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The mechanical behaviour of drainage pipeline under traffic load before and after polymer grouting trenchless repairing

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ABSTRACT

Polymer grouting technology is an economical and efficient trenchless way to repair leakage and settlement of drainage pipeline. In this paper, the mechanical behaviours of drainage pipeline under traffic load before and after polymer grouting and cement grouting trenchless repairing are investigated through three-dimensional (3D) finite element method (FEM). Four different working conditions, including normal pipeline, disengaging pipeline, polymer-repaired pipeline, and cement-repaired pipeline are considered. The effects of load type, load location, buried depth on the mechanics of pipe are discussed in detail. The results show that the traffic load has great impact on both sides of the load position within 4 m, and the dangerous points of the pipeline are located at the bell and spigot joints. The most unfavorable condition occurs when the location of the disengaging corresponding to the load position. The greater influence on the disengaging pipeline with deeper buried depth applied. The disengaging pipeline can be repairing effectively and reliably by both the polymer and the cement grouting technology. However, the polymer material is more valuable than the cement material in terms of the Mises stresses after repairing.

1. Introduction

Urban drainage pipeline is an indispensable infrastructure of modern cities. With the development of the economic and enlargement of city scale, the construction of drainage pipeline develops rapidly in China. As shown in Fig. 1, the total length of drainage pipeline in China's large and medium-sized cities, has been more than 500,000 km up to 2015. However, with the increasing numbers of drainage pipeline, the ground subsidence, leakage and other accidents have occurred frequently, due to deterioration of pipeline system.

Digging and replacing are the traditional ways to repair the drainage pipeline in China. However, there are some limits about these methods, such as high construction costs, high disturbance to nearby residents, and also in many cases, the excavation construction is impossible because of lots of buildings on the ground, full of underground pipeline and the complex surrounding environment. Trenchless technology can repair and update the existing defective pipeline with no-dig or micro-excavation, and it has little impact to surrounding environment. The development of pipeline trenchless repair technology began in the 1960s, and currently, the trenchless repair technology of pipeline include Insertion Method (Scholze et al., 1991; Ahmad, 1989), Internal Lining Method (Tianfeng and Zhigang, 2016; Jaganathan et al., 2007; Kuliczkowski et al., 2010), Cured-In-Place Pipe (Das et al., 2016; Allouche et al., 2014), Pipe Splitting Method (Chapman et al., 2007), and so on. Most of the existing trenchless repair technology can repair common pipe diseases such as corrosion and leakage effectively. However, these methods cannot restore the subsidence pipeline and reinforce the weak foundation, which leads to damage again after repairing.

The polymer grouting technology is a rapid maintenance technology for infrastructures based on a self-expansion and non-water-reacted polymer material. As shown in Figs. 2 and 3, the polymer grouting technology injects a two-component polymer material to the outside of the pipe wall, the polymer material expands and solidifies rapidly after reacting to reinforce the foundation, fill the disengaging and uplift the pipeline. The advantages of this method include:

(1) fast construction (polymer material after reacting can reach 90% of the final strength in 15-min);
(2) low weight (the quality of polymer material is one sixth of the cement);
(3) high tensile strength (as described in Figs. 4 and 5, the tensile

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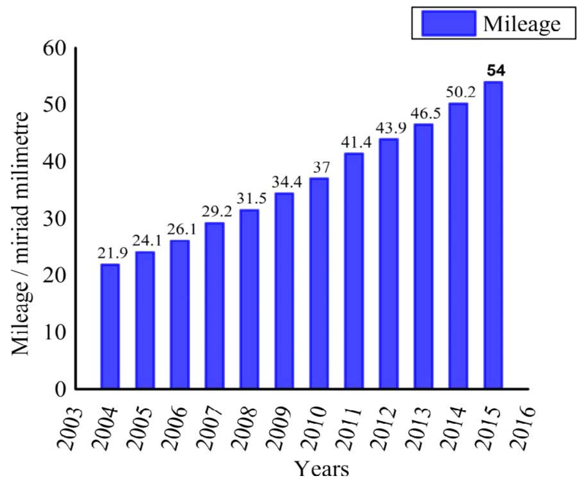

Fig. 1. Development of drainage pipeline in China.

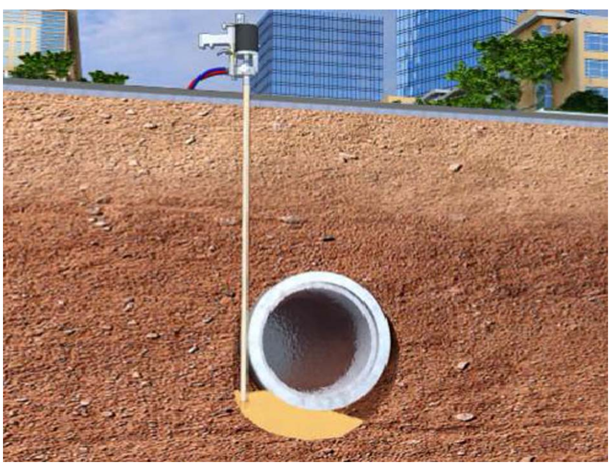

Fig. 2. Filling the cavities outside the pipeline.

