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Ultimate Load in Beam Column Joints under Opening Moment using Genetic Algorithm

Neeru Singla, Ashok Kumar Gupta, Yeshpal Vasishta

Abstract**: *Genetic Programming (GP) is an independent domain, an approach for problem-solving which evolved the computer programs for finding solutions to the problems. The study was carried out by performing the experiments and validation of obtained results under opening moments was done analytically using finite element modelling (FEM) of fibrous and non-fibrous concrete corner joints. Genetic Programming is used to generate the mathematical formula. Fibers like flat crimped-type steel fibers, hooked steel fibers and straight steel fibers with aspect ratio (AR) 30 & 50 and four volume fraction 0.5%, 1.00%, 1.50% and 1.75% have been used. Ultimate load is calculated using GP by generating a mathematical model for various types of fibers and compared with experimental values obtained which proved to be in the closed proximity.***

Keywords: Genetic Programming, Opening, closing bending moment, Finite Element Modelling.

I. INTRODUCTION

In most of the structures, it is necessary to have continuity between two adjacent members and the joint thus formed is referred as "corner". The corner joint is formed by joining two flexural members from the ends at 90º. In most of structures like bridges, portal frame buildings, retaining walls etc. and in hydraulic structures such as dams, tanks, reservoirs, flumes and culverts etc. concrete corners are used. Different systems detailing has been used and significant efforts have been carried out for achieving the desired structural behavior. The failure of corners under opening bending moment is consistently categorized by the low tensile strength of concrete, resulting in the commencement of a split tensile cracks originating at the reentrant corner that gradually moves out along the diagonal moves towards the exterior corner (Nilsson, 1973, Nilsson and Losberg, 1976). However, concrete is a brittle material due to its low strain capacity and tensile strength. For improving the physical properties of mix use of randomly distributed discrete fibers is an old concept. Straw fibers and horsehair fibers have been used to reinforce sunbaked bricks and the plaster respectively. For the reinforcement of portland cement, the asbestos fibers have been used, as they posed health hazards so get paid to further use it for manufacturing of asbestos cement roofing elements. The objective of all the applications quoted above is to improve the tensile strength of matrix. Fibers are formed from different materials like steel, glass, plastic, carbon, and many other organic and inorganic materials in numerous shapes and sizes. Characterization of fiber is done by numerical parameter called aspect ratio (A.R.). The A.R. used is generally in the range of 20 to 150 for fiber length dimensions of 6-mm to 76-mm. The volume fraction used for fibers varied from 40 to 120 kg/m of concrete. The development of fibrous material in early stages, the problem in the fibers mixing with matrix arises.

Addition of higher fiber volume fraction, fibers clump together or ball up during the mixing thus affecting the workability of mix due to inclusion of fibers. This problem is overcome by the use of superplasticizers which without paying a price in terms of high ratio of water-cement, provide adequate workability to matrix.

By using random fibers, the concrete reinforced is called “Fiber Reinforced Concrete” or “Fibrous Concrete”. The addition of randomly distributed discrete fibers in concrete-mortar mix can enhance the ductility of concrete. As a result of this a two phase or composite system is formed wherein the basic properties of one phase is improved by another phases.

The composite or two-stage idea of materials prompted the improvement and utilization of new materials where the frail framework is strengthened by solid firm filaments to deliver a composite material with unrivalled properties and execution. The principle preferred position of this framework is improvement of post-split burden conveying limit of cement rather than the typical standards of weak disappointment, saw in plain concrete.

The look of cracks in concrete are not on time due to addition of fiber which acts as crack arresters, delaying the appearance of cracks therefore developing a level of slow crack propagation. In evaluation to the unreinforced matrix, the ductility of composite matrix is increased on adding the fibers which elevated the tensile strength of concrete. Despite of different types of fibers used in cement concrete, steel fibers are found to be extensive in in-situ and pre cast engineering applications. If the elasticity modulus of the fiber is greater than matrix, the matrix (concrete or mortar binder) on addition of fiber carry load by increasing tensile strength. The properties like tensile strength, fracture toughness, resistance to fatigue, flexural strength,

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* Correspondence Author
Neeru Singla, Assistant Professor, IK Gujral Punjab Technical University, Jalandhar.
Ashok Kumar Gupta*, Professor and Head, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, Solan, Himachal Pradesh 173234, India.
Yeshpal Vasishta, Executive Engineer, Himachal Pradesh Public Works Department (HPPWD), Shimla HP.

effect and thermal surprise or spalling may be advanced by using adding fibers to them. The diploma of enhancement of the properties of the hardened concrete depends upon the type, length, volume fraction, shape, and aspect ratios of fibers. The fibers addition in traditional simple concrete makes it more flexible and versatile within the technique of manufacturing and competitive as construction material.

The fibers used for reinforcing cement concrete is called "Fiber Reinforced Concrete". The analysis of the strength of concrete using fibers has been carried out experimentally in many researches but no research has been carried out for analytical validation of results. Therefore, this study is conducted to perform the experimental analysis and the validation under opening moment has been done for fibrous and non-fibrous concrete corner joint using finite element modelling.

