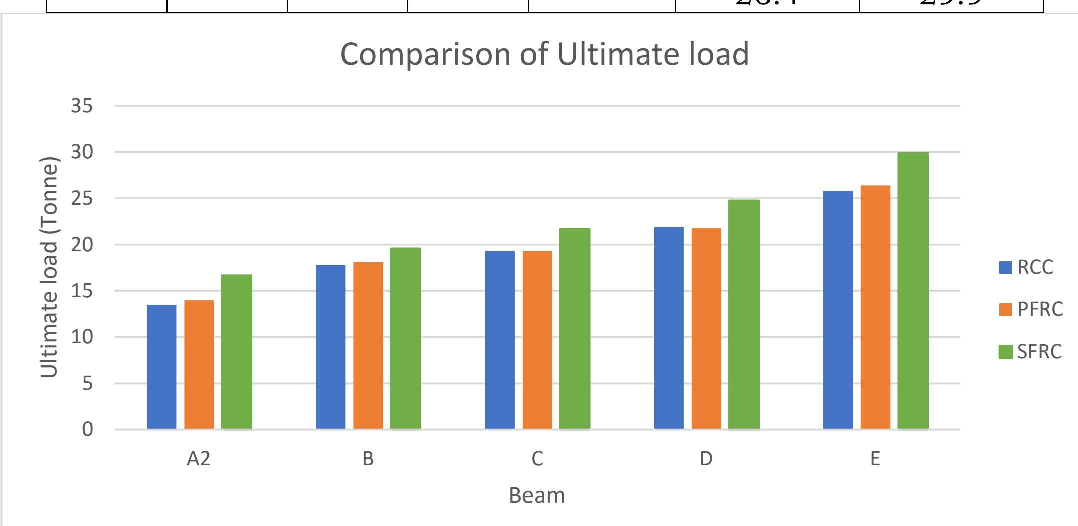
9.MODIFICATION OF SHEAR STRENGTH FORMULA BY INCORPORATEING SIZE EFFECT PARAMTER IN CSACODE

Different size of beams were taken for testing in UTM machine. During test the Ultimate load, Nominal Shear stress tabulated for RCC, PFRC and SFRC beam. From the graph it was observed that the Nominal shear stress decrease with increase in depth of the beam as per basic fundamental equation $\tau c = Vu/bd$. The nature is same for all type of beams.

9.1 Comparison of Ultimate Load For Different Series of Beam

Table 9-1 Comparison of Ultimate Load for Different Series

Beam	L (mm)	B (mm)	D (mm)	Experimental Ultimate Load (Ton)		
				RCC	PFRC	SFRC
A2	900	75	225	13.5	14	16.7
B	1000	75	275	17.8	18.1	19.6
C	1100	75	325	19.3	19.3	21.7
D	1200	75	375	21.9	21.8	24.8
E	1300	75	425	25.8	26.4	29.9



Graph 9-1 Ultimate Load Comparison

Ultimate load of RCC and PFRC beams were almost same but in SFRC series Ultimate loads increases up to 25 % due to steel fibers.

PFRC series Ultimate loads were varying from RCC about 2 to 5 % so it was concluded that fiber content 0.7 % were not optimum dosage. Fiber content must be increases in concrete to increase the Ultimate shear strength.

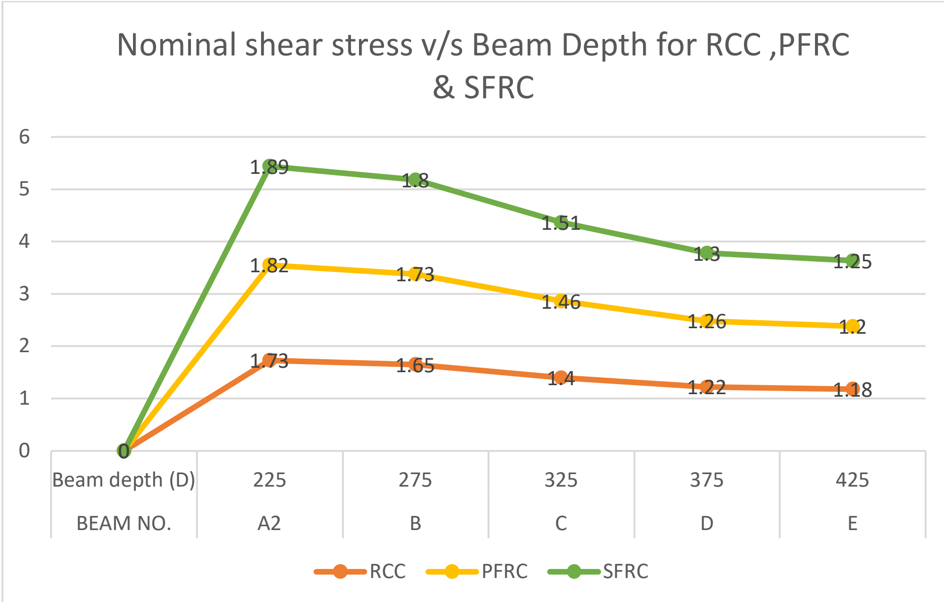
9.2 Size Effect for RCC Series and Graphical Representation

Table 9-2 Nominal Shear Stress for RCC Series

RCC						
BEAM NO.	**Length(l)**	**Width**	**Beam depth (D)**	**fck**	**Ultimate load IN (TON)**	**Nominal shear stress in (N/mm^2)**
A2	900	75	225	31.11	16.25	1.73
B	1000	75	275	31.11	18.95	1.65
C	1100	75	325	31.11	19.02	1.40
D	1200	75	375	31.11	19.10	1.22
E	1300	75	425	31.11	21.76	1.18

Table 9-3 Nominal Shear Stress for RCC, PFRC & SFRC Beams

		RCC	PFRC	SFRC
BEAM NO.	**Beam depth (D)**	**Nominal shear stress in (N/mm2)**	**Nominal shear stress in (N/mm2)**	**Nominal shear stress in (N/mm2)**
A2	225	1.73	1.82	1.89
B	275	1.65	1.73	1.8
C	325	1.4	1.46	1.51
D	375	1.22	1.26	1.3
E	425	1.18	1.2	1.25



