

# Glass: Superhero in the World of Construction Materials

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The role played by glass in the modern structures is no less than those of superheroes. In each of its application be the “Glass Bridge” in China or “Glass Envelope” of the world’s tallest building Burj-Khalifa, glass ensures that you are thrilled, awestruck by functional performance and mesmerized by its classy and elegant appearance. It has become the enduring symbol of transparency and glittering prosperity. But the journey of glass to this star-status was not easy and still is an on-going process. My research work, performed under the umbrella of Structural Glass Research and Testing Facility at IIT Madras, is part of this on-going process. It consists of evaluating the critical loading scenarios through experimental investigation, analyze it and then formulate effective design methodologies, to ensure safe and reliable application of glass in envelope of high-rise buildings. To understand the technical terms in a simpler and appealing manner, let me draw an interesting analogy between research developments in glass and turning points (milestones) in the lives of superheroes from famous movies/comics. Figure-1 gives an overview and explains the analogy adopted.

**Hidden Potential :** Potential of glass as construction material was recognized from very early times, but its pros like transparency and ability to enhance aesthetics were overshadowed by its cons. Low load carrying capacity, shattering of glass pieces on failure, difficulty to produce the glass of large dimensions or glass with uniform thickness, distortional defects reducing the transparency were some of the major drawbacks. These lacunas limited the use of glass to specific locations like

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\* Mr. Omkar Powar, Ph.D. Scholar from Indian Institute of Technology, Madras, is pursuing his research on “Wind Tunnel Evaluation of Glazed Building Facades with Various Edge Configurations.” His popular science story entitled “Glass: Superhero in the World of Construction Materials” has been selected for AWSAR Award.

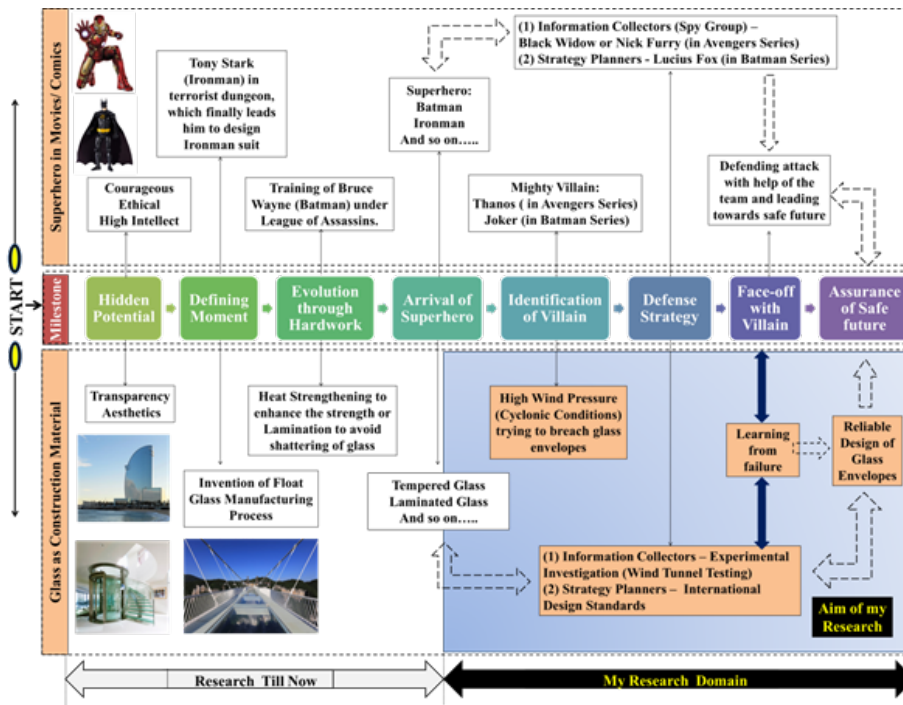


Figure 1: Analogy showcasing Glass as Superhero

windows and gave it a status of ordinary construction material.

**Defining Moment :** Time when the lead character in a superhero movie recognizes that, if he allows his weakness to govern the path for future, then it will lead to a disaster. And hence, he decides to counteract. For example in the movie “Iron Man”, when Tony Stark is kidnapped and put into a dungeon by a terrorist group which eventually leads him to counteract by designing the Ironman suit to rescue himself. Similarly, the defining moment in the life of glass was established by Sir Alastair Pilkington, when he invented the “float glass manufacturing process” in year 1959. This invention allowed the production of large size flat glass with controlled thickness at a comparatively low cost. It also resolved most of the problems related to the optical distortion increasing transparency. This was the defining moment which initiated the process to raise the bar for glass as a construction material and called upon it to embrace its extraordinary destiny.