Experimental investigation of fibrous concrete in the corner region has been carried out consisting of 25 portal type opening corner specimen and the corner behavior depending upon the type of fiber and aspect ratio of fiber is observed by each specimen. The testing of all corner specimen is performed under monotonically increasing static loads. In this context, six types of steel fibers this is crimped fibers having AR of 30 and 50, hooked fibers having AR of 30 and 50 and immediately fibers having AR of 30 and 50 and 4 quantity fractions of the fibers having 50 and 30 AR viz. 0. 5, 1.00, 1.50 and 1.75% have been used. As per the specifications of Indian Standard, the physical properties of constituents of concrete i.e. cement, steel, fine and coarse aggregates were determined to confirm their relevance. Design mix for the plain and mixed concrete has been used for performing the experimental analysis. The analysis and calculation of cracking characteristics, first crack load, deflection, ultimate load, corner efficiencies and ductility have been done during the course of test. It has been observed from the test that ultimate load at failure increases with increase in volume fraction ratio from 0 to 1.50% i.e. up-to volume fraction ratio of 1.50%. the percentage increase in ultimate load in case of crimped fiber of aspect ratio of 30 and 50, is observed to be 36.65 and 40.27 % respectively. Further this increase is about 66.03 and 70.43% for hooked fiber and 18.27 and 21.40% for straight fiber with aspect ratio of 30 and 50 respectively. The present study showed that corner efficiency increases as volume fraction ratio increases from 0 to 1.50%. With the aspect ratio 30 and 50, the maximum increase in corner efficiency for crimped fibers is 30.43 and 8.26%, 55.43 and 52.80 % for hooked fibers and 21.16 and 19.14% for straight fibers respectively. In crimped fibers, hooked and straight fiber the value of ductility index also increases for different aspect ratio and volume fraction. Another finding of this study revealed that with AR 30 and 50 and specimen volume fraction ratio of 1.75% of the crimped, hooked and straight fibers, the toughness increases with increase in volume fraction ratio and all fibrous concrete specimen have the high toughness than plain concrete. The ultimate load, corner efficiency and ductility index of hooked fibers were found to be maximum for particular volume fraction ratio and aspect ratio which further reduced for crimped and straight fibers. Thus, for certain type of fiber with particular volume fraction ratio, the ultimate load value increases with increase in aspect ratio. Genetic Algorithm formula for calculation of ultimate load in beam column joints using different parameters has also been developed in this study and results have been compared between the experimental values and values obtained from mathematical formula.

II. LITERATURE REVIEW

GP is a domain unbiased, problem-solving approach wherein computer packages (which in standard are the equations) are advanced to locate solutions to the issues. The answer technique is based totally at the Darwinian precept of "Survival of the Fittest" (Gaur et al. 2008). T.Balogh and L.G.Vigh (2012) studied the genetic algorithm based optimization of regular steel building structures subjected to seismic effects. In their study, they discussed the development of an optimization algorithm using genetic algorithm and simplified seismic analysis procedures.

The study of Aggarwal D. (2013) showed that to forecast the wind induced pressures on tall rise buildings, GP can be used to obtain mathematical model. The ability of multi-gene genetic programming (MGGP) primarily based category method to evaluate liquefaction potential of soil the use of a large database from publish liquefaction cone penetration check (CPT) and subject manifestations is tested by Muduli et al. (2013). Further, the formula of compressive strength of carbon fiber reinforced plastic (CFRP) limited cylinders the usage of Linear Genetic Programming (LGP) is proposed by Gandomi et al. (2010). Two models in gene expression programming (GEP) approach has been developed by Saridemir (2010) for predicting compressive strength of concretes comprising rice husk ash at the age of 1, 3, 7, 14, 28, 56 and 90 days. Kermani et al. (2009) showed use of GP for prediction of equations for the ratio of most speed to most acceleration (vmax/amax) of robust ground motions. Flowchart for the genetic programming paradigm has been developed by (Koza, 1992). Additionally, using the wind information, GP is also used for estimating the oceanic parameter i.e. Significant Wave Height (SWH) (Nitsure et al. (2009). Heshmati et al. (2008) proposed new formulations for soil classification the use of Linear Genetic Programming (LGP) which used soil properties like liquid limit, plastic restriction, colour of soil, gravel percentage, sand and fine-grained particles as input parameter. Also, Genetic Programming approach was used for prediction of the soil-water characteristic curve (SWCC) by Johari et al. (2006). It used input variables like initial void ratio; preliminary gravimetric water content material, logarithm of suction normalized with admire to atmospheric air strain, clay content and silt content material and gravimetric water content similar to the assigned input suction is taken into consideration as output set. Greco. A et al. (2016) studied an approach for evaluating the plastic load and failures nodes of planner frames. This technique is based on the generation of elementary collapse mechanisms and on their linear combination aimed toward minimizing the collapse load factor.

The minimization method is efficaciously finished with the aid of genetic set of rules which lets in computing an approximate collapse load factor. R.Taba Tabaei Mirhosseini (2017) studied an method based on NURBUS (non-uniform rational B-splines) to attain a seismic response surface for a group of points obtained via using an analytical version of RC joints. NURBS primarily based at the genetic algorithm is a critical mathematical tool and consists of generalizations of Bezier curves, surface and B-splines.

Qiubing ren, Mingchao, Mengxizhang (2019) studied axial compression tests on short column with different geometric sizes and material properties. Total of a hundred and eighty agencies of experimental facts are acquired. The dataset lays a foundation for Nu value prediction the usage of gentle computing approach.

III. GENETIC PROGRAMMING ALGORITHM

The GP model propagate computer applications for solving the issues by the use of the following steps:

1. An initial population of an individual program is randomly created composing functions available and terminals.
2. The preliminary populace is now examined for its fitness. The best fitted individual application is then selected for collaborating in the genetic operations to be performed to shape a new populace.

For measuring the health, Coefficient of determination (COD), root mean rectangular blunders (RMS), Unit Error (deviation from dimensional error) and fitness according to node (dimension of the simplicity of the expression of the people) can be used. Also, for a few or all of the health parameters referred to above population can be tested.

To shape a new individual program for the new populace, numerous genetic operators at the moment are implemented to the best-fitted individual program. Within a GP system, three major evolutionary operators are available:

Reproduction This process entails choice of a person from or within the contemporary populace, to be copied exactly into the next generation.

Crossover

Mimics sexual recombination in nature, wherein two determine solutions are chosen and components in their sub tree are swapped.

