International Journal of Engineering and Techniques - Volume 4 Issue 3, May – June 2018

RESEARCH ARTICLE OPEN ACCESS

Experimental Study on Alignment of Lapped Bars in Tension Region in Fiber Reinforced Concrete Beams

SoumyaChandran P[1], Linjesh Sebastian[2]
1(*Civil Engineering Department, VimalJyothi Engineering College, Chemperi, Kannur, Kerala ,India*
2 (*Civil Engineering Department, VimalJyothi Engineering College, Chemperi,Kannur,Kerala ,India*

Abstract:
Lap splices are widely used in masonry structures because of limited lengths of rebars combined with relative ease of construction and cost when compared to other splicing methods. Major design codes encourage staggering lapped joints in tension by imposing a penalty on lap length depending on the proportion of bars lapped at the same section .Staggering lapped joints increases the complexity of detailing and steel fixing, and may require additional resources and slow construction on site. An experimental program has been conducted in order to investigate the flexural behaviour of concrete beams by changing the alignment of tension reinforcement lap splice. A test series of four simple beams containing different lap splice length is been going to conduct in this investigation. The beams are of 2000 mm total length and 180*230 mm cross section. The parameters included in the experimental program are the splice length and the bar diameter 12mm. A traditional volume fraction of hooked steel fibers was adopted for FRC. The beam which is lapped in staggered manner without leaving a gap is found to fail at 110.6kN with a deflection of 11.95mm.Which has got good load carrying capacity as compared to other beams. As compared to control specimen the beam which is lapped in staggered manner without leaving a gap (B3) is found to have an increase of 13.38% of ultimate load and 62% of increase of deflection and first crack is formed at load of 40kN has got an increase of increase of 33.5%.

Keywords —**lap splice, stirrups, steel fibers, beam.**

I. INTRODUCTION

An adequate bond between concrete and reinforcing bars in a splice is an essential requirement in the design of reinforced concrete structures. Among the different coupler systems to link the steel rebars in concrete members (loops, welded bars, mechanical splices, splices) the lap splices are the most used in the construction process of Reinforced Concrete (RC) members for their cost-effectiveness, laying speed and simplicity of design. Splicing of reinforcing bars is one of the common practices used in concrete structures. Lap splicing, which is often achieved by the overlapping of two parallel bars with enough length, has long been considered as an effective and economical splicing method. Good bond strength of the lap splice with the surrounding concrete reduces the probability of bar slippage or splitting failure before the yielding of reinforcing steel bars. The bond strength of spliced bars in concrete depends on several factors such as concrete cover, bar spacing, bar casting position, development/splice length, bar diameter, bar surface deformation and condition (coated or un-coated), shape of splice end, yield strength, and embedment length of reinforcing bars, concrete compressive and tensile strength, and mix additives such as silica fume or fibers, aggregate type and quantity, concrete slump and workability admixtures, environment conditions, and loading conditions, the amount of transverse reinforcement provided in the splice or development region.The modern development of Fiber Reinforced Concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fibers or matrix or material failure. Fiber-Reinforced Concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented.

Aims and objectives:

- To study the lap-splices in conventional Fiber Reinforced Concrete beam with a fraction volume of fiber added to it.
- To study the lap-splice behavior in beam by varying the alignment of lapped bars.
- To study the flexural behaviour and crack pattern in beam under varying alignment of lapped bars

II. EXPERIMENTAL PROGRAMME

Lapped joints are mainly usedto provide continuity for reinforcement in concrete structures. The force in one bar is transferred to the surrounding concrete through bond stress over the bar surface, then from the concrete to the other lapped bar. Lapping of all reinforcing bars at same section are usually avoided. If all bars in the section need to be lapped, then laps should either be staggered in the longitudinal direction so that at any section only some of the bars are lapped, or the length of the lap increased. The beams are lapped in different position and their flexural behaviour, crack pattern and mode of failure was observed during testing

A. *Specimen Details and Materials*

Four test specimens were designed to study the influence of the following parameter on the flexure and bond performance (i) splice length, (ii) concrete type, (iii) type of fibers. The control specimen was casted with a beam size of 2 m long, 0.25 m deep and 0.18 m wide. The 12 mm diameter reinforcement bars is used as main reinforcement .The 10mm diameter reinforcement bars is used as distribution bars. The 25mm cover is provided. The 8mm diameter reinforcement bars is used as transverse reinforcement. All beams have the same dimensions and the reinforcement ratio. The steel fiber is added to the specimen as per the company dosage and bars are lapped at different region with different alignment.