Graph 9-2 Nominal shear stress vs Depth for RCC , PFRC and SFRC

9.3 Size Effect for PFRC Series and Graphical Representation:

Table 9-4 Nominal Shear Stress for PFRC Series

PFRC						
BEAM NO.	**Length(L) mm**	**Width mm**	**Beam depth (D) mm**	**fck**	**Ultimate load IN (TON)**	**Nominal shear stress in (N/mm²)**
A2	900	75	225	31.78	17.32	1.82
B	1000	75	275	31.78	20.14	1.73
C	1100	75	325	31.78	20.00	1.46
D	1200	75	375	31.78	19.93	1.26
E	1300	75	425	31.78	22.70	1.20

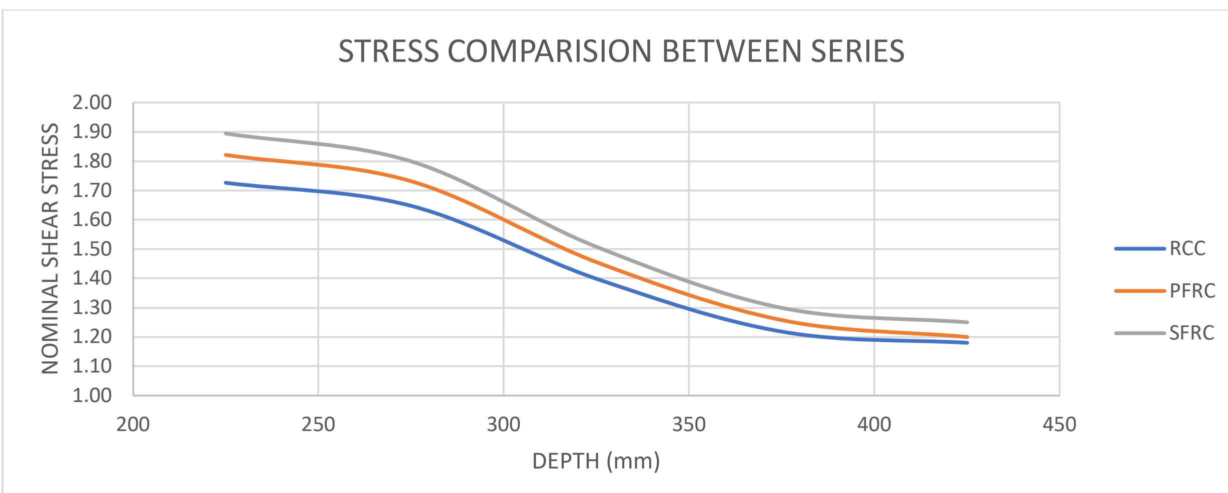
The Nominal shear stress for RCC beam (Table 9-1), For PFRC beam (Table 9-2) and for SFRC beam (Graph 9-3).The Graph 9-2 shows the Nominal shear stress is decreasing with Depth of the beam increasing which is termed as Size effect.

9.4 Size Effect for SFRC Series and Graphical Representation

Table 9-5 Nominal Shear Stress for SFRC Series

SFRC						
BEAM NO.	**Length(l)**	**Width**	**Beam depth (D)**	**fck**	**Ultimate load IN (TON)**	**Nominal shear stress in (N/mm^2)**
A2	900	75	225	34.25	18.71	1.89
B	1000	75	275	34.25	21.72	1.80
C	1100	75	325	34.25	21.51	1.51
D	1200	75	375	34.25	21.38	1.30
E	1300	75	425	34.25	24.34	1.25

9.5 Comparison of Nominal Stress Between RCC, PFRC And SFRC Series:



Graph 9-3 Nominal Stress Vs. Depth Comparison Between Series

As per Kani for slender beam (a/D)>2.5 without shear reinforcement the Nominal shear strength decreases as the member depth increases. Graph 9-3 shows that the Similar nature of reduction in Nominal shear strength observed in depth varying from 225 mm to 425 mm. Strength reduced to 32 % in RCC, 34 % in PFRC and 33.86 % in SFRC beams.

9.6 Modification of Shear Strength Formula from Canadian code

There were many formulas for Prediction of Shear strength for Moderate Deep beams. Different countries have unique code provisions and suggested **Imperial formula**. Some researcher gives their contribution to Modify the formula. Each country applied its own approach to predict the shear strength of Moderate deep beams. **Canadian Structural Association code formula (CSA A23.3-04)[(6)]**used here to predict the shear strength of Moderate deep beam.

9.6.1 Canadian Standard Association CSA-A23.3-04:

As per CSA-A23.3-04[(6)] design for shear in beams were given in chapter 11 from clause no 11.3 to 11.7 (page no.57 to 66) (Appendix V). Shear resistance for concrete beam can be determined as per cl.11.3.3 which are as,

The factored shear resistance shall be determined by:

$$\boldsymbol{V_r = V_c + V_s + V_p}$$

V_c = Shear resistant offered by concrete

V_s = Shear resistant offered by stirrups (vertical reinforcement)

V_p = Shear resistant offered by restressing of concrete

The value of $V_c$shall be computed from:

$$\boldsymbol{V_c = \beta \times \sqrt{f'_c} \times \lambda \times \phi_c \times b_w \times D}$$

Where,

$\boldsymbol{\beta}$ = size effect constant

$\boldsymbol{f'_c}$ = compressive strength of cylinder in MPa

$\boldsymbol{\lambda}$ = factor used for light weight concrete (for normal concrete taken as unity)

$\boldsymbol{\phi_c}$ = resistant factor for concrete (taken as 0.65)

$\boldsymbol{b_w}$ = width of member

D = overall depth of member

In the determination of V_c the term $\sqrt{f'_c}$ shall not be taken greater than 8 MPa.

Where β is determined as specified in Clause 11.3.6.3

$$\beta = \left(\frac{230}{1000 + d}\right)$$

d = effective depth of member

The above β factor is only applicable when (as per cl.11.3.6.3),

- Concrete section contains no transverse reinforcement and specified nominal maximum size of coarse aggregate is not less than 20mm.
- Specified concrete strength does not exceed 60 MPa.

