PREDICTION OF SHEAR STRENGTH OF DEEP BEAM USING GENETIC PROGRAMMING

Department of Civil Engineering,

National Institute of Technology, Rourkela, India

PREDICTION OF SHEAR STRENGTH OF DEEP BEAM USING GENETIC PROGRAMMING

A thesis submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

In

Civil Engineering

By

Himanshu Kumar Singh

(110ce0059)

Final Year B.Tech student,

Supervised by- ***Prof. Manoranjan Barik***

Department of Civil Engineering,

National Institute of Technology, Rourkela, India

Department of Civil Engineering,

National Institute of Technology, Rourkela, India

CERTIFICATE

This is to certify that the thesis entitled"PREDICTION OF SHEAR STRENGTH OF DEEP BEAM USING GENETIC PROGRAMMING" submitted by Himanshu Kumar Singh (110CE0059) of Civil Engineering Department, National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter included in the thesis has not been submitted to any other institution for any degree or awards.

Date:

Place:Rourkela

Prof. Manoranjan Barik
Department of Civil Engineering
National Institute of Technology
Rourkela, Odisha-769008

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor Prof. Manoranjan Barik for providing me a oppurtunity to work under him. His supervision helped me a lot in my research work and thesis writing. I appreciate his ability and the support which he provided me throughout this academic year. Without his assistance and commitment, my work might not have come to this stage of fulfilment of my bachelor degree.

I would like to thank each and every faculty of my department for their knowledge, assistance, motivation and care throughout the study period.

I would like to thank S Tausif Akram (B.Tech Student) and Gumpalli Sai Prasanth (B.Tech Student) for their help in clearing my doubts whenever I faced a problem.

ABSTRACT

This research project consists of Genetic Programming (GP) to predict an empirical model for the convoluted non-straight relation between distinct parameters related with Reinforced Concrete (RC) deep beam and its ultimate shear capacity. It is a manifestation of artificial intelligence and thoughts, which is focused around the Darwinian hypothesis of evolution and genetics. The structural and size intricacy of the empirical model advances as a component of the prediction. Model evaluated by GP is developed specifically from experimental database accessible from prior literature. The legitimacy of the acquired model is analyzed by comparing the GP response and the shear capacity ascertained according to distinctive design codes. The created model produced is utilised for study of relationship between the shear strength of deep beam and its distinct influencing parameters.

TABLE OF CONTENTS

LIST OF FIGURES

List of tables

35

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The objective of the present work is to develop an empirical relation between the shear strength capacity of deep beam and parameter on which its shear strength depends utilizing the genetic programming. The data utilized for this are collected from the earlier literature. The results subsequently acquired are to be contrasted and those obtained using the following codes.

1. IS code.
2. ACI code

1.2 INTRODUCTION

Reinforced Concrete (RC) deep beams are utilized for load distribution within a wide range of structures; for instance in tall buildings, offshore gravity structures, as pile caps, folded plates, transfer girder, and foundation wall. shear walls are also considered as cantilever deep beam. Deep beams are regularly placed on the edge of surrounded structures where they give stiffness against horizontal loads. The American Concrete Institute (ACI) code 318-95 (condition 10.7.1) (ACI 1995) classify the beam as a deep beam if the clear span/effective-depth ratio is less than 5 for simply supported beams. According to Indian code (Is456 clause 29), a simply supported beam is considered as deep beam when the effective span to its overall depth is less than 2. Continous beam are considered as deep beam when the effective span to its overall depth is less than 2.5. In Deep Beam a non linear strain profile is noticed even in the elastic range which is not genuine in normal beam. Strength of deep beam is administered by shear because of non linear strain profile even in the elastic range. Conduct of shear force in deep beam are analysed by strut and tie model or tied arch action.

1.3 COMPARISON

DEEP BEAM	SLENDER BEAM
✓ Plane section before bending does not remain plane after bending	✓ Plane section before bending remains plane after bending.
✓ Shear deformations become significant compared to pure Flexure	✓ Shear deformation is neglected.
✓ The stress block is non linear even at elastic stage	✓ The stress block can be considered linear at elastic stage
✓ It is subjected to two dimensional state of stress.	✓ It is subjected to one dimensional ✓ state of stress.
✓ The resulting strain is non linear.	✓ The strain is linear.

1.4 BEHAVIOR OF DEEP BEAM

Deep beams transfer a significant load to supports by forming a compression thrust between load and the reaction. The diagnal compression combined with the tension bars along the beam constitute the strut and tie model for deep beam. The force-transferring mechanism can be recognised by tied arch action of deep beams. Crushing of a compression strut or loss of anchorage in beam bars are responsible for the failure of deep beam. In general, shear force governs the design of deep beam, rather than flexural. A large amount of compressive forces are transferred to supports by “arch action" directly.

Shear strength of deep beam is controlled by the following parameters:-

- ✓ The effective span of deep beam
- ✓ Width of deep beam

- ✓ Effective depth of deep beam
- ✓ Shear span of deep beam
- ✓ Characteristics compressive strength of concrete
- ✓ Yield strength of longitudinal tensile steel
- ✓ Yield strength of vertical web steel
- ✓ Yield strength of horizontal web steel
- ✓ Longitudinal tensile steel reinforcement ratio
- ✓ Horizontal web steel reinforcement ratio
- ✓ Vertical web steel reinforcement ratio

Input Parameter of deep beam

A deep beam subjected to a point load, has the input parameter as shown in fig 1 where

D=overall depth of beam

A_v=shear span of beam

L= length of beam

A_v= vertical Reinforcement

A_h= horrizontal Reinforcement

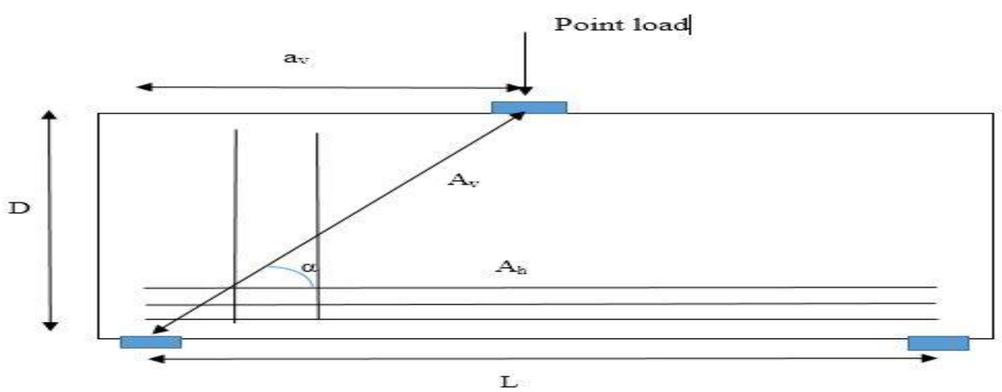


FIG 1

1.5 FAILURE MECHANISM

Failure mechanism for deep beam in shear is based on modified coloumb failure criteria with zero tension cutoff as proposed by A.F.Ashour for two symmetrical point loading. Two types of failure mechanism are observed, one is symmetrical mechanism and another is unsymmetrical mechanism. In symmetrical mechanism three rigid blocks are separated by two yield lines whereas in unsymmetrical mechanism two rigid blocks are separated by one yield line. Unsymmetrical mechanism occurs if the symmetry of beam are slightly disturbed. Both types of failure mechanism are shown in fig 2

