

Buried Fiber Concrete Sewer Pipes: Studies, Design and Testing

Tural Rustamli^{1,*}, Nijat Mastanzade²

¹Transport Faculty, Azerbaijan Architecture and Construction University, Baku, Azerbaijan

²Research Institute of Building Materials, Baku, Azerbaijan

Email address:

rustamli.tural.90@gmail.com (T. Rustamli)

*Corresponding author

To cite this article:

Tural Rustamli, Nijat Mastanzade. Buried Fiber Concrete Sewer Pipes: Studies, Design and Testing. *Composite Materials*.

Vol. 4, No. 2, 2020, pp. 25-29. doi: 10.11648/j.cm.20200402.12

Received: September 23, 2020; **Accepted:** October 9, 2020; **Published:** October 17, 2020

Abstract: The article discusses the stress-strain state of fiber concrete sewer pipes manufactured by the method of dry vibrocompression. The use of large-diameter underground pipes has increased the number of accidents from soil settlement and seismic impact. The main purpose of this work is to study the effect of the transverse component of the seismic load on underground fiber-reinforced concrete pipes. The change in the stress-strain state was carried out using the Plaxis 2D, Plaxis 3D and SAP2000 programs and was confirmed in experimental tests. At the test site of the Research Institute of Building Materials laboratory tests of fiber-reinforced concrete samples for compression, bending, crack resistance, tension and splitting were carried out. The main objective of researches is determination of the optimum quantity of a fiber in a pipe and the necessary design mechanical characteristics of a fiber concrete. The elasticity modulus, Poisson's ratio and the tension loadings were defined. When testing steel fibers of 3D and polypropylene fibers were used. The test results of fiber concrete pipes with various content of steel fiber (20, 30 and 40 kg/m³) showed that 30 kg of fiber per one cubic meter of concrete can be considered optimal for the structure.

Keywords: Fiber Concrete, Pipe, Stress, Strength, Tension

1. Introduction

Underground sewer pipes are made of reinforced concrete, 1-2 m long, diameter within Ø600-3000mm and keep within underground at depth of 4-6 m. Pipes are made at the reinforced concrete plant by method of dry vibrocompression on the special equipment. The problems arising after production of pipe is non-compliance with protective layer of concrete, on an internal and external surface existence of cracks, cavities, porous structure that increases time of production of pipes. Feature of underground pipelines is that the soil massif is considered in engineering calculations not only as the operating loading, but also has to be accepted as the external environment for the pipeline. Therefore when calculating of the intense deformed condition of pipeline we deal with the "underground pipeline-soil massif" system. If the issue of the strength of pipelines has been sufficiently studied, then the forces acting on the structure and the resulting loads and stresses in the current codes are insufficiently analyzed [1, 2, 10]. The set of cases of failures of pipelines reveals that all

authors as the main reason note existence of the longitudinal tension. It generally takes place in case of welded metal pipelines. Reinforced concrete pipes have simple joint connection; an entrance part of pipe does not exceed 10 cm. Therefore the cross and sedimentary deformations arising at seismic influence create danger of disconnection of pipes with formation of cracks. Uneven soil settlement is one of the reasons of accidents. For pipes of large diameter transverse loads have a great influence. Replacement of a steel reinforcing framework in pipes with fibers considerably reduces the arising problems listed above [3, 12, 14]. Full replacement of steel reinforcement reduces welding works and volume of the spent electric power. Concrete tensile strength increases, longitudinal cracks and a splitting off are as a result decreased. Depending on type, sizes and volume of the fiber content, strength and deformation characteristics of fiber concrete sharply change. In order to determine the characteristics of fiber concrete pipes – elastic modulus, Poisson's ratio, tension loadings, laboratory experimental studies of longitudinal tension, bend, crack resistance, splitting and various physical and mechanical tests for determination of

water tightness, frost resistance, abrasion and resistance to dynamic impact, as the primary properties of fiber-reinforced concrete samples, were conducted.

