IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Optimization of Bond strength in CFST Columns using GRA (Grey Relational Analysis)

Anusha T S[1], Dr.N.S.Kumar[2]

[1] PG Student, Department of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India

[2] Professor and HoD, Former Director R&D, Department of Civil Engineering, Ghousia College of Engineering, Ramanagara, Karnataka, India.

Abstract:

Concrete filled steel tubes are extensively used in high rise structures and bridges. The characteristics such as ease of Construction, ease of Maintenance, Corrosion Resistance have made Concrete Filled Steel Tubes to have potential application in many Structures with high requirement of Durability. Extensive researches have been carried out in past decades on the behavior of CFST columns. Experimental investigation was carried out on concrete filled steel tube columns with concrete, manufactured using glass fiber, with different aspect ratios. In this paper the experimental results obtained from Experiments were normalized to enhance the performance. The performance characteristics are then introduced to calculate the Grey Relational coefficient and Grey Relational grades according to Grey Relational Analysis (GRA). From this research work, Parametric Optimization and Factors influencing the response is well predicted. For the given diameter to thickness ratio, The Highest Grey Relational Grade of 1.0000 was observed during several Experimental runs For the Average GRG. Which results in the optimal combination of control factors Viz., diameter, thickness, L/D Ratio resulting in nominal Bond Strength

KEYWORDS:*CFST, Bond Strength, Columns, Grey Relational analysis.*

Introduction

Concrete Filled Steel Tubes nowadays are increasingly used in High-rise buildings and arch structures. The characteristics of aesthetic appearance, excellent durability, good seismic behavior and easy of construction as well as maintenance provide CFST with potential application in onshore buildings, offshore platforms, bridges and many structures.

Composite columns integrate the favorable characteristics of steel and concrete materials, therefore providing the merits of high strength and stiffness, energy dissipation and considerable economy. In composite columns steel-concrete interface bond plays a major role in the regionsof end connections where force transfer takes place.

Past studies have indicated that a continuity of strains between steel and concrete can be assured if the concrete core and steel tube at the column end are loaded simultaneously. In this case, the actual bond between the steel and the concrete has little or no significant influence on the performance of CFST. However bond stress demand is excessively high where longitudinal shearing stresses are likely to be predominant.

Grey relational analysis was proposed by Deng in 1989, it is widely used for measuring the degree of relationship between sequences by grey relation grade. Several researchers adopted the grey relational analysis for optimizing the control parameters. To optimize the Bond Strength, Taguchi method with grey relational analysis is adopted. The following are the steps:

1. Identify the size of the tubes like length, diameter, thickness of the tube and grade of the concrete as infill.
2. Determine the number of levels for the Taguchi approach.
3. Select the appropriate orthogonal array.
4. Conduct the experiments based on the arrangement of the orthogonal array.
5. Normalize the experiment results of axial load and the deformation.
6. Perform the grey relational generating and calculate the grey relationalcoefficient.
7. Calculate the grey relational grade by averaging the grey relational coefficient.
8. Analyze the experimental results using the grey relational grade.

2. Experimental Datasheet:

The Experimental results of Shivadharshan et.al 2019[1] considered here for the analysis.

Table:1 Experimental results of Pushout Test Conducted on CFST columns for evaluatingBond Strength

Sl No	Grade of Concrete	Diameter of tube D in mm	Percentage of glass fiber	Thickness of the tubeT in mm	L/D ratio	Pushout Load (Nu) KN	Bond Strength τu KN/mm^2
1	M20	33.7	0	2.6	12	66.36	1.5507
2		33.7	0.2	3.2	14	111.63	2.2360
3		33.7	0.4	4	16	108.8	1.9069
4		42.2	0	3.2	16	192.34	2.1498
5		42.2	0.2	4	12	39.45	0.5879
6		42.2	0.4	2.6	14	142.23	1.8168
7		48.3	0	4	14	111.69	1.0891

