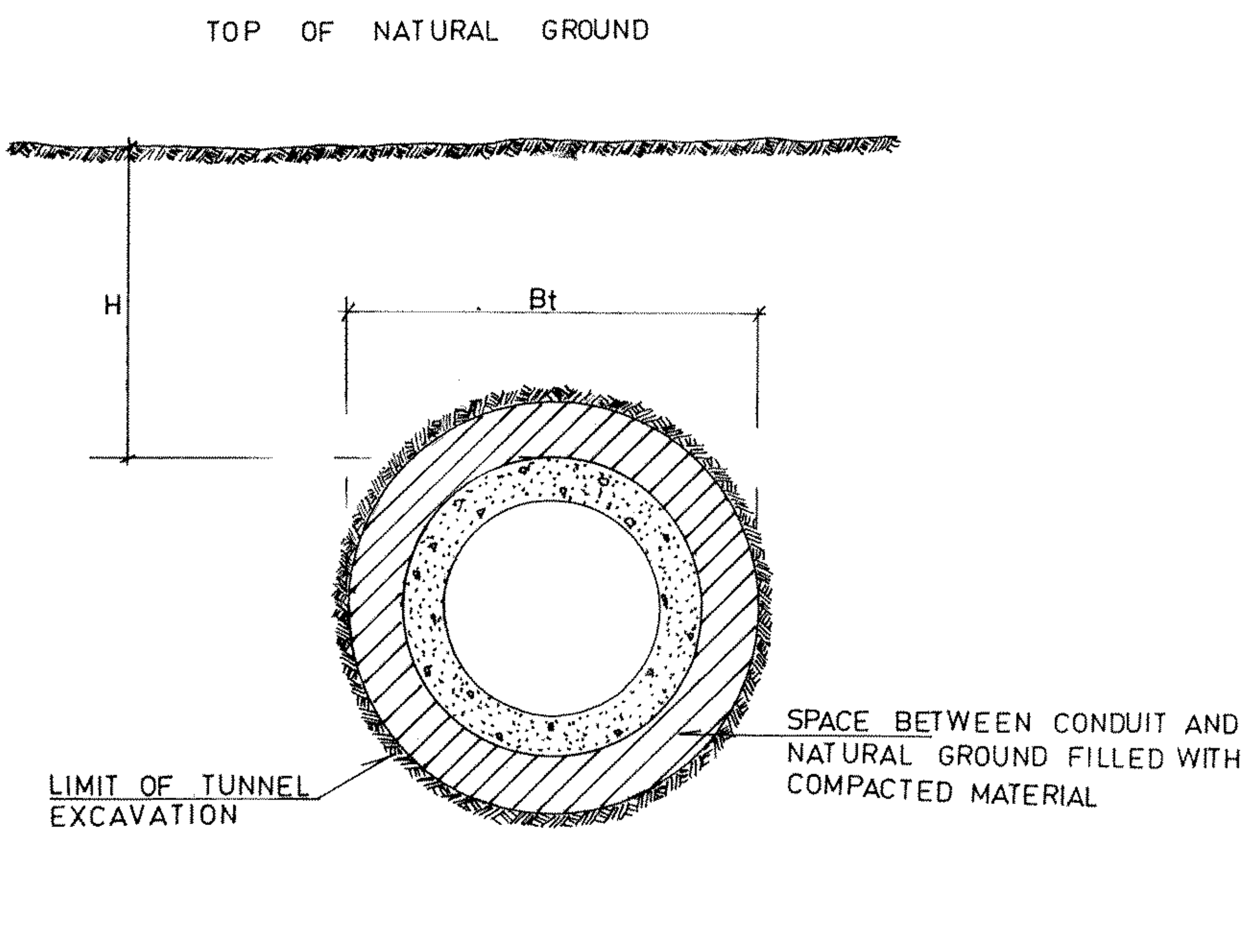

FIG. 6.10: CONDUIT IN TUNNEL

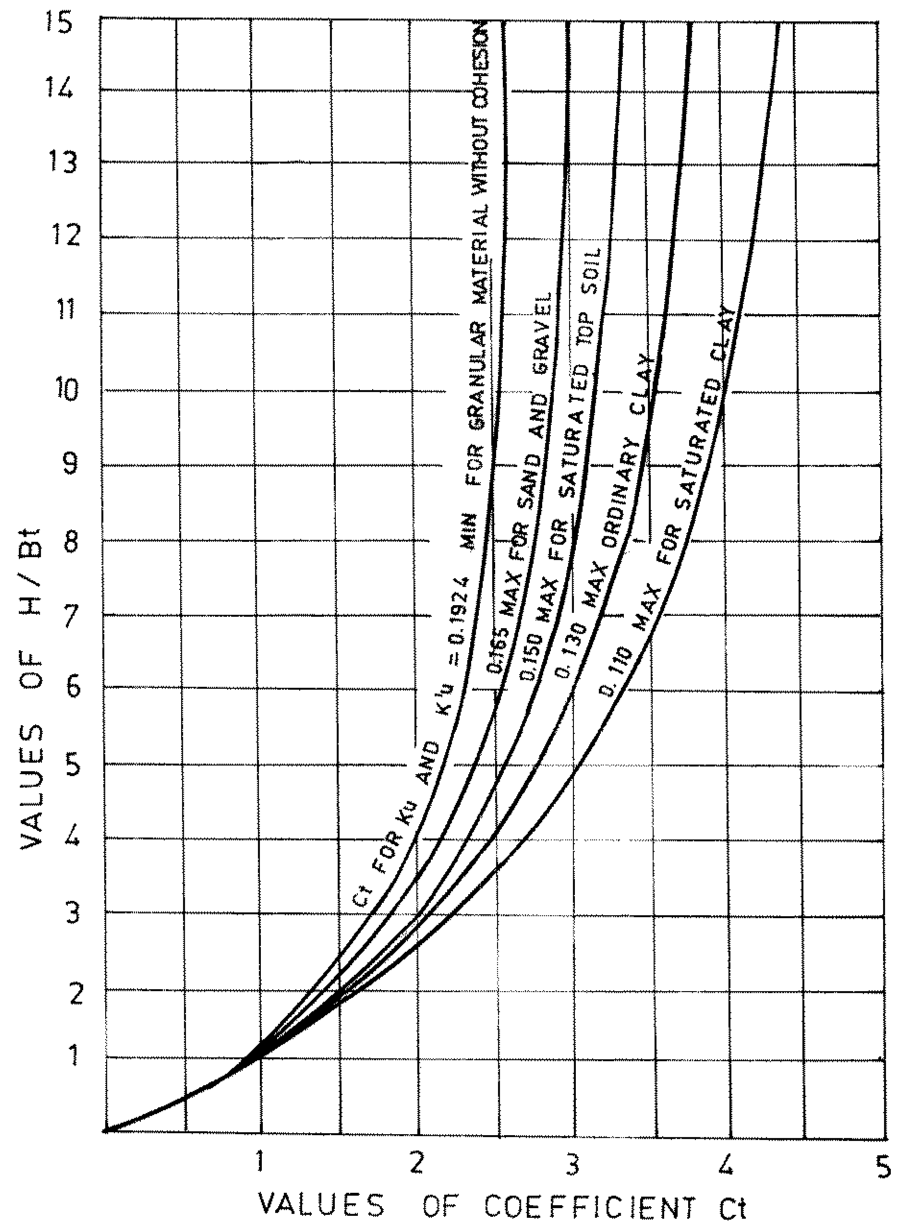

FIG. 6.11: DIAGRAM FOR COEFFICIENT Ct FOR TUNNELS IN UNDISTURBED SOIL.

Recommended values of coefficient of cohesion for different types of soils are given in Table 6.4

TABLE 6.4
COHESION COEFFICIENTS FOR DIFFERENT SOILS

Type of Soil	Kg/m^2
Soft Clay	200
Medium Clay	1200
Hard Clay	4700
Loose Dry Sand	0
Silty Sand	500
Dense Sand	1400
Saturated top soil	500

6.3.2.4 Effect of Submergence

Sewers may be laid in trenches or under embankment in areas which may be temporarily or permanently submerged in water. The fill load in such cases will be reduced and will correspond to the buoyant weight of the fill material. However, effect of submergence could be ignored which provides an additional factor of safety, but it may be necessary to check whether a pipe is subject to flotation. Under submergence, the minimum height of the fill material that will be required to prevent flotation ignoring the frictional forces in the fill can be determined from the equation.

$$H_{min}\ B_c\ (w_s - w_o) + W_c = (\pi/4)\ B_C^2\ w_o \qquad (6.9)$$

Where

H_{min} = minimum height of fill material in m

w_s = the saturated density of the soil in kg/m^3

w_o = the density of water in kg/m^3

W_c = the unit weight of the empty pipe in kg/linear meter and

B_c = the outside width of the conduit in m.