**Evolution through hard work :** To be a superhero, only recognizing the potential is not sufficient. Skills must be thoroughly polished and weaknesses should be overcome. This was done with glass through the processes like: (1) Heat Strengthening, which enhanced (almost doubled) the load bearing capacity of glass and (2) Lamination, where the two glass panel are bonded together by adhesive interlayer which prevents the shattering of glass by holding broken pieces of glass in place even after failure.

**Arrival of Superhero :** Today, glass has overcome almost all lacunas like low strength,

production difficulties like size limitation and uneven thickness, danger of shattering of glass hurting people nearby, optical distortions and so on. These all are nothing but the super-heroic achievements, expanding the applications of glass at exponential rate and announcing the arrival of a superhero.

**Identification of Villains :** Journey of a superhero does not end with just the attainment of the power and finding the possible avenues to use them. It actually begins when the superhero is confronted by a mighty villain. In case of glass, the villains differ depending upon the type of application. In my research work, I am concentrating on the application of glass in envelopes of high rise buildings. It is a well established fact that the wind loads increase rapidly with increase in height of building. Hence, high wind pressure acting on the surface of the glass panel trying to breach the envelope, is identified as the major villain. The primary objective of my research is to formulate strategies to ensure safety of these glass envelopes under extremely high wind pressures, as even a small breach in envelopes has dangerous consequences. First of all it restricts the building from performing its most important and primary function, which is to protect the occupants from harsh exterior environment. It also alters the pressure inside the building, increasing the chances of propagation of envelope failure to a large extent. Once this first line of defense formed by envelope falls, all the expensive interior is exposed to the secondary villains like rainwater, which further increases the economic loss. Failure of glass at higher elevation also endangers the life of people in proximity and in the case of cyclone these broken glass panes add to the wind-borne debris, which can cause serious injuries even to people far away. All these consequences emphasizes the need of the current research which aims to pave the path towards safe and reliable design of glass envelopes in future.

**Defense Strategy:** No superhero can be effective against the mighty villains unless he has a strong team backing him. Generally, team consist of “Information Collectors” a group of spys (like Black Widow or Nick Furry in the Avenger Series) who collect all the critical information about the villain like his plan of attack, time of attack and so on. One of the major objective of my research is based on the task performed by this team. As discussed, in case of glass building envelopes, wind load are the major source of damage (main Villain). Hence, the information like wind pressure distribution over the envelope surface and the direction of critical wind load are very important. In my research, this task of acquiring information is accomplished by performing several wind tunnel tests on scaled models of the high-rise building. In this testing , the wind profiles resembling the actual wind at building location are simulated with help of big fans inside a tunnel shaped experimental setup. Then these generated wind profiles are passed over the building models, which are planted with the pressure gauges to measure the pressure distribution over the envelope surface. This experiment is repeated for 36 wind directions (at interval of 10 degrees) so as to ascertain the most critical wind load and its direction. Further team of superhero also consist of “Strategy Planners”. This is the group which analyses the information obtained and make superhero ready to take up the challenge presented by the villains.(E.g: Techno-genius Mr.Lucius Fox, who helps the Batman to design his Bat-suit and Bat-pod (modified street-bike) in Batman Series). In my research this role of strategy planner is performed by “International Design Standards” which

provide guidelines on how to design glass panels for the wind loads. I have developed a computer program, based on these guidelines to help reliable design of glass envelopes. Program can be linked with pressure data obtained from wind tunnel test and ascertain the level of safety available as per the different glass design standards. Results from parametric study showed that there are some limitations and inconsistencies, which need to be overcome to increase safety in design of glass envelope. Details of this study are discussed in my paper titled “Issues in Probability Based Design of Architectural Glass in Building”, presented at the International Conference on Advances in Glass Sciences and Technology held at CSIR- Central Glass and Ceramic Research Institute, Kolkata in January 2017.

**Face-off with Villain:** This is the unwanted situation where mighty villain attacks. In real life, this situation arise when extreme wind events like cyclone hits the urban landscape and glass building envelopes here are challenged by the high velocity winds. I was able to witness one such event when Cyclone Vardah caused destruction in Chennai and surrounding areas. Events like this though very unfortunate, can be considered as an opportunity to learn from the failures. Hence, immediately after Cyclone Vardah, I carried out a detailed field investigation with specific focus to evaluate the failure of glass building envelopes. The information obtained from observation of 164 building envelope failure is classified into different categories, damage potential of each category is ascertained and the corrective measures are being formulated. The research paper about learning from failure during Cyclone Vardah is in process and will be soon available in public domain.

**Assurance of Safety:** This is the final milestone and sole purpose of a superhero, which is in sync with the direction of my research work, to achieve safe and reliable design of glass envelopes in high-rise buildings. With this research I wish to contribute a step towards establishing glass as the superhero in the world of construction materials.