STRUCTURAL BEHAVIOR ON REINFORCED CONCRETE BEAMS

VENKATA NARSI REIDDY SAGILI
Research Scholar
Civil Engineering
Sri Krishna University
sangilivnarsireddy@gmail.com

Dr. INDRAJEET N. YADAV
Assistant Professor
Civil Engineering
Sri Krishna University

Abstract

This research aims to investigate the experimental structural behavior of reinforced concrete beams. Beams are the major structural element that is capable of carrying and transferring load which is designed primarily for bending and shear. A careful approach in its design will lead to efficient use of concrete and steel reinforcement. Only recently have engineers started to pay attention to the hard problem of making public infrastructure that is also good for the environment. Using cutting-edge structural designs or building materials is one way to make structures that last a long time and need little maintenance. The main goal of this study is to look into the structural behaviour of M30 grade fiber-reinforced concrete parts that are made with both small and large steel fibres. For this goal to be reached, experimental research will have to be done. Both analytical and experimental methods were used to find out what effect micro and macro fibres have on beams.

Keywords: *Reinforced concrete, beams, structural design. Fiber, public infrastructure*

Introduction

Concrete is a material known for its great strength. Regardless, there are a few weaknesses, which must be taken in consideration in the design of concrete structural elements. Basically, concrete is made of three main ingredients: Portland cement, water, and aggregates (sand and stone). Portland cement reacts chemically in contact with water to form a rigid matrix that bonds the aggregates together. The final result is a material with a relatively consistent strength in all directions. Concrete can withstand large compressive loads. However, when subject to tensile forces, its resistance is much less and failure is usually sudden. In order to improve tensile strength and ductility (capacity to stretch and deform prior to failure) in concrete elements, reinforcement is used, usually in the form of steel, fiberglass or carbon fibre bars. Commonly referred to as rebar, reinforcement has a tensile strength far superior to concrete. The use of rebar allows the design of smaller and lighter elements, but also helps control cracking. We must understand that whether it is reinforced or not, cracks will occur naturally in concrete elements once in service. Sometimes invisible to the naked eye and sometimes very large, cracks in concrete can be quite alarming to the users of the structure.

Reinforced Beam

A reinforced beam is typically a concrete beam that is reinforced by steel and supports large weight loads on a vertical scale. These are generally used in large buildings for longitudinal support. They add stability to a structure and are used in areas, like floors and ceilings, to withstand large amounts of stress.

These beams are commonly used to add extra support to buildings located within an earthquake zone. They transfer the weight they bear to nearby support columns, which also act to support and strengthen the building. For example, many structures throughout China are constructed using reinforced beams due to the country's frequent earthquakes. A reinforced beam experiences a certain amount of yield when pressure is applied to it. These beams are usually divided into two separate zones, a compression zone and a tension zone. Steel reinforcements in these two pressure zones ensure that the concrete of the beam does not crumble beneath its applied weight load. Since steel is stronger than concrete, the two substances act together to bear these heavy loads.

Such a beam may be singly or doubly reinforced. These designations refer to the types of pressure that can be applied to the beams. A reinforced beam that has steel supports in the tension zone is known as singly reinforced. A beam with steal supports in both the compression and tension zones is generally referred to as doubly reinforced. Doubly reinforced beams are typically easier to construct and allow the beam to remain thinner than the singly reinforced kind. When weight is applied to the beam, the steel will provide yield without creating the need for a large beam, while the concrete ensures that the steel does not, in turn, snap under the pressure.

Beams may be reinforced diagonally as well as in a perpendicular manner. This helps avoid an excess of joints during construction and allows a more streamlined appearance in the architecture of the building. These diagonal reinforcements are equally secure when providing support during an earthquake.