9.6.2 Modification of Formula with Size Effect Parameter

Size effects factors affected the shear strength of moderate deep beam. The research work includes mainly three parameters effect.

1. **Shear span to depth ratio (a/D)**
2. **Longitudinal reinforcement ratio (ρ)**
3. **Effective length to overall depth ratio (l_e/D)**

The above parameter selected as per literature survey. One combined factor S_f introduced in the CSA-A-23.3-04[6] formula for computing shear strength of concrete.

The Modified equation is shown as,

$$V_c = \beta \text{ x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } b_w \text{ x D x } S_f$$

Where,

$S_f = \frac{k \text{ x } \rho^b}{\left(\frac{a}{D}\right)^c}$ and $k = a \text{ x } \left(\frac{l_e}{D}\right)$

In above equation constant a, b and c were found out by data analysis.

9.6.3 Regression Analysis

Data analysis is a process of inspecting and transforming modeling data with the aim of discovering useful information, conclusions and supporting decision-making. Data analysis has multiple facts and approaches, encompassing diverse techniques under a variety of names.

In statistics, Nonlinear Regression is a form of Regression analysis in which observational data are modeled by a function which is a nonlinear combination of the model parameters and depends on one or more independent variables. The data are fitted by a method of successive approximations. In this research Non-linear regression analysis used for determining constant of **Model Equation.**

SPSS-IBM.v20 is powerful software that solves many statistical problems with ease. This software is frequently used in area of Mathematics, Statistics, Economics, and Engineering. This is a general-purpose statistical computing system, designed especially for students and researchers. SPSS-IBM is designed to be used interactively. This means that a command is immediately carried out and the results are taken. For the research purpose Regression Analysis has been carried out using this software.

For the shear database, the response variable is the Ultimate shear strength, predicted by code equation. The Size effect parameter incorporates in equation as longitudinal main steel reinforcement ratio ρ, effective length to overall depth ratio l_e/D and shear span to depth ratio a/D.

The theoretical equation for find out shear strength of beams is as:

$$\boldsymbol{W_{eq} = 2 \text{ x} V_c = 2 \text{ x} \left(\frac{230}{1000+d}\right) \text{x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } b_w \text{ x D}}$$

$$\boldsymbol{W_{exp} = W_{eq} \text{x } S_f} \text{ .... } \mathbf{(9.1)}$$

$$\frac{\boldsymbol{W_{exp}}}{\boldsymbol{W_{eq}}} = \boldsymbol{S_f}$$

For dependent variable $\boldsymbol{W_{exp}/W_{eq}}$was taken as Y. while independent variable forms the size effect parameter in eq. (9.1) was,

X (independent variable) = $\boldsymbol{S_f} = \dfrac{a \text{ x} \left(\frac{l_e}{D}\right) \text{x } \rho^b}{\left(\frac{a}{D}\right)^c}$

Where, a, b and c were constant which find out by Nonlinear Regression Analysis in SPSS-2.0. Iteration range for variables were as follows:

Table 9-6 VARIABLE RANGE

Variable name	Iteration range
a	0.1
b	0.001
c	0.1

9.6.4 DATA ANALYSIS BY SPSS SOFTWARE

Data of 77 Beams specimens from literature is used for regression analysis. Explanation of procedure for iterative nonlinear analysis in SPSS.

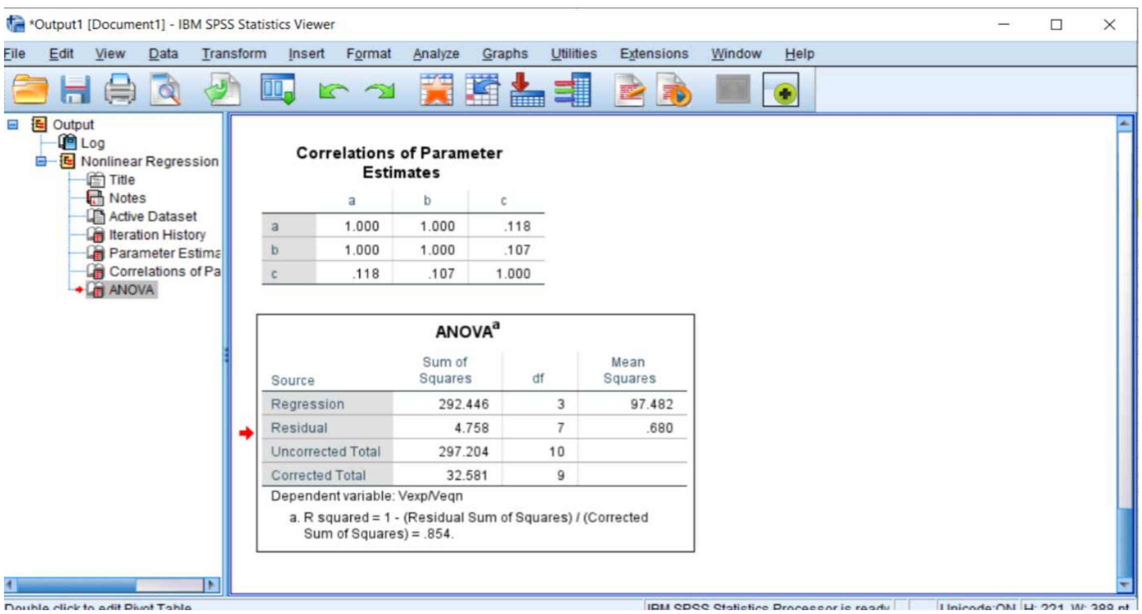


Figure 9-1 ANOVA Result

From the above Regression Analysis constant values were obtained as per below table:

TABLE 9-7 Constant Value for Size Effect Parameter

Variable name	Constant value
a	11.963
b	0.344
c	1.236

By putting above constant value in equation no (9.1), Modified equation looked as:

$$W_{mod} = W_{eq} \text{x}\, S_f$$

$$W_{mod} = 2 \text{ x } \left(\frac{230}{1000+d}\right) \text{ x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } b_w \text{ x D x } \frac{k \text{ x } \rho^{0.344}}{\left(\frac{a}{D}\right)^{1.23}}$$