2. Literature Review

While a lot of research has been devoted to testing fiber-reinforced concrete pipes, which are a mandatory requirement of international standards, the issues of numerical modeling of pipes in soil have been considered much less works [1, 2, 10]. Romanian scientist Z. Doru tested large diameter pipes Ø1400 mm and Ø2200 mm. Compression and fracture toughness tests were carried out according to RILEM TC 162-TDF standard. Numerical modeling based on the finite element method was carried out using the MIDAS GTS NX program [7]. A group of scientists from the University of Auckland New Zealand C. Heyes et al. performed numerical simulations in a 3D system using the SAP2000 and ABAQUS programs. A model of a pipe in soil is considered. The ground connection was modeled as a spring system. The pipe loading simulated landslide ground movements [4]. Argentine scientists F. L. Fernando and others carried out a numerical simulation of a pipe with steel fibers for a 2D model and obtained stress and strain diagrams from the action of a vertical load [6]. Mexican scientists R. Flores-Berrones and X. L. Liu examined the modeling of an underground pipe from seismic impact. The connection of the pipe to the ground was modeled by a system of springs. The soil massif was modeled by the finite element method [2]. Scientists from the University of Catani (Italy) D. Casamichela carried out a numerical simulation of a pipe in the ground in a 3D system. The section of soil where the transverse seismic load acts is marked as an unstable zone. The connection of the pipe with the ground is modeled as a system of springs with a given stiffness [5, 15]. The Dutch scientists used PLAXIS 2D software for pile row modeling [13]. The Spanish scientist A. De La Fuente carried out numerical modeling and testing of pipes with steel fibers [8, 9]. Among the few studies in the field of numerical modeling in a 3D system, the work of the Polish scientist B. Kliszczewicz should be noted [11]. In a three-dimensional diagram, the stress-strain state of a pipe in soil from ring loading

and arising bending moments is obtained.

3. Numerical Modeling of the Stress State of Pipe

The underground pipeline and the soil massif surrounding it is accepted as a uniform object. The soil massif around the pipeline is modelled by means of PLAXIS 2D software according to the square and diagonal scheme on a rectangular site (figure 1). The external circle marked in green in the figure shows the contact element (interface) of the interaction of the structure with the soil. Properties of this massif is characterized by two constants - the module of elasticity of soil and Poisson's ratio. The geometrical change of the system (pipeline and soil massif) is associated with a change in mesh points. The cross contour of a pipe is also divided into finite elements. Pipe material (fiber concrete) is characterized by the module of elasticity and Poisson's ratio. PLAXIS 2D is a powerful finite element software package intended for calculation of the stress-strain state condition of structures, foundations and bases. Calculation was made in the conditions of plane deformation. In the calculation 15 nodal elements were used. In the study of the effective stresses arising in the pipe the weight of backfill over the pipe, loads from a roadbed and dynamic loads from transport were considered together with the seismic influence. Stresses were calculated separately for the case of a reinforced concrete and fiber concrete pipe with a steel and polypropylene fiber (figure 2 a, b). The similar procedure was carried out to determine the displacement of the pipe from the combination of acting vertical loads together with seismic loads. In the calculation, 2 layers of continental soil with a total height of 50 m with a crushed stone base 10 cm thick under the base of the pipe were taken. Under the influence of seismic force and the top of the underlying soil, the pipeline has horizontal (u_x) and vertical (u_y) displacement. For a pipe with a diameter of 3 m when exposed to seismic force, the horizontal displacement is $u_x=35\text{cm}$, $u_y=10\text{cm}$. Seismic acceleration was accepted 0.3g.

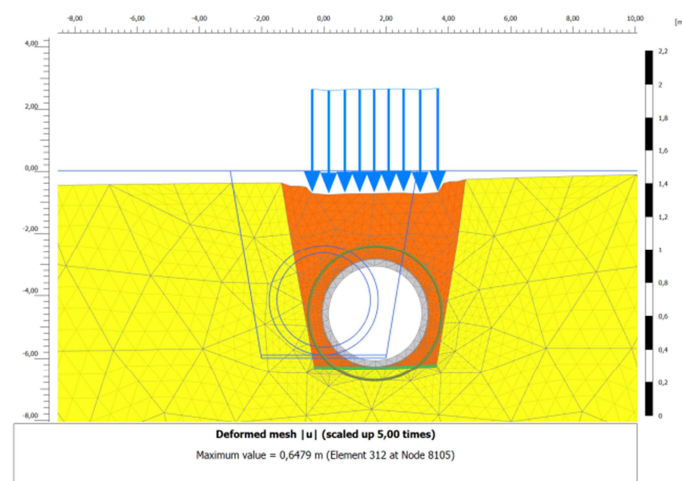


Figure 1. Design scheme of the soil massif around the pipeline modelled by means of PLAXIS 2D.

