Road Crossing Calculations

Project: Mabrouk North East Development Project- FEED

PL1 to PL6 16" PRODUCTION HEADER from RMS to CEMS

Design factor for Hoop stress

$DF_{Hs} := 0.6$

Design factor for Effective stress

$DF_{ES} := 0.9$

Design factor for Fatigue stress for Heavy Transporte

$DF_{FSH} := 0.6$

Design factor for Fatigue stress for Rig62

$DF_{FSR} := 1.0$

pipe size, Outside Diam

$D := 16\ \text{in} = 0.4064\ \text{m}$

Corrosion allowance for DSS

$t_{corr} := 0\ \text{mm}$

Pipe nominal thickness

$t := 10.5\ \text{mm}$

Corroded wall thickness

$t_w := t + t_{corr} = 10.5\ \text{mm}$

SMYS of linepipe material

$SMYS := 65000\ \text{psi}$

Longitudinal joint factor

$E_j := 1.0$

Design pressure

$P := 120\ \text{bar}$

Design temperature

$T_2 := 110\ °\text{C}$

Installation (backfill) temp

$T_1 := 26\ °\text{C}$

$\Delta T := T_2 - T_1 = 84\ \Delta°\text{C}$

Youngs modulus of steel

$E := 1.9995 \cdot 10^5\ \text{MPa}$

Poisson ratio

$\nu := 0.300$

Soil density

$\gamma := 18.9 \frac{kN}{m^3} = 18900 \frac{Pa}{m}$

This is not normal density; it's **force density**, in which it's the negative gradient of pressure; hence, measured in force/volume.

Thermal expansion coefficient

$\alpha := \left(1.3000 \cdot 10^{-5}\right) \cdot \frac{1}{\Delta °C}$

Modulus of soil reaction

$E' := 3.40 \frac{N}{mm}$

Soil resilient modulus

$E_r := 69.00 \frac{N}{mm^2}$

Depth of cover

$H := 1500\ mm = 4.9213\ ft$

Bored diameter

$B_d := 406.4\ mm$

$SHi_{Barlow} := \frac{P \cdot D}{2 \cdot t_w} = 33681.9066\ psi$

Allowabe stress

$AS := DF_{FSH} \cdot E_j \cdot SMYS = 39000\ psi$

Check Point 1

$\begin{cases} \text{"Increase WT; go to step 5.1"} & \text{if } SHi_{Barlow} \le AS \\ \text{"proceeed"} & \text{otherwise} \end{cases} = \text{"Increase WT; go to step 5.1"}$

Diameter ratio

$n_{Dai} := \frac{t_w}{D} = 0.0258$

For above tw / D value, from Fig 3 API 1102, find KHe (Stiffness factor for earth load circumferential stress)

Stiffness factor for earth load circumferential stress

$K_{He} := 1800$

Depth to bored diameter

$n_{Depth} := \frac{H}{B_d} = 3.6909$

For above H / Bd value, from Fig 4 API 1102, find Be (Burial factor for earth load circumferential stress)

Burial factor for earth load circumferential stress

$B_e := 0.88$

Bored diameter to outside diameter ratio

$n_{Bored} := \frac{B_d}{D} = 1$

Refer to API 1102 4.7.2.1 & Fig 5 API 1102, find Ee (Excavation factor for earth load circumferential stress)

Excavation factor for earth load circumferential stress

$E_e := 0.83$

API 1102 equation 1

$S_{He} := K_{He} \cdot B_e \cdot n_{Bored} \cdot \gamma \cdot D = 12.1666\ \mathrm{MPa}$

Check Impact factor, Fi and applied design surfaces pressure, w

Impact factor from Fig 7 API 1102

$F_i := 1.5$

Step 2.0 for ABRAJ RIG

Contact area over applied wheel load

$A_{p.RIG62} := 0.74\ \mathrm{m}^2$

$P_t := 895\ \mathrm{kN} = 2.012 \cdot 10^5\ \mathrm{lbf}$

$w := \frac{P_t}{A_{p.RIG62}} = 1.2095\ \mathrm{MPa}$

applied surface pressure

$w = 1.2333 \cdot 10^5\ \frac{\mathrm{kgf}}{\mathrm{m}^2}$

From Fig 15 API 1102, & D value find GHh (Geometry factor for cyclic circumferential stress from highway vehicle load)

