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# Effect of 3D, 4D, 5D Steel Fibres on the Flexural Behavior of Reinforced Concrete Beams.

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## INTRODUCTION

Concrete characteristics have long been improved in practice using steel fibers (SF) and synthetic fibers. However, the commercial application of fibers in concrete began in the 1970s, primarily in Europe, Japan, and the USA. Steel fiber reinforced concrete (SFRC) has replaced reinforced concrete (RC) in various applications and has shown improvements in flexural strength, shear capacity, toughness, stiffness, and crack reduction.

Different forms of steel fibers are available, with hooked-end fibers considered highly effective. Recently, multiple hooked-end fibers, such as 4D and 5D, have been introduced. Studies have shown that these fibers significantly improve the tensile strength of SFRC. However, most studies have focused on mechanical properties of small-scale specimens, with limited research on large-scale reinforced concrete structures.

Therefore, the research aims to investigate the effects of fiber dosages and different shapes of hooked-end steel fibers on the flexural behavior of large-scale RC beams. It will consider three fiber dosages (20, 40, and 60 kg/m3) and three types of hooked-end steel fibers (3D, 4D, and 5D), along with two different longitudinal reinforcement ratios

## Experimental Program

The flexural behavior of RC beams with two different longitudinal reinforcing ratios, both with and without SF, was examined to determine the impact of introducing novel multiple hooked ends SF to concrete mixtures. Four-point bending tests were carried out. The specimens were divided into two groups according to the longitudinal reinforcement ratios (0.44% and 1.12%). Each group consisted of 10 beams: (1) one RC control beam without SF; (2) three RC beams for 3D SF which included 20, 40, and 60 kg/m3 (0.25%,0.5%, and 75% by volume) fiber content; (3) three RC beams for 4D SF which included 20, 40, and 60 kg/m3 fiber content; (4) three RC beams for 4D SF which included 20, 40, and 60 kg/m3 fiber content. The total number of RC beams in this study was 20 beams.

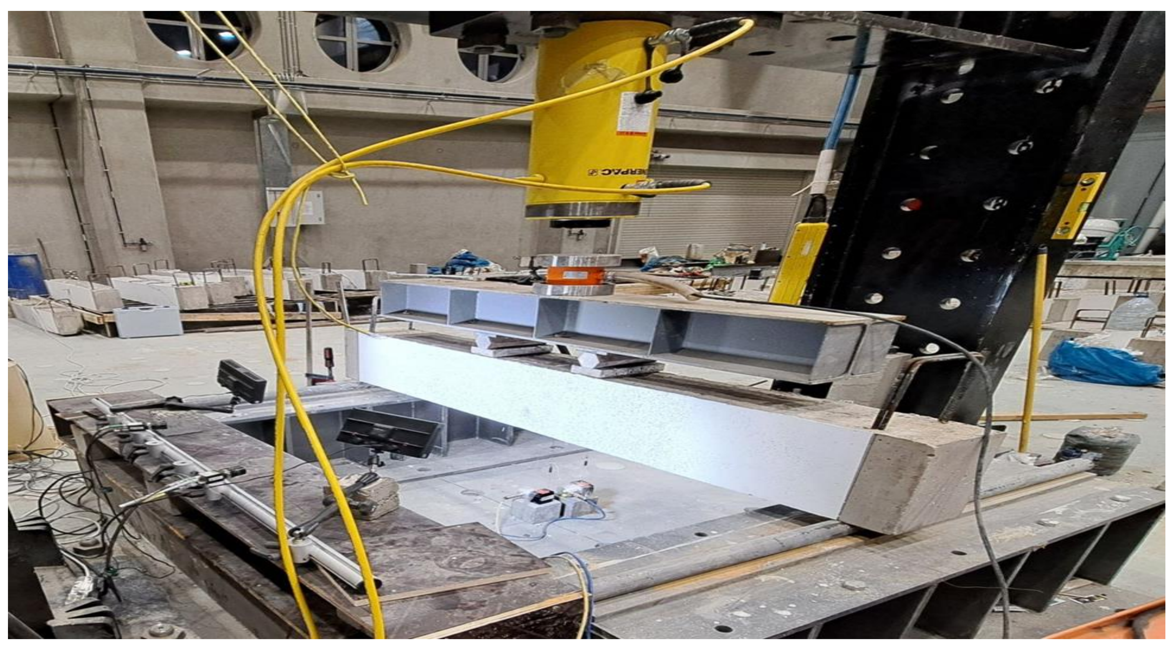

Figure 1 :Test Setup

## The Experimental Results

### Fiber Dosage Effect On Flexural Strength

As Shown from Figure 2 ,when steel fiber is added to the concrete mix at different amounts of 20, 40, and 60 kg/m3, it results in varying increases in the crushing load. For a reinforcement ratio of 0.44%, the addition of 20 kg/m3 of steel fiber leads to a 15% increase in the crushing load, while adding 40 kg/m3 results in a 13.7% increase, and 60 kg/m3 leads to a significant 47.62% increase. On the other hand, for a reinforcement ratio of 1.12%, the increase in the crushing load is 14% for 20 kg/m3 of steel fiber, 9.48% for 40 kg/m3, and 16.19% for 60 kg/m3.

