TECHNICAL REPORT 7074

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Performance requirements for plastics pipes and fittings for use in underground drainage and sewage

Aptitude à l'emploi des tubes et raccords en matière plastique utilisés pour l'assainissement enterré

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ISO/TR 7074 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids.*

The reasons which led to the decision to publish this document in the form of a technical report type 3 are explained in section 1.

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SECTION 1 - HISTORICAL BACKGROUND

1. DISCUSSIONS IN ISO

Work within ISO/TC 5/SC 6 (now ISO/TC 138) on a specification for plastics pipes and fittings made of UPVC for use in underground sewage was approved at the sub-committee meeting in Stockholm in 1969 when Working Group A was established and the responsibility for drafting the specification allocated later on to a Task Group (now ISO/TC 138/SC 1/AGH-1 - Buried drain and sewer pipes).

At the WG 1 meeting in Berlin in 1972 the U.K. proposed that TG 1 should give consideration to the so-called Box Loading Test (BLT) as described in BS 4660. This was accepted.

The "Specification for pipes and fittings of unplasticized polyvinyl chloride (UPVC) for buried drain and sewer pipes" (doc. 138/1 N 161) was forwarded to TC 138 level by resolution in Madrid in 1972 without any functional test requirements for pipes or fittings and at the same time it was decided that TG 1 should continue its specification work on the quality testing of fittings.

The above mentioned specification, now ISO/DIS 4435, was accepted with 24 approvals, 2 disapprovals and no abstensions (see doc 138 N 153).

After having finalized the leakproofness tests for fittings, TG 1 was, by resolution of WG 1 in Bremen in 1974, to continue under the leadership of Finland developing suitable tests for pipes and fittings.

Since then, in the period 1974-1978, nine further Task Group meetings were held keeping in mind the following terms of reference:

- To prepare a functional performance test (type test by nature), considering the long term durability of fittings, which simulates, as far as possible, practical conditions.

- To develop a simple production quality control test, especially for injection moulded drainage fittings, which examines the strength of the weld line, which may be weaker than the the fitting in general.

The main task, being derived from the actual initiative, was to study the testing of UPVC assemblies but the AHG has also studied the applicability of the methods established to other plastics materials: no final conclusions have been drawn however.

During the work of TG 1 it became evident that no unanimous proposal could be reached within the TG upon the methods to be used and therefore TG 1 agreed that all prepared descriptions of test methods should be circulated to the WG 1 meeting in Tel Aviv for wider consideration. At the meetings in November 1977 it was agreed that documents 138/1 N 369, N 370 and N 371 should be compiled into a Technical Report.

SECTION 2 - BASIC TECHNICAL PROBLEMS

2. INTRODUCTION

When flexible plastic pipe is used for underground drainage and sewage, a so-called pipe structure is formed by the interaction of the mechanical properties of the pipe and the surrounding soil. The behaviour of the pipe structure over a long period depends on the ageing properties of both components, i.e. changes in the pipe or fitting material and variations in the earth pressure distribution cause diminishing pipe strength.

The main loading factors, which should be taken into account when dimensioning the pipe structure are:

a) static and dynamic loads which cause bending stresses and fatigue phenomena in the pipe and fitting wall;

b) thermal loads which cause accelerated ageing and possible softening in the material and bending stresses in the pipe and fitting wall;

c) chemical influence of waste water.

These factors cause changes of differing degrees in pipe and fitting materials depending on:

- dimensions and geometry;
- elasticity and stiffness;
- creep and relaxation properties;
- frozen-in-stresses;
- tensile, compressive and fatigue properties;
- softening temperature;
- molecular weight and its distribution.

3. QUALITY CONTROL PROBLEMS

With manufactured products, quality is mainly determined by quality of design and quality of manufacture:

- Quality of design is defined as the excellence of the design in relation to ease of manufacture and to the customer's requirements

- Quality of manufacture is defined as the fidelity with which the product conforms to the design.

When discussing the quality control, which is defined according to the European Organization For Quality Control (EOQC) as a system for programming and coordinating the efforts of the various groups in an organization to maintain or improve quality, at an economical level, we see that the document ISO/TC 138/WG 1 N 299 gives a definition for Quality

Control Test that should preferably be called a Production Control Test. The Type Tests and Performance Tests fall under the heading Quality of design:

- The definition of Performance Tests states that they are carried out in order to assess the ability of a product or assembly of components to fulfill its function

- The definition of Type Tests states that they are carried out in order to prove the general suitability of materials and components.

