International Journal of Civil Engineering and Geo-Environmental

Journal homepage:http://ijceg.ump.edu.my
ISSN:21802742

Collapse Analysis of Car Porch Steel Structure due Wind Storm

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ARTICLE INFO

Keywords:
Wind Storm, Roof Steel Frame, Non-Engineered Structure

ABSTRACT

Malaysia is a country with tropical climate. During the monsoon season, heavy rains and thunderstorm affect many places, especially at the east coast of Peninsular Malaysia and East Malaysia. Strong wind that produced significant wind force has proven to cause damage especially to low-rise non-engineered structures. Currently, numerous evidences of damages and loss caused by thunderstorm can be obtained. In 30st July 2009, a car porch steel frame in Taman Murni, Parit Buntar, Perak, was badly damaged during a heavy down fall and strong wind. An investigation had been carried out. From the result it show that the actual steel frame at the site was tremendously under designed which reflect the non-involvement of structural engineers.

1. Introduction

Unlike in cyclone prone region, the thunderstorms in Malaysia occurs in micro scale (Yusoff , 2005). Despite their small size and short duration of thunderstorm which is about 15 to 30 minutes, thunderstorms are still capable of producing hail, heavy rain, frequent lightning and strong gusty wind (Holmes, 2001). An incident occurred at Taman Murni, Parit Buntar where a car porch steel frame was damaged during a particular thunderstorm. It was observed that several trusses deflect excessively as well of dislocation of bolts from their joints. It was strongly believed that the steel frame was constructed without proper engineering considerations such as loading and factor of safety. In the case of low-rise engineered structures, failure due to strong wind always associated to poor workmanship, inferior materials or underestimation of the wind speed. (Stathopoulos, 1984)This issue can be reduced effectively if proper design work is carried out in the first place without ignoring the economical aspect. An investigation of collapse car porch has been carried out, appropriate in-situ and laboratory tests as well as modeling and analyzing a car porch steel frame which was previously damaged during a thunderstorm event. The analysis is carried out under linear elastic condition with the aid of STAAD Pro 2007. Steel grade for all structural members is taken as steel grade S275 according to BS 5950:2000.

Calculation of wind pressure is based on the rules set by MS 1553: 2002, Code of practice on wind loading for building structure. Only unfactored load comprising of member self weight, wind load and hydrostatic pressure due to rain are used in the analysis.

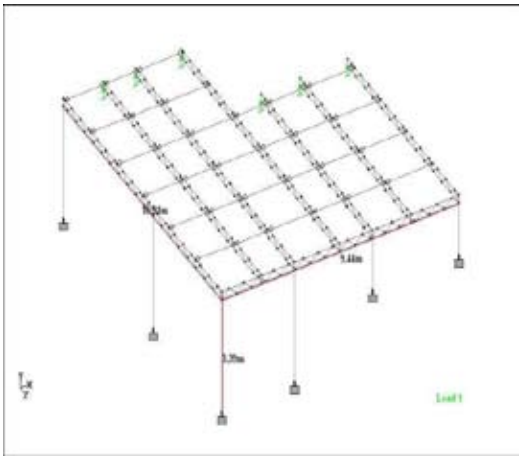

Figure 1. Car Porch Analyses using STAAD Pro 2007

Table 1: Actual STAAD Pro 2007 output vs. estimated secondary truss support capacity

Wind pressure (kN/m^2)	STAAD support reaction (kN)	Truss support capacity (kN)	Condition
0.200	1.584	3.475	Pass
0.290	2.359	3.475	Pass
0.300	2.430	3.475	Pass
0.400	3.145	3.475	Pass
0.430	3.360	3.475	Pass
0.440	3.431	3.475	Pass
0.445	3.467	3.475	Pass
0.450	3.503	3.475	Fail
0.500	3.860	3.475	Fail
0.600	4.770	3.475	Fail

Table 2: Comparison between actual STAAD Pro 2007 output and estimated base support capacity