Where, $\boldsymbol{k} = \mathbf{11.96} \text{ x } \left(\frac{l_e}{D}\right)$

For fiber reinforced concrete fiber factor V_{fb} as per G.Arslan[46] added to above equation.

$$W_{mod} = 2 \text{ x } \left(\frac{230}{1000+d}\right) \text{ x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } b_w \text{ x D x } \frac{k \text{ x } \rho^{0.344}}{\left(\frac{a}{D}\right)^{1.23}} + V_{fb}$$

$$V_{fb} = r \text{ x} \sqrt{\rho * (1+4F) f_c}$$

For PFRC constant r = $\left(\frac{2}{a/D}\right)$

For SFRC constant r = $\left(\frac{3.5}{a/D}\right)$

In above equation **F** = $\frac{L_f}{D_f}$ **x** V_f **x** d_f

Where,

$\frac{L_f}{D_f}$ = Aspect ratio of fiber

V_f = Volume of fiber

d_f = Shape factor of fiber (for circular cross section take 0.5, for crimped fiber section take as 0.7)

9.7 MODIFIED FORMULA FOR PRIDICTION OF SHEAR STRENGTH OF REINFORCED CONCRETE MODERATE DEEP BEAM

$$W_{mod} = W_{eq} \text{x } S_f$$

$$W_{mod} = 2 \text{ x } \left(\frac{230}{1000+d}\right) \text{ x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } \frac{k \text{ x } \rho^{0.344}}{\left(\frac{a}{D}\right)^{1.23}} \text{ x } b_w \text{ x D}$$

Where, $\boldsymbol{k} = \mathbf{11.96} \text{ x } \left(\frac{l_e}{D}\right)$

f'_c = Compressive strength of cylinder in MPa

λ = Factor used for light weight concrete (for Normal concrete taken as unity)

ϕ_c = Resistant factor for concrete (taken as 0.65)

b_w = Width of member in mm

D = Overall depth of member in mm

d = Effective depth of member in mm

a = Shear span in mm , l_e= Effective length of beam in mm

9.8 MODIFIED FORMULA FOR PRIDICTION OF SHEAR STRENGTH OF FIBEROUS CONCRETE MODERATE DEEP BEAM

$$W = W_{mod} + V_{fb}$$

$$W = 2 \text{ x } V_c + V_{fb}$$

$$W = 2 \text{ x } \left(\frac{230}{1000+d}\right) \text{ x} \sqrt{f'_c} \text{ x } \lambda \text{ x} \phi_c \text{x } \frac{k \text{ x } \rho^{0.344}}{\left(\frac{a}{D}\right)^{1.23}} \text{ x } b_w \text{ x D} + r \text{ x} \sqrt{\rho * (1 + 4F) f_c}$$

Where, $k = 11.96 \text{ x } \left(\frac{l_e}{D}\right)$

f'_c = Compressive strength of concrete cylinder in MPa

f_c= Compressive strength of concrete cube in MPa

λ = Factor used for light weight concrete (for normal concrete taken as unity)

ϕ_c = Resistant factor for concrete (taken as 0.65)

b_w = Width of member in mm

D = Overall depth of member in mm

d = Effective depth of member in mm

a = Shear span in mm

l_e= Effective length of beam in mm

For PFRC constant r = $\left(\frac{2}{a/D}\right)$For SFRC constant r = $\left(\frac{3.5}{a/D}\right)$

F = $\frac{L_f}{D_f} \text{ x } V_f \text{ x } d_f$

$\frac{L_f}{D_f}$ = Aspect ratio of fiberV_f = Volume of fiber

d_f= Shape factor of fiber (for circular cross section take 0.5, for crimped fiber section take as 0.7.

9.8.1 GRAPHICAL REPRESENTATION OF SHEAR STRENGTH PREDICTED BY ORIGINAL EQUATION, EXPERIMENTAL VALUE AND MODIFIED EQUATION:

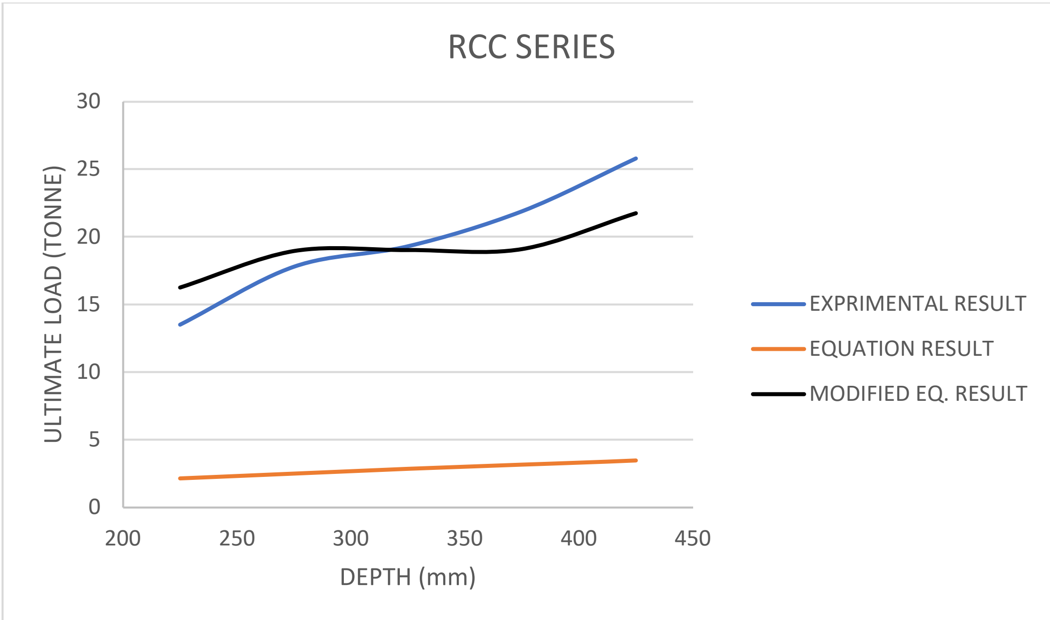
TABLE 9-8 COMPARISION OF SHEAR STRENGTH OBTAINED BY DIFFERENT EQUATION

Beam		L_{eff}	b	D	a/D	f_c	% STEEL	P_u	P_{eq}	P_{eq} modified	Pu/Pe	Pu/Peq Modified
		mm	mm	mm		MPa		Ton	Ton	Ton		
RCC	A2	800	75	225	1	31.11	0.67	13.5	2.1	16.3	6.43	0.83
	B	900	75	275	1	31.11	0.84	17.8	2.5	19	7.12	0.94
	C	1000	75	325	1	31.11	0.7	19.3	2.9	19	6.66	1.02
	D	1100	75	375	1	31.11	0.6	21.9	3.2	19.1	6.84	1.15
	E	1200	75	425	1	31.11	0.75	25.8	3.5	21.8	7.37	1.18
PFRC	A2	800	75	225	1	34.25	0.67	14	2.1	17.3	6.67	0.81
	B	900	75	275	1	34.25	0.84	18.1	2.5	20.1	7.24	0.90
	C	1000	75	325	1	34.25	0.7	19.3	2.8	20	6.89	0.97
	D	1100	75	375	1	34.25	0.6	21.8	3.1	19.9	7.03	1.10
	E	1200	75	425	1	34.25	0.75	26.4	3.4	22.7	7.76	1.16
SFRC	A2	800	75	225	1	31.78	0.67	16.7	2.2	18.7	7.59	0.89
	B	900	75	275	1	31.78	0.84	19.6	2.6	21.7	7.54	0.90
	C	1000	75	325	1	31.78	0.7	21.7	2.9	21.5	7.48	1.01
	D	1100	75	375	1	31.78	0.6	24.8	3.3	21.4	7.52	1.16
	E	1200	75	425	1	31.78	0.75	29.9	3.6	24.3	8.31	1.23

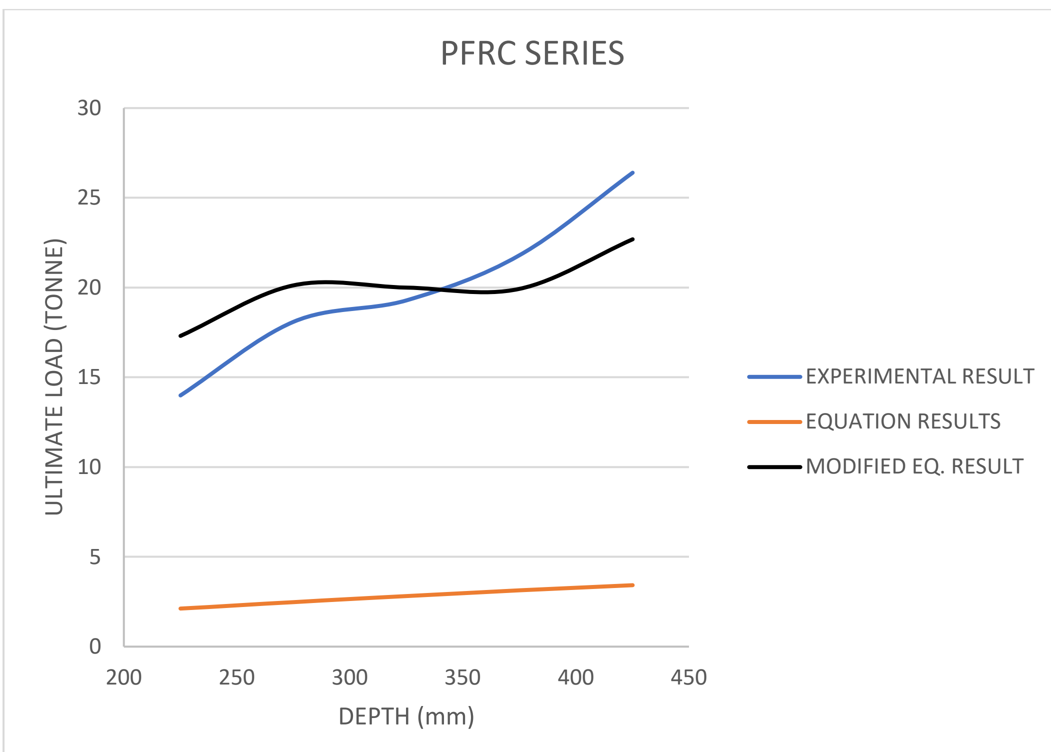
It reveals from Table 9-5 that the ratio Experimental results and Theoretical original equation is very high. Here by incorporating size effect parameter the ratio of experimental results and Modified equation is nearly unity. The Modified equation results is convergent with the experimental results.

Experimental results of the present work were compared with theoretical result of RCC and Fibrous beam series. Theoretical results are calculated using **Canadian standard formula CSA A23.3-04**(6) by observing theoretical results all the experimental results were showing 84 to 89 % of variation. This result generates to Modify the Canadian standard formula by incorporating the size effect parameter.

