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Rehabilitation of lengthy sewer pipelines by polymer-composite CIPP

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Abstract. This study examines the feasibility of Cured-in-Place Pipe (CIPP) technology for trenchless rehabilitation of aging sewer pipelines, addressing the severe deterioration of Karaganda's sewer networks. A 3 km section was inspected using CCTV, ultrasonic, and shock-pulse methods to assess pipeline conditions, revealing structural defects with depreciation levels reaching 70-100%. The CIPP method was successfully applied to restore the integrity of 2.6 km pipelines while minimizing excavation, stabilizing the average flow rates and velocity of 0.8-1.2 m pipelines at 710 liter/s and 1.2 m/s, respectively. Hydraulic analysis confirmed that rehabilitated pipelines maintained sufficient flow velocity for self-cleaning and increased capacity, reducing blockage risks. The findings demonstrate that CIPP is a sustainable alternative to pipeline replacement, offering a viable solution for long-length sewer rehabilitation and supporting strategic urban infrastructure renewal.
Keywords: sewerage, rehabilitation, CIPP, ultraviolet curing, CCTV.

1. Introduction

Water is a key element of sustainable development, directly affecting life on Earth. As urban populations grow, urban functioning will depend on water management and water-related risks will be concentrated in cities [1]. Urban development increases impervious surfaces, intensifying the load on sewer systems through greater stormwater volume [2]. Sewer networks play an important role in protecting health and the environment, but aging pipelines can lead to leaks and malfunctions, creating environmental and health risks [3]. In this regard, the sewerage systems in Kazakhstan face many problems that require comprehensive solutions [4]. The majority of these systems were built in the 60s and require significant investment in rehabilitation and modernization [5]. In particular, the deterioration rate of Karaganda sewer networks had already reached 80% by 2006 [6]. Obviously, these networks have become even more dilapidated in the nearly 20 years that have passed and have accumulated so much stagnant household waste that they need either complete replacement or unconventional treatment approaches. Since the traditional systems, even pressurized ones [7], may not be able to handle the flushing of stagnation. Besides the friction of even small stagnations may disturb flow rate and quickly increase in size with clinging sludge and debris. Therefore, Karaganda sewer networks should be urgently inspected and rehabilitated using modern techniques considering the length of exhausted sections, to help reduce the risks and costs associated with their failure.

[25] presents a detailed analysis of design and rehabilitation methods for underground pipelines, including modern remediation technologies. The main attention is paid to engineering calculations and design, while rehabilitation issues are considered only superficially. The work does not fully take into account the complex mechanical stresses arising in real operating conditions. [8] reviews the various trenchless technologies used for pipeline repair and replacement, with a focus on modern remediation methods. The authors emphasize the reduced urban environmental impacts of trenchless methods, but the study does not analyze secondary effects. In particular, changes in soil permeability

can lead to land subsidence and localized increases in groundwater levels, which can have long-term consequences for the stability of buildings and utility infrastructure. [9] provides a comparative analysis of existing pipeline rehabilitation methods. However, this study does not include large-scale field tests with long-term monitoring of the condition of the rehabilitated pipes. This may lead to errors in predicting their operational durability since laboratory tests and theoretical models do not always reflect real operating conditions. [10] compares conventional (excavation) and trenchless technologies for the rehabilitation of sewer networks in terms of their carbon footprint. The study shows that trenchless methods reduce CO_2 emissions by 59.2% compared to excavation. However, the experimental data are derived from the example of the historical center of Brno, Czech Republic, where the infrastructure and building materials may differ significantly from other regions. Consequently, the results may vary in modern areas with different soil types, building densities, and hydrogeological conditions. [11] presented an innovative approach to trenchless rehabilitation of underground pipes using vacuum transfer molding of a resin combined with a fiberglass fabric blank. However, fiberglass composites can lose mechanical properties at high temperatures and cracks may appear in lower temperatures.

