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STUDY ON THE BEHAVIOR OF REMOVAL COVER CONCRETE OVER REINFORCED CONCRETE BEAM

R. Ramasubramani*, S. Divya and K.S. Satyanarayanan
Department of Civil Engineering, SRM University, Chennai, India.

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ABSTRACT

In the process of engineering design and construction, the concrete cover thickness is very critical. If the concrete cover thickness does not reach to design specifications and drawing requirements, it will be easy to cause some defects, such as surface cracks on building components and even reduce the structure strength and durability etc. In this paper, strength criteria is consider with three specimens with gradual removal of clear cover thickness (50-25-0 mm) of different grade of concrete to investigate the flexure behavior of over reinforced concrete beam. The results of laboratory investigation on removal clear concrete are present. Data presented includes load v/s deflection characteristics, crack width and stiffness when tested on 28 days.

Keywords: Cover concrete; clear cover; flexure.

1. INTRODUCTION

1.1 General

Concrete is a composite material composed mainly of water, aggregate, and cement The word concrete comes from the Latin word "concretus" (meaning compact or condensed), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow). In modern times, researchers have experimented with the addition of other materials to create concrete with improved properties, such as higher strength, electrical conductivity, or resistance to damages through spillage [1]. Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. Concrete is also the basis of a large commercial industry. Globally, the ready- mix concrete industry, the largest segment of the concrete market, is projected to exceed $100 billion in

*E-mail address of the corresponding author: ramasubramani.r@ktr.srmuniv.ac.in
(R. Ramasubraman)

revenue by 2015. In the United States alone, concrete production is a $30-billion-per-year industry, considering only the value of the ready-mixed concrete sold each year. Given the size of the concrete industry, and the fundamental way concrete is used to shape the infrastructure of the modern world, it is difficult to overstate the role this material plays today. With the advancement of technology and increased field application of concrete and mortars the strength, workability, durability and other characteristics of the ordinary concrete is continually undergoing modifications to make it more suitable for any situation.

1.2 Need for this study

The work on removal of cover concrete in RCC beam has limited experimental works. The result on this can bring out the R.C.C beams with increased or decreased strength without cover concrete.

2. COVER CONCRETE

In the process of engineering design and construction, the concrete cover thickness is very critical. If the concrete cover thickness does not reach to design specifications and drawing requirements, it will be easy to cause some defects, such as surface cracks on building components and steel corrosion earlier etc., and even reduce the structure strength and durability etc. Therefore, firstly, the concrete cover thickness should be selected and designed reasonably as per building structure types and its environment in engineering design [2]. Secondly, the construction process should be controlled strictly, i.e., take some measures to ensure the design thickness of concrete cover, control the location of steel bar and formwork, formwork removal time and enough concrete curing period.

In the concrete structure, the rebar and concrete are so different in nature but they can work together mainly due to bonding stress between rebar and concrete. As to the high-strength deformed rebar, if the concrete cover is not thick enough, its external concrete will crack, resulting in bonding strength descending and affecting the durability of structure thereby [3].

3. MIX PROPORTIONS

As per IS10262: 2009 and IS456: 2000 the concrete mix design was carried out for concrete grade M25, M35, M40 which is the grade of concrete to be used throughout the experiments is calculated in appendix A [4]. The mix proportion of M25, M35, and M40 grade concrete mix is shown in Table 1.

Table 1: Mix proportions of M25, M35, and M 40 grade of concrete

S.No	Grade of concrete	Mix proportions C:C.A:F.A	Water cement ratio
1	M25	1:1.45:2.50	0.50
2	M35	1:1.35:2.53	0.45
3	M40	1:1.32:2.57	0.40

4. EXPERIMENTAL INVESTIGATION

4.1 Details of specimen

The cross sectional dimension of beam is taken as 100×150 mm and length of the beam is taken as 1500 mm is used with varying removal of clear cover of 50mm, 25mm and 0mm for M25, M35, and M40 grade of concrete. The plan and cross section of the beam with varying clear cover at bottom is given in Fig. 1 and Fig. 2.[5]