Wherever sufficient height of fill material is not available, anti-flotation blocks should be provided. (As shown in Example IX in Appendix 6.2).

6.4 LOAD ON CONDUIT DUE TO SUPER IMPOSED LOADS

The types of superimposed loads which are generally encountered in buried conduits may be categorised as (a) concentrated load and (b) distributed load. These are explained diagramatically in Fig.6.12.

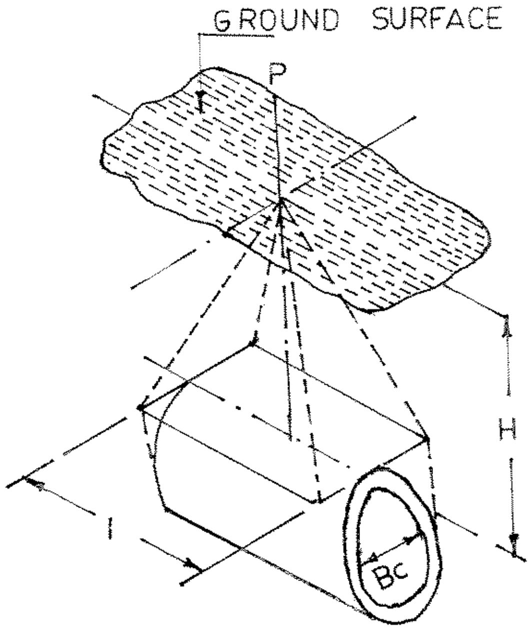

FIG6.12A: CONCENTRATED SUPERIMPOSED LOAD VERTICALLY CENTRED OVER CONDUIT.

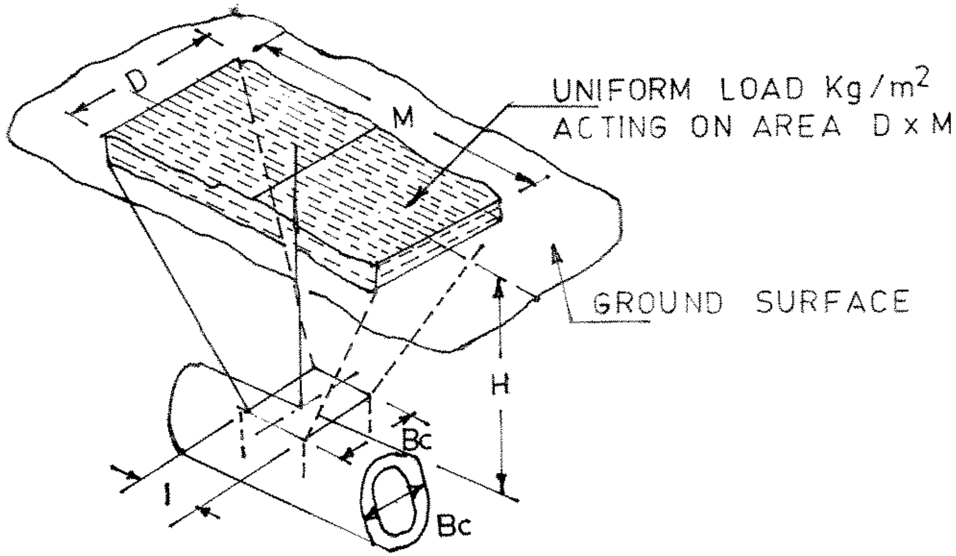

FIG6.12B: DISTRIBUTED SUPERIMPOSED LOAD VERTICALLY CENTRED OVER CONDUIT.

6.4.1 Concentrated Load

The formula for load due to superimposed concentrated load such as a truck wheel (Fig.6.12) is given in the following form by Holl's integration of Boussinesq's formula

$$W_{sc} = C_s \,(PF/L) \qquad (6.10)$$

Where

W_{sc} = the load on the conduit in kg/m

P = the concentrated load in kg acting on the surface

F = the impact factor (1.0 for air field runways, 1.5 for highway traffic and air field taxi ways, 1.75 for railway traffic) and

C_s = the load coefficient which is a function of

$$\frac{B_c}{2H} \quad \text{and} \quad \frac{L}{2H}$$

Where

H = the height of the top of the conduit to ground surface in m

B_c = the outside width of conduit in m, and

L = the effective length of the conduit to which the load is transmitted in m.

