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Calculation of Loads on DBK Pipe Supports Installed in Gravel

The Technological Institute, Department of Plastics & Packaging, has been commissioned by Dansk Byggekomponent ApS to carry out calculations of the loads acting on two types of DBK pipe supports in the case of covering pipe installations with uncompacted gravel.

When pipe installations and pipe supports are covered with gravel, settlements occur over time both in the gravel material and in the underlying soil layers. These settlements cause a downward movement of the gravel material, which leads to loading of the pipe installations as well as of the pipe supports.

Within the scope of the calculations, three different load scenarios are applied in which the gravel cover affects the pipe installations and pipe supports in different ways:

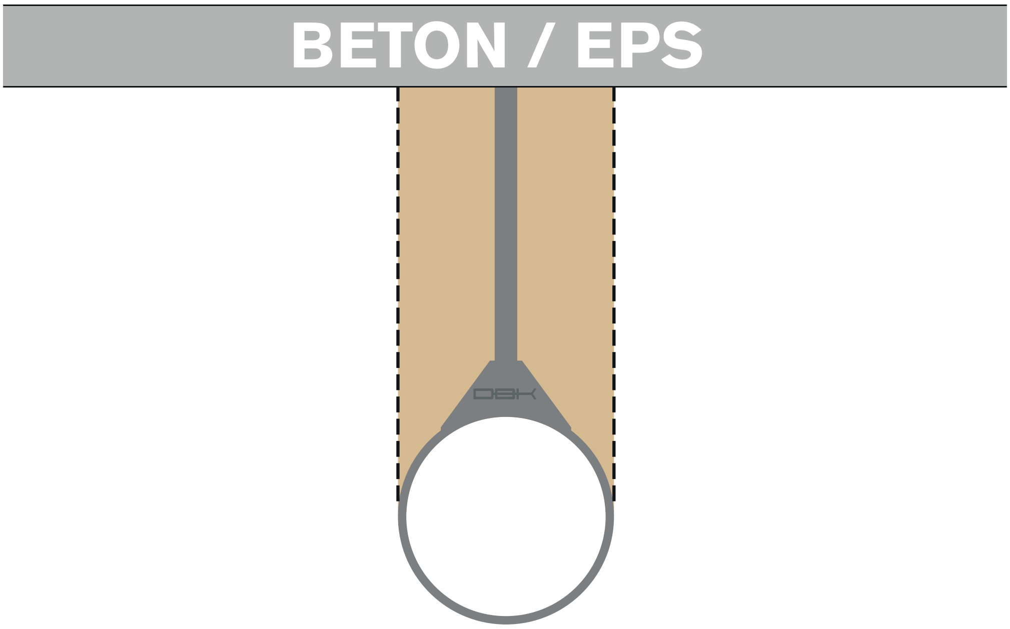
Scenario 1	Gravel is located directly above the pipe across the full pipe width (corresponding to the pipe diameter).
Scenario 2	Gravel is located at an angle of 45° against the pipe; the load acts in the form of a triangle with the deepest point located on the centre line above the pipe.
Scenario 3	Gravel is located at an angle of 45° against the centre point of the pipe.

The calculations are carried out for two sizes of DBK pipe supports, namely nominal diameter 110 mm and nominal diameter 160 mm.

Assumptions:

• Thickness of the gravel cover above the pipe:	$t = 0{,}25$ m
• Bulk density of the gravel material:	$\gamma = 11$ kN/m^3
• Angle of internal friction (conservatively assumed):	$\phi = 45°$
• Pipe diameter (Ø110 mm):	dØ110 = 0,11 m
• Pipe diameter (Ø160 mm):	dØ160 = 0,16 m
• Self-weight of the water-filled pipe Ø110 mm:	mØ110 = 93 N/m
• Self-weight of the water-filled pipe Ø160 mm:	mØ160 = 197 N/m
• Spacing between the pipe supports:	lb = 0,5 m

Scenario 1: Gravel covers the pipe to the width of the pipe diameter.



Load per pipe support (Ø110 mm):

$F_{1a} = (P_{1a} * l_b * \gamma) + (m_{ø110} * l_b)$, hvor

$$P_{1a} = \left(d_{ø110} * \left(t + \frac{d_{ø110}}{2}\right)\right) - \left(0{,}5 * \frac{\pi}{4} * {d_{ø110}}^2\right)$$

$$P_{1a} = \left(0{,}11 * \left(0{,}25 + \frac{0{,}11}{2}\right)\right) - \left(0{,}5 * \frac{\pi}{4} * 0{,}11^2\right) \text{ [m}^2\text{]}$$

$P_{1a} = 0{,}024$ [m²]

Load per pipe support:

$F_{1a} = (0{,}024 * 0{,}5 * 11 * 10^3) + (93 * 0{,}5) = 178{,}8$ [N] = 18,2 [kg]

Load per pipe support (Ø160 mm):

$F_{1b} = (P_{1b} * l_b * \gamma) + (m_{ø160} * l_b)$, hvor

$$P_{1b} = \left(d_{ø160} * \left(t + \frac{d_{ø160}}{2}\right)\right) - \left(0{,}5 * \frac{\pi}{4} * {d_{ø160}}^2\right)$$

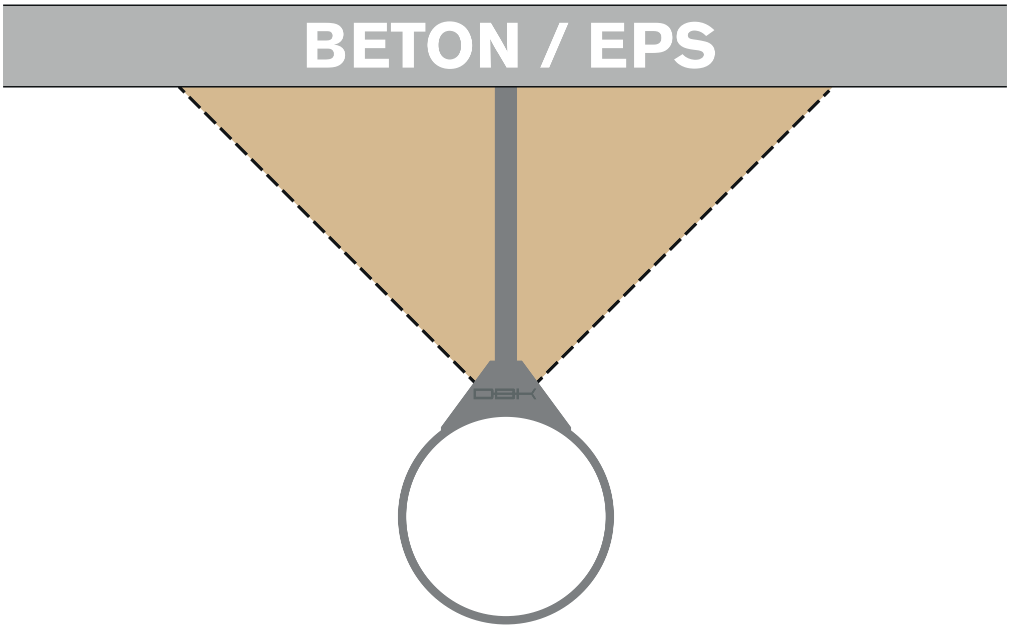
$$P_{1b} = \left(0{,}16 * \left(0{,}25 + \frac{0{,}16}{2}\right)\right) - \left(0{,}5 * \frac{\pi}{4} * 0{,}16^2\right) \text{ [m}^2\text{]}$$

$P_{1b} = 0{,}033$ [m²]

Load per pipe support:

$F_{1b} = (0{,}033 * 0{,}5 * 11 * 10^3) + (197 * 0{,}5) = 278{,}3$ [N] = 28,3 [kg]

Scenario 2: Gravel sloping down at a 45° angle to the pipe (triangle, point in the center line)



Load per pipe suppor (Ø110 mm):

$F_{2a} = (P_{2a} * l_b * \gamma) + (m_{ø110} * l_b)$, hvor

$P_{2a} = \left(\frac{1}{2} * t * (2 * t)\right) = (t * t)$

$P_{2a} = (0{,}25 * 0{,}25)$ [m²]

$P_{2a} = 0{,}063$ [m²]

Load per pipe support:

$F_{2a} = (0{,}063 * 0{,}5 * 11 * 10^3) + (93 * 0{,}5) = 390{,}3$ [N] = 39,7 [kg]

Load per pipe support (Ø160 mm):