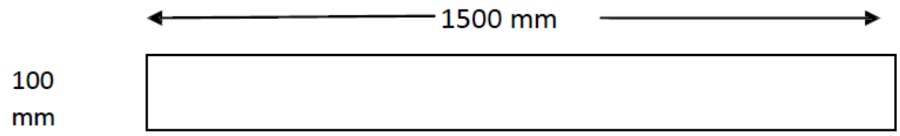

Figure 1. Plan of the beam

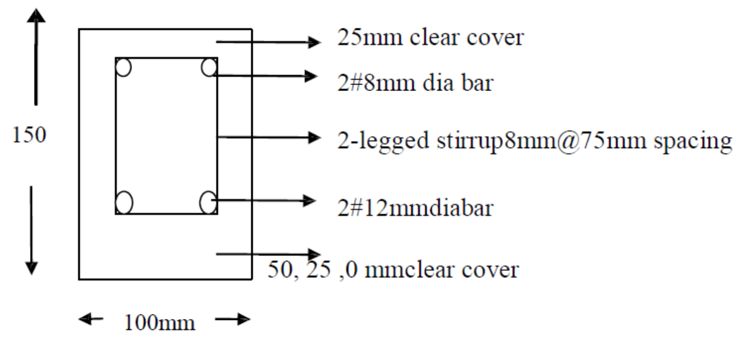

Figure 2. Cross section of beam with bottom zero clear cover

4.2 Making of specimen

The reinforcement bars were cut to the required lengths. Plywood moulds for the beams were made. The inner surfaces of the mould were coated with a thin film of oil to prevent adhesion of concrete to the mould. All the ingredients of the mix were weighed and machine mixed. The concrete was placed in the plywood moulds in three layers compacted using table vibrator. Care was taken to give uniform compaction in the specimens. The reinforcement with moulds is shown in Fig. 4 shows the casting of beams.

Figure 3. Moulds and reinforcements for beams

Figure 4. Casting of beams

4.3 Curing of specimens

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. The result of this process is increased strength and decreased permeability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability. After 24 hours of casting, the beams were covered with gunny bag and left for curing and the specimens are allowed for 28 days curing as shown in Fig. 5. Before testing a coat of white wash was applied to the beams to facilitate the observations of cracking patterns during the tests as shown in Fig. 6.

Figure 5. Curing of beams Figure 6. Beams after 28 days of curing with white wash

4.4 Experimental setup

The beam to be tested was lifted and kept in the loading platform. The testing was carried out in a loading frame of 40-ton capacity. All the specimens were white washed in order to facilitate marking of cracks. The beams are simply supported and two point loads are applied at L/3 distance from each end of supports under a load control mode. Dial gauge was fixed at bottom of beam for measuring deflections. The development of cracks was observed and the crack widths were measured using a hand-held microscope with an optical magnification of 40 and a sensitivity of 0.01 mm.

4.5 Tracing of cracks

Cracks, which were visible to the naked eye, have been marked with indelible marker pen as and when they appeared. The profiles of the cracks were recorded in the beam by drawing lines parallel to the crack about 2 mm away from the crack as observed. During the testing of specimen crack width are measured corresponding to ultimate load in each case.

5. RESULTS AND DISCUSSION

5.1 Compression test

The compressive strength of M25, M35, and M40 grade of concrete is given Table 2 to 4. Cubes of size 150 × 150 × 150 mm are used in the present work with different grade of concrete. After 3, 7, and 14 days of curing, the cubes are tested in a Compression Testing Machine (CTM) .The compressive strength of M25 grade of concrete is given in Table 2.

Table 2: Compressive Strength of M25 grade of concrete

S.No	Curing	Compressive strength (N/mm^2)
1	3 days	12.64
2	7 days	18.51
3	14 days	23.28

The compressive strength of M35 grade of concrete is given in Table 3.

Table 3 Compressive Strength of M35 grade of concrete

S.No	Curing	Compressive strength (N/mm^2)
1	3 days	15.02
2	7 days	26.2
3	14 days	35.7

The compressive strength of M40 grade of concrete is given in Table 4

Table 4: Compressive Strength of M40 grade of concrete

S.no	Curing	Compressive strength (N/mm^2)
1	3 days	18.92
2	7 days	28.3
3	14 days	40.4

5.2 Split tensile test

Cylinders of size 100 mm diameter and length 200 mm are used in the present work to determine the tensile strength of concrete. After 3, 7, and 14 days of curing, the cylinders are tested in a Compression Testing Machine (CTM). Set the compression-testing machine for the required range. Keep the plywood strip on the lower plate and place the specimen. Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate. Place the other plywood strip above the specimen. Bring down the upper plate to touch the plywood strip. Note down the breaking load. The spilt tensile strength of M25, M35, and M40 grade of concrete is given in Table 5 to 7.