Values of c_s for various values of (B_c / 2H) and (L / 2H) are obtained from Table 6.5

The effective length of the conduit is defined as the length over which the average load due to surface traffic units produces the same stress in the conduit wall as does the actual load which varies in intensity from point to point. This is generally taken as 1m or the actual length of the conduit if it is less than 1m.

6.4.2 Distributed Load

For the case of distributed superimposed loads, the formula for load on conduit is given by

$$W_{sd} = C_s \, p \, F \, B_c \qquad (6.11)$$

Where

W_{sd} = the load on the conduit in kg/m

p = the intensity of the distributed load in kg/m^2

F = the impact factor

B_c = The width of the conduit in m

C_S = The load coefficient, a function of D/2H and L/2H from Table 6.5

H = The height of the top of conduit to the ground surface in m and

D and L are width and length in m respectively of the area over which the distributed load acts.

TABLE - 6.5

VALUES OF LOAD COEFFICIENTS, Cs FOR CONCENTRATED AND DISTRIBUTED SUPERIMPOSED LOADS VERTICALLY CENTRED OVER CONDUITS

$\frac{D}{2H}$ or $\frac{Bc}{2H}$	$\frac{M}{2H}$ or $\frac{L}{2H}$: 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

For class AA IRC loading, in the critical case of wheel load of 6.25 tonnes, the intensity of distributed load with wheel area 300mm x 150mm is given by

$$P = \frac{6.25}{0.3 \times 0.15} \text{ in } T/m^2$$

6.4.3 Conduits Under Railway Track

The load on conduits under railway track is given by

$$W = 4C_S\, UB_c \qquad (6.12)$$

Where

U is the uniformly distributed load in tonnes/m^2 from the surface directly over the conduit and equal to

$$U = \frac{PF+2W_tB}{4AB} = \frac{PF}{4AB} + \frac{W_t}{2A} \qquad (6.13)$$

Where

- P = axle load in tonnes (22.5 tonnes for Broad guage)
- F = impact factor for railroad = 1.75
- $2A$ = length of the sleeper in m (2.7m for Broad guage)
- $2B$ = distance between the two axles (1.84m for broad gauge)
- W_t = weight of the track structure in tonnes/m (0.3 tonnes/m for broad gauge)
- C_S = load coefficient which depends on the height of the top of sleeper from the top of the conduit and
- B_c = width of the conduit in m.

For broad guage track the formula will reduce to:

$$W = 32.14\, C_s\, B_c \qquad (6.14)$$

6.5 SUPPORTING STRENGTH OF RIGID CONDUIT

The ability of a conduit to resist safely the calculated earth load depends not only on its inherent strength but also on the distribution of the vertical load and bedding reaction and on the lateral pressure acting against the sides of the conduit. The inherent strength of a rigid conduit is usually expressed in terms of the three edge bearing test results, the conditions of which are, however, different from the field load conditions. The magnitude of the supporting strength of a pipe as installed in the field is dependent upon the distribution of the vertical load and the reaction against the bottom of the pipe. It also depends on the magnitude and distribution of the lateral pressure acting on the sides of the pipe.

6.5.1 Laboratory Test Strength

All rigid pipes may be tested for strength in the Laboratory by the three edge bearing test (ultimate load). Methods of test and minimum strength for concrete (unreinforced and reinforced) stoneware and AC pipes and other details are given in Appendix 6.1

6.5.2 Field Supporting Strength

The field supporting strength of a rigid conduit is the maximum load per unit length which the pipe will support while retaining complete serviceability when installed under specified conditions of bedding and backfilling. The field supporting strength, however does not include any factor of safety. The ratio of the strength of a pipe under any stated condition of loading and bedding to its strength measured by the three edge bearing test is called the load factor.

The load factor does not contain a factor of safety. Load factors have been determined experimentally and analytically for the commonly used construction condition for both trench and embankment conduits.

