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REVIEW

# A review of design considerations in glass buildings

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**Abstract**
In the past few decades, the use of glass in buildings has remarkably increased. As a result, several transparent buildings have been constructed, in which the materials have almost disappeared. Given that the advancement of architecture is inextricably linked to the acquisition of general knowledge on future developments, this study was conducted to predict the paths of development that glass structures are likely to take in the future. Investigations such as this increase the possibility of advancing both design and construction at the same speed as technology. To achieve this goal, this study evaluates the present situation by investigating new possibilities and assessing their effect on the development of glass buildings. The findings of this study show that the durability, safety, appearance, and efficiency of transparent buildings can be improved through continuous refinement of designs, replacement of aged elements, prompt repair of damaged protective coatings, and greater exploitation of double-sided screens.


**Contents**



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## 1. Introduction

Glass has been used in construction since approximately 2000 years ago (Knaack, 2008; Mocibob, 2008). In recent decades, the application of this environment-friendly material has been developed in the field of construction because of the following characteristics of glass:

- Very high compressive strength (Hess, 2004; Luible and Crisinel, 2004).
- Resistance to corrosion (Hess, 2004; Wilson and Vasilchenko-Malishev, 2005).
- Recyclability (Nijsse, 2003; Siebert, 2002).
- Reduction of energy consumption (Siebert, 2002; Tückmantel, 2009).
- Recent advancements in glass coatings (Bostick, 2009; Tückmantel, 2009).
- Development of computers and programs.
- Growth of the demand for the architecture of thinner and more transparent structures (Bostick, 2009; Luible and Crisinel, 2004).

More transparent buildings have been constructed, in which the visual presence of materials has decreased. To refine the design and construction of transparent buildings and modify their structural behavior, both before and after damage, as well as all the remaining opportunities, should be carefully identified. For this purpose, this study analyzes the opportunities presented by recent advancements to improve both the appearance and efficiency of glass buildings. It then predicts how each novel approach can affect the future of transparent buildings.

The results of the study indicate that scientific and technological progress opens up the opportunities to select the optimum solutions in the course of an interactive design process, to replace aged elements and repair transparent protective coatings in a very short time. Moreover, through the application of revolutionary reversible adhesives, transparent double-sided screens can be fully exploited in glass buildings. Thus, advancements in science and technology ensure that the next generation of transparent buildings are more beautiful, more durable, safer, and even more useful.

## 2. Design optimization

### 2.1. Selection of materials

#### 2.1.1. Laminated glass

Lamination modifies the structural behavior of glass, both before and after breakage (Bon, 2003; Callewaert et al., 2009). On the one hand, laminated glass is more resistant to buckling given that each layer of laminate is laterally supported by other layers (White, 2007). On the other hand, it exhibits quasi-ductile behavior (Vandebroek et al., 2014; White, 2007) because after breakage, the broken pieces of glass remain bonded to the interlayer (Bagger et al., 2007a; Delincé et al., 2008; Hess, 2004). Given that the crack blocking mechanism of the interlayer prevents cracks from opening up over the full width of the laminate (Bos, 2009; Louter, 2011; Louter et al., 2011), the local cracks in one layer can be bridged by the glass fragments of the lateral layers so that forces can be transferred over the cracks via shear in the interlayer (Bos, 2009; Louter, 2011). For this reason, the damaged laminate shows higher residual strength (Bos, 2009).

Moreover, the properties of laminated glass can now be enhanced with the SentryGlas® Plus (SG) interlayer (Bennison et al., 2002, 2006; O'Callaghan, 2003; Puller et al., 2011), so that both larger and thinner (Puller et al., 2011) laminated panels can be manufactured using this interlayer (Bennison et al., 2006; O'Callaghan and Coult, 2007). In addition, given its superior flow characteristics, this interlayer opens up the possibility of laminating metal within the body of the glass (O'Callaghan and Coult, 2007), thereby resulting in thinner joints (Figure 1a-d). Furthermore, the SG interlayer maintains its bond strength and shear stiffness within the temperature range of $-20\,^{\circ}C$ to $+60\,^{\circ}C$ (Bos, 2009; Louter et al., 2011).

#### 2.1.2. Tempered glass

In the process of annealing, glass is cooled slowly (Chinzi, 2013). As a result, internal stresses, which significantly decrease the overall strength of glass, are significantly reduced (CMog, 2011). Furthermore, annealed glass can transfer compressive forces even after breakage because it breaks into large shards (Bos et al., 2005; Feirabend, 2008). Consequently, laminated glass made of annealed glass has higher post-breakage strength (Feirabend, 2008). Nonetheless, annealed glass is not only sensitive to thermal shocks but also unsafe in the case of fire incidents (Veer et al., 2001b; Wilson and Vasilchenko-Malishev, 2006).

The structural performance of glass can be improved through artificial pre-stressing (Núñez et al., 2011). Pre-compression increases the tensile strength of glass, thereby decreasing its susceptibility both to thermal shocks and to static fatigue (Unknown, 2000; Tokunaga et al., 2007; Wurm, 2007). Thus, the cross-sections of structural elements may be thinned using tempered glass (Núñez et al., 2011). However, thinner cross-sections are more sensitive to buckling (Belis et al., 2005).