Mutation

Mutation reasons random changes in an individual before it is added into the succeeding population. During mutation, a new department is randomly created both all functions and terminals are eliminated under an arbitrarily determined node or swapping of a single node is carried out for some other. As proven in figure1 character (c) is muted wherein terminal 2 is picked as the mutation site and a sub tree is inserted in its region which once more is randomly created to form an individual (b) of the new populace as shown in figure 2.

After the above-mentioned, on current population the operations are performed and replacement of old population by the population of off-spring (new generation) is done. Each individual is again measured for fitness and the process is repeated for several generations in new computer program. GP is a never-ending process and thus it required to define some control parameters as:

Population size: A large population permits a greater exploration of the problem at every generation and will increase the risk of evolving a solution.

Maximum variety of generations: More the wide variety of generations, greater is the chance of evolving a solution. However, despite the fact that after the evolution of a population, a solution isn't always found then it's far better to begin once more with an extraordinary initial population. However, after a user-described quantity of generations, a sufficiently a success individual has no longer advanced then the manner needs to prevent.

Probability of crossover: it is the proportion of the population a good way to go through crossover before coming into the new population. If the chance of crossover is 0.90, it means that the crossover is completed on 90% of the populace for each generation.

Probability of reproduction: is the proportion of people in a populace that will undergo reproduction.

IV. GENERATION OF MATHEMATICAL RELATION USING GP

The input parameters: breadth of specimen (B), Depth of specimen (D), Aspect Ratio (AR), Volume Fraction (VF) and Modulus of Rupture (Fcr) of concrete has been used and ultimate load (experimental) because the output parameter. Table 1 has presented the records for various ultimate loads.

The equations were evolved for closing load, the use of the values of enter and output parameters for various combinations of crossover fee, number of generations, populace size and no. of youngsters to supply. By accomplishing maximum range of generations, the manner is continued until the maximum correct equation is received. The statistic measures used to degree the accuracy of the equations is Coefficient of Determination (COD) and Root Mean Square (RMS) wherein the objective is to have COD nearly equal to one and RMS nearly equal to zero.

The equations obtained are:-

(a) Hooked fibers

$$\text{Ultimate Load} = \frac{mb(m+v)}{[b^2(m+v)+b(2m+v)-m(v+m)]\,[b(2m-a)+(}$$

(b) Crimped fibers

$$\text{Ultimate Load} = \frac{(b+v)}{(v^2 - vma + 3m + 4v + 2a + b + d)} \times 100$$

(c) Straight fibers

$$\text{Ultimate Load} = \frac{d}{(2m+2b+3a)-(a+2av+v)} \times 100$$

b = (Breadth of specimen/100)   d = (Depth of spec

a = (Aspect Ratio /100)   v= Volume Fractic

m= Modulus of Rupture of concrete

Table I: Input Values used to generate the Ultimate Load by GP
INPUT VALUES

B	D	AR	VF	Fcr	Ultimate Load (experimental)
200	150	0	0	4.68	11.27
200	150	30	0.50	5.11	14.84
200	150	30	1.00	5.16	16.29
200	150	30	1.50	5.00	18.71
200	150	30	1.75	4.90	18.12
200	150	50	0.50	4.96	15.80
200	150	50	1.00	4.93	17.81
200	150	50	1.50	5.22	19.21
200	150	50	1.75	5.14	18.62
200	150	30	0.50	5.01	12.24
200	150	30	1.00	5.05	13.41
200	150	30	1.50	4.91	15.40
200	150	30	1.75	4.81	14.91
200	150	50	0.50	4.87	13.00
200	150	50	1.00	4.83	14.66
200	150	50	1.50	5.12	15.81
200	150	50	1.75	5.04	15.35
200	150	30	0.50	4.67	11.43
200	150	30	1.00	4.71	11.61
200	150	30	1.50	4.57	13.33
200	150	30	1.75	4.83	12.91
200	150	50	0.50	4.53	11.48
200	150	50	1.00	4.50	12.69
200	150	50	1.50	4.77	13.68
200	150	50	1.75	4.69	13.29

V. APPLICATION OF GENETIC PROGRAMMING FOR PREDICTING ULTIMATE LOAD

The obtained experimental results for different type of fibers (Hooked, Crimped, Straight), with different A.R. (30, 50) and volume fraction (0.5, 1.0, 1.5, and 1.75 percent) were compared with obtained value from the expression. Figures 4 to figure6 showed the plot of ultimate load by GP and experimental results with GP.

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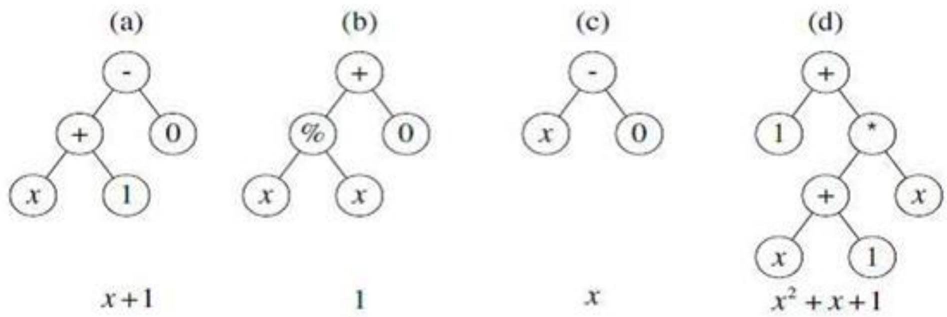
It was clear from the figures that values of experimental analysis and GP are similar to some extent. In ultimate load experiment and GP, average error in 8 design specimens with aspect ratio 30, 50 and volume fraction of 0,0.5,1.0,1.50 and 1.75% of fibers was found to be 6.3% for hooked fibers, 4% for crimped and 2% for straight fibers.

