ANALYTICAL STUDIES ON CFST COLUMNS (SCC INFILLED) USING FUZZY LOGIC

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Abstract: - A circular concrete-filled steel tube (CFST) has several advantages compared with reinforced concrete member or hollow steel tube, since the tri-axial state of compression of the concrete infill increases its strength and strain capacity. In this research investigation on the behaviour of Self Compacting Concrete Filled steel tube (CFST) is carried out. Composite Circular hallow steel tubes with infill of different grades of Self Compacting Concrete are tested for ultimate load capacity.steel tubes are compared for different lengths, thickness and grade. The Obtained results were compared with American Concrete Institute (ACI), Euro Code-4(EC-4) and modelling is carried out using FL (Fuzzy Logic) technique which is a soft tool in Matlab-R2018b.

Fuzzy logic is a problem-solving control system methodology that tends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC and control systems. It can be implemented in hardware, software, or a combination of both. A fuzzy logic controller can be regarded as an expert system that is able to process qualitative variables and to infer crisp values out of uncertainty. Hence, fuzzy logic can be find application in many aspects of real life, where there is a lack of information, there is uncertainty.

Keywords: Fuzzy logic, MATLAB, Concrete-filled steel tube (CFST).

1. INTRODUCTION

A concrete-filled steel tube (CFST) has been widely used as structural members, such as a building column and a bridge pier due to several advantages. The primary advantage of CFST is that the concrete infill is confined by the steel tube, which results in tri-axial state of compression that increases the strength and strain capacity of the concrete infill.

Column occupies a vital place in any civil engineering structural system.Weakness or failure of a column destabilizes the entire structure. In India reinforced concrete members are mostly used in the framing system for most of the buildings since this is the most convenient & economic system for low-rise buildings. However, for medium to high rise buildings this type of structure is no longer economic because of increased dead load, high stiffness, span restriction and hazardous formwork.

In this study, an alternative method using fuzzy logic to predict the axial load capacity of CFST was presented. In general, fuzzy logic can be used to simulate complex engineering problems. Its feasibility as universal approximators has been proven. In structural engineering practice, fuzzy logic is applied to assess various structural properties such as concrete durability and punching shear strength of the slab.

Fig. 1. Example of application of CFST member to a building column (U.S. Federal Courthouse, Seattle, WA, USA).

1.1 Fuzzy Logic:

The term fuzzy refers to things which are not very clear or are vogue. In real life, we may come

across a situation where we can't decide whether the statement is true or false. At that time, fuzzy logic offers very valuable flexibility for reasoning. We can also consider the uncertainties of any situation. Fuzzy logic algorithm helps to solve a problem after considering all available data. Then it takes the best possible decision for the given input. The fuzzy logic method imitates the way of decision making in human which consider all the possibilities.

Fuzzy logic deals with real world vagueness. Fuzzy logic provides a method to formalize reasoning when dealing with vague terms. It is an extension of multivalued logic: everything, including truth, is a matter of degree.

Fuzzy is a branch of mathematics. In mathematics fuzzy is subject and this fuzzy actually comes under artificial intelligence or soft computing.

Why we call this fuzzy method as soft computing.

We have two types of computing they are.

