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Technical note

Forensic investigations of buried utilities failures in Poland

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Abstract

This paper discusses the problem of failures of sewerage and water-supply systems. Typical kinds of damage to pipelines are described and classified according to reliability theory and their causes. Results of the author's examination of damaged sewerage and water-supply pipelines, including the causes of four failures, are presented. In the conclusion, the principal hazards to failure-free operation of underground infrastructure are indicated.

Keywords: Underground infrastructure; Damages; Case studies

1. Introduction

1.1. Classification and causes of damage

Damage to a pipeline, as also to other technical facilities, is a transition from the state of fitness for use to that of unfitness for use, understood as failure of the pipeline to meet the set requirements (Madryas, 1993; Wieczysty, 1990). The transition of a pipeline from being fit for use to being unfit for use may occur in a way which classifies the damage as catastrophic or parametric. According to reliability theory, in both cases one can distinguish primary and secondary damage, mostly irreversible and sometimes – reversible. A classification of damage is schematically shown in Fig. 1, where $\overline{c_{mi}}$ and $\underline{c_{mi}}$ denote respectively the upper and lower limit of the pipeline's required parameter.

The causes of damage can be classified as determinate – dependent on the decisions of the parties involved in the realization and maintenance of pipelines – and random, i.e. independent of such decisions. The former group of causes comprises design, workmanship and operating errors. Random causes include failures of the facilities adjacent to the pipelines and natural aging processes. A damage mechanism results from the objectives and course of determinate processes and from the course and rate of random events.

Objectives of determinate processes, boundary conditions, errors and typical failures due to the above factors are shown in Table 1 (Karangwa, 1999).

A similar breakdown can be made for random events, as shown in Table 2 (Karangwa, 1999).

1.2. Degrees of damage

A pipeline's technical condition is described by its hydraulic parameters specifying its throughput and by parameters specifying the condition of its structure. As regards the latter, two degrees of damage can be distinguished: complete damage to the structure and partial damage to the structure (Madryas, 1993; Wieczysty, 1990).

Complete damage to the collector structure means that the latter has lost its capacity to carry external mechanical loads. This may occur in the case of longitudinal cracks and fractures, large cave-ins and local cavities (e.g. holes). The symptom of this condition is a construction failure which is quickly noticed even if the collector maintenance program does not provide for systematic surveying.

Partial damage to the collector structure means that the latter maintains its strength properties to a degree sufficient

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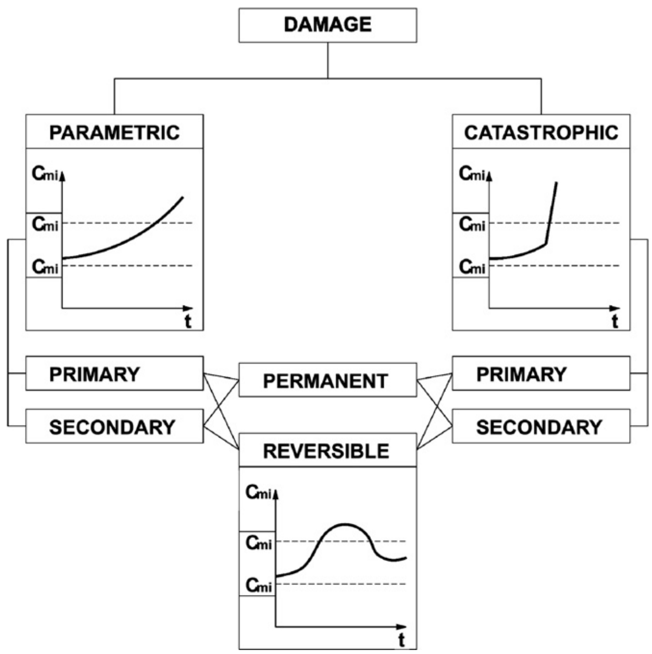

Fig. 1. Classification of damage.

for a failure not to occur. In this condition, corrosion processes are clearly in evidence and in the case of gravity sewerage, the structure may start leaking and crack or fracture across. Since the consequences are not immediately noticed outside, the transition from fitness for use to unfitness for use is slow and the damage can be discovered only during a regular survey or if due to degradation the pipeline is completely damaged (fails) or another structure is damaged as a result.

This means that if a network is operated without regular surveys, partially damaged pipes may destroy the immediate environment. Visual inspection, which consists in observing the inside of a pipeline and making an inventory of all the noticed damage, is most commonly used in regular surveying. The results of such surveys have a qualitative character and require professional interpretation. If they are insufficient, additional (diagnostic) surveys should be carried out, which means that sometimes the pipeline has to be dug up (particularly when it is not of the walk-through type).

2. Examples of pipeline investigations

2.1. Investigation of damage to collector sewer

A 5600 m long pressure sewerage collector made from prestressed concrete pipes 1400 mm and 1600 mm in diameter was investigated (Kolonko et al., 2004). The pipes had been made of class B50 concrete (according to the manufacturer's specification), using cements with C_3A content not higher than 6.52% (according to BN-87/897, C_3A content should not be lower than 7%). The collector's reinforced concrete chambers were monolithic and their vents were made from reinforced (B30) concrete rings. The outer insulation was made of R + P *abizol* and 4 mm thick *bitgum*. The sewage side was not insulated. The collector had been built in the 1990s.

The investigations were undertaken because of the very bad condition of the collector, as assessed by its user through a CCTV inspection. The aim of the investigations, carried out by a research team led by the author, was to determine the causes of this and to collect enough information about the structure's condition to select a proper rehabilitation technique and technology. For this purpose the design documents had to analysed, the condition of the collector was to be surveyed to inventory the damage to its structure, geometry of the cracks and fractures was to be measured and their morphology assessed, the extent of the corroded zones (including carbonization) was to be determined, photographic documentation was to be made and samples were to be taken for laboratory tests covering physical parameters of the concrete (compression strength and absorbability), pH and harmful salt content as well as the harmful substance content in the water and soil environment and in the sewage. Prior to evaluation of the condition of the collector and its chambers and the selection of a suitable rehabilitation technology, structural strength calculations based on the results of the laboratory material tests were carried out. The investigations and analysis of their results showed:

- a very low pH (pH 3.7) and a high sulphate content (about 2.6%) of the deposit on walls of the chambers – this kind of environment is considered to be strongly aggressive to concrete;
- low quality of concrete of the chambers (B15 < B30), absorbability 6–7% > 4%);
- considerable surface corrosion of the concrete in the chambers and in the pipes (as much as 20 mm deep) – Fig. 2;
- insufficient load capacity of the chambers;
- improper insulation of the chambers or lack of insulation;
- carrying capacity of the pipes close to the required minimum.

The principal causes of the bad condition of the structure (particularly of the chambers) were found to be:

- design errors which consisted in not foreseeing so strong environment aggressiveness and not adapting the design appropriately (insulation or ventilation),
- defective workmanship as a result of which the structure's actual parameters did not conform to the design parameters (which were too low).

2.2. Investigations of damage to water main

A water main consisting of two steel pipelines with a diameter of 1200 m and a wall thickness of 14 mm, laid on a flyover with a concrete deck (12 cm thick B20 con-