The value obtained for COD is 0.98 and for RMS it is 0.01 in Hooked fibers, in crimped fibers COD is equal to 0.94 and RMS is 0.007 and for s traight fibers, COD is 0.86 and RMS is 0.003. In Figures four, 5 and 6 the plot among experimental and GP of last load showed that some values calculated using GP are extra or much less identical to experimental values, and few matches exactly with the experimental values which are coinciding with the line. The graph displaying the version of Ultimate Load (values acquired from GP and values obtained experimentally) and quantity fraction have additionally been plotted for Crimped, Hooked and Straight varieties of fibers having exclusive issue ratios of 30 and 50 (see Figure 7, 8, 9, 10, 11 and 12). The comparison between experimental and GP analysis of ultimate load for certain type of fiber having certain aspect ratio is shown in figures 7 to 10. Table 2, 3 and 4 gives the output values obtained using Genetic Programming in Hooked Fibers, Crimped Fibers and Straight Fibers.

FIGURE 1: Showing the Initial Population of Four Randomly Created Individuals



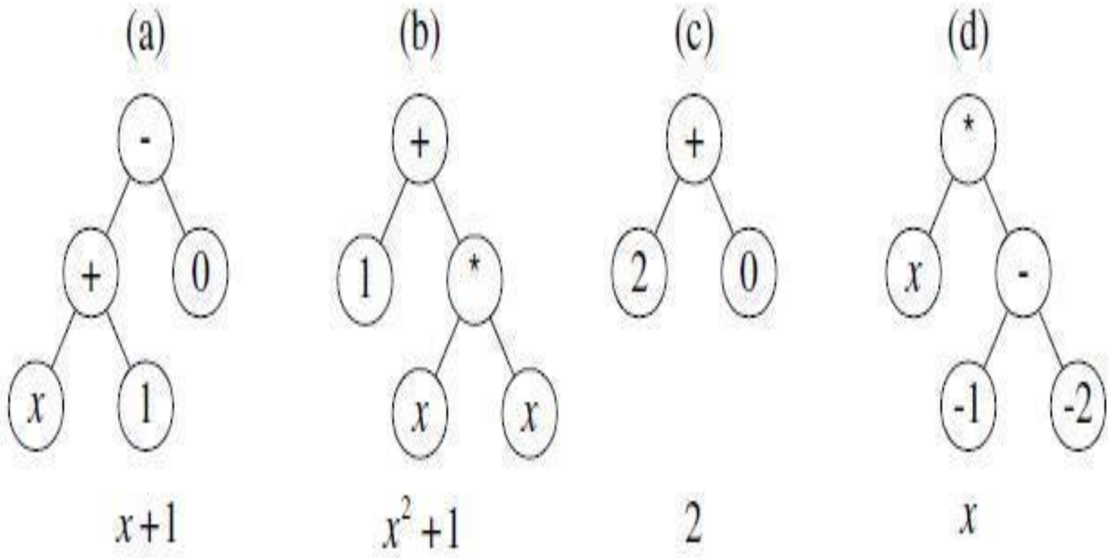


Figure 2: Showing the New Population (a) After Reproduction, (b) After Mutation and (c) & (d) After Crossover Operation

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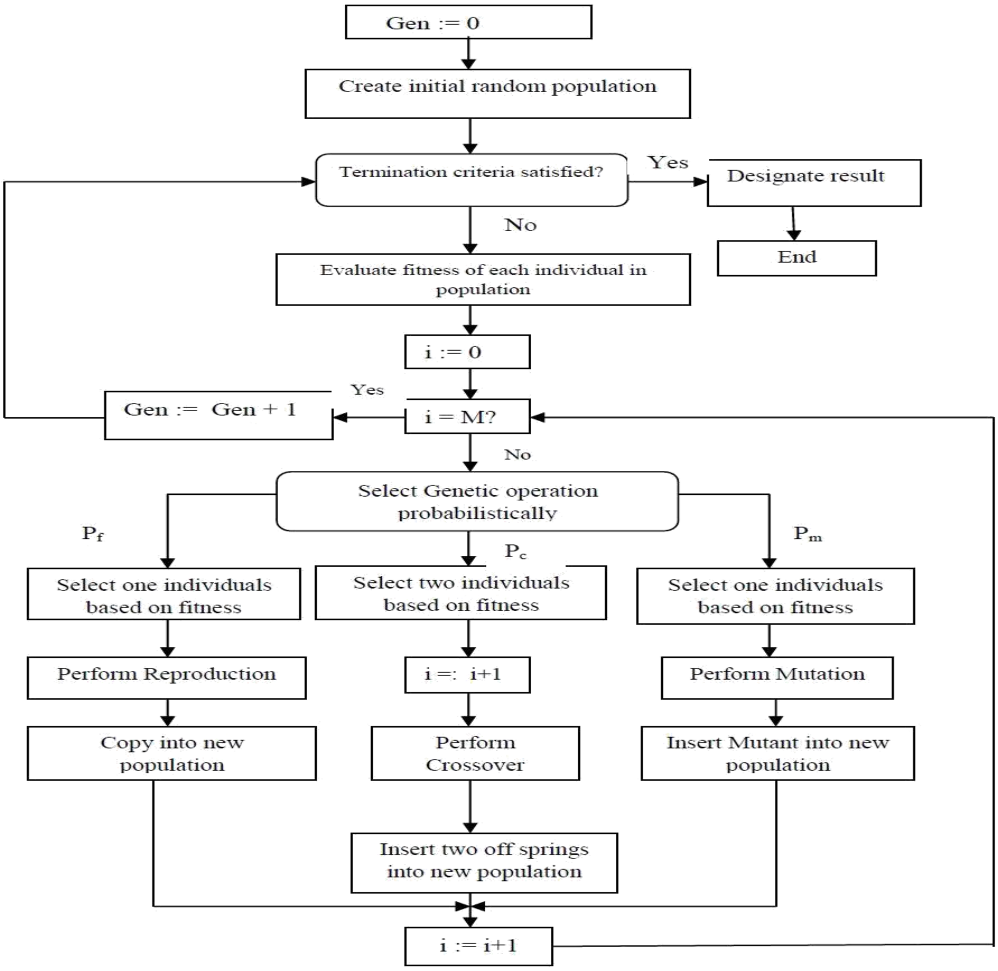

Figure 3: Flow Chart of Genetic Programming.

