A STUDY ON THE WIND RESISTING CAPACITY OF TRADITIONAL ROOFING SYSTEM

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Abstract

Widespread and repeated failures of roof systems due to windstorm have become a frequent occurence of late. Records show that traditional roofs are the most and worst affected structures. The research aims to determine the reasons for the poor performance of the traditional roofing system and explore measures for improvement. The study is focused on two of the most common traditional roofing system, the Drangim roof and Jamthok roof. The capacity of these roofs for wind loading as per the prevailing codal requirement will be assessed.

For a more conservative analysis, a basic wind speed of 47m/s is considered and the resultant pressure acting on the roofs is determined. The adeqauacy of the member sections and joineries of these system will also be assessed. Mitigation measures, both passive (non intrusive) and active(intrusive) in nature, to improve the perfomance and protect the roof system from the harmful effects of the wind load are proposed.

Keywords : *traditional roofing system, windstorm, pressure, mitigation measures, intrusive, non intrusive.*

1. INTRODUCTION

Bhutan has witnessed violent weather conditions in the recent years. One such event is the windstorm. Recently, windstorm has become one of the most frequently occurring natural phenomena in our country, destroying lives and properties each year (Lotay, 2015). Roofs of traditional buildings are often the most and worst affected structure by the wind.

Conventionally, roofs of the our traditional houses are mostly made of timber trusses with timber shingles placed in position with stones/ boulders, mainly because of its availability but also due to its following advantages of timber (Hwa, 2008) :

- ✯ Lowest overall cost
- ✯ Fast to install
- ✯ Requires ordinary tools
- ✯ Doesn't require skilled labor to install
- ✯ Virtually any roof and ceiling is possible

With the arrival of the modern construction materials, the traditional wooden shingles are gradually replaced with light corrugated galvanized iron (CGI) sheets and other similar materials. These material are considered to be more durable and convieneint to work with requiring minimal maintenance.

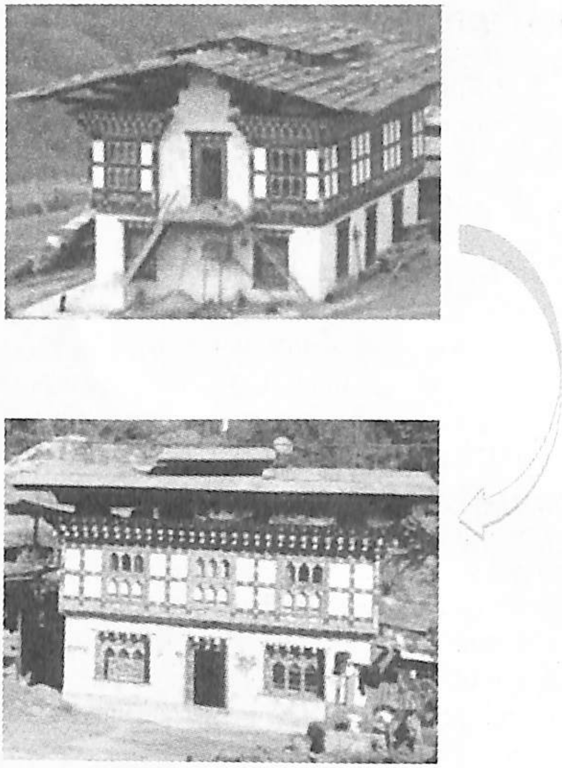


Fig.1 Transition from Shingles to CGI Sheeting

2. PROBLEM STATEMENT

Windstorms appears to occur with increasing frequency every year, causing repeated and ever more widespread catastrophic damages to our built infrastructures. Past records indicate that the traditional roofs are the most vulnerable and the most affected by such hazard (Lotay, 2015).

According to a damage assessment report, 674 rural home roofs were damaged out of 748 total damaged structures (90.1%) during the year 2015 alone.

The traditional roofing system are mostly designed and built by local artisan based on acquired experience. Not much attention is rendered on the impact of wind load on the roofs. There is a general lack of understanding regarding the interaction between the wind and the roof structure.

