International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 08 | Aug 2022 www.irjet.net p-ISSN: 2395-0072

Effect of Factors Influencing of Shear Resistance on the Energy Dissipation Capacity of RC Beams

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Abstract - *As more complex earthquake research and design approaches are created it is necessary to accurately predict the cyclic behaviour of RC elements, which is defined by strength, deformability and energy dissipation capacity. This report describes the experimental results of RC beams under cyclic loading. The main objective of this study is effect of RC beam with same percentage of longitudinal reinforcement and varying transverse reinforcement. Hysteresis curve isolated for each cycle, relative energy dissipation in successive cycle, variation in relative energy dissipation and variations in secant stiffness of various specimens are plotted and studied. It is observed that lower stirrup spacing has higher initial stiffness when compared to higher spacing. The relative energy dissipated by the specimens with less stirrup spacing was more.*

***Key Words*: cyclic loading, energy dissipation capacity, hysteresis curves, stiffness degradation, stirrups spacing variation.**

1. INTRODUCTION

The primary purpose of transverse reinforcement in beams is to withstand shear stresses or forces that act perpendicular to the longitudinal direction of reinforced concrete beams. Shear strength is determined by the concrete's grade, the amount of tension steel, the size and spacing of the stirrups, and the characteristics of the steel used for the RC element. The quantity of energy lost by RC elements, one of the most important variables to take into account, is a crucial factor in determining earthquake resistance. By enhancing the system's capacity for deformation and compressive strength, stirrups and ties are two parts that aid in the dissipation of energy. When earthquake loads are applied to a structure, the energy emitted by the loads should be dispersed. The degree of damage to the structure will grow if the capacity of the structure to disperse energy is diminished. As more complex earthquake research and design approaches are created, it is necessary to accurately predict the cyclic behaviour of RC elements, which is defined by strength, deformability, and energy dissipation capacity.

2. SCOPE OF STUDY

In the present study, the effect of stirrup spacing of beam on its energy dissipation capacity is studied experimentally. To study this effect the relative energy dissipated in each successive cycle of loading is determined to establish the variation pattern in energy dissipation. Also, the change in secant stiffness in consecutive cycles is obtained to study the variation in stiffness of beam.

2.1 OBJECTIVE

To study the effect of spacing of transverse reinforcement on the stiffness degradation and energy dissipation capacity of RC beams.

3. METHODOLOGY

The methodology employed in the study includes casting of test specimens to the required specifications and then testing these specimens according to a testing regime under a dynamic actuator.

3.1 CASTING OF SPECIMENS

RC beam specimens were cast with required specifications using hand-mixed concrete. RC beam specimens were cast with varying spacing of vertical stirrups. In these specimens the percentage of longitudinal steel is kept constant. (Details in Table 1)

Table- 1 Specimen Specification

Description	**Specimen 1**	**Specimen 2**	**Specimen 3**
Length	1000mm	1000mm	1000mm
Breadth	100 mm	100 mm	100 mm
Depth	100 mm	100 mm	100 mm
Clear cover	25 mm	25 mm	25 mm

Effective span	800 mm	800 mm	800 mm
Grade of concrete	M25	M25	M25
Grade of steel	Fe 500	Fe 500	Fe 500
Transverse reinforcement	6Ø @50mm C/C	6Ø @75mm C/C	6Ø @100mm C/C
Longitudinal reinforcement	3#6Ø= 84.82 mm^2 T&B	3#6Ø= 84.82 mm^2 T&B	3#6Ø= 84.82 mm^2 T&B

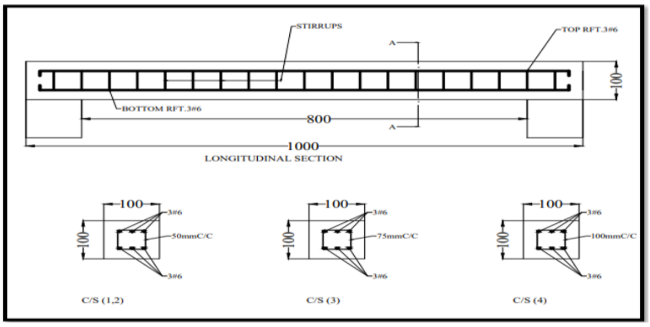


Fig. 1. Longitudinal and Cross Section of Specimens

3.2 TESTING OF SPECIMENS

The specimens were cured for 28 days and tested in a dynamic actuator. Each specimen was tested for a specific level of mid-point displacement (35mm) under cyclic loading for 20 cycles. Load versus displacement plot is obtained for each of the specimens to compare the hysteretic behavior.