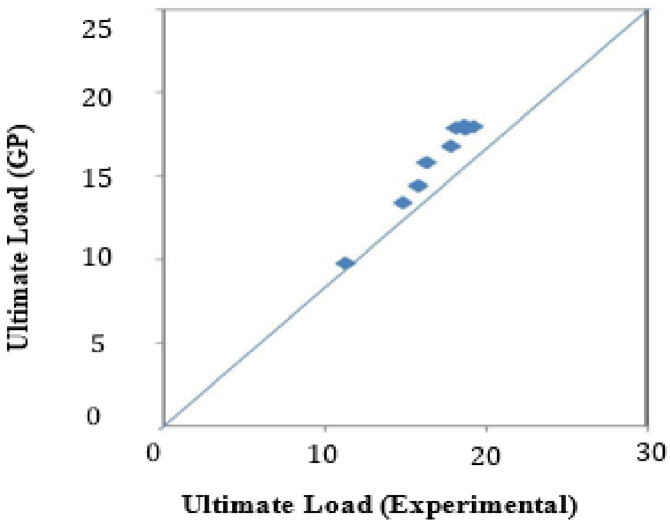

Figure 4. Comparison of Ultimate Load Obtained Experimentally and By GP in Specimens Having Hooked Fibers

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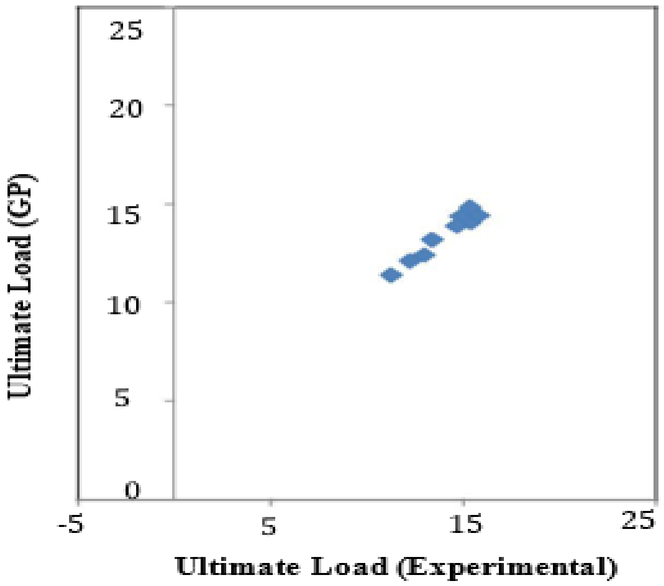

Figure 5. Comparison of Ultimate Load Obtained Experimentally and by GP in Specimens Having Crimped Fibers

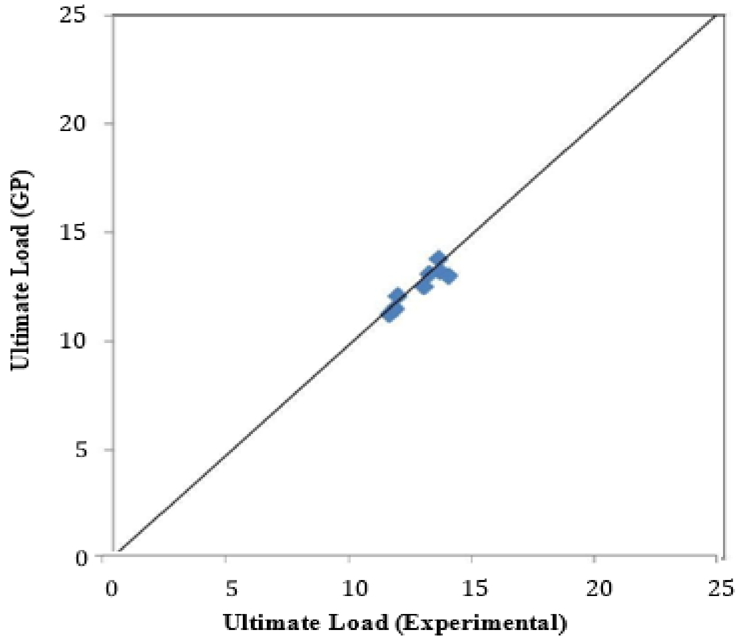

Figure 6. Comparison of Ultimate Load Obtained experimentally and by GP in Specimens having Straight Fibers