Machine crushed granite obtained from a local quarry was used as coarse aggregate of size 20mm. The size of manufactured sand (M-Sand) is less than 4.75mm, used as fine aggregate. Portland Pozzolana cement is used. Hooked-end steel fibers with length 30mm and diameter of 0.60mm.Addition of fibers to concrete influences the structural integrity which significantly depends on the type and percentage of fiber used.

Fig 1 Hooked end steel fibers

Total four number of beams:

•The control specimen is casted according to IS 456:2000 code with addition of 1.8kg of hooked end steel fibers

•The first beam is lapped in aligned position with addition of 1.8kg of hooked end steel fibers.

•The second beam is lapped in staggered position, by center to center lap distance with addition of 1.8kg of hooked end steel fibers

•The third beam is lapped in staggered position without leaving gap between one lapped to another lapped section with addition of 1.8kg of hooked end steel fibers.

1) ***Control Specimen:***The control specimen is made with references to standard code 1S 456:2000. There are three main reinforcement bars of 12mm diameter. These main reinforcement bars in tension region are lapped. These bars are lapped here at different position and their leaves a gap between the lapped bars, the gap is 18.4cm from each lapped bars which is not less than 1.3Ld. The first bar is lapped at a distance 50cm from the support. The second bar is lapped at a distance of 125cm from the support. The third bar is placed at a distance of 50cm from the support. Thespecimen is made with addition of 1.8 kg hooked end steel fibers.

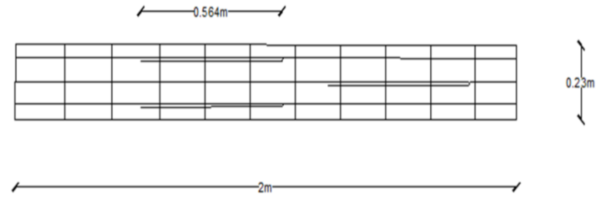

Fig 2 Control specimen

2) ***Beam with Aligned lapping*.:**If the length of a bar which is provided is not enough to keep the reinforcement, then lapping should to done for two steel bars. Lapping is normally done where the minimum shear force is acting. In first beam lapping is done in aligned position, which is done at a distance 50cm from the support and the lapping length is 56.4cm which is done according to codalspecification.steelfiber is added at 1.8kg to total volume.

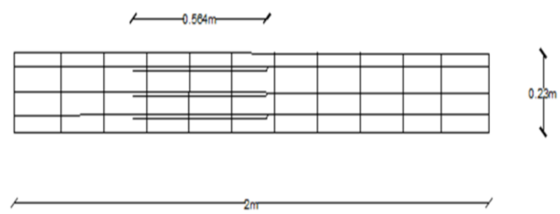

Fig 3 Beam with Aligned Lapping

3) ***Beam with staggered lapping at centre to centre:***In this specimen the bars are lapped at from centre to centre from one lapped bar to other bar. The bars will be lapped in different position and lapping of bars is done in such a way that, there will not be any gap between the lapped bar as we move from one bar to the other in staggered manner. The first bar is lapped at a distance 50cm from the support. The second baris lapped at a distance of 78.2cm from the support. The third bar is placed at a distance of 50cm from the support. The specimen is made with addition of 1.8 kg hooked end steel fibers.

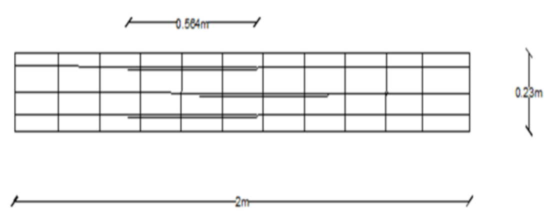

Fig 4 Beam with lapped at centre to centre in staggered manner

4) ***Beam with staggered lapping without leaving gap*:**In this specimen the bars will be lapped in different position and lapping of bars is done in such a way that the, there will not be any gap between the lapped bar as we move from one bar to

the other in staggered manner. The first bar is lapped at a distance 50cm from the support. The second bar is lapped at a distance of 106.4cm fromthe support. The third bar is placed at a distance of 50cm from the support. The specimen is made with addition of 1.8 kg hooked end steel fibers. Stirrups are arranged at equal spacing with 8mm diameter reinforcing bars. The lapping is done in 12mm reinforcement bars which are provided at tension zone. The lapping distance is 56.4cm

