Buried PA 12 pipes for then transport of gas & water; No sand embedding necessary?

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Introduction

In the past the service life of buried pipe has been shown to be reduced due to stress concentrations caused by external point loads. The service life of the pipes is closely related to the material‘s resistance against slow crack growth.

This raises the question, whether the creep rupture strength of current PA 12 resins has reached a state of development where a failure of pressure pipes with additional external point loads should not be expected during their service life.

Service Experience

Buried polyethylene pipes can be damaged by point or linear loads which are acting in addition to the design loads (e.g. internal pressure, earth and traffic load). Linear loads can for example be produced by wood used as supports below the pipe during installation and not removed before the trench was backfilled.

The starting point of the crack is located at the inside of the pipe wall and travels to the outside. The fracture surface shows very low deformations which is typical for creep rupture failure. The creep rupture failure is caused both by the internal pressure and the additional load generated by an object pressing against the external pipe wall.

Such failures won’t occur if the creep rupture strength at the inside of the pipe wall is above the overall local stress at this point.

Test Material

Polyamide 12 pipes[1] 110 x 10 mm (SDR 11) were used for the investigations.

The resistance against slow crack growth of the samples was tested using the Full Notch Creep Test (FNCT) following EN 12814-3 Annex A. This test method is also described in supplementary sheet 2 of guideline DVS 2203 part 4 and in ISO-draft: „ISO/DIS16770 „Plastics – Determination of environmental stress cracking (ESC) of polyethylene (PE) – Full–notch creep test (FNCT)“.

The test specimens were cut from the pipes in the axial direction with parallel sides and approximately square cross-sections. Each specimen was notched perpendicular to the parallel length in the middle of the test specimen.

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[1] Resin: Vestamid BS0942: EVONIK, Germany; Pipe Producer: EGEPLAST, Germany

The specimens were loaded by a constant tensile stress between 14 and 8 ± 0,05 N/mm²
relating to the remaining unnotched cross-sections. The deviation from the nominal test temperature was ± 0.2 K.

The tensile creep tests were performed on 3 test specimens per temperature using an aqueous solutions of NM 5 (mixture of anionic and kationic tensides) in demineralised water (2/100, w/w).

Principle and Limiting Conditions of the Tests

External Point Load

The maximum stress that the pipe material will experience from a point load is the yield stress. Therefore in this test it was ensured that the displacement of the point load into the pipe wall was sufficient to cause yielding of the material at the inside of the pipe.

Since the additional stress in the pipe wall far from the point of load will be zero all possible stresses that might occur in the field due to a pint load are represented in this test.

There are two scenario which are not covered: One the penetration of a sharp object - e.g. a nail – through the pipe wall and two the complete crushing of the pipe, e.g. by a large rock. In the last case the pipe is no longer functioning, but the force on the pipe is comparable to the test load in the point loading test.

The required surface elongation at the inner pipe wall (i.e. the above yield elongation) was produced by the displacement of a tool along the radius of the pipe with a tool tip radius of 5 mm. The tool loading was carried out at room temperature with no internal pressure in the pipe. The tool was loaded until a cord with a length of 5 mm was measured at the inside surface of the pipe (fig. 1).

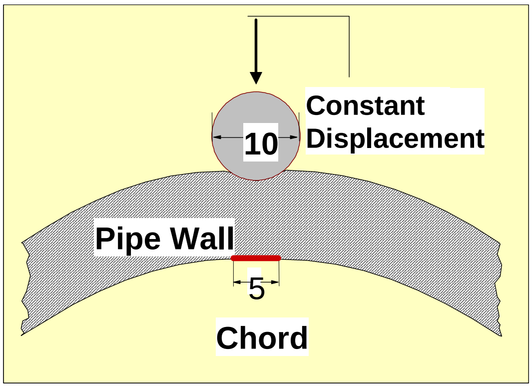

Fig. 1: Loading by an external point load before starting the internal pressure test

The elongation at the inside surface can be calculated using the following equation:

$$\varepsilon = [0{,}318 * F * R] / [b' * s * E(t)]$$

where:

ε	Elongation at the inner surface of the pipe wall
F	Radial acting force (single load)
R	Mean pipe radius
s	Wall thickness
E(t)	E-modulus
b‘	Supporting width

The supporting width of the load (b') can be determined experimentally by measuring the force on the tool with the pipe under internal pressure.

Finite element calculations (fig. 2) confirm that the tool loading with a pipe under internal pressure of 8 bar exceeds the yield elongation of PA 12 which is at 6 %.

