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Roof Pressure Coefficients in Successive Eurocode Standards: Derivation, Divergence and Implications for Irish Wind Load Assessment

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SUMMARY

This study investigates the evolution of roof wind pressure coefficients in Eurocode wind loading standards by comparing the previous and current Eurocode provisions. For comparable roof geometries and exposure conditions, differences of up to 25% are identified, with significant implications for structural design in wind-dominated regions such as Ireland. The origins of these discrepancies are traced by examining how pressure coefficients were derived in both Eurocode versions and by comparing them with corresponding values in earlier British Standards and the foundational experimental work of N. J. Cook that informed early code development. By analysing the historical basis, methodological assumptions, and empirical data underpinning these coefficients, the study evaluates their relevance to Irish climatic and topographic conditions. The outcomes clarify the reasons for code differences and assess which coefficients provide a more accurate basis for Irish wind load assessment, informing future Eurocode revisions and National Annex development.

Keywords: *keyword 1, keyword 2 (one line of text but not more than 6 keywords, Times New Roman 10 pt italic, use style 'Keywords', keywords must be separated by commas)*

1. INTRODUCTION

Wind actions are a primary driver of both global and local design demands for many building typologies, particularly through roof suctions that govern cladding, fixings and secondary steelwork (Holmes 2015, Simiu and Yeo 2019, Uematsu and Isyumov, 1999). Modern codified approaches reflect the probabilistic description of extreme winds and gustiness developed within wind engineering, with Davenport's statistical framework forming an enduring basis for contemporary design formats (Davenport 1961). Equivalent-static representations and gust-loading-factor concepts have since been refined to better capture background and resonant contributions in practical design procedures (Kareem and Zhou, 2003).

Despite broadly similar calculation workflows across major standards - wind climate, exposure/terrain, peak velocity pressure and pressure coefficients - non-trivial divergence persists between codes and between code predictions and underlying datasets (Stathopoulos and Alrawashdeh, 2020 and Pierre et al 2005). These differences are particularly consequential for roof pressure coefficients, where zoning, averaging area and assumed separation behaviour can materially alter predicted design pressures (Uematsu and Isyumov, 1999).

In Ireland, this issue is timely due to ongoing updates to Eurocode wind-loading provisions and the need to maintain consistency between European harmonisation and national calibration (EN 1991-1-4, Irish National Annex). This modernisation, led nationally through the NSAI Eurocodes National Implementation Programme, necessitates targeted re-examination of wind-loading inputs that directly control design pressures. Historical context reinforces this need: during the earlier transition from British Standards to the first-generation Eurocode, calibration work identified departures from established Irish practice and informed guidance used in Irish design (Arup, 2009, BS 6399-2:1997).

Cunningham et al. (2025) quantifies how revisions to structural factor formulation, peak velocity pressure, net/global pressure coefficients, façade element coefficients and the treatment of upwind terrain transitions can produce marked differences in predicted global actions, with implications that vary strongly by site context and building geometry. However, whilst Cunningham et al. identifies pressure-coefficient issues (including roofs) as a potentially significant change area, the study's primary focus is on *global* outcomes (e.g., base shear) across multiple building typologies and Irish site conditions, rather than on roof-specific effects. Specifically, it notes that the Irish National Annex directs engineers to BS 6399-2 for flat-roof pressure coefficients due to previously identified discrepancies between Eurocode provisions and prior Irish practice. Furthermore, for flat roofs with a representative parapet height (1.1 m), BS 6399-2 Zone F/G coefficients can be substantially higher than the Eurocode values in the second-generation draft for low-rise buildings, with direct implications for the design of purlins, cladding and edge-zone detailing.

Building directly on this analysis, the paper adopts a more forensic, roof-specific focus: examining how and why roof external pressure coefficients have changed between successive Eurocode provisions and what those changes mean for Irish design practice when comparable roof geometries and exposure conditions are considered. This includes comparative analysis of earlier British Standards and the foundational experimental work of N. J. Cook. Roof external pressure coefficients are particularly sensitive to separation and reattachment patterns at roof leading edges, parapets and corners, and they directly govern the design of purlins, cladding, fixings and local load paths. An additional Irish-specific consideration is the treatment of exposure and upwind terrain transitions: heterogeneous Irish terrain can challenge discrete terrain-category approaches and materially affect the peak velocity pressures used in conjunction with external pressure coefficients (Cook, 1997; Stathopoulos and Alrawashdeh, 2020). By tracing historical derivations, methodological assumptions and empirical foundations, the study evaluates whether current coefficients are fit-for-purpose for Irish climatic and topographic conditions and establishes implications for National Annex development and future Eurocode revisions.