8		48.3	0.2	2.6	16	41.54	0.3544
9		48.3	0.4	3.2	12	99.2	1.1285
10	M25	33.7	0	2.6	12	58.35	1.3635
11		33.7	0.2	3.2	14	81.21	1.6266
12		33.7	0.4	4	16	96.7	1.6948
13		42.2	0	3.2	16	178.38	1.9938
14		42.2	0.2	4	12	50.84	0.7577
15		42.2	0.4	2.6	14	185.51	2.3697
16		48.3	0	4	14	82.05	0.8001
17		48.3	0.2	2.6	16	111.71	0.9531
18		48.3	0.4	3.2	12	54.762	0.6230
19	M30	33.7	0	2.6	12	60.22	1.4072
20		33.7	0.2	3.2	14	103.64	2.0759
21		33.7	0.4	4	16	92.7	1.6247
22		42.2	0	3.2	16	136.63	1.5271
23		42.2	0.2	4	12	54.71	0.8153
24		42.2	0.4	2.6	14	197.93	2.5283
25		48.3	0	4	14	104.83	1.0222
26		48.3	0.2	2.6	16	88.87	0.7582
27		48.3	0.4	3.2	12	134.85	1.5341

3. *Grey Relation Analysis:*

3.1 Data pre-processing:

The data pre-processing is the first step to be performed in the grey relational analysis to normalize the random grey data with different measurement units to transform them to dimensionless parameters. Thus, data pre-processing converts the original sequences to a set of comparable sequences. Different methods are employed to pre-process grey data depending upon the quality characteristics of the original data. The original reference sequence and pre-processed data (comparability sequence) are represented by $X^{(0)}(k)$ and $X^{(0)}(k)$, i=1,2,3,…..m; k=1,2,….,n respectively, where m is the number of experiments and n is the total number of observations of data. Depending upon the quality characteristics, the three main categories for normalizing the original sequence are identified as follows: If the original sequence data has quality characteristicsas 'larger-the-better' then the original data is pre-processed as 'larger-the-best'

$$x_i^*(k) = \frac{x_i^{(0)}(k) - \min x_i^{(0)}(k)}{\max_i x^{(0)}(k) - \min_i x^{(0)}(k)}$$

If the original data has the quality characteristic as 'smaller the better', then original data is pre-processed as 'smaller-the best':

$$x_i^*(k) = \frac{\max x_i^{(0)}(k) - x_i^{(0)}(k)}{\max_i x^{(0)}(k) - \min_i x^{(0)}(k)}$$

However, if the original data has a target optimum value (OV) then quality characteristic is'nominal-the-better' and the original data is pre-processed as 'nominal-the-better':

$$x_i^*(k) = 1 - \frac{|x_i^{(0)}(k) - OV|}{\max\{\max_i x^{(0)}(k) - OV, OV - \min_i x^{(0)}(k)\}}$$

Also, the original sequence is normalized by a simple method in which all the values of thesequence are divided by the first value of the sequence.

$$x_i^*(k) = \frac{x_i^{(0)}(k)}{x_i^{(0)}(1)}$$

Where max $x_i^{(k)}$ and min $x_i^{(k)}$ are the maximum and the minimum values respectively of the original sequence $x_i^{(0)}(k)$. Comparable sequence $x_i^*(k)$ is the normalized sequence of original data.

3.2 Grey relational grade:

Next step is the calculation of deviation sequence, Δoi(k) from the reference sequence of pre-processes data $x_i(k)$ and the comparability sequence $x_i(k)$. The grey relational coefficient is calculated from the deviation sequence using the following relation:

$$\gamma(x_0^*(k), x_i^*(k)) = \frac{\Delta min + \xi \Delta max}{\Delta oi(k) + \xi \Delta max} \qquad 0 < \gamma(x_0^*(k), x_i^*(k)) \leq 1$$

Where Δoi(k) is the deviation sequence of the refernce sequence $x_0^*(k)$ and comparabilitysequence $x_i^*(k)$. and comparibility sequence $x_i^*(k)$.

$$\Delta oi(k) = |x_0^*(k) - x_i^*(k)|$$

$$\Delta max = \underset{\forall j \in i}{max} \underset{\forall k}{max} |x_0^*(k) - x_i^*(k)|$$

$$\Delta min = \underset{\forall j \in i}{min} \underset{\forall k}{min} |x_0^*(k) - x_i^*(k)|$$