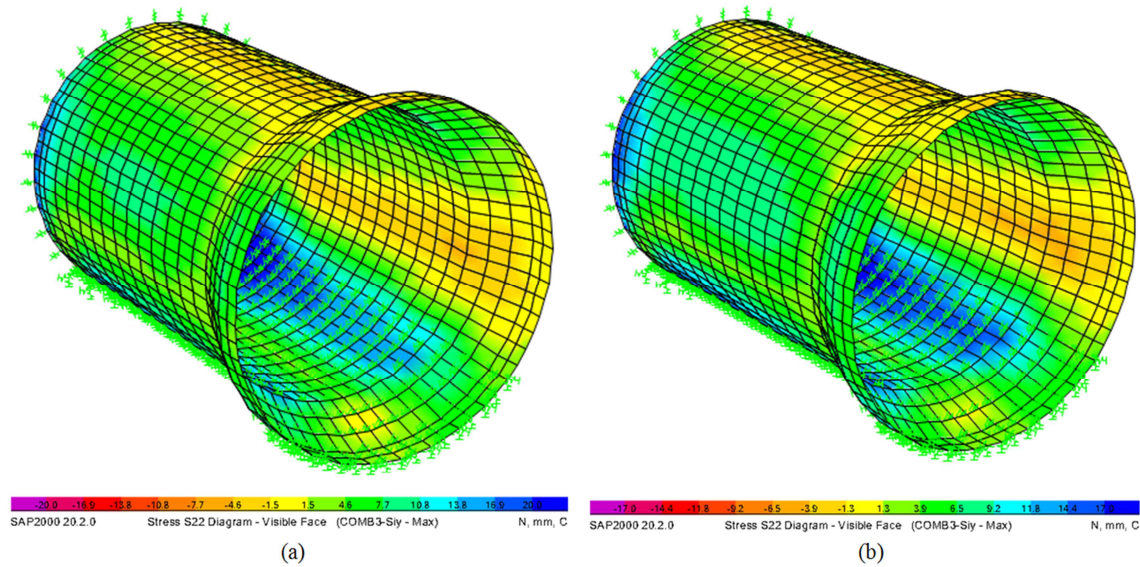


Figure 2. Contour plots of the main effective stresses arising in the pipe section from a combination of seismic loads: a) reinforced concrete pipe; b) fiber concrete pipe with a metal fiber.

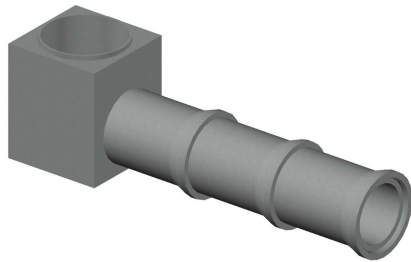


Figure 3. Connection detail of water and sewer pipes.

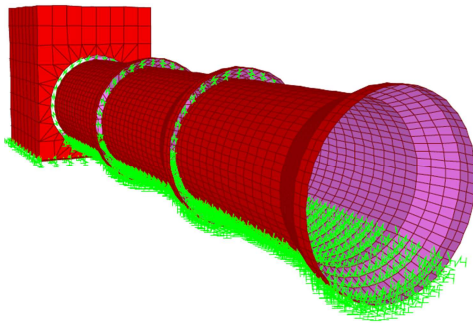


Figure 4. Pipeline modeling in SAP2000 program.

4. Experimental Determination of Parameters of Fiber Concrete and Strength Testing of Natural Pipe

To determine the mechanical characteristics of fiber concrete pipes at the test site of the Research Institute of Building Materials laboratory tests were carried out. Steel and polypropylene fibers were used in tests. As a result of $\text{tes}\mu=0.214$ was obtained. For samples with polypropylene fibers the module of elasticity of $E=25000$ MPa, Poisson's ratio $\mu=0.248$ was obtained. To determine the stress-strain state of sewer pipes natural tests were carried out. Together with reinforced concrete pipes, fiber concrete pipes were made of steel and polypropylene fiberests for concrete samples with steel fibers the module of elasticity of $E=60000$ MPa, Poisson's coefficient. For definition of mechanical characteristics the fiber concrete of pipes on the proving ground of the Research Institute of Building Materials were carried out [8]. Here tests on a bend (b), crack resistance (c), longitudinal stretching (a), compression and splitting (d) (figure 5) were carried out.