2. HISTORICAL CONTEXT

During the mid-2000s transition to the first-generation Eurocode wind standard (EN 1991-1-4:2005), calibration work comparing the Eurocode roof pressure coefficients with BS 6399-2 identified significant differences for flat roofs for selected building geometries. Those discrepancies are important because roof corner/edge zones (e.g., the Eurocode roof zones often denoted F and G) can govern cladding, fixings and secondary members for low-rise buildings.

Because of those identified differences, the Irish National Annex includes an advisory note that redirects designers to BS 6399-2 for determining roof pressure coefficients (rather than using the Eurocode flat-roof coefficient tables). This means that, in practice, Irish roof external pressure coefficients may be taken from BS 6399-2 even when other aspects of wind loading follow EN 1991-1-4 with the Irish NA.

The draft 2nd-generation Eurocode (prEN 1991-1-4:2025) retains the same flat-roof external pressure coefficient values as the first-generation Eurocode. The draft also places these flat-roof coefficients in a normative annex, where Cunningham et al. (2025) notes removes national choice for those specific roof coefficients within the Eurocode framework.

A key practical difference is that the BS 6399-2 flat-roof coefficients vary with the building's windward width, whereas the Eurocode procedure used in the comparison depends on building height and parapet height (not windward width). Using a representative parapet height of 1.1 m (selected in the comparative work to align with Irish building-regulation minimum requirements), the paper shows BS 6399-2 Zone F/G coefficients can be of the order of 50% higher than the Eurocode values for buildings below 20 m height, with continuing (though smaller) differences for mid- and high-rise cases.

3. THE BRE WIND-TUNNEL PROGRAMME

A substantial portion of the experimental basis that underpinned early quasi-static codification and peak-factor style approaches was developed through boundary-layer wind-tunnel testing led by N. J. Cook and colleagues at the Building Research Establishment (BRE) over an extended multi-year programme (Cook, 1982). The BRE facility is described as an open-return boundary-layer wind tunnel, with air driven by a downstream centrifugal fan and controllable mean speeds from approximately 0 to 20 m/s, held to within about 1%. Pressure/force measurements were acquired and processed in real time using a digital data processor, with typical records taken over an observation period intended to represent ~10 minutes at full scale (Cook, 1982).

Cook's tests focused strongly on low-rise structures tested in simulated atmospheric boundary layers generated using the roughness, barrier and mixing-device technique (Cook, 1982). Reported scaling choices were typically around 1:250 (length) with 1:100 (time) for suburban exposure, and around 1:500 (length) with 1:200 (time) for open country.

Matching the intended geometric and boundary-layer simulation scales is critical: a mismatch in linear scale on the order of a factor of two can produce systematic errors, including underestimation of loads in high local suction regions by roughly 20–30% (Cook, 1997). A further documented defect concerns overly aggressive "artificial acceleration" via a barrier that is too high, which can generate excessive vertical turbulence (w-component) and even yield non-physical negative zero-plane displacement values (H_d), signalling a flawed terrain simulation. Acoustic resonance in the tunnel was also identified as a potential contamination mechanism, selectively amplifying frequencies related to tunnel dimensions, and measurement-chain distortions (e.g., tubing dynamics) were addressed by estimating the system transfer function and applying an inverse transfer-function correction to recover pressure time series.

The Cook–Mayne approach is grounded in selecting an averaging period (typically 10 minutes to 1 hour) that lies within the spectral gap of the natural wind-speed spectrum, separating macro-meteorological fluctuations from micro-meteorological turbulence so they can be treated as statistically independent (Cook & Mayne, 1979). The calibration datasets are described as being based on six representative building shapes.

4. METHODS

This paper will benchmark Eurocode roof pressure coefficients against high-quality boundary-layer wind-tunnel datasets rather than relying only on inter-code comparisons. The analysis will use publicly accessible experimental data associated with Gregory A. Kopp and collaborators that will be distributed via the NIST aerodynamic database. This will provide a well-documented, traceable experimental basis for examining roof pressure distributions and peak suctions under controlled boundary-layer conditions, using a dataset that is already widely used for data-to-code evaluation. This will allow a direct, like-for-like comparison between experimental peaks and the roof pressure coefficients currently adopted in Eurocode provisions for comparable roof forms and exposure assumptions. The intent is to quantify where code coefficients provide suitable envelopes and where systematic bias may exist for critical roof regions that typically govern cladding and secondary member design.

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