$F_{2b} = (P_{2b} * l_b * \gamma) + (m_{ø160} * l_b)$, hvor

$P_{2b} = (t * t)$

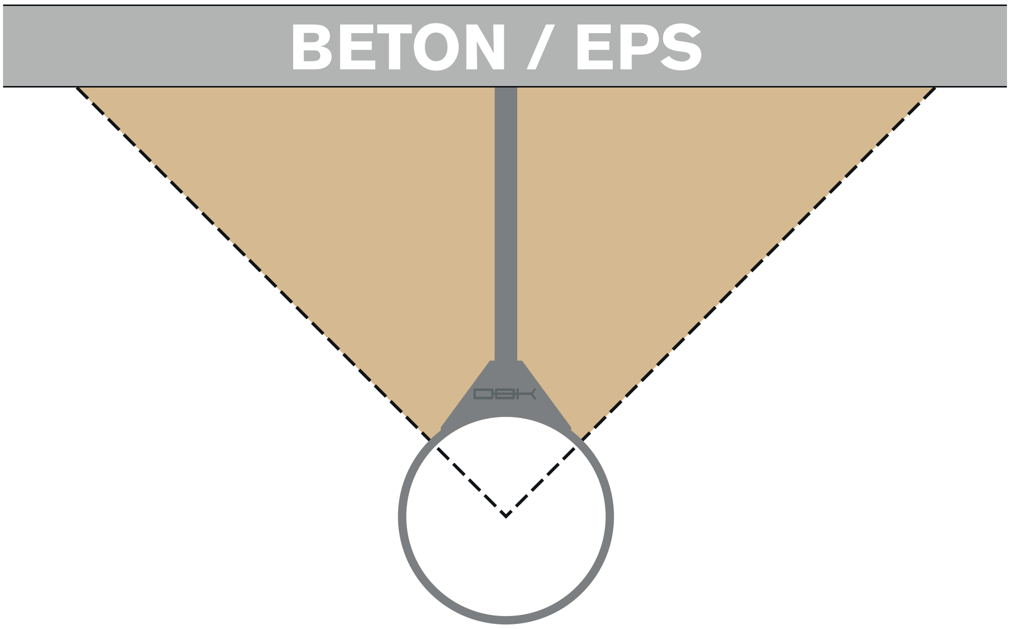
$P_{2b} = (0{,}25 * 0{,}25)$ [m²]

$P_{2b} = 0{,}063$ [m²]

Load per pipe support:

$F_{2b} = (0{,}051 * 0{,}5 * 11 * 10^3) + (197 * 0{,}5) = 440{,}3$ [N] = 44,8 [kg]

Scenario 3: Gravel sloping down at a 45° angle towards the center of the pipe (triangle, point in the middle)



Load per pipe support (Ø110 mm):

$F_{3a} = (P_{3a} * l_b * \gamma) + (m_{ø110} * l_b)$, hvor

$P_{3a} = \left(t + \frac{d_{ø110}}{2}\right) * \left(t + \frac{d_{ø110}}{2}\right) - \left(\frac{1}{4} * \frac{\pi}{4} * d_{ø110}{}^2\right)$

$P_{3a} = (0,31 * 0,31) - \left(\frac{1}{4} * \frac{\pi}{4} * 0,11^2\right)$ [m^2]

$P_{3a} = 0,091$ [m^2]

Load per pipe support:

$F_{3a} = (0,091 * 0,5 * 11 * 10^3) + (93 * 0,5) = 545,1$ [N] $= 55,5$ [kg]

Load per pipe support (Ø160 mm):

$F_{3b} = (P_{3b} * l_b * \gamma) + (m_{ø160} * l_b)$, hvor

$P_{3b} = \left(t + \frac{d_{ø160}}{2}\right) * \left(t + \frac{d_{ø160}}{2}\right) - \left(\frac{1}{4} * \frac{\pi}{4} * d_{ø160}{}^2\right)$

$P_{3b} = (0,33 * 0,33) - \left(\frac{1}{4} * \frac{\pi}{4} * 0,16^2\right)$ [m^2]

$P_{3b} = 0,104$ [m^2]

Load per pipe support:

$F_{3b} = (0,104 * 0,5 * 11 * 10^3) + (197 * 0,5) = 669,8$ [N] $= 68,2$ [kg]

Safety

Previously conducted tests of the DBK pipe supports showed the following average values of failure load / load-bearing capacity:

- Ø110 mm: 152 kg
- Ø160 mm: 124 kg

At the maximum load according to the above calculations, the safety factor against failure at short-term load is:

$$S_{ø110} = \frac{Brudstyrke}{Maks.last} = \frac{152}{F_{3a}} = \frac{152}{55{,}5} = 2{,}7$$

Based on the maximum calculated loads, adequate safety against failure under short-term loading is achieved for both pipe support sizes.

$$S_{ø160} = \frac{Brudstyrke}{Maks.last} = \frac{124}{F_{3b}} = \frac{124}{68{,}2} = 1{,}8$$

Comments

Of the three calculated scenarios, Scenario 3 corresponds most closely to a classical geotechnical foundation calculation in soil. In the calculation of Scenario 3, an internal friction angle of 45° has been applied, which is regarded as conservative for uncompacted gravel.

The actual loads acting on the pipe installations and pipe supports are expected to be lower than the loads calculated in all three load scenarios.

As the use of uncompacted gravel is specified, any load build-up in the overlying gravel material will be of very short duration. The gravel will slide to the sides past the pipe, after which the pipe supports will again be loaded solely by the self-weight of the pipe and its contents.

Yours sincerely

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