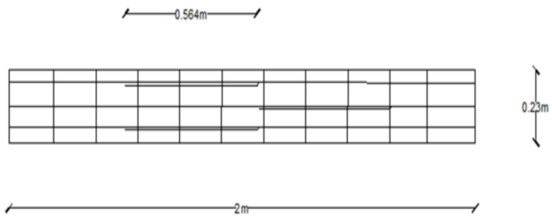

Fig 5 Beam with staggered lapping without gap

B. *Test Set Up and Test Procedure*

The specimens were simply supported and subjected to two point loading. The load was applied through a mechanical screw jack and was transferred to the test beam through a steel spreader beam that was supported on two steel rollers covering the entire width of the beam. The load was measured using an electrical load cell under the screw jack with a maximum capacity of 200KN. The deflections were measured by Linear Variable Displacement Transducers (LVDTs), placed under the middle of the beam span. The Load cell and LVDTs were connected to a data acquisition system to record the data. The load is applied at each step and continued until failure. The load was applied to the specimens until cracking was observed on the tension side of the beams. While the load was held constant, the cracks were traced. Cracks at the faces of the specimens were marked for further analysis. To measure the load applied to the specimen, compression type load cell was used. .

The experimental set up for all four beams is given in fig 6&7, where LVDT are connected in the mid span of the beam. Support is given by leaving a cover of 150cm from both edge of the beam and two point loading is provided at a distance of 56.66cm from the support.

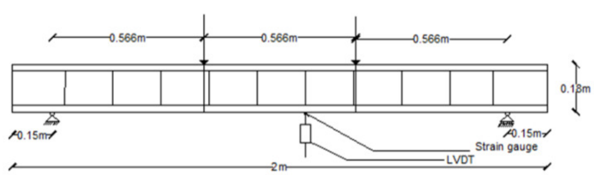

Fig 6 Test set up

Fig 7 Test set up

III. RESULTS AND DISCUSSIONS

The experimental programme consists of four specimens. These specimens were casted with addition of 1.8kg of hooked end steel fibers and cured for 28 days. The testing is carried under loading frame for two point loading. All four beams are tested and their results and observations are given below. The behaviour of all the tested beams were noted .The slightly non-linear behaviour of FRC beams is noted during the transition from the un-cracked to the cracked stage.

C. *Load- Deflection Curve*

As the load increases the deflection in the beam also increases. When the load is given to the beam specimen, the fiber present in the beam is more efficient and due to fiber bridging effect it will control the crack propagation and opening. It will enable the lap splices to reach higher bond strength before failure. After reaching the maximum load, fibers in the matrix started to pull-out, allowing a softening bond failure. The failure was smooth and ductile. After peak load, the bond strength decreased gradually due to the crack propagation. Load at which beam fails is taken as the ultimate load or the maximum load and deflection at that load is taken as maximum deflection at mid-span. After breaking point load goes on decreasing and deflection is increased. After attaining maximum load, deflection is noted and is illustrated in the table 1. When the load attains maximum, the specimen got crushed due to the load applied by the load cell.

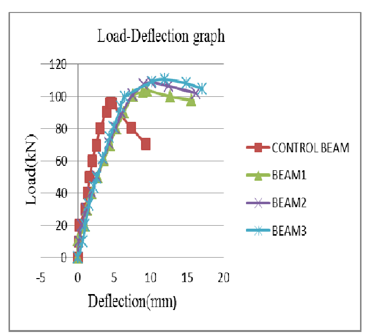

Fig 8 Load vs deflection graph for all beam

Table 1 Details of maximum load and maximum deflection

Specimen	Maximum load (kN)	Maximum deflection (mm)
Control specimen	95.8	4.54
B 1	103.7	9.53
B 2	108.6	10.11
B 3	110.6	11.95

