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Triangular Stone Buttress Cross-Section Designed to Mitigate Damp

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INTRODUCTION

Figure 1. St. Lawrence Church, Abbots Langley, Hertfordshire used as main case study (Cox 2006)

Empirical evidence of damp is found on stone buttresses and their adjoining walls.

A geometrical change in cross-sectional shape from a traditional rectangular section to that of a triangular section has been designed and tested to determine its effectiveness for mitigating damp, and staining, on stone buttresses.

Figure 2. Evidence of damp on Southwest corner, St. Lawrence Church (Simons 2017)

Figure 3. Evidence of buttress damp, St. Andrews Church 2017, Castle Combe, U.K.

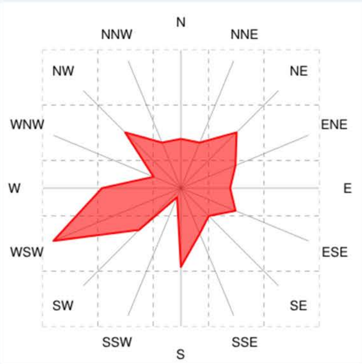


Figure 4. Prevailing magnitude of wind direction intensity for Reigate weather station, U.K. (Reigate Grammar School Weather Station 2017)

CAUSES

Wind-driven rain was determined to be the most likely source of moisture on the buttresses and their adjoining walls.

Watermarks were found near to the base of the buttresses, not to be confused with high wall runoff moisture from roofs.

The facing direction of the damp in case studies were aligned towards the prevailing southwest winds in Southeast U.K.

OBJECTIVES

By changing the geometrical cross-section from a rectangular shape to a triangular one, a design solution could potentiate the alleviation of moisture on said surfaces through a preventative measure as opposed to a corrective one. The experimental shapes have identical cross-sectional volumes; idealised for testing conditions.

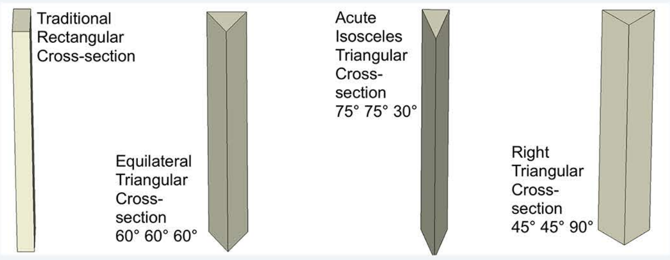


Figure 5. 4 Experimental cross-sectional shapes used in the 3 experiments

METHODOLOGY: 3 Tests

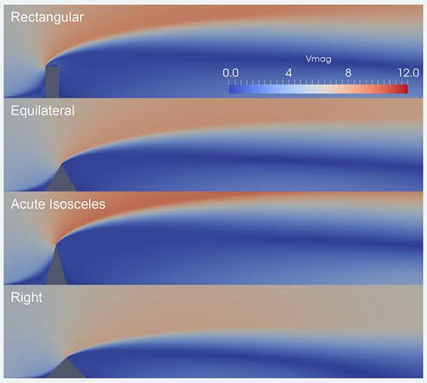


Figure 6. A plan view comparison of the time averaged velocity fields for the turbulent flow over the various shapes (Neal 2017)

CFD Simulations:
Reynolds Number determined the wind flow in Hertfordshire to be turbulent over the 4 buttresses in question.

Time-lapse RANS averages were recorded to potentially link flow vortices to precipitation on the 4 cross-sectional shapes and their adjoining walls.

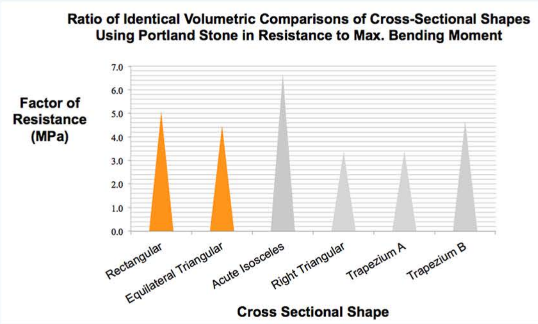


Figure 7. Structural comparisons of the 4 shapes applying the flexural strength of Portland Stone. 2 Trapezium sections were also compared to the rectangular and the triangular sections as potential design solutions

Structural analysis:
The primary purpose of a buttress is to support the lateral thrust of a roof, vault, or arch; therefore ensuring that the 4 shapes are structurally comparable to the rectangular section (> 80%).