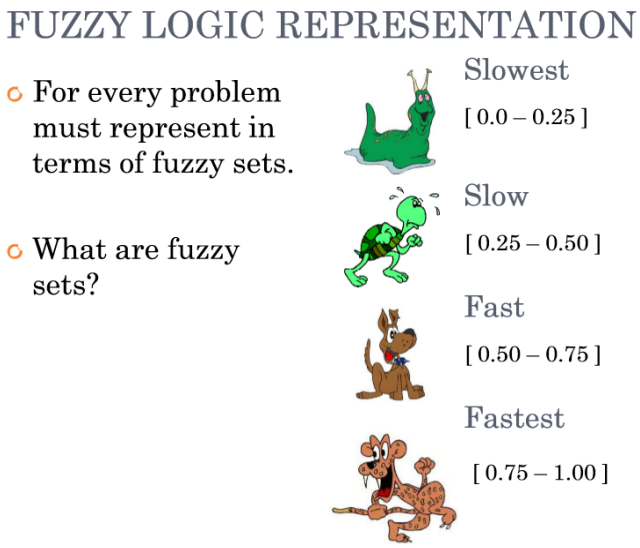
1) Soft computing

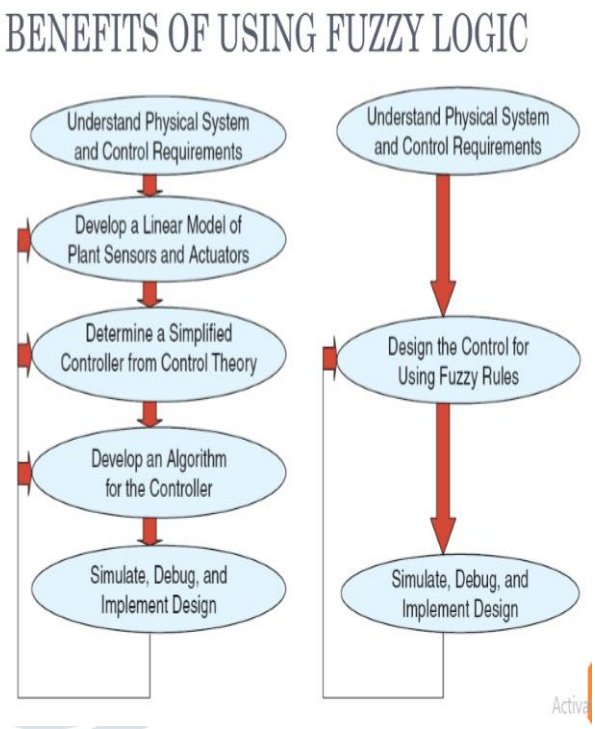
2) Hard computing

1) Hard computing software's are C, C++, and Mat Lab etc. For any problem to solve differential equation, Eigen value problem, linear and non linear equation we can write in C, C++, and Mat Lab.For any high level language we use that is called hard computing. Because there we write all instructions one by one.

2) Soft computing methods are

1) ANN (Artificial neural network)
2) GA (Genetic Algorithm)
3) Fuzzy Logic





Advantages of fuzzy logic system:

1) This system can work with any type of inputs whether it is imprecise, distorted or noisy input information

2) The construction of fuzzy logic is easy and understandable

3) It requires little amount of data

4) It is applicable for all kinds of uncertainty

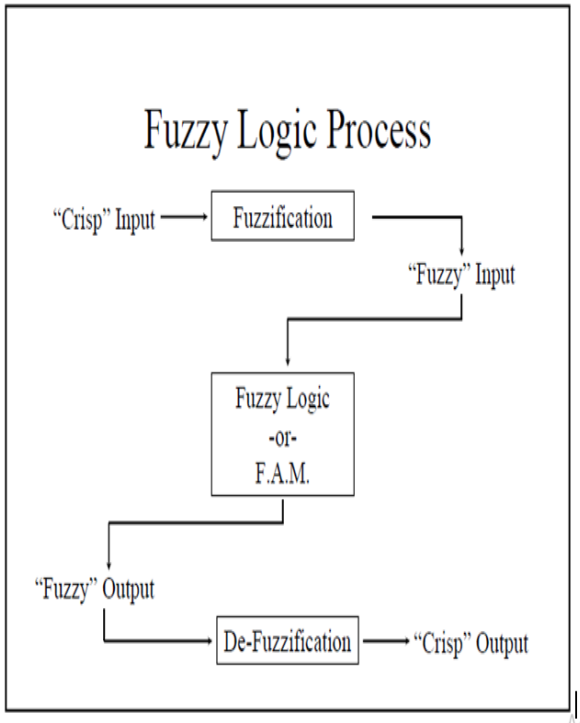
5) It is completely comprehensive in nature

Disadvantages of fuzzy logic systems:

1)As fuzzy logic works on precise as well as imprecise data so most of the time accuracy is compromised.

2) Proof of its characteristics is difficult or impossible in most cases because every time we do not get mathematical description of our approach.

1.2 Fuzzy logic process:



Steps:

1) Fuzzy Inputs: The first step is to take the crisp inputs, x1 and y1 and determine the degree to which these inputs belong to each of the appropriate fuzzy sets.

2) **Apply Fuzzy Operators**: The second step is to take the fuzzified inputs and apply them to the antecedents of the fuzzy rules

3) **Aggregate All Outputs**: Aggregation is the process of unification of the outputs of all rules. We take the membership functions of all rule consequents previously clipped or scaled and combine them into a single fuzzy set.

4) **Defuzzify**: The last step in the fuzzy inference process is defuzzification. Fuzziness helps us to evaluate the rules, but the final output of a fuzzy system has to be a crisp number.