Case studies on few traditional roofs revealed that nails are randomly used to secure connection between the various roof truss members. It is observed that the trusses are simply placed onto the building structure with no proper anchorages.

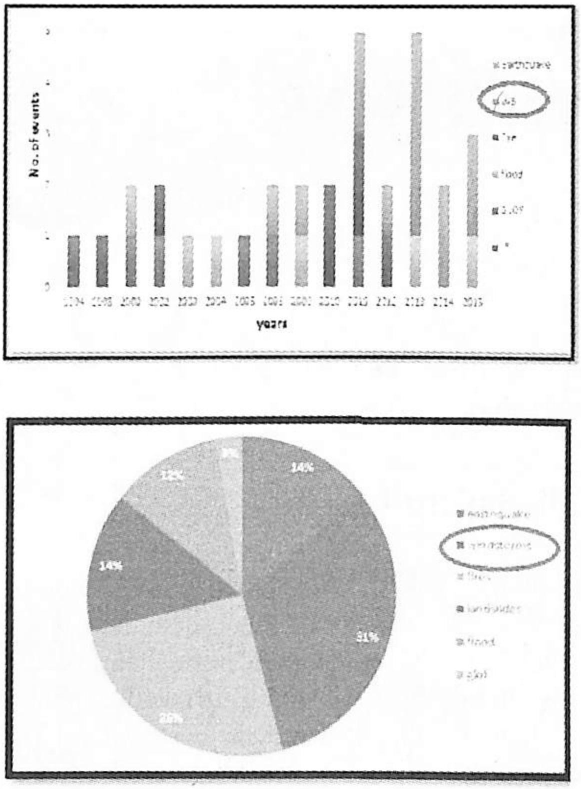


Fig.2 Number of Windstorm occurence (DDM)

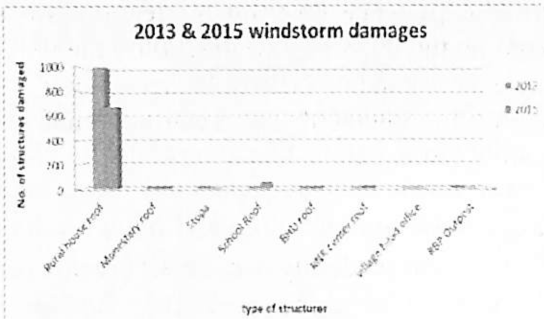


Fig.3 Type of structures affected by the windstorm(DDM)

Fig.4 Wind damaged roofs(2011)

3. AIMS AND OBJECTIVES

The main aims of this research study is to:

1. Assess the capacity of a typical traditional roofing system for wind loading.
2. Suggest remedial measures (both in geometry as well as structural) to minimize roof failures

The research project is based on the following objectives:

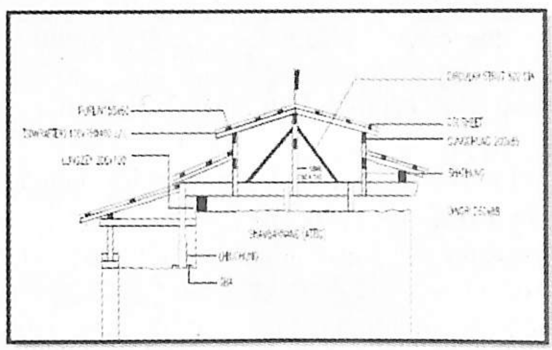
1. To study the wind damage pattern for traditional roofs
2. To determine the critical design wind loading for traditional roofs
3. To analyze member forces for the critical load and assess the capacity
4. To propose recommendation for damage mitigation
5. To propose members and joinery design improvement

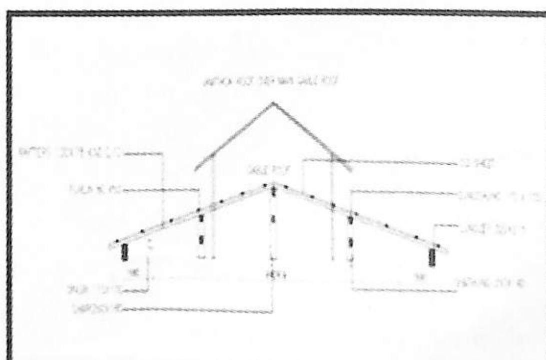
4. METHEDOLOGY

4.1.Case Study

Our research principally revolves around the case study focused on two of the most common traditional roofing system in the country, Drangim roof and Jamthok roof. Both the buildings chosen for the case study are located in Thimphu.