3.3 INSTRUMENTATION USED

i Dynamic actuator capable of applying horizontal sinusoidal loading. Maximum amplitude 100mm; operating frequency range 0-5Hz; max load capacity 100k/N; max velocity of piston 120mm/s.

ii LVDT to measure displacements.

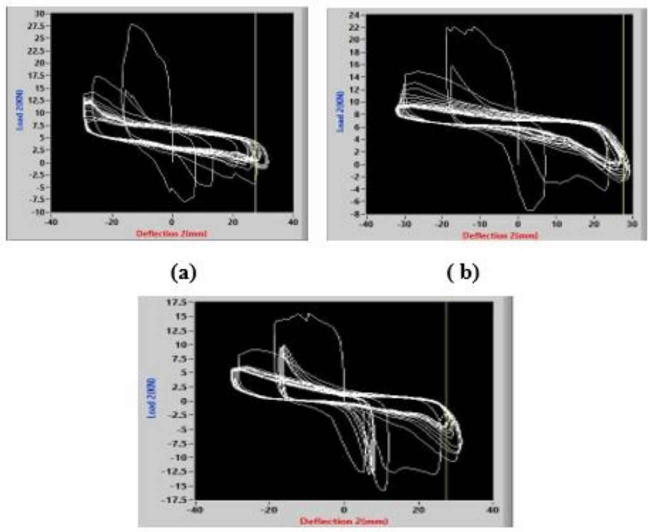
iii Data acquisition system to record load versus displacement plots and to produce this data in CSV format.

4. RESULTS AND DISCUSSION

The results from the cyclic load test were obtained from the data acquisition system in the form of hysteresis curves (cyclic load versus displacement plot) and the load and displacement data recorded at closely spaced time intervals in tabular (CSV format) form. The data in the tabular form was further processed to get insights in the behavior of specimens with regards to energy dissipation and stiffness degradation.

4.1 HYSTERESIS CURVES (CYCLIC LOAD VERSUS DEFLECTION PLOTS)

Fig 2. shows the hysteresis curves for the three specimens obtained from the specimen and their stiffness degradation in successive loading cycles.

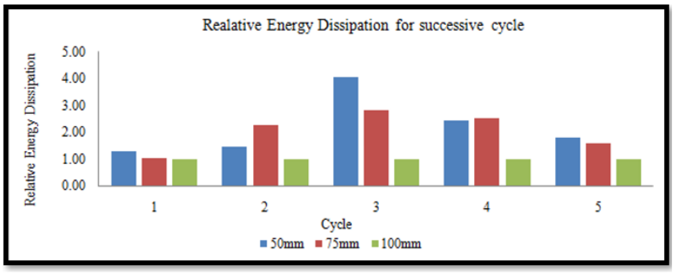


(a) (b) (c)

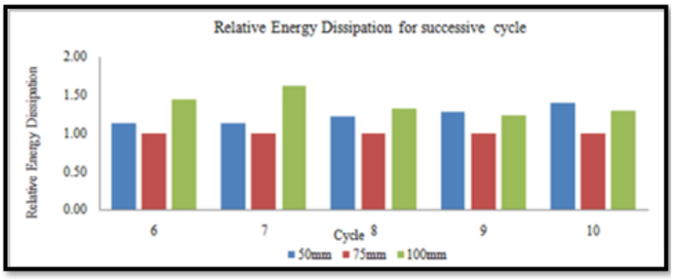
Fig. 2. Hysteresis Curve: (a) 50mm spacing; (b) 75mm spacing; (c) 100mm spacing

4.2 HYSTERESIS CURVE ISOLATED FOR EACH CYCLE OF LOADING

The data in the CSV file is used to develop the hysteresis curve for one cycle of loading at a time using the graph tool in MS Excel. These isolated cycles (cycles 1-20) are used to obtain the area enclosed within the loop. This area is then normalized by dividing it by the smallest area to obtain relative energy dissipated in each cycle of loading. The relative energy dissipation in successive cycles of loading. (Fig. 3)