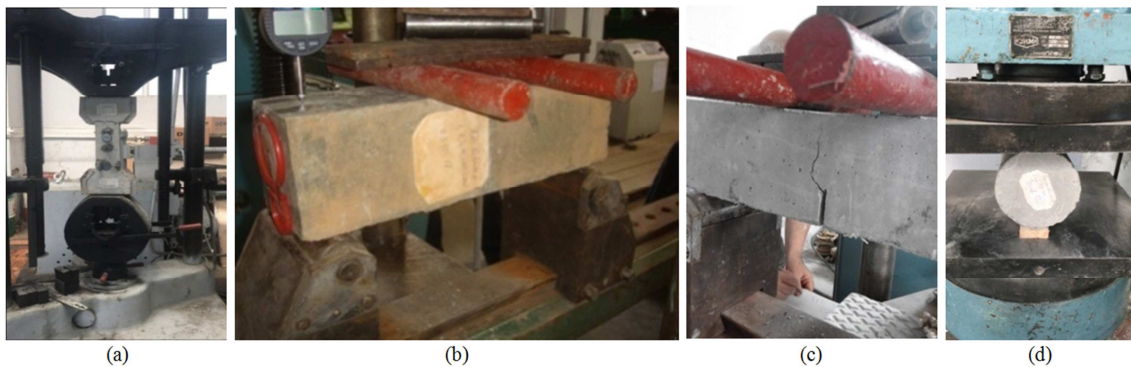


Figure 5. Test on longitudinal tension (a), a bend (b), crack resistance (c) and splitting (d).

In tests steel and polypropylene fibers were used. As a result of tests for concrete samples with steel fibers the module of elasticity of $E=60000$ MPa, Poisson's coefficient $\mu=0.214$. For samples with polypropylene fibers the module of elasticity of $E=25000$ MPa, Poisson's ratio $\mu=0.248$. For definition of the intense deformed condition of water sewer pipes natural tests were carried out. Together with reinforced concrete pipes fiber concrete pipes were made fiber concrete

without reinforcing framework, with a steel and polypropylene. Each step of loading was maintained 5 min. Tests of compression and crack resistance of a pipe be carried out on a hydraulic press of the FORE A. Ş. brand. Deformations were fixed by the electronic SDP-100C sensors having a direct exit to the computer (figure 6). Results of tests are presented on schedules and in tables form (figure 7).

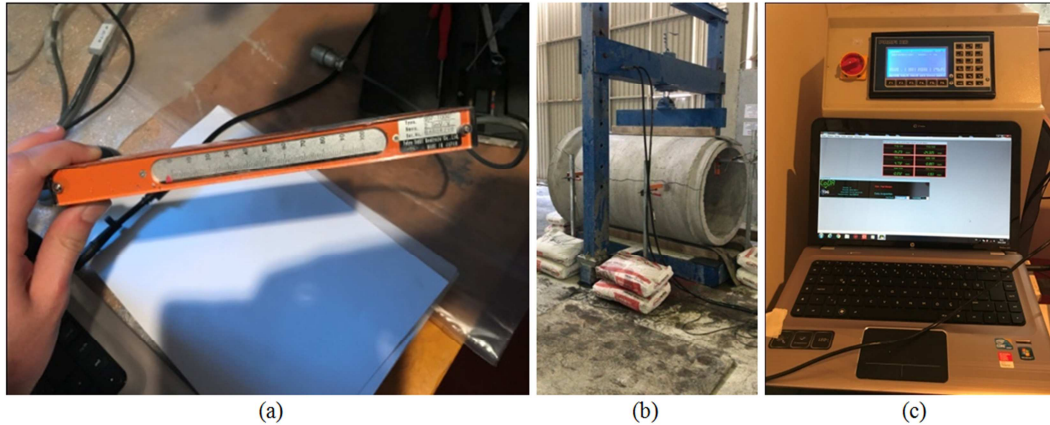


Figure 6. Test of a fiber concrete pipe: a) electronic SDP-100C sensor; b) the moment of destruction of a pipe during test on a hydraulic press; c) panel of a hydraulic press of the FORE A. Ş. brand.

