MODELLING ULTIMATE LOAD CAPACITY OF STEEL FIBRE REINFORCED CONCRETE CORBELS: PART2. PARAMETRIC STUDY

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Abstract

In this study, parametric studies effecting ultimate load capacity of sfrc corbels were presented by using the formulations proposed in part 1 of the article. Also 3d graphs were introduced to provide comprehensive information regarding the structural behaviour of sfrc corbels. The interaction graphs were presented in terms of splitting tensile strength, shear span, effective depth, width and height of the corbel and amount of steel reinforcement.

Keywords: steel fibre reinforced concrete, corbels, ultimate load, formulation, interaction graphs, main effect graphs

1. Introduction

Ultimate Load Capacity of steel fibre reinforced concrete (sfrc) corbels are influenced by several parameters including geometry of corbel, shear span to effective depth ratio, amount and aspect ratio of steel fibre, strength of concrete and amount of reinforcement. Because of these various input parameters, strength of steel fibre reinforced concrete corbel should be analyzed in detail and effective parameters should be clarified.

Each parameter has its own effect on the ultimate load capacity of sfrc corbel and these effects should be analyzed for full understanding of mechanical behavior of them. After determination of the effective parameters, a number of problems can be handled about load carrying mechanism of sfrc corbels.

Parametric study is an important tool to decide generalization capability of proposed formulations about ultimate load capacity of sfrc corbels. The formulation has to meet the expectations for much of the database that exist in the literature to be an acceptable formulation.

The aim of this part of the study is to make parametric studies of the formulation of ultimate load capacity of sfrc corbels proposed in the part 1 of this study and to prove the applicability of the formulation to ultimate load capacity of sfrc.

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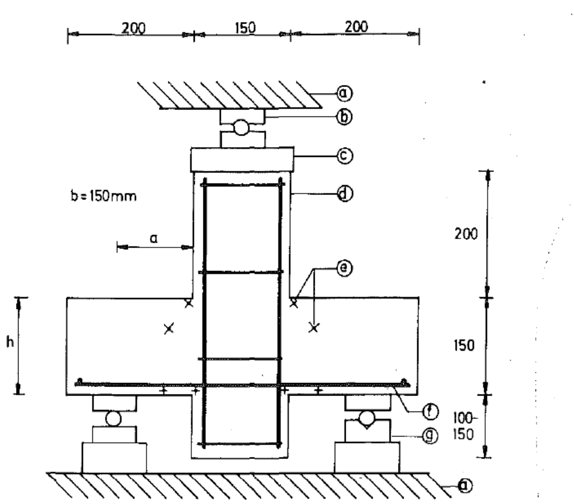
2. Effective parameters on ultimate load capacity of SFRC Corbels

Fattuhi and Hughes [1-7] carried out extensive experimental studies on ultimate load capacity Steel fiber reinforced concrete corbel to investigate the effect of material and geometric parameters.

The experiments were carried out for 84 steel fiber reinforced corbels subjected to vertical load. During experimental studies, volume and aspect ratio of fibres, amount of main reinforcement and shear span to effective depth ratio were changed. Volume fraction and aspect ratios of steel fibres ranged between 0.7% and 2.5%, 48 and 100 respectively. Geometric configuration of the experimental program is shown in Figure 1. Shear span was altered between 60 and 140. Concrete properties were determined from three 100 mm cubes, three 150 mm cubes and three 100-mm diameter by 200-mm long cylinders for each corbel.



Test Arrangement: (*a*) Testing Machine; (*b*) Spherical Seat; (*c*) Loading Plate; (*d*) Concrete Specimen; (*e*) Demec Discs; (*f*) Main Bars; (*g*) Roller Support

Fig. 1 Test Configuration of the Corbels Experimented by Fattuhi and Hughes

The experimental tests were carried out with an upside-down configuration as shown in Figure 1. All the corbels were vertically symmetrical to avoid bending effects.

Loading were achieved in displacement controlled mode to able to record measurements near the ultimate load.