6.5.3 Supporting Strength in Trench Conditions

6.5.3.1 Classes of Bedding

Four classes, A,B,C and D of bedding used most often for pipes in trenches are illustrated in figure 6.13. Class A bedding may be either concrete cradle or concrete arch. Class B is a bedding having a shaped bottom or compacted granular bedding with a carefully compacted backfill. Class C is an ordinary bedding having a shaped bottom or compacted granular bedding but with a lightly compacted backfill. Class D is one with flat bottom trench with no care being taken to secure compaction of backfill at the sides and immediately over the pipe and hence is not recommended. Class B or C bedding with a compacted granular bedding is generally recommended. Shaped bottom is impracticable and costly and hence is not recommended. The pipe bedding materials must remain firm and not permit displacement of pipes.

The material has to be uniformly graded or wellgraded. Uniformly graded materials include pea gravel or one size materials with a low percentage of over and undersized particles. Well graded materials containing several sizes of particles in stated proportions, ranging from a maximum to a minimum size,coarse sand, pea gravel, crushed gravel, crushed screenings, can be used for pipe bedding. Fine materials or screenings are not satisfactory for stabilising trench bottoms and are difficult to compact in a uniform manner to provide proper pipe bedding.

Well graded material is most effective for stabilizing trench bottom and has a lesser tendency to flow than uniformly graded materials. However, uniformly graded material is easier to place and compact above sewer pipes.

