General study on testing and retrofitting of beams

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1. Abstract

Natural disasters such as earthquakes have consistently shown current structures' vulnerability to seismic effects. Increased service loads, changes in the structure's use, design and/or construction defects, corrosion issues, and seismic retrofits are all examples of engineering challenges. It's obvious that completely rebuilding an entire structure isn't the most cost-effective option. Therefore, retrofitting is used to improve the overall structure's strength. This paper presents general study on beam behaviour and their retrofitting. The retrofitting of RC beams is carried out by using wire mesh and mild steel plates. To carry out the research, a total number of 9 RC beams were casted, 6 beams were retrofitted, each of three were retrofitted with externally bonded mild steel plate and wrapped wire mesh. The analysis under simulated loads was carried out using STAAD pro. The study found that retrofitting a beam with MS plates and wire mesh significantly increases its flexural ability. The behavior of the beams was consistent with the STAAD report. In the case of retrofitted means, the cracking was limited to the retrofitted central portion of the beam.

2. Introduction

Cement concrete is made by hardening a cement mixture (binding material) and a predetermined proportion of finely aggregated (sand), coarse compounds (e.g., broken stones (sandstones), gravels etc.) and water. The matrix is thoroughly mixed to produce a functional mixture that can be shaped in different components. In addition to cement from Portland, cement-based materials are commonly used in concrete for economy, reduced hydration heat, enhanced consistency, increased strength and/or improved durability within the expected range. These products are known as admixtures or performance improvers. Concrete attains full strength with age. Plastic concrete hardens as a result of a chemical reaction between cement and water that lasts for a long time. Plain Cement Concrete, or PCC, has a high compressive strength, is less expensive than steel, and is not corrosive or susceptible to other wear effects. It is most commonly used for building foundations and floors. The unit weight of PCC is 24kN/m3. When exposed to stress, it has a low tensile strength and is vulnerable to cracking. As a result, plain cement concrete cannot be used in members or systems that can develop tensile stress. In order to solve this problem, reinforcements in the form of bars, tendons or wires are used in concrete. The composite material formed by combining steel with concrete is reinforced cement concrete or RCC.

Structures should be planned and constructed in such a way that resources are adequately used and a positive economic effect is achieved. Various retrofitting or strengthening methods are used to improve the efficiency of an existing structure. Some structural elements, such as columns and beams, may be strengthened to extend the life of the building. A structural element can be retrofitted by adding an accessory, technology, feature, or part. When there is a rise in loads, a shift in occupancy or loading, or when the structure deteriorates, retrofitting becomes essential. It may also extend the life of buildings that would otherwise be uneconomical to demolish.