The considered studies make a significant contribution to the development of trenchless pipeline rehabilitation technologies but the solutions they propose appear costly, labor-intensive, and time-consuming making them unsuitable for the long-length exhausted pipelines of Karaganda sewer networks. To overcome these shortcomings, this study considers the adoption of Cured-in-place pipe (CIPP) technology [12] for trenchless rehabilitation. Since it enables pipeline restoration without replacement while minimizing associated costs [13]. The CIPP is poorly examined in local conditions due to its recency in the region. Therefore, this study aims to assess its performance for the long-length sewer pipelines of Karaganda.

2. Methods

The study area is represented by 3 km of sewerage pipelines located in the residential zone of Maikuduk in Karaganda, Kazakhstan, passing under the streets of Maylina, Orken, and Tsetkin. Unfortunately, no archival data for the site survived, but it was assumed that the networks had already operated for over 50 years. The study area was inspected according to [14]. The inspection aimed to determine the types of pipes, their burial depth, dimensions, materials, and defects. Visual inspection was performed by accessing sewer manholes. The instrumental inspection incorporated a Closed-circuit television inspection (CCTV) [15], ultrasonic [16] and shock-pulse [17] methods. The cleaning and washing of pipelines from the debris was performed mechanically and hydrodynamically under pressure. The rehabilitation of pipelines was carried out by the trenchless method [18] using polymer-composite CIPPs “Berolina-HF-Liner” [19] with wall thicknesses of 9.2 and 10.2 mm (Figure 1).

a) Laying smooth film b) CIPP lifting c) CIPP pulling d) CIPP inflating

Figure 1 – Installation of polymer-composite CIPPs

Each CIPP was lifted through the manholes (Figure 1b) and pulled through the pipe to the next manhole using a winch (Figure 1c). A smooth film was pre-laid to protect the CIPP against damages (Figure 1a). The molding of CIPPs was conducted pneumatically (Figure 1d). The epoxy resin adhesive was used to bond CIPPs with existing pipes. Curing of the adhesive was carried out utilizing ultraviolet emission [20]. The hydraulic calculation of newly erected CIPPs were carried out according to [21].

3. Results and Discussion

Inspection of the study area revealed they are gravity sewers and that their pipelines were erected by 8 m pipes made of reinforced concrete according to [22] and embedded in depths of 3.5-6.5 m from the ground surface corresponding to the elevations of 530-545.5 m above sea level. Depending on the condition of the pipelines, some parts of the pipelines were rehabilitated with trenchless CIPP, and the other parts with the excavation method (Figure 2).

