Solution to increase the strength when the large wind, the storm for the type of rural houses in mountainous areas of Thai Nguyen province in Vietnam

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***Abstract*— Strengthening resilience to strong winds and storms for rural houses in mountainous areas of Thai Nguyen province in Vietnam is an urgent requirement in the current global climate change conditions. The paper identifies the possibilities to enhance resilience to wind and storms of rural areas in Thai Nguyen province in Vietnam. Then select three reinforcement options suitable to economic and social conditions. and practical local techniques. Thereby modeling three structural options selected by Etabs software, comparing the internal forces of each plan to choose the best option for rural mountainous areas in Thai Nguyen province in Vietnam.**

***Index Terms*— Rural houses in mountainous areas, Enhance wind resistance capacity, Enhance the bearing capacity.**

I. INTRODUCTION

With the current global climate change conditions, abnormal wind storm events are likely to occur [1]. For rural and mountainous areas with particularly difficult economic and technical conditions, it is necessary to find a plan to improve and enhance the resilience of houses for unusual wind and storm phenomena. Several solutions have been proposed to enhance the resilience of housing as mentioned in [2] but still not suitable for local economic, cultural, social and technical conditions. The article goes to research to find solutions to strengthen resilience for rural mountainous areas in Thai Nguyen province, Vietnam.

II. SUBJECTS AND METHODS OF RESEARCH

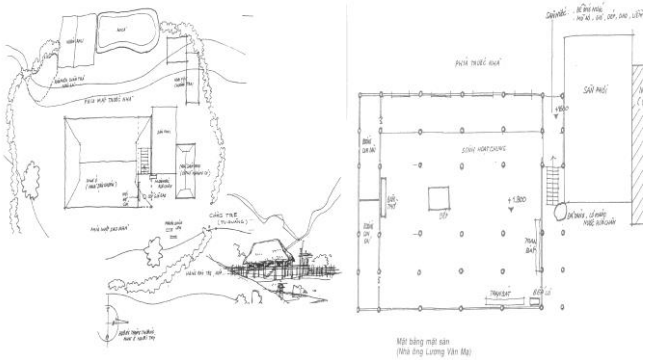
A. Objects

The study area consists of Dai Tu, Dinh Hoa, Dong Hy and Vo Nhai districts of Vietnam (Figure 1), which features topography that is flat land in the valley, the climate is cold in winter. Rural housing types in this area include: stilt houses, brick houses, half-floor houses and half-brick houses. Rural houses are often made up of villages gathered together.

The campus is fenced, planted with fruit trees and vegetables. The house has three rooms with two wings, four roofs.

Figure 1. Location of Dai Tu, Dinh Hoa, Dong Hy and Vo Nha districts of Thai Nguyen province, Vietnam [3]

The interior space is divided horizontally into two parts, the outside is the place of ancestor worship, common activities, reception of guests, the inside is the kitchen, the upper part is guarded so that rice corn and supplies need to be preserved. Typical house type is shown in Figure 2.



a. Project campus *b. Floor plan 1*

Figure 2. Rural housing in mountainous areas of Thai Nguyen province, Vietnam [4]

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B. Solutions to strengthen resistance to high wind and storm in accordance with local economic and technical conditions

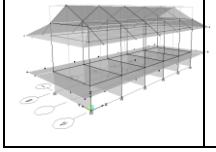
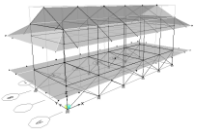
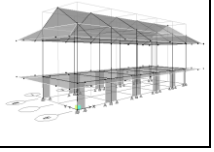
In order to enhance the bearing capacity of the structure, we can reinforce the components: Roof, column, beam, floor. Specific solutions are shown in Table 1.

Table 1. Solutions to strengthen the resilience of structural systems

STRUCTURE SYSTEM	SOLUTIONS TO INCREASE THE RESISTANCE ABILITIES			
Roof	Steel truss roof	Cement tile roof		
Linking roof with column girder system	Tied off bamboo	Bolts	Bamboo latches	Rivets
Roof bracing system	Horizontal bracing system	Vertical bracing system	Cross bracing system	
Link between roof beams	Additional link bolts			
Floor	Replace steel floor			
Column	Increase the number of columns			
Build more walls	Build horizontal walls	Build vertical walls	Addition of the whole wall	Build half-house walls
Bracing columns with beams	1st floor: cross bracing, horizontal bracing, vertical bracing	2nd floor: cross bracing, horizontal bracing, vertical bracing	1st & 2nd floor: cross bracing, horizontal bracing, vertical bracing	

Due to the characteristics of rural mountainous areas, Thai Nguyen province has difficult economic conditions and construction techniques are not developed. Through actual surveys and proposed architectural solutions suitable to the function and culture and the needs of the people [5], it is possible to identify three options to enhance resilience when there are high winds and storms: building walls bearing along the structural frame, adding braces for the frame system, building walls to increase the hardness of the corner for houses in rural mountainous areas of Thai Nguyen province as shown in Table 2.

