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ANFIS and statistical based approach to prediction the peak pressure load of concrete pipes including glass fiber

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ABSTRACT

In this paper, Adaptive Neural Fuzzy Inference System (ANFIS) and Multiple Linear Regression (MLR) models are discussed to determine peak pressure load measurements of the 0, 0.2, 0.4 and 0.6% glass fibers (by weight) reinforced concrete pipes having 200, 300, 400, 500 and 600 mm diameters. For comparing the ANFIS, MLR and experimental results, determination coefficient (R^2), root mean square error (RMSE) and standard error of estimates (SEE) statistics were used as evaluation criteria. It is concluded that ANFIS and MLR are practical methods for predicting the peak pressure load (PPL) values of the concrete pipes containing glass fibers and PPL values can be predicted using ANFIS and MLR without attempting any experiments in a quite short period of time with tiny error rates. Furthermore ANFIS model has the predicting potential better than MLR.

1. Introduction

Concrete pipes are integral components of the community's infrastructure, being employed in a wide range of applications from storm-water drainage to external casing for composite piles (Fisher, Bullen, & Beal, 2001). Underground pipe systems have presented to improve human being standard of living since the dawn of civilization. Nowadays, underground pipe systems serve in various applications such as sewer lines, drain lines, water mains, gas lines, telephone and electrical conduits, culverts, oil lines, coal slurry lines, subway tunnels, and heat distribution lines (Moser, 2001). There are many types of piping materials in the construction sector today, ranging from rigid concrete to flexible thermal plastic. Pipes must have adequate strength and/or stiffness to perform their intended function. They must also be durable enough to last for their lifetime. Concrete pipes may be produced which conforms to the requirements of the respective specifications but with increased wall thickness and different concrete density. Concrete pipe products are made by several processes included nonreinforced products in sizes ranging from 4- to 36-in. diameter and various reinforced products in sizes 12- to 144-in. diameter (Moser, 2001, http://www.concrete-pipe.org/pdf/cp-manual.pdf). Concrete pipes have been in widespread usage area for water or sewage conveyance in many areas like municipal, industrial, plant piping systems, etc. (Haktanir, Ari, Altun, & Karahan, 2007; Xiong, Li, & Li, 2010).

Glass fibers are type of high-strength fiber materials have many application areas in construction sector. Glass fibers commonly used composite materials in concrete owing to its great tensile strength and tensile module; glass fibers have great potential for use in concrete due to their superior characteristics in terms of high stiffness, low density and water absorption, high tensile strength, corrosion resistance etc. (Asokan, Osmani, & Price, 2009, 2010; Bai, Zhang, Yan, & Wang, 2009).

Designers utilize principles of science and mathematics to develop specific technologies. These technologies are then used to create engineered tools such as products, structures, machines, processes or entire systems. It has already been seen that different tasks in engineering problem solving require different analysis (Krishnamoorthy & Rajeev, 1996). Recently, artificial intelligence and statistical analysis have been extensively using in the fields of civil engineering applications such as construction management, building materials, hydraulic, geotechnical and transportation engineering etc. (Akkurt, Başyigit, Kilincarslan, & Beycioglu, 2010; Emiroglu, Bilhan, & Kisi, 2010a, 2010b; Erdem, 2010; Kisi et al., 2009; Li, Huang, & Nie 2010; Mashrei, Abdulrazzaq, Turki, & Rahman, 2010; Moghaddamnia, Gousheh, Piri, Amin, & Han, 2009; Saltan & Terzi, 2008; Shiqiao, Haipeng, & Lei, 2009; Sobhani, Najimi, Pourkhorshidi, & Parhizkar, 2010; Subaşı, 2009; Słoński, 2010; Talei, Chua, & Wong, 2010; Terzi, 2007; Wu, Chau, & Fan, 2010; Yarar, Onucyıldız, & Copty, 2009; Yilmaz, Kok, Sengoz,

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Sengur, & Avci, 2010; Yurdusev & Firat, 2009; Zarandi, Türksen, Sobhani, & Ramezanianpour, 2008).

One of the most popular artificial intelligence method is ANFIS. The acronym ANFIS derives its name from adaptive neuro-fuzzy inference system. ANFIS is the implementation of fuzzy inference system (FIS) to adaptive networks for developing fuzzy rules with suitable membership functions to have required inputs and outputs. The neuro-adaptive learning method works similarly to that of neural networks. Neuro-adaptive learning techniques provide a method for the fuzzy modeling procedure to learn information about a data set. Fuzzy Logic Toolbox software computes the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. The Fuzzy Logic Toolbox function that accomplishes this membership function parameter adjustment is called ANFIS. The ANFIS function can be accessed either from the command line or through the ANFIS Editor GUI (Jang, 1993;http://www.mathworks.cn/access/helpdesk/help/toolbox/fuzzy/fp715dup12.html#FP43142).

