Design And Analysis Of An Aerodynamic Window Lintel For Air Drag Reduction On A Square Cros Sectional Structure

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Abstract. Every building must be provided with some way of ventilation or a streamlining design to reduce the air drag and turbulence, in order to prevent stress on the underlying pilings. Every multistorey building in a cosmopolitan city is constructed with a non-rectilinear structure such as helical, circular, etc to be a streamlined structure. For the vent/passage of air, there are some cases where they left an entirety of a floor to ensure air passage. But, looking at the layout we can conclude that there is a massive waste of the carpet area/ living space. So, in order to reduce the effect of turbulent air on a regularly shaped building, a modification in the design of the regular window lintel is made. A normal window frame/lintel, which is usually provided for shade and as a canopy, is constructed with bricks and cement. Considering a sample lintel, it has more than 2 feet in depth. Now, using this length can be made a design that can reduce the turbulence of the air that is passing through the building. This helps us to reduce the air drag and stresses on the building's pilings or joints, without wasting much of the area. Considering the elevation, the design will be made to look aesthetically pleasing. A comparative study will be made with respect to the published papers and past theories.
Keywords: Lintel, Stream Lining, Aerodynamics, Turbulence

1 Introduction

Construction of tall buildings and other structures increased significantly in the second half of the 20th century, especially in developing economies. Construction of tall buildings was in its infancy until the 1970s. The approaches used by structural engineers to create tall buildings during that decade demonstrated a noticeable increase in complexity, and the design trends of enormous unresponsive structures were discontinued.[1] .The changes in altitude result in variations in wind velocity. Powerful winds, such as gusts or typhoons, can cause extensive destruction and damage to the internal structure of buildings. Only over Gujarat and south Tamil Nadu have winds that average more than 15 kmph in India. Wind speeds of 10 to 15 kmph are common in some areas of Rajasthan, west Madhya Pradesh, Maharashtra, north Karnataka, neighbouring Andhra Pradesh, and some areas along the west and east coasts.[2]

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Globally, There are some peak cases of gust winds such as: Typhoon Maemi, which made landfall on Miyakojima Island in Japan in September 2003, had a maximum peak gust of 74.1 m/s (the seventh highest recorded in Japan) and a lowest pressure of 912 h Pa (the fourth lowest recorded in Japan), as measured by an official meteorological station on the island.[3].

The major issue in the structural design of a modern skyscraper is related to the behaviour under lateral loads, and in particular to its slenderness, which can be quantified by means of the aspect ratio, i.e., the ratio of the height to the footprint depth of the lateral load resisting system [4]. A concept of diagrid structures, has become one of the most widely used lateral load resisting methods for tall buildings over the past twenty years. The fundamental concept is simple: increase the shear stiffness of the structural pattern in the façade while maintaining the bending efficiency of the tube structure. In order to accomplish this, the diagrid is designed as a small grid of diagonal members arranged in a triangulated tessellation similar to the building façades. Under lateral loads, diagonals serve as both inclined columns and bracing elements, carry only axial forces, and experience only axial deformations, minimising racking deformations and shear lag effects, which are the main causes of tube inefficiency [5]. To mitigate the negative effects of turbulent winds, the creation of building openings as a minor adjustment involving removing façade features from service floors while keeping the basic structure intact was performed. The most efficient placement for a single opening was found to be at 70% of the building's height.[6] A square-sectioned tall, lean skyscraper was the subject of a wind tunnel research. By adding apertures or "gaps" to the top part of the building, the aerodynamics are changed. These holes run the length of the structure. Two types of data are presented and various gap sizes are studied. The impacts of these gaps on the total forces and reactions of a 9:1 aspect ratio building, as measured by a high frequency force balance, are covered first. Second, a 2-dimensional model evaluated in uniform flow is used to examine the effects on the time-varying pressures.[7] However, this results in a significant reduction in usable floor space. Thus the thought of making a new device got replaced with an idea of altering the design of a regular body, making sure to reduce the floor wastage. A two-stage aerodynamic lintel design has been developed on FUSION 360. The lintel is initially designed with specified dimensions that allow it to divert wind in any direction within a 180-degree range.

