Ring Stiffness
Alternative Test Method
for Thermoplastic Pipes

1. General preface to importance of stiffness

The measurement of Pipe-stiffness is described in different national and international standards. The Ring-Stiffness of Pipes is one of the important indicators for the evaluation of Pipe stability.

But Ring-stiffness should not be overvalued, always it has to be considered that the results are measured under Laboratory-conditions. The flexible behaviour of thermoplastic pipes is requested and it's one of the reasons for the positive experience we made worldwide with thermoplastic pipes in the last 50 years.

It is important that pipes provide enough stiffness to avoid higher deformation than permitted and that the wall structure provides enough structural stability to avoid local buckling. Thermoplastic pipes have the capability to avoid or at least to reduce stress concentrations due their flexibility. The creep-behaviour under load is characteristic for thermoplastics and is very helpful to control the deflection-process, due the relaxation of stress-loaded areas.

Mostly the static designs are following international standards like AWWA M55 or the German DWA A 127, but in any case the procedure always considers the flexible behaviour of pipes and working with limits for maximal deformation (e.g. DWA A 127 : 6 %). The long-term experience shows clearly that the static calculations provide very realistic results and the pipe-deformation is lower than the calculated limit. The standards for Ring stiffness-Tests are concentrating on a deformation range of 3%, but also larger deformations can be tested.

2. Standard Ring Stiffness Test Procedures

Mainly we differ two different procedures to measure and evaluate the pipe-stiffness:

a) Testing under constant load
   acc. DIN 16961-2: Thermoplastic pipes with profiled wall and smooth pipe inside
b) Testing under constant speed
   acc. DIN EN ISO 9969: Thermoplastic Pipes – determination of Ring stiffness

At both procedures a cut length of pipe (typically up to 1 m long) is being horizontal supported and compressed vertically between two parallel flat plates.

Testing under constant load goes back to the early standard of DIN 16961, where the procedure until now is standardized. Typically the Test takes 24 hours and a 24h value for stiffness is defined = SR_{24} But also long-term tests up to 2000 or 10000 hours are applicable.

The steps of the test procedure can be summarized as follows:

1. Geometrical analysis of the used wall structure
2. Calculating the theoretical pipe stiffness under consideration of results for geometrical analyses and E_C modulus for the expected testing-time
3. Calculating the test-load (weight) under consideration of chosen theoretical deflection (typical 3%)
4. Beginning Test by loading the pipe crown with calculated weight
5. Measuring deflection during testing time
6. Result for deflection has to be equal or lower than theoretical deflection

Testing under constant speed is standardized in DIN EN ISO 9969 and it is mainly a short-term test.
The ring stiffness is determined by measuring the force and the deflection while deflecting the pipe at a constant deflection speed. The ring stiffness is calculated as a function of the force necessary to produce a 3% diametric deflection of the pipe.
The deflection speed depends on the nominal diameter of the pipe, for large diameters, nominal diameter > 710 mm the speed is specified as 0,03 x Inner diameter [mm/min] with a tolerance of ± 5%

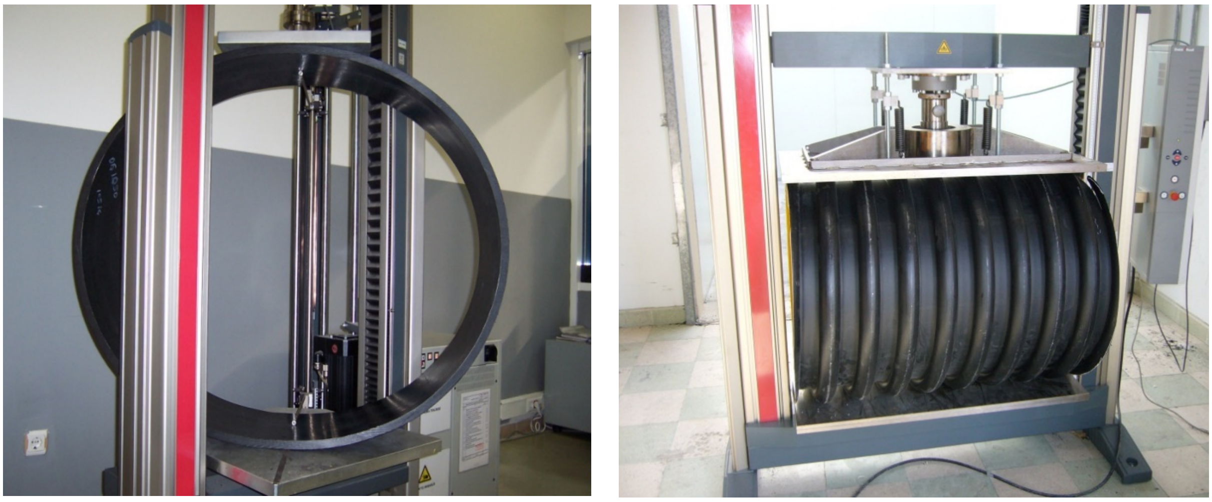
Typically the stiffness is categorized in classes according to the mentioned standards, SN classes = SN 2; SN 4; SN 8; SN 16, but intermediate stiffness values are also often used for technical description: e.g. S = 7 kN/m²

Roughly the stiffness can be calculated theoretically for both procedures so far as the creep modulus E is known and also the geometrical data for moment of inertia and distance of gravity is determined.

$$SN \cong \frac{E_{1min} \times I}{(ID+2\,e)^3} \times 10^3; \text{[kN/m}^2\text{]}$$

$$SR_{24} \cong \frac{E_{24\,h} \times I}{(R+e)^3} \times 10^3 \text{ ; [kN/m}^2\text{]}$$