- **Analytical and Experimental program**

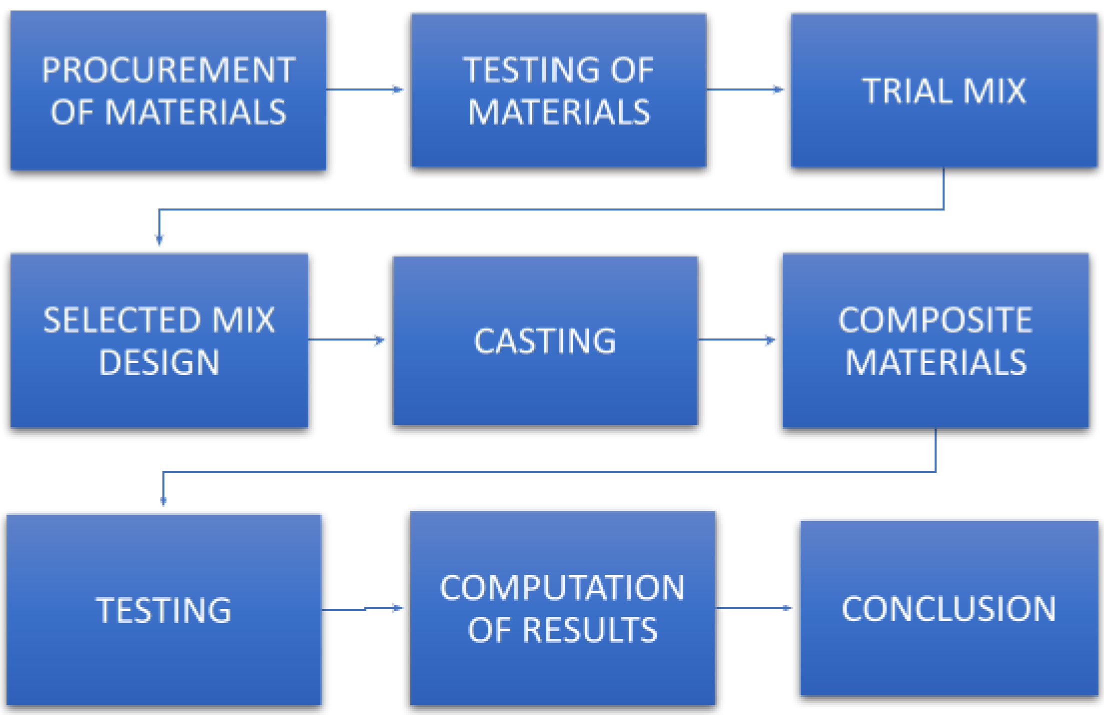
Analytical program

Two software's were used for analysis and design of the beam. The concrete beam was analysed in STAAD.Pro V8i and designed in STAAD RCDC. STAAD is a powerful analysis and design software licenced by Bentley. Software was available in the National Institute of Technology (NIT) Srinagar, Concrete lab.

Experimental program

The experimental research program consisted of designing, building, retrofitting, and testing the beams for their flexural behaviour in order to meet the thesis' objectives. The beam specimens were tested for load and deflection measurements as part of the experimental program. The National Institute of Technology's (NIT) Srinagar's Structural Testing Laboratory was used for testing of samples.

3. Methodology



DESIGN MIX PROPORTION

Mix	Cement	Fine Aggregate	Coarse Aggregate
M25	1	1.530	2.725

Table 1. Design mix proportion.

QUANTITY OF MATERIALS USED

Mix	Cement (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (litres)
M25	446	681	1215.80	160

Table 2. Quantity of materials used.

CASTING OF BEAMS

A total of nine 150 mm wide, 200 mm deep, and 1200 mm long beams were cast. They are divided into three categories: Group A is for normal concrete beams (control beams), Group B is for MS Plate retrofitted beams, and Group C is for wire mesh retrofitted beams.

Mixing of concrete: Hand mixing was used to mix the concrete for the casting of the specimens. Hand mixing was used to balance the uniformity and quality of the concrete blend. Until mixing, the stone aggregates were washed with water to remove any dust, dirt, or other foreign material.

Placing of concrete:

Concrete is poured into formwork to achieve the desired shape and scale. A temporary formwork made of wood was constructed to support fresh concrete until it hardened. The formwork was built on the spot. At intervals, binding wire was used to maintain tight joints, brace it against lateral strain, and prevent slurry loss. Oiling was performed on the bottom and inner surfaces to ensure easy removal of specimen without any damage.

Compaction of concrete: Concrete was manually compacted in layers using steel rod. To expel entrapped air, the rod was vertically inserted into the concrete and rotated up and down. Two 8mm steel handle bars were also installed within to assist with beam transportation.

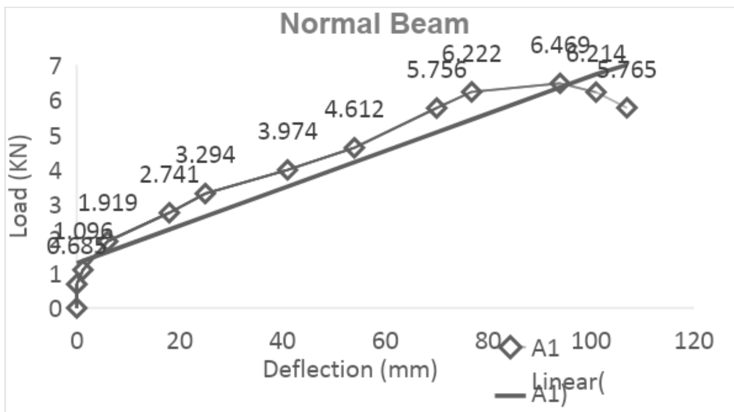
Curing of concrete: The surface of the concrete beam was cured by wrapping moist gunny bags around it. They have a high-water retention rate and do not allow water to evaporate quickly. To keep the gunny bag wrapped beams moist, they were watered two to four times a day. This was carried out for 28 days before they were checked.