To ensure the design's effectiveness, Computational Fluid Dynamics (CFD) was conducted to evaluate the velocity gradient of strong winds. The design incorporates two stages of air damping, including the beak of the lintel at the front edge and the propeller system in the lintel's groove, acting as a secondary air damping mechanism and a means to generate electricity. Since, the idea of drag reduction of a high-rise building is combined with wind energy extraction in exit channels. The accumulated air is thus used for turning the fans of the generator. [8] This led to the idea of power generation in buildings. So, the thought of power generation in a building is put forth in a form of an exhaust air energy recovery wind turbine generator, where the hot air from the ducts and exhausts of a building leave and travel up due to their low pressure characteristic and an two vertical axis wind turbines (VAWTs) positioned in a cross-wind configuration has been set up above a cooling tower to generate electricity using the wind discharged from the tower. The installation has been placed at a particular distance and location above the cooling tower outlet. The enclosure, comprising of multiple guide-vanes and diffuser plates, serves as a wind power enhancement mechanism to enhance the effectiveness of the VAWTs [9]. The Wind turbine is huge and is installed on a terrace, the same methodology of VAWT can be replaced with HAWT (Horizontal Axis Wind Turbine) where a horizontal axis provides housing for propellers that are connected in series to the common axis, which we call it a shaft. These propellers are made to rotate due to the wind which in turn rotate the shaft to produce energy.

2. EXPERIMENTAL PROCEDURE

2.1 Design of the lintel

An aerodynamic lintel has been designed in Fusion 360 that is used to dampen air blowing from 180 degrees. The lintel is equipped with a shaft and a propeller, which is powered by the damped wind that gets accumulated and turns the blades, producing electricity. The wall mount provides

Fig 1**:** Dimensions of lintel

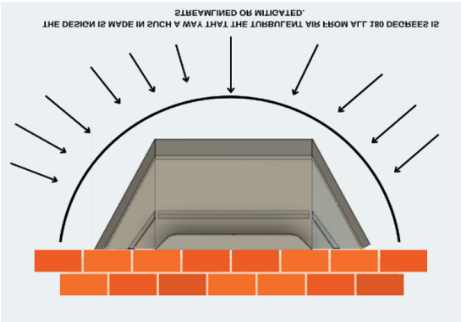

Fig 2: 180-degree wide angle

housing for the wiring to be connected to the lintel. The lintel is designed to be aerodynamic and efficient, allowing for maximum energy production. The frontal region is designed in the shape of a beak, which helps to divert the turbulent air away from the lintel. Additionally, a panel with a depression angle is provided to further divert the damped air towards the shaft, allowing for maximum energy production. The dimensions of the lintel are 48 inches in width, 24 inches in depth, and 7 inches in maximum breadth. The longitudinal stability for modern fighters flying at a high angle of attack reduces as the angle of attack rises. Even at small angles of attack, flying wing aircraft can experience these situations; in particular, the lift curve exhibits a nonlinear increase and the nonlinear change in pitching moment has the potential to become unstable.[10] Hence, the future design modifications can be made in this perspective

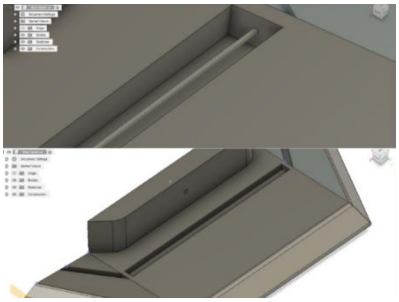

Fig 3**:** slotting for accommodating propeller system

Fig 4**:** Placement of lintel

Propellers with 3 blade separated at 120 degrees each are placed along the shaft that is provided in the depth cut of the lintel. The air is made to concentrate at the propeller region, to generate electricity and as well as act as another mitigating stage.

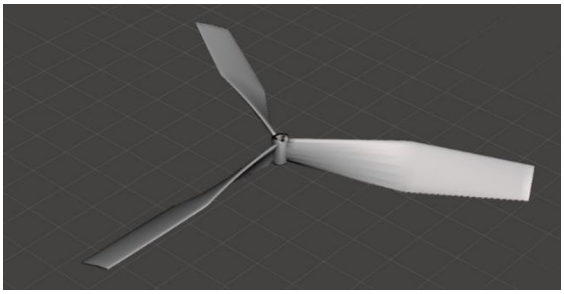

Fig5 : Propeller with 3 blades each at 120-degree separation

Carbon Fibre: Carbon fibre combines strength with a low weight making it an ideal material for aircraft and motor racing parts where weight is a premium. Its use in the printing industry for rollers and cylinders is not well documented despite the fact that it is being used, albeit infrequently, and its use is normally not advertised [11]. According to Material Science journal, the properties of Carbon Fibre are suitable for making a lintel. Carbon atoms are joined in a long chain via chemical bonds to create carbon fibre. The fibres, which have great stiffness, strength, and lightness, are employed in a variety of processes to produce top-notch building materials. To make composite parts, carbon fibre material can be broken down into a number of "raw" building pieces, such as yarns, uni-directional weaves, braids, and more. A carbon fibre component has characteristics similar to those of steel and weighs about the same as plastic. Therefore, a carbon fibre object has a far higher strength to weight ratio (as well as stiffness to weight ratio) than either steel or plastic. Carbon fibre is incredibly robust. Carbon fibres can be used in the construction of the lintel due to their high vibration damping nature. [12]