Wind pressure (kN/m^2)	STAAD support reaction (kN)	Truss support capacity (kN)	Condition
0.200	2.386	5.688	Pass
0.290	3.423	5.688	Pass
0.300	3.516	5.688	Pass
0.400	4.450	5.688	Pass
0.430	4.729	5.688	Pass
0.440	4.873	5.688	Pass
0.445	4.869	5.688	Pass
0.450	4.916	5.688	Pass
0.500	5.383	5.688	Pass
0.600	6.319	5.688	Fail

Table 3: Comparison between STAAD Pro 2007 output (tensile stress for member 774) and theoretical fillet weld capacity

Wind pressure (kN/m^2)	Tensile stress (N/mm^2)	Theoretical weld capacity (N/mm^2)	Condition
0.200	99	220	Pass
0.290	140	220	Pass
0.300	145	220	Pass
0.400	194	220	Pass
0.430	208	220	Pass
0.440	214	220	Pass
0.445	216	220	Pass
0.450	214	220	Pass
0.500	223	220	Fail
0.600	282	220	Fail

2. Roof failure of the car porch steel truss

The root failure of the steel frame is determined when any of the possible failure triggered due to a particular value of wind force. The threshold limit for truss support capacity, base support capacity and fillet weld capacity are set at the first place. The actual truss support system consist two bolts with 3.5 mm diameter. These bolts are off inferior quality and each bolt only posses shear strength of 1.3735 kN, associated to shear strength capacity of 143 N/mm^2. This value is low compared to bolt grade 4.6 where the minimum shear strength is 180 N/mm^2 as stated in Table 30 BS 5950-1: 2000. The bolt was installed by post-drilled technique to the wall and fascia board in simple connection. Obviously, in simple connection only shear force will be experienced by the bolts. As such, simple connection requires bolts with high shear capacity.

By inspecting the theoretical load path, failure to secondary truss support system resemble a cantilever with all loads resisted only at one end. The magnitude of load at the resisted end (in this case, the resisted end being supported by main truss) increase tremendously and resulting an increase in tension to chord members. As chord members are connected by fillet weld, tensile stress in the chord members that exceeded the welding capacity of 220 N/mm^2 had caused failure to the chord member. In this case, member 774 failed due to this reason.

3. Estimation of wind speed

In this study, the wind force triggering the initial failure was back calculated in order to obtain wind speed, following the steps set by MS 1553. The results show that the minimum wind force triggering the first failure is 0.45 kN/m^2 reflecting a wind speed of 37.796 m/s. This value is above the maximum basic wind speed of 32.5 m/s for Zone 2 or 33.5 m/s for Zone 1 as stated in MS 1553. Since this location is situated at northern region of peninsular Malaysia which is bordering to the Thailand Country in Zone 4a and Zone 4b. The Thailand code where referred. In Thailand code the basic wind speed for the southern region which is classifies as zone 4a is 25 m/s base one-hour average speed at 10 m. (Boonyapinyo, 2009) If this wind speed converted to 3 second gust it will be equal to 37.5 m/s (Majid et. al, 2010).

However, the basic wind speeds stated in MS 1553:2002 are derived statistically based on mean 3.0 second gust. Although this value is safe to be adopted in designing structures less than 200 meter, this study found out that the actual wind speed increased during a particular thunderstorm event or experiencing high turbulence intensities as stated earlier in the case of low rise building that usually immersed within the layer of aerodynamic roughness. Unfortunately these effects are difficult to quantify.

Under Beaufort Scale, wind speed of 37.796 m/s is classified as hurricane where the effect can cause damaged to poorly constructed sheds (Meaden et. al., 2007). Although in Malaysia the term ‘huricane’ is not technically used, the effect agrees with the damage observed at Taman Murni as well as in many states in Malaysia. Under Fujita Scale, wind speed 37.796 m/s or 136 km/h is classified as F1 scale resulted in moderate damage which include damage to attached garages (Doswell et. al, 2009) . Again, the effect agrees with the local damage.

4. Conclusion

From the investigation, the initial members that form the car porch steel frame were found to be under sizes leading to inadequacy in design under ultimate limit state. The structural arrangement was improper where basic engineering knowledge in terms of the load path, obviously was not applied.

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