1.3 Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand.
- Fuzzy logic is a more intuitive
- Fuzzy logic is flexible.
- Fuzzy logic is tolerant of imprecise data

1.4 Fuzzy Logic theory

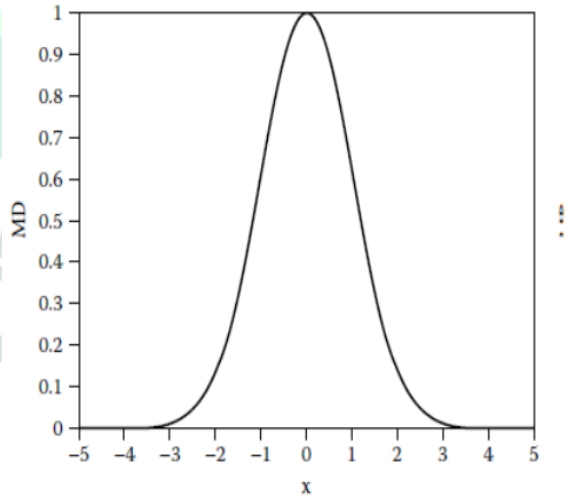
Definition (Zadeh, 1965) Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function:

$\mu(x)$ is interpreted as the degree of membership of elements in fuzzy set A for each $x \epsilon X$.

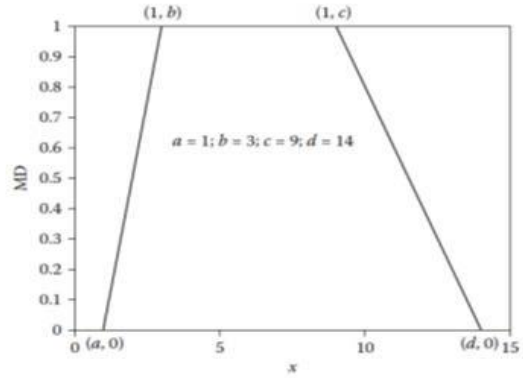
Let μ be a fuzzy subset of X; the support of A, denoted supp(A), is the crisp subset of X whose elements all have nonzero membership grades in A.

Membership functions are (show in Fig 1 a, b, c, d and e respectively)

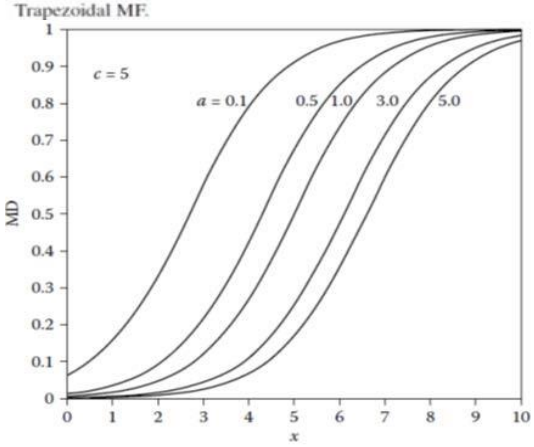
a- Triangular
b- Trapezoidal
c- Sigmoid
d- Gaussian
e- Generalised bell shaped MF



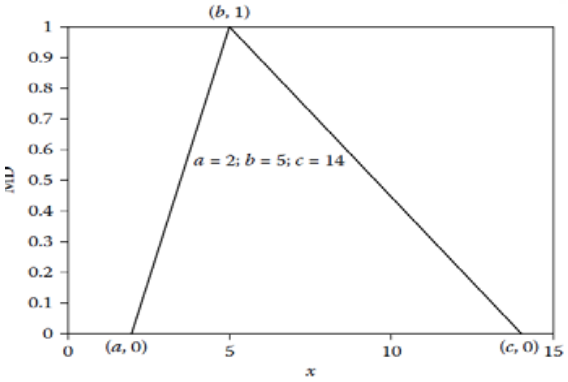
Gausian MF



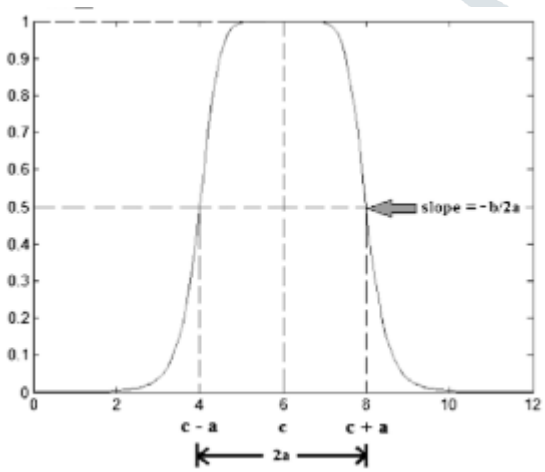
Trapezoidal MF.



Sigmoid MF.



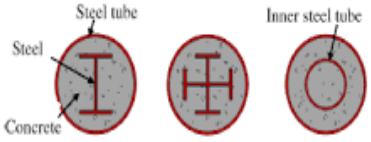
Triangular MF.