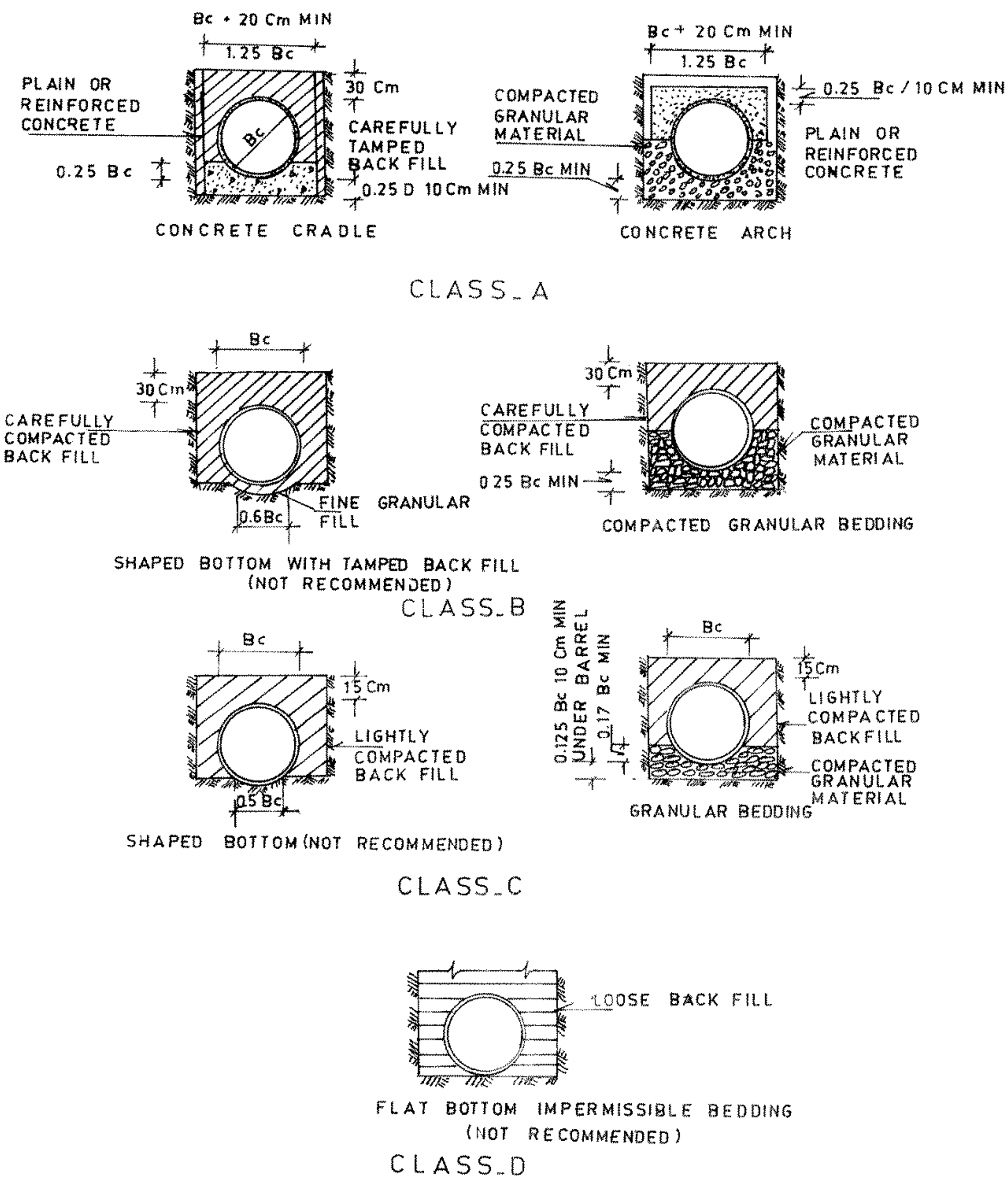

FIG.6.13: CLASSES OF BEDDING FOR CONDUIT IN TRENCH

NOTE: IN ROCK, TRENCH IS EXCAVATED ATLEAST 15 Cm BELOW THE BELL OF THE PIPE EXCEPT WHERE CONCRETE CRADLE IS USED.

6.5.3.2 LOAD FACTORS

The load factors for the different classes of Bedding are given in Table 6.6.

TABLE 6.6
LOAD FACTORS FOR DIFFERENT CLASSES OF BEDDING

Class of Bedding		Condition	Load Factor
A	a	Concrete cradle-plain concrete and lightly tamped backfill	2.2
A	b	Concrete cradle-plain concrete with carefully tampled backfill	2.8
A	c	Concrete cradle - RCC with P-0.4%	upto 3.4
A	d	Arch type-plain concrete	2.8
		RCC with P-0.4%	upto 3.4
		RCC with P-1.0%	upto 4.8
		('P' is the ratio of the area of steel to the area of concrete at the crown)	
B		Shaped bottom or compacted granular bedding with carefully compacted backfill	1.9
C		Shaped bottom or compacted granular bedding with lightly compacted backfill	1.5
D		Flat bottom trench	1.1

The granular material used must stabilize the trench bottom in addition to providing a firm and uniform support for the pipe. Well graded crushed rock or gravel with the maximum size not exceeding 25mm is recommended for the purpose.

Where rock or other unyielding foundation material is encountered, bedding may be according to one of the Classes A,B or C but with the following additional requirements.

Class A: The hard unyielding material should be excavated down to the bottom of the concrete cradle.

Class B or C: The hard unyielding material should be excavated below the bottom of the pipe and pipe bell to a depth of atleast 15cm.

The width of the excavation should be atleast 1.25 times the outside dia of the pipe and it should be refilled with granular material.

Total encasement of non-reinforced rigid pipe in concrete may be necessary where the required safe supporting strength cannot be obtained by other bedding methods. The load factor for concrete encasement varies with the thickness of concrete. The effect of M-200 concrete encasement of various thicknesses on supporting strength of pipe under trench conditions is given in Fig. 6.14.

6.5.4 Supporting Strength in Embankment Conditions

The soil pressure against the sides of a pipe placed in an embankment may be significant in resisting the vertical load on the structure.

