SURVEILLANCE, INSPECTION AND MONITORING OF FIBRE-REINFORCED POLYMER COMPOSITES

INTRODUCTION

The use of Fibre-reinforced Polymer Composites (commonly known as FRPs) for strengthening concrete structures was presented in Technical Note (TN) 63, discussed the main issues relating to constituent materials and properties and presented the key aspects relating to installation, end performance testing and durability. This technical note, which should be read in conjunction with TN 63, covers the required surveillance during installation of the FRP material system and subsequent inspection and monitoring of the already strengthened structures.

SURVEILLANCE DURING STRENGTHENING WORKS

Knowledgeable personnel in both the material aspects and the installation of FRP systems should conduct surveillance of FRP strengthening works. The surveillance should ensure compliance with the relevant specifications, and standards and material manufacturer's recommendations as required by the specifications. The surveillance officer should be familiar with the project specification, design drawings and the contractor's quality plan including procedures and inspection and test plans (ITPs) for the works. During the installation process the surveillance officer should ensure that the contractor addresses the following list of surveillance items. These are simply a list of recommendations and therefore may be overwritten by actual specification requirements.

(a) Maintenance of Records:–

As per specification, quality plan and safety requirements.

(b) Materials:-

- Conformance of materials with specification;
- Certificates of compliance;
- Scale calibration certificates;
- Handling, storage and correct cutting, with no splits at the ends of materials;
- Batch numbers of adhesives, mixing proportions, times and speed, correct colour; and
- Batch numbers of FRP and approximate location in structure.

(c) Surface preparation of concrete and FRP:-

- Preparation in accordance with the specification and resulting profile; (refer fig 1)
- Surface roughness with amplitude of 0.5mm to 1mm;
- Cleanliness of surface;
- Epoxy injection of cracks > 0.2mm, blow holes and surface defects to be repaired;
- Surface of FRP plate prepared in accordance with material supplier's requirements (distinct rough and smooth sides). Surface of lapped strips prepared; and
- Concrete substrate minimum of 28 days old.

(d) Surface condition and environmental requirements:-

- Surface moisture condition (i.e. dryness) and moisture content (<8%);
- Flatness of concrete surface – gap under a 2m straightedge not to exceed 5mm;
- Air temperature (5 ^{O}C – 35 ^{O}C), concrete temperature (8 ^{O}C – 35 ^{O}C), general weather information (fine, overcast, rain, wind etc); and
- Relative humidity (< 85%), dew point (temperature of concrete surface shall not be less than 3 ^{O}C above the dew point).

(e) FRP plates, strips, sheets or roll and fabrics:-

- Correct orientation and placement tolerances of plates or fabric; (refer fig 2)
- Movement or springing away of plates after coming in contact with the concrete surface
- Carbon fibre plates or fabric in contact with metallic parts;
- Correct amount of resin used;

- Installed fibres are straight with no wrinkles or ripples;
- Visual inspection of each layer to ensure uniformity of fibres and full wetting with resin; and
- Apply protective coating material if required.

(f) Adhesive:-

- Ensure proper mixing and compressive and tensile strength testing per material data sheet;
- Required thickness of adhesive;
- Application of adhesive completed before the end of open time; and
- Correct curing of resin without abnormal loading or vibration.

(g) Inspection and Testing:-

- Visual inspection and tapping to identify air voids, delaminations etc;
- Testing for flatness of FRP plate, laminate, strip or fabric sheet;
- Adhesion (Pull-Off) Testing to verify tensile bond between FRP composite and concrete;
- Tensile strength of substrate if required (>1.5MPa);
- Correct lap splice lengths ; and
- Trial preparation and application as per specification requirements, frequency of testing.

INSPECTION AND MONITORING OF STRENGTHENED STRUCTURES

Routine visual inspections should be undertaken by trained inspectors familiar with FRP systems. These inspections should be on a more frequent basis in the first two years after commissioning (i.e. every six months) and then on a yearly basis, until sufficient confidence develops in the performance of the strengthening system (then reduce to once every two to three years). The following items including extent and location should be checked during the inspection.