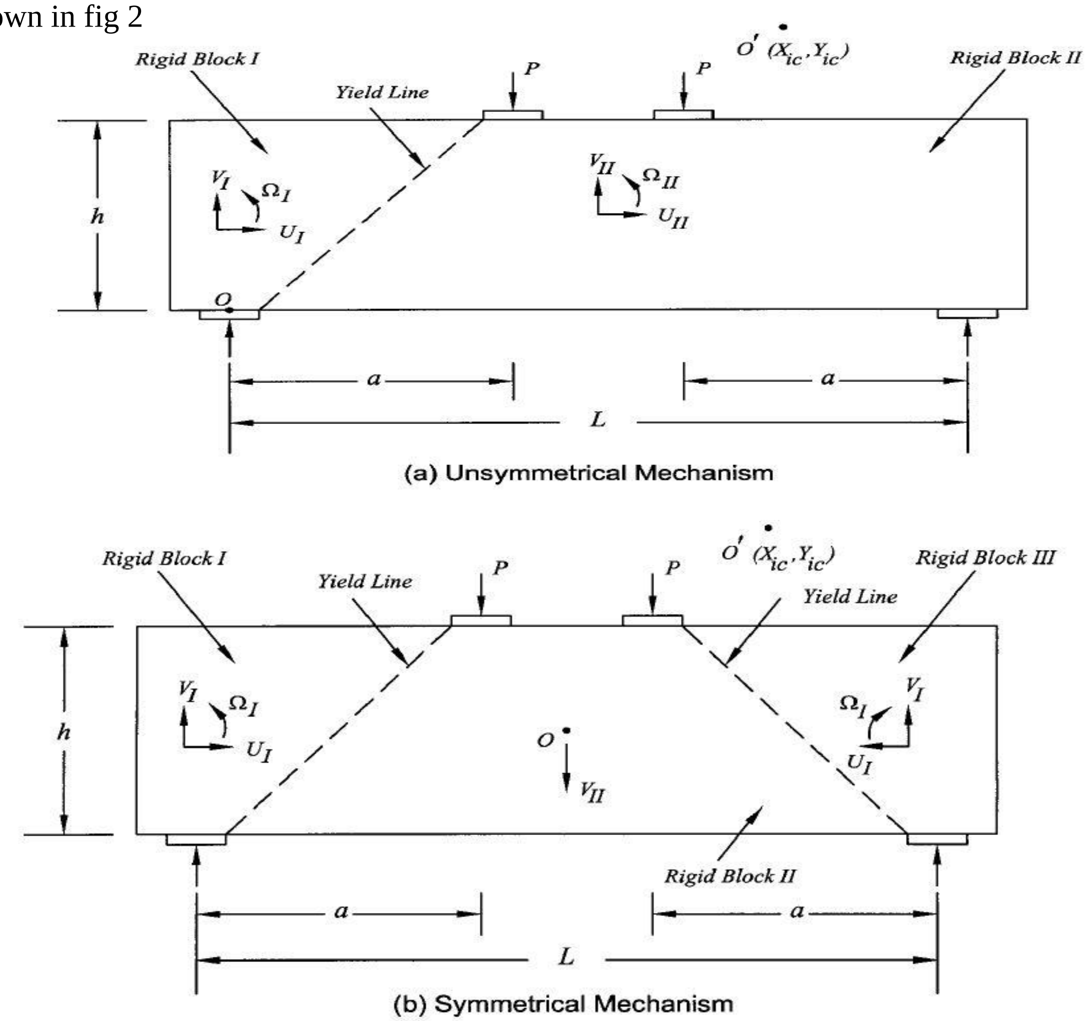


FIG 2

CHAPTER 2

REVIEW OF LITERATURE

- In an attempt to develop guidelines for design Ilekar, Faith and Kara [6] choose the genetic programming approach to develop the shear strength capacity. For development of empirical relation, they collected shear strength of 104 specimen, from published literature. Collected specimens include 91 number of simply supported beams and 13 number of simply supported one way slabs tested against either 3-point bending or 4-point bending. Two types of reinforcement were used, one was carbon FRP Bars and another was Glass FRP Bars. Specimen were not provided with any type of shear reinforcement. They included six main parameter as input variables. While modelling they randomly selected 56 sets for training set and 28 sets were selected as testing set and remaining were used as validation set.
- Ashour AF [1], presented a mechanism for analysis of shear failure for simply supported Reinforced Concrete deep beam. He modeled concrete and steel reinforcement as perfectly rigid plastic material. He considered deep beam to be in a state of plane stress. Modified coloumb failure criteria with zero tension cut-off were used to study the shear failure mechanism. In his analysis he considered yield line to represent the failure zone where two rigid blocks were separated along which in plane displacement discontinuities occur. Optimum shape of the yield line is a hyperbola as proved by Jensen, Ashour and Morley. He observed modes of shear failure for simply supported deep beams under 2-point loading andtwo modes of failure were observed, one is symmetrical mode of failure and another is unsymmetrical mode of failure.

Failure mechanism consist two rigid blocks separated by the yield line. He did the different parametric study between the input parameters of deep beam and its shear capacity. He considered a deep beam without web reinforcement to study the effect of longitudinal tensile bar on the shear strength of deep beam. He also study the effect of shear span-depth ratio on shear capacity of beam.

- Ashour A.F, Alvarez L.F, Toropov V.V_[7], in their work they used the genetic programming to create an emperical relation to find the shear strength capacity of deep beam.They obtained experimental database from earlier literarature to create the GP model. They did the parametric study to known the validation of the predicted GP model on its input parameter. To reduce the number of input parameters they converted the input parameter and its shear strength into normalised form. Mathematical operator used in GP modelling were addition, multiplication, division, square and negation. they choose the population size of 1000 with mutation rate of 0.001.

CHAPTER 3

METHEDOLOGY

3.1 GENETIC PROGRAMMING

The method to be used while creating the empirical relation will be genetic programming(GP). GP is a domaininant autonomous, problem-solution approach through which computer programs are generated to find solutions for the problems. The technique is based on the Darwinian hyphothesis of 'survival of the fittest'. Every result predicted by GP is compiled from two sets of primary nodes; terminals and functions. The terminal set holds nodes that provide a framework to the GP system while the function set contains nodes that processes values already inside the system. There are three major evolutionary operators within a GP framework:

Reproduction: it chooses an individual from the initial population to be replicated exactly into the subsquent generation. In reproduction a strategy is made to kill the under performed program. There are few methods of selection from which individual is duplicated which includes fitness measure, selection, rank selection and tournament selection.

Crossover: it is a recombination technique, where two parent results are picked and parts of their subtree are exchanged in light of fact that each function holds the property 'closure' (each tree member can transform all possible argument values), every crossover operation ought to bring a legal structure. It follows the folowing principle:

1. Two trees are selected from the population lot.
2. One node is randomly selected from each trees
3. Selected nodes subtrees are exchanged to bring two children of new population

Mutation: it is responsible for irregular changes in a tree before it is brought into the next population. Dissimilar to crossover, it is abiogennetic and works on one single individual. Throughout mutation process either all functions or terminals are separated undereneath an arbitrarily determined node and a new limb is randomly generated or a single node is exchanged with each other.

- Perspective to portray GP as far as the structures that experiences adaptation are
  - Initial structure generation
  - Fitness measure test, which assess the structure
  - Operation which change the structure
  - The state (memory) of the framework at each stage
  - The system for terminating the process
  - The system for designating an output, and the parameters that control the process
- GP has the five following component
  - Function set
  - Terminal set
  - Fitness function
  - Control parameter
  - Stop condition

Parameters that control the shear strength of deep beams are input variables and its shear capacity are the output variable. Initially GP model use single gene and two lengths of head and is incresed after the subsequent run.

FLOW CHART

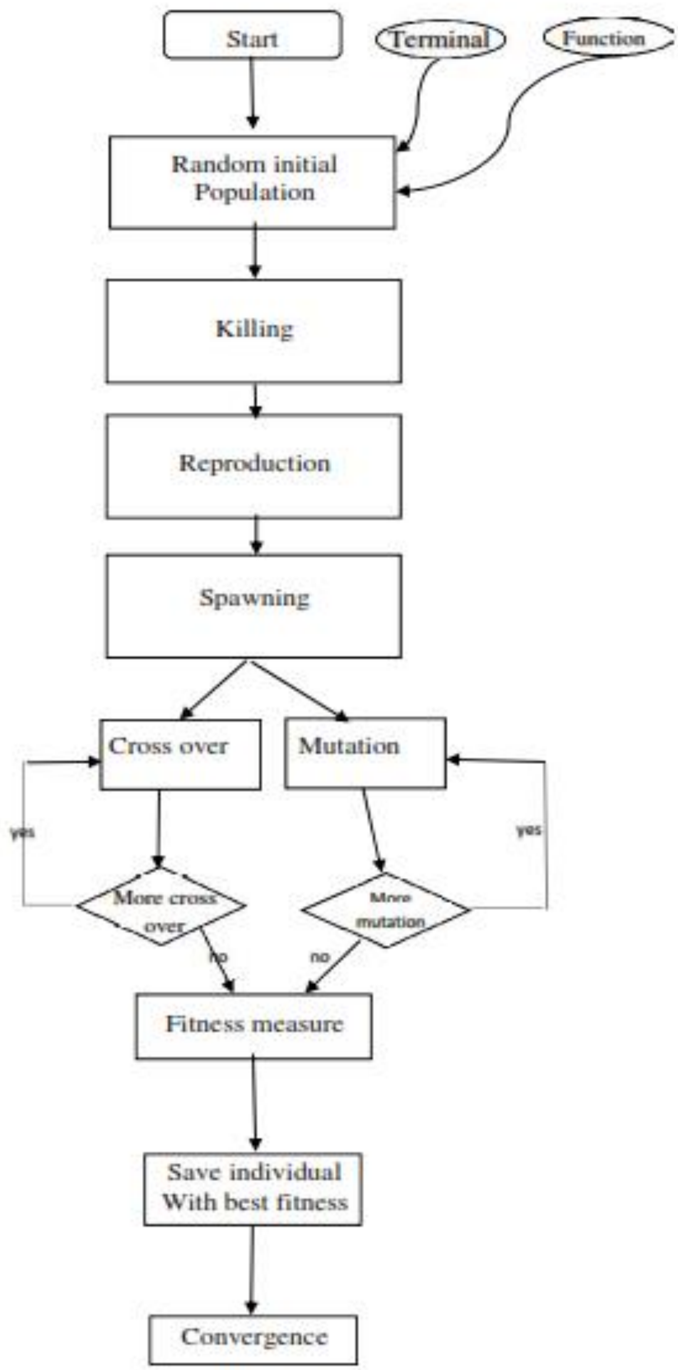


FIG 3

3.2 MATLAB

Matrix Laboratory commonly Known as Matlab is a high level programming language which gives an interective environment for numerical computation,data analysis, simulation, visualisation and programming. With the help of matlab one can develop algorithm, can do the data analysis and can generate models and application. Matlab can be used for a range of application such as image processing, financial computation, and control system.