Table 1: Material Data Sheet of ABS

Physical Properties	**Metric**	**English**	**Comments**
Density	1.04 g/cc	0.0376 lb/in^3	Grade count = 3
Melt	18-23 g/10 min	18 -23 g/10 min	Average = 21.3 g/10 min; Grade Count = 3
Mechanical Properties			
Hardness, Rockwell R	103 - 112	103 - 112	Average = 110; Grade Count = 3
Tensile Strength, Yield	42.5 – 44.8 MPa	6160 – 6500 psi	Average = 44 MPa; Grade Count = 3
Elongation at Break	23 – 25 %	23 – 25 %	Average = 24.3 %; Grade Count = 3
Flexural Modulus	2.25 – 2.28 GPa	326 – 331 ksi	Average = 2.3 GPa; Grade Count = 3
Flexural Yield Strength	60.6 – 73.1 MPa	8790 – 10600 psi	Average = 68.9 Mpa; Grade Count = 3
Izod impact, Notched	2.46 – 2.94 J/cm	4.61 – 5.51 ft-lb/in	Average = 2.8 J/cm; Grade Count = 3

ABS: Acrylonitrile butadiene styrene, also known as ABS, is a popular thermoplastic polymer that is frequently utilised in injection moulding applications. This engineering plastic is well-liked because it is inexpensive to produce and is simple for plastic makers to machine. Even more, the ABS material's desirable qualities are not compromised by its

inherent advantages of cost and machinability: 1.Impact Resistance 2.Structural Strength and Stiffness 3.Chemical Resistance 4.Excellent High and Low Temperature Performance. In the below Table 1, the various properties regarding ABS is shown.

Moulding is a process of shaping or forming a material such as plastic, metal, or wood into a desired shape. It is done by using a variety of tools and techniques, such as casting, extrusion, injection moulding, and blow moulding. Moulding is used to create a variety of products, from everyday items such as cups and plates to complex parts for vehicles and aircraft. It is also used to create custom parts for industrial and medical applications. This is one of the process that are greatly preferred in manufacturing industry because it can produce complex-shape plastic products and having good dimensional accuracy with short cycle times typical examples are automobile industry, casings and housings of products such as computer monitor, mobile phone and which has a thin shell feature [13].
Moldex3D is a software package that helps to simulate the entire injection moulding process. It can help to optimize the mould design and process parameters to reduce costs and improve product quality. It can also be used to simulate the filling, packing, cooling, and warpage of the moulded part. This helps to ensure that the part meets the required specifications and performs as expected. Generally, materials that are suitable for moulding must be able to withstand high temperatures and pressures, have good flow characteristics, and have a low shrinkage rate. Other important properties include impact strength, chemical resistance, and surface finish. Hence, ABS has been used for a testing sample of moulding operation.
The following figures describe the process of moulding through simulation. Various parameters such as Filling time, Filling pressure, Melt front time, Cycle time, Ejection temperature etc are displayed with their values. The figures also show the temperature profile and the pressure profile of the moulding process. The temperature profile shows the temperature of the moulding material at different points in the moulding process. The pressure profile shows the pressure exerted on the moulding material at different points in the moulding process. The figures provide a visual representation of the moulding process and allow the user to adjust the parameters to optimize the process. The figures can also be used to diagnose any issues that may arise during the moulding process. The Lintel is shaped into two identical panels to make it easier to replace if needed.