(a) FRP on beams, columns and deck soffit:-

- Condition of adhesive contact with concrete and FRP;
- Changes in colour of FRP;
- Delamination of FRP/Drummy appearance (if <35x35mm -o.k, if <400x400mm- adopt resin injection, if >400x400mm-adopt repair/overlap);
- Tears, cuts, cracking, crazing on the surface of the FRP composite;
- Any cracks at boundary of concrete/FRP-strengthened area;
- Any spalling at boundary of concrete/FRP strengthened area;
- Are strain gauges installed? Readings? Estimates?;
- Are temperature gauges installed? Temperature Readings?;
- Is temperature > 60 ^{O}C - 80 ^{O}C? Can affect adhesive;
- Any sensors installed? Take readings?;
- Any signs of damage due to fire, impact, vandalism, any holes cut through the FRP material;
- Condition of existing coating on FRP, any additional coating applied to the FRP since the last inspection;
- Any FRP test areas for pull-off testing over time, arrange for testing;
- Breakage in the anchorage zones- soffit of beams, slabs or flange of T-beams;
- Delamination or peeling away from the concrete at the FRP strip ends;
- Areas of splicing of FRP per drawings – bond slippage, de-bonding;
- Any cracking in the adhesive;
- Evidence of shear and flexural cracking of concrete in the area of FRP strengthening;
- Uniformity of adhesive thickness and any out of plane sections of the strips;
- Flatness/sagging of the strips (not more than 5mm deviation from a 2 m straightedge);
- Any contact of carbon fibre composite with metallic parts on the concrete structure; and
- Any sign of multiple layers of FRP separating

(b) FRP on Deck Surface:-

If the FRP elements have been fixed to the deck surface, then they would normally be covered by a bituminous wearing surface and not be visible. The inspection should note the following:

- Any new cracking or deformation in the road surface in the strengthened area (further inspection of bituminous wearing surface); and
- Readings of any strain gauges or temperature sensors (road surface temperature could reach glass transition temperature of epoxy).

SPECIAL INSPECTION AND TESTING

When a routine visual inspection has identified a problem a detailed inspection and testing should be undertaken by a specialist engineer with appropriate experience of fibre composites who can adequately assess and interpret the findings. Tapping the surface to identify voids and areas of de-bonding is still

considered the standard test for the integrity of the FRP strengthening, although it is somewhat operator sensitive. Several non-destructive methods (i.e. thermal and acoustic etc) are currently at the research stage and they may be more suitable for the laboratory.

They should be used where reliability has been established. The installation of instrumentation such as strain gauges or fibre-optic gauges embedded within the FRP, bonded to the structure or FRP surface or on additional band of FRP for monitoring and testing purposes should be seriously considered for every new FRP strengthening project. Such devices can provide invaluable information as to the ongoing performance of the FRP system as affected by bending and structural in-service live loads or abnormal loadings.

REFERENCES

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3. American Concrete Institute, ACI No. 440-2R (2002), "Guide for the design and construction of externally bonded FRP Systems for strengthening concrete structures".
4. FIB Bulletin 14 (2001), "Externally bonded FRP reinforcement for RC structures".
5. Concrete Society, Concrete Bridge Development Group (2000), Technical Guide No. 3, "The use of Fibre composites in concrete bridges".
6. VicRoads Draft Specification (2003), "Fibre Reinforced Polymer (FRP) Strengthening".

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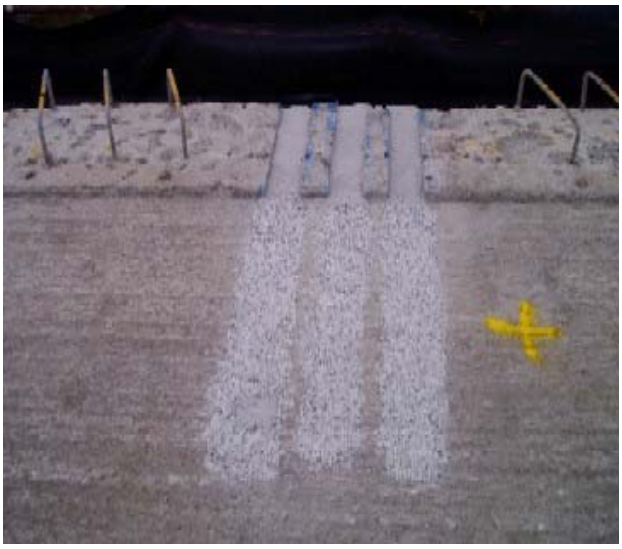

Fig. 1 Preparation of the concrete substrate with acceptable surface roughness

Fig. 2 Placement of the FRP with correct orientation and placement tolerances