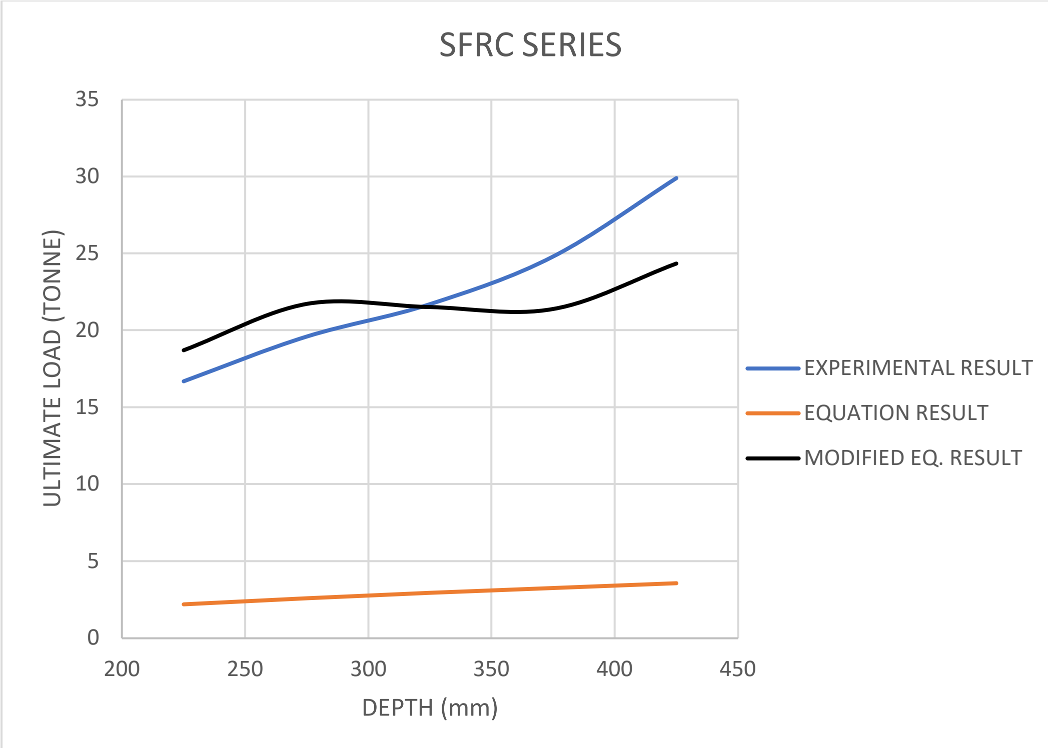
Experimental results of the present research work are compared with Modified CSA A23.3-04(6) formula and the results show that $\pm$ 20% variation in all the cases. For Fiber reinforced concrete series additional fiber factor added to the Modified equation for better prediction of shear strength for better accuracy of the proposed equation. One need the larger number of test results and experimental results are required to obtain best fit equation for predicting the shear strength of Moderate deep beam.



Graph 9-4 Ultimate Load Vs. Depth for RCC Series



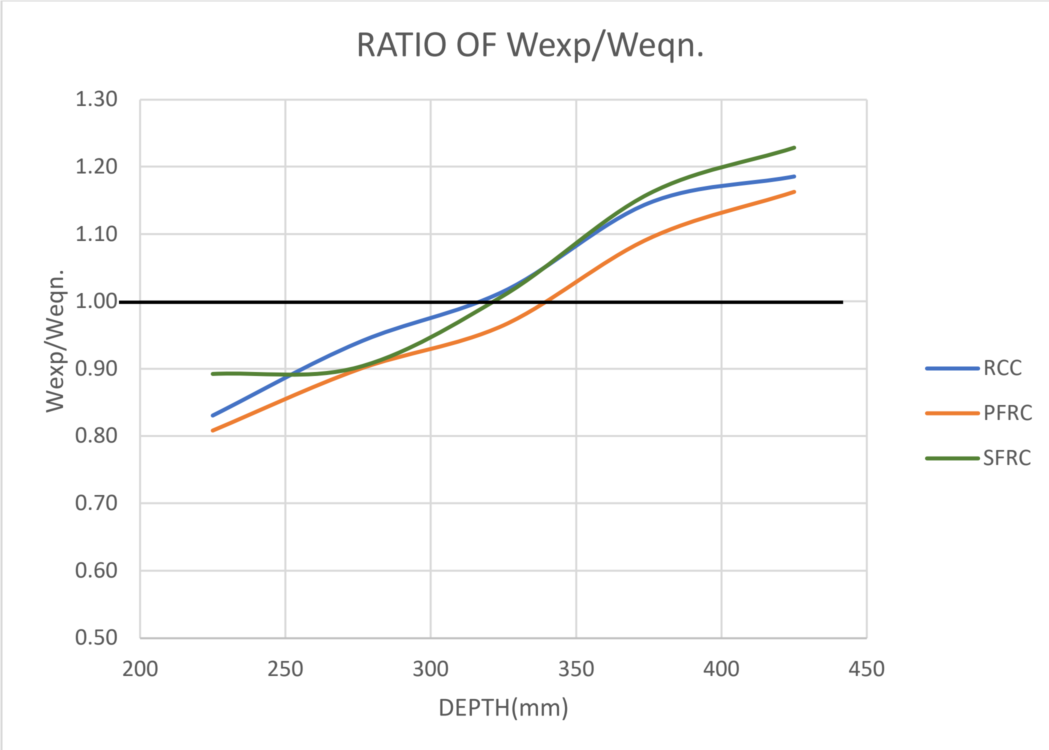
Graph 9-5 Ultimate Load Vs. Depth for PFRC Series



Graph 9-6 Ultimate Load Vs. Depth for SFRC Series

Table 9-9 Ratio of Experimental & Theoretical Results

Beam		L	b	D	W_{exp}	$W_{eqn.}$	$W_{exp}/W_{eqn.}$
		mm	mm	mm	ton	ton	
RCC	A2	900	75	225	13.5	16.3	0.83
	B	1000	75	275	17.8	19.0	0.94
	C	1100	75	325	19.3	19.0	1.01
	D	1200	75	375	21.9	19.1	1.15
	E	1300	75	425	25.8	21.8	1.19
PFRC	A2	900	75	225	14	17.3	0.81
	B	1000	75	275	18.1	20.1	0.90
	C	1100	75	325	19.3	20.0	0.96
	D	1200	75	375	21.8	19.9	1.09
	E	1300	75	425	26.4	22.7	1.16
SFRC	A2	900	75	225	16.7	18.7	0.89
	B	1000	75	275	19.6	21.7	0.90
	C	1100	75	325	21.7	21.5	1.01
	D	1200	75	375	24.8	21.4	1.16
	E	1300	75	425	29.9	24.3	1.23



Graph 9-7 Depth Vs. Wexp/Weqn.