ξ is the distinguishing coefficient ξ ϵ [0,1]. The distinguishing coefficient (ξ) value to be chosen as 0.5. A grey relational grade is weighed average of the grey relational coefficient and isdefined as follows:

$$\gamma(x_0^*, x_i^*) = \sum_{k=1}^{n} \beta k \gamma((x_0^*(k), x_i^*(k)), \sum_{k=1}^{n} \beta k = 1$$

The grey relational grade γ (x_o^*,x_i^*) represents the degree of correlation between the reference and comparability sequences. If two sequences are identical, then grey relational grade value equals unity. The grey relational grade implies that the degree of influence related between the comparability sequence and the reference sequence. In case, if a particular comparability sequence has more influence on the reference sequence than the other ones, the grey relational grade for comparability and reference sequence will exceed that for the other grey relational grades. Hence, grey relational grade is an accurate measurement of the absolute difference in data between sequences and can be applied to appropriate the correlation between sequences.

The experimental results for ultimate load (P_u), Axial shortening (Δ_s) listed in the Table below. Typically, larger values of P_u and nominal values of Δ_s are desirable. Thus the data sequences have the nominal-the-better characteristic, the "nominal-the-better" methodology, wasemployed for data pre-processing.

Table 2: Orthogonal array L_9 (3^3) of the experimental runs and results

slno	A	B	C	D	Bond Strength τu KN/mm²(M20)	Bond Strength τu KN/mm² (M25)	Bond Strength τuKN/mm² (M30)
1	1	1	1	1	1.5507	1.3635	1.4072
2	1	2	2	2	2.2360	1.6266	2.0759
3	1	3	3	3	1.9069	1.6948	1.6247
4	2	1	2	3	2.1498	1.9938	1.5271
5	2	2	3	1	0.5879	0.7577	0.8153
6	2	3	1	2	1.8168	2.3697	2.5283
7	3	1	3	2	1.0891	0.8001	1.0222
8	3	2	1	3	0.3544	0.9531	0.7582
9	3	3	2	1	1.1285	0.6230	1.5341

The values of the τu are set to be the reference sequence $x_o^{(0)}$ (k), k =1–3.Moreover, the results of nine experiments were the comparability sequences $x_i^{(0)}$ (k), i=1, 2... 9, k =1–3. Table V listed all of the sequences after implementing the data preprocessing using Equation (2). The reference and the comparability sequences were denoted $x_0^*(k)$ and $x_i^*(k)$, respectively.

Table: 3-a Data Processing Results

Comparability Sequence	Reference Sequence		
Run No	Bond Strength τu KN/mm^2(M20)	Bond Strength τuKN/mm^2 (M25)	Bond Strength τuKN/mm^2 (M30)
1	0.6358	0.4240	0.3667
2	1.0000	0.5746	0.7444
3	0.8251	0.6136	0.4895
4	0.9542	0.7848	0.4344
5	0.1241	0.0771	0.0322
6	0.7772	1.0000	1.0000
7	0.3905	0.1014	0.1491
8	0.0000	0.1890	0.0000
9	0.4114	0.0000	0.4383

Table: 3- b Data Processing Results (contd…)

Comparability Sequence	Reference Sequence		
Run No	Bond Strength τu KN/mm^2(M20)	Bond Strength τu KN/mm^2 (M25)	Bond Strength τuKN/mm^2 (M30)
1	0.36419	0.57601	0.63335
2	0.00000	0.42539	0.25558
3	0.17491	0.38637	0.51050
4	0.04580	0.21521	0.56563
5	0.87591	0.92290	0.96775
6	0.22277	0.00000	0.00000