Geometry factor for cyclic circumferential stress

$G_{Hh} := 1.05$

Refer to Table 2, API 1102, and find Highway pavement type factor (R) and Highway axle configuration factor (L)

Highway pavement type factor

$R := 1.10$

Highway axle configuration factor

$L := 0.65$

From Fig 14 API 1102, & tw / D value, find KHh (Highway stiffness factor for cyclic circumferential stress)

Highway stiffness factor for cyclic longitudinal stress

$K_{Hh} := 13.00$

Cyclic stresses

$\Delta S_{Hh} := K_{Hh} \cdot G_{Hh} \cdot R \cdot L \cdot F_i \cdot w = 17.706 \text{ MPa}$

Circumferential stress due to internal pressurization

$$S_{Hi} := P \cdot \frac{\left(D - t_w\right)}{\left(2 \cdot t_w\right)} = 226.2286 \text{ MPa}$$

$K_{Lh} := 9.00$

$G_{Lh} := 1.20$

$\Delta S_{Lh} := K_{Lh} \cdot G_{Lh} \cdot R \cdot L \cdot F_i \cdot w = 14.0092 \text{ MPa}$

API 1102 equation 9: Single Axle (PDO Rig 62)

$S_1 := S_{He} + \Delta S_{Hh} + S_{Hi} = 2.561 \cdot 10^8 \text{ Pa}$

API 1102 equation 10: Maximum longitudinal stress

$S_2 := \Delta S_{Lh} - \left(E \cdot \alpha \cdot \Delta T\right) + \nu \cdot \left(S_{He} + S_{Hi}\right) = -1.3282 \cdot 10^8 \text{ Pa}$

API 1102 equation 11: Radial stress

$S_3 := -P = -1.2 \cdot 10^7 \text{ Pa}$

API 1102 equation 12: Effective stress for Single Axle (PDO Rig 62)

$$S_{eff} := \sqrt{\frac{1}{2} \cdot \left(\left(S_1 - S_2\right)^2 + \left(S_2 - S_3\right)^2 + \left(S_3 - S_1\right)^2\right)} = 344.7703 \text{ MPa}$$

API 1102 equation 13

$$\begin{cases} \text{"Check Fatigue stresses"} & \text{if } \left(SMYS \cdot DF_{ES}\right) \geq S_{eff} \\ \text{"Increase WT; Go to Step 5.1"} & \text{otherwise} \end{cases} = \text{"Check Fatigue stresses"}$$

Refer Table 3 API 1102, and get fatigue endurance limit of girth weld,SFG for pipe

$S_{FG} := 12000\ \text{psi} = 8.2737 \cdot 10^{7}\ \text{Pa}$

Allowable SFG for Rig62

$S_{AFG} := DF_{FSR} \cdot S_{FG} = 82.7371\ \text{MPa}$

API 1102 equation 14

$\begin{cases} \text{"Pass; Check Longitudinal welds"} & \text{if } \Delta S_{Lh} \le DF_{FSR} \cdot S_{FG} \\ \text{"Increase WT; Go to Step 5.1"} & \text{otherwise} \end{cases} = \text{"Pass; Check Longitudinal welds"}$

Refer Table 3 API 1102, and get fatigue endurance limit of Longitudinal weld, SFL for pipe