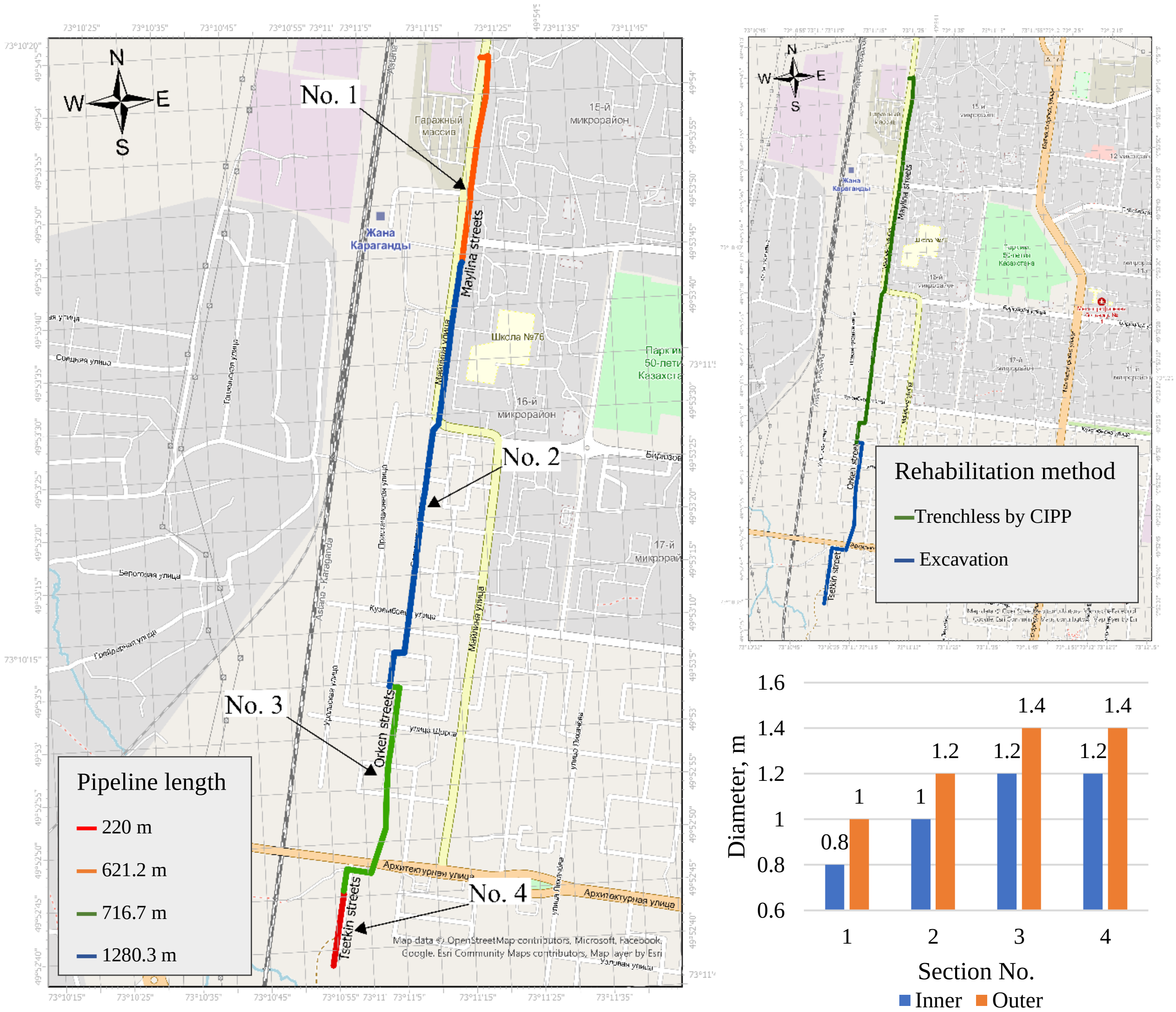

Figure 2 – Map of pipeline rehabilitation

Figure 2 above shows a rehabilitation map of pipelines, which are split into 4 sections and colored differently, with lengths of 621.2, 1280.3, 716.7, and 220.0 meters, respectively, altogether amounting to 2838.2 m, including 2618.2 m rehabilitated with the trenchless CIPP, and 220 m with the excavation method. It also shows the inner and outer diameters of the pipes, which range from 0.8 to 1.2 m for the inner diameter, and from 1.0 to 1.4 for the outer diameter.

Figure 2 below shows the results of instrumental inspection using the CCTV method.

Figure 2 – Pipelines condition before CIPP installation

As shown in Figure 4 above, the CCTV revealed and recorded distinct defects and debris in pipelines, which indicate their extensive deterioration, reduction in sewage flow rate, and expectance of failure. These issues include the cracking, splitting, and corrosion of pipe material, damage of reinforcement up to 70%, displacement of joints leading to groundwater infiltration, presence of silt and stagnations, coarse household wastes, and stones. The study revealed that the degree of depreciation of sections No. 1-3 of pipelines amounted to 70%. Section No. 4 of the pipelines encountered the worst damage with a deprecation degree of 100% indicating its unserviceability leading to soon subsidence of land above. Therefore, for this section, a decision was made to replace the pipes by excavation, which overcomes the [8] and [10] omissions.