The spilt tensile strength of M25 grade of concrete is given in Table 5.

Table 5: Split tensile strength of M25 grade of concrete

S.No	Curing	Split tensile strength (N/mm^2)
1	3 days	1.5
2	7 days	1.97
3	28 days	2.45

The spilt tensile strength of M35 grade of concrete is given in Table 6.

Table 6: Split tensile strength of M35 grade of concrete

S.No	Curing	Split tensile strength (N/mm^2)
1	3 days	1.65
2	7 days	2.29
3	28 days	2.7

The split tensile strength of M40 grade of concrete is given in Table 7.

Table 7: Split tensile strength of M40 grade of concrete

S.No	Curing	Split tensile strength (N/mm^2)
1	3 days	1.84
2	7 days	2.48
3	28 days	2.92

5.3 General observations

Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection. When the maximum load was reached, the concrete cover on the compression zone started to fall for the beams. Crack formations were marked on the beam at every load interval at the tension steel level [6]. The crack patterns of the beam are shown in Fig. 7, crack pattern of 0 mm clear cover of M35 grade of concrete beams is given. Crack width and Crack pattern of the 50 mm Clear cover of M25 grade of concrete beam is given in Fig. 8 respectively. All 9 beams showing the ultimate loading after the removing of beam from loading frame is shown in Fig. 9.

Figure 7. Crack pattern of beam

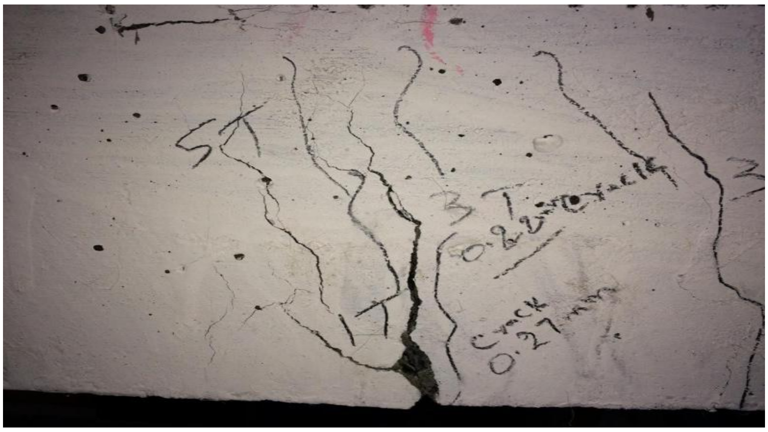

Figure 8. Crack width and Crack pattern of the 50 mm clear cover of M25 grade of concrete beam

Figure 9. Picture showing 9 nos. of specimens after Ultimate Loading

5.4 Load deflection curve

The experimental load v/s deflection curves of the RC beams with clear cover of 50 mm, 25mm, and 0 mm are tested at 28 days, values are given in Table 8 to 10. The corresponding individual graphs are drawn for load-deflection for M25, M35, and M40 grade of concrete of 50 mm, 25 mm and 0 mm clear cover respectively [7]. The comparison of ultimate loads, initial crack, type of crack, crack pattern, initial crack width, and maximum crack width and stiffness for M25, M35, M40 grade of concrete of 50 mm, 25 mm and 0 mm clear cover are given inrespectively.

Table 8: Comparison of ultimate load, maximum crack width and stiffness of M25, M35, M40 of 50 mm, 25 mm, 0 mm clear cover

S no	**Grade of concrete**	**Clear Cover (CC) mm**	**Initial crack (T)**	**Ultimate load (kN)**	**Type of crack**	**Crack pattern**	**Initial Crack width (mm)**	**Maximum Crack width (mm)**	**Stiffness of the beam (N/mm)**
1	M25	50	0.25	58.8	Flexure	Bending	0.02	0.27	3.96
		25	0.25	53.4	Flexure	Bending	0.03	0.26	2.73
		0	0.5	51.5	Flexure	Bending	0.03	0.6	2.67
2	M35	50	0.75	66.2	Flexure	Bending	0.02	1.6	3.89
		25	1	61.3	Flexure	Bending	0.02	1.2	4.46
		0	1	49	Flexure	Bending	0.04	0.9	3.22
3	M40	50	1.25	68.6	Flexure	Bending	0.05	1.4	4.58
		25	1.25	63.7	Flexure	Bending	0.04	0.9	4.74
		0	0.75	51.5	Flexure	Bending	0.03	0.8	2.81

The graph shows the load v/s deflection for M25, M30, M40, grade of concrete with 50mm, 25mm, and 0mm clear cover in Fig. 10 to 18.