7	0.60954	0.89861	0.85088
8	1.00000	0.81099	1.00000
9	0.58859	1.00000	0.56169

Table 4: Calculated Grey Relational Coefficient and Grey Relational Grade

Comparability Sequence	Reference Sequence				
Run No	Bond Strength τu KN/mm^2(M20)	Bond Strength τu KN/mm^2 (M25)	Bond Strength τu KN/mm^2 (M30)	Grey Relational Coefficient(GRC)	Grey Relational Grade (GRG)
1	0.5786	0.4647	0.4412	0.4948	5
2	1.0000	0.5403	0.6617	0.7340	2
3	0.7408	0.5641	0.4948	0.5999	4
4	0.9161	0.6991	0.4692	0.6948	3
5	0.3634	0.3514	0.3407	0.3518	8
6	0.6918	1.0000	1.0000	0.8973	1
7	0.4506	0.3575	0.3701	0.3928	7
8	0.3333	0.3814	0.3333	0.3494	9
9	0.4593	0.3333	0.4709	0.4212	6

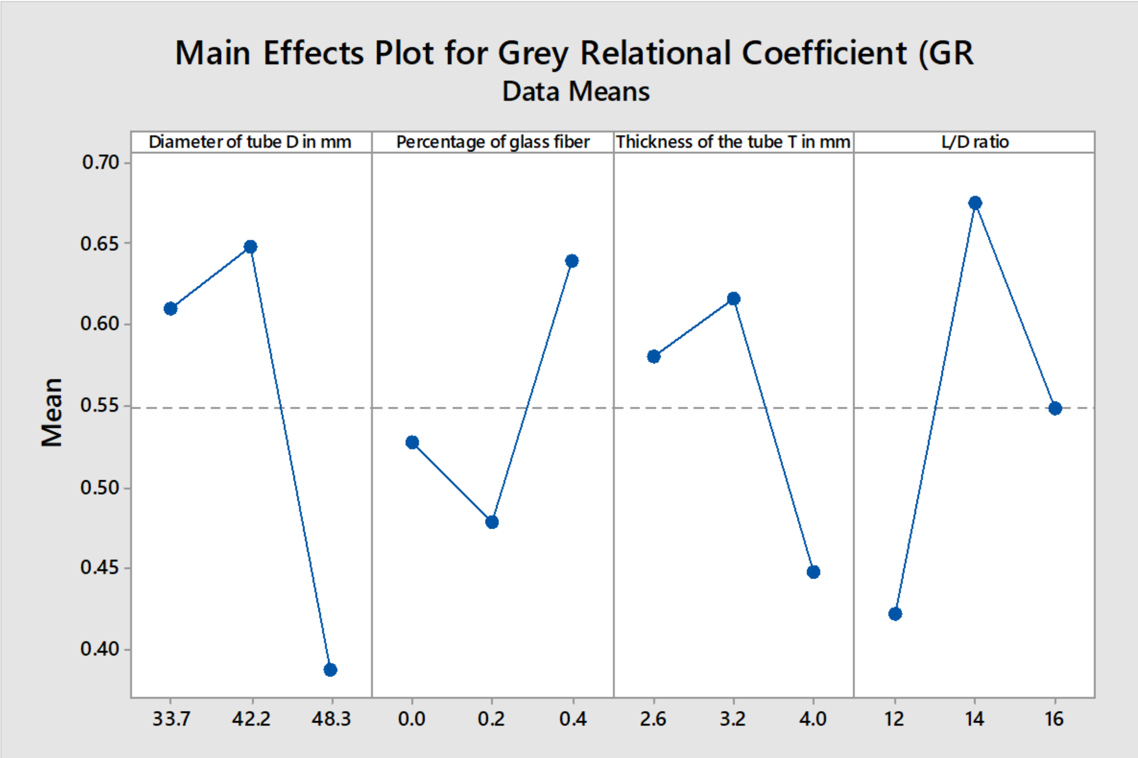


Fig: Main Effects Plot for Grey Relational Coefficient (GRC)

