APPLYING POLYNOMIAL REGRESSION WITH COMPUTER SIMULATION TO STRUCTURAL ELEMENTS

Selcuk Sevgen, Ruya Samli
Department of Computer Engineering
Istanbul University
Istanbul, Turkey

Baris Sayin
Department of Construction and Technical Works
Istanbul University
Istanbul, Turkey

Abstract—**As parallel to today's technologic developments, experimental researches have important role in scientific studies. Although experimental studies which are closely associated with laboratory possibilities cost and time give realistic results, they are limited with the properties of the elements used. On the other hand, computer softwares provide great convenience and divert the design phase, although they compensate the experiments exactly. In this study, a civil engineering problem is handled. It is aimed to transfer one of the experimental studies about resistance of structural being elements to computer environment. Numerical results are obtained by graphics and the coherence with experimental results are investigated.**

Keywords-polynomial regression; computer simulation; structural elements; beams.

I. Introduction

It is known that many problems in some engineering fields are as complex as they cannot be solved with simple relations and algorithms, consequently, importance of experiments and experimental results in the solutions of these problems. Correspondingly to today's technological developments, experimental researches play a crucial role. To investigate the behaviors of the materials that will be used in experimental studies, model experiments must be done in laboratories or computer simulation techniques must be used. Although experimental studies can give realistic results, they are limited with the properties of elements used. Also experiments are studies that needs long time, high cost and laboratory resources. Besides, structural element that is desired to be examined can be modeled in computer environment without the aforementioned limitations. It must not be forgot that the accuracy of the computer model is related to material assumptions and experiment environment conditions on a large scale. Computer softwares, although they don't compensate the experiments yet, they provide many easiness and steers the design phase. Within the scope, in recent years, experimental studies are simulated by different methods like optimization methods, regression analysis, neural networks etc [1-7].

In this study, a problem of civil engineering is dealt. It is very important for evaluating the situation of structures in Turkey as an earthquake country. Because of this reason, experimental studies are done about load bearing elements. But for many structural elements, these experiments are not possible because of the limitations of time cost. One of the experiments that can be done is strengthening the structural elements. In this study, used data are the data that are obtained by the strengthening the elements by using carbon fiber reinforced polymer (CFRP). When the literature is explored, in the papers that FRP is applied to structural elements: Barbato used finite elements method [1], Tanarslan et al. used neural networks [2], Martines et al. used serial/parallel mixing theory [3], Godat et al. also used finite elements method [4] for simulating the experimental data in computer environment. The aforementioned data in this study are investigated by polynomial regression that is used for finding the relationship between dependent variable with one or more independent variables. In the study, the experimental data are tried to be compared by the simulation results and by this operation, it is aimed to measure the efficiency of the system.

The study is formed of these sections: the second section mentions about polynomial regression, the third section contains the experimental elements and results, in the fourth section the simulation study and results take part, and these results are evaluated in the last section.

II. Polynomial Regression

Regression analysis is a statistics technique that tries to model the relationship between some variables. The function of the relationship that is obtained by regression analysis is called regression function. This method is often used for prediction of a behavior of some variables. There are different types of regression analysis method. One of them is polynomial regression which is a subset of linear regression and we used in this study. It also tries to determine the relationship between independent and dependent variables, but is uses a standard type function which is an nth order polynomial. Let x become the independent and y become the dependent variable. Polynomial regression handles the x value and corresponding y, it is usually denoted by $E(y|x)$ and find the nonlinear phenomena between these values. Although statistical data and estimation problems are linear and polynomial regression is nonlinear, it doesn't make any problem since $E(y|x)$ is linear in the unknown parameters.

The polynomial regression model can be described below.

$$y_i = a_0 + a_1 x_i + a_2 x_i^2 + \ldots + a_m x_i^m + \varepsilon_i \quad (i = 1,2,\ldots,n) \qquad (1)$$

III. EXPERIMENTAL STUDY

In the experimental study, totally 16 RC beams were produced as two series. The first series is composed of eight flexural beams while the second one is composed of eight shear beams which were designated as FB and SB, respectively. For RC beams, three concrete strength classes, i.e., C8, C14 and C20, were identified, see Table 1 for details. The details of flexural and shear beams are shown in Fig. 1.