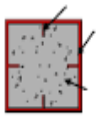
Genaralised bell-shaped MF

1.5 Composite Steel Column:

A steel-concrete composite column is conventionally a compression member in which the steel element is a structural steel section. There are three types of composite columns used in practice which are Concrete Encased, Concrete filled, Battered Section.



(e) Concrete-encased CFST columns



(f) Stiffened CFST columns

Fig.3.Types of CFST

Advantages of composite structure*:*

1. Most effective utilization of materials viz. concrete in compression and steel in tension.
2. Steel can be deformed in a ductile manner without premature failure and can withstand numerous loading cycles before fracture. Such high ductility of steel leads to better seismic resistance of the composite section.
3. Steel component has the ability to absorb the energy released due to seismic forces.
4. Ability to cover large column free area. This leads to more usable space. Area occupied by composite column is less than

1.6 Self-compacting concrete:

Self-compacting concrete is a high-performance concrete which is highly flow able or self-levelling cohesive concrete that can be easily placed in the tight reinforcement. It is also known as super workable concrete. As the name

suggest,this concrete compacts by itself without the use of external vibrators. Some admixtures are used to reduce the yield stress in SCC such as HRWR (high range water-reducing admixture), and the viscosity is increased by using VMA (viscosity modifying admixture).

Advantages of SCC

1. Faster construction and requires less manpower reduce the overall cost of production.
2. SCC can be placed easily in complicated formwork and dense reinforcement.
3. It is super workable due to its low water-cement ratio, which gives rapid strength development, more durability, and best quality.

4. As it is self-compacted there are no needs to use any vibrator.
5. Bleeding and segregation problems are almost nil.

2. Material Properties:

STEEL
a) Material: Structural Steel Fe 250
b) Young's Modulus E=210000Mpa
c) Poison's ratio =0.3
d) Density =7860kg/m3.

CONCRETE
a) Grade of Concrete: M30
b) Young's Modulus E=25000Mpa
c) Poison's ratio = 0.16
d) Density=2400kg/m3

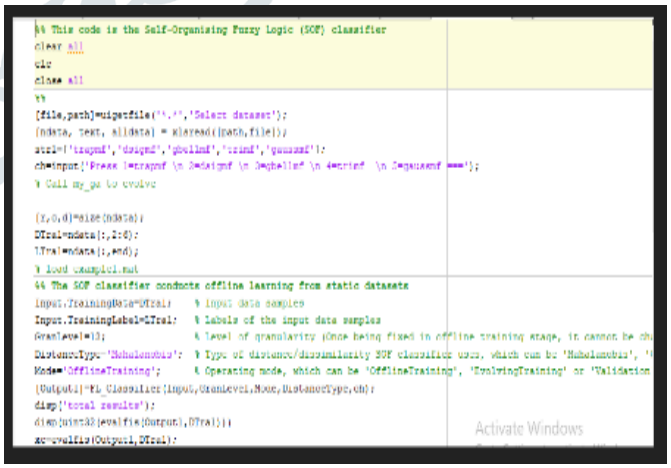
WORK FLOW

1) Defining Structural problem.
2) Determination of Objective Function, Design Variables and Constraints.
3) Development of VBA (visual basic application) code for design.
4) Development of MATLAB programme.
5) Solving problem Using Optimization Technique