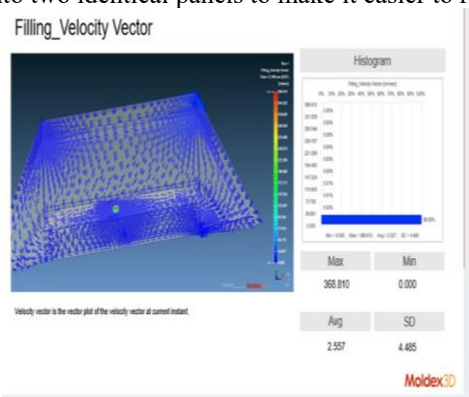

Fig 6: Filling velocity vector

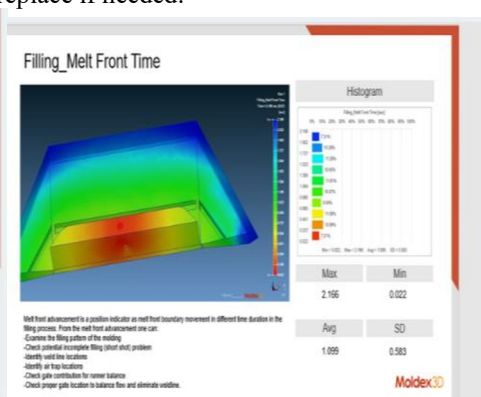

Fig 7**:** Melt Front Time

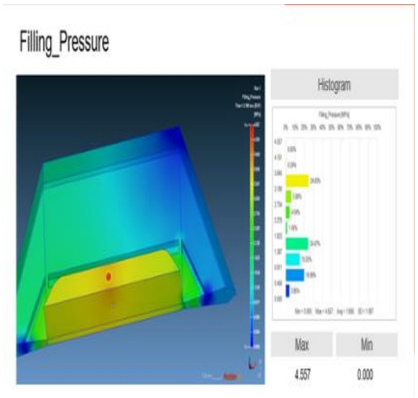

Fig 8: Filling Pressure

Summary - Process Condition

Cooling	Item Data	Unit
Cooling Time	25.6	sec
Mold Open Time	5	sec
Ejection Temperature	163	°C
Air Temperature	25	°C
Cycle Time	46.02	sec

Fig 9: Pressure condition of moulding process

Based on the available metrological data, the Mumbai region's average wind speed is approximately 10 metres per second. It is possible to simulate the airflow around the building as a Newtonian fluid with a turbulent, viscous, incompressible, and steady flow. The body force can be disregarded because the flow behaviour is defined by mass and momentum conservation with an appropriate turbulence model.[14]
Hence, Ansys Fluent software was used to import the IGES file of the design and generate the geometry. A Boolean was created, tool and target bodies were assigned, and the inlet velocity face and outlet pressure face were selected using the geometry. An enclosure was created around the lintel, treated as a Surrounding Flow Channel, where air flows. Mesh was generated and the setup was initiated, selecting the Viscous-K epsilon model and air as the fluid. In the boundary conditions, the velocity of air was entered as 15kmph, the average speed of air in India on a normal day, and 200 iterations were entered. The solution was then run and the results were observed in the end.

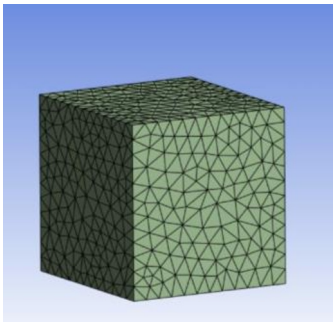

Fig 10**:** Mesh

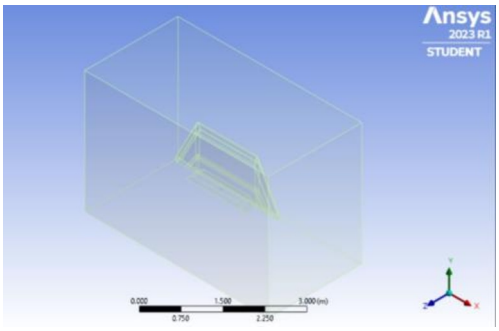

Fig 11: Enclosure around the Lintel

3.RESULTS AND DISCUSSIONS

The use of computer simulation has increased significantly during the last few of decades. Although modern CFD software is becoming more user-friendly and precise than it ever was, mesh production for a model can still be challenging and take a lot of skill. These programmes are reusable over and over. Moreover, a wide range of test cases can be used to evaluate flying capabilities in diverse contexts. There are also numerous programmes that are easily

accessible and have a high degree of dependability. The cost and time needed for prototyping have decreased significantly with the application of CFD throughout the years, hastening the design and development of contemporary aircraft [15]. The Ansys Workbench software is used for the component analysis. The simulation's output allows us to determine the degree of turbulent air damping as well as potential adjustments to the geometries, which we can then adjust during the design phase. The results are shown in the graph below.1. The Y-axis shows the air-damping of fluid flowing the lintel 2. Throughout the 200 iterations there is a significant decrease in the inlet velocity of air 3. The epsilon graph which represents the turbulent kinetic energy dissipation is shown. 4. The possibility of producing the lintel using moulding or other thermoforming methods is confirmed by the Moldex-3d simulation.