3. Parametric Studies of the Proposed Formulation

Proposed formulation for ultimate load capacity of steel fiber reinforced concrete corbels which was suggested in the first part of the study (Modelling Ultimate Load Capacity of Steel Fibre Reinforced Concrete Corbels: Part2. Parametric Study) is;

$$V_u = 0.04226 bh \left(\frac{d}{a}\right)^{0.8323} (f_{ct})^{0.3344} \left(0.01\left(\frac{A_s}{bh}\right)\right)^{0.5903} \quad (1)$$

where b and h are width and height of the corbel respectively, f_{ct} is the tensile strength of fibrous concrete, $\frac{d}{a}$ is the reciprocal of the shear span to depth ratio and A_s is the sectional area of main reinforcement.

The proposed formula has five main input parameters (b, h, f_{ct}, d/a and A_s/bh). Therefore these parameters were considered for parametric studies.

1024 samples were generated for each parameter according to upper and lower limit values of them. Generated values were substituted into the proposed formulation to obtain related ultimate load capacity. Obtained outputs and generated inputs were processed in a special statistics software which is called “MiniTab”. Main effects plots, interactions plots and surface plots for ultimate load capacity of steel fiber reinforced concrete corbels were obtained to check the effectiveness of the formulation. Upper and lower limits for the generation of input values are listed in Table 1.

Tab. 1 Lower and Upper Limits for generation of input parameters

Input Parameter	Lower Limit	Upper Limit
b (m)	160	190
h (m)	150	180
d/a	1.01	1.99
f_{ct} (MPa)	4.41	8.06
A_s/bh	0.66	1.31

3.1 Main Effects Graphs for Ultimate Load Capacity of SFRC Corbels

A main effect takes place when the mean response alters through different degrees of a parameter. The aim of this plot is to investigate the degree means for each parameter, to compare the degree means for numerous factors and to compare the proportional effectiveness of the influences across parameters.

The effectiveness of the main plot is apparent when several parameters exist to examine. Thereafter, the most efficient parameter on the response can be determined by comparing the changes in the degree means. A main effect exists, if the response is affected in different manner for different values of a parameter. For instance, one degree of a parameter can increase the mean when compared to the other degree. This situation causes a main effect.[8]

When main effect plots were achieved for the input parameters of the proposed formulation. The following graphs were obtained:

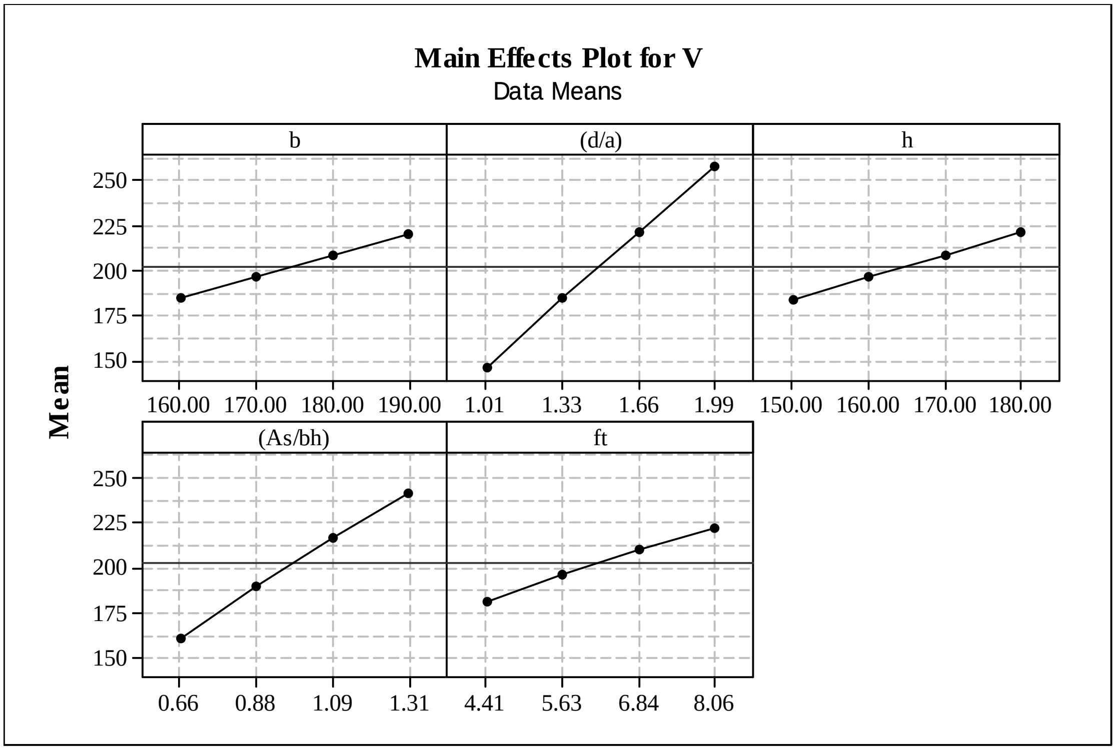


Fig. 2 Main effect graphs of input parameters on the Ultimate Load

In the light of the above discussions about main effect plots and according to main plots shown in Figure 2, each parameter has an effect on the ultimate load capacity of sfrc corbels and all parameters are directly proportional to the mean response. The most effective parameters are reciprocal value of the shear span to depth ratio d/a and ratio of sectional area of reinforcement to cross sectional area of the corbel A_s/bh. Tensile strength of fibrous concrete f_{ct} is also efficient parameter for the response due to change in fibre volume fraction and fibre aspect ratio.

3.2 Interaction Graphs for Ultimate Load Capacity of SFRC Corbels

Interaction plots exhibit interaction and relationship between two parameters according to the response variation. An interaction exists, if the variation in response for two degrees of a parameter is different from the variation in response for the same two degrees of a second parameter. That is, the effect of one factor is dependent on a second factor. The aim of interaction plot is to determine the necessity and importance of the two-way interactions of parameters to be included in the formulation, to prove the reliability and generalized applicability of the formulation and to compare the proportional effectiveness of the influences across parameters.[8]

According to Figure 3, it is proved that every parameter has an effect on the response. The interaction plot is compatible with the main plot. Therefore the proposed formulation can be applied for obtaining the ultimate load capacity of steel fiber reinforced corbels.