TABLE I. TESTED BEAMS (BEAM SERIES FB AND SB)

Beam No	Concrete strength class
FB01	C20
FB02	C20
FB03	C14
FB04	C14
FB05	C14
FB06	C14
FB07	C14
FB08	C14
SB01	C14
SB02	C20
SB03	C20
SB04	C14
SB05	C14
SB06	C8
SB07	C8
SB08	C14

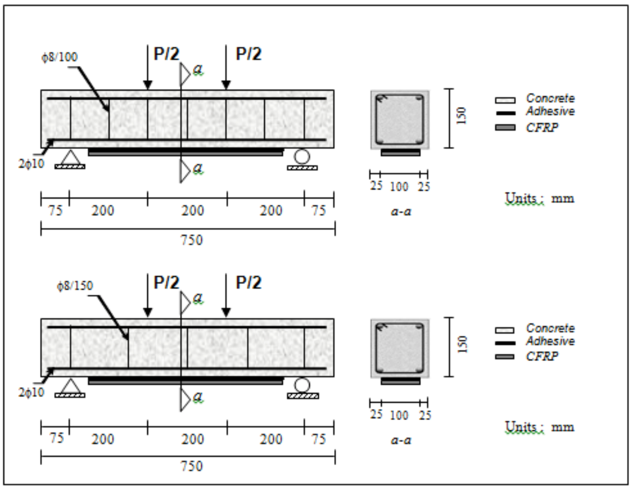

Figure 1. The details of the beam series: (a) Flexural beam (FB) series, up (b) Shear beam (SB) series, down

Out of 16 RC beams, two of them do not contain carbon fiber as reinforcement and called as control beams. The rest 14 RC beams were reinforced by carbon fiber plates from their sides where tensile forces arise during loading. In experimental study, all beams were statically loaded until they collapsed. The test results on the strength and deflection of the control specimens and strengthened beams are reported in Table 2.

IV. NUMERICAL RESULTS

The data for being used in the polynomial regression are 4 of the series of FB beams and 3 of the series of SB beams determined in the Table 2 according to their C14 (concrete strength class) are handled. These are FB03, FB04, FB05, FB07 for FB series and SB01, SB04, SB05 for SB series.

In the analysis, first of all, load-deflection data of the beams are used. The load values of the beams from maximum load capacity to failure weren't taken for evaluating.

The data about the beams (FB and SB) aforementioned beams are put together in one matrix by using MATLAB simulation program and the graphics about experimental results are obtained. After that, by MATLAB again, optimum polynomial parameters are calculated for obtaining the corresponding polynomial of these graphics. Fig. 2 and 3 show the experimental results and graphics also for series of FB and SB beams. For FB and SB beams, the obtained polynomials were like that, respectively:

$$y_1 = 0{,}0011x^3 - 0{,}0181x^2 + 0{,}1394x - 0{,}2772 \qquad (2)$$

For y_1, ratio of error between polynomial and experimental measurements is 0,0067.

$$y_2 = -0{,}0025x^3 + 0{,}0345x^2 - 0{,}1999x + 0{,}4551 \qquad (3)$$

For y_2, ratio of error between polynomial and experimental measurements is 0,0081.

in where, x is load and y is deflection.

V. CONCLUSIONS

In this study, it is aimed to have computer simulation results that are suitable to the experimental results about load-deflection and load-test duration. For this reason by using experimental results in MATLAB, appropriate polynomials are calculated and these polynomials are shown by graphics.

By presented graphics, it is seen that the polynomial regression results and experimental results coincide in the way of load-deflection relation of beams. The results obtained by numerical part of this study can only be generalized after doing experimental studies with more type and numbered elements and transferring the results to computer environment. Nevertheless, this study is important because it shows that it is possible that experimental results can be transferred to computer simulations and so cost and time savings can be done.

In the following studies, it is thought to transfer different behavior parameters of the experimental elements that weren't considered in this study. While doing these, different analysis methods can be necessary.

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TABLE II. LOADS AND DEFLECTIONS AT THE LOAD BEARING CAPACITY OF THE TESTED BEAMS

Beam No	**Concrete strength class**	**Load When FRP Applied (kN)**	**Ultimate load (kN)**	**Mid-span deflection δ, (mm)**	**Test duration (sn)**
FB01	C20	-	85.88	16.40	91
FB02	C20	-	90.96	12.60	94
FB03	C14	-	71.20	13.01	39
FB04	C14	-	68.88	11.47	70
FB05	C14	-	74.01	10.99	78
FB06	C14	-	73.30	10.82	no data
FB07	C14	-	73.39	16.30	103
FB08	C14	(control beam)	55.44	12.65	87
SB01	C14	-	73.44	16.01	98
SB02	C20	-	88.94	9.26	27
SB03	C20	-	88.89	14.83	98
SB04	C14	-	77.97	9.26	30
SB05	C14	-	67.07	13.96	91
SB06	C8	-	44.84	10.70	91
SB07	C8	-	51.88	15.17	83
SB08	C14	(control beam)	54.67	14.36	85

