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Design and dynamic behaviour of footbridges
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New materials for modern footbridges

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Summary

A brief overview of some developments in the use of new and traditional materials for footbridges is presented, illustrated by some recent examples. The factors affecting the choice of structural material are discussed, together with some of the benefits and dangers of innovation and the advantages of a whole-of-life costing approach.

Keywords: Materials, footbridges, innovation, advanced materials.

1. Introduction

A large number of notable footbridges have been designed and constructed in recent years. Developments in computational techniques and the use of new materials, coupled with the desire to produce something unique and different, have led designers to reach beyond some of the conventional boundaries and explore new bridge technologies and techniques. This paper highlights some recent developments in the use of engineering materials, and touches on a few example both from the author's own experience and from other eminent designers. It is not an exhaustive review, and specifically excludes the repair and strengthening of existing bridges. Instead, the paper concentrates on the use of new materials for primary structural elements in new footbridges.

2. Developments in Traditional and New Materials

Some recent developments in the use of both traditional and relatively new materials are discussed, illustrated by examples, recognising that the latter are often not new materials at all but are merely borrowed from other technologies and used in new applications.

Concrete: Compressive strengths of about 60 to 120 N/mm^2 can be achieved using High Strength Concrete. Even higher strengths are possible, with some loss in workability and ductility in Ultra High Strength Concrete which uses very small size aggregates. Self-Compacting Concrete flows, de-aerates and fills cavities in the formwork merely under gravity, with no need for mechanical vibrators, enabling high quality components to be cast, even in the presence of heavy reinforcement or with complicated geometry.

Stone: Natural stone can be non-homogeneous with discontinuities and cracks which reduce the strength and long-term durability. However, with appropriate material selection, stone blocks can be used, often in conjunction with pre-stressing steel, to produce exciting structures which have a warmth and texture well suited to many urban and rural contexts.

Steel: High performance steels with yield strengths >800 N/mm^2 have been used to reduce the deck weight in long spans, but the challenge with these is to maintain ductility and weldability. Significant developments have also been made in corrosion resistance and in corrosion protection systems, an in the use of high strength stainless steels.

Aluminium: In spite of its relative familiarity, aluminium is only rarely used as the primary structural material for bridges. Improvements in alloy composition and treatments have meant that there are now many different structural grades of aluminium, including high strength weldable grades. With high strength-to-weight ratio and excellent durability, aluminium can deliver an elegant, attractive and durable solution at a competitive price, particularly if an enlightened client is willing to adopt a whole-of-life approach to costing.

Fibre-Reinforced Polymers: Fibre-reinforced polymers combine excellent durability with a high strength to weight ratio, and can be easily formed into a variety of shapes and components to suit the designer's needs. These composite materials essentially comprise non-metallic fibres, typically carbon, glass or aramid, embedded within a polymer matrix. The designer must select not only the appropriate fibre and resin, but also the fibre alignment and the manufacture method, as well as other factors, before he can determine the material properties. Vacuum infusion involves extracting air from the fibre-resin composite to achieve very low air voids and a high fibre to resin ratio. Layers of cloth pre-impregnated with resin are laid in a mould, the air is extracted and the component left to cure, sometimes at an elevated temperature depending upon the resin. Large flat panels can be made in a similar manner. Sections produced by pultrusion have the majority of the structural fibres aligned axially along the length for high axial strength and stiffness. The fibres are pulled through a shaped die as resin is injected, and spirally wound fibres or chopped strands are introduced to provide transverse integrity and bind the matrix together. Components made using vacuum infusion or pultrusion have a relatively high modulus, and since design capacities tend to be limited by strain this permits the use of relatively high allowable stresses. Their properties can be more reliably predicted than those formed by hand lay methods, and this enables the use of a lower partial strength factor in design.

Glass: Glass has been used more and more adventurously in structural applications in recent years, and not just for glazed screens and roofs. Examples are given of structural glass applications in pedestrian bridge decks.

Titanium: Titanium shares many of the characteristic advantages and disadvantages of aluminium, although it is much less commonly used. Relatively large sections and plates are now available and costs are beginning to reduce as more applications are found.

3. Conclusion

New materials and recent developments in some conventional materials present new opportunities for structural expression in footbridges, as illustrated by some recent notable examples. Long term durability and economy is achievable, together with an elegant appearance and high strength-to-weight ratios. The development of suitable design codes and standards will help to increase confidence in their use, and a whole of life costing philosophy would enable their long term economic benefits to be achieved.