E_{1min} = Short term flexural modulus [N/mm²]
E_{24} = Flexural modulus for 24 h loading time [N/mm²]
ID = Inner diameter [mm]
R = Inner Radius [mm]
I = specific moment of inertia of wall structure [mm^4/mm]



Pic.1 and 2: Ring stiffness test process acc. ISO 9969 and DIN 16961

3. Alternative Test Procedures for Ring Stiffness

All Manufacturers of large diameter plastic pipes face the same challenge regarding regular testing of ring stiffness. Especially dimensions bigger than DN 2000 are problematic, because of typical existing infrastructure in laboratories. The weight of the cut pipe length and the size itself require special equipment to handle the samples and more than that often bigger laboratories are necessary.

In earlier times thermoplastic pipes did not reach sizes and weights as they do today. Pipe weights of more than 2 ton/m are now realistic. The mentioned practical reasons but also commercial reasons were the beginning for developing an alternative test method for testing pipe stiffness. Furthermore the bigger the pipes the more complicate become the testing of samples by external laboratories and third party control.

Pic.3: 16 ton polyethylene pipes
DN/ID 3600 – 2.7 ton/m

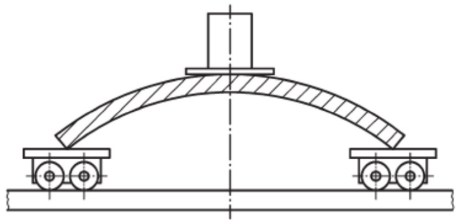
Thermoplastic pipes are homogenously manufactured and provide uniform static properties around the circumference and length. A cut pipe segment should have same characteristics if the disturbing load differences are considered. A group of large diameter pipe producers made many tests to verify the theoretical assumptions and in the meantime in the German DIN 16917 the procedure is described in detail.

3.1 Determination of ring stiffness under use of pipe segments

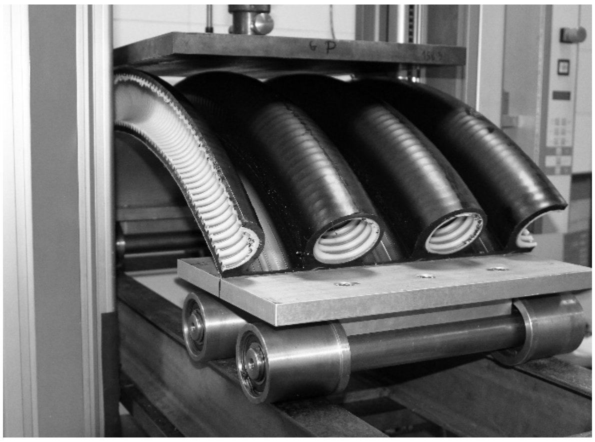
In the following abstract the most important details of the procedure acc. DIN 16917 are explained.
A mathematic investigation has proven that there exists a relationship between testing 79° pipe segments and the standard test procedure according to DIN EN ISO 9969. The same ring stiffness can be calculated. However, it is recommendable to also apply other testing procedures under prevailing working conditions and profile types before this alternative method is exclusively taken. A comparison and evaluation of the results of both methods is recommended.

The ring stiffness test acc. DIN 16917 is carried out with 79° segments, extracted from one pipe. The procedure correlates with DIN EN ISO 9969 in terms of setup and implementation and simply uses another test body. Instead of using a complete pipe, pipe segments are used. References on testing equipment, test body width, conditioning and implementation can be viewed in DIN EN ISO 9969. The cutting of the support surfaces of the segments must be carried out with special care, because the bearing must be rigidly supported. Another crucial point, which should be treated with special care, is plane parallelism!

The ring stiffness is defined by measuring of strength and deformation under a constant deformation rate. Therefore, a pipe segment is used instead on a complete pipe. The pipe segment is deformed vertically under a constant rate (see Pic. 4 and 5). The deformation of a segment corresponds to the amount of deformation of a complete pipe (3 %).



Pic. 4: schematic test procedure with 79° segments as test bodies



Pic. 5: testing pipe segment 79° with structured wall

The test body (79° pipe segment) is pressed together at a constant speed acc. specification of the standard ISO 9969. The measuring values of force and deformation has to be recorded continuously until a deformation corresponding to a deformation of the complete pipe of 0.03di is reached.

3.2 Determination of the deformation of the segment

The segment is deformed to an extent as it would be during a deformation of the whole pipe of 3%. The deformation of the segment is calculated according to the following equation:

$$y_{RS} = y_S \times \alpha_{79°} = 0{,}03 \times di \times 0{,}296$$

y_{RS} = deformation of pipe segment [mm], which corresponds to a pipe-deformation of 3%

y_S = the vertical deformation of the pipe [mm], which corresponds to a pipe-deformation of 3%, $\frac{y_S}{d_i} = 0{,}03$

α_{79} = conversation factor for deformation of 79° segment = 0,296 (derived analytically)

3.3 Calculating the ring stiffness

The ring stiffness S of each test body can be calculated with the formula

$$S = (0{,}0186 + 0{,}025 \times \frac{y_S}{d_i}) \times \frac{F_{79\alpha}}{L \times y_S}$$

$F_{79\alpha}$ = test force when deformation of pipe segment y_{RS} is achieved [kN]

y_s = vertical deformation of the pipe [m]

d_i = inner diameter of pipe segment [m]

L = length of pipe segment [m]

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