3.3 GPTIPS

Genetic Programming tool box for use with MATLAB also known as GPTIPS is a machine learning method which is biologically inspired. It is done by randomly creating a population of program represented by tree structures and then to modify the population crossover and mutation is performed to create a new population. The process is iterated until the program comes with the best result. It can be configured to produce multigene individual which is one of the important features of GPTIPS.

CHAPTER 4

MODELLING OF DEEP BEAM

4.1 EXPERIMENTAL DATABASE

The following table shows the experimental results obtained from earlier literature and its input parameter named x1 through x8 where

X_1= width of deep beam (in mm)

X2=depth of deep beam (in mm)

X3= shear span ratio

X4= characteristics strength of concrete (in N/mm^2)

X5=characteristics strength of longitudinal steel (in N/mm^2)

X6=longitudinal reinforcement steel ratio (in %)

X7=characteristics strength of web steel (in N/mm^2)

X8=web reinforcement steel ratio (in %)

TABLE 1

EXPERIMENTAL RESULT FROM PRIOR LITERATURE									
SL. No	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**Shear Force(EXP)**
	mm	mm		N/mm2	N/mm2	%	N/mm2	%	KN
1	100.000	375.000	1.100	43.790	444.980	0.600	445.380	0.000	90.000
2	100.000	375.000	1.100	43.680	444.980	0.600	445.380	0.500	105.000
3	100.000	375.000	1.100	43.740	444.980	0.600	445.380	0.750	125.000
4	100.000	375.000	1.100	43.810	444.980	0.600	445.380	1.250	150.000
5	100.000	375.000	1.100	43.700	444.980	0.600	445.380	2.250	160.000
6	100.000	375.000	1.100	43.790	445.980	2.400	445.280	0.000	185.000
7	100.000	375.000	1.100	43.680	445.980	2.400	445.280	0.500	292.000
8	100.000	375.000	1.100	43.740	445.980	2.400	445.280	0.750	315.000
9	100.000	375.000	1.100	43.810	445.980	2.400	445.280	1.250	320.000
10	100.000	375.000	1.100	43.700	445.980	2.400	445.280	2.250	330.000
11	100.000	375.000	1.100	43.000	445.380	0.800	445.280	0.000	98.250
12	100.000	275.000	1.100	43.270	444.120	0.600	445.280	0.000	84.000
13	100.000	225.000	1.100	47.550	444.120	0.600	445.280	0.000	88.000
14	98.000	270.000	1.130	24.913	430.940	2.150	437.350	0.280	161.240
15	98.000	270.000	1.130	24.040	430.940	2.360	437.350	0.280	148.341
16	98.000	270.000	1.130	21.420	430.940	2.460	437.350	0.280	141.224
17	98.000	270.000	1.130	27.396	430.940	2.460	437.350	0.280	170.937
18	98.000	270.000	1.130	28.040	430.940	2.670	437.350	0.280	184.080
19	98.000	270.000	1.130	28.913	430.940	2.150	437.350	0.630	174.495
20	98.000	270.000	1.130	26.339	430.940	2.360	437.350	0.630	170.581
21	98.000	270.000	1.130	27.120	430.940	2.460	437.350	0.630	171.915
22	98.000	270.000	1.130	25.512	430.940	2.670	437.350	0.630	161.907
23	98.000	270.000	1.130	24.547	430.940	2.150	437.350	1.250	161.018
24	98.000	270.000	1.130	25.649	430.940	2.360	437.350	1.250	172.716
25	98.000	270.000	1.130	27.764	430.940	2.460	437.350	1.250	178.543
26	98.000	270.000	1.130	26.569	430.940	2.670	437.350	1.250	168.134
27	98.000	270.000	1.363	29.419	430.940	2.150	437.350	0.240	147.451
28	98.000	270.000	1.363	26.799	430.940	2.360	437.350	0.240	143.559
29	98.000	270.000	1.363	27.764	430.940	2.460	437.350	0.240	140.334
30	98.000	270.000	1.363	26.017	430.940	2.670	437.350	0.240	153.345

TABLE 1 (CONTINUED)

31	98.000	270.000	1.363	25.557	430.940	2.150	437.350	0.420	128.992
32	98.000	270.000	1.363	25.328	430.940	2.360	437.350	0.420	131.216
33	98.000	270.000	1.363	23.305	430.940	2.460	437.350	0.420	126.101
34	98.000	270.000	1.363	29.051	430.940	2.460	437.350	0.420	149.898
35	98.000	270.000	1.363	26.339	430.940	2.670	437.350	0.420	145.227
36	98.000	270.000	1.363	21.651	430.940	2.150	437.350	0.630	130.771
37	98.000	270.000	1.363	27.212	430.940	2.150	437.350	0.770	158.949
38	98.000	270.000	1.363	25.328	430.940	2.360	437.350	0.770	158.349
39	98.000	270.000	1.363	25.649	430.940	2.460	437.350	0.770	155.013
40	98.000	270.000	1.363	27.535	430.940	2.670	437.350	0.770	166.133
41	98.000	270.000	1.363	22.800	430.940	2.150	437.350	1.250	153.456
42	98.000	270.000	1.693	25.649	430.940	2.150	437.350	0.180	118.984
43	98.000	270.000	1.693	29.189	430.940	2.360	437.350	0.180	123.432
44	98.000	270.000	1.693	30.247	430.940	2.460	437.350	0.180	130.994
45	98.000	270.000	1.693	29.051	430.940	2.670	437.350	0.180	122.320
46	98.000	270.000	1.693	26.477	430.940	2.150	437.350	0.310	124.099
47	98.000	270.000	1.693	25.649	430.940	2.360	437.350	0.310	103.638
48	98.000	270.000	1.693	25.741	430.940	2.360	437.350	0.310	115.314
49	98.000	270.000	1.693	27.259	430.940	2.460	437.350	0.310	124.544
50	98.000	270.000	1.693	27.672	430.940	2.670	437.350	0.310	124.099
51	98.000	270.000	1.693	28.040	430.940	2.150	437.350	0.560	140.779
52	98.000	270.000	1.693	22.064	430.940	2.360	437.350	0.560	124.989
53	98.000	270.000	1.693	24.363	430.940	2.460	437.350	0.560	127.658
54	98.000	270.000	1.693	25.328	430.940	2.670	437.350	0.560	137.221
55	98.000	270.000	1.693	26.109	430.940	2.150	437.350	0.770	146.462
56	98.000	270.000	1.693	24.731	430.940	2.360	437.350	0.630	128.547
57	98.000	270.000	1.693	25.649	430.940	2.460	437.350	0.770	152.344
58	98.000	270.000	1.693	24.684	430.940	2.460	437.350	0.770	152.566
59	98.000	270.000	1.693	28.316	430.940	2.670	437.350	0.770	159.461
60	98.000	270.000	1.693	21.420	430.940	2.670	437.350	0.420	89.405
61	73.500	671.000	0.379	28.683	286.830	0.520	279.940	2.450	238.858
62	73.500	551.000	0.461	32.728	286.830	0.630	279.940	2.450	224.179
63	73.500	424.000	0.599	28.316	286.830	0.800	279.940	2.450	189.485
64	73.500	301.000	0.844	28.316	286.830	1.090	279.940	2.450	164.131
65	73.500	181.000	1.403	28.867	286.830	1.730	279.940	2.450	89.405
66	73.500	666.000	0.381	34.797	286.830	0.520	303.380	0.860	249.088
67	73.500	544.000	0.467	24.823	286.830	0.630	303.380	0.860	224.179
68	73.500	424.000	0.599	26.477	286.830	0.800	303.380	0.860	215.283
69	73.500	304.000	0.836	30.339	286.830	1.090	303.380	0.860	139.667
70	73.500	179.000	1.419	26.844	286.830	1.730	303.380	0.860	99.635
71	73.500	632.000	0.402	24.731	279.940	1.140	279.940	0.610	239.302
72	73.500	512.000	0.496	25.649	279.940	1.240	279.940	0.610	208.166
73	73.500	392.000	0.648	26.844	279.940	1.410	279.940	0.610	172.582
74	73.500	274.000	0.927	29.235	279.940	1.700	279.940	0.610	127.213
75	73.500	159.000	1.597	30.063	279.940	2.340	279.940	0.610	77.840

4.2 IS CODE COMPUTATION

From [9]

Shear capacity of section of deep beam(V_u) = V_c+V_s

V_c= Shear capacity carried by concrete

V_s= Shear capacity carried by steel

1. $V_c= C_1(1-0.35(a_v/d))f_tbD$

Where,

C_1 = 0.72 (a constant)

A_v = shear span

D = total depth

b = width

f_t = tensile strength of concrete

2. $V_s =C_2\sum A_{i*}(y_i/D)*\sin^2\alpha$

Where,

C_2 = 225 (for fe415)

A_1= horrizontal reinforcement area

A_2= vertical reinforcement area

α= angle between bar considered and critical diagnol crack

n= no. of bars including tension steel cut by assumed crack

y_i= depth from top of beam to the point where bar intersects the critical diagonal crack line

D= total depth of the beam

4.3 <u>ACI CODE COMPUTATION</u>

[From 9]

Shear capacity of section (V_u) = V_c+V_s

V_c= Shear capacity carried by concrete

V_s= Shear capacity carried by steel

1. $V_c= 0.13f_{ck}^{0.5}(bd)$

Where,

d = effective depth

b = width

f_{ck} = compressive strength of concrete

2. $V_s =0.85[f_y d*\{(A_v/S_1)*(1+f)/12+(A_h/S_2)(11-f)/12\}]$

Where,

f= L_n/d

A_h= horrizontal reinforcement area

A_v= vertical reinforcement area

S_1= Spacing of vertical reinforcement

S_2= Spacing of horizontal reinforcement

4.4 RUN PARAMETER

There are large number of test results in prior literature for R C deep beam. Out of them, results of 75 deep beams are taken to create the GP Response. Out of 75 numbers of data 52 nos. data are randomly selected and used as training indices, and 25 data are randomly selected and used as test indices. Out of 52 data which are selected for training indices 33 data are used for validation purpose. Initially 100 population size were selected and increased to 1000 for better result. The mathematical operators used while creating the GP response are addition, multiplication, sin, square, substraction and exponential. Rate of mutation and crossover used are 0.1 and 0.85 respectively.The input parameters should be in the following range to obtained the best result.