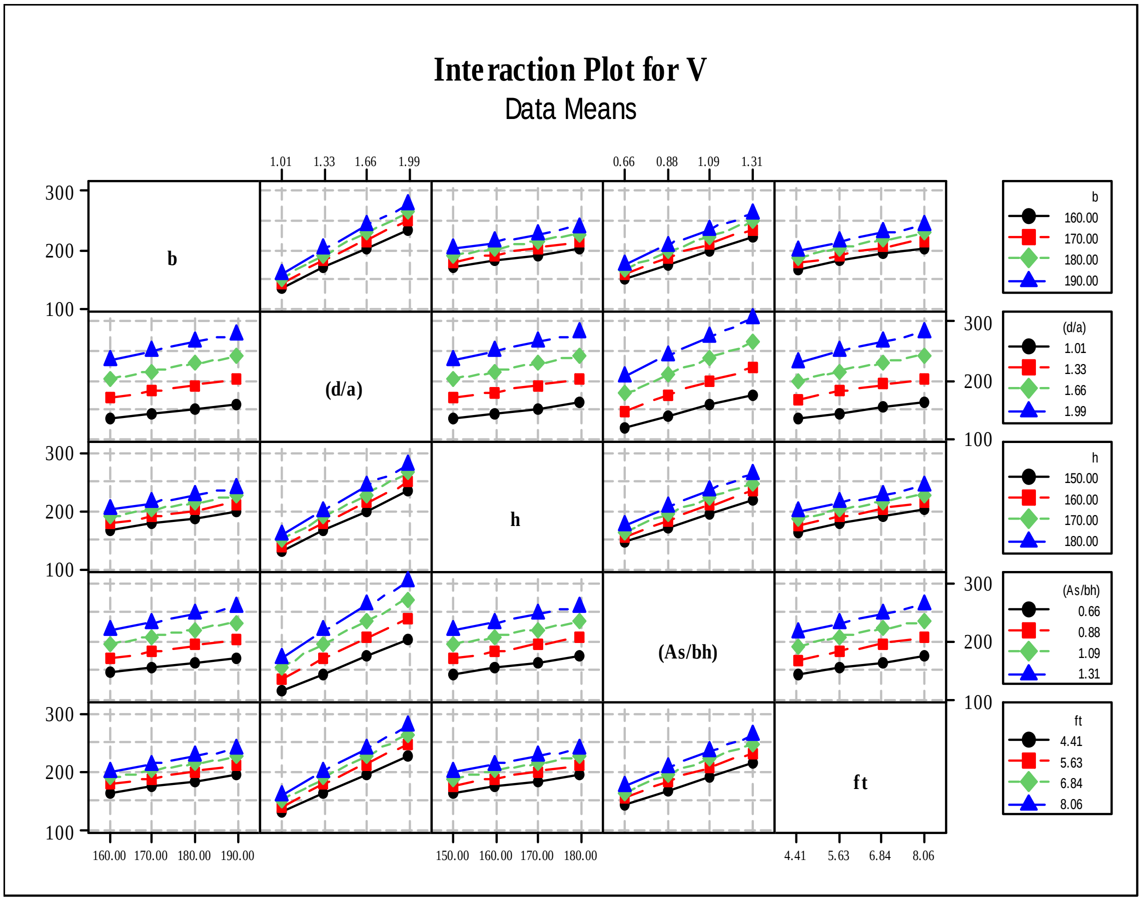


Fig. 3 Interaction Graphs For the Input Parameters for the Proposed Formulation

3.3 3D Graphs of Interaction parameters

3D plot of input parameters for a response is useful to investigate the relationship between three parameters on a single graph and to visualize combinations of input parameters that develop suitable response values. In Figure 4, all combinations of the parameters with the ultimate load capacity of sfrc corbels are sketched in three dimensional spaces.