Measurements were taken, the various member sizes and their dimensions were noted and roof geometry is mapped in AutoCAD. Photographs of the respective buildings were taken followed by topographical and terrain survey of the location.





4.2. Analysis of the Uplift Forces on the Roof

Determination of the wind loads on the roof was carried out using IS 875(Part-III). The physical paramenters for the buildings required for calculation were obtained through field measurements. In the abscense of reliable windspeed record for the sites, a basic windspeed of 47m/s as per the IS 875 Part –III is considrerd for the analysis.The wind pressure acting on the roofing is dertermined and the netforce acting on each roof was determined. The self weight of the roof is determind by considering the unit weight of the wood/timber (Blue Pine) materials used.

4.3. Findings from the Analysis

Windloading analysis revealed that both the roofs experiences a resultant net suction (uplift) pressure. Comparision between the total suction force acting on the roofs and the counteracting force (self weight/dead load) showed that the net suction (uplift) force is substantially large in both the roof types.

The dead load of the roof structure alone is not sufficient to hold the roof down whenever there is a strong wind. Moreover, the roof elements do not function as a single unit given the lack of their structural inregtity because of poor connection and anchorages, making them more susceptible to damages.

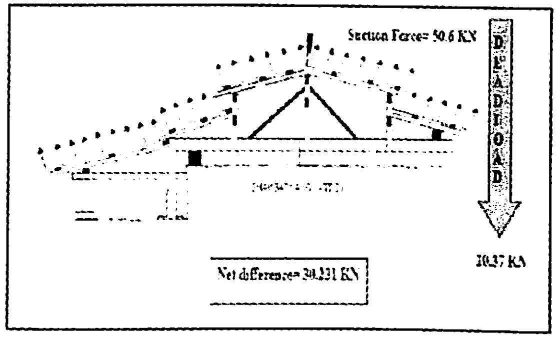


Fig. 7 Net force difference on a Drangim roof

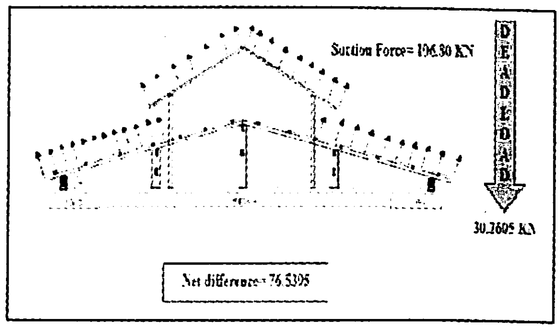


Fig. 8 Net force difference on a Jamthok roof

Table 1: Wind Pressure Calculation for Drangim Roof

Wind angle	Pressure coefficient			Total pressure(Cpe-Cpi)*Pz	
	External - Cpe		Internal	Windward(N/m^2)	leeward(N/m^2)
	Windward	Leeward	Cpi		
0°	-0.796	-0.524	0.2	-1320.09	-959.58
			-0.2	-789.94	-429.43
90°	-0.8	-0.6	0.2	-1325.4	-1060.32
			-0.2	-795.24	-530.16

4.4. Potential Mitigation Measures

The following potential mitigation measures are proposed. These measures can be grouped under two categories: Passive (Non Intrusive) and Active (Intrusive)

4.4.1. Passive Measure

Two measures are suggested under passive measure to reduce the net force difference.

1. Increase the dead load of the roof:

A simple way of increasing the dead load of the roof is by increasing the member sizes, making them bulkier and also by providing additional roof members.

Such a measure has been proposed in the case study and additional truss are suggested making a total of 5 trusses in the case of drangim roof. Increasing the member size option is also proposed..