Input parameter	Range	
	Min	Max
compressive strength of concrete	21	48
width of beam	73.5	100
depth of beam	159	671
shear span of beam	0.3785	1.6927
tensile steel reinforcement ratio	0.52	2.67
charcteristics stress of tensile steel	279.94	445.98
vertical shear reinforcement ratio	0	2.45
characteristics stress of web steel	279.94	445.98

CHAPTER 5

RESULT &DISCUSSION

5.1 INPUT FREQUENCY ANALYSIS

The graphical input frequency analysis of single model or of a user specified fraction of the population is used to provide the identification of input variables that are significant to the output. The most significant input variable is X4, where X4 is the characteristics compressive strength of concrete.

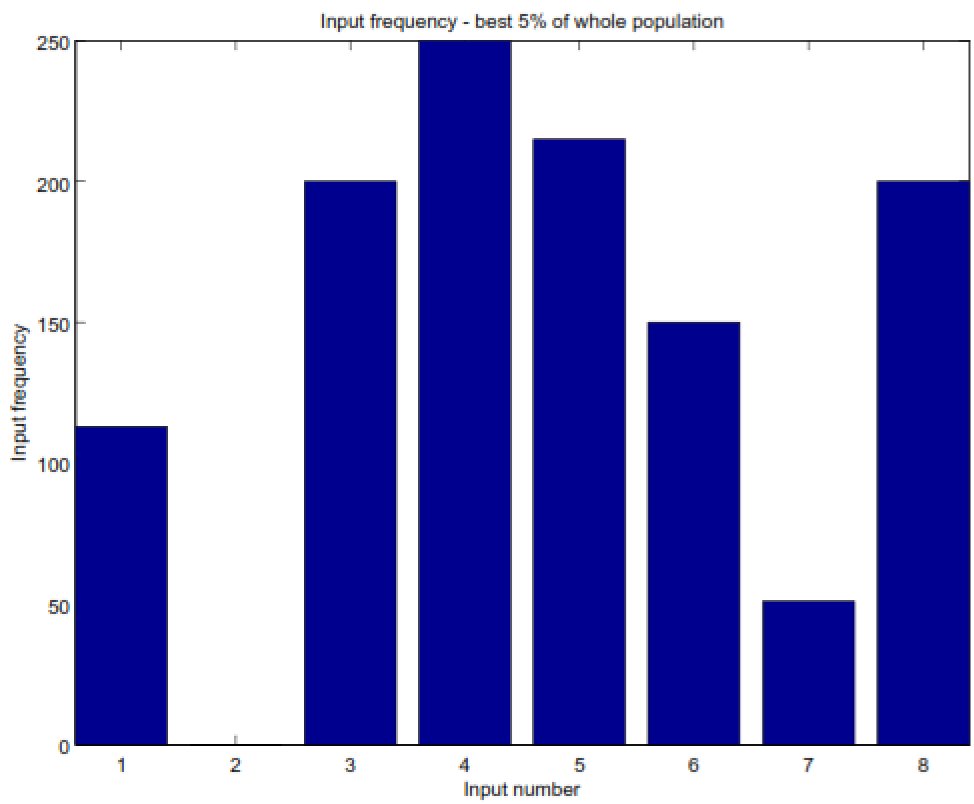


FIG 4

5.2 FITNEESS GENERATION

It is the plot of log of fitness found corrosponding to its generation and best fitness found at 398 generation

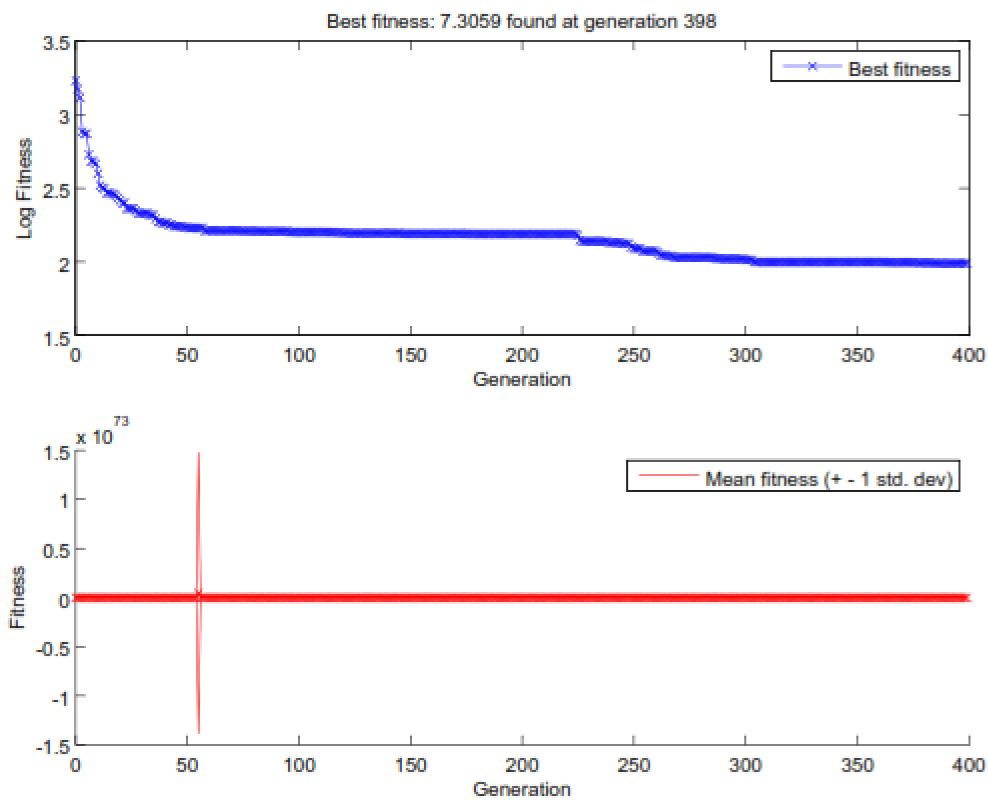


FIG 5

5.3 ERROR ANALYSIS

In this the predicted output are compared with the actual values on training set, test set and validation test. Maximum deviation from actual in training set error is 7.3059, in test set error is 15.3164 and in validation set error is 7.2325.

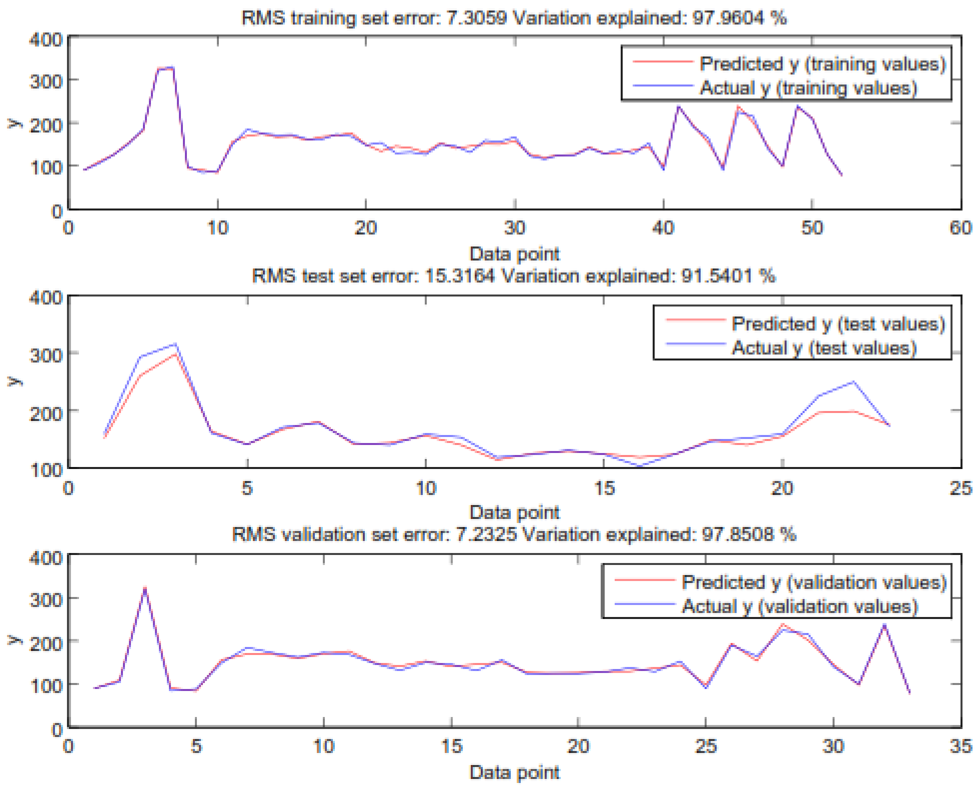


FIG 6

5.4 SCATTER PLOT

It is the scatter plot of predicted output value and the actual value. It shows that the GP results are close to the Experimental results.

