Hybrid Concrete/FRP Bridge Development

Reinforced concrete is a “fibre composite” material (steel fibres in a concrete matrix), but is relatively heavy and prone to corrosion, compare with fibre reinforced polymer (FRP) materials. In the USA alone, the damage to concrete bridge decks caused by salting roads during winter runs into billions of dollars. Research has therefore been directed at the use of fibre composites in bridge structures. FRP materials are strong, light weight, and corrosion resistant, but are generally quite flexible and can be subject to impact damage.

Fibre Composites Design and Development (FCDD) at the University of Southern Queensland, Australia began considering ways of combining the benefits of traditional bridge building materials such as concrete with FRP materials and developed an innovative new generation composite bridge that outperforms traditional concrete and steel bridges in a number of areas. Traditional reinforced concrete beam concepts can be used as a starting point to illustrate this hybrid concept (see attached figures). For slender concrete beams under flexural loading it is assumed that the strains vary linearly over the depth with compressive strains in the top and tensile strains in the bottom of the beam. The tensile strength of concrete is extremely low and is ignored when determining the ultimate load carrying capacity. Consequently the main load carrying elements of the beam consist of the concrete compression zone (approximately 20-25% of the cross section) and the steel reinforcement. The two main disadvantages of reinforced concrete beams are the potential corrosion of the reinforcement and the high self weight. The latter in particular is an important issue given the fact that 75-80% of the material that contributes to the weight (concrete in the tensile zone) does not directly contribute to the overall load carrying capacity. The low cost of concrete is probably the main reason that this has not been a major issue in the past. FRP materials can be used to improve this traditional concept in a number of areas. For example, replacement of the steel reinforcement with FRP reinforcement eliminates the corrosion problem. However, this replacement addresses the corrosion issue only, and does not provide any significant reduction in the self weight.

With the steel reinforcement replaced by FRP reinforcement, the main function of the cracked concrete is to locate the tensile elements relative to the compression zone. Locating a number of individual reinforcement bars is considerably more difficult than locating a single tensile flange. Hence, replacement of the FRP bars with a continuous FRP tensile flange is a logical next step. A continuous tensile flange can be easily positioned using a single or double web as is common for steel beam cross sections. By orientating the fibres in the web members at $+45_{o}$ and -45_{o} the webs are ideally suited to carry the shear forces in the beam thereby eliminating the need for shear stirrups. However, the cracked concrete not only located the reinforcement relative to the compression zone, it also enabled the compression zone to carry localised loads. In order to reinstate this capability, additional FRP reinforcement is placed under the concrete compression flange. Composite action between the concrete and the FRP reinforcement can be achieved through use of a high quality epoxy adhesive. Finally, additional carbon fibre reinforcement can be added to the tensile flange in order to increase the stiffness of the beam.

The final “hybrid” cross section combines both traditional (concrete) and new high performance FRP materials to create a highly optimised structure. The weight of the hybrid beam is about 1/3 that of a concrete beam and due to the elimination of all steel, corrosion problems are basically eliminated. Each component can be tailored to suit specific structural functions, which is economical and resource efficient. Such optimum combination of materials in structural design is becoming increasingly important in a highly competitive society. The hybrid concrete-composites concept has been developed independently by a number of researchers and has been recognised as the way forward. However, the way in which hybrid mechanisms have been translated into a real beam structure is significantly different in this concept. The failure mechanism of the FRP box beam concept with integral concrete compression flange (to control serviceability deflections) exhibits pseudo-ductile behaviour.

After development (2001) and extensive evaluation (2002) of the prototype structure (attached illustrations), including testing with a 75 tonne GVM mine haul vehicle, the concept was utilised by Wagners Composite Fibre Technologies (WCFT) for Australia’s first fibre composite bridge in a road network (documented by the BRITE project of the CRC for Construction Innovation, headquartered at the Queensland University of Technology, Australia). WCFT are proceeding with commercialisation of the concept and have recently installed the first bridge of its type in New York State, USA. The leading nature of this innovative concrete/FRP hybrid structure was recently recognised in “Composites Technology” (February 2004). It demonstrates the need to utilise high performance materials in combination with traditional construction materials in order to achieve the price/performance trade-off’s demanded by the bridge infrastructure market.

This innovative concept was developed by staff at USQ involved in a collaborative R&D project involving WCFT, Huntsman Chemical Company, NSW and Queensland state road authorities, the Queensland Department and State Development and AusIndustry. Full commercialisation of this concept (in progress) will provide bridge and deck structures that combine the robustness of concrete structures with significantly reduced mass, and dramatically better durability.

