C. Appendix. Sample of back calculated soil modulus using SDM

Soil steel culvert number 6, Newport

$D = 3855\ mm$

$h_c = 500\ mm$

$E_s = 205000\ MPa$

$I_s = 163,6\ \dfrac{mm^4}{mm}$

$\dfrac{R_t}{R_s} = 1$ (Pipe arch)

$P_{traffic} = 163\ \dfrac{kN}{m}$

$\dfrac{h_c}{D} = 0,1297$

$M_t = 6,1\ \dfrac{kN \cdot m}{m}$

Calculations

$$M_t = f_4' \cdot f_4'' \cdot f_4''' \cdot f_4^{IV} \cdot D \cdot p_{traffic} + S_{ar}\left(\frac{R_t}{R_s}\right)^{0,75} \cdot f_1 \cdot f_{2,\,cover} \cdot q \cdot D^2$$

as there isn't any distributed load acting over the culvert, the parameter q is set to 0 and the equation stays like this:

The parameter λ_f is unknown and I want to solve the equation to know its value. I named x to the value of $^{10}\log(\lambda_f)$ to make the equation easier to solve.

$$f_4' = 0,65 \cdot \left(1 - 0,2 \cdot {}^{10}\log(\lambda_f)\right) = 0,65 \cdot (1 - 0,2x)$$

$$f_4'' = 0,12 \cdot \left(1 - 0,15 \cdot {}^{10}\log(\lambda_f)\right) = 0,12 \cdot (1 - 0,15x)$$

$$f_4''' = 4 \cdot \left(0.01^{(h_c/D)} + 0.1 \right) = 2.6$$

$$f_4^{IV} = \left(\frac{R_t}{R_s} \right)^{0.25} = 1$$

Then the equation is rewritten using the equations defined above and the known values of D and $p_{traffic}$:

$$M_t = 0.65(1 - 0.2x) \cdot 0.12(1 - 0.15x) \cdot 2.6 \cdot 1 \cdot 3.855 \cdot 163$$

now the factor M_t is replaced by the value extracted fro the report:

$$6.1 = 0.65(1 - 0.2x) \cdot 0.12(1 - 0.15x) \cdot 2.6 \cdot 1 \cdot 3.855 \cdot 163$$

and the equation become a second degree equation and the solutions are:

$$x_1 = 7.345 \rightarrow \lambda_{f1} = 22.181.964,2 \qquad \text{Incorrect solution}$$

$$x_2 = 4.32 \rightarrow \lambda_{f2} = 20.892,96 \qquad \text{Correct solution}$$

Now knowing the value of λ_f we can continue and finally calculate the soil modulus

$$E_{sd} = \frac{\lambda_f \cdot (EI)_s}{D^3} = 12.23 \; MPa$$