Longitudinal weld endurance limit

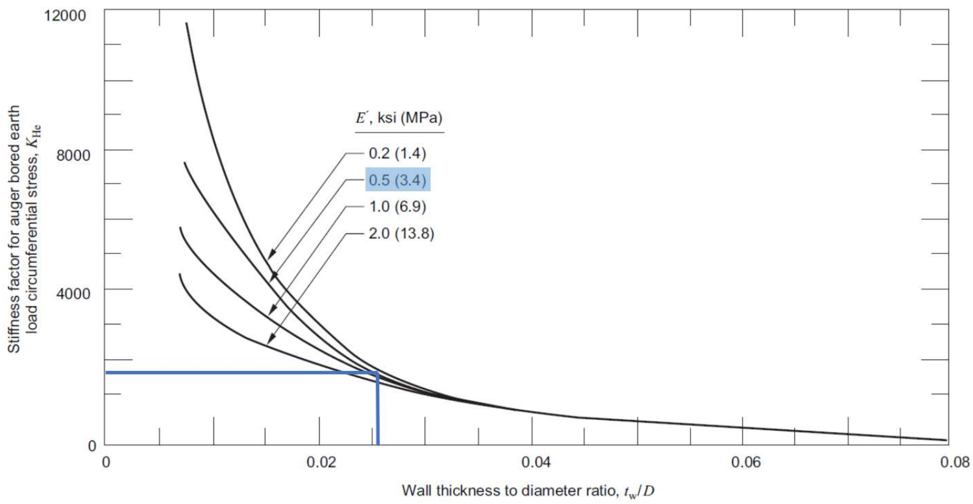
$S_{FL} := 158.579\ \text{MPa}$

Allowable SFL for Rig62

$S_{AFL} := DF_{FSR} \cdot S_{FL} = 158.579\ \text{MPa}$

$\begin{cases} \text{"Pass; calculations completed"} & \text{if } \Delta S_{Hh} \le S_{AFL} \\ \text{"Increase WT; Go to Step 5.1"} & \text{otherwise} \end{cases} = \text{"Pass; calculations completed"}$

⊟— Figures



NOTE See Table A-1 for soil descriptions.