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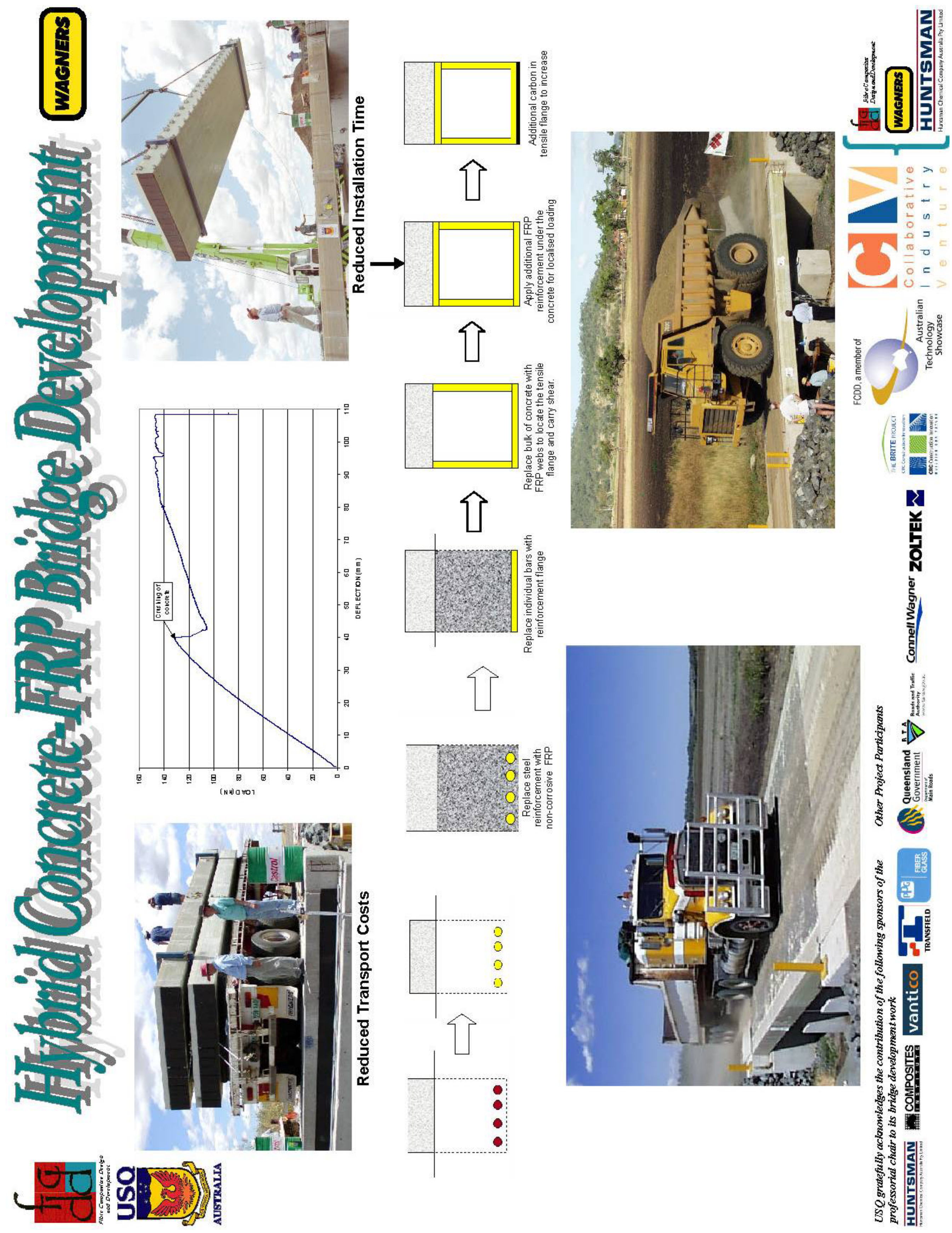
Hybrid Concrete-FRP Bridge Development
Reduced Transport Costs
Reduced Installation Time
LOAD (kN)
DEFLECTION (mm)
Cracking of concrete
Replace steel reinforcement with non-corrosive FRP
Replace individual bars with reinforcement flange
Replace bulk of concrete with FRP webs to locate the tensile flange and carry shear.
Apply additional FRP reinforcement under the concrete for localised loading
Additional carbon in tensile flange to increase
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