Among all four beams, beam 3(Beam with staggered lapping without leaving a gap) has got greater ultimate load as is 110.6kN and the deflection is 11.95mm. It has got an increase of 13.38% ultimate load and a deflection of 62% as compared to the control specimen. Beam 2(Beam with staggered lapping at centre to centre) has got an ultimate load of 108.6kN and deflection is 10.11mm.It has got an increase of 11.78% of ultimate load and a deflection of 55.05% as compared to the control specimen. Beam 1 (beamwith aligned lapping) has got an ultimate load of 103.7kN and deflection is 9.53mm. It has got an increase of 7.61% ultimate load and 52.36% increase of deflection as compared to control specimen. The ultimate load and deflection of control specimen is 95.8kN and 4.54mm.The ultimate load and mid span deflection of beam specimen is plotted separately in fig 8 & 9.

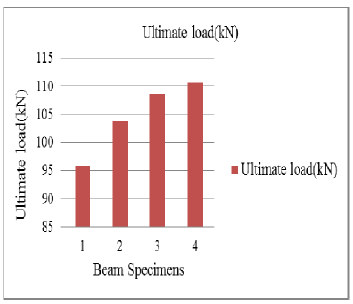

Fig 9 details of Ultimate load in beam specimens

The ultimate load for all four beam specimen is shown in Fig 9. The maximum ultimate load is obtained for beam 3. Load is 110.6kN.Then beam 2 with a ultimate load of 108.6 kN and beam 1 with ultimate load of 103 .7kN.The control specimen has got an ultimate load of 95.8kN.

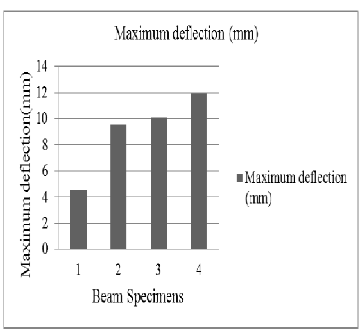

Fig 10 details of maximum deflection in beam specimens

The mid span deflection for all four beam specimen is shown in Fig 10. The maximum mid span deflection is obtained for beam 3. It has got a deflection of 11.95mm.Then beam 2 with a deflection of 10.11mm and beam 1 with mid span deflection of 9.53mm.The control specimen has got an mid span deflection of 4.54mm

D. Crack Pattern

The first visible fine splitting cracks occurred around 75-85% of the ultimate load. The failure of the beam with lapped bars was governed by the formation of cracks along the splices before bar yielding. FRC beams showed mainly cracks on the bottom surface of the beam with narrow and less evident side splitting cracks occurred when all bars were lapped. The cracks progressed towards the centre along the lap splice through the concrete cover on the front faces of the specimens .The addition of 1.8kg of hooked end steel fibers is more efficient in fiber bridging effect, which contributed to control crack opening and propagation, enabling the lap splices to reach higher bond strength before failure. When the cracks began tolocalise some cracks slightly grew oblique due to the external bars tendency to move outward. After reaching themaximum load, fibers in the matrix started to pull-out, allowing a softening bond failure. The failure was smooth and ductile. After peak load, the bond strength decreased gradually due to the splitting crack propagation. This softening behaviour can be attributed to fiber bridging effect. Detailed study on the splitting crack opening behaviour on similar specimen with UHPFRC can be found in Lagier et al. [4]. Here flexural shear is observed in all four beams.

Table 2 details of Ultimate load and load at first crack

Sl no	Ultimate load(kN)	First crack(kN)
Control beam	95.8	26.6
B1	103.7	30.5
B2	108.6	35.8
B3	110.6	40