A model for reinforced concrete beams

To develop a simplified one-dimensional reinforced concrete beam model, that should be able to describe the interaction between the cracked concrete and the rebars, a standard procedure was followed regarding the establishment of the finite element model. According to that process, a derivation took place first, which started from stating the strong form for the 'problem' of a reinforced concrete beam subjected to transverse and longitudinal distributed loading. Then, the weak form of the differential equations that cover the pertinent problem was obtained. Later on, the finite element formulation of the non-linear problem was derived, together with the linearization of the non-linear relationships. Finally, appropriate iterative/incremental procedures and integration schemes were employed for the numerical solution of the non-linear finite element form. The theoretical foundations of the derivation mentioned in the previous paragraph was the basis for the finite element code constructed at the next step. The outputs from the developed computer program were then used for comparison with relevant tests from literature, figures obtained from analytical calculations, the finite element stiffness adaptation method, as well as with a 'perfect bond' model performed using the Diana software. Furthermore, the fundamental problem solved in the present thesis was that of a reinforced concrete beam with vertical distributed load. The definition of the beam and the loading conditions can be seen in Figure

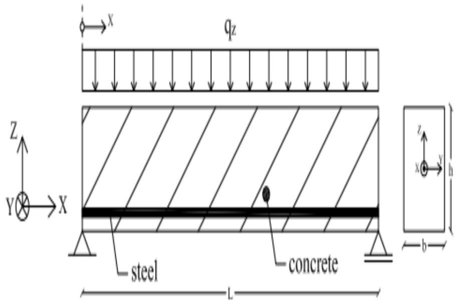

Figure: Example of a simply supported reinforced concrete beam

Literature Review

Amol Suresh Satpute [2017] investigated the feasibility of retrofitting beams with externally bonded GFRP wraps. Four spots on a cast beam specimen measuring 150 mm by 150 mm by 700 mm were used to assess its bending strength. Four tensionally reinforced beams, one top and bottom reinforced beam, four plain concrete beams, and shear reinforcement consisting of two-legged stirrups with a diameter of 8 mm were all cast. GFRP wraps were used to join the exteriors of second-type beams in groups of one, two, and three.

Sasi M. Kumar [2020] In this study, the structural behaviour of hybrid fiber-reinforced concrete specimens is investigated. We look at how the presence of the fibres changed the shape of the hybrid-reinforced specimens. We'll look at the samples' volume percentage of fibre. Compression, flexure, and tensile tests are all kinds of structural characteristics tests. The percentage of steel and polyester (Recron 3S) fibres in the overall volume might range from 0.1% to 1%. The research showed that the 0.5% concrete samples performed better structurally than the other samples. The results are also compared to what was expected for the beam and beam-column junction specimens.

Methodology

Dimensions and Reinforcement Details of Beam

For casting beam specimens, wooden moulds of size1.5 m × 0.1 m × 0.15 m made of quality timber is used. Two numbers of High Yield strength deformed bars (HYSD) of 8 mm diameter rods at both top and bottom are used as longitudinal reinforcement and 6 mm diameter stirrups spaced at 100 mm centre to centre are used as shear reinforcement. The dimensions and reinforcement details of the beam are shown in Figure.