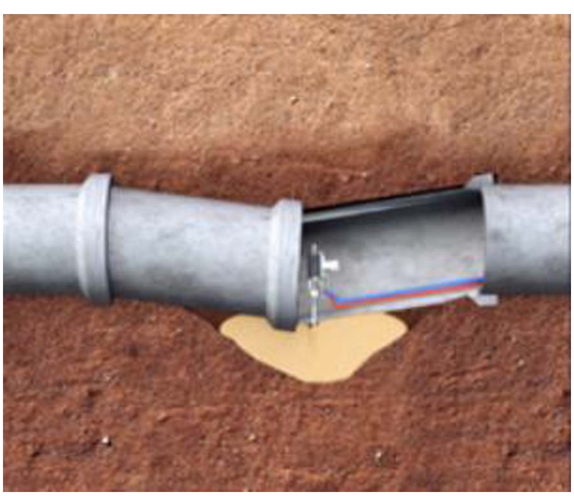

Fig. 3. Uplifting the pipeline settlement.

strength and compressive strength of polymer are one order of magnitude (Shi et al., 2010));

(4) micro-damaged (diameter of grouting hole is 16 mm, which causes small structural damage). At present, the technology has been successfully applied to roads, tunnels, dams, pipelines and other underground structures reinforcement and repair projects (Guo and Wang, 2012; Naudts, 2003; Xun et al., 2012).

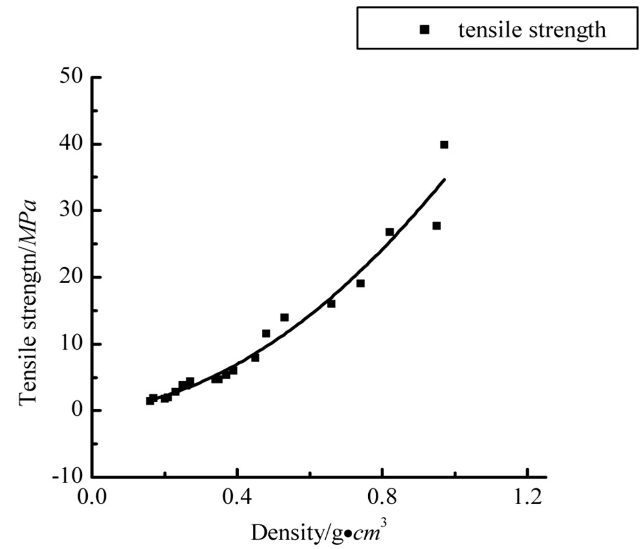

Fig. 4. Relationship between polymer density and tensile strength (Shi, 2011).

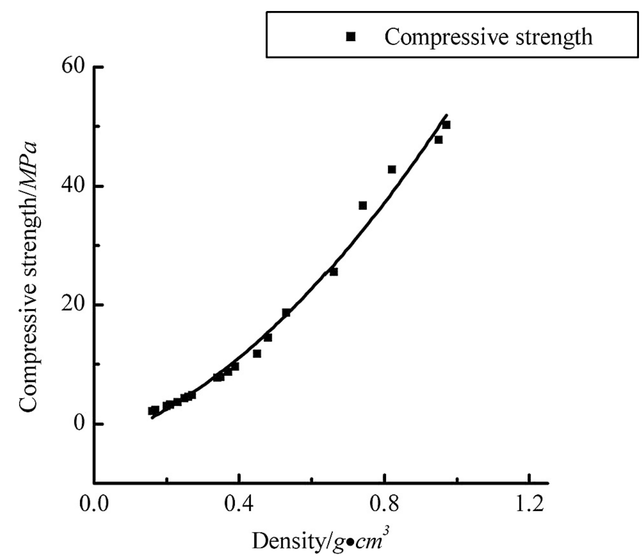

Fig. 5. Relationship between polymer density and compressive strength (Shi, 2011).

In this paper, the 3D numerical model of the bell and spigot concrete drainage pipelines with different states under various working conditions of traffic loads were investigated by using the FEM method. Normal pipeline, disengaging pipeline, polymer-repaired pipeline and cement-repaired pipeline were considered, the effects of the load types, load locations, buried depths on mechanical responses of pipelines were discussed, the repairing effects of cement and polymer were contrasted. However, the fluid filled in pipelines and the ground water table (Saeedzadeh and Hataf, 2011; Ling et al., 2008) was not taken into account.

2. Numerical simulation model

2.1. Model state description

The 3D FEM models of concrete drainage pipe were performed by using ABAQUS software. As described in Figs. 6 and 7, the length, width and depth of the model is 12 m, 10 m and 8 m, respectively. The road structure was divided into the surface layer, base layer, subbase layer and subgrade with the depths are 20 cm, 40 cm, and 20 cm, respectively. The elastic constitutive was adopted to the surface layer, the

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