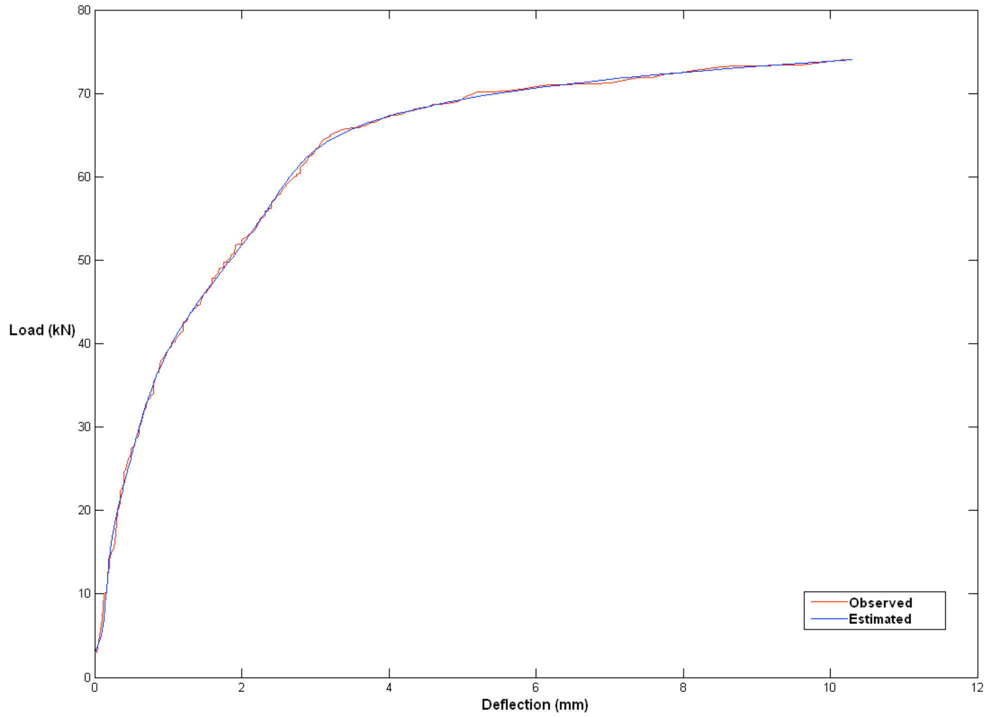

Figure 2. Comparison of experimental and numeric results for FB series

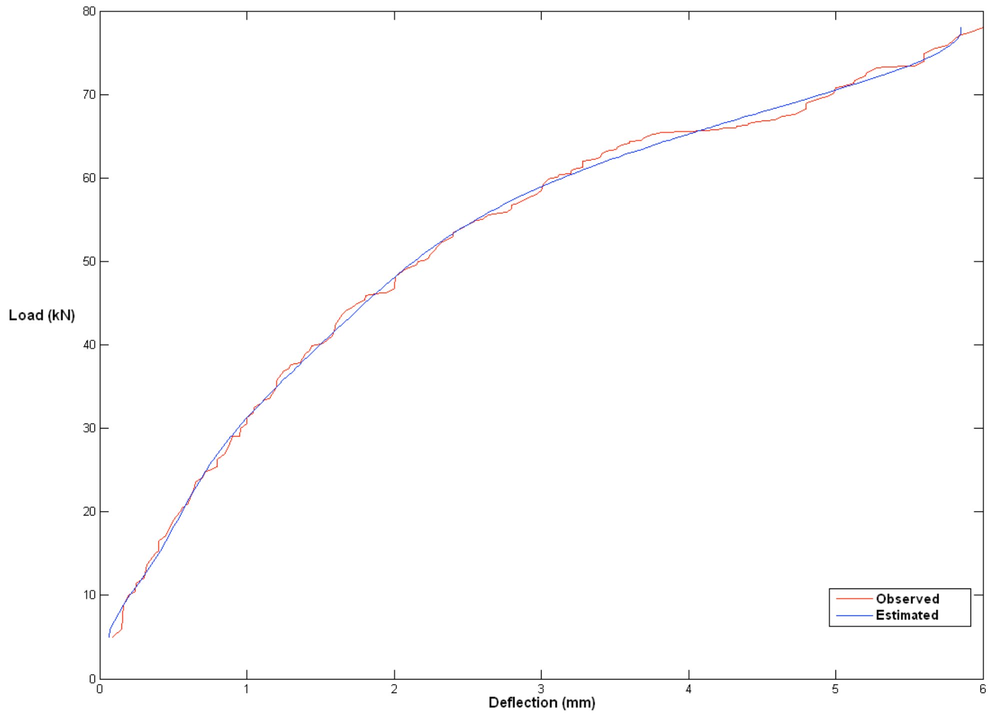

Figure 3. Comparison of experimental and numeric results for SB series