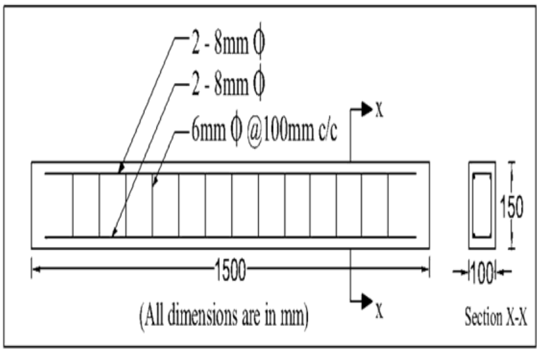

Figure: Reinforcement details of beam

Casting and Curing of Beam

There are eight cast beam specimens altogether, representing four distinct sets of tests. There is one concrete beam specimen and three beam specimens composed of fibrous concrete, each with a different geometry and length. Each fibrous concrete sample accounts for 1.5% of the total volume. Using a concrete mixer machine, concrete is mixed mechanically. To prevent the fibres from balling up during casting, the following method is utilised. After mixing the aggregates and cement for a full minute, you can begin slowly adding the water over the course of the next two minutes. After that, a gradual increasing technique is used to disperse the fibres uniformly throughout the mass. At this point, after three minutes of mixing time, you'll pour the concrete in layers into the mould and compact it as tightly as possible. The mold's top is then uniformly smoothed out afterward. The specimens are demoulded after 24 hours andplaced in water for 28 days of curing. The casting of beam specimen is shown in Figure

Figure: Casting of beam

RESULTS

BEHAVIOR OF CC BEAM

Load-Deflection Behavior

A two-point flexural loading method is applied at one-third points along the beam specimen so that the cyclic behaviour may be studied. A hydraulic jack is used as the source of the load, and all of the samples are put through a forward cyclic loading procedure. The load sequence will continuously advance by three kilonewtons right up to the point when the specimen breaks. The CC specimen is loaded and unloaded a total of three times during testing. During the course of the experimental investigation, a collection of data is made about the starting crack load, the maximum load, and the fracture patterns. In order to measure the deflection at midspan, LVDTs are used. It was discovered that the amount of deflection rose from 2.1 millimetres during the first cycle of loading to 15.7 millimetres after the third cycle of loading was completed. With each subsequent cycle, there would be a rise in the load, along with the related deflection.

The measured deflection is always greater than it was in the cycles that came before when a certain load is applied. The load sequence that has traditionally been used for the duration of the CC beam testing technique is shown in figure 4.1. A plot of the load-deflection response envelope for a CC beam specimen is shown in Figure 4.2, and the comparable static load-deflection response for a CC beam specimen is displayed in Figure 4.3. Both figures are included in this article.

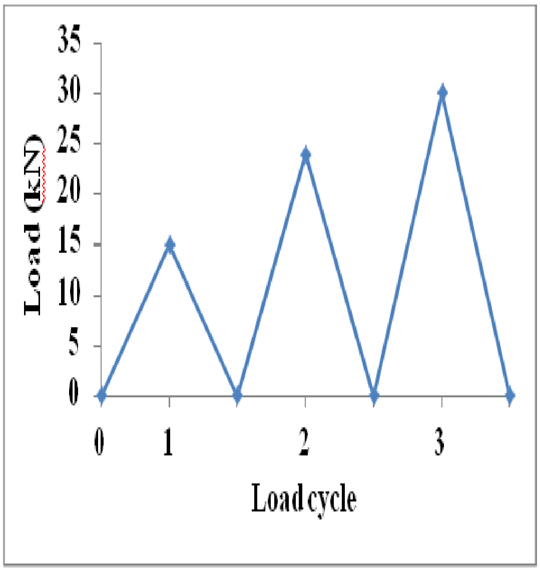

Figure: Load sequence diagram for CC beam

Load Carrying Capacity

The first fracture in the material emerges during the first cycle of loading, when the load is raised to 12 kN. This is when the load is being applied. When the load was raised even more, the consequence was the appearance of cracks that were both larger and more numerous. After the third cycle has been completed, the maximum load capacity of the CC beam is evaluated using a load level of 30 kN as the benchmark.