Table 9: Comparison between experimental and theoretical Load values at service stage

S no	Grade of concrete	Clear cover (mm)	Experimental valve of load (p) in kN	Theoretical valve of load (p) in kN	Capacity ratio (exp/theo)
1	M25	50	58.8	54.3	1.08
		25	53.4	51.2	1.04
		0	51.5	47.4	1.09
2	M35	50	66.2	64.6	1.03
		25	61.3	58.2	1.05
		0	49	43.6	1.13
3	M40	50	68.6	63.2	1.08
		25	63.7	60.8	1.06
		0	51.5	46.1	1.11

5.5 Calculation of load and stiffness

The experimental valve of load is compared with theoretical load and the theoretical load sample calculation is given in Table 9 .The comparisons of experimental and theoretical stiffness valves are given in Table 10 [8].

Table 10: Comparisons of experimental stiffness and theoretical stiffness

S No	Grade of Concrete	Clear cover (mm)	Experimental Stiffness (N/mm)	Theoretical Stiffness (N/mm)
1	M25	50	3.96	2.9
		25	3.28	2.4
		0	2.67	2.45
2	M35	50	3.8	3.6
		25	4.4	4.1
		0	3.22	2.9
3	M40	50	4.5	4.3
		25	4.7	4.6
		0	2.81	3.1