Table 1: Collection of data and comparison

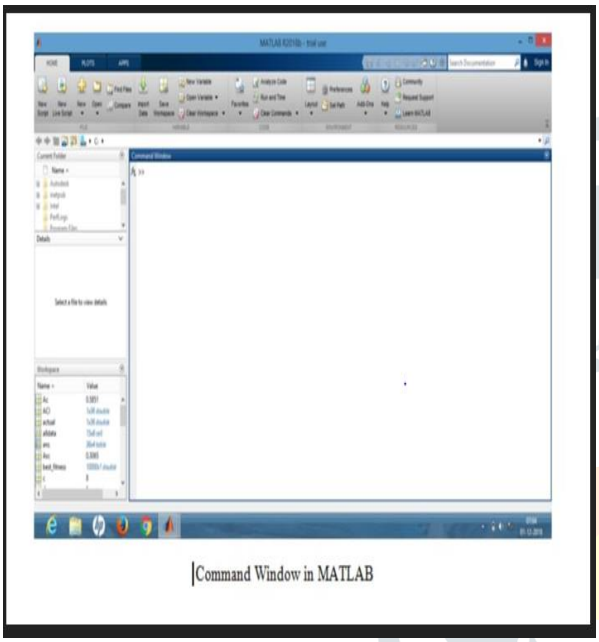
No of specimens	L (mm)	H(mm)	t(mm)	fy(Mpa)	fc'(Mpa)	Pexp(KN)	Pu(EC4) (KN)	P_u(ACI) (KN)	Pu(ANN) (KN)
12	360	99.2	4.91	762	100	2520	2250	2223	2300
	1514	198.99	4.95	762	113	7506	6950	6901	6950
18	1512	98.87	4.89	762	113	2087	1860	1920	1867
	3512	200.67	4.95	762	113	6329	5850	5723	5840
15	450	150	8	446	147	5911	5426.5	5326	5400
	450	150	12.5	779	164.1	8912	8122.5	8200	8100
6	600	197	6.1	381.68	16.68	2730	2420	2513	2520.5
	600	201	10.3	437.88	18.37	3980	3650	3520	3640
8	1000	101.6	3	334.8	25	718.88	650	632.5	656
	2700	150	4.5	483.9	28.8	1516.26	1350	1323	1352.55
8	330	110	5	701	54.5	2203	1950	1942	1970
	570	190	5	701	54.5	3882	3550	3450	3540
3	750	249.6	3.7	324.3	29.93	2677	2400	2353	2450
	750	251.1	3.75	324.3	29.93	3131	2800	2750	2820
2	675	150	3	324.4	40.73	1516	1350	1323.5	1360
	900	150	3	324.4	40.73	1599	1450	1400	1460
4	1230	410	10	358	42.5	12800	11500	11475	11502
	1500	500	16	389	42.5	17900	16500	16420	16520
10	300	99.9	2.85	268	21.5	705	640	630.2	64303
	450	152	4.9	458	60.65	1976	1750	1770.3	1760

Fig-2 Different Tools in Matlab



```
acc=((sum(LTral)-sum(abs(LTral-xc)))/sum(LTral))*100;
acc=abs(100-sum(abs(LTral-xc)));
disp(['Accuracy of ',strl(ch),' ==',acc,'  %'])
figure,plot(LTral,'-r');
hold on
plot(evalfis(Output1,DTral),'ob');
xlabel('Number of data');
ylabel('Load capacity of CFST');
legend('Original data','Fuzzy logic output');
grid on
% Output1.TrainedClassifier  - Offline primed SOF classifier
while(1)
     ch1=input('If you want test press 1 else any');
     if ch1==1
ch(1)=input('Diameter');
ch(2)=input('Length');
ch(3)=input('Thickness');
ch(4)=input('Enter D/t');
ch(5)=input('Enter L/d');
disp('predicted load capacity is =')
evalfis(Output1,ch)
     else
     break;
     end
```

