

Design of innovative fabric formed beams in shear

John ORR

PhD Candidate
University of Bath,
Department of Architecture
and Civil Engineering.
Bath, BA2 7AY, UK
j.j.orr@bath.ac.uk

Antony DARBY

Reader
University of Bath,
Department of Architecture
and Civil Engineering.
Bath, BA2 7AY, UK
a.p.darby@bath.ac.uk

Timothy IBELL

Professor
University of Bath,
Department of Architecture
and Civil Engineering.
Bath, BA2 7AY, UK
t.j.ibell@bath.ac.uk

Mark EVERNDEN

Lecturer
University of Bath,
Department of Architecture
and Civil Engineering.
Bath, BA2 7AY, UK
me234@bath.ac.uk

Mike OTLET

Director,
Atkins Engineering and
Major Projects,
Oxford, OX29 4AH

Abstract

Concrete is our most widely used man-made material ($\geq 1.5\text{m}^3/\text{person}/\text{year}$) and whilst its constituent materials are widely and readily available, cement manufacturing is estimated to account for some 5% of global carbon dioxide emissions. Recent research has shown that as much as 40% of the concrete used in new office buildings does little but add weight, adding credence to the suggestion that concrete should be cast in variable section elements whose final form is determined by the requirements of the design loading envelope.

However, cost concerns, construction difficulties and an increased complexity in structural analysis have all hampered the widespread use of non-prismatic concrete elements. Recent research at the University of Bath has shown that using simple design methods and replacing conventional steel or timber moulds with flexible sheets of fabric can provide an effective means by which optimised (and therefore low carbon) concrete structures can be cast. The resulting forms have provided us with a new architectural language for concrete structures.

This paper reports on recent advances in the design of fabric formed concrete elements. The shear behaviour of non-prismatic steel reinforced concrete beams is discussed, and the results of an extensive testing program are presented and analysed, with recommendations for code writers presented. The results demonstrate that fabric formwork may be used to create optimised structures in which material is provided where it is needed, providing significant new opportunities for savings in the embodied carbon of our new concrete structures.

Keywords: fabric formwork; shear behaviour; concrete; optimisation; low carbon design.

1 Introduction

It can readily be seen that when subject to a uniformly distributed load, a prismatic steel reinforced concrete beam with constant longitudinal and transverse reinforcement percentages is inefficient. However, by following simple optimisation routines (as described by Orr *et al* [1]) it is possible to design beams whose flexural and shear capacities reflect the requirements of their loading envelope. Such elements tend to be non-prismatic (Figure 1).



Figure 1: Non-prismatic, optimised, fabric formed beams [1].