Figure 3—Stiffness Factor for Earth Load Circumferential Stress, K_{He}

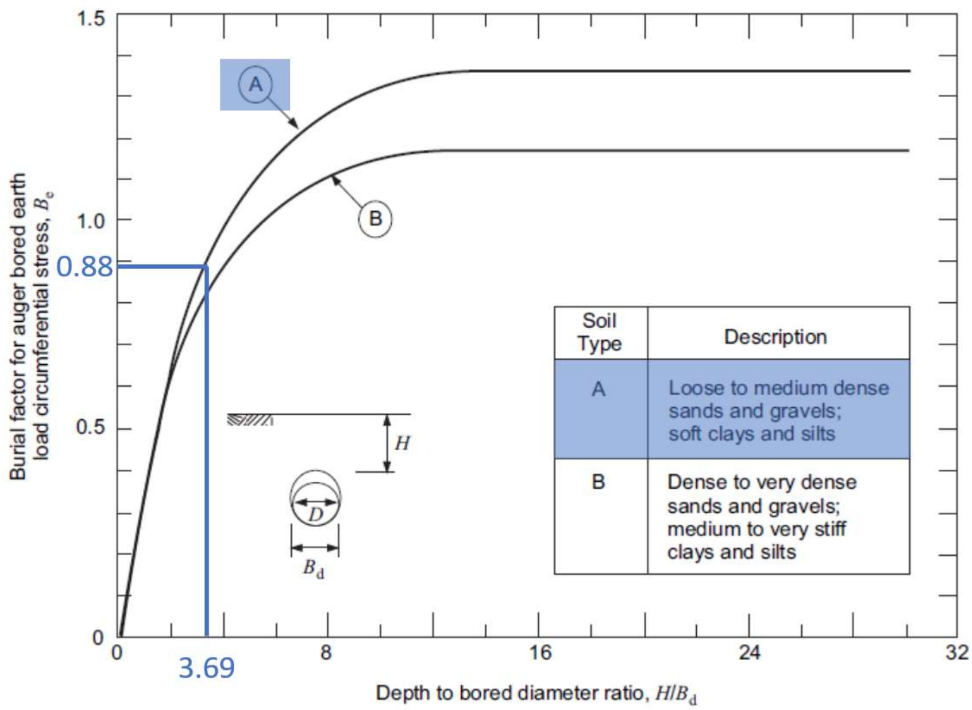


Figure 4—Burial Factor for Earth Load Circumferential Stress, B_e

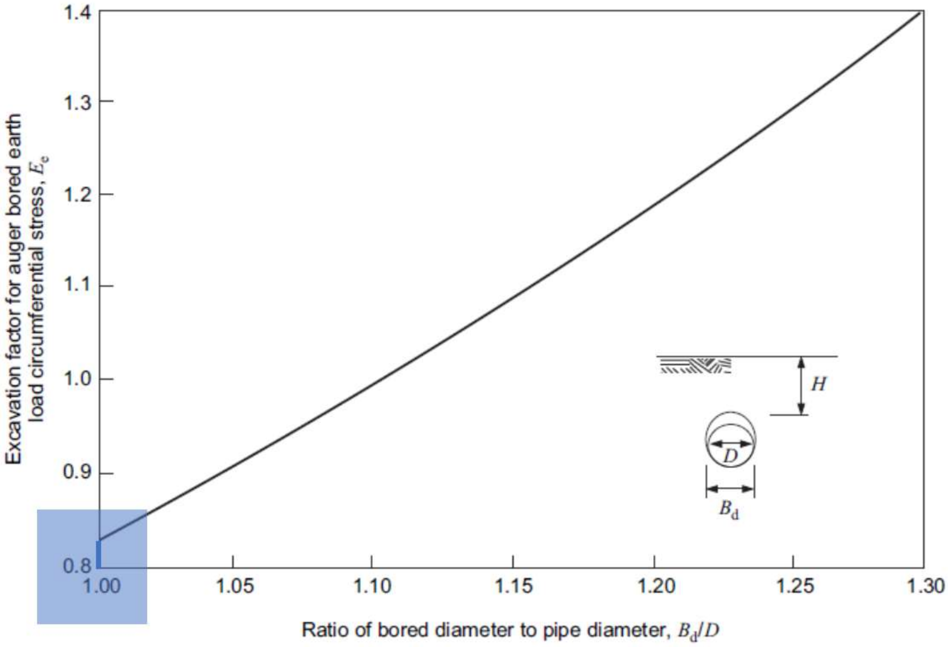