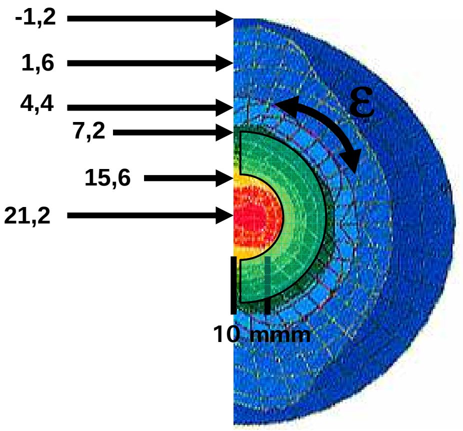

Fig. 2: Edge fiber expansion in % at the inside wall of the pipe due to an external point load and an internal pressure of 8 bar

The internal pressure of the pipes was chosen to produce a hoop stress of 10 N/mm² at 80 °C during the testing (ISO 1167).

Test Temperatures and Medium

The tests were performed at 80 °C, 60 °C and 40 °C.

To accelerate the tests they were performed using an aqueous solution of 2 % detergent and demineralised water. The test fluid was continuously mixed in the pipes to prevent separation.

Failure Mechanism

Assuming that the process of slow crack growth (stress cracking) is the relevant long term failure mode at pipes under additional external point load the resistance against stress cracking is tested in FNCT.

Results

FNCT

The FNCT's were performed in the range between 16 and 8 N/mm². There are obviously two parts of the creep rupture curve (fig. 3). In the flat part (between 16 and 14 N/mm²) the ductile failure mode dominates (fig. 4).

At a test stress of 8 N/mm² typical brittle failure mode can be observed (fig. 5).

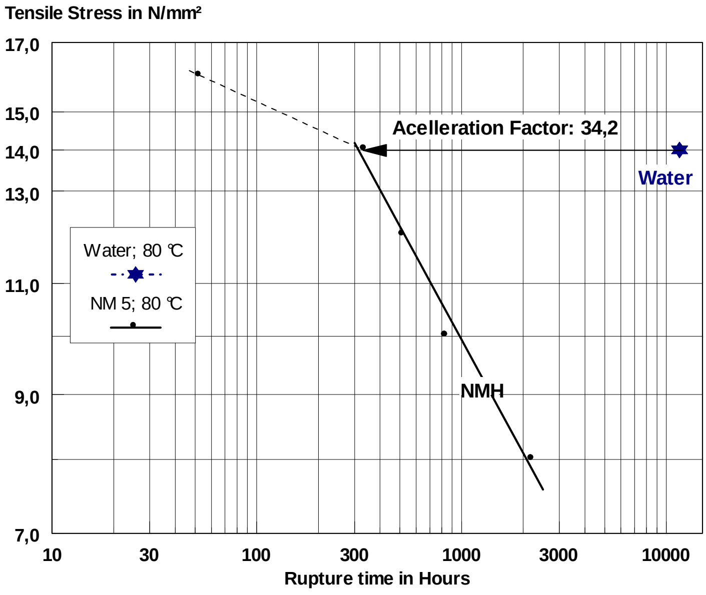

Fig. 3: Creep rupture of PA 12 in the FNCT at 80 °C

Fig. 4: Fracture surface of a FNCT-specimen taken from a PA 12-pipe (16 N/mm²)

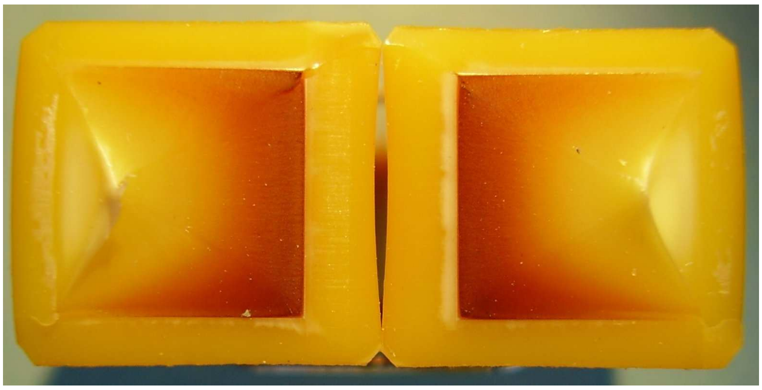

Fig. 5: Fracture surface of a FNCT-specimen taken from a PA 12-pipe (8 N/mm²)

Point loading tests

The specimens tested in the point loading tests did not fail up to the end of July 2008 and have a testing time of 4500 hours at 80 °C.

The final results should be available at the date of the presentation.

Conclusion

The installation of PA 12-pipes for the transport of gas or water without sand embedding should be possible if the internal pressure is limited. The critical pressure will be discussed after all test results are available (at the date of the conference).