Strengthening and repair of RC beams with sugarcane bagasse fiber reinforced cement mortar

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Abstract. The use of a jacket made of fiber reinforced cement mortar with tensile hardening behaviour for strengthening RC beams was investigated in this study. A full-scale test was conducted on beams measuring 1000mm in length. A 25mm jacket was directly applied to the surface of the beams to test its ability to repair and strengthen the beams. The beams were initially damaged and eventually repaired. Three types of beams which included unrepaired beams, beams repaired with normal mortar jacket and beams repaired with 10% sugarcane bagasse fiber mortar jacket were studied. The jacket containing 10% of sugarcane bagasse fiber enhanced the flexural strength of the beams.

1. Introduction
Concrete structures are prone to damage due to natural disasters such as earthquakes or other factors such as heavy traffic loading and aging. It is important to consider whether the damaged structure should be removed, repaired or replaced with a new one. In recent years, many research studies have focused on the repair and rehabilitation of deteriorated structures due to the magnitude of such problems on a global level [1-5]. The major portion of the infrastructure consists of reinforced concrete structures. The corrosion of steel which is normally used as reinforcement in concrete structures due to alkali-silica reactions or sulphate attacks is the principal cause of deterioration. In addition, deterioration could also be caused by impact loads such as the concrete bridge girders damaged by vehicle impact. Such deterioration results in loss of strength and stiffness of the concrete member. The need for rehabilitation and repair and the cost involved are matters of great concern among those responsible for the assessment and maintenance of affected structures [6-12].

Normally, designers prefer to use traditional techniques that utilise externally bonded steel plates or RC jacketing. However, it is now common to use externally bonded fiber reinforced polymer [13]. This technique has demonstrated a certain degree of success, but there are a number of limitations. This is because the R/C jacket can only be used by adding layers of concrete with a thickness of more than 60-70mm because the presence of rebar requires a minimum concrete cover [14-15]. The use of externally glued steel plates as FRP is also limited in terms of fire resistance. This technique may not satisfy the minimum requirement for serviceability limit states [16].

The use of concrete reinforced with fibers has increased in the past 15 years due to its enhanced properties after cracking of the cementitious matrix [17]. Some studies have demonstrated that fiber can be used to partially substitute shear reinforcement in concrete beams [18]. In addition, fiber reinforcement can be used as a total or partial replacement for conventional reinforcement such as rebar or welded mesh. The use of fiber reinforced cement mortar for strengthening or repairing
existing RC beams is proposed in this study. In order to verify the effectiveness of this application, experiments were conducted on full-scale beams measuring 1000mm in length. The proposed technique will consider the use of a thin sugarcane bagasse fiber cement mortar (SCBFCM) jacket which is 25mm thick. The main parameters and effects governing the behaviour of sugarcane bagasse fiber reinforced cement mortar jacketed beams were analysed and discussed in detail.

2. Experimental
The application of the SCBFCM jacketing technique was initially aimed at strengthening and repairing existing RC beams. It was applied to undamaged elements that required a higher load-carrying capacity.

2.1. Beam geometry and material properties
Full-scale tests were performed on beams measuring 1000mm in length with a width of 150mm and a depth of 200mm as shown in figure 1. All the beams were reinforced with three bottom longitudinal rebars (Ø=12mm) and two top longitudinal rebars (Ø=12mm) as well as stirrups having a diameter of 8mm and a spacing of 125mm.

The beams were cast with concrete which has a nominal cube strength of 35MPa. Concrete was chosen in order to simulate the real case of a weak existing beam and to better highlight the strengthening effect.

One of the reinforced beams was used as a control specimen while SCBFCM jackets which were 25 mm thick were applied on two beams. Another two normal mortar jackets which were 25 mm thick were applied on another two beams as shown in figure 1.

The strengthening mortar material had a maximum aggregate size of 0.6mm and a water/binder ratio equal to 0.4 by volume. The mortar was reinforced with 10% (by volume) of sugarcane bagasse fiber. It had a maximum length of 12mm and a maximum diameter of 0.6mm. The compressive strength of the SCBFCM, as measured on the 50mm side cube after 28 days of curing was 11.7 MPa.

A direct tensile test called the three-point bending test was performed on small beams in order to characterise the material under tension.

![Figure 1. Strengthening scheme](image)

2.2. Jacket application technology
The surface of the full-scale beams was hacked in order to produce a roughness that was considered enough to avoid the use of bonding products. The SCBFCM material was directly cast on the beams without any vibration. Since the beams were cured under ambient temperature and humidity, a wet gunny was placed on the surface of the beams in order to limit water evaporation. The SCBFCM jacket was applied 28 days after casting the normal concrete beams while the test was performed 28 days after that.

3. Test Procedures
The full-scale beams were tested using a three-point bending scheme. The beams were placed on a 900mm span and loaded at one point located at a distance of 450mm from the support as shown in figure 2. The LVDT was adopted for measuring the vertical displacement.
4. Results and Discussion
The tests were conducted on the control beams (RC beam without the SCBFCM strengthening jacket), followed by beams strengthened with normal cement mortar (0%) and beams strengthened with SCBFCM jacketing (10%). Figure 3 shows the curve of the total applied load versus the mid-span displacement. The main experimental observations are the following:

- The control specimens indicated the lowest value of deflection which was 5.03 mm. For specimens strengthened with (0%) SCBFCM, the value of deflection was 13.94 mm. The value of deflection for (10%) SCBFCM was 7.37 mm.
- The difference between (10%) and (0%) SCBFCM was 6.57 mm. From the analysis, the SCBFCM improved by 47% compared to normal cement mortar and proved that mortar can be applied in concrete repair.
- The maximum load for repaired (10%) SCBF was 112 kN followed by repaired (0%) SCBF which was 109 kN. The flexural strength for repaired specimens with (10%) and (0%) SCBFCM improved by 13% and 10% respectively.

5. Conclusion
This paper provides information on the structural behavior of beams strengthened and repaired using a thick layer of Sugarcane Bagasse Fiber Cement Mortar (SCBF). Experimental and numerical results demonstrated that this appears to be a promising technique. Based on the results discussed in this paper, the following remarks can be drawn:
- The application of a 25mm thick SCBFCM jacket on RC beams increased the ultimate load by 13%.
- The beams repaired with 10% SCBFCM improved by 47% compared to unrepaired beams.
- The proposed technique provides significant structural enhancement in terms of stiffness due to the remarkable increase of the maximum load of the specimen.

Finally, it is worth mentioning it is possible to increase the durability of the structure by applying the SCBFCM jacket due to the improvement in flexural strength.

6. References

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