Figure 5—Excavation Factor for Earth Load Circumferential Stress, E_e

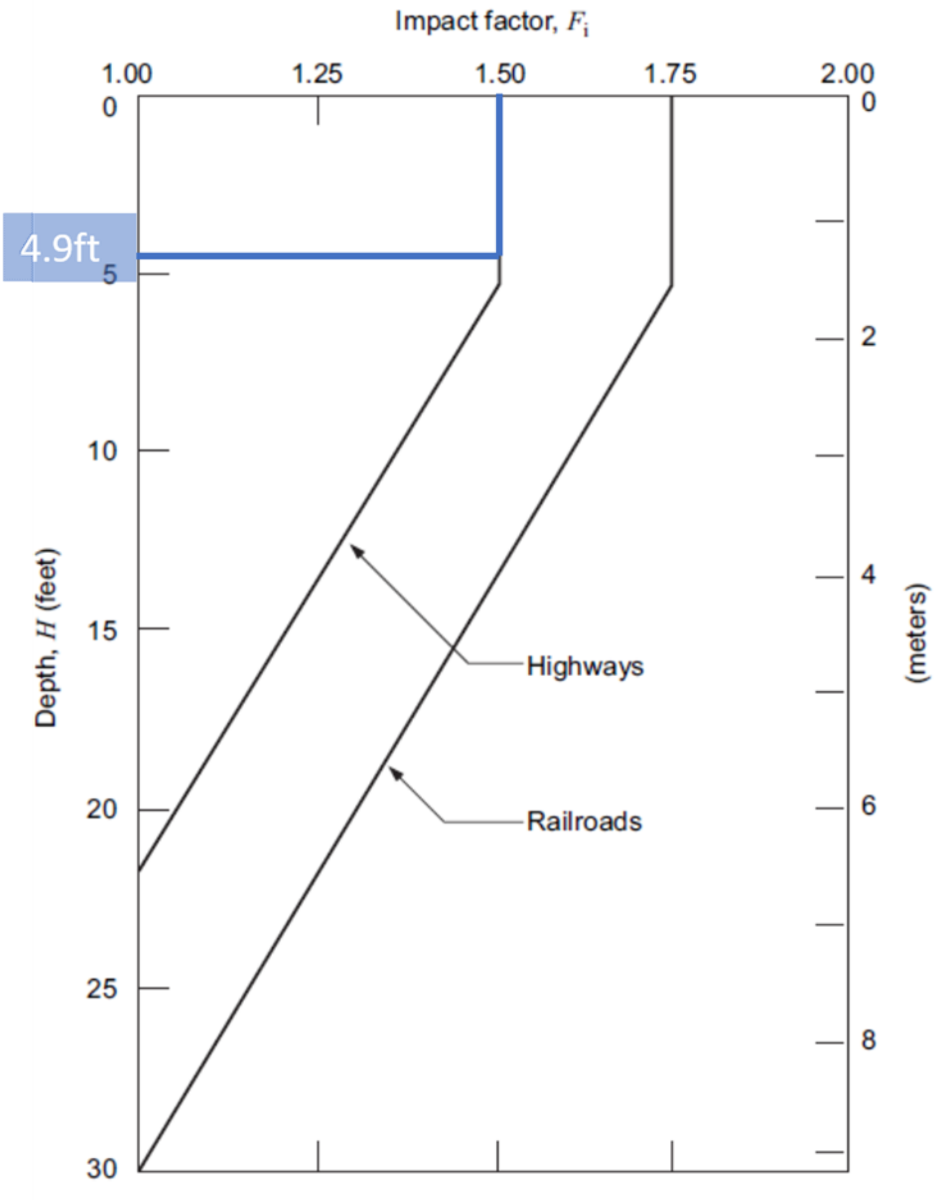


Figure 7—Recommended Impact Factor Versus Depth

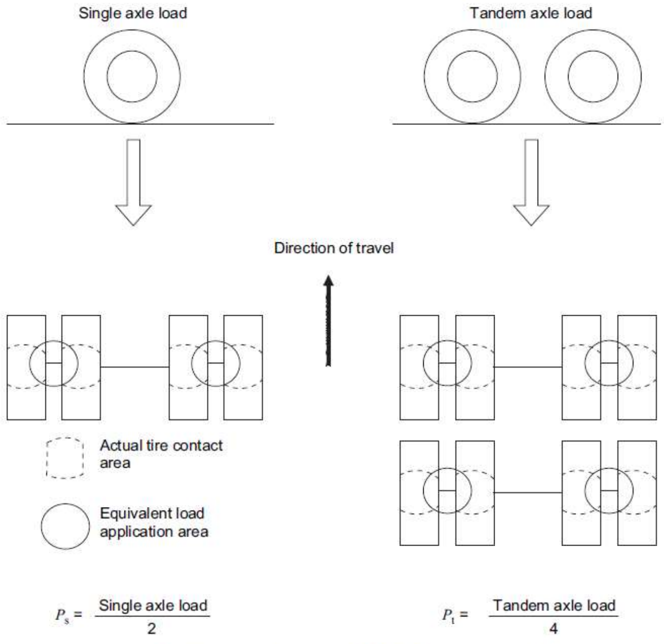
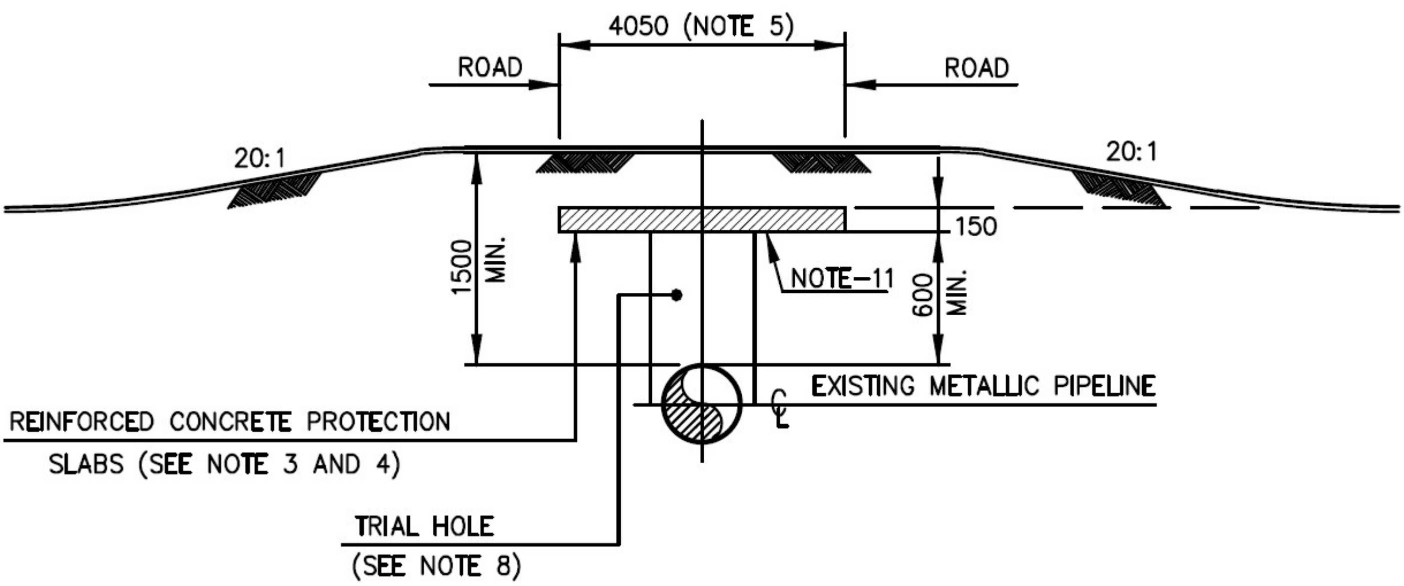