(a)



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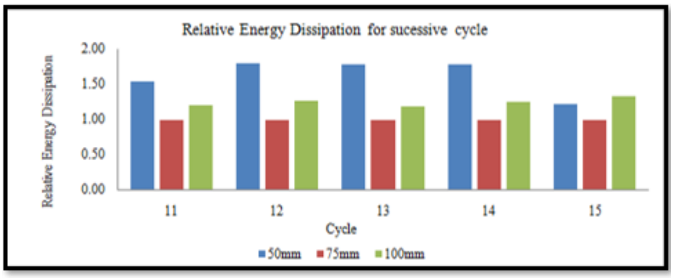

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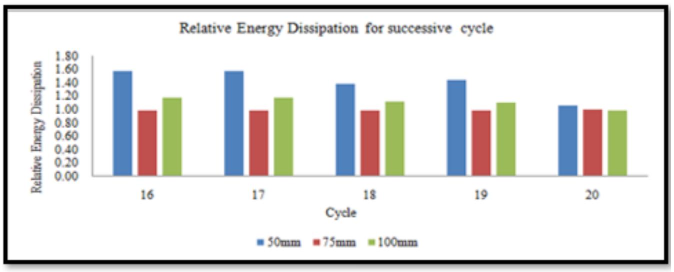

(d)

Fig. 3. Relative Energy Dissipation for Cycle: (a) 1-5; (b) 6-10; (c) 11-15; (d) 16-20

Table-2 Variation in Relative Energy Dissipation

Cycle	Relative Energy Dissipation		
	50mm	75mm	100mm
1	5.99	4.91	4.66
2	2.17	3.42	1.48
3	4.08	2.86	1.00
4	2.51	2.57	1.01
5	2.52	2.22	1.41
6	3.13	2.75	3.97
7	2.74	2.43	3.96
8	2.60	2.12	2.83
9	3.03	2.37	2.93
10	3.05	2.18	2.83
11	2.93	1.88	2.29
12	3.86	2.15	2.75
13	4.00	2.24	2.67
14	3.75	2.09	2.62
15	3.63	2.07	2.58
16	3.88	2.45	2.94
17	3.78	2.39	2.84
18	2.88	2.05	2.32
19	3.19	2.21	2.45
20	3.55	2.98	2.94

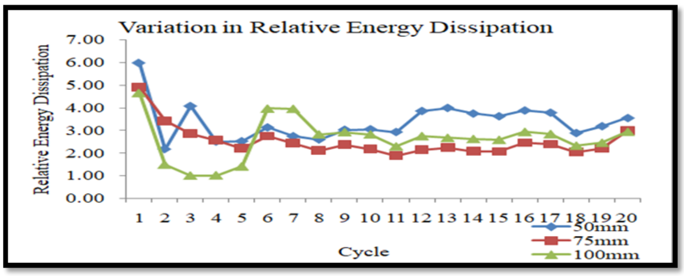

Fig. 4. Variation in Relative Energy Dissipation

4.3 STIFFNESS DEGRADATION

To study the degradation of stiffness of the specimens in every consecutive cycle of loading the peak load in each cycle and the corresponding displacement (Table 3) are used to obtain secant stiffness of the beam in that cycle of loading.