Based on these findings, it can be concluded that the effect of the fiber in improving the crushing load is greater when a lower reinforcement ratio is used. However, it is worth noting that increasing the fiber content from 20 to 40 kg/m3 did not result in significant improvement in the crushing load.

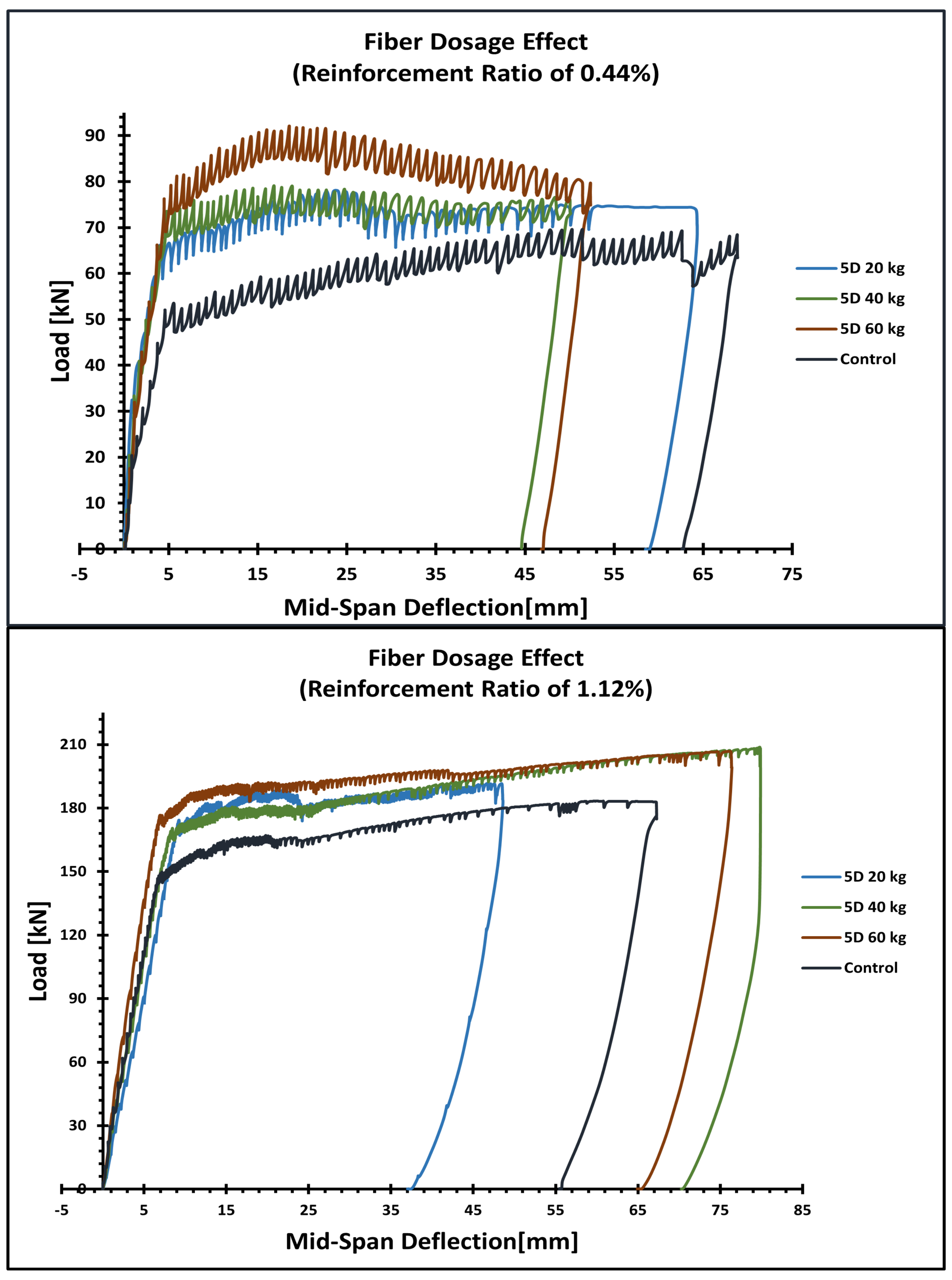


Figure 2 :Fiber Volvme Effect

### Fiber Type Effect On Flexural Strength

According to Figure 3, the addition of steel fiber to the concrete mix at different types, namely 3D, 4D, and 6D kg/m3, with a constant fiber volume of 60 kg/m3, leads to varying increases in the crushing load. For a reinforcement ratio of 0.44%, incorporating 3D steel fiber results in a 25.9% increase in the crushing load, while adding 4D leads to a 31.16% increase, and 5D leads to a significant 47.62% increase. Conversely, for a reinforcement ratio of 1.12%, the increase in the crushing load is 18.358% for 3D steel fiber, 15.54% for 4D, and 16.23% for 5D.