Fig.3 Programming in FL software



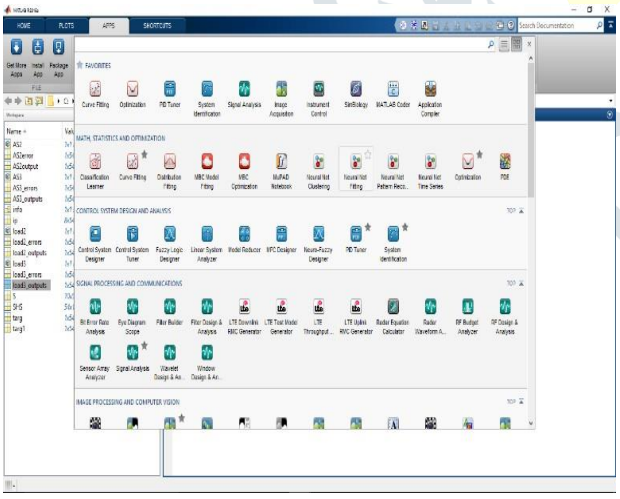


Fig-4 command window in Matlab

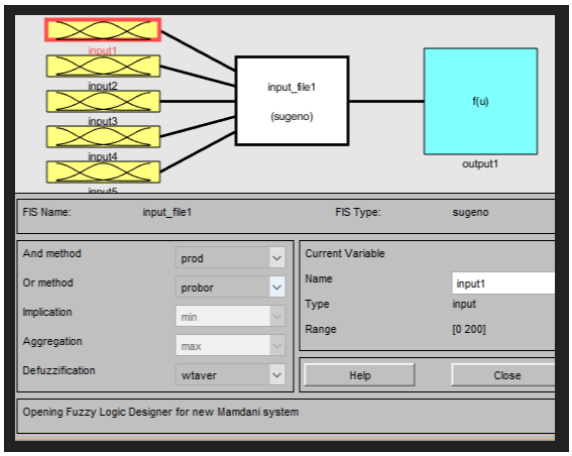


Fig-5 Adding input variable

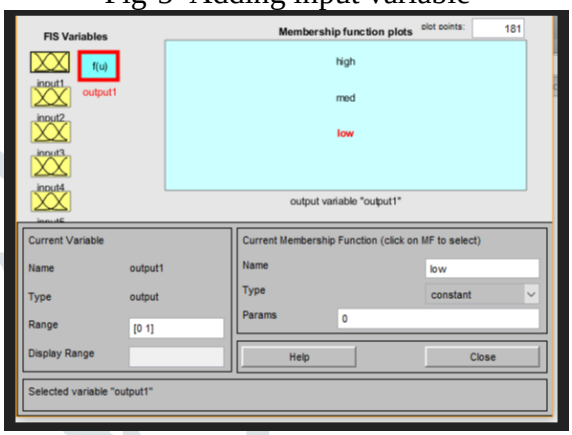


Fig-6 Adding output variable

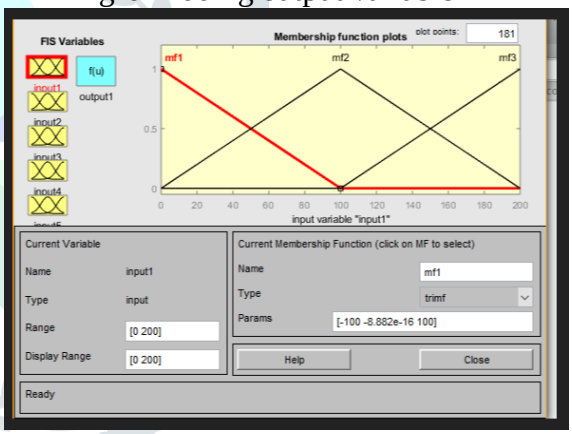


Fig-7 Triangular membership function

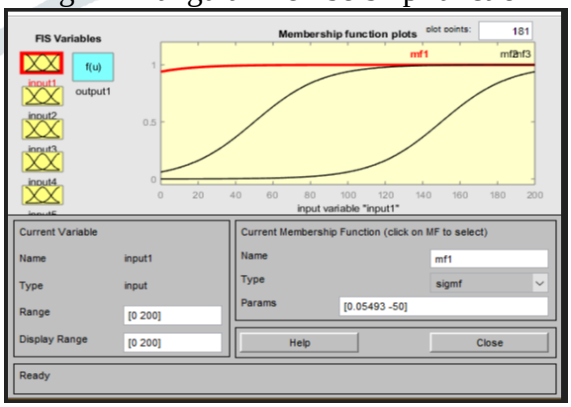


Fig-8 Sigmidal membership function

3. Predicted and experimental results:

After collecting the data from experiment conducted by previous researches and creating the model using fuzzy-logic soft-tool to train the the input data to predict the ultimate axial load capacity of the CFST tubes, The below table shows the values obtained from the analysis from different Iterations.

