Design and operation of transparent adaptive façades from a visual comfort and energy use perspective

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Abstract:

Transparent adaptive façades are building envelope technologies able to dynamically adjust their thermo-optical properties according to environmental stimuli or to external custom-defined inputs. This ability can be exploited to respond to ever-changing performance requirements and boundary conditions, aiming at improving the overall energy performance of a building and/or the comfort condition of its occupants. Although transparent adaptive technologies show high potentialities in improving the overall building performance, both in terms of energy use and visual comfort for the occupants, their successful building integration currently results as a challenging task. This is mainly due to: (i) a low awareness in the possibilities and drawbacks relative to the integration of these components in the building envelope; (ii) intrinsic difficulties of the currently available Building Performance Simulation (BPS) tools to assess their performance on the different domains they affect in a reliable way. As regard the latter aspect, the BPS main limitations were identified in: (i) inability to simultaneously evaluate in an accurate and comprehensive way the effects of the behaviour of a transparent adaptive component on energy and visual comfort aspects; (ii) inability to model complex phenomena relative to the behaviour of some transparent adaptive technologies.

In this framework, the Ph.D. thesis proposes a novel integrated simulation methodology for a simultaneous and comprehensive evaluation, with a high degree of accuracy, of the effects of the behaviour of transparent adaptive façade technologies on the energy performance of a building and on the visual comfort condition of its occupants. As regard the latter, this is evaluated at a spatial level both as daylight availability on the visual task and as daylight glare condition of the occupants. This was enabled by the introduction of a simplified approach aimed at classifying a whole space according to daylight glare comfort classes, by means of solely the eye vertical illuminance. The main advantage of such simplified approach is that of allowing a spatial evaluation of the glare condition with a significantly lower computational effort compared to that necessary for evaluating Daylight Glare Probability (currently the most widespread and accurate metric for the assessment of daylight glare) for the whole space.

The proposed integrated methodology proved to be suitable for the evaluation of the performance related both to passive and active transparent adaptive façade components. In more detail, this one was applied to assess the effects of the behaviour over energy and visual comfort aspects of a passive transparent adaptive component, namely a thermochromic glazing, showing a complex hysteretic behaviour. In addition, the performance of different active transparent adaptive technologies, operated according to both mono-objective and advanced multi-objective rule-based control strategies, was assessed.

The application of such methodology enabled: (i) a simultaneous, accurate and comprehensive quantification of the effects of the behaviour of a transparent adaptive component over energy and visual comfort aspects; (ii) the simulation of complex phenomena relative to the behaviour typical of some transparent adaptive technologies (e.g. hysteretic behaviour of thermochromic and thermotropic

glazing). Such methodology could effectively support with reliable outcomes the decision-making relative to the design and the operation of transparent adaptive components. A comprehensive evaluation of the energy and visual comfort performance of transparent adaptive technologies could in fact increase the understanding of possible risks and advantages related to their integration in the building envelope, helping thus exploiting their full technical potential. As a result, a more aware use of such technologies could make the expected improvements in the building energy use, as well as in the overall visual comfort condition of their occupants, really achievable.