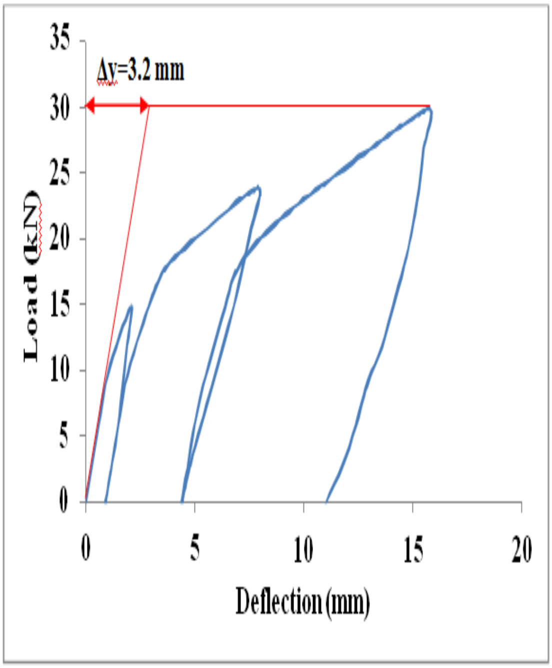

Figure: Load-deflection response for CC beam

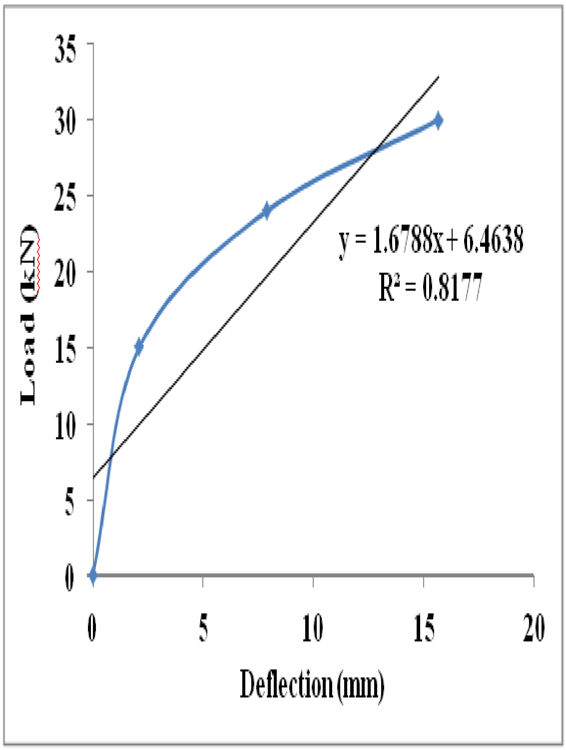

Figure: Equivalent static load-deflection response for CC beam

Ductility Characteristics

A material is considered to be ductile if it maintains its load-carrying capabilities despite being exposed to inelastic deformations higher than the material's yield deformations. It is computed by comparing the initial yield deflection to the maximum deflection that occurs during a certain load cycle. In a cyclic load-deflection diagram, the initial yield deflection illustrates the projected bilinear behaviour of a CC beam. This is shown in the image. Using the data in Figure 4.2, we can conclude that the initial yield deflection of the CC beam is 3.2 millimetres. The material's ductility improves with each succeeding loading cycle, rising from 0.66 after the first cycle to 4.91 after the third. By adding the ductility factor at the greatest load point reached in each cycle up to the cycles observed when the structure is exposed to cyclic loading, the cumulative ductility up to any load cycle may be determined. This enables the calculation of cumulative ductility up to any load cycle. This statistic is critical when designing a building to withstand the impacts of an earthquake since it indicates the overall ductility of the structure.

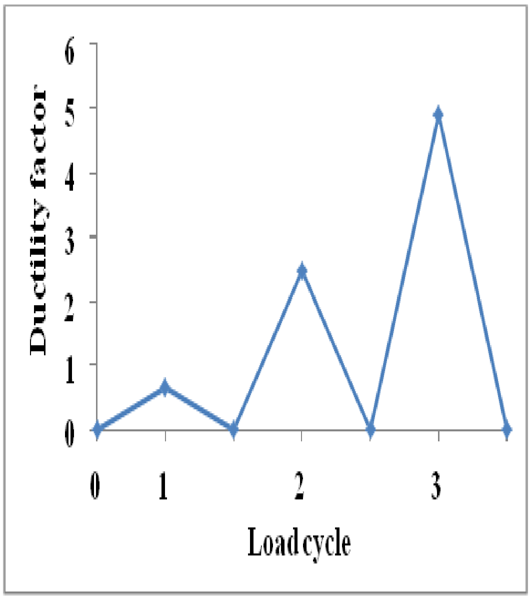

Figure 4.4 Variation of ductility factor with load cycles for CC beam

Table shows the CC beam's ductility factor and cumulative ductility factor. The total ductility is 8.03 after the third loading cycle. Both the ductility factor and the cumulative ductility factor for a CC beam show how load cycles affect their properties.