Based on the above observations, it can be concluded that the type of fiber has a slight impact on improving the crushing load in the case of a low reinforcement ratio. However, it does not show any improvement in the case of high reinforcement ratios.

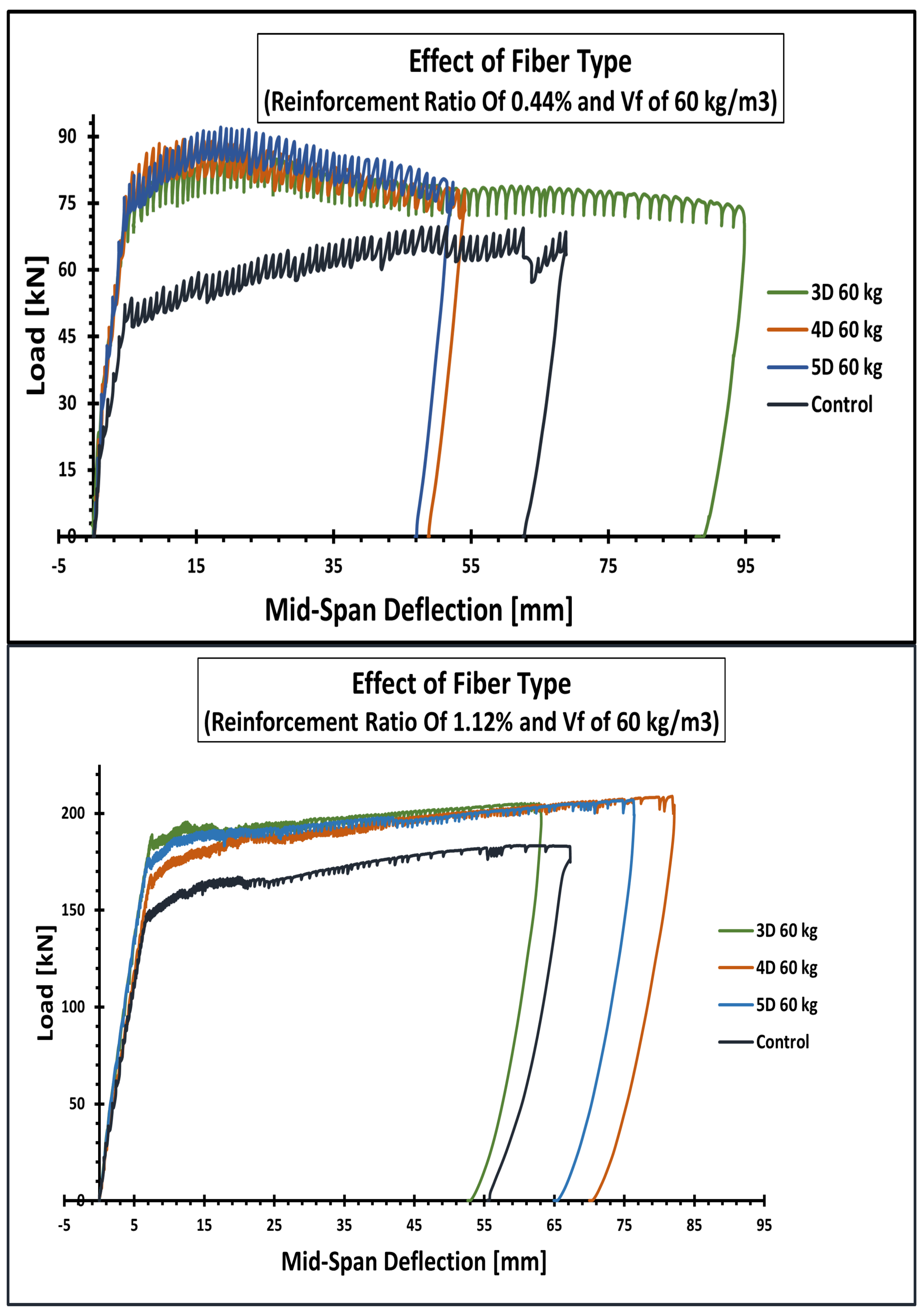


Figure 3:Fiber Type Effect

### Fiber Dosage Effect On Crack Propagation

Figure 4 illustrates typical failure modes and crack patterns based on the fiber volume fraction. The results indicate that the addition of steel fibers and increasing their volume fraction restricts the propagation of flexural cracks into the compressive