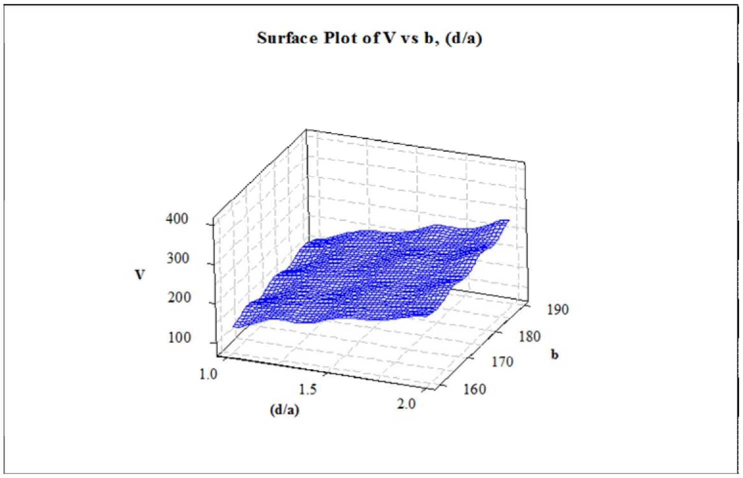


Fig. 4a 3D Interaction Graphs Between V , d/a and b

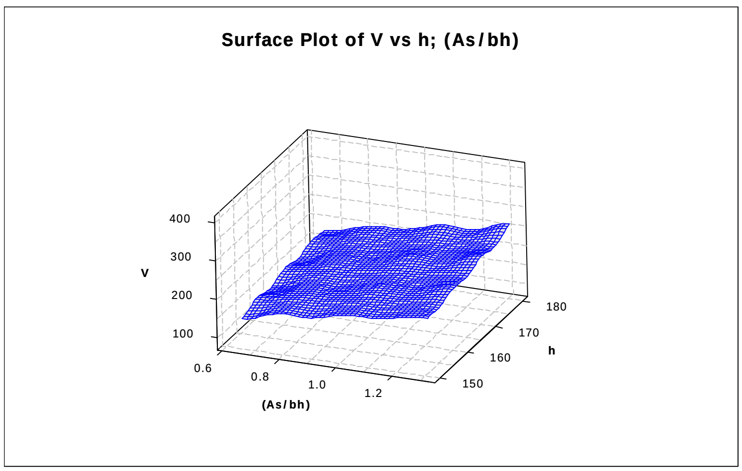


Fig. 4b 3D Interaction Graphs Between V , A_s/bh and b

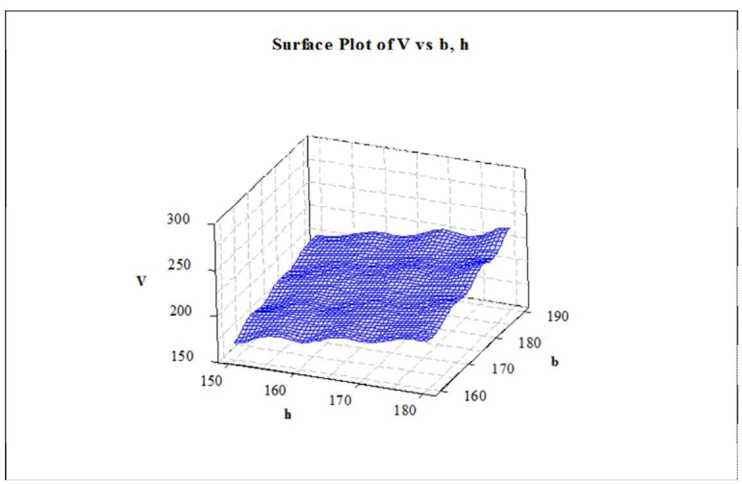


Fig. 4c 3D Interaction Graphs Between V , h and b

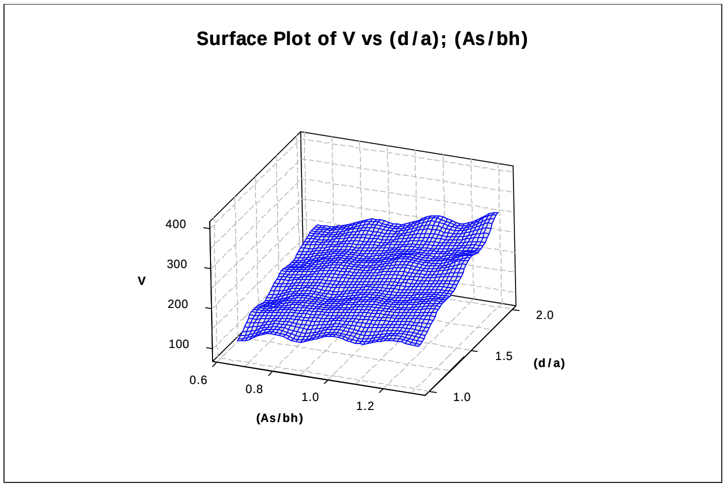


Fig. 4d 3D Interaction Graphs Between V , A_s/bh and d/a

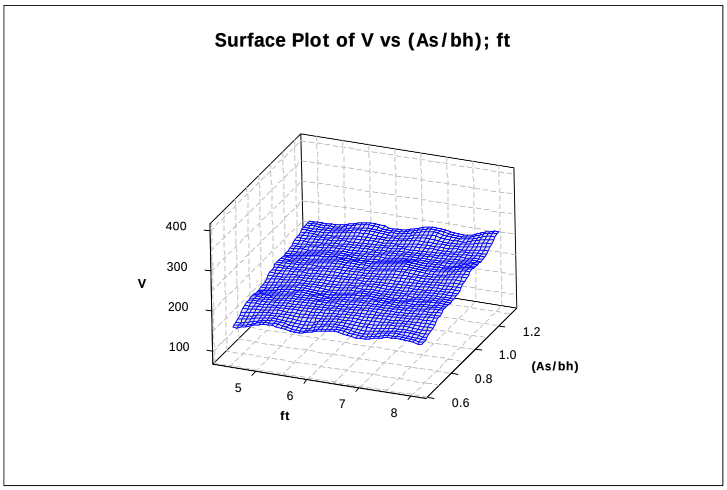


Fig. 4e 3D Interaction Graphs Between V , A_s/bh and f_{ct}

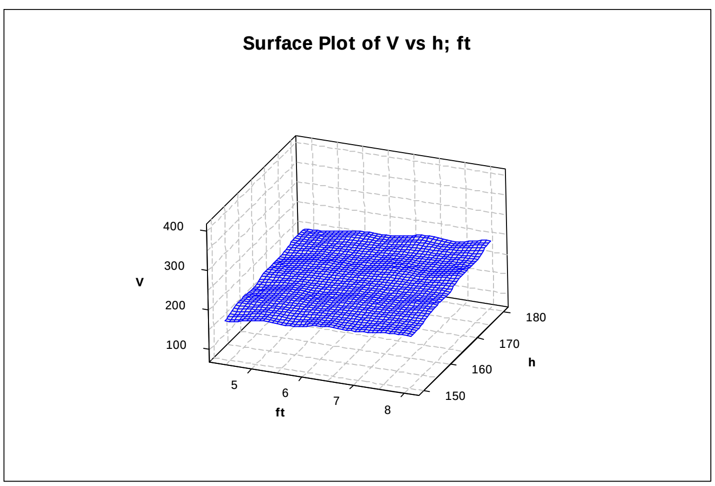


Fig. 4f 3D Interaction Graphs Between V , h and f_{ct}

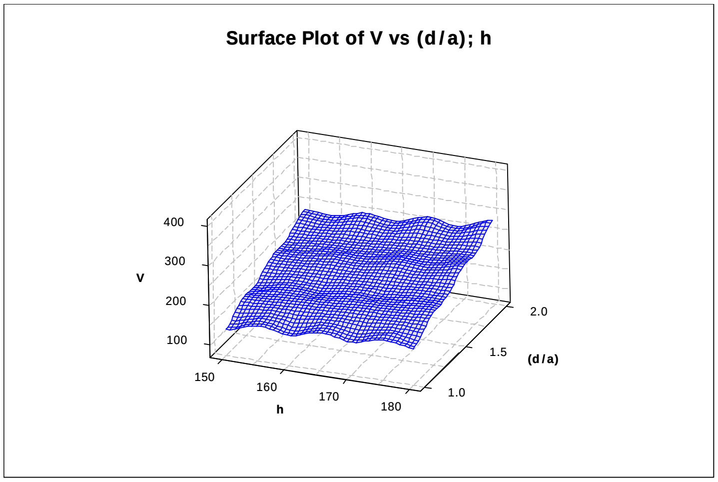


Fig. 4g 3D Interaction Graphs Between V , h and d/a

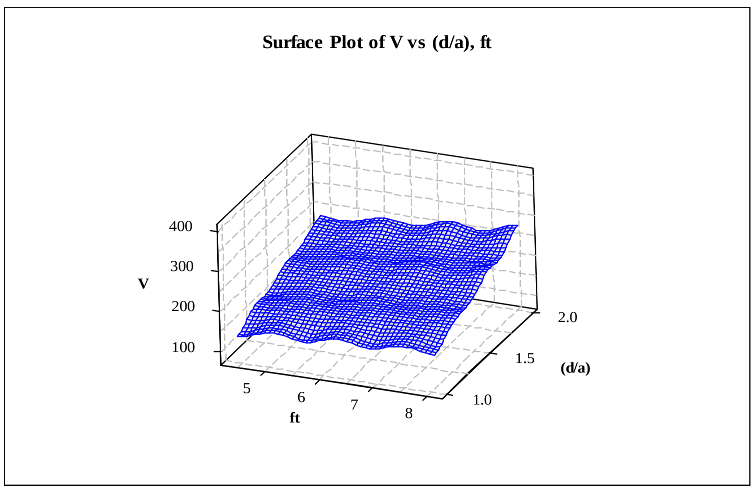


Fig. 4h 3D Interaction Graphs Between V , f_{ct} and d/a

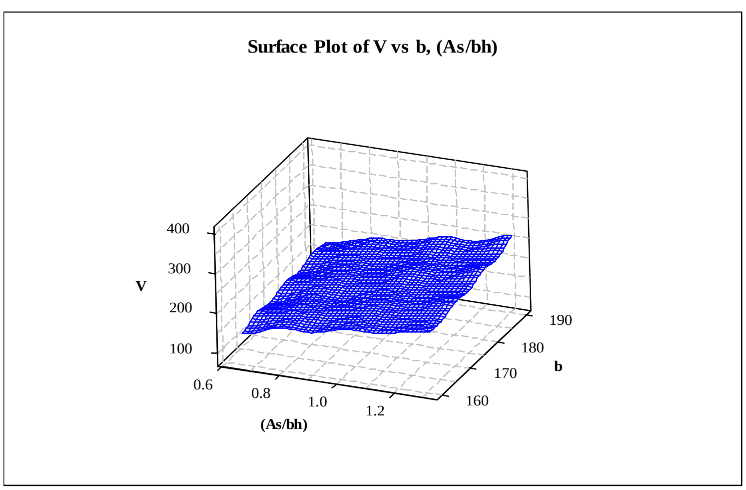


Fig. 4ı 3D Interaction Graphs Between V , A_s/bh and b

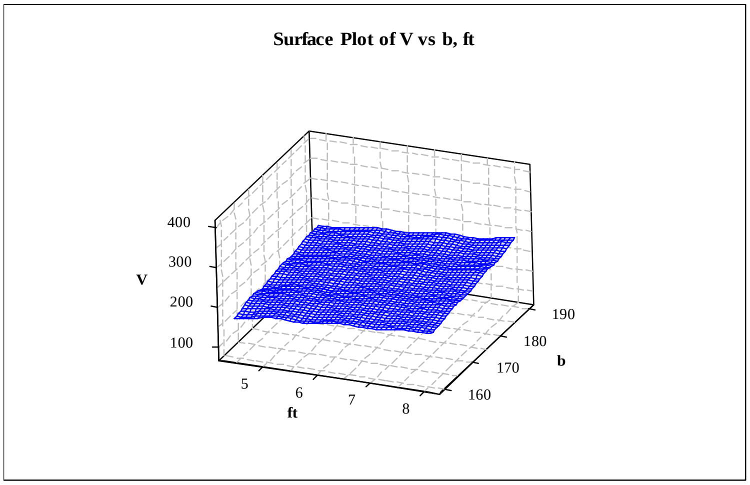


Fig. 4j 3D Interaction Graphs Between V , f_{ct} and b

