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# An optimized approach to the structural design of unitized double skin facades

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**SUMMARY:**
Structural verifications of double skin facades are frequently still approached with overdesign of the elements, more than thirty years after their entry into the market and while several revisions of the major codes have been issued. For instance, in EN 1991-1-4 on wind actions, the accuracy of the problem description and of the proposed solutions have been downgraded from the initial version in 1995 to the following ones. The authors believe that façade contractors should propose more optimised calculations, supported by experimental and numerical evidences, especially considering the demand for sustainability that is everyday increasing and will govern the design criteria during the next years. After identifying the different double skin systems, the authors focus on the unitized compact construction type, for which it is already possible to define an efficient structural verification method. Besides the well-established ventilated cavity system, the opposite scenario of closed cavity is becoming more and more common, still being the less regulated in standards. Finally, recommendations will be given to the designer, concerning the use of systems with variable permeability properties, such to manage proactively the load sharing mechanism.

*Keywords: double skin facade, load sharing, closed cavity facade*

## 1. INTRODUCTION

The best practices and structural codes for the verification of the double skin façade under wind loading are nowadays not yet developed enough, especially when the closed cavity façade is considered. Closed Cavity Façade (CCF) (Laverge et al., 2010) is a relatively novel façade system that represents an opposite trend with respect to the classical ventilated façade systems (Ganguli and Dalgliesh, 1968; Straube, 1998). Indeed, when the cavity is ventilated, the behaviour is governed by the pressure equalization mechanism (Van Den Bossche et al. 2020), so under stable conditions the external skin of the façade has an almost negligible net pressure, while the full net pressure applied to the façade is taken by the internal skin. For this reason, in past guidelines for net pressure calculation to verify the strength of each skin, safe side allowance has been considered to take into account the largest possible instantaneous net pressure occurring on the external skin because of imperfect equalization and transient behaviour. Consensus has been reached with regards to a value of two thirds of the external overpressure and one third of the external underpressure, as described along all the revisions of (EN 1991-1-4, 2005). The first version of the code of 1995, contained recommendations for the calculation of the load sharing mechanism in double skin facade under a wide range of permeability conditions. However, further revisions have reduced the scenarios, mainly because the drafting committees have considered that uncertainties did not allow application of an optimized though safe calculation approach. It should be said that during the last thirty years, in parallel with the more frequent use of double skins, several studies have challenged the existing guidelines, suggesting the application of the net pressure criterion only up to a certain value of the cavity depth, and raising a warning about possible underestimations of the net overpressure (Wellershoff and Hortmanns, 1999) , questioning whether the permeability limit set in the code (open surface not less than 0.1% of the surface area) would guarantee sufficient pressure equalization over all the relevant frequency ranges. However, experimental studies were in general targeting large cavities (Gerhardt and Kruger, 1997) and not compartmented cavity volumes. Aerodynamics plays an important role when applying the formers, and it is responsible of significant pressure variation in the different cavity zones.

Existing codes limit themselves to general guidelines (CWCT, 2017), and set strict criteria for their applicability. On the contrary, it would be advisable that they could define criteria for the optimization of the load-sharing (Ricciardelli et al., 2022). In this perspective, the authors believe that, for unitized double skins, an optimized approach is possible and could be applied, also to balance the safety needs with the demand for cost effectiveness and environmental sustainability.

## 2. RESEARCH METHOD AND RESULTS

During the last years, double skin façade systems have gained success mainly because of the excellent performances in terms of thermal and acoustic insulation. Even if characterized by a very large variability of construction types, the favourite design solution is the unitized compact one, with fully compartmented cavity. This type of double skin is not subjected to possible pressure differences along the cavity. On the contrary, the pressure can be considered uniform on the full volume of the single facade unit. This condition allows to apply an optimized calculation approach, based on the mechanical, geometrical and permeability characteristic of the double skin. Permasteelisa Group has developed during the last years a numerical tool (Lori et al., 2022) for the assessment of the design net pressure on the skins, based on one side on the load sharing mechanism by means of the skin stiffness (likewise insulating units) and on the other side on the pressure equalization by mutual permeability, according to Latta’s equation (Van Den Bossche, 2013). When the stiffness governs the behaviour, the cavity pressure build-up is given by the equilibrium between the pressure-volume gas cavity ideal law and the relationship between the net pressure applied on the skins and their volume variation under the same net pressure. The resulting behaviour is summarized for a façade system as in Figure 1.

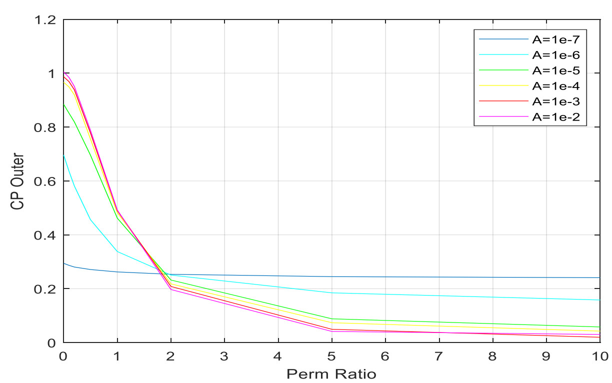


**Figure 1.** External skin net pressure coefficient as a function of the permeability ratio μ between the two skins and for different levels of total permeability A in $mm^2$ (sum of all the cavity outward and inward openings)

Figure 1 was obtained by means of the numerical tool, varying the permeability ratio and magnitude, although maintaining the same mechanical and geometrical system properties. CpOuter represents the net pressure on the outer skin, when a unit pressure is applied to the double skin and it has been calculated for each combination of total permeability A and permeability ratio μ. For systems governed by permeability, the resulting pressure coefficient varies as function of the permeability ratio μ (ratio between the permeability of internal and external skin) as described by Latta's equation. On the contrary, with very small permeability, the load sharing is almost constant with the permeability ratio, matching the load sharing ratio expected for an equivalent fully closed system and representative of the novel CCF system (Figure 2). In between the two extreme scenarios, there is a variety of intermediate cases for which the permeability ratio and the total permeability of the cavity determine the resulting load sharing.