The question is to which definition should be added the words "over the required time", which is defined as the period of time (for pipes and fittings normally 50 years) during which the user expects the item to be in a condition to perform its required function. Does the testing of wear-out or degradation failures belong to both groups? It is clear that in order to get reliable results from a test which simulates functional and environmental stresses the test shall include an accelerating factor. What accelerating means should be chosen is dependent on the parameters to be investigated. The Task Group has studied the effects of temperature, which is known from previous experience to be a reliable factor, increment of induced stress and dynamic loading.

An accelerated test is defined as a test in which the applied stress (loading) level is chosen to exceed that stated in the reference conditions in order to shorten the time required to observe the stress response of the item, or magnify the response in a given time. To be valid, an accelerated test must not alter the basic modes and/or mechanisms of failure, or their relative prevalence.

In order to be able to state the reference conditions one should carry out Field Reliability Tests, which are defined as a reliability compliance or determination tests made under stated and controlled conditions of use and recorded conditions of environment in the field.

Because results over a 50 years period are not yet available, field data and results from Endurance Tests have been studied by the Task Group.

The idealized target of the TG could be crystallized as follows: To establish a simple, easy and quick test, which by simulation takes account of the performance requirements set by the environment and the function stresses, reveals inadequate design strength in view of long term durability, which could be used as a reliability test, as a production control test and as a screening test. A screening test is intended to remove unsatisfactory items or those likely to exhibit early failures.

Not surprisingly this proved to be unreasonable and therefore the task Group split the programme into smaller individual Tasks.

SECTION 3 - TEST METHODS STUDIED

4. MOTIVE

The reason why tests were developed is contained in the sewer pipe specification ISO/DIS 4435. It is stated under the heading "wall thickness" that "Note: The wall thickness of a given fitting may require greater values than given in the table in order to comply with the test requirements of this specification".

Up to now no guidance has been given within ISO for the choice of the class of fittings to be connected to a specific pipe.

5. BOX LOADING TEST (BLT)

Originally the work of TG 1, in its present composition, began with a so-called BLT method, which is a Laboratory Reliability Test by nature. The BLT is meant to be a a simulating test which contains thermal shock as an accelerating factor.

5.1 Background

The background to the BLT and the objectives it achieves when pipes and fittings are subjected to it lies in the failures of soil stocks reported during 1966 and 1967 in U.K. A number of

UPVC soil discharge pipes collapsed due to conveyance of hot discharges. Investigations following these failures were carried out by BPF. From this survey two sets of conditions emerged which could have caused the soil systems then in use to fail. These conditions were:

a) A rapid discharge of the contents of a boiler.

b) The use of washing machines where the temperature of the water can be as high as 95 °C.

It was subsequently establised that plastics soil systems should undergo an elevated temperature cycling test. The idea was that the test would indicate that when a system satisfactorily performed after the test had been completed then for all practical purposes other pipes and fittings identical to those tested would perform satisfactorily in service. This test is now included in relevant ISO Draft International Standards for soil and waste discharge systems inside buildings.

When the U.K. came to examine the question of drainage pipes from the house to sewer it was immediately thought necessary for a similar test to be included to determine the performance of these pipes under the influence of thermal shock. However, because the pipes would be buried in the ground and subjected to external loads, additional criteria would be applied.

Opinions from building authorities, road construction specifiers, transportation authorities and organizations were examined and certain load criteria emerged. These load criteria can be said to be the maximum possible normal loadings that would pass over or remain on a buried sewer pipe for a length of time. A similar examination with regard to the temperature of the effluent, as carried out for the soil system programme, showed that the effluent conveyed in underground drainage was at a lower and more constant temperature. The practical questions were then raised concerning applying these criteria to a test and it was very quickly seen that to install pipes and fittings in trenches on a continuous basis for test purposes was not practical and an artificial trench had to be designed and specified. Ultimately this artificial trench emerged as the box detailed in the test description which follows this report. It was considered acceptable for all practical purposes that if the physical properties of the box were toleranced, different laboratories could construct boxes and test components in them to a standard method. This method of determining a pass/fail for the products tested by each group would be satisfactory. As for soil systems, the object of the Box Loading Test is to confirm that pipes and fittings which do not deflect by more than a given percentage during the test, and at the test conclusion show no signs of leaks, will give a satisfactory performance when in use. Again, as with the soil systems, it is not intended that systems so tested in the box should be given a numerical value whereby systems from one manufacturer can be directly compared with those of another.

5.2 Objections

The Task Group studied the original U.K. proposal and the corresponding Finnish standard SFS 3143 - 1975. The main arguments against these methods were:

Lack of information concerning

a) The weld line quality, because of the small number of test pieces

b) The stiffness, because the temperature is as high as 85° C,

c) The long term behaviour, because the testing time is short and cannot be sufficiently related to practice

d) the method is costly, time consuming and complicated

e) The reproducibility is doubtful.