When all of the 3D graphs are analyzed, it can be seen that there are no big differences in the peak values of input parameters and responses and there are no much higher peak values which violate trend of waves in the graphs. This situation demonstrates the applicability and suitability of the proposed formulation for determining the ultimate load capacity of sfrc corbels.

4. Conclusions

In the current study, parametric analysis of the proposed formula for the ultimate load capacity of steel fiber reinforced corbels was carried out. As a consequence of the study, it was concluded that geometry of the corbel, tensile strength of fibrous concrete, amount of reinforcement and effective depth to span ratio are effective parameters for ultimate load capacity of sfrc corbels.

When main plots, interaction plots and 3D plots of the input parameters were analyzed, it can be concluded that there are no extreme and contradictory cases which prevent the effectiveness of the formulation. Therefore the proposed formulation can be effectively and safely used to obtain ultimate load capacity of sfrc corbels in practical applications.

References

[1] Fattuhi, N. Sfrc Corbel Tests. Structural Journal, American Concrete Institute, 1987. p. 119-123.

[2] Fattuhi, N., Hughes, B. Reinforced steel fiber concrete corbel with various shear span-to-depth ratios. ACI Materials Journal, 1989. p. 590–596. Volume 86. No.6.

[3] Fattuhi, N., Hughes, B. Reinforced steel and polypropylene fiber concrete corbel tests. The Structural Engineer, London, 1989. p. 68-72. Volume 67. No.4.

[4] Fattuhi, N., Hughes, B. Ductility of reinforced concrete corbels containing either steel fibers or stirrups. ACI Structural Journal, 1989. p. 644-651. Volume 86. No. 6.

[5] Fattuhi, N. Column-load effect on reinforced concrete corbels. Journal of Structural Engineeing, ASCE, 1990. p. 188-197. ISSN 0733-9445/90/0001-0188.

[6] Fattuhi, N. Strength of SFRC corbels subjected to vertical load. Journal of Structural Engineeing, ASCE, 1990. p. 701-718. ISSN 0733-9445/90/0003-0701.

[7] Fattuhi, N. Strength of FRC Corbels in Flexure. Journal of Structural Engineeing, ASCE, 1994. p. 360-377. ISSN 0733-9445/94/0002-0360.

[8] *Minitab* Software Program Documentations.