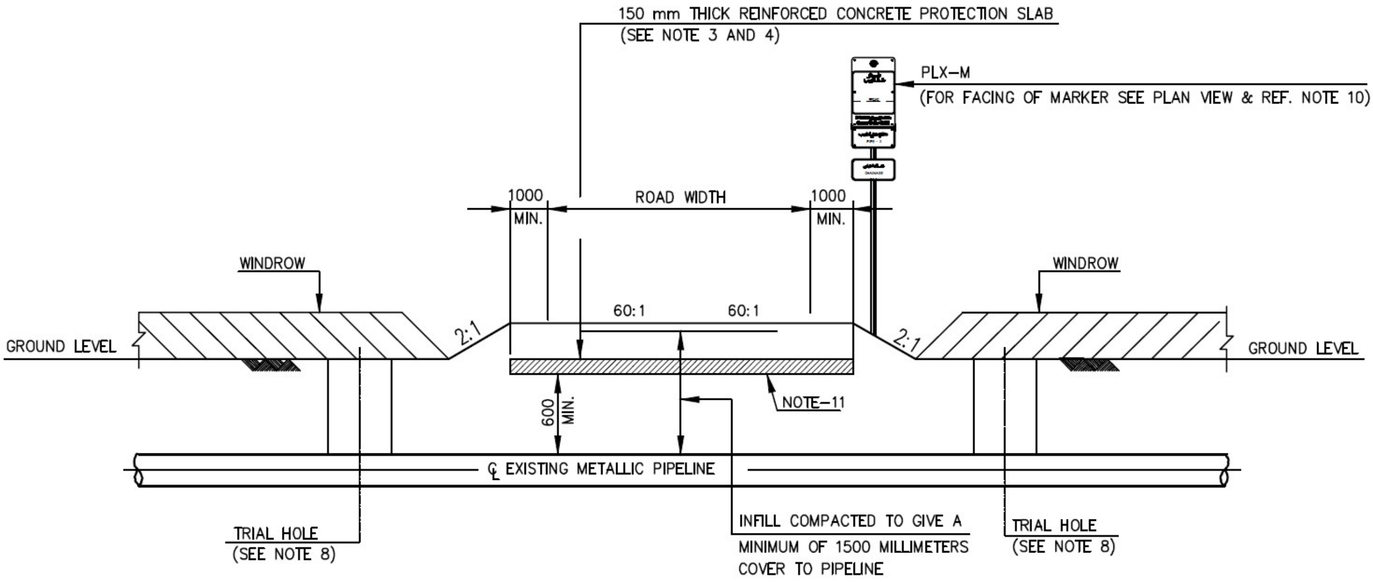
Figure 6—Single and Tandem Wheel Loads, P_s and P_t

Table 1—Critical Axle Configurations for Design Wheel Loads of P_s = 12 Kips (53.4 kN) and P_t = 10 Kips (44.5 kN)

Depth of burial, H, < 4 ft (1.2 m) and diameter, D, ≤ 12 in. (305 mm)	
Pavement Type	Critical Axle Configuration
Flexible pavement No pavement Rigid pavement	Tandem axles Single axle Tandem axles
Depth, H, < 4 ft (1.2 m) and diameter, D, > 12 in. (305 mm) Depth, H, ≥ 4 ft (1.2m) for all diameters	
Pavement Type	Critical Axle Configuration
Flexible pavement No pavement Rigid pavement	Tandem axles Tandem axles Tandem axles