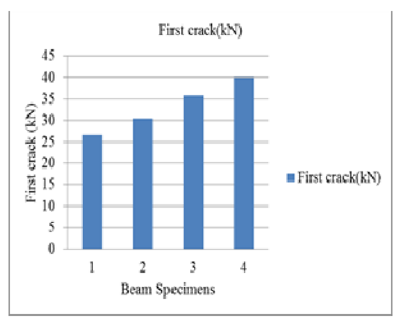

Table 11 details of Ultimate load and load at first crack

Fig 12 Control beam with after application of load

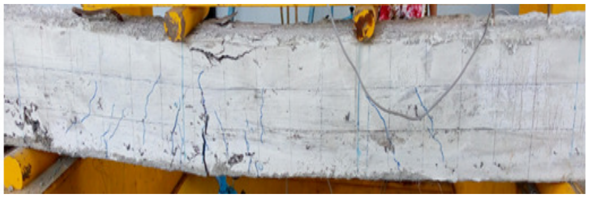

Fig 13After application of load for beam with aligned lapping

Fig 14After application of load for beam lapped at centre to centre

Fig 15 After application of load for lapped beam without gap

Beam 1 (beam with aligned lapping) has got an increase of 13.63% as compared to control beam. Beam 2 (Beam with staggered lapping at centre to centre) has got an increase of 25.69% as compared to control beam. Beam 3 (Beam with staggered lapping without leaving a gap) has got an increase 33.5% as compared to control beam. All specimens show an outstanding damage tolerance during post-cracking propagation without any spalling of concrete. FRC is able to limit the crack propagation within the concrete cover. The typical cracks of a FRC element is flexural shear cracks can be observed. Larger flexural cracks developed at the splice ends, both due to the slip of lapped bars at failure.

E. Discussions

Experimental investigations were carried out on the control beam and beam with different in alignment of reinforced bar in tension region.Load carrying capacity, maximum deflection, load at first crack and failure patterns were analysed for control beam and beam with different in alignment of reinforced bar in tension region.

•The flexural capacities of beam with different alignment were studied. There is an increase in flexural capacity, which is increased due to addition of steel fibers.

•The load carrying capacity for beam 3(beam which is lapped in staggered manner without leaving a gap) is 110.6kN.whereas control beam has 95.8kN. It has got an increase of 13.38% load carrying capacity.

•The load carrying capacity for beam 2(Beam with staggered lapping at centre to centre) is 108.6kN.It has got an increase of 11.78%, as compared to the control specimen.

•The load carrying capacity for beam1 (beam with aligned lapping) is 103.7kN. It has got an increase of 7.61%, as compared to control specimen.

•The load carrying capacity is higher in beam 3, due to arrangement of reinforcement bars in tension region and also due to the addition of hooked end steel fibers.

•The mid span deflection for beam 3(Beam with staggered lapping without leaving a gap) is 11.95mm.And beam 2(Beam with staggered lapping at centre to centre) is 10.11mm. For beam 1(beam with aligned lapping) is 9.53mm.

•The mid span deflection as compared to control specimen, beam 3 is increased by 62%. And beam 2 with 55.05% .for beam 1 the increment is 52.36%.

•The maximum mid span deflection obtained for beam 3, the reason is that as the load increases the deflection also increases .The maximum load is obtained for beam 3 and hence deflection also increases. Here all beam specimen are casted of same amount of cement, fine aggregate, coarse aggregate, reinforcement and steel fibers.

•The first crack for beam 1 (beam with aligned lapping) is 30.5kN. It has got an increase of 13.63% as compared to control beam

•The first crack for beam 2 (Beam with staggered lapping at centre to centre) is 35.8kN. It has got an increase of 25.69% as compared to control beam.

•The first crack for beam 3 (Beam with staggered lapping without leaving a gap)is 40kN. It has got an increase 33.5% as compared to control beam.

•The beam 3 has got a better resistance to first crack due to addition of fibers and also due to alignment of reinforcing bars.

•The first flexural cracks in all beams occurred randomly in the constant moment region on the tension side of the beam outside the splice length, as load increased, cracks formed along the entire length of the constant moment region including the splice region.

IV.CONCLUSIONS

This project examines the results of experiments on lap-splices in FRC with a low volume fraction of fibers, significant for many practical applications. Beam specimens were designed so that the splice behavior could be investigated by varying the alignment of lapped bars at a section with addition of steel fibers, with the aim at understanding the potential capacity of the post-cracking residual strength of FRC to enhance splice behavior and flexural behaviour. When the length of reinforcement bar has to be extended in reinforced concrete structural member splicing is used to join two reinforcement bars to transfer the force from one bar to the joining bar. The forces are transferred from one bar to the other through bonds in concrete. Force is first transferred to the concrete through bond from one bar and then it is transferred to the other bar forming the splice through bond between it and concrete. Thus concrete at the point of splicing is subjected to high shear and splitting stresses which may cause cracks in concrete. Four beams were casted and tested under loading frame. All the three main reinforcement bars at the tension region were lapped. When all bars were spliced, the addition of fibers led to a significant increase in the lap strength. From the testing of specimens using loading frame, following conclusion are made:

•The beam 3, (beam lapped in staggered manner without leaving a gap) is found to have a better load carrying capacity.