In this study, the effects of glass fiber content on peak pressure load of concrete pipes were investigated by using ANFIS Editor GUI and statistical approach. For this purpose, concrete pipes having varying diameters were prepared with using 0, 0.2, 0.4 and 0.6% glass fiber by weight. Prediction of peak pressure load of concrete pipes produced with varying amount of glass fiber was determined as statistical and ANFIS approximation.

Table 1
Properties of glass fiber.

Fiber length (μm)	Fiber diameter (μm)	Specific gravity	Young's modulus (GPa)	Tensile strength (GPa)	Strength at failure (%)
30–50	9–15	2.6	70–80	2.4	2–3.5

Table 2
Chemical, physical and mechanical properties of the cement.

Chemical composition	(%)	Physical properties	
SiO_2	20.42	Initial setting time, (h/m.)	02:25
Al_2O_3	5.92	Final setting time, (h/m.)	03:55
Fe_2O_3	2.81	Specific gravity	3.00
CaO	65.87	Specific surface (cm^2/g)	3927
MgO	3.23	Mechanical properties (compressive strength (MPa)	
SO_3	0.97	7th day	27.5
$Na_2O + K_2O$	0.15	28th day	38.5
Loss on ignition	2.16		
Unknown	0.18		

Table 3
Properties of the concrete specimens.

Glass fiber ratio (%)	Compressive strength (MPa)	Weight lost after 25 cycles of freeze–thawing (%)	Tensile strength (MPa)	Three point bending strength (MPa)
0.0	41.57	12.70	1.78	1.98
0.2	36.83	12.68	1.91	2.38
0.4	35.67	12.71	2.27	2.74
0.6	32.00	12.76	4.00	3.32

2. Material and method

The experimental program was designed to examine the peak pressure load of concrete pipes. The materials used to develop the concrete mixes in the study were aggregate, cement, water and short glass fibers. The aggregate having 31.5 mm maximum aggregate diameter and 2.70 g/cm^3 specific gravity were obtained from Elazığ/Çemişgezek region. CEM I 32,5 R was used in all mixes. The properties of glass fibers and cement used in this study are listed in Tables 1 and 2 respectively.

A plain concrete mix was designed as a control (without glass fiber) mix. The mix required 0.39 water-cement ratio. In the rates of 0.2, 0.4 and 0.6% by weight glass fibers were supplemented to the concrete mix for preparing the glass fiber reinforced concrete specimens. Because of water absorption capacity of glass fiber water-cement ratio was increased depending on glass fiber content, thus water-cement ratio was ranged from 0.39–0.48. Prepared concrete mixes were moulded and cured during 28 days for determining the compressive strength. 28th day compressive

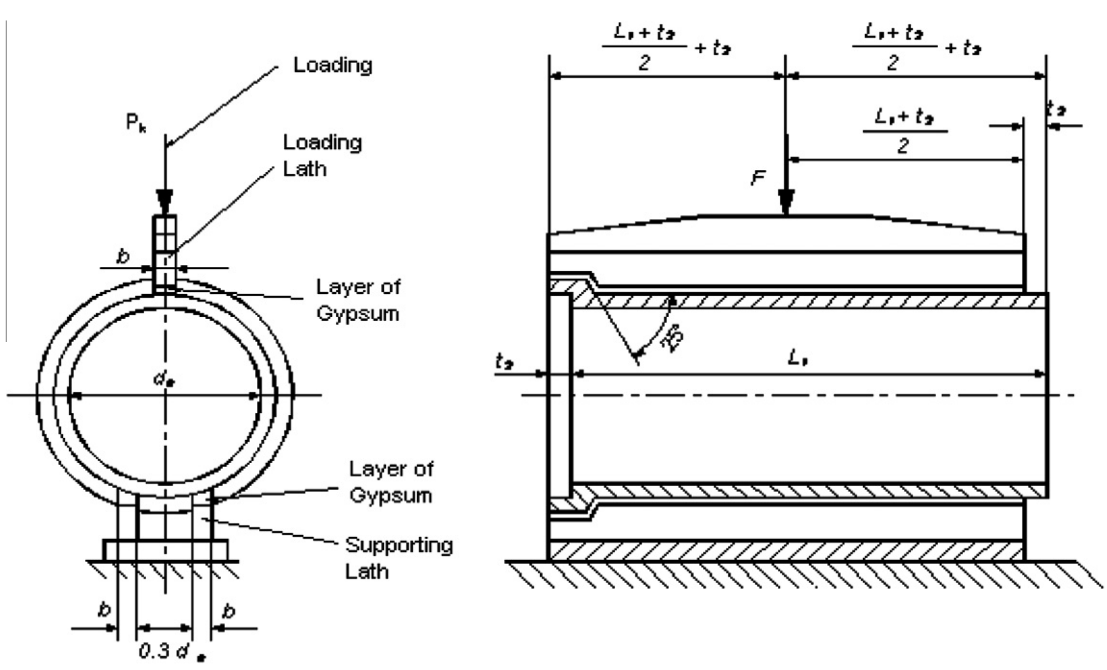

Fig. 1. Peak load pressure test setup.