2.4 Manufacturing of composite strengthening laminates

A total of six kenaf fiber composite laminates with size of 100 mm x 6 mm x 1400 mm, as shown in Fig. 4, were prepared according to the method used to prepare the composite samples. However, this process is more manpower demanding. Constraint also lies in the period of composites polymerization where precautions have to be seriously taken into consideration. The strengthening laminate was glued with epoxy adhesive onto the soffit of the RC beams after both contact surfaces were roughed down.

2.5 Test on beams

The composite beam samples were prepared and tested according to BS (EN) 1504-4:2004. A total of six beams strengthened with composite laminates were tested for flexural under a four-point load system. Two beams were not strengthened to serve as control samples. Before the test was conducted, three concrete strain gauges and two polymer composite strain gauges were glued respectively onto the top and side surfaces of every RC beam and the surface of strengthening composites laminates. The strengthening composites laminate was ended inside the support. Each beam’s symmetrical cross section (neutral axis) was taken as the reference line to determine the locations of strain gauges at the side of all beams using the common transformed-section method.

Three LVDTs were used and placed at selected positions in order to measure the deflection of beams. Two LVDTs were placed directly under the applied force and a LVDT was placed at the middle span of the beams. The LVDT, 300 kN of load cell and all strain gauges were connected to the data logger. Subsequently, the four-point bending test was set up by arranging the beam at the correct position. The reading of strain gauge and displacement were recorded every 1 kN increment of load. All samples were tested until the subjected load started to reduce and maximum displacement at the middle span had been reached. The structural failure mode was observed visually and the cracks were marked at every load increment.

2.6 Theoretical and experimental moment capacity

The theoretical moment capacity was calculated conventionally according to ACI 440.2R-02 guidelines. Initially, the neutral axis, NA (shown in Fig. 5), was fixed at the centroid of the transformed-section for the strengthened beam. The equation stipulated in the first moment theory derived from Eq. 1 is Eq. 2, while adopted values of compression concrete parameter can be obtained from Eqs. 3 to 5.

\[
\chi = \frac{\sum A h}{\sum A} \quad (1)
\]

\[
\chi = \left( \frac{n_{cu} A_{cu} h_{cu}}{(n_{cu} A_{cu}) + (n_{st} A_{st}) + (n_{ct} A_{ct})} \right) \quad (2)
\]

where:

\[
A_{cu} = 0.9b \chi \quad (3)
\]

\[
h_{cu} = \frac{0.9b \chi}{3} = 0.3 \chi \quad (4)
\]

\[
A_{cu} h_{cu} = (0.9b \chi)(0.3 \chi) = 0.27b \chi^2 \quad (5)
\]

Since the width of beam, \( b = 100 \) mm, therefore:

\[
A_{cu} h_{cu} = (0.9(100) \chi)(0.3 \chi) = 27 \chi^2 \quad (6)
\]

All the parameters that can be calculated include the material modula ratio, \( n_{sc}, n_{cu}, n_{ct}, \) and \( n_{ct} \). The modula ratio is calculated against the Young’s modulus of the concrete, where:

\[
A = \text{Area of the materials (mm}^2\text{)}
\]

\[
h = \text{Distance between centroid of material’s particular area and datum (mm)}
\]

\[
n_{sc} = \text{modula ratio for compression reinforcing bar against the concrete Young’s modulus}
\]

\[
n_{cu} = \text{modula ratio for compression concrete against the concrete Young’s modulus}
\]

\[
n_{st} = \text{modula ratio for tension reinforcing bar against the concrete Young’s modulus}
\]