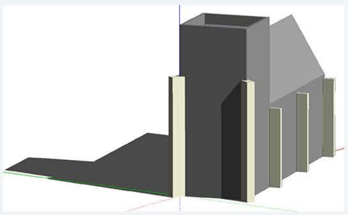


Figure 8. An extensive Autumnal Equinox shadow was cast onto St. Lawrence's Tower from the Rectangular Cross-Section

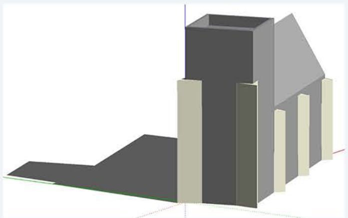
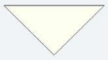


Figure 9. No Autumnal Equinox shadow was cast onto St. Lawrence's Tower from the Equilateral Cross-Section

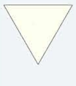
Sun-path shadowing effects:
Shadowing effects impact annual drying durations on stone surfaces due to moisture build-up and lack of sun exposure. This experiment assumed cloudless days throughout analysis. By aligning the 4 shapes with the day arc on St. Lawrence Church during Equinoxes and Solstices, shadowing effects were measured both on the buttresses and their adjoining walls.

RESULTS

Rectangular
The rectangular section has more erratic downstream behaviour, while producing extensive shadowing effects both on itself and adjoining walls. - Figure 6, 8.



Right
The structural factor of resistance did not meet the criteria to warrant a cross section shape change. - Figure 7.



Equilateral
The equilateral triangle was nearly as structurally compatible as the Rectangle while diminishing shadow extensions considerably.
- Figure 7, 9.

Acute Isosceles
The acute isosceles cross section was the structural resistance outlier. Its extensive shadowing affects negatively effected drying times similar to the Rectangular cross section.
- Figure 7, 8.

CONCLUSIONS

The Equilateral Triangular cross-section has the highest potential for replacing the traditional rectangular section buttress for damp mitigation. 3D CFD analysis is needed to further link precipitation wind vortices to the 4 shapes in question.

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MSc Thesis

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ABSTRACT

This paper addresses the problem of staining on stone buttresses and their adjacent, perpendicular, walls due to damp. It hypothesizes a potential geometric cross-section design solution for buttresses to mitigate the effects of staining on stone surfaces. By testing 3 varying triangular cross-sectional properties: An Equilateral Triangular Cross-section, an Acute Isosceles Cross-section, and a Right Triangular Cross-section and comparing all 3 variations in 3 separate test cases to a traditional Rectangular Cross-section implemented for traditional buttress design. Through Computational Fluid Dynamic (CFD) Analysis, there appear noteworthy but not definitive variations regarding the tested 2 dimensional fluid flows over the varying 4 cross-sections in question; more definitive data is needed in a 3rd dimension to draw any decisive conclusions in regards to staining patterns in relationship to fluid flows. The positive fluid analysis outliers however were in the horizontal and vertical flow directionality, the equilateral and right triangular cross-sections created both less stagnation on the windward side and decreased upward directionality for fully developed fluid boundary layers, potentially reducing stagnation flows. Further results strongly indicate in the Shadowing Effect models, both an equilateral triangular cross-section,

and a right triangular cross-section cross-sectioned buttress may increase drying times both along the buttress in question, and more importantly, its adjacent walls due to its triangular sides having increased exposure to sunlight throughout the annual sun-cycle as opposed to a traditional rectangular cross-section. Through cross-section structural analysis of the resistance capacity against lateral roof thrust, the equilateral cross-section is within 80% of the structural resistance capacity of the rectangular cross-section, while the acute isosceles triangular cross-section had an increased structural resistance capacity against lateral thrust than the rectangular cross-section. The right triangular cross-section was insufficient in its lateral thrust capacity and is thus termed unfit for a buttress, of which, lateral support, is its primary objective. The acute isosceles triangular cross-section, however structurally reliable, proved to create as many shadows, both on itself and on its adjacent walls, throughout the annual sun-cycle as the rectangular section. Therefore the equilateral cross-section both mitigated shadowing effects, decreased windward stagnation and upward fluid boundary layer flows, all the while retaining its structural resistance capacity, and is thus the cross-sectional shape noteworthy enough to merit its continued research and application for future implementation for newly built stone buttresses; potentiating a mitigation in damp through simplified design.

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