Another crude option is to place stones on the roofs, like in the traditional way. Placing stone boulders over CGI Sheeting, howver, is not feasible.

2. Closing of the openings:

Closing of the openings can also be carried out to reduce the suction force coming on the roof.

In the present case study, however, even with the internal pressure coefficient (+/- 0.2) for the least opening ratio of 5%, the net suction force on the roof was found still very substantial.

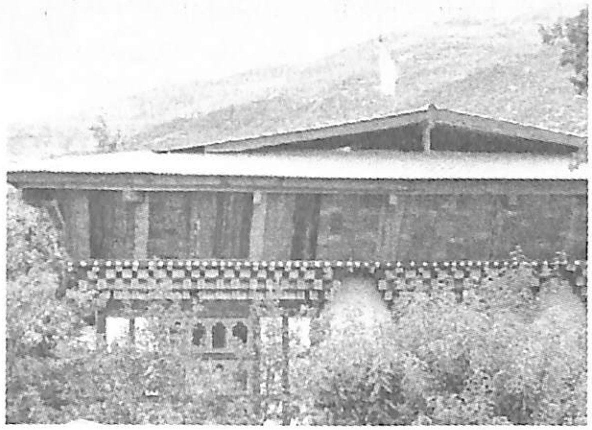


Fig.9 Enlcosed Roof.

Futher, complete closure may not be feasible since traditional architecture demands a small opening to be kept for the purpose of aeration of the timber members and for drying of the food grains, vegetables and hays.

Therefore, there is a need for some active measures entailing some physical interventions.

4.4.2. Active Measure

The active measures are as follows:

1. Improve the integrity of the roof structure

The structural intregity of the roof elements has to be improved for whole roof structure to behave as a single unit. This can be achieved by providing adequate connection between the vaiours roof members. Most roof failures are observed along the connection between the members.

The connections that need to be secured are:

1. Roof ridge connection
2. Sheeting to purlin connection

3. Purlin to rafter connection
4. Rafter and beam(dhingri) connection
5. Dhingri to vertical struts connection
6. Truss to building connection

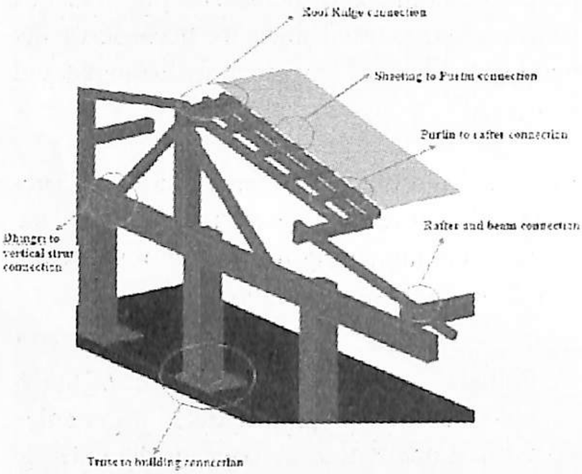


Fig. 10 Connection Points.

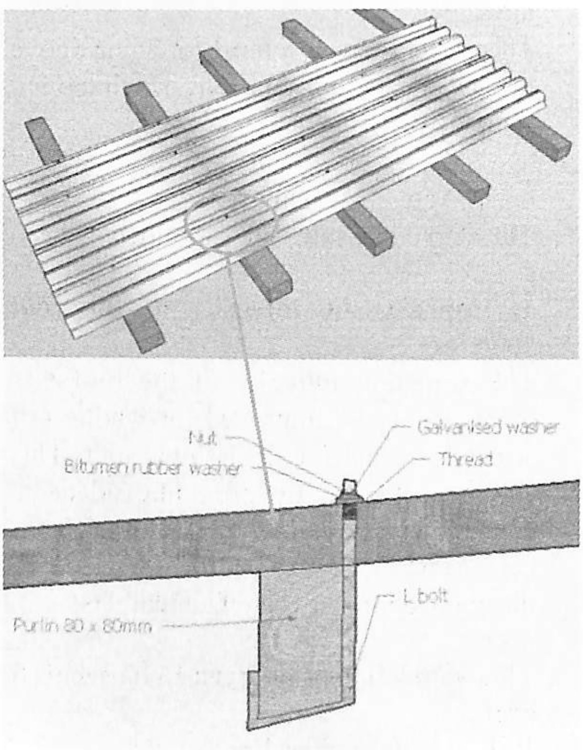


Fig.11 Sheeting to purlin connection detailings.