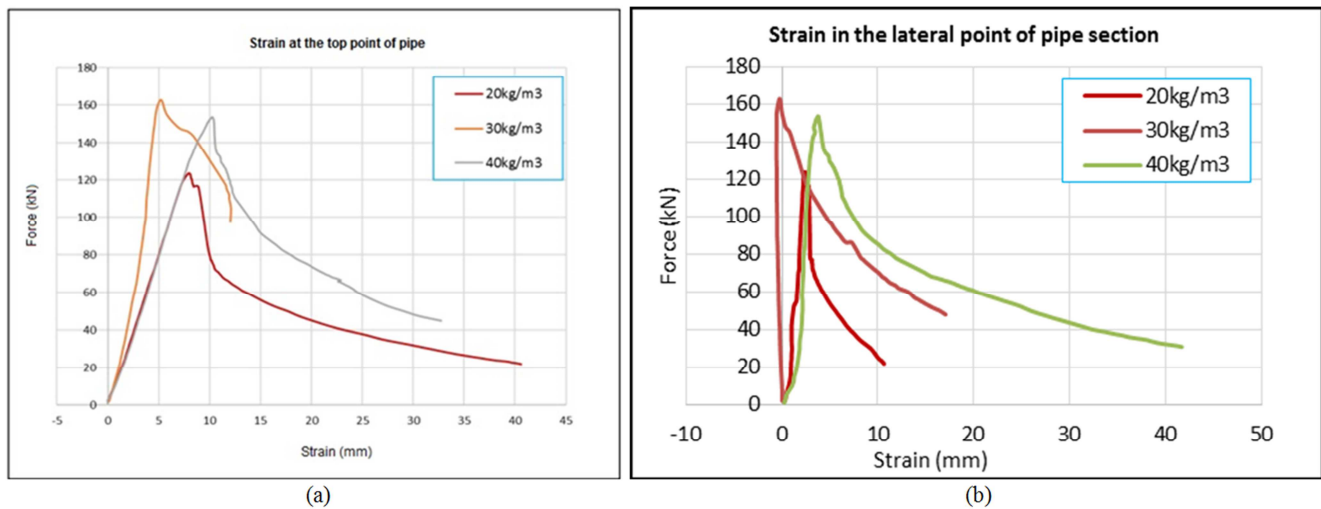


Figure 7. The schedule of dependence loading deformation ($P-\epsilon$) for the fiber concrete of pipes with a diameter of 1200 mm from class B25 concrete: a) deformation at pipe top; b) deformation in extreme points of the middle of a pipe.

Table 1. Tests results for fiber concrete pipes with metal fiber.

Type of the sample	Strength, MPa	Concrete grade	Note
Concrete pipe with dosage of steel fiber 20 kg/m ³	41,2	B25	Corresponds
	44,4		
	48,9		
Concrete pipe with dosage of steel fiber 30 kg/m ³	49,8	B30	Corresponds
	55,6		
Concrete pipe with dosage of steel fiber 40 kg/m ³	54,4	B35	Corresponds

5. Conclusions

The test results of the fiber concrete pipes (diameter

Ø1200mm) with various content of a steel fiber (20, 30 and 40 kg/m³) showed that the optimum composition can be considered 30 kg of fiber in 1 cubic meter of concrete. This composition showed the maximum compression resistance of

the fiber concrete pipe. This once again confirms the fact that increasing the amount of fiber increases the resistance of concrete to a certain level. Then recession is observed. The surplus of a fiber leads to delimitation of concrete structure, which reduces its resistance. Replacing the reinforcing cage with fibers increases the output of pipe production more than three times. The economic effect of replacing a reinforcement cage with fibers is 30%.

The electronic sensors used during the test for recording deformations allowed to obtain a plot of force versus strain.

The test results showed the advantages 3D steel fibers. This is especially effective when designing subway stations, tubings, in the construction of bridges and other unique constructions.

With an increase in the diameter and accordingly the weight of the pipe, the horizontal and vertical displacement increases. In this regard, for large-diameter pipelines, structural measures are necessary under the base of the pipeline.

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Biography



Tural Rustamli, was born in 1990, in Baku, Azerbaijan. Received his MS degree from Azerbaijan University of Architecture and Construction (2015). Has been working as structural engineer in Research Center «Gidrotransproyekt» Ltd. Has an experience in bridge design and underground hydraulic structures. Currently is a PhD Student and

working on doctoral dissertassion about fiber concrete water sewer pipeline investigation.



Nijat Mastanzade, was born in 1957, in Baku, Azerbaijan. Received his MS degree from Azerbaijan University of Architecture and Construction (1980) and Ph. D. degree from VAK USSR, Moscow, in 1989. Received his Associate Professor degree in 1992 at VAK USSR, Moscow. Published more 100 publications in more than fifteen countries.

Has been working in Istanbul since 1998 to 2012, in Istanbul University, Istanbul Technical University and Istanbul Kultur University as Associated Professor. In this he giving lectures on Calculus, Statics, Strength of Matherials, Assessment and Retrofit of damaged structures and two books "Mathematics with engineering applicatins". Istanbul. 2002.