The instrumental inspection by ultrasonic and shock-pulse methods revealed that the reinforced concrete elements of inspected pipes correspond to the strength class of B7.5. This indicates a fourfold loss of strength since it is supposed to be the class of B30 according to [22].

Figure 3 shows the reshoot images of CCTV representing the CIPP installation results after the careful treatment (cleaning and washing) of existing pipelines.

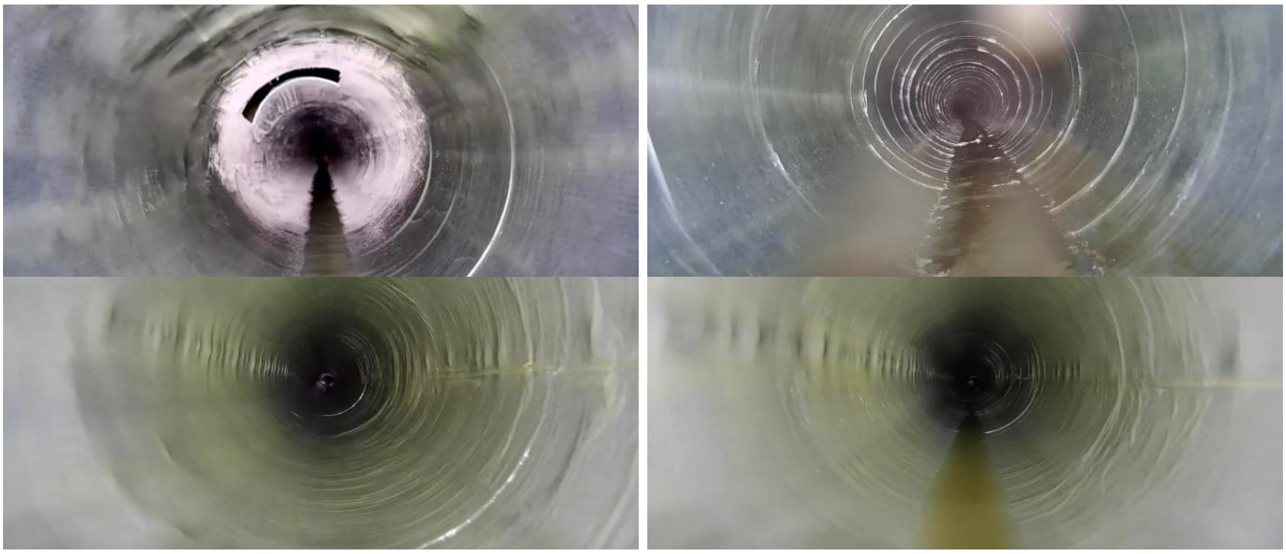

Figure 3 – Pipelines condition after CIPP installation

Figure 3 above clearly demonstrates how much the pipes were transformed after the cleaning, washing, and installation of CIPPs. It is possible to observe an increase in diameter, and consequently stabilization of sewage flow. The post-installation CCTV images clearly show a significant improvement in the structural condition of the pipelines. The previously observed cracks, joint misalignments, and obstructions were eliminated after the cleaning and CIPP installation. The increase in pipeline smoothness is expected to enhance sewage flow and reduce the likelihood of further debris accumulation.

Figure 4 below presents the results of a hydraulic calculation for CIPPs of different diameters under sewage taking their 70%.