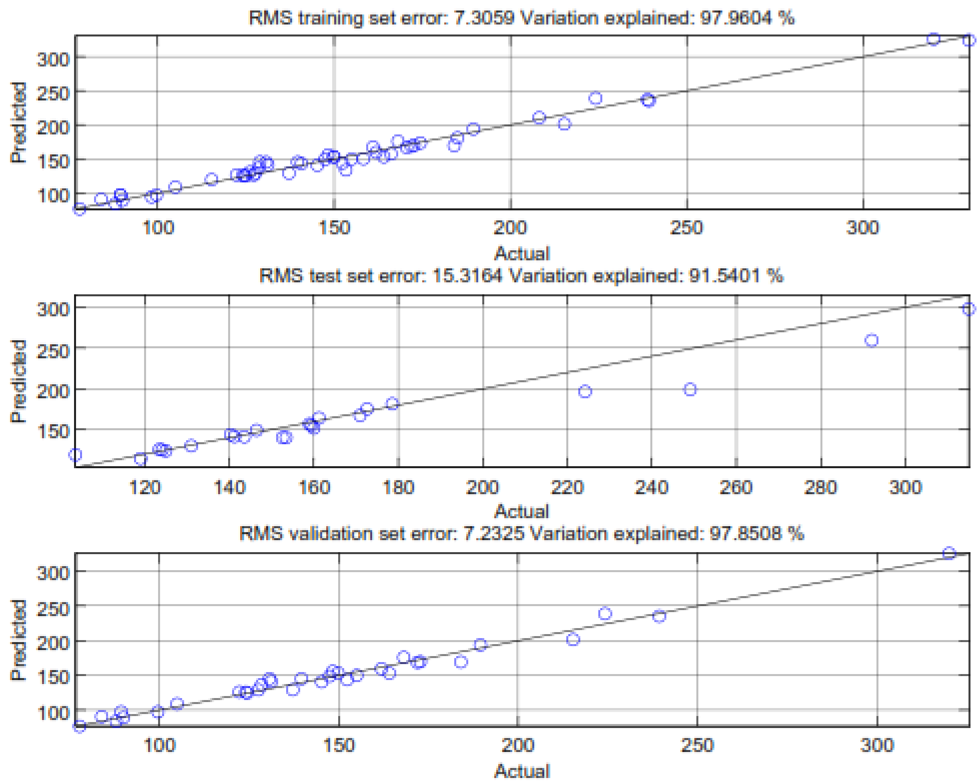


FIG 7

5.5 <u>GENE WEIGHTAGE</u>

As number of gene involved while creating the model is 4 and the most significant gene is the bias gene with gene 2 as least significant.

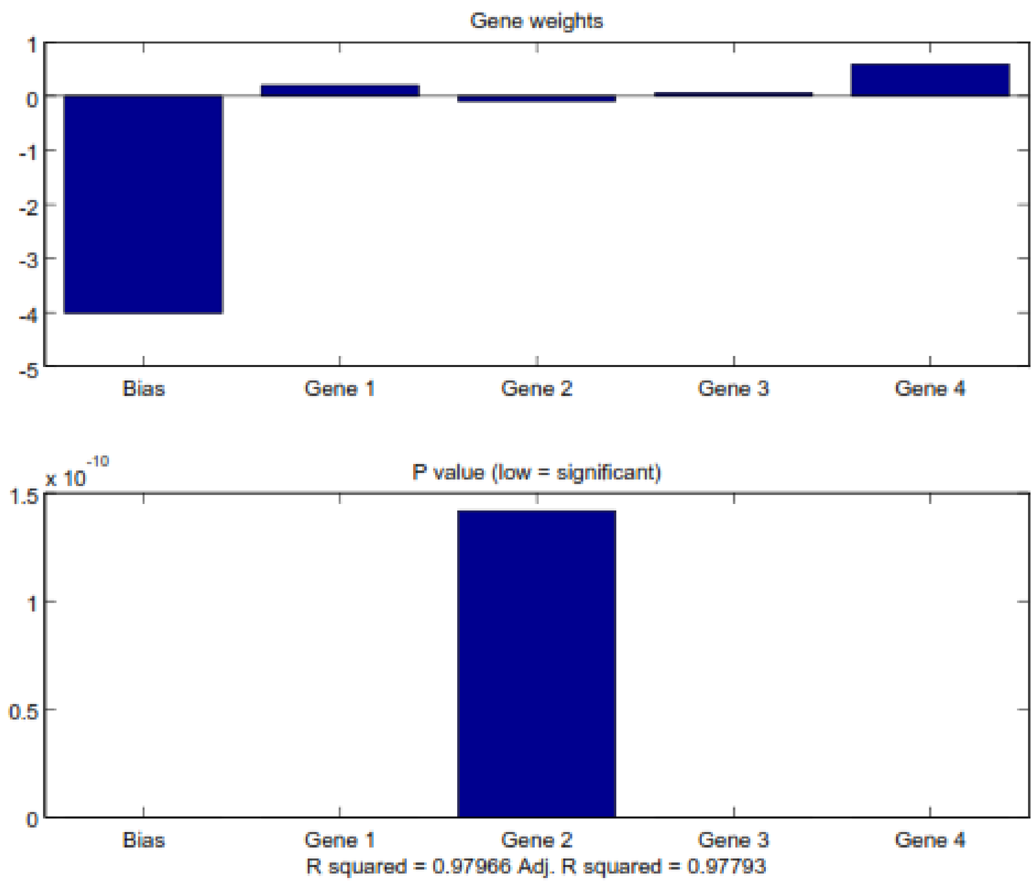


FIG 8

5.6 EMPERICAL RELATION

$Y=0.5976X_5+0.5976X_4X_6+0.06164e^{(X1+X4+SIN(X8))}square(X_5+X_6)+0.2096$

$(X_3+sin(sin(x_8))-2.895)(x_1+x_3-x_5+0.4603)-$

$0.09253square(sin(x_8))(x_4^2+X_3)(sin(X_8)-X_4(X_3-X_6)+4.303)+0.2668$

Where,

Y= shear strength of deep beam (in KN)

X_1= width of deep beam (in mm)

X2=depth of deep beam (in mm)

X3= shear span ratio

X4= characteristics strength of concrete (in N/mm^2)

X5=characteristics strength of longitudinal steel (in N/mm^2)

X6=longitudinal reinforcement steel ratio (in %)

X7=characteristics strength of web steel (in N/mm^2)

X8=web reinforcement steel ratio (in %)