5.3 Progress

a) Weld line quality

From the investigations made it can be concluded that "frozen-in-stresses" in injection moulded fittings have a certain effect in relation to the weld line and thus the weld line can be the weakest part of the fitting. This is evident because when the weld line is placed in the water flow the deformation is often at its maximum and small cracks in the weld line can be found. Because the method was not originally meant for determining the weld line quality by measuring the depth of the crack and because statistically the number of test specimens is too small, it was agreed that in the standard only a reference for further investigations was to be made in the case of crack development.

b) Test temperatures

The water temperature of the hot water cycle was proposed originally as 85 °C. This was enough to raise the mean temperature through 60 °C in the material. This in return can cause acceleration of degradation (ageing) failures and thus select bad material quality from good. When resting and cooling the original test schedule required care to be taken that the crown temperature fell to a maximum of 30 °C. This keeps the total assembly temperature at about a constant level. It is interesting to note the relationship of the wall temperature with the long term pressure test for pipes. Experiments made with water at 70 °C show that the deformations are much smaller.

The Task Group discussed the test temperatures on several occasions and studied many reports in which the conclusions were equal:

Though the temperature from a washing machine can be as high as 95 °C when poured into the soil system, it rapidly decreases and seldom exceeds 60 °C when running in the underground drainage system. There are, however, certain types of housing where hot water is discharged into the underground drainage system at a temperature of at least 85 °C. This was concluded from several field measurements. Thus it can be seen that 85 °C presents a severe, but in some cases relevant figure.

Summary: The hot water temperature was not fixed, because it is dependent on national codes of practice and other mandatory requirements.

c) Long term durability

The Task Group could find only passive and indirect demonstrations of the method's ability to serve as a reliable endurance test.

These are:

- During the 10 years' knowledge of the BLT no failures are known to have occured in practice to those types of pipes or fittings which have passed the BLT.

- Extensive series of tests made on UPVC show that the long term burst strength is strongly influenced by the combined effect of the K-value and the Vicat point of fittings material. This is more generally revealed at the elevated pressure test temperature of 60 °C. The results from the BLT tests using the hot water temperature of 85 °C show similar results and this gives the right to suppose that BLT may be used for determining the long term durability.

- The functional stresses in practice consist of among others those caused by thermal shocks. This kind of fatigue loading on the construction is repeated in the BLT for a reasonable number of cycles which correlates to practice.

d) Costs

The BLT apparatus is not a cheap test device for plastic pipes and fittings, however, the test is intended to be carried out only when a new material or construction is introduced.

e) Reproducibility

The main reasons postulated for the poor reproducibilty of the original test where:

- the filling method was not described clearly enough
- the filling material and its compactness varied too much from one test station to another
- the possible deformation of the box was not restricted

The Task Group studied these points and on the ground of separate investigations these factors were eliminated or restricted to a reasonable level when considering the practical nature of the test.

f) Other objections

2500 cycles are recommended. This is based on the fact that it corresponds in practice to approximately one thermal attack per week during 50 years. The fact that the deformation is continuously rising towards the end of the test brings up for discussion the possibility of increasing the test to 2700 cycles which simulates full 50 years service life. This is contrary to the proposed reduction of the test to 1500 cycles.

The Task Group has also discussed the magnitude of the superimposed load which originally was 36 kN for 110 mm pipe. This relates to a backfill height of about 3 m where as the proposed 50 kN relates to a backfill height of 4 m. According to the tests made with 36 kN and 50 kN there is no marked difference between the deformations produced. Therefore in order to obtain more reproducible results the Task Group suggests a load of 50 kN for all underground drain pipes and fittings up to 160 mm.

5.4 The advantages of the BLT

The main advantages of the BLT are:

a) It can be used for studying of the long term behaviour of pipes, fittings and assemblies in respect of stability of construction and tightness.

b) The method has proved to give good simulation of the pipe structure in real field conditions. That is, the deformation caused by the soil load is of the same magnitude.

c) The method gives information of the material's general suitability, of the soundness of construction and of possible weak points caused by manufacture.

d) The method is applicable to all flexible pipe and fitting materials.

5.5. Work still to be undertaken

5.5.1

The original method used in North European countries consists of two parts:
a) for drain pipes and fittings up to and including DN 160 mm using cycling thermal-shocks with water temperature 85/10 °C

b) for sewer pipes and fittings of 200 mm and above using continuous water flow with a temperature of 50 ° C and a load as per table 1.