4. Results

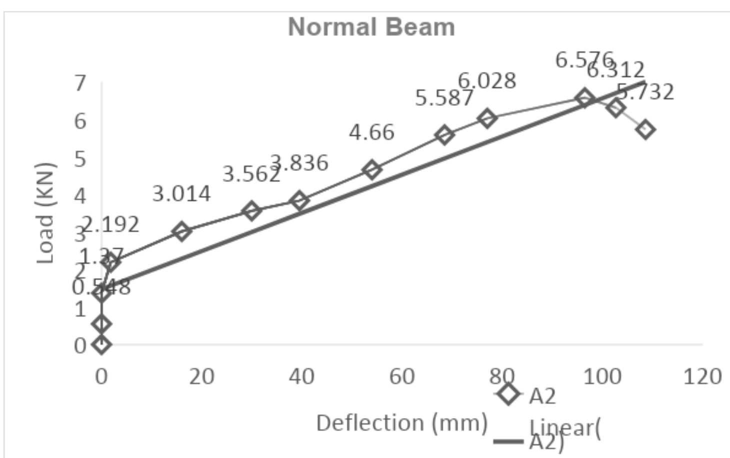
Beam Specimen	*Maximum Load and Deflection*	*Failure type*
A1	The specimen A1 failed with a midspan deflection of 93 mm at a maximum load of 6471 N.	Crushing of concrete
A2	The specimen A2 failed with a gross deflection of 97 mm and a maximum load of 6573 N.	-
A3	The specimen A3 failed with a gross deflection of 98 mm and a maximum load of 6849 N.	-
B1	The maximum load retained by beam was 8632 N. The deflection recorded by strain gauge at this load was 70.8 mm.	Debonding of plates
B2	The maximum load retained by beam was 8825 N. The deflection	-

	recorded by strain gauge at this load was 74 mm.	
B3	The maximum load retained by beam was 8765 N. The deflection recorded by strain gauge at this load was 73 mm.	-
C1	The maximum load retained (ultimate load) by specimen was 7941 N. Strain gauge recorded a deflection of 84.2 mm at this load.	Tearing of wire mesh
C2	The maximum load retained (ultimate load) by specimen was 8219 N. the strain gauge recorded a deflection of 86 mm at this load.	-
C3	The maximum load retained (ultimate load) by specimen was 8501 N. The strain gauge recorded a deflection of 89 mm at this load.	-

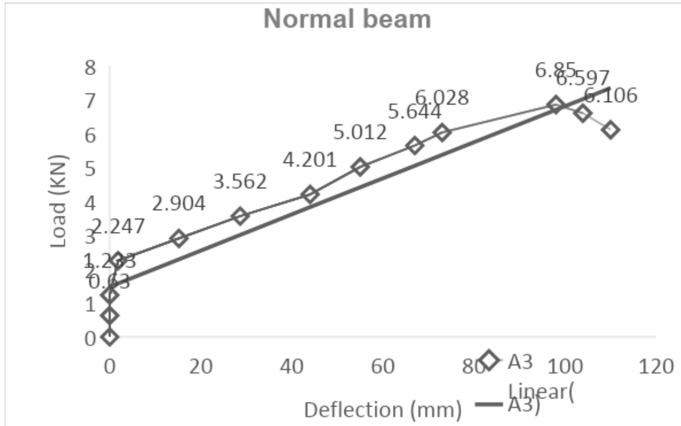
- Result insights from graphs :