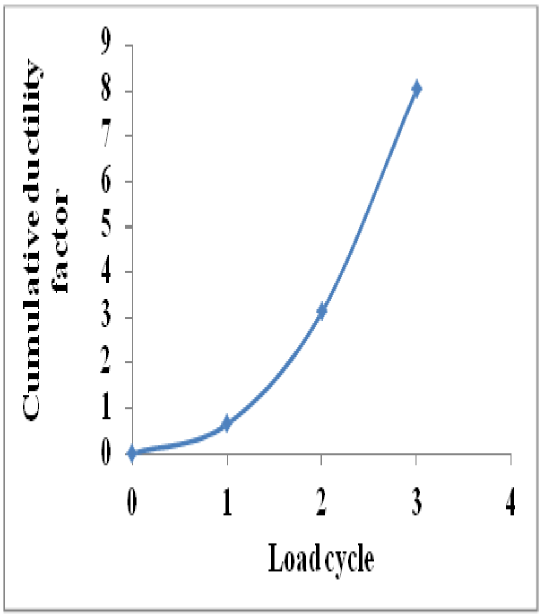

Figure 4.5 Variation of cumulative ductility factor with load cycles forCC beam

Energy Absorption Characteristics

Every time the beam is loaded and unloaded, it loses some of its energy. The area under the load-deflection curve shows how well the specimen can take in energy. When the first and third loading cycles are compared, it is found that the first cycle took in 11 kN-mm of energy and the third cycle took in 184 kN-mm. Figure 4.6 shows how the relative amount of energy the CC beam can absorb changes as the load cycles. You can find out how much energy the beam can take in over the course of a whole cycle by adding up how much energy it can take in over the course of individual cycles. The standard concrete beam takes in 273 kN-mm of energy at the end of the third cycle. Figure shows how the number of load cycles affects the amount of energy that can be stored. In Table, the relative and total amounts of energy that a CC beam can absorb are shown.

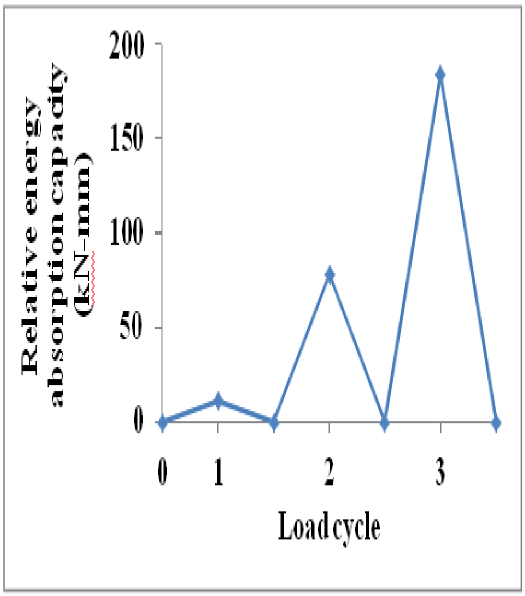

Figure Variation of relative energy absorption capacity with loadcycles for CC beam