•The load at which the beam 3 fails is 110.6kN. As compared to control specimen it is found to have an increase of 13.38% due to arrangement of reinforcement bars in tension region and also due to addition of steel fibers.

•The mid span deflection of beam 3, (beam lapped in staggered manner without leaving a gap) is 11.95mm. As compared to control specimen it isincreased by 62%. As the load increases deflection also increases since it has got same amount of cement, fine aggregate,coarse aggregate and steel fibers .The maximum load is obtained for beam 3 and hence deflection also increases.

•The first crack for beam 3 (Beam with staggered lapping without leaving a gap) is 40kN. As compared to control specimen, beam 3 (Beam with staggered lapping without leaving a gap) has got an increment of 33.5% .

•The beam 3 has got a better resistance to first crack due to addition of fibers and also due to alignment of reinforcing bars.

•First crack is mainly obtained outside the lapped region.

•The first flexural cracks in all beams occurred randomly in the constant moment region on the tension side of the beam outside the splice length, as load increased, cracksformed along the entire length of the constant moment region including the splice region.

•Cracks are mainly observed on the place where the lapping is done.

Future Scope

However, further experimental research is needed to better investigate the role of the position and distribution of the transverse reinforcements along the lap length.

REFERENCES

[1] Ahmed H. Abdel-Kareem, Hala. Abousafa, Omia S. El-Hadidi(2013), *Effect of Transverse Reinforcement on the Behavior of Tension Lap Splice in High-Strength Reinforced Concrete Beams,* International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering,7,12, 989-996.

[2] Ahmed El-Azab, Hatem M. Mohamed(2014), Effect of tension lap splice on the behavior of high strength concrete (HSC) beams, Housing and Building National Research Center,10, 287–297.

[3] Ahmed H. Abdel-Kareem1*, Hala Abousafa1, Omaia S. El Hadidi1(2015),Behavior Of A Confined Tension Lap Splice In High-Strength Reinforced Concrete Beams, Slovak Journal of Civil Engineering,23,1-8.

[4] F. Lagier, B. Massicotte , J.-P. Charron (2015), Bond strength of tension lap splice specimens in UHPFRC, Construction and Building Materials 93, 84–94

[5] G. Metelli , E. Marchina, G.A. Plizzari (2017), Experimental study on staggered lapped bars in fiber reinforced concrete beams, Composite Structures 179,655-664

[6] John Cairns (2014), *Staggered lap joints for tension reinforcement,*44-55

[7] Magda I. Mousa(2015),*Flexural behaviour and ductility of high strength concrete (HSC) beams with tension lap splices*,Alexandria Engineering Journal, (2015)551–563.

[8] Mohamed A. Safan(2012),*Behaviour of Fiber Reinforced Concrete Beams with Spliced Tension Steel Reinforcement*,3 ,1 ,346-358

[9] Mohamed A. Safan(2012), *Behaviour of Fiber Reinforced Concrete Beams with Spliced Tension Steel Reinforcement*,3(1),346-358.

[10] Rasha T.S. Mabrouk *, Ahmed Mounir(2017), *Behavior of RC beams with tension lap splices confined with transverse reinforcement using different types of concrete under pure bending*, Alexandria Engineering Journal ,1-14

[11] Won-Chang Choi a, Seok-Joon Jang b, Hyun-Do Yun b,(2017) ,*Bond and cracking behavior of lap-spliced reinforcing bars embedded in hybrid fiber reinforced strain-hardening cementitious composite(SHCC)*, Composites Part B 108,35-4

[12] IS 10262: 2009. Indian Standard Concrete Mix proportioning-guidelines

[13] IS 456: 2000. Indian Standard Plain and reinforced concrete – code of practice.

[14] IS 383:1970. Specification for coarse and fine aggregates from natural source for concrete.

[15] IS: 2386(part I) : 1963 Indian Standard Methods of test for aggregates for concrete.

[16] IS: 2386(part III): 1963 Indian Standard Methods of test for aggregates for concrete.

[17] Varghese, P.C., Limit State Design of Reinforced Concrete, Prentice-Hall

[18] Shetty, M.S., Concrete Technology, Chand & Co.