Prime Conduit, Inc.

External Load Calculations for Direct Buried Conduit

External loads on direct buried PVC conduit or duct fall into two categories, dead loads (earth loads) and live loads. Dead loads are based on the weight of the column of soil above the buried conduit or duct. Live loads are from different sources such as highways, airport runways or railways. Live loads have little effect on conduit performance except at shallow depths (4’ or less for highway loads).

The total load is the summation of the dead loads and of the live loads. The total load shall be less than the load (maximum load) required to change the inside diameter of the conduit or duct by arbitrary datum of 5% deflection. This deflection, caused by the total load, is far below that which would cause damage to the PVC wall of the conduit or duct.

The maximum load (W) can be calculated with the following formula:

$$W = [\Delta X * (0.149 * PS + 0.061 * E^1)]/[D * K]$$

W = MAXIMUM LOAD (lb/in²)
ΔX = DEFLECTION (%/100)
PS = PIPE STIFFNESS (lb/in²)
E¹ = BEDDING SOIL MODULUS (lb/in²)
D = DEFLECTION LAG FACTOR
K = BEDDING CONSTANT

Deflection (ΔX) is the ratio of the inside diameter (loaded) verse the inside diameter (unloaded) of the conduit or duct **(5% = 0.05)**. The inside diameter (I.D.) can be calculated by taking the outside diameter (O.D.) and subtracting two (2) times the wall thickness (t). **I.D. = (O.D. - 2*t)**.

Bedding soil modulus (E^1) shall be 2000 lb/in² for Type I soil and 1000 lb/in² for Type III soil.

A deflection lag factor (D) of 1.5 is a commonly used value.

A bedding constant (K) of .1 is a commonly used value.

Pipe stiffness (PS) of the conduit or duct is either predetermined or calculated by using the following formula:

$$PS = E * I/(0.149 * r^3)$$

PS = PIPE STIFFNESS (lb/in²)
E = MODULUS OF ELASTICITY IN TENSION (lb/in²)
I = MOMENT OF INERTIA (in³)
r = MEAN RADIUS (in)

Modulus of elasticity (E) of PVC for the conduit or duct is equal to 500,000 lb/in².

The moment of inertia (I) equals the wall thickness (t) cubed, divided by twelve (12). **$I = t^3/12$**.

The mean radius (r) equals the outside diameter (O.D.) minus the wall thickness (t) divided by two (2).

$$r = (O.D. - t)/2$$

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Pipe stiffness for DB60 is equal to 60 lb/in² and for DB120 is equal to 120 lb/in². 4" Schedule 40 conduit will have a pipe stiffness of 346 lb/in² (minimum wall thickness).

Materials suitable for foundation and embedment are defined according to the Unified Soil Classification Systems (USCS) in ASTM D2487, "Standard Method for Classification of Soils for Engineering Purposes". Bedding soil modulus (E^1) shall be 2000 lb/in² for Class IA and IB soils and 1000 lb/in² for Class III soil. Class IA materials provide maximum stability and pipe support for a given density due to angular interlock of particles. Class III materials provide less support for a given density than Class I materials. High levels of compactive effort may be required unless moisture content is controlled.

Dead load (DL) is equal to the unit weight of the backfill (γ) times the height of cover (H) divided by 144.

DL = γ * H/144
DL = DEAD LOAD (lb/in²)
γ = UNIT WEIGHT OF BACKFILL (lb/ft³)
H = HEIGHT OF COVER (ft)

120 lb/ft³ is a commonly used value for the unit weight of backfill.

Live loads (LL) can be calculated by using the Boussinesq formula for a point load at the surface of the semi-infinite elastic soil or by using the predetermined values in the following table:

LIVE LOADS ON PVC CONDUIT OR DUCT
(LIVE LOADS TRANSFERRED TO CONDUIT lbs/in²)

HEIGHT OF COVER	HIGHWAY	RAILWAY	AIRPORT		HEIGHT OF COVER	HIGHWAY	RAILWAY	AIRPORT
H (ft)	H20[1]	E80[2]	[3]		H (ft)	H20[1]	E80[2]	[3]
1	12.50	*	*		14	*	4.17	3.06
2	5.56	26.39	13.14		16	*	3.47	2.29
3	4.17	23.61	12.28		18	*	2.78	1.91
4	2.78	18.40	11.27		20	*	2.08	1.53
5	1.74	16.67	10.09		22	*	1.91	1.14
6	1.39	15.63	8.79		24	*	1.74	1.05
7	1.22	12.15	7.85		26	*	1.39	*
8	0.69	11.11	6.93		28	*	1.04	*
10	*	7.64	6.09		30	*	0.69	*
12	*	5.56	4.76		35	*	*	*
					40	*	*	*

[1] SIMULATES 20 TON TRUCK TRAFFIC + IMPACT
[2] SIMULATES 80,000 lb/ft RAILWAY LOAD + IMPACT
[3] SIMULATES 180,000 lbs DUAL TANDEM GEAR ASSEMBLY. 26 INCH SPACING BETWEEN TIRES AND 66 INCH CENTER-TO-CENTER SPACING BETWEEN FORE AND AFT TIRES UNDER A RIGID PAVEMENT 12 INCHES THICK + IMPACT.
* NEGLIGIBLE LIVE LOAD INFLUENCE.