5.7 COMPARISION OF RESULTS (TABULATION FORM)

TABLE 2

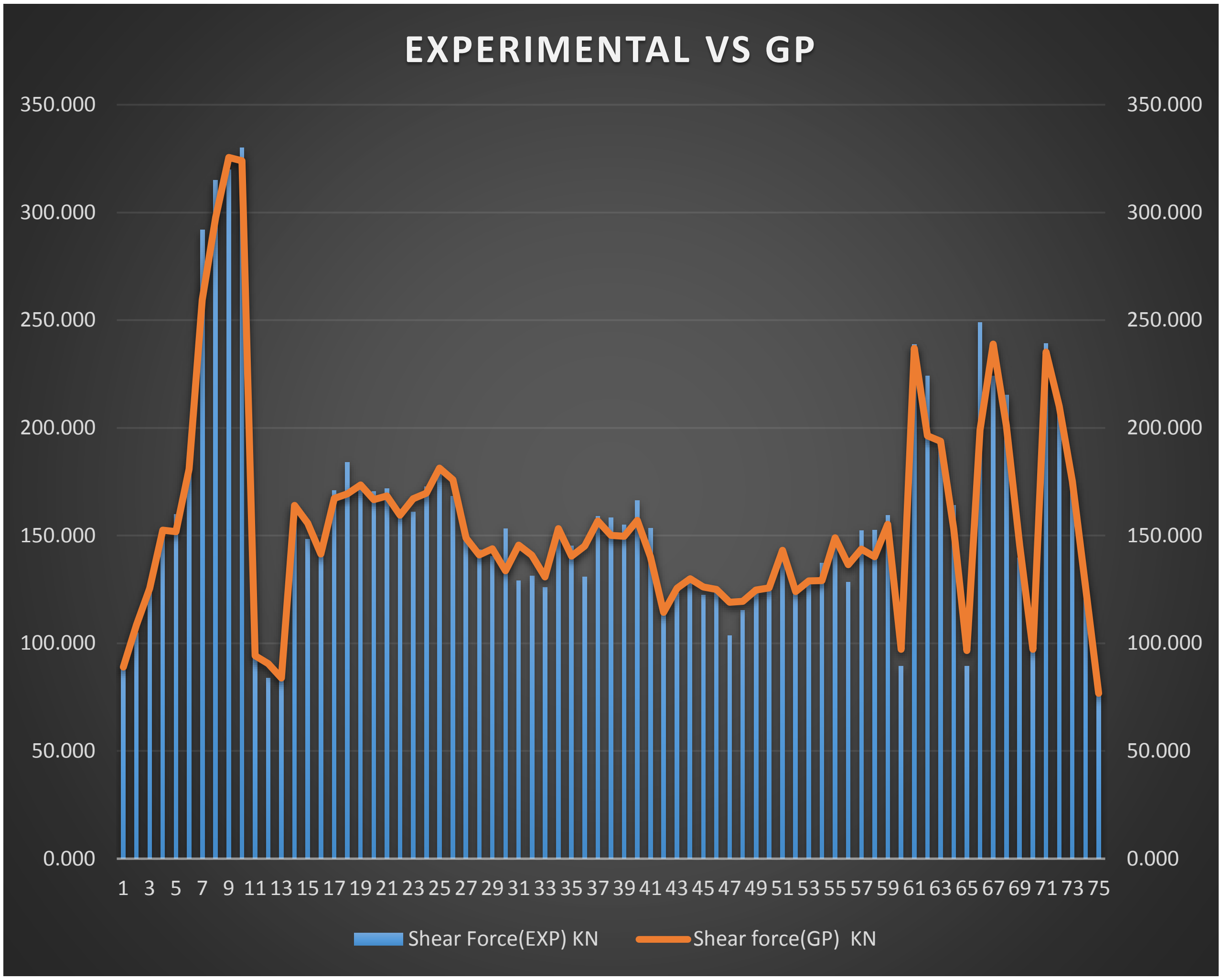
RESULT COMPARISON BETWEEN EXPERIMENTAL AND GP										
SL. No	X1	X2	X3	X4	X5	X6	X7	X8	Shear Force(EXP)	Shear force(GP)
	mm	mm		N/mm2	N/mm2	%	N/mm2	%	KN	KN
1	100.000	375.000	1.100	43.790	444.980	0.600	445.380	0.000	90.000	88.935
2	100.000	375.000	1.100	43.680	444.980	0.600	445.380	0.500	105.000	108.566
3	100.000	375.000	1.100	43.740	444.980	0.600	445.380	0.750	125.000	125.379
4	100.000	375.000	1.100	43.810	444.980	0.600	445.380	1.250	150.000	152.509
5	100.000	375.000	1.100	43.700	444.980	0.600	445.380	2.250	160.000	151.836
6	100.000	375.000	1.100	43.790	445.980	2.400	445.280	0.000	185.000	180.849
7	100.000	375.000	1.100	43.680	445.980	2.400	445.280	0.500	292.000	259.420
8	100.000	375.000	1.100	43.740	445.980	2.400	445.280	0.750	315.000	297.680
9	100.000	375.000	1.100	43.810	445.980	2.400	445.280	1.250	320.000	325.569
10	100.000	375.000	1.100	43.700	445.980	2.400	445.280	2.250	330.000	323.917
11	100.000	375.000	1.100	43.000	445.380	0.800	445.280	0.000	98.250	94.198
12	100.000	275.000	1.100	43.270	444.120	0.600	445.280	0.000	84.000	90.541
13	100.000	225.000	1.100	47.550	444.120	0.600	445.280	0.000	88.000	83.817
14	98.000	270.000	1.130	24.913	430.940	2.150	437.350	0.280	161.240	164.030
15	98.000	270.000	1.130	24.040	430.940	2.360	437.350	0.280	148.341	155.816
16	98.000	270.000	1.130	21.420	430.940	2.460	437.350	0.280	141.224	141.408
17	98.000	270.000	1.130	27.396	430.940	2.460	437.350	0.280	170.937	167.298
18	98.000	270.000	1.130	28.040	430.940	2.670	437.350	0.280	184.080	169.327
19	98.000	270.000	1.130	28.913	430.940	2.150	437.350	0.630	174.495	173.458
20	98.000	270.000	1.130	26.339	430.940	2.360	437.350	0.630	170.581	166.686
21	98.000	270.000	1.130	27.120	430.940	2.460	437.350	0.630	171.915	168.409
22	98.000	270.000	1.130	25.512	430.940	2.670	437.350	0.630	161.907	159.468
23	98.000	270.000	1.130	24.547	430.940	2.150	437.350	1.250	161.018	167.184
24	98.000	270.000	1.130	25.649	430.940	2.360	437.350	1.250	172.716	169.671
25	98.000	270.000	1.130	27.764	430.940	2.460	437.350	1.250	178.543	181.308
26	98.000	270.000	1.130	26.569	430.940	2.670	437.350	1.250	168.134	175.935
27	98.000	270.000	1.363	29.419	430.940	2.150	437.350	0.240	147.451	148.875
28	98.000	270.000	1.363	26.799	430.940	2.360	437.350	0.240	143.559	141.063
29	98.000	270.000	1.363	27.764	430.940	2.460	437.350	0.240	140.334	143.923
30	98.000	270.000	1.363	26.017	430.940	2.670	437.350	0.240	153.345	133.592
31	98.000	270.000	1.363	25.557	430.940	2.150	437.350	0.420	128.992	145.499
32	98.000	270.000	1.363	25.328	430.940	2.360	437.350	0.420	131.216	140.854
33	98.000	270.000	1.363	23.305	430.940	2.460	437.350	0.420	126.101	130.767
34	98.000	270.000	1.363	29.051	430.940	2.460	437.350	0.420	149.898	153.171
35	98.000	270.000	1.363	26.339	430.940	2.670	437.350	0.420	145.227	140.488

TABLE 2 (Continued)

36	98.000	270.000	1.363	21.651	430.940	2.150	437.350	0.630	130.771	145.170
37	98.000	270.000	1.363	27.212	430.940	2.150	437.350	0.770	158.949	156.770
38	98.000	270.000	1.363	25.328	430.940	2.360	437.350	0.770	158.349	150.137
39	98.000	270.000	1.363	25.649	430.940	2.460	437.350	0.770	155.013	149.704
40	98.000	270.000	1.363	27.535	430.940	2.670	437.350	0.770	166.133	156.993
41	98.000	270.000	1.363	22.800	430.940	2.150	437.350	1.250	153.456	140.233
42	98.000	270.000	1.693	25.649	430.940	2.150	437.350	0.180	118.984	114.296
43	98.000	270.000	1.693	29.189	430.940	2.360	437.350	0.180	123.432	125.545
44	98.000	270.000	1.693	30.247	430.940	2.460	437.350	0.180	130.994	129.965
45	98.000	270.000	1.693	29.051	430.940	2.670	437.350	0.180	122.320	126.158
46	98.000	270.000	1.693	26.477	430.940	2.150	437.350	0.310	124.099	125.005
47	98.000	270.000	1.693	25.649	430.940	2.360	437.350	0.310	103.638	119.017
48	98.000	270.000	1.693	25.741	430.940	2.360	437.350	0.310	115.314	119.404
49	98.000	270.000	1.693	27.259	430.940	2.460	437.350	0.310	124.544	124.712
50	98.000	270.000	1.693	27.672	430.940	2.670	437.350	0.310	124.099	125.743
51	98.000	270.000	1.693	28.040	430.940	2.150	437.350	0.560	140.779	143.184
52	98.000	270.000	1.693	22.064	430.940	2.360	437.350	0.560	124.989	123.946
53	98.000	270.000	1.693	24.363	430.940	2.460	437.350	0.560	127.658	128.949
54	98.000	270.000	1.693	25.328	430.940	2.670	437.350	0.560	137.221	129.069
55	98.000	270.000	1.693	26.109	430.940	2.150	437.350	0.770	146.462	148.986
56	98.000	270.000	1.693	24.731	430.940	2.360	437.350	0.630	128.547	136.553
57	98.000	270.000	1.693	25.649	430.940	2.460	437.350	0.770	152.344	143.674
58	98.000	270.000	1.693	24.684	430.940	2.460	437.350	0.770	152.566	140.236
59	98.000	270.000	1.693	28.316	430.940	2.670	437.350	0.770	159.461	155.202
60	98.000	270.000	1.693	21.420	430.940	2.670	437.350	0.420	89.405	97.267
61	73.500	671.000	0.379	28.683	286.830	0.520	279.940	2.450	238.858	236.9481
62	73.500	551.000	0.461	32.728	286.830	0.630	279.940	2.450	224.179	196.346
63	73.500	424.000	0.599	28.316	286.830	0.800	279.940	2.450	189.485	193.8205
64	73.500	301.000	0.844	28.316	286.830	1.090	279.940	2.450	164.131	153.0452
65	73.500	181.000	1.403	28.867	286.830	1.730	279.940	2.450	89.405	96.5815
66	73.500	666.000	0.381	34.797	286.830	0.520	303.380	0.860	249.088	199.0221
67	73.500	544.000	0.467	24.823	286.830	0.630	303.380	0.860	224.179	238.8321
68	73.500	424.000	0.599	26.477	286.830	0.800	303.380	0.860	215.283	201.1875
69	73.500	304.000	0.836	30.339	286.830	1.090	303.380	0.860	139.667	145.1783
70	73.500	179.000	1.419	26.844	286.830	1.730	303.380	0.860	99.635	97.1695
71	73.500	632.000	0.402	24.731	279.940	1.140	279.940	0.610	239.302	235.2198
72	73.500	512.000	0.496	25.649	279.940	1.240	279.940	0.610	208.166	210.1324
73	73.500	392.000	0.648	26.844	279.940	1.410	279.940	0.610	172.582	175.2592
74	73.500	274.000	0.927	29.235	279.940	1.700	279.940	0.610	127.213	126.358
75	73.500	159.000	1.597	30.063	279.940	2.340	279.940	0.610	77.840	76.7757

5.8 COMPARISON OF RESULTS (GRAPHICAL FORM)

It is the result comparison between value obtained from GP response and actual value obtained from earlier literature.