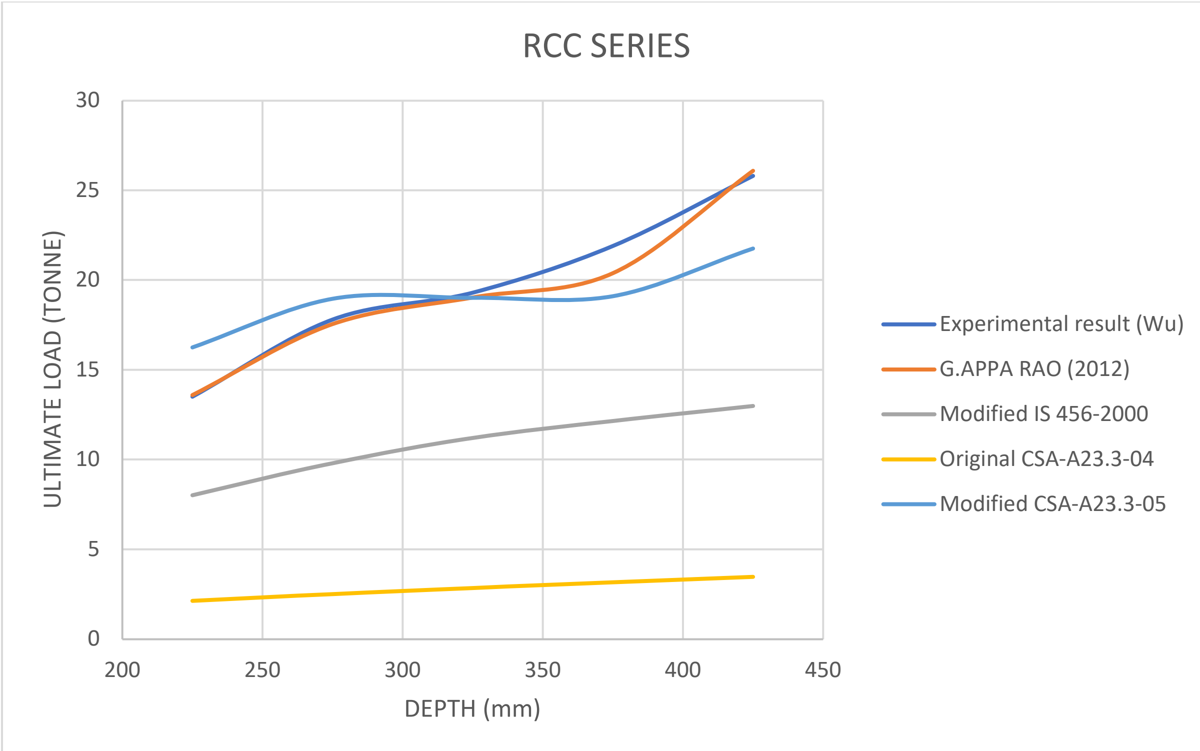
9.9 COMPARISION OF EXPERIMENTAL TEST RESULTS OF ULTIMATE LOAD WITH VARIOUS ORIGINAL FORMULA:

Experimental results are taken and compared with theoretical results for RCC beams. Theoretical results were calculated from Original CSA-A23.3-04[(6)] formula, G.APPA RAO (2012) formula, Modified IS -456 formula and Modified CSA-A23.3-04 formula.

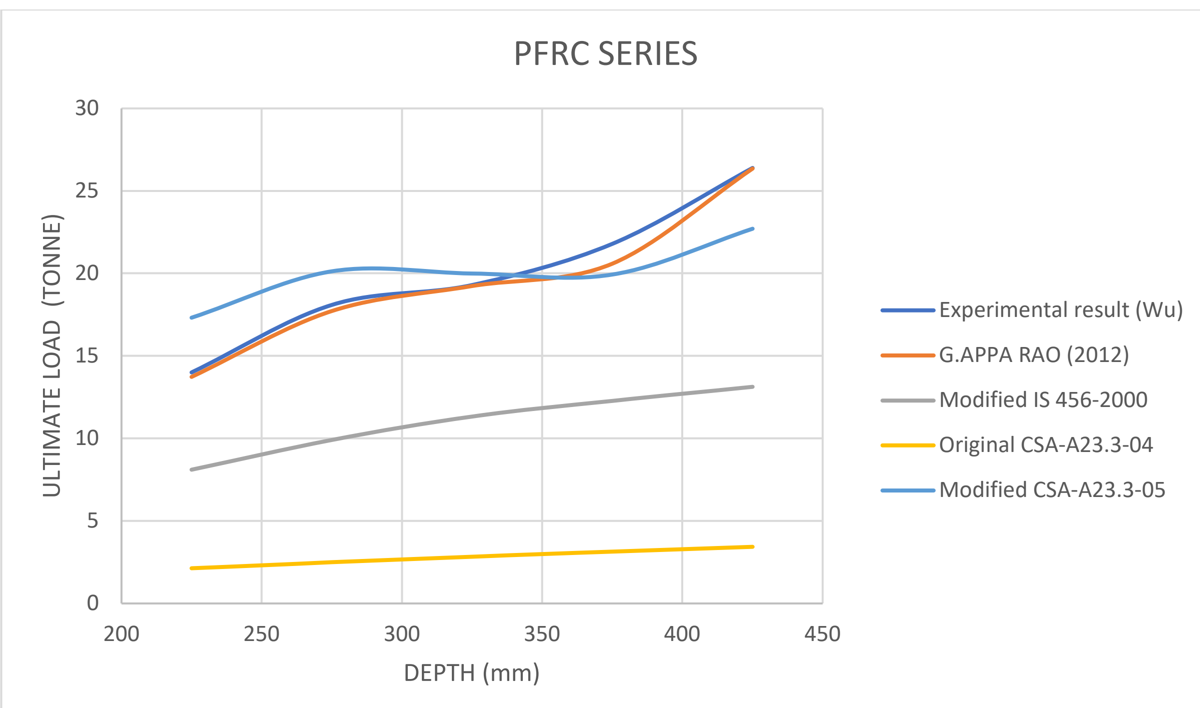
Table 9-10 Comparison of Shear Strength Results with Other Formula