SECTION A-A
(SCALE: N.T.S)



SECTION B–B
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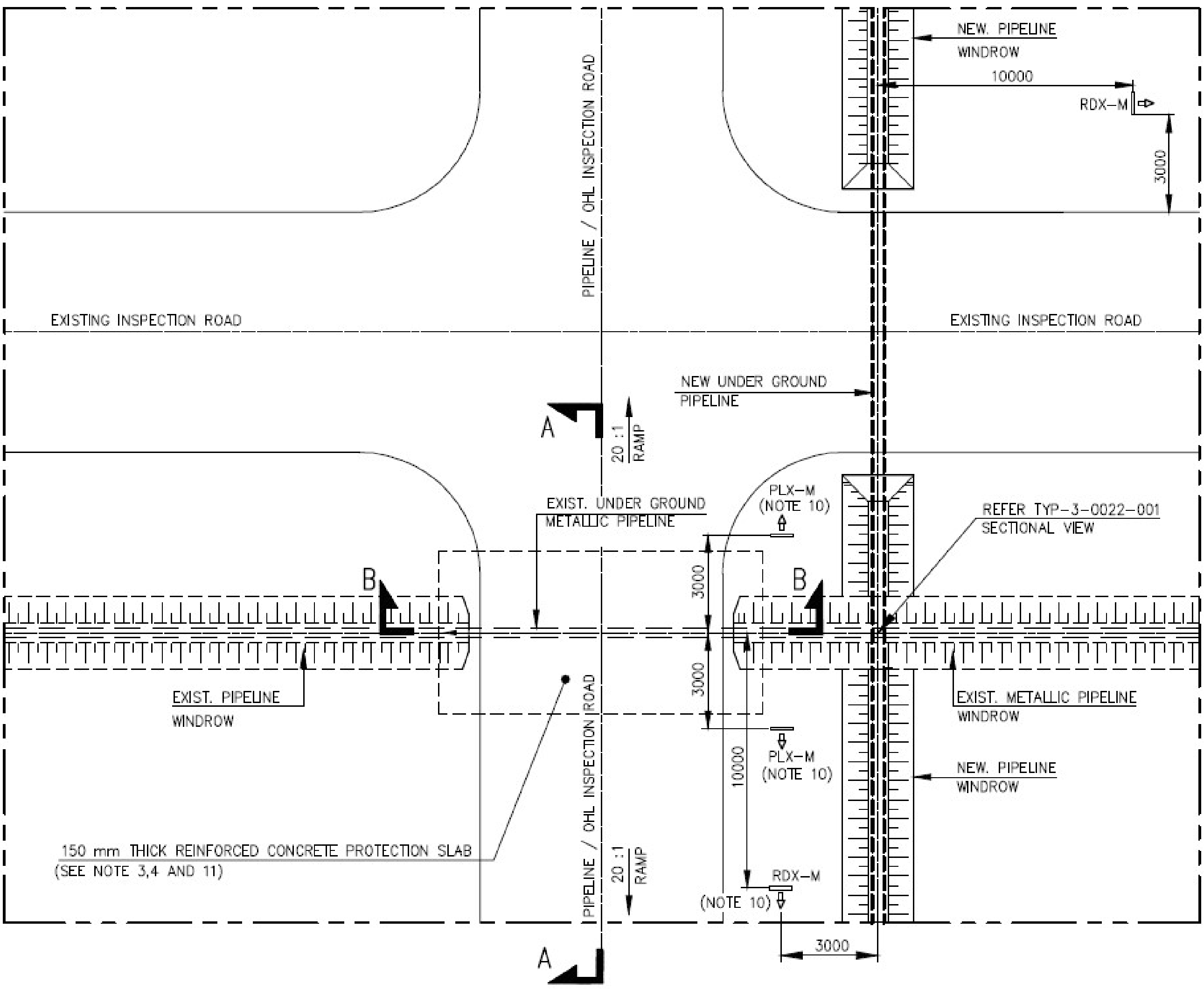
TYPICAL ROAD CROSSING OVER EXISTING UNDER GROUND PIPELINE



PLAN VIEW
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