X-AXIS= SL. NO.

Y-AXIS= SHEAR STRENGTH IN KN/m^2

FIG 9

CHAPTER 6

CALCULATION USING DESIGN CODE

6.1 INPUT VARIABLE

The input parameter tabulated below are used to calculate the shear strength using IS code, ACI code and emperical relation developed by GP Response

TABLE 3

INPUT VARIABLE								
SL.NO.	b	D	Av/d	fck	fy	long.steel	fy	vert. steel
	mm	mm		N/mm2				
	x1	x2	x3	x4	x5	x6	x7	x8
1	80	350	1.100	30	415	0.28	415	0.00
2	85	400	1.100	30	415	0.42	415	0.00
3	90	450	1.100	30	415	0.60	415	0.00
4	100	500	1.100	30	415	0.60	415	0.00
5	80	550	1.100	30	415	1.20	415	0.00
6	85	600	1.100	30	415	1.80	415	0.00
7	90	350	1.100	30	415	2.40	415	0.00
8	100	400	1.100	30	415	0.60	415	0.00
9	100	450	1.100	30	415	0.60	415	0.50
10	100	500	1.100	30	415	0.60	415	0.75
11	100	550	1.100	30	415	0.60	415	1.25
12	80	600	1.100	30	415	0.60	415	2.25
13	85	400	0.763	30	415	2.40	415	0.00
14	90	400	0.763	30	415	2.40	415	0.50
15	100	400	0.763	25	415	2.40	415	0.75
16	100	400	0.763	25	415	2.40	415	1.25
17	100	400	0.763	25	415	2.40	415	2.25
18	100	400	0.763	25	415	0.80	415	0.00
19	100	350	0.871	25	415	0.80	415	0.00
20	100	400	0.763	25	415	0.80	415	0.00
21	80	450	0.678	25	415	0.80	415	0.00
22	85	500	0.610	25	415	0.80	415	0.00
23	90	550	1.670	25	415	0.80	415	0.00
24	100	600	0.508	35	415	0.60	415	0.00
25	100	350	0.871	35	415	0.60	415	0.00
26	100	300	1.227	35	415	0.60	415	0.00
27	100	250	1.472	35	415	0.60	415	0.00
28	100	343	1.073	35	415	2.15	415	0.28
29	100	343	1.073	35	415	2.36	415	0.28
30	100	343	1.073	35	415	2.46	415	0.28

TABLE 3 (Continued)

31	80	343	1.073	35	415	2.46	415	0.28
32	85	343	1.073	35	415	2.60	415	0.28
33	90	343	1.073	35	415	2.15	415	0.63
34	100	350	1.051	35	415	2.36	415	0.63
35	100	400	0.920	30	415	2.46	415	0.63
36	100	450	0.818	30	415	2.67	415	0.63
37	100	500	0.736	30	415	2.15	415	1.25
38	100	550	0.669	30	415	2.36	415	1.25
39	100	600	0.613	30	415	2.46	415	1.25
40	100	343	1.073	30	415	2.60	415	1.25
41	100	343	1.332	30	415	2.15	415	0.24
42	100	343	1.332	30	415	2.36	415	0.24
43	100	343	1.332	30	415	2.46	415	0.24
44	80	343	1.332	30	415	2.67	415	0.24
45	85	343	1.332	30	415	2.15	415	0.42
46	90	343	1.332	30	415	2.36	415	0.42
47	100	343	1.332	30	415	2.46	415	0.42
48	100	343	1.332	30	415	2.46	415	0.42
49	100	350	1.306	25	415	2.67	415	0.42
50	100	400	1.143	25	415	2.15	415	0.63
51	100	450	1.016	25	415	2.15	415	0.77
52	100	500	0.914	25	415	2.36	415	0.77
53	100	550	0.831	25	415	2.46	415	0.77
54	100	600	0.762	25	415	2.67	415	0.77
55	100	343	1.332	25	415	2.15	415	1.25
56	100	343	1.332	25	415	2.15	415	0.18
57	80	343	1.332	25	415	2.36	415	0.18
58	85	343	1.332	35	415	2.46	415	0.18
59	90	343	1.332	35	415	2.67	415	0.18
60	100	343	0.741	35	415	2.15	415	0.31
61	100	343	0.741	35	415	2.36	415	0.31
62	100	343	0.741	35	415	2.36	415	0.31
63	100	343	0.741	35	415	2.46	415	0.31
64	100	343	0.741	35	415	2.60	415	0.31
65	100	343	0.741	35	415	2.15	415	0.56
66	100	350	0.726	35	415	2.36	415	0.56

TABLE 3 (Continued)

67	100	400	0.635	35	415	2.46	415	0.56
68	100	450	0.564	35	415	2.60	415	0.56
69	100	500	0.508	30	415	2.15	415	0.77
70	100	550	0.462	30	415	2.36	415	0.63
71	100	600	0.423	30	415	2.46	415	0.77
72	100	343	0.741	30	415	2.46	415	0.77
73	100	343	0.741	30	415	2.67	415	0.77
74	100	343	0.741	30	415	2.67	415	0.42
75	100	625	1.200	30	415	0.52	415	2.45
76	100	613	1.200	30	415	0.63	415	2.45
77	100	350	1.200	30	415	0.80	415	2.45
78	100	400	1.200	30	415	1.09	415	2.45
79	100	450	1.200	30	415	1.73	415	2.45
80	100	500	1.200	30	415	0.52	415	0.86
81	100	550	1.200	30	415	0.63	415	0.86
82	100	600	1.200	30	415	0.80	415	0.86
83	100	368	1.050	25	415	1.09	415	0.86
84	100	245	1.050	25	415	1.73	415	0.86
85	100	635	1.050	25	415	1.14	415	0.61
86	100	613	1.050	25	415	1.24	415	0.61
87	100	490	1.050	25	415	1.41	415	0.61
88	100	368	1.050	25	415	1.70	415	0.61
89	100	245	1.050	25	415	2.34	415	0.61
90	100	300	1.100	25	415	0.60	415	0.63
91	100	325	1.100	25	415	0.60	415	0.77
92	100	350	1.100	35	415	0.60	415	0.77
93	100	400	1.100	35	415	2.15	415	0.77
94	100	450	1.100	35	415	2.36	415	0.42
95	100	500	1.100	35	415	2.46	415	2.45
96	100	550	1.100	35	415	2.46	415	2.45
97	100	600	1.100	35	415	2.60	415	2.45
98	100	500	1.100	35	415	2.15	415	2.45
99	100	525	1.100	35	415	2.15	415	2.45
100	100	550	1.100	35	415	2.36	415	0.86
101	100	575	1.100	35	415	2.46	415	0.86
102	100	600	1.100	35	415	1.60	415	0.86

6.2 COMPARISON OF RESULTS (TABULAR FORM)

SHEAR CAPACITY			
sl.no	Shear capacity (IS Code) KN	Shear capacity(ACI Code) KN	shear capacity using gp KN
1	42.233	17.089	222.523
2	56.623	98.621	206.732
3	75.722	119.340	190.537
4	93.894	149.175	158.612
5	112.488	132.600	218.243
6	165.510	154.976	203.055
7	118.026	89.505	189.513
8	74.376	116.025	158.612
9	108.773	153.765	158.500
10	135.471	184.450	161.100
11	180.647	230.421	174.755
12	212.688	247.452	235.482
13	108.213	98.621	264.388
14	127.607	117.783	232.805
15	143.986	118.955	180.717
16	158.462	133.800	184.077
17	187.414	163.490	183.901
18	75.947	96.688	240.566
19	67.093	82.875	219.746
20	75.947	96.688	240.566
21	67.559	88.400	320.381
22	78.839	105.666	319.919
23	96.643	124.313	141.693
24	120.298	212.713	236.326
25	69.288	116.025	156.543
26	56.737	96.688	104.706
27	44.287	77.350	84.046
28	131.345	122.199	161.898
29	138.753	122.199	169.243
30	142.281	122.199	172.956

31	113.825	97.759	234.799
32	125.137	103.869	225.388
33	129.323	119.970	195.534
34	153.080	136.137	174.357
35	165.023	137.063	176.118
36	182.358	154.564	191.740
37	194.150	194.592	208.502
38	208.643	213.004	222.823
39	218.410	231.416	234.613
40	178.055	136.777	171.524
41	136.880	105.998	129.608
42	145.735	105.998	130.467
43	149.952	105.998	130.979
44	127.046	84.798	193.684
45	122.800	95.751	179.206
46	137.993	101.384	165.220
47	157.543	112.649	134.356
48	157.543	112.649	134.356
49	165.674	98.481	114.164
50	167.168	121.022	143.266
51	185.637	141.374	155.605
52	205.454	156.318	161.828
53	218.621	171.262	169.919
54	235.502	186.207	174.965
55	176.326	127.129	128.128
56	131.205	87.592	117.677
57	112.048	70.074	174.265
58	127.767	101.974	187.659
59	143.253	107.972	180.197
60	111.554	121.073	215.398
61	116.458	121.073	223.134
62	116.458	121.073	223.134
63	118.792	121.073	227.039
64	122.061	121.073	232.748
65	117.391	127.327	207.565
66	123.604	130.149	218.107