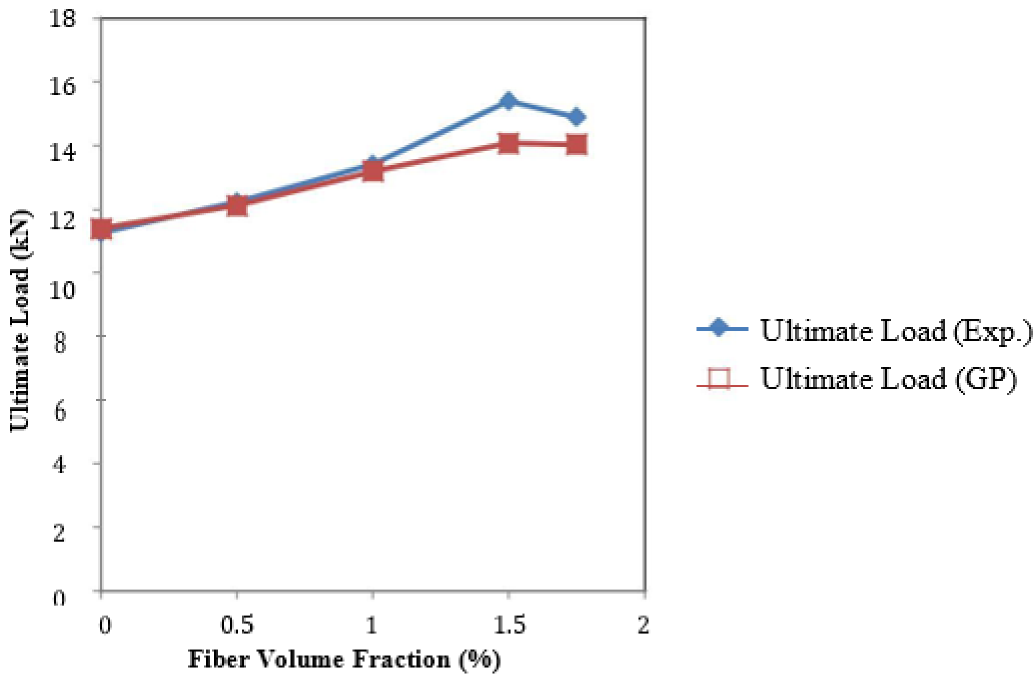

Figure 7. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Crimped Fibers having A.R. 30

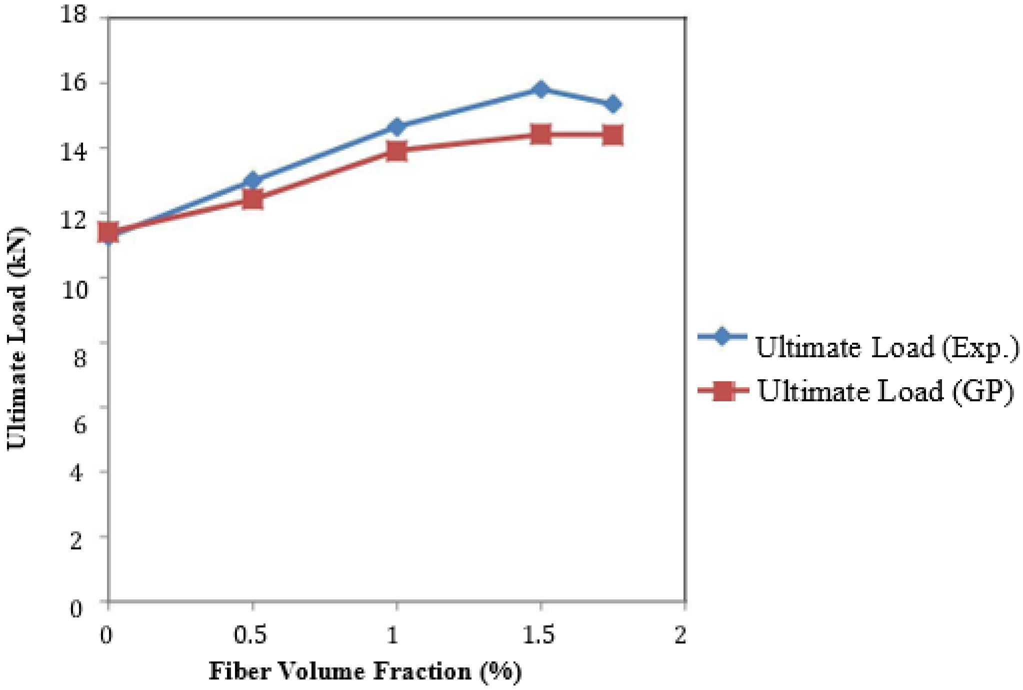

Figure 8. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Crimped Fibers having A.R. 50

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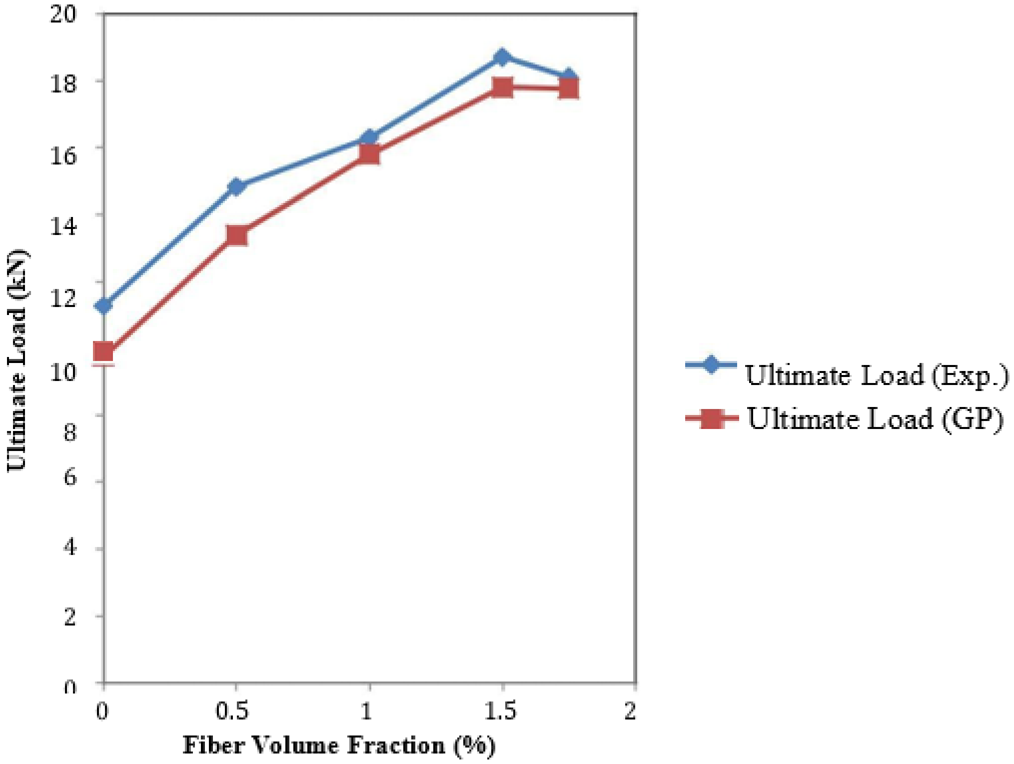