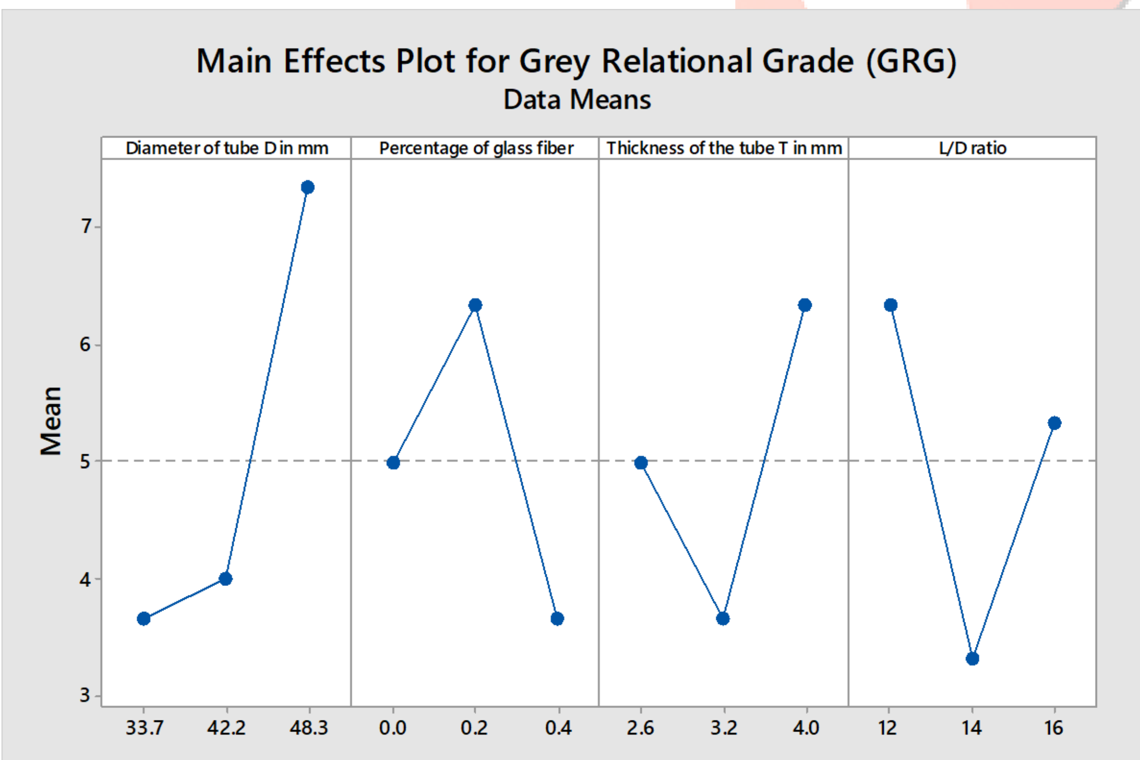


Fig: Main Effects Plot for Grey Relational Grade (GRG)

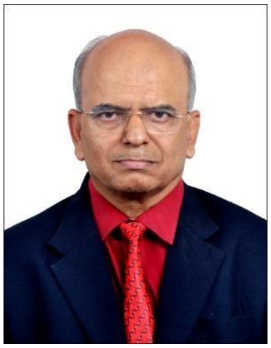
Conclusions:

- ➢ The push out test conducted on CFST columns in this study showed that the bondstrength is dependent on the type of concrete mixes is used as an in-fill material inthe CFST column the reason is that the different adhesive force in different concretedue to the fines content variation in different type of concrete.
- ➢ It was also found that the use of conventional concrete with Glass fibre as a in fill material inCFST columns is highly disadvantage, as it reduces bond strength.
- ➢ Generally, as Length of the section increases, the bond strength increases.
- ➢ The highest Grey relational grade of 1.0000 was observed for the experimental run 5, shown in response table (Table No. 4) of the average Grey relational grade, which indicates that the optimal combination of control factors and their levels. D_2, T_1, and L/D_2will gives nominal bond strength.
- ➢ From this research work, parametric optimization and Factors influencing the response can be well predicted.

