The Institution of Structural Engineers

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2014/15 Undergraduate Research Grant Scheme

Project title: The stability of stone pinnacles under wind loading

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Aims of research:
Recently, a pinnacle of Beverley Minster came down in a gale, punching a hole in the lead of the high roof and punching a hole in the aisle roof. Similar damage is not uncommon. The rebuilding of such pinnacles has called into question the wind force on a pinnacle, and the method of fixing the stones together.

The general aim of this project is to provide useful data to aid the appropriate retrofit of stone pinnacles. In particular, the aim is to better quantify the expected loading conditions, and to quantify the capacity of existing iron cramp reinforcement techniques.

Description of method:
Initially, site visits to Beverley Minster and similar structures will be conducted to survey the damage and the specific reinforcement techniques employed. The reinforcing methods will be evaluated within the broader context of typical methods used in similar buildings throughout the UK.

Then, to achieve the first aim of better quantifying the wind-induced drag force on pinnacles, wind tunnel testing will be conducted in the Cambridge University Engineering Department. Wind-induced drag forces will be quantified for different pinnacle geometries, including investigation of the effect of the crockets (decorative elements) on the induced drag force. The pinnacles will be 3D printed in the Department of Architecture. Results will be compared with calculations using simple analytical methods.

To achieve the second aim of improving strengthening methods, testing of reinforcing elements and reinforced stone joints will be conducted in the Cambridge University Structures Laboratory. First, testing of the capacity of degraded iron cramps extracted from existing structures will be tested to observe the residual capacity at various levels of corrosion. Second, joints reinforced with iron cramps will be tested in bending to evaluate the tensile capacity of the joint. It is envisioned that mock concrete specimens will first be created and tested, followed by testing real stone joints with iron cramps extracted from existing structures. Multiple tests will be designed so that either the stone or the iron cramp is expected to fail in different tests. Results will then be used to calculate the capacities of case study pinnacles, and evaluate whether iron cramps or other means of reinforcement are more appropriate.

Benefits to structural engineering:
First, the project will improve the fundamental understanding of the wind-induced drag force on stone pinnacles. This will enable the design and retrofit of stone pinnacles under more accurate loading conditions. Second, the project will provide useful data regarding the strength of existing reinforcing methods within stone structures, including data to quantify the capacity of degraded reinforcing, and data to quantify the capacity of stone joints with cramps in tension. This will aid in the repair of existing pinnacles that are significantly damaged, and the retrofit if existing structures where proper reinforcement is not present.

Proposed finish date: May 2015