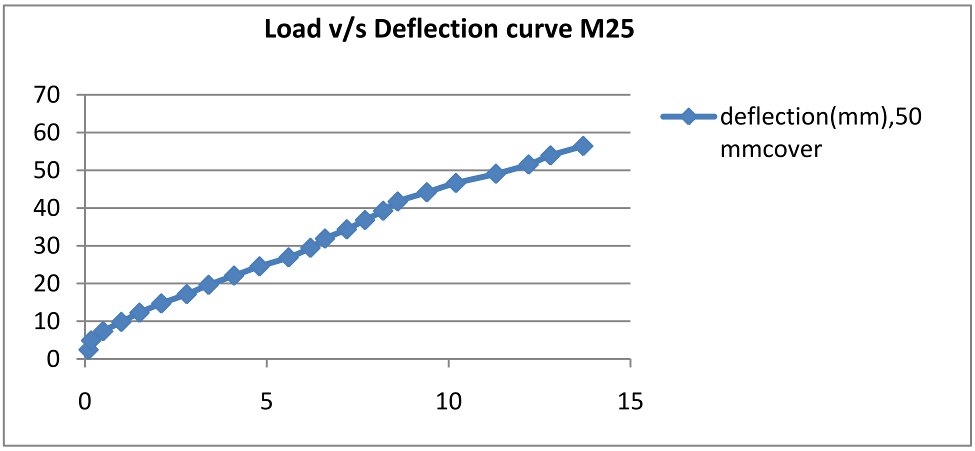

Figure 10. Shows the load v/s deflection curve M25, 50 mm cover

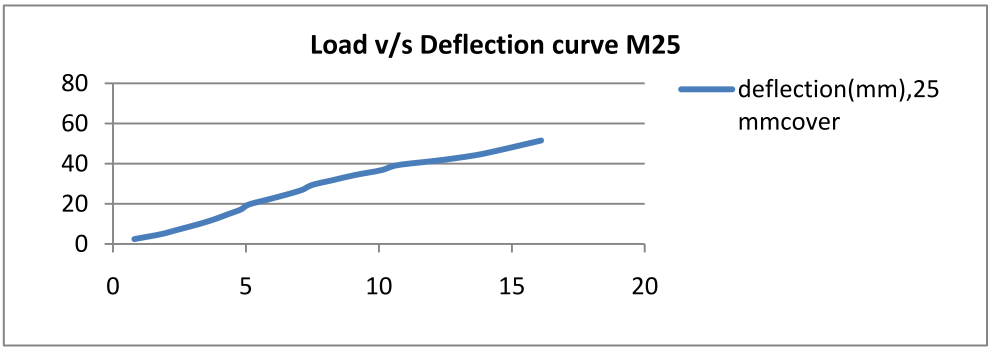

Figure 11. Load vs. Deflection curve M25, 25 mm cover

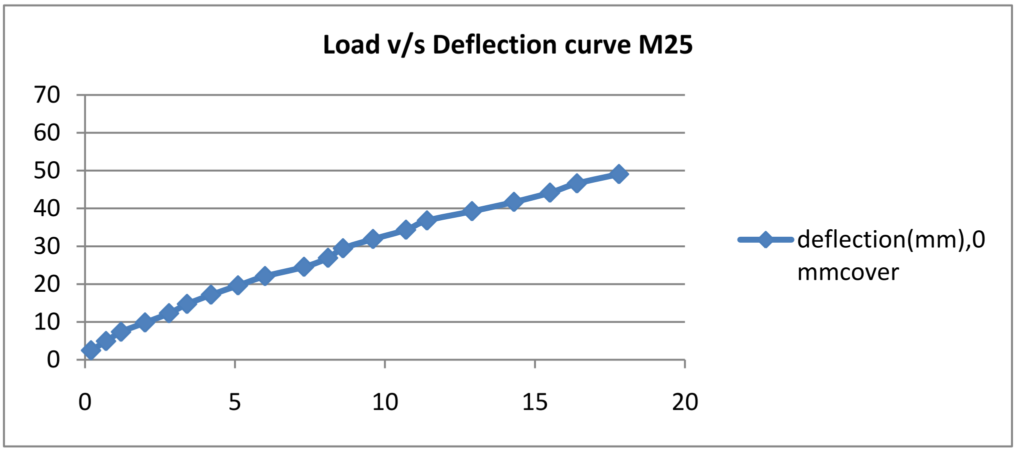

Figure 12. Load vs. Deflection curve M25, 0 mm cover

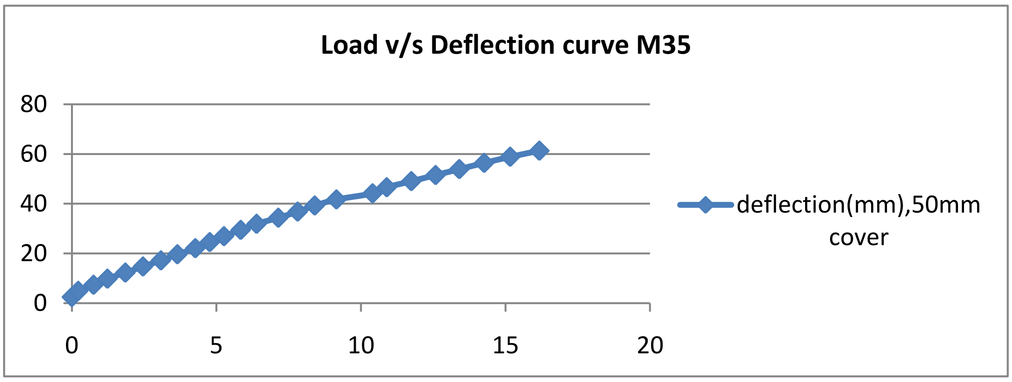

Figure 13. Load vs. Deflection curve M35, 50 mm cover

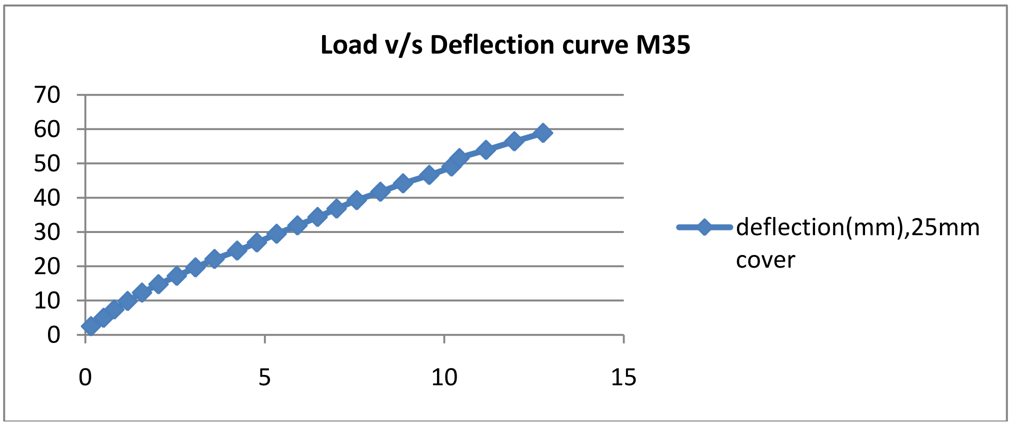

Figure 14. Load vs. Deflection curve M35, 25 mm cover

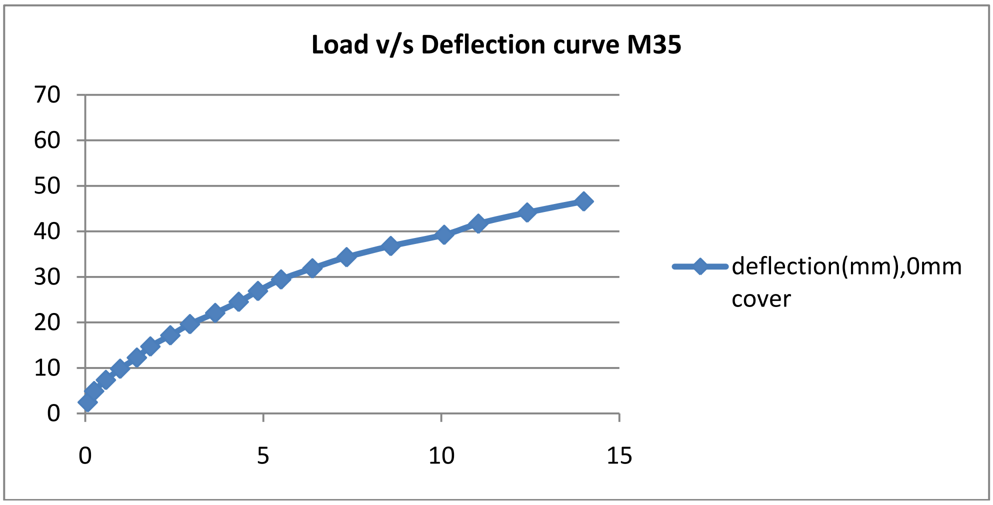

Figure 15. Load vs. Deflection curve M35, 0 mm cover

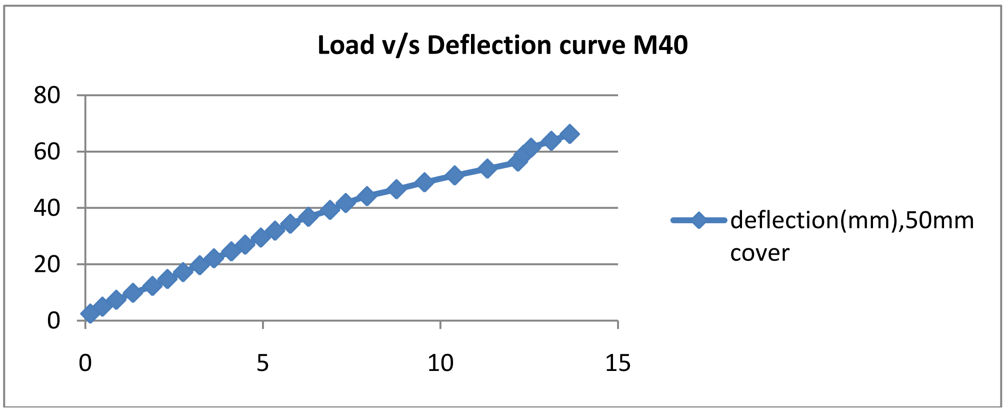

Figure 16. Load vs. Deflection curve M40, 50 mm cover