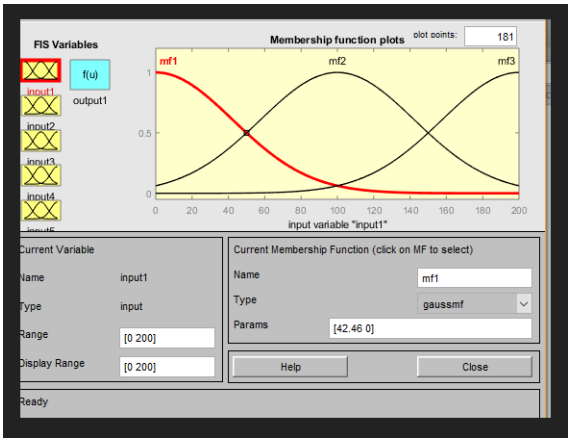


Fig-9 Gaussian membership function

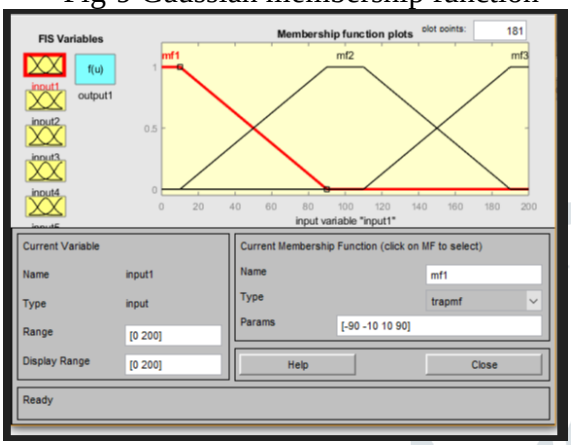


Fig-10 Trapezoidal membership function

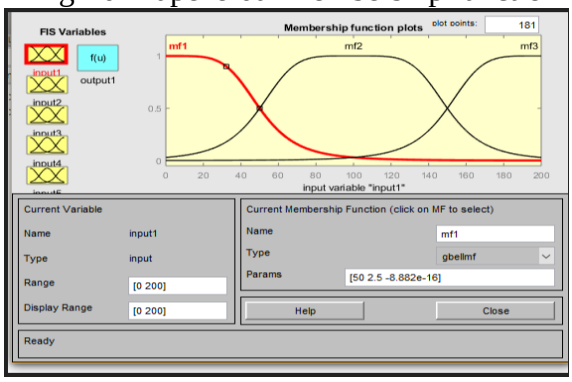
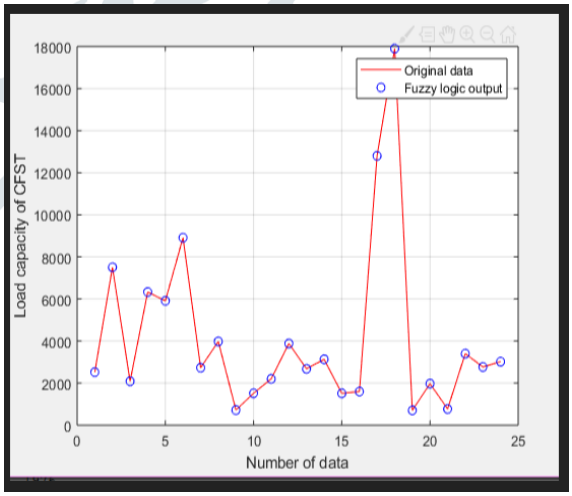


Fig-11 Generalised bellshaped mf

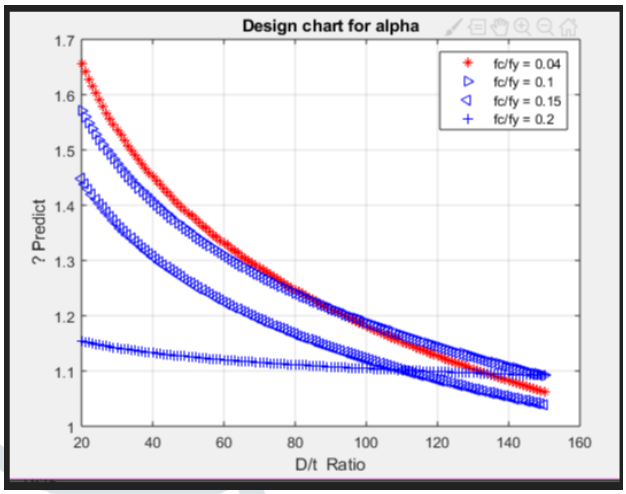
Table 2.Ultimate Load values in Fuzzy-logic software

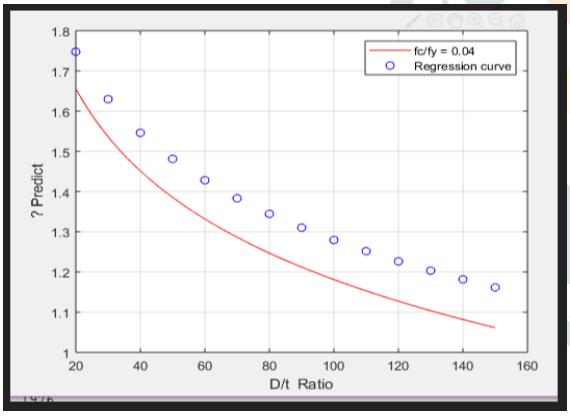
No of specimens	L (mm)	H(mm)	t(mm)	fy(Mpa)	fc'(Mpa)	Pexp(KN)
12	360	99.2	4.91	762	100	2520
	1514	198.99	4.95	762	113	7506
18	1512	98.87	4.89	762	113	2087
	3512	200.67	4.95	762	113	6329
15	450	150	8	446	147	5911
	450	150	12.5	779	164.1	8912
6	600	197	6.1	381.68	16.68	2730
	600	201	10.3	437.88	18.37	3980
8	1000	101.6	3	334.8	25	718.88
	2700	150	4.5	483.9	28.8	1516.26
8	330	110	5	701	54.5	2203
	570	190	5	701	54.5	3882
3	750	249.6	3.7	324.3	29.93	2677
	750	251.1	3.75	324.3	29.93	3131
2	675	150	3	324.4	40.73	1516
	900	150	3	324.4	40.73	1599
4	1230	410	10	358	42.5	12800
	1500	500	16	389	42.5	17900
10	300	99.9	2.85	268	21.5	705
	450	152	4.9	458	60.65	1976