Table- 3 Variations of Secant Stiffness

Cycle	Specimen1			Specimen 2			Specimen 3		
	50mm			75mm			100mm		
	Peak Load (kN)	Deflection at Peak Load (mm)	Secant Stiffness (N/mm)	Peak Load (kN)	Deflection at Peak Load (mm)	Secant Stiffness (N/mm)	Peak Load (kN)	Deflection at Peak Load (mm)	Secant Stiffness (N/mm)
1	27.9	13.47	2071.27	22.1	17.11	1291.64	15.5	9.63	1609.55
2	14.5	15.65	926.52	15.9	17.47	910.132	10	16.23	616.143
3	17.3	24.57	704.11	14.9	26.44	563.54	9.8	16.39	597.926
4	14.2	27.13	523.41	12.8	30.4	421.053	9.6	16.83	570.41
5	13.2	27.38	482.10	12.2	28	435.714	9.5	17.16	553.613
6	12.9	26.63	484.42	11.3	30.9	365.696	8.7	17.38	500.575
7	12.6	27.95	450.81	10.5	31.25	336	9	25.63	351.151
8	12.3	29.25	420.51	10.2	27.76	367.435	5.9	28.93	203.941
9	12.2	29.22	417.52	9.8	27.55	355.717	5.7	26.23	217.308
10	12.2	27.46	444.28	9.6	28.43	337.671	5.9	26.55	222.222
11	12.1	27.95	432.92	9.5	27.51	345.329	5.9	29.3	201.365
12	12.1	27.07	446.99	9.4	28.83	326.049	5.9	28.35	208.113
13	12	28	428.57	9.5	28.15	337.478	5.8	27.73	209.16
14	11.8	29.2	404.11	9.5	28.43	334.154	5.7	27.81	204.962
15	11.6	29.22	396.99	9.4	27.49	341.943	5.6	27.58	203.046
16	11.2	27.74	403.75	9.4	28.04	335.235	5.6	28.29	197.95
17	10.2	29.2	349.32	9.3	27.75	335.135	5.6	28.37	197.392
18	9.3	28.97	321.02	9.2	27.96	329.041	5.5	27.69	198.628
19	8.7	28.69	303.24	9.2	28.07	327.752	5.5	27.97	196.639
20	8.6	25.5	337.25	9.2	27.95	329.159	5.5	28.38	193.798

Table- 4 Percentage Reduction of Secant Stiffness

Cycle	Specimen 1		Specimen 2		Specimen 3	
	50mm		75mm		100mm	
	Secant Stiffness (N/mm)	Percentage Reduction	Secant Stiffness (N/mm)	Percentage Reduction	Secant Stiffness (N/mm)	Percentage Reduction
1	2071.27		1291.64		1609.55	
2	926.52	55.268	910.132	29.53	616.143	61.71
3	704.11	24.0049	563.54	38.08	597.926	2.95
4	523.41	25.6636	421.053	25.2843	570.41	4.60
5	482.1	7.89247	435.714	-3.482	553.613	2.94
6	484.42	-0.4812	365.696	16.0697	500.575	9.58
7	450.81	6.93819	336	8.12041	351.151	29.85
8	420.51	6.72124	367.435	-9.3557	203.941	41.92
9	417.52	0.71104	355.717	3.18914	217.308	-6.55
10	444.28	-6.4093	337.671	5.07313	222.222	-2.26
11	432.92	2.55695	345.329	-2.2679	201.365	9.38
12	446.99	-3.25	326.049	5.58308	208.113	-3.35
13	428.57	4.1209	337.478	-3.5053	209.16	-0.50
14	404.11	5.70735	334.154	0.98495	204.962	2.00
15	396.99	1.7619	341.943	-2.331	203.046	0.93
16	403.75	-1.7028	335.235	1.96173	197.95	2.50
17	349.32	13.4811	335.135	0.03	197.392	0.28
18	321.02	8.10145	329.041	1.81837	198.628	-0.62
19	303.24	5.5386	327.752	0.39174	196.639	1.00
20	337.25	-11.216	329.159	-0.4293	193.798	1.44

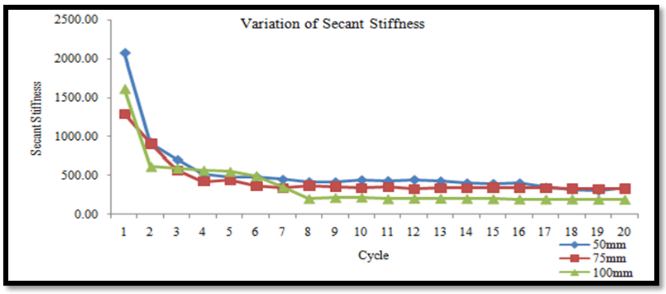

Fig. 5. Variation of Secant Stiffness

5. CONCLUSION AND SCOPE OF FUTURE WORK

The following conclusion are made from the experimental work carried out the extension of the present work that can be taken up in future is also presented.

5.1 CONCLUSIONS

i Specimen having lower stirrup spacing has higher initial stiffness when compared to higher spacing.

ii The relative energy dissipated by the specimens with less stirrup spacing was more compared to the specimen with higher stirrup spacing.

5.2 SCOPE FOR FUTURE WORK

Specimens having different stirrup spacing with different percentage of longitudinal reinforcement can be casted and tested.

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