67	134.598	150.310	237.769
68	145.623	170.470	256.977
69	141.707	171.991	234.462
70	150.050	185.343	249.043
71	161.525	207.404	253.193
72	125.518	116.392	199.041
73	130.421	116.392	201.627
74	122.249	107.636	209.048
75	298.245	343.655	161.951
76	300.363	336.738	159.329
77	169.495	185.154	155.780
78	210.269	213.972	151.133
79	273.484	242.790	147.163
80	139.643	192.152	157.013
81	161.827	213.024	155.025
82	189.853	233.897	152.338
83	115.059	116.687	181.596
84	87.481	73.069	162.848
85	193.081	196.904	179.493
86	192.677	189.604	176.528
87	160.651	148.788	171.613
88	128.566	108.304	163.595
89	95.764	67.488	147.530
90	71.091	86.841	191.603
91	82.389	99.509	192.933
92	96.475	141.376	134.408
93	178.293	164.335	162.148
94	195.929	172.479	167.148
95	337.679	289.269	179.159
96	374.472	320.130	179.159
97	420.750	350.991	187.744
98	320.494	289.269	163.087
99	337.936	304.700	163.087
100	270.376	237.869	171.988
101	290.035	249.560	176.959
102	245.265	261.251	144.739

6.3 COMPARISON OF RESULTS (GRAPHICAL FORM)

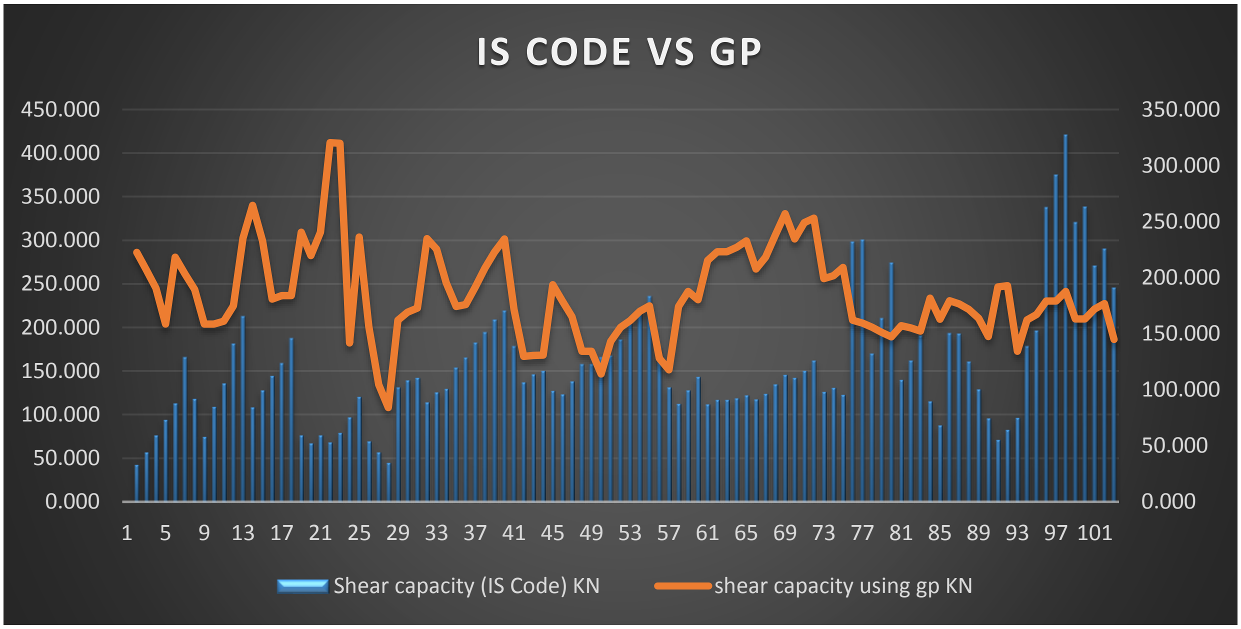


FIG 10

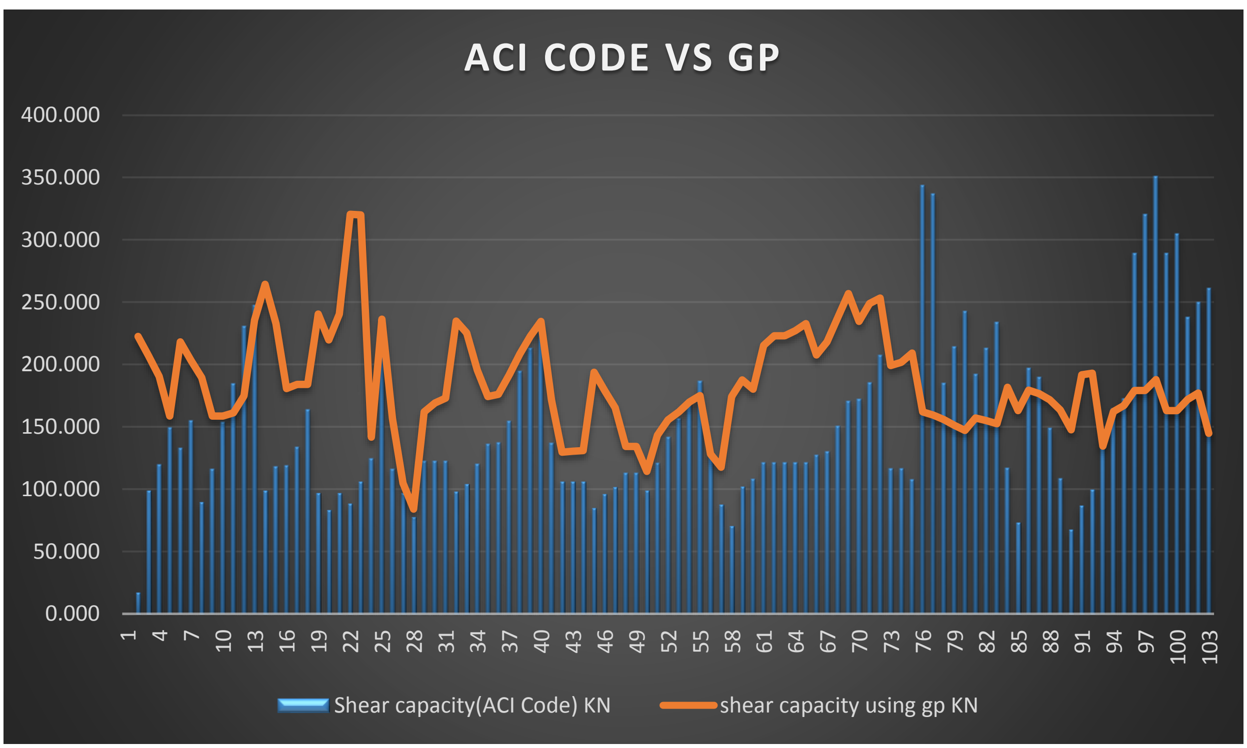


FIG 11

CONCLUSION

An empirical model was predicted to determine the shear strength capacity of deep beam using Genetic Programming (GP). Good validation of results were obtained between experimental results and predicted results. GP Prediction would have been more accurate if the experimental results were more. From the empirical relationship, shear strength capacity of some imput variables were computed and result were validated with the output obtained using IS Code and ACI Code. The effect of shear span to depth ratio, horizontal steel ratio and vertical web steel ratio are most significant on the shear strength capacity of deep beam.

REFERENCES

1. Ashour AF. Shear capacity of reinforced concrete deep beams. Struct Eng J ASCE 2000;126:1045–52
2. Koza JR. Genetic programming: on the programming of computers by means of natural selection. London: MIT Press; 1992.
3. Kong FK, Robins PJ, Kirby DP, Short DR. Deep beams with inclined web reinforcement. ACI J 1972;69:172–6.
4. Smith KN, Vantsiotis AS. Shear strength of deep beams.ACI Struct J 1982;79:201–13.
5. Londhe R.S, Shear strength analysis and prediction of reinforced concrete transfer beams in high-rise buildings. Structural Engineering and Mechanics, Vol. 37, No. 1 (2011) 39-59
6. Ilker Fatih Kara**,** Prediction of shear strength of FRP-reinforced concrete beams without stirrups based on genetic programming. Advances in Engineering Software 42 (2011) 295–304
7. Ashour A.F, Alvarez L.F, Toropov V.V . Empirical modelling of shear strength of RC deep beams by genetic programming. Computers and Structures 81 (2003) 331–338
8. ACI Committee 318. Building code requirements for structural concrete (ACI 318-99) and commentary (ACI318R-99). Detroit: American Concrete Institute; (1999).
9. Varghese P.C, Advanced reinforced concrete design. New Delhi: Phi learning private limited. (2012)
10. IS 456. "Indian Standard for Plain and Reinforced Concrete." Code of practice, bureau of Indian standards, New Delhi.(2000)