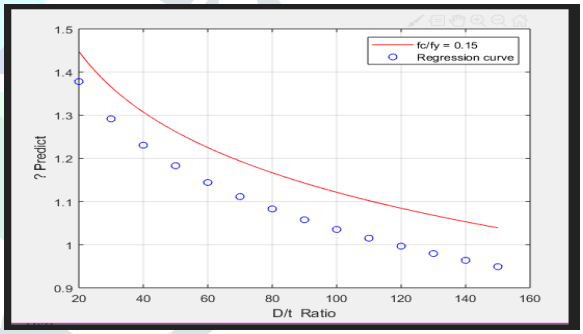
4. Graphical Representation of FL Results:

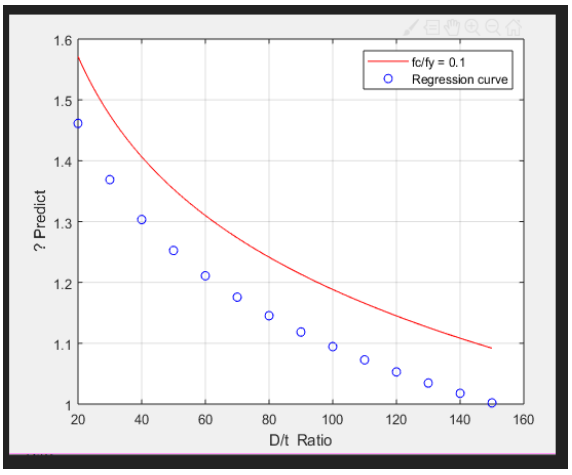


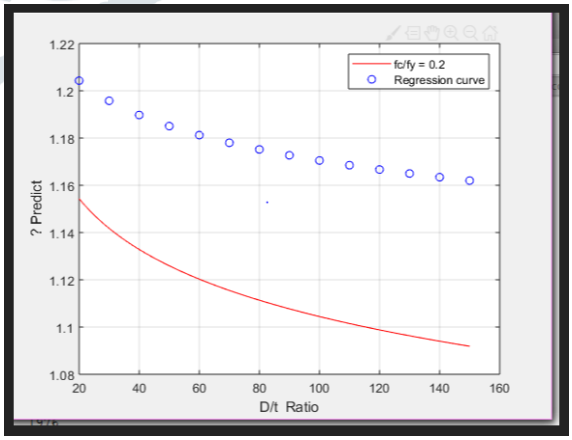
Trapezoidal.mf	Sigmoid.mf	Generalised bell shaped.mf	Tiangular.mf	Gaussian.mf
2390	2380	2382	2372	2353
7230	7212	7210	7190	7195
1980	1972	1955	1956	1947
6112	6118	6100	6085	6032
5613	5590	5612	5490	5593
8620	8625	8550	8420	8626
2625	2623	2550	2530	2629
3825	3816	3806	3755	3740
690	680	685.55	675	665.3
1480.5	1470	1466.5	1450.5	1432
2113	2110	2115	2100	2114
3800	3750	3755.5	3743	3720
2620	2610	2618.88	2520	2500
2981	2975	2986	2973	2982
1483	1475.55	1460	1430	1455.5
1520	1511.23	1523.4	1560	1523
12320	12259	12324	12400	12322
17420	17410.5	17415	17413	17429.5
675	655.5	662	661.3	672.35
1900.5	1890	1901	1880.5	1900.6











5. Results and discussion:

The FL is a soft-tool in MATLAB R2018b Software (matrices laboratory) is one way of including specimen irregularities in the model using the results of the behavior of SCC infilled composite tubes subjected to different loadings.

The Fuzzy Logic Programming has been shown to successfully predict the ultimate load of the composite steel tubes. In which input layer consists of 6 parameters like grade, dia, length, thickness, D/t and L/D and one target value i.e., exp Pu. FL shows good results with less error. (8%)

6. Conclusion

- On observing Five tpes of membership function results, trapezoidal membership function is in par with experimental results, vary only by 5%
- In all cases, variation of experimental results with Fuzzy modelling, variation is not more than 8%
- The results are compared with EURO CODE-4, ACI and the variation is 10 to 15% compared with fuzzy modelling.
- The results are compared with ANN software and the variation is 8 to 12% .
- Fuzzy modelling is very effective way of predicting than ANN modelling.
- Objective functions play a very crucial role in predicting ultimate values.

7. References

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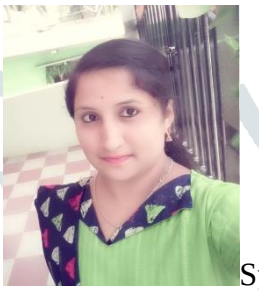

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