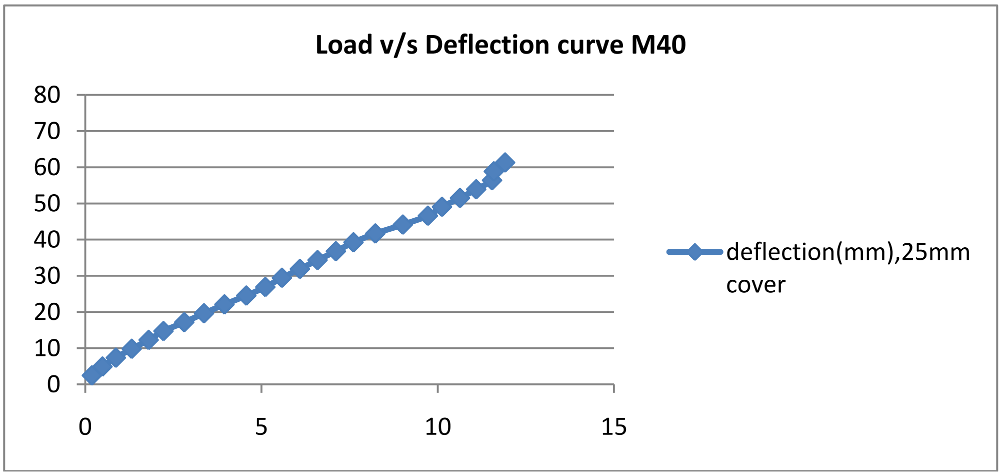

Figure 17. Load vs. Deflection curve M40 , 25 mm cover

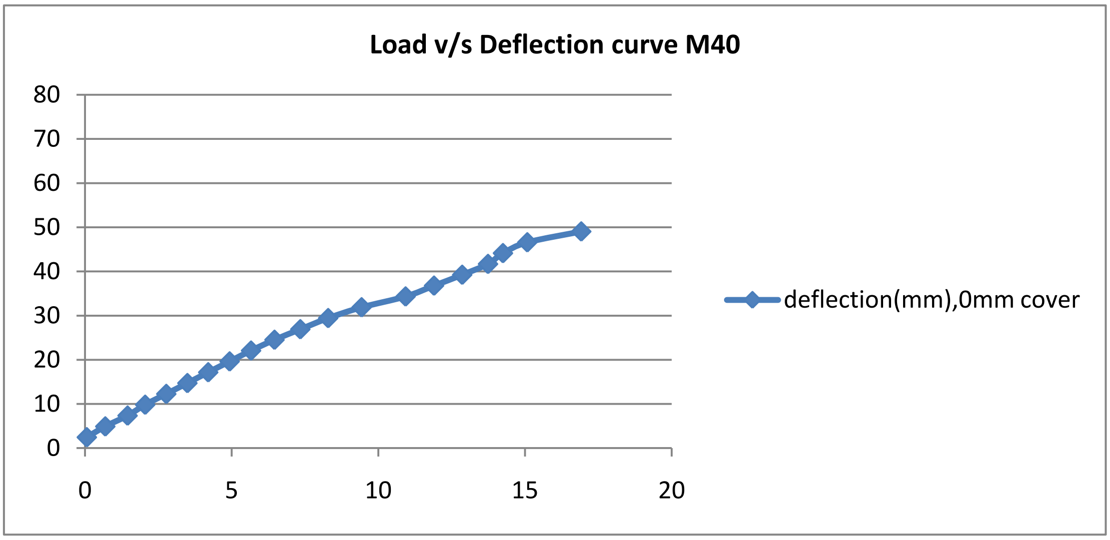

Figure 18. Load v/s Deflection curve M40 , 0 mm cover

6. CONCLUSION

The following conclusions can be drawn from the experimental investigation is carried out. The stiffness of the beams with 0 mm clear cover of M25 grade of concrete was 48.3% and 22.8% lesser than the beams with 50 mm and 25 mm clear cover made of same grade of concrete. The stiffness of the beams with 0 mm clear cover of M35 grade of concrete was 18% and 36% lesser than the beams with 50 mm and 25 mm clear cover made of same grade of concrete. The stiffness of the beams with 0 mm clear cover of M40 grade of concrete was 60.1% and 67.2% lesser than the beams with 50 mm and 25 mm clear cover made of same grade of concrete. The deflection of concrete beam with 0 mm clear cover of M25 grade of concrete is 30% and 10.55% more when compared with 50 and 25 mm clear cover. The deflection of concrete beam with 0 mm clears cover of M35 grade of concrete is15.5% and 9.8 % more when compared with 50 mm and 25 mm clear cover. The deflection of concrete beam with 0 mm clear cover of M40 grade of concrete is 24% and 42% more when compared with 50 mm and 25 mm clear cover.

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