Graph 1. Load vs deflection for beam A1

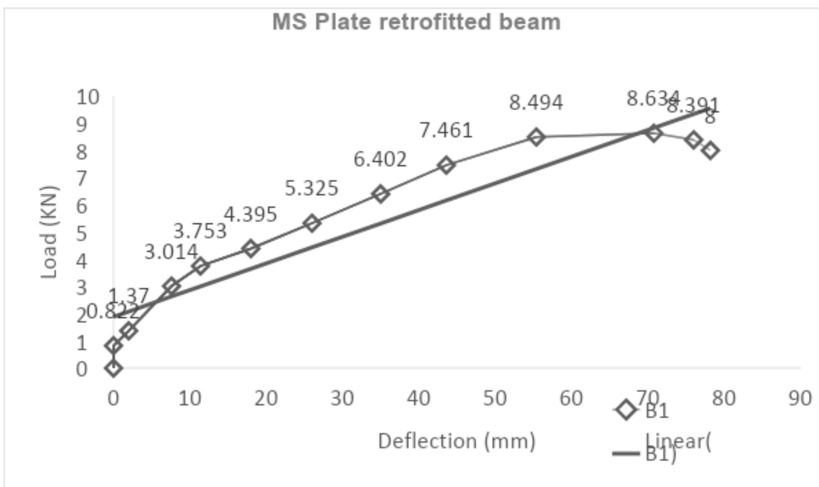


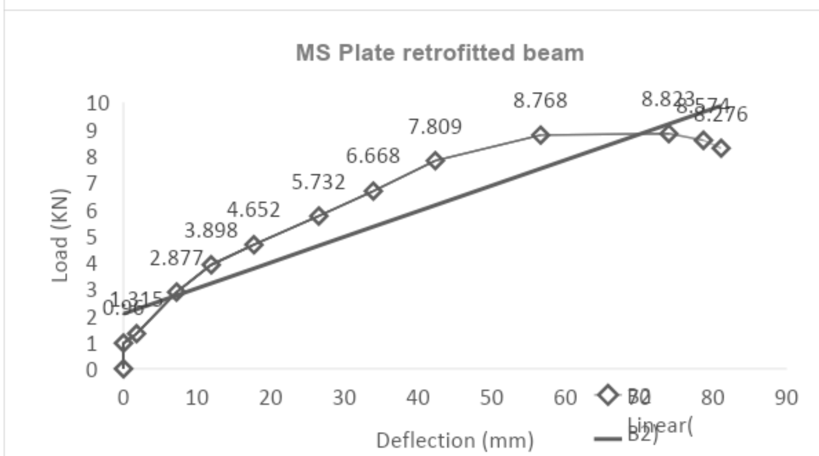
Graph 2. Load vs deflection for beam A2



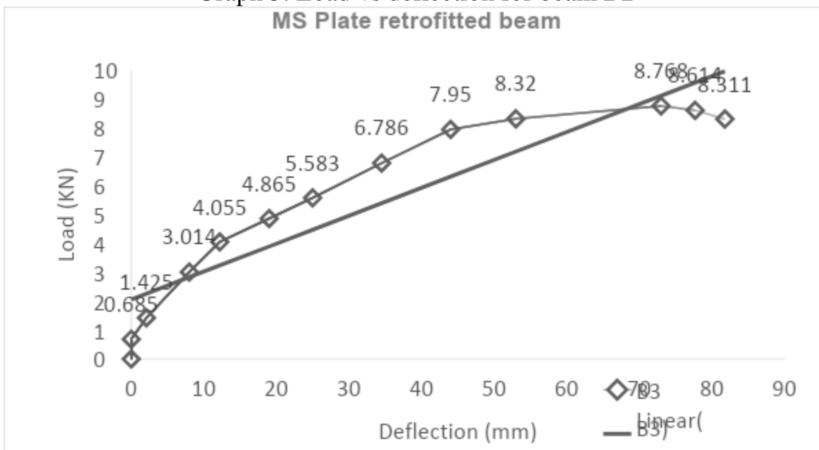
Graph 3. Load vs deflection for beam A3

Graph 4. Load vs deflection for beam B1



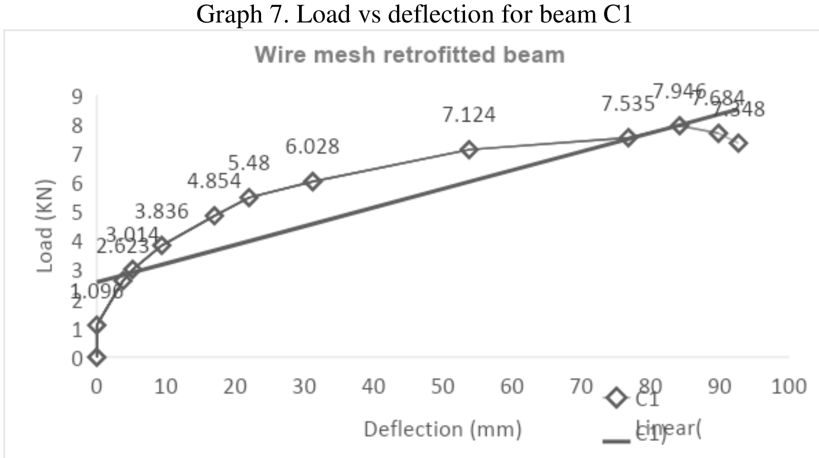


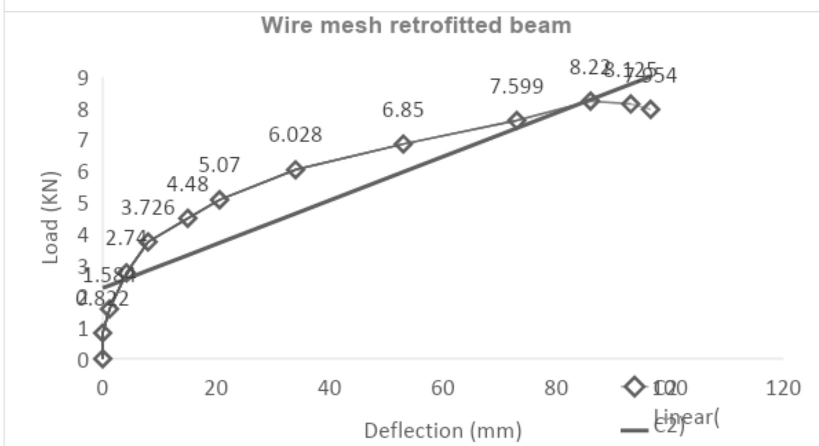
Graph 5. Load vs deflection for beam B2



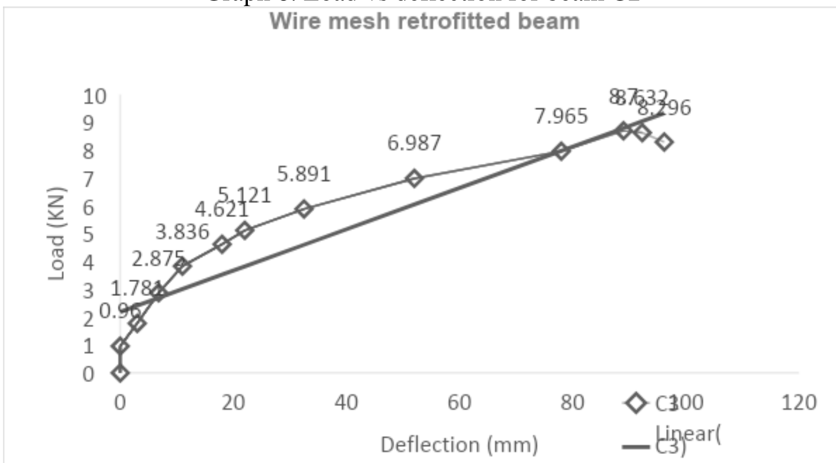
Graph 6. Load vs deflection for beam B3

Graph 7. Load vs deflection for beam C1





Graph 8. Load vs deflection for beam C2



Graph 9. Load vs deflection for beam C3

5. Conclusion

From above results it is concluded that :

- With a deflection of 70.90mm, the beam with MS plate had the least deflection of the three specimens.
- The MS plate retrofitted beam is 5.17 percent better (in terms of load carrying capacity) than the wire mesh retrofitted beam.
- In flexure, a normal beam collapsed with vertical cracks near the center of the beam and diagonal cracks spreading to the ends of the supports.
- When a mild steel plate retrofitted, beam was compared to a regular beam, the flexural strength increased by around 31%.
- Cracks in the retrofitted mild steel plate beam were confined to the central portion of the beam where the steel plate was attached.
- As compared to a regular beam, the flexural strength of the wire mesh retrofitted beam increased by 25%.
- The retrofitted wire mesh beam behaved as a single assembly, with no concrete disintegration or spalling.
- Since wire mesh has a higher strength-to-weight ratio than mild steel plate, it is a more cost-effective form of retrofitting.

6. References

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