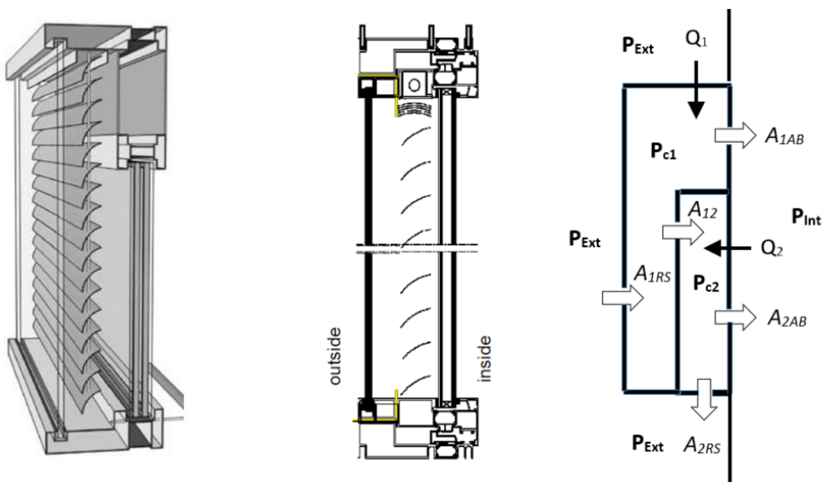


**Figure 2.** Representation of the permeability scheme for a classical layout of Closed Cavity Facade

For instance, Figure 3 shows the relevance of the mean wind component on the assessment of the pressure in the cavity of a CCF. Indeed, the green curve represents the numerically simulated cavity pressure, ignoring the permeability of the cavity, so assuming a fully closed cavity, likewise an insulating unit. It is clear that only by including the permeability effect, mostly acting on the mean wind component, the match of the red numerical curve with experimental measurement will be effective. The numerical tool was calibrated by means of a large testing campaign on several types of double skin, both under controlled testing facility environment and under on site conditions. Its adoption in the design process of double skins allows to use in total 120-130% of the design pressure, shared by the two skins, against the 160-200% that should be adopted when the code specifications are applied. Obviously the proposed approach results in a sustainable, tough safe method that the façade contractor can't ignore, when applicable. Once it is understood how the system works, under the simultaneous action of stiffness and permeability properties, the role of the designer will be in the future to try to build systems with variable properties under variable environmental conditions. So, a system that nowadays has the same behaviour under large and small wind loading, could be designed to change setup, for instance closing or opening holes and gaps, to modify the total and relative permeability in order to move the load sharing ratio in the ideal direction.

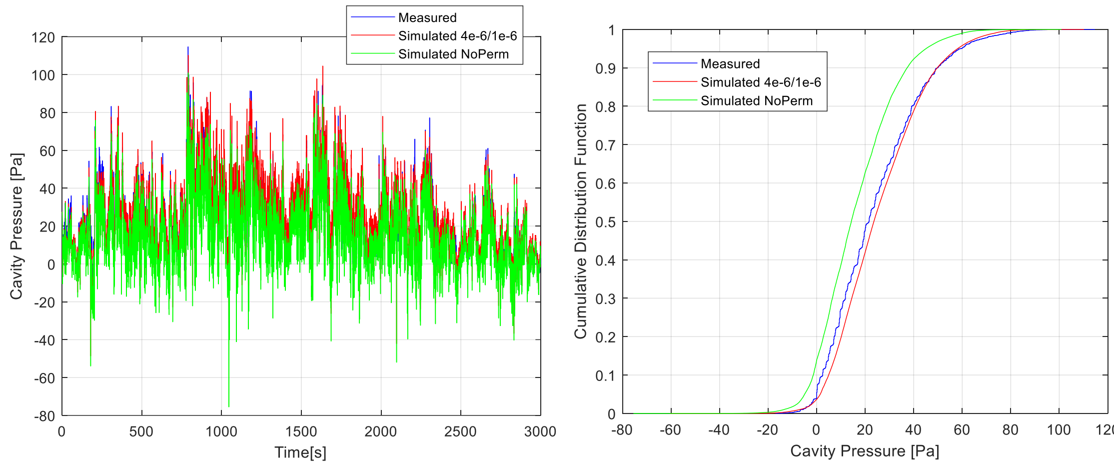


**Figure 3.** Experimental measurement of the cavity pressure for a CCF unit on site (blue) and numerical simulation with (red) and without (green) permeability effect (left). Corresponding CDF of pressures (right).

## 3. CONCLUSIONS AND FUTURE WORK

The adoption of the numerical tool for the analysis the load sharing in double skin façades allowed Permasteelisa Group to develop a design and calculation method for unitized double skins that assess in an optimized way the load sharing behaviour and so the net pressure to design the different skins. This efficient method allows to reduce the total pressure used for design up to 40% the values recommended by codes. Future work will consist of an attempt to simplify the different system behaviours in empirical closed form formulations, suitable for the integration in future codes.

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