zone. In contrast, plain RC beams demonstrate deeper propagation of flexural cracks, accompanied by only a small portion of uncracked concrete at the top of the compressive zone. Conversely, the presence of steel fibers effectively inhibits crack propagation, leading to significantly shallower flexural cracks in the RC beams reinforced with steel fibers (R-SFRC). Specifically, when the fiber volume fraction is equal to or greater than 40 kg/m3, a crack localization phenomenon is observed

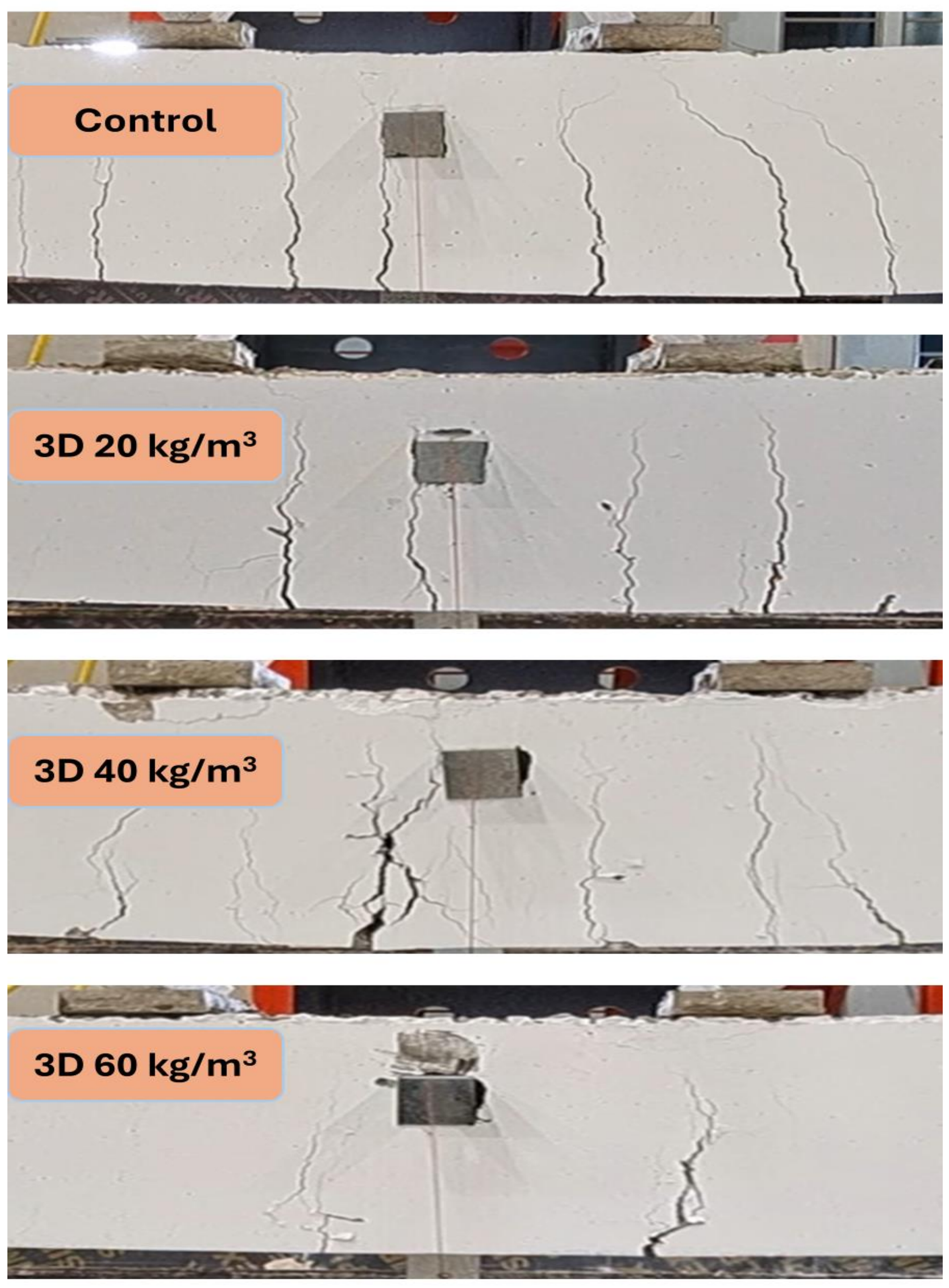


Figure 4 : Typical failure modes and crack patterns based on the fiber volume fraction