Figure 9. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Hooked Fibers having A.R. 30

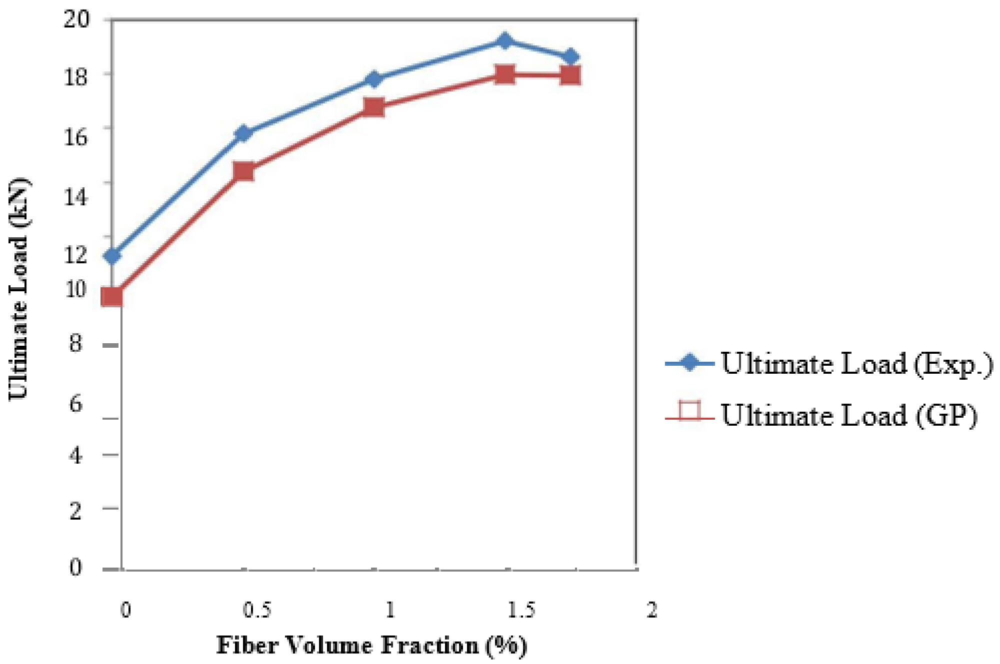

Figure 10. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Hooked Fibers having A.R. 50

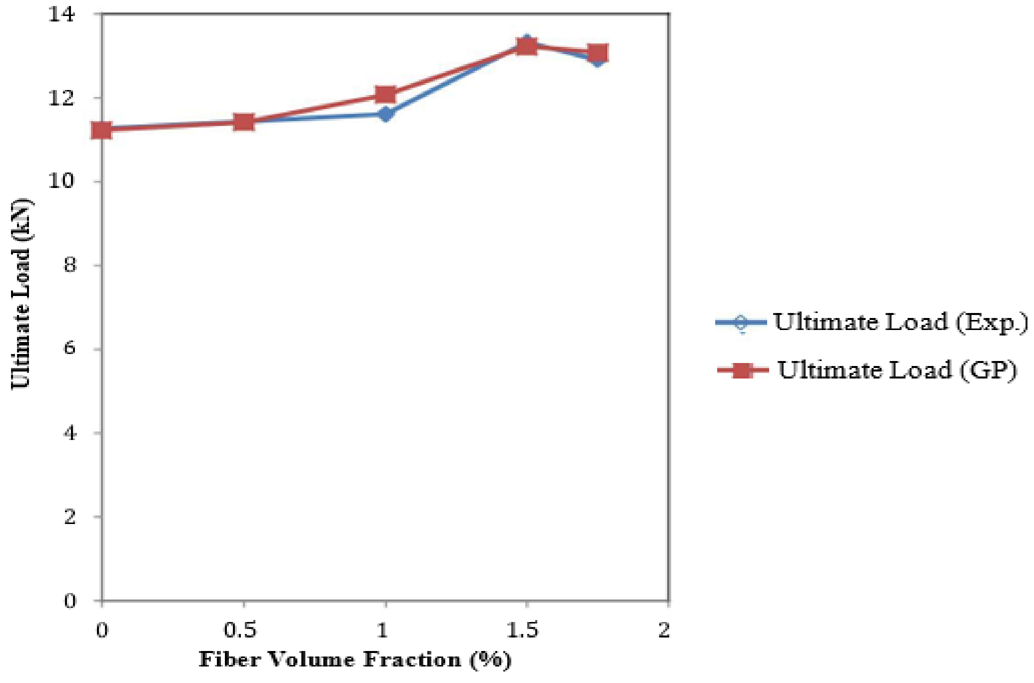

Figure 10. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Straight Fibers having A.R. 30