REFERENCES

1. Shivadharshan, Chethan Kumar S, Dr.N.S.Kumar "ExperimentalInvestigation on Bond Strength in Self Compacting Concrete Filled SteelTube" Volume:6 Issue:7, pp216-224, International Research Journal ofEngineering and Technology-ISSN: 2395-0072, July 2019
2. Shakir-Khalil, H. (1991). ''Bond strength in concrete-filled steel hollowsection.'' Int. Conf. of Steel and AluminumStruct., Elsevier Science
3. Abe H, Wakida T, Yuda T. Experimental investigation of bond strength of concrete – filled centrifugally cast stell tubes. In: Proceedings of 3rd international conference on steel–concrete, Fukuoka, Japan; 1991, p. 207–12.
4. Shakir-Khalil H, Hassan NKA. Push out resistance of concrete-filled tubes. In: Grundy P, Holgate A, Wong B, Balkema AA (Eds.), Proceedings of the sixth international symposium on tubular structures. 1994.
5. Parsley MA, Yura JA, Jirsa JO. Push-out behavior of rectangular concrete-filled steel tubes. Composite and hybrid systems, ACI SP-196. Farmington Hills, Michigan: ACI;2000.
6. Han L-H, Yang Y-F. Influence of concrete compaction on the behavior of concrete filled steel tubes with rectangular sections. AdvStructEng 2001
7. GB/T 228-2002. Metallic materials—tensile testing at ambient temperature. Chinesestandard; 2002.
8. Gourley BC, Tort C, Denavit MD, Schiller PH, Hajjar JF. A synopsis of studies of the monotonic and cyclic behavior of concrete-filled steel tube members, connections and frames. Report No. NSEL-008. Urbana-Champaign: Newmark Structural Engineering Laboratory, Department of Civil and Environmental Engineering, University of Illinois; 2008.
9. Chen ZH, Qu XS,Wang XD, Sun RR, Li LM. Experimental study on the interface bearing capacity on concrete-filled square steel tube. J Harbin Inst Tech 2009
10. AntanasKudzys, RomualdasKliukas "Reliability Index Design In Reinforced Concrete Structures Of Annular Cross Sections"
11. N. Natural, Y. Yamaha, High speed machining of Inconel 718 with ceramics tools, Ann. CIRP 42 (1) (1993) 103-106.
12. M. Alauddin, M.A. EI Baradie, M.S.J. Hashmi, End milling machinability of Inconel 718, J. Eng. Manuf. 210 (1996) 11-23.
13. T.I. Elwardany, E. Mohammed, M.A. Elbestawi, Cutting temperature of ceramic tools in high speed machining of difficultto cut materials, Int. Journal of mechanical Tool Manufact 36 (5) (1996) 611–634.
14. E.O.Ezugwu, Z.M. Wang, A.R. Machado, The machinability of nickel-based alloys: a review, J. Mater. Process. Technol. 86(1999) 1-16.

About Authors



Dr. N S Kumar, Graduated in the year 1985 from Mysore University, M.E. in Structural Engineering., in the year 1988 from Bangalore University and earned his PhD from Bangalore University during the year 2006 under the guidance of Dr. N Munirudrappa, the then Chairman and Prof. UVCE, Faculty of Civil Engineering, Bangalore University. Presently, working as Prof. & HoD, Department of Civil Engineering, Ghousia College of Engineering, Ramanagaram and completed 32 (Thirty two) years of teaching and director of R&D for a decade (2010-2020). He is involved in the Research field related to thebehavior of Composite Steel Columns and Nano Materials for more than a decade. To his credit, over 200 publications and travelled abroad Viz., USA, Australia, Canada and China including World Conference. Also, he has guided more than three PhD's and Guiding five more PhD's as on date affiliated to VTU Belgavi. Also, He has completed Funded Projects worth of 60 Lakhs from VTU, Belagavi and VGST, GoK. Also presently handling more than a crore project sanctioned from IT/BT, GoK. He has also credit of authoring more than Eight books as per the curriculum of Banglore University and VTU, Belagavi.

Anusha T S, Completed Bachelor degree in Civil Engineering from G.Madhegowda Institute of Technology, Karnataka under VTU in the year 2017. Presently pursuing M.Tech in Structural Engineering in Ghousia College of Engineering, under VTU.