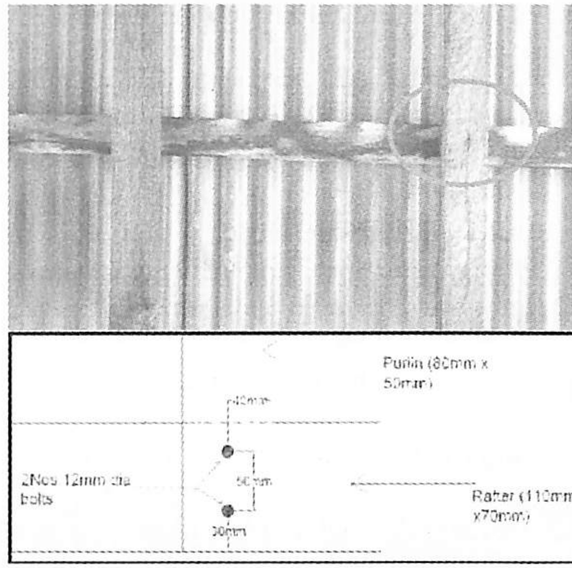


Fig.12 Purlin to rafter connection detailings.

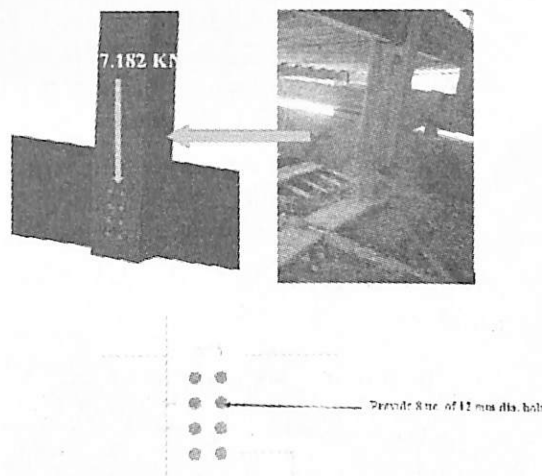
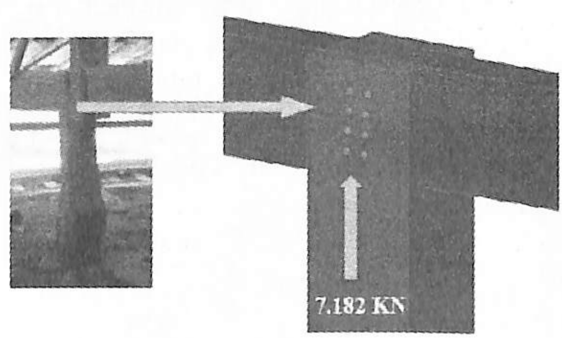


Fig.13 Vertical struts to Dhingri connection detailings



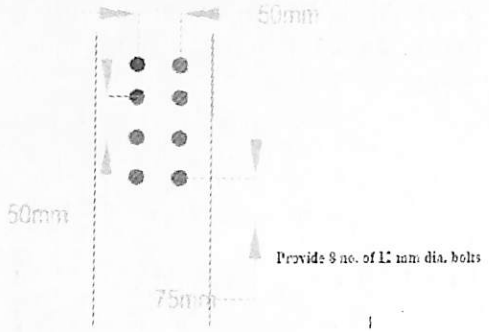


Fig.14 Lower strut to Dhingri connection detailings.