Once the dead load and live load are known they shall be added together to obtain the total load **(TL = DL + LL)**. The total load shall be less than the maximum load.

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Article 300-5 of the 1996 National Electrical Code (NEC) specifies the minimum cover requirements for cable, conduit and other raceways up to 600 volts. Table 710-4(b) specifies the minimum cover requirements for applications over 600 volts.

The following are some sample calculations.

EXAMPLE 1: *4" SCHEDULE 40 CONDUIT WILL BE BURIED 20 FEET BELOW A RAILWAY IN TYPE I SOIL. 4" SCHEDULE 40 CONDUIT HAS AN OUTSIDE DIAMETER OF 4.500" AND A MINIMUM WALL THICKNESS OF 0.237".*

1. CALCULATE THE MEAN RADIUS (r)

$$\mathbf{r = (O.D. - t)/2 = (4.500\ in - 0.237\ in)/2 = 2.132\ in}$$

2. CALCULATE THE MOMENT OF INERTIA (I)

$$\mathbf{I = t^3/12 = (0.237\ in)^3/12 = 0.001\ in^3}$$

3. CALCULATE THE PIPE STIFFNESS (PS)

$$\mathbf{PS = E*I/(0.149*r^3) = [500{,}000\ lb/in^2*0.001\ in^3]/[0.149*(2.132\ in)^3] = 346.3\ lb/in^2}$$

4. CALCULATE THE MAXIMUM LOAD FOR 5% DEFLECTION (W)

$$\mathbf{W = [\Delta X*(0.149*PS + 0.061*E^1)]/(D*K) = [0.05*(0.149*346.3\ lb/in^2+0.061*2000\ lb/in^2)]/(1.5*0.1) = 57.87\ lb/in^2}$$

5. CALCULATE THE DEAD LOAD (DL)

$$\mathbf{DL = \gamma * H/144 = 120\ lb/ft^3*20\ ft/144 = 16.67\ lb/in^2}$$

6. DETERMINE THE LIVE LOAD (LL) USING THE TABLE

$$\mathbf{LL = 2.08\ lb/in^2}$$

7. CALCULATE THE TOTAL LOAD (TL)

$$\mathbf{TL = DL + LL = 16.67\ lb/in^2 + 2.08\ lb/in^2 = 18.75\ lb/in^2}$$

4" SCHEDULE 40 CONDUIT IS A SUITABLE CONDUIT FOR THIS APPLICATION SINCE THE TOTAL LOAD OF 18.75 lb/in^2 IS LESS THAN THE MAXIMUM LOAD OF 57.87 lb/in^2 THE 4" SCHEDULE 40 CONDUIT WOULD DEFLECT LESS THAN 5%.

EXAMPLE 2: *4" DB-60 DUCT WILL BE BURIED 3 FEET BELOW A RAILWAY IN TYPE III SOIL. 4" DB-60 HAS A PIPE STIFFNESS OF 60 lb/in^2 .*
NOTE: SINCE THE PIPE STIFFNESS IS KNOWN, MEAN RADIUS AND THE MOMENT OF INERTIA IS NOT REQUIRED TO BE CALCULATED.

1. CALCULATE THE MAXIMUM LOAD FOR 5% DEFLECTION (W)

$$\mathbf{W = [\Delta X*(0.149*PS + 0.061*E^1)]/(D*K) = [0.05*(0.149*60\ lb/in^2+0.061*1000\ lb/in^2)]/(1.5*0.1) = 23.31 lb/in^2}$$

2. CALCULATE THE DEAD LOAD (DL)

$$\mathbf{DL = \gamma * H/144 = 120\ lb/ft^3*3\ ft/144 = 2.5\ lb/in^2}$$

3. DETERMINE THE LIVE LOAD (LL) USING THE TABLE

$$\mathbf{LL = 23.61\ lb/in^2}$$

4. CALCULATE THE TOTAL LOAD (TL)

$$\mathbf{TL = DL + LL = 2.5\ lb/in^2 + 23.61\ lb/in^2 = 26.11\ lb/in^2}$$

4" DB-60 DUCT IS NOT A SUITABLE DUCT FOR THIS APPLICATION SINCE THE TOTAL LOAD OF 26.11 lb/in² EXCEEDS THE MAXIMUM LOAD OF 23.31 lb/in². THE 4" DB-60 DUCT WOULD DEFLECT MORE THAN 5%.

IF THE CALCULATION WAS REPEATED USING DB-120 DUCT THE MAXIMUM LOAD WOULD BE 26.29 lb/in². THE NEW MAXIMUM LOAD WOULD EXCEED THE TOTAL LOAD OF 26.11 lb/in² INDICATING THAT THE DB-120 DUCT WOULD BE ACCEPTABLE TO USE.

Calculation for actual design criteria is conducted by Professional Engineers. This document is meant for informational purposes only.