Beam		L	b	D	Experimental Result (W_u)	G.APPA RAO (2012)	Modified IS 456-2000	Original CSA-A23.3-04	Modified CSA-A23.3-05
		mm	mm	mm	Tonne	Ton	Ton	Ton	Ton
RCC	A2	900	75	225	13.5	13.6	8.0	2.1	16.3
	B	1000	75	275	17.8	17.5	9.8	2.5	19.0
	C	1100	75	325	19.3	19.0	11.2	2.9	19.0
	D	1200	75	375	21.9	20.4	12.2	3.2	19.1
	E	1300	75	425	25.8	26.1	13.0	3.5	21.8
PFRC	A2	900	75	225	14	13.7	8.1	2.1	17.3
	B	1000	75	275	18.1	17.7	9.9	2.5	20.1
	C	1100	75	325	19.3	19.2	11.3	2.8	20.0
	D	1200	75	375	21.8	20.6	12.3	3.1	19.9
	E	1300	75	425	26.4	26.4	13.1	3.4	22.7
SFRC	A2	900	75	225	16.7	14.3	8.4	2.2	18.7
	B	1000	75	275	19.6	18.4	10.3	2.6	21.7
	C	1100	75	325	21.7	20.0	11.8	2.9	21.5
	D	1200	75	375	24.8	21.4	12.9	3.3	21.4
	E	1300	75	425	29.9	27.4	13.6	3.6	24.3

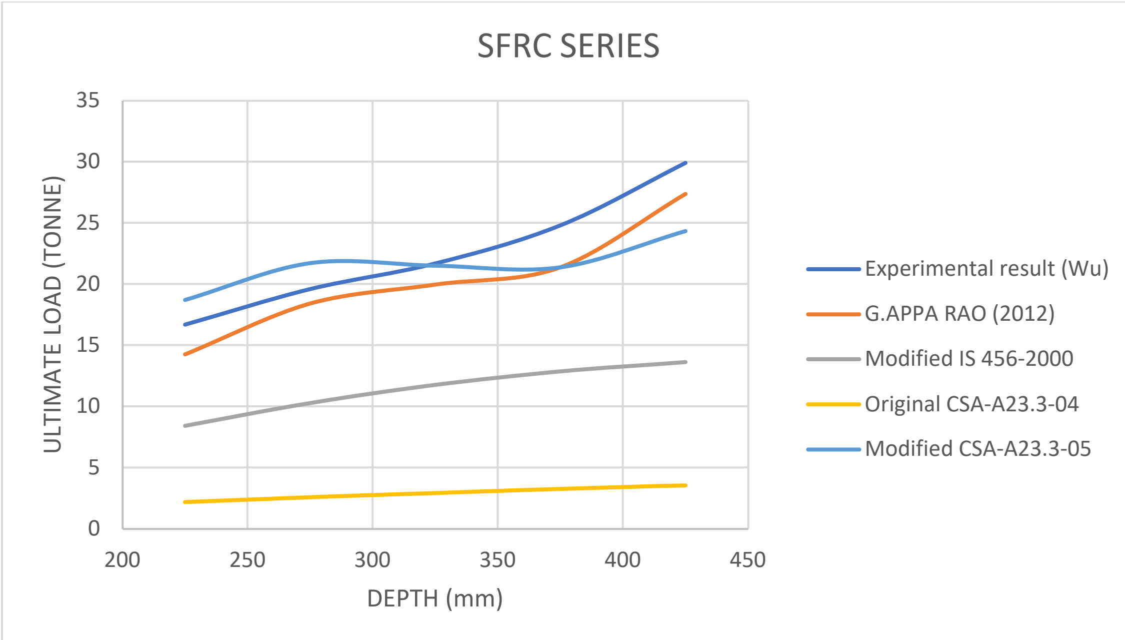
Experimental results of the present work were compared with the existing formula of size effect proposed by various researchers as APPA RAO (2012) and Modified IS 456-2000 formula. All the results of RCC series are near about the G. APPA RAO'S proposed formula while in the cases of fibrous concrete results are differ by10 to 12%. All the beams result of Original CSA-A23.3-04. varying by 84-87 % from experimental results. After Applying size effect parameter all results varying by 4 – 20 % from experimental results.



Graph 9-8 Comparison of Ultimate Load Vs. Depth for RCC Series



Graph 9-9 Comparison of Ultimate Load Vs. Depth for PFRC Series



Graph 9-10 Comparison of Ultimate Load Vs. Depth for SFRC Series

Table 9-11 Ratio of Wexp/Weqn for Various Formula

Beam		G.APPA RAO (2012)	Modified IS 456-2000	Original CSA-A23.3-04	Modified CSA-A23.3-05
RCC	A2	0.99	1.68	6.31	0.83
	B	1.01	1.82	7.09	0.94
	C	1.01	1.72	6.77	1.01
	D	1.07	1.80	6.91	1.15
	E	0.99	1.99	7.45	1.19
PFRC	A2	1.02	1.73	6.60	0.81
	B	1.02	1.83	7.28	0.90
	C	1.00	1.70	6.83	0.96
	D	1.06	1.77	6.94	1.09
	E	1.00	2.01	7.69	1.16
SFRC	A2	1.17	1.98	7.59	0.89
	B	1.06	1.91	7.59	0.90
	C	1.09	1.84	7.39	1.01
	D	1.16	1.93	7.61	1.16
	E	1.09	2.19	8.39	1.23

Table 9-8 shows the experimental results and with Modified formula results are almost nearer after applied the size effect parameter in the CSA A23.3-04[6] Shear strength formula.

Table 9-8 shows the ratio of Experimental load and theoretical load. Other researcher's ratio is more than unity while using Modified equation the ratio is almost nearer to unity. So Size effect parameter incorporate in original equation of CSA A23.3-04[6] code shear strength formula.

Experimental results of the present work were compared with the existing formula of size effect proposed by various researchers such as APPA RAO (2012) and modified IS 456-2000 formula. All the results of RCC series are near with G. APPA RAO'S proposed formula but in the cases of Fibrous concrete results are differ by10 to 12%. All the beams results predicated by modified IS 456 2000 varying by 40-54 % from experimental results.(Table 9-7).All the beams result of Original CSA-A23.3-04. varying by 84-87 % from experimental results. After Applying size effect parameter all results varying by 4 – 20 % from experimental results.