Table 1 Test conditions

Nominal outside diameter DN	Width of the box a mm	Length of the box b_{min} mm	Heigth of the box h mm	Load F kN	Hot water temp. T_1 °C
100	700	1200	810	50 ± 2	85 ± 2
125	700	1200	825	50 ± 2	85 ± 2
160	700	1200	860	50 ± 2	85 ± 2
200	800	1500	900	50 ± 2	50 ± 2
250	900	1500	950	50 ± 2	50 ± 2
315	1000	1500	1015	55 ± 2	50 ± 2
400	1300	1500	1100	55 ± 2	50 ± 2
500	1800	1500	1200	60 ± 2	50 ± 2

The latter application is deleted from the present ISO test method, however, the need for such a test should be evaluated.

5.5.2

The hot water temperature and the permitted end deformation are left to be fixed by the national member bodies. However, it is recommended that the water temperatures used should be the same for all materials. The final end deformation value may vary from material to material depending on proven practical field experience.

6. WATER CYCLING TEST (WCT)

6.1. Background

By testing several kinds of fittings in the BLT it can be shown that for certain types the weld line has a tendency to open. It was therefore suggested that this phenomena could be investigated using a cheaper method than the BLT.

The Task Group studied a few different methods and came to the conclusion that the "Elevated temperature cycling test on fittings" as decribed in BS 4660 serves as a relatively easy method for determining the weld line strength. The cycling of hot and cold water is made in the same manner as in the BLT but the fittings are mechanically unloaded. Comparative tests have shown that the same tendency of cracking is achieved, when the test is made with the test piece surrounded by air, as in the WCT, compared to the results from the BLT. During the test the weld line is of course placed in the water flow. The cycling test is primarily a kind of a functional type test for fittings exposed to hot water, i.e. for diameters 110, 125 and 160 mm. Test work has shown that the method is not suitable for testing polyethylene fittings.

6.2 Summary

The Task Group prefers the WCT to the BLT in terms of weld line strength testing. For production quality control purposes the method is not particularly suitable since it is time consuming. Its usefullness is evident for repeated type testing made by the manufacturer or control inspector.

7. FATIGUE BENDING TEST (FBT)

7.1 Background

In order to find a suitable quick test on weld lines, the Task Group started to examine the so-called Fatigue Bending Test (FBT). When comparing the newest version to the original proposal from from the Netherlands, the test description has changed a lot. The Task Group has studied the influence of

- frequency
- amplitude
- type of loading
- test sample size
- positions from where the sample should be taken
- temperature

7.2 Objections

During the work the following objections to the proposed method were made:

- As it now stands the method is unsuitable for its originally expected end use: quick quality control

- The method is of such a nature that it is necessary to use quite large numbers if test pieces in order to obtain sta tistically significant results.

- The method is not suitable for fittings made of polyolefins.

7.3 Advantages

- The method is shown to give information of the weld line quality

- The method can be used to measure the material's fatigue properties. Thus its simulates in one way or other the dy namic loading characteristics of the fittings more accurately than the BLT.

7.4 Work still to be undertaken

In further investigations stress should be laid on following features:

- the criteria for pass/fail should be established

- the statistical parameters should be clarified

- tests in a cooled liquid bath should be carried out in order to try to prevent this possible source of unreliable results: i.e. the warming up of the material.

7.5. Summary

The method is still under development. Promising results have been obtained especially when considering the possibilities which the method may serve for product development and processing technology.

8. IMPACT RESISTANCE TESTS (IRT)

8.1 Background

The need for a quick quality test for weld lines was the motive of the Netherlands when beginning the work with the IRT. The method has been developed from the common method ISO R 179 which has been used for the testing of fitting quality for example in specifications for ABS and PP soil and waste discharge systems in buildings.

When comparing the latest edition to the original proposal it can be seen that the test description has been changed notably only in one detail, that is, the strinking edge hits the specimen on the outer surface, which the Task Group regards as an improvement.

The test can be performed with less striker energy than described at the moment in the draft standard.

8.2 Objections

The main arguments against the method are:

- Due to the weld line there is often a small notch in the test bar. This causes much variation in the test results.

- The method does not give an indication of the fitting's overall performance ability; only giving results from various points of the fittings.

- The original intention was to substitute the FBT by the IRT but there is doubt that the IRT tests the same parameters.

- The machining of the test bars can easily affect the results.

- The method is not suitable for PE at the test temperature of 23 °C.

- The number of test pieces must be quite large in order to obtain statistically significant results.

8.3 Advantages

- The method may give information of the weld line quality more easily than the FBT.

- The method gives information of the material's impact resistance properties which the BLT is unable to do.