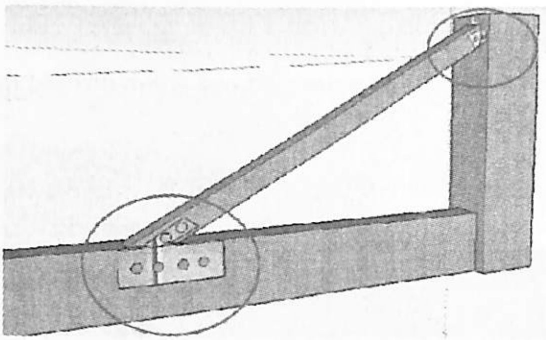


Fig.15 Inclined strut connection points

2. Anchor the whole roof truss to the ground

The anchorage of the whole truss to the building strucuture needs to be secured. It was observed that the most effective means to secure propore anchorage of the truss is to anchor the truss to the ground. This could be achieved via the use of tension cables.

Anchorage can be provided along the Dhingri member as the dhingris the most common roof feature in all the traditional roofs. After securing all the connections between the various roof elements, anchorage along the Dhingri can be provided.

5. CONCLUSION

The study revealed that the individual roof members sections are adequate to withstand the force acting onto them. The problem lies in lack of structural intregity because of the manner in which the member are arranged and connected.

It is found out that there exisit a high net suction (uplift) force acting on the roof and the avialable counteracting foces are not sufficient to counteract this suction force.

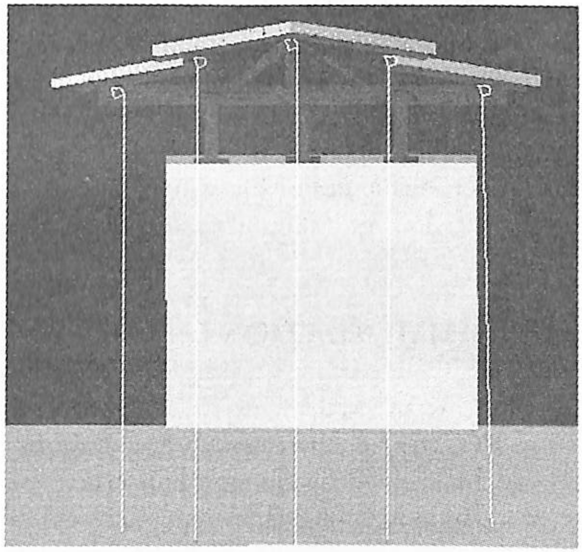


Fig.16 Tension Cable connection from the roof ridge

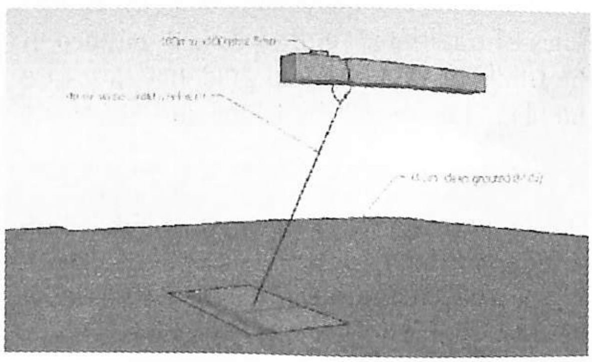


Fig.17 Tension cable detailings

Through the site visits and field observations, it was observed that traditional Bhutanese roofs do not have proper connection between roof members and walls and the roof truss are simply placed on the main building structure.

The replacement of the traditional wooden shingles and stone boulders by modern light corrugated galvanized iron (CGI) sheets appears to have aggravated to problem further for the tradiontal roofing.

Some non intrusive(passive) measures are recommended but in most cases active intervention are necessary.

Securing adequate connection between the various roof members to ensure structural integrity and proper anchorage of the whole roof truss is necessary to avoid/minimize damages due to wind.

6. RECOMMENDATION

The study is focused on two traditional roof types. To understand the actual behavior of traditional roofs in each region, traditional roofs in each region may be considered and assessed in detail.

A detail study should be carried out on all four types of traditional roofing system outlined by the Bhutanese architecture guideline, to assess the behavior of each roof type during a windstorm.

There is a lack of data on wind. Wind records needs to be maintained and ultimately, there is a need for a wind zone map for our country.

The recommedations made can be corrobarted further by model simulation and practical experiments.

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