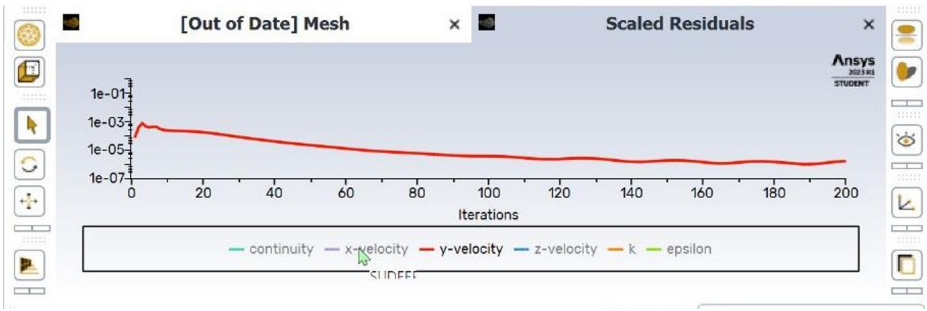

Fig 12: Decrement of velocity throughout the iterations

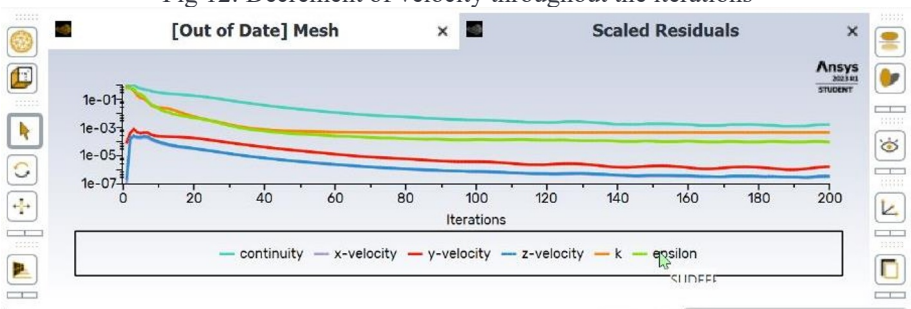

Fig 13: Result after CFD

4.Power generation through propellers:

The formula given for calculating the power generated by a shaft with a 3-inch propeller and 3 blades is:

Power = (ρ * A * V^3 * η * Cp) / 2,

Where:

ρ is the density of air in kg/m^3

A is the area swept by the blades in square meters

V is the velocity of the wind in meters per second

η is the efficiency of the system, expressed as a decimal between 0 and 1

Cp is the coefficient of performance, expressed as a decimal between 0 and 1

To calculate the power, we substitute the given values for each of these parameters, including:

ρ = 1.225 kg/m^3 (density of air at sea level)

A = 0.0004545 m^2 (area swept by the blades with a 3-inch diameter)

V = 8.89 m/s (wind velocity of 32 kmph)

η = 0.35 (efficiency assumed to be between 30% and 40%)

Cp = 0.45 (coefficient of performance assumed to be 0.45)

Substituting these values, we get:
Power = (1.225 * 0.0004545 * (8.89^3) * 0.35 * 0.45) / 2 = 0.155 watts
Therefore, the estimated power generated by the shaft is approximately 0.155 watts. Note that this is a rough estimate based on several assumptions and simplifications, and the actual power generated would depend on a variety of factors, including the efficiency of the system and the design of the propeller blades.

5.CONCLUSION:
In conclusion, the above paper highlights the importance of the proper design of the lintel to reduce air drag and stress on building foundations. The proposed solution is to modify the design of regular window lintels, which can reduce the turbulence of the air passing through the building without wasting much space. The design is aesthetically pleasing and is supported by published papers and past theories. The study includes CFD analysis that shows the velocity gradient of air flowing with average velocity. Additionally, the Thermoforming process has been shown to demonstrate the flexibility to manufacture the lintel. The proposed design also includes the use of propellers to generate power. Overall, the proposed solution has several advantages, including efficient use of space, damping the turbulent air, improved building stability, and enhanced energy production, making it a viable option for modern building design.

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