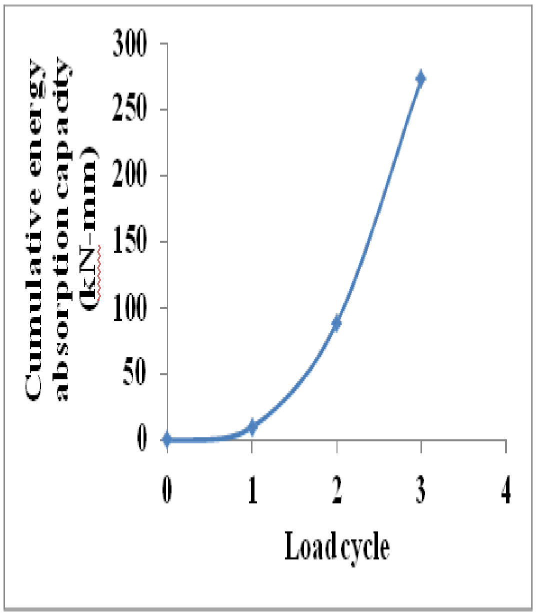

Figure Variation of cumulative energy absorption capacity withload cycles for CC beam

Stiffness Characteristics

The stiffness of a sample is defined as the amount of force required to bend one unit of the sample. A tangent is drawn at 75% of the maximum load for each iteration of the load-deflection curve. If you look at the slope of the tangent, you can get an idea of the stiffness at that loading cycle. The beam's rigidity would peak during the first load cycle and gradually decrease thereafter. The effect that repeated loading has on the rigidity of a CC beam is seen in Figure ,Table displays the stiffness values for each CC beam cycle.

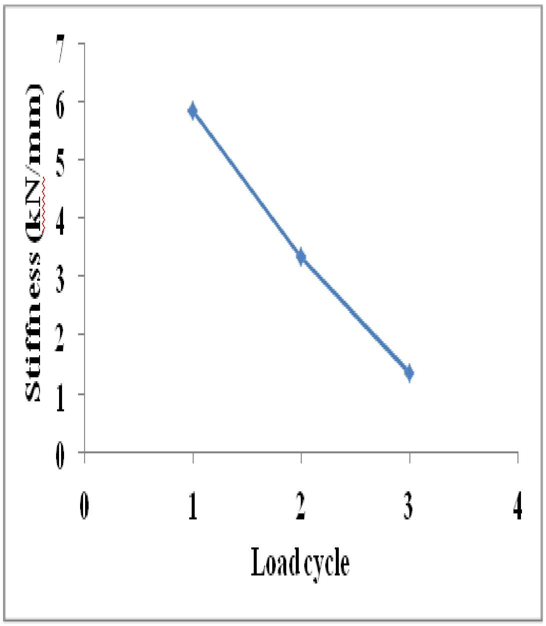

Figure Stiffness degradation with load cycles for CC beam

Behavior and Mode of Failure

By subjecting a standard concrete beam to three different loading cycles, the behaviour of the specimen can be demonstrated. A conventional concrete beam will develop hair cracks from the bottom fiber, working their way to the top fibre as the load increases. All along the beam, the existing cracks are widening, and new ones keep appearing. The concrete's top fibre was crushed, and the cracks in the base widened.

Table 4.1 Experimental results of CC beam

S. No.	No. of cycle	Ultimate load (kN)	Deflection at ultimate load (mm)	Ductility factor	Cumulative ductility factor	Relative Energy absorption capacity (kN-mm)	Cumulative energy absorption capacity (kN-mm)	Stiffness (kN/mm)
1	1	15	2.1	0.66	0.66	11	11	5.85
2	2	24	7.9	2.47	3.13	78	89	3.33
3	3	30	15.7	4.91	8.03	184	273	1.36

Conclusion

In this study the role of fiber type in reinforcement on the mechanical characteristics of concrete, and the torsional capacity and ductility of reinforced concrete beams (solid and hollow sections) have been investigated. The yield loading, the ultimate loading, the yield displacement and the ultimate displacement of RC beams increased distinctly with the increasing loading rate. The crack loading, the ultimate loading and the failure loading increased with the increasing loading rate and the crack loading and the ultimate loading and the logarithmic of the loading rate followed linear. The energy dissipation capacity of RC beams increased dramatically with the increasing loading rate.

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