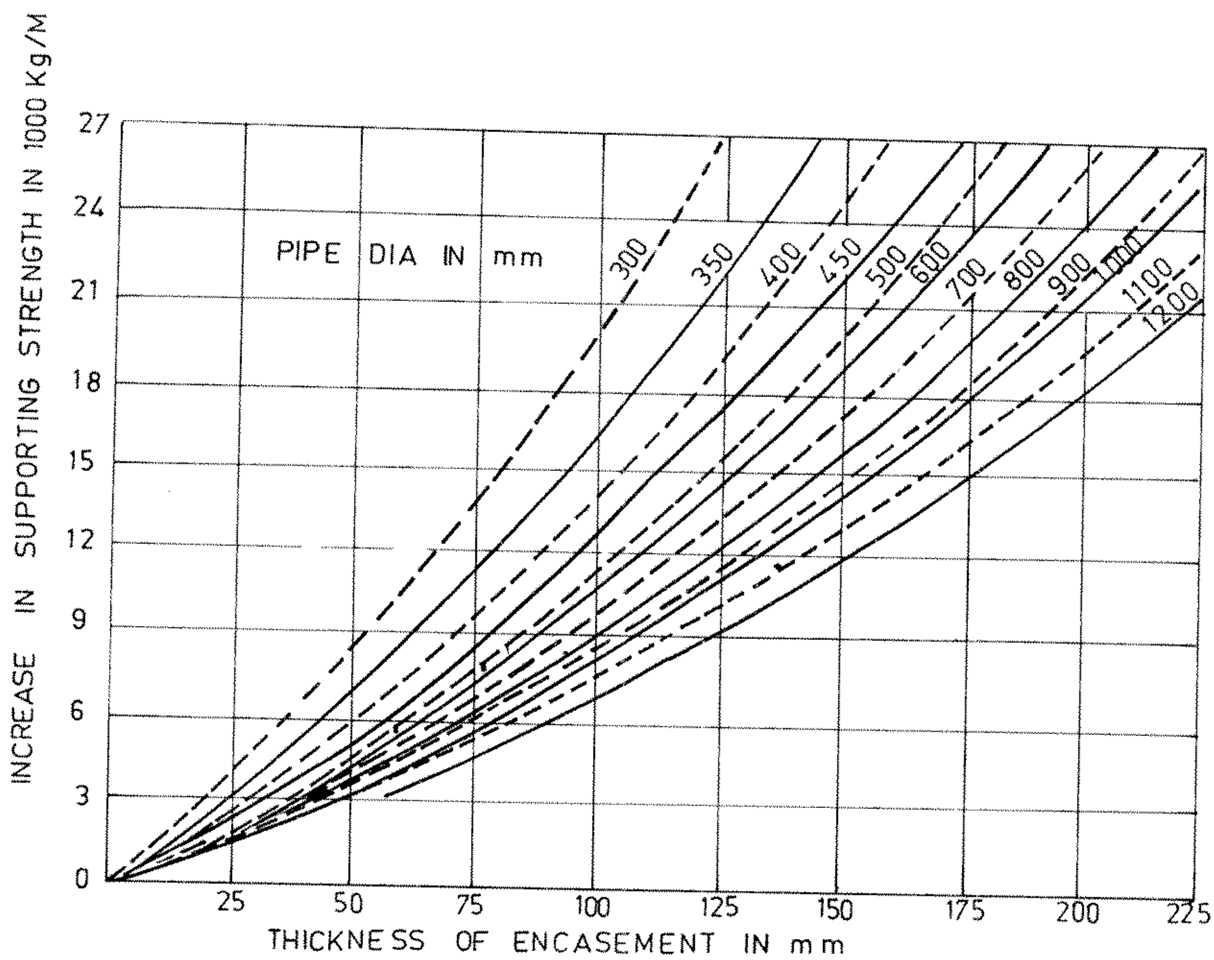

FIG.6.14: EFECT OF M-200 CONCRETE ENCASEMENT OF VARIOUS THICKNESS ON SUPPORTING STRENGTH OF PIPE UNDER TRENCH CONDITIONS.

6.5.4.1 Classes of Bedding

The beddings which are generally adopted for projecting conduits laid under the embankment conditions of installation are illustrated in Figure 6.15. The classification of the beddings are as under:

CLASS A: In this case the conduit is laid on a mat of concrete.

CLASS B: The conduit is laid on accurately shaped earth to fit the bottom of the pipe and the sides are filled with thoroughly tamped earth.

CLASS C: In this type of bedding the conduit is laid on accurately shaped earth to fit the bottom surface of the conduit. For rock foundations the conduit is laid on a layer of granular cushion and the sides of the conduit are filled up.

CLASS D: The conduit is laid on earth not shaped to fit the bottom of the conduit. In case of rocky soil the conduit is laid on a shallow granular cushion.

6.5.4.2 Load Factors

The load factor for rigid pipes installed as projecting conduits under embankments or in wide trenches is dependent on the type of bedding, the magnitude of the active lateral soil pressure and on the area of the pipe over which the active lateral pressure acts.

The load factor for projecting circular conduits may be calculated by the formula

$$L_f = \frac{1.431}{Nzq} \qquad (6.15)$$

Where

L_f = the load factor

N = a parameter dependent on the type of bedding

z = a parameter dependent upon the area over which the lateral pressure acts effectively and

q = the ratio of total lateral pressure to total vertical load on pipe.

a) ***Positive Projecting Conduits***

The ratio 'q' for positive projecting conduits may be estimated by the formula

$$q = (mk / C_c) \, [\, (H/B_c) + (m/2) \,] \qquad (6.16)$$

Where

k = the 'Rankine's ratio which may be taken as 0.33. The value of N for different types of beddings for circular pipes are given in Table 6.7.