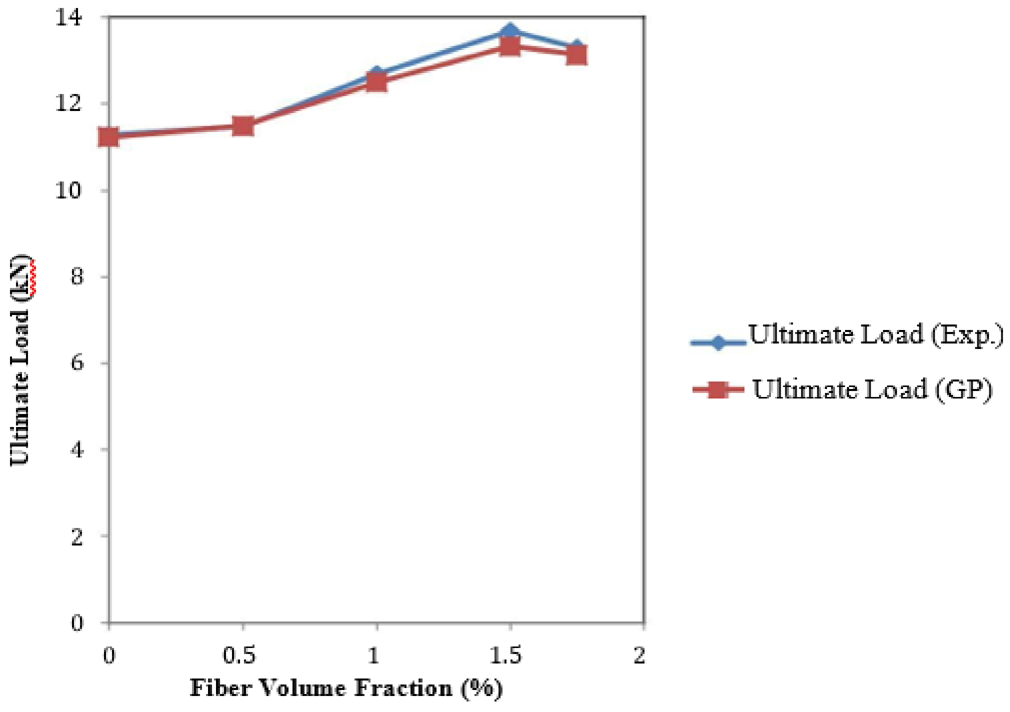

Figure 10. Variation of Ultimate Load (Exp. And GP) with Fiber Volume Fraction for Straight Fibers having A.R. 50

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Table 2. Output Values obtained using GP in Hooked Fiber.

Ultimate Load(experimental) (kN)	Ultimate Load (GP) (kN)
11.27	9.77
14.84	13.40
16.29	15.80
18.71	17.80
18.12	17.78
15.8	14.41
17.81	16.77
19.21	17.97
18.62	17.94

Table 3. Output Values obtained using GP in Crimped Fiber.

Ultimate Load (experimental) (kN)	Ultimate Load (GP) (kN)
11.27	11.40
12.24	12.12
13.41	13.20
15.40	14.07
14.91	14.04
13.00	12.41
14.66	13.90
15.81	14.42
15.35	14.40

Table 4. Output Values Obtained using GP in Straight Fibers

Ultimate Load (experimental) (kN)	Ultimate Load (GP) (kN)
11.27	11.23
11.43	11.42
11.61	12.08
13.33	13.23
12.91	13.09
11.48	11.49
12.69	12.50
13.68	13.33
13.29	13.13

VI. CONCLUSION

1.The final model generated using GP relates the ultimate load to specimen breadth, depth, aspect ratio, modulus of rupture of concrete, volume fraction having the values almost similar to experimental values. Hence, these models can be used for prediction of ultimate load in beam-column joints with fair accuracy.

2. The average error in experimental analysis and Genetic programming of ultimate load is obtained as:

Type of fiber	COD	RMS	Error
Hooked	0.98	0.01	6.3
Crimped	0.94	0.007	4
Straight	0.86	0.003	4

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AUTHORS PROFILE

Dr. Neeru Singla is an Assistant Professor at Punjab Technical University Jalandhar. She served as Associate Professor as well as Professor in different private reputed Engineering Colleges in Punjab from 2005 to 2016. She received her BE in Civil Engineering from Thapper Institute of Engineering and Technology Patiala in 2003 and Master"s Degree in Civil Engineering with specialization in Structural Engineering from Thapper Institute of Engineering and Technology Patiala in 2005. She received her Degree in Doctor of Philosophy in Civil Engineering from Punjab Technical University Jalandhar in 2015 with specialization in FEM Modeling of Beam Column joints under opening bending moment. The author has four publications to her credit.

Prof. Ashok Kumar Gupta is Professor and Head of Department of Civil Engineering, Jaypee University of Information Technology (JUIT), Waknaghat, Solan, Himachal Pradesh, India. He obtained his B E degree in Civil Engineering from University of Roorkee (now IIT Roorkee), ME degree in Geotechnical Engineering from University of Roorkee, and PhD degree in Civil Engineering from IIT Delhi. His interest areas cover testing and modeling of geotechnical materials, finite element modeling and its applications to geotechnical engineering, continuum damage mechanics and its application to rockfill materials modeling, engineering rock mechanics and environmental geotechnics. He is Founder Chairman of Indian Geotechnical Society (IGS) Shimla Chapter.

Dr. Yeshpal Vasishta is Executive Engineer in Himachal Pradesh Public Works Department. He obtained his diploma in Civil Engineering in year 1983 from Govt. Polytechnic Hamirpur Himachal Pradesh. He received his AMIE in Civil Engineering from Institute of Engineers, (India) Kolkata and Master"s Degree in Civil Engineering in Structural Engineering from Thapper Institute of Engineering and Technology Patiala in 2005. He received his Doctor of Philosophy in Civil Engineering from Punjab Technical University Jalandhar in 2014 with specialization in Rock fill material. The author is a life member of Institute of Engineers. The author has three publications to his credit.