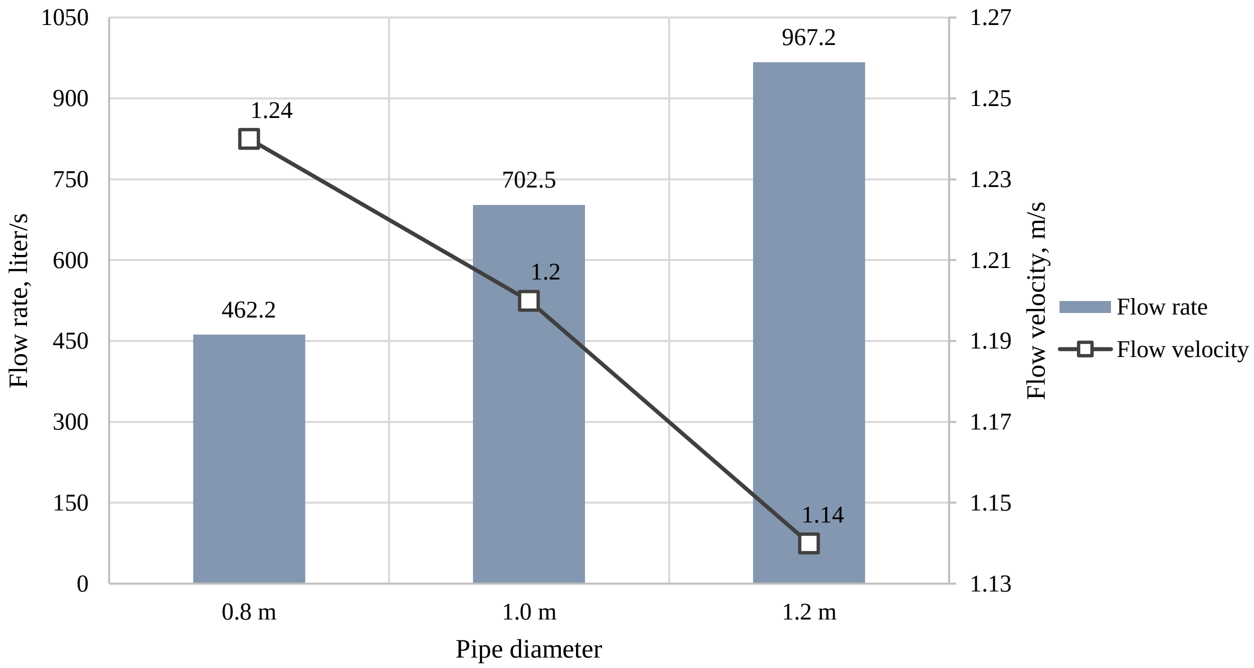

Figure 4 – Results of flow rate estimates

According to Figure 4 above, for a 0.8 m diameter pipe, the flow rate is 462.2 liter/s with a velocity of 1.24 m/s, for 1.0 m – 702.5 liter/s at 1.2 m/s, and 1.2 m – 967.2 liter/s at 1.14 m/s (710 liter/s and 1.2 m/s in average). A clear trend is observed: as the pipe diameter increases, the water flow rate rises, while the flow velocity decreases. This is explained by the fact that a larger diameter increases the cross-sectional area of the pipe, allowing a greater volume of water to pass through while simultaneously reducing the flow velocity under the same hydraulic conditions. These results suggest that the rehabilitated pipelines are better suited to handle peak flow conditions, minimizing risks of overflows and blockages.

4. Conclusions

The CIPP trenchless method effectively rehabilitates deteriorated sewer pipelines with a deprecation degree of up to 70%, restoring their structural integrity, improving sewage flow conditions, and minimizing excavation activities.

Based on the experience in Karaganda, the study confirms the feasibility of CIPP for long-length pipelines, providing a sustainable alternative to full pipeline replacement.

The hydraulic analysis demonstrates that rehabilitated pipelines with CIPP maintain sufficient flow velocity for self-cleaning while increasing flow capacity, reducing the risk of blockages, and improving long-term operational efficiency.

The study provides essential data on the types, materials, and condition of the 3 km sewer pipeline section in Karaganda, addressing the lack of archival records and offering a comprehensive assessment that supports future rehabilitation planning and maintenance strategies.

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Alizhan Kazkeyev – interpretation.
Tymarkul Muzdybayeva – editing.

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