Table 2. Solutions to strengthen resistance to high winds and storms for rural housing types in Thai Nguyen province in Vietnam

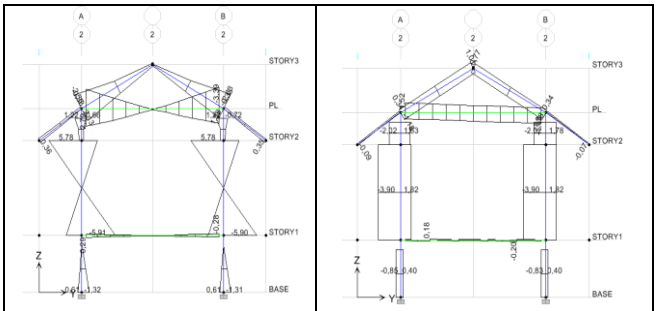
Case 1	Case 2	Case 3
Construction of load-bearing walls along the structural frame	Add a tie for the frame system	Build walls to increase the hardness of the corner
		

C. Method

In the modeling process for research related to materials, bonding and practical interactions, in this paper, it is limited to compare the bearing model of the construction by simulation in Etabs software. First modeling the structure of the house for the current conditions defining the internal forces of the structural frame (torque, shear force). Then build structural models with the case of building walls in the horizontal direction of the house, adding slant bars along the house, building reinforced walls on both sides of the column to determine the internal force results of the alternatives. From the internal force calculation results compare the largest internal forces of the options to choose the best option for rural housing in mountainous areas of Thai Nguyen province in Vietnam.

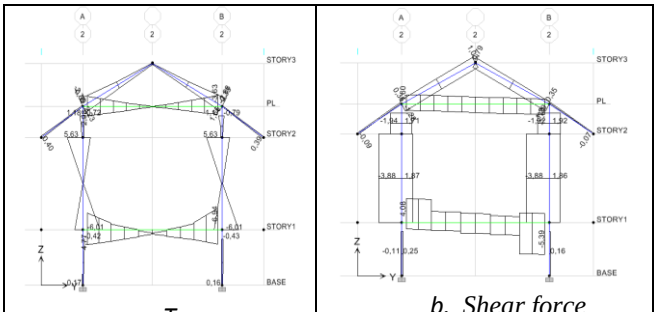
III. RESULTS AND DISCUSSION

Modeling and calculating structural by Etabs software are internal force in beams, column of wall construction in horizontal direction shown in Figure 3, adding anti-slant anti-vertical bars shown in Figure 4, built Reinforced wall two sides of the column shown in Figure 5.



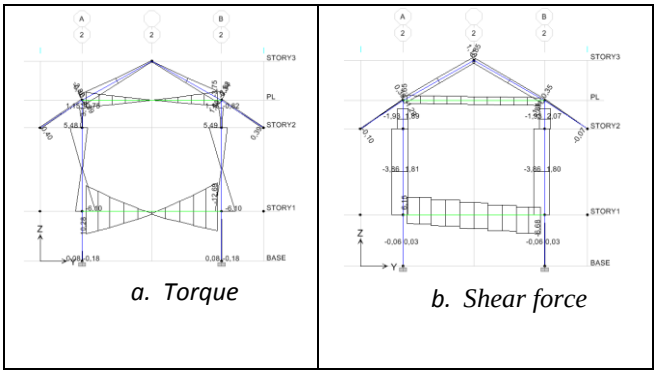
a. Torque *b. Shear force*

Figure 3. Internal force in beams, column with wall construction in horizontal direction of the house



a. Torque *b. Shear force*

Figure 4. Internal force in beams, columns with forced anti-oblique addition along the house



a. Torque *b. Shear force*

Figure 5. Internal force in beams, columns with reinforced walls on both sides of columns

From the calculation results of Etabs, we have the largest internal force in beams and columns on the 1st and 2nd floor with the value as shown in Table 3 and comparison graph as in Figure 6.

Table 3. The largest internal forces in the column of the first floor and the beam of the second floor

Case	The maximum torque in the 1st floor column (kNm)	The maximum shear force in the 1st floor column (kN)	The maximum torque in the beam of the 2nd floor (kNm)	The maximum shear force in the beam of the 2nd floor (kN)
Case 0	4.11	4.00	6.94	5.39
Case 1	1.32	0.83	0.29	0.2
Case 2	0.17	0.29	6.94	5.39
Case 3	0.18	0.06	12.9	6.68

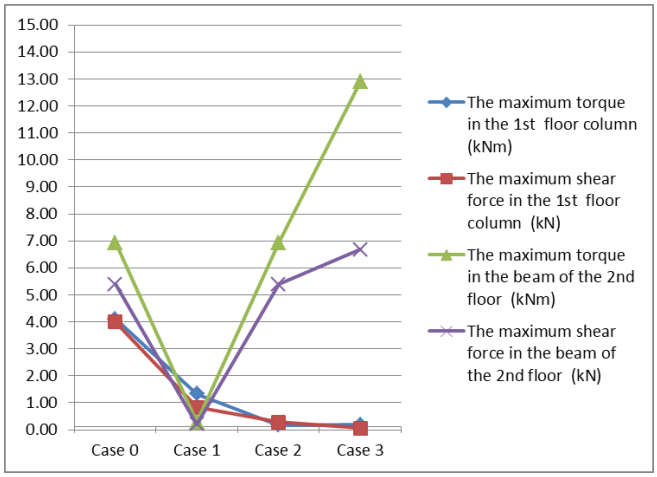


Figure 6. Comparison of shear and torque forces in columns, beams on the 1st and 2nd floor in the cases

The comparison of the above results shows that case 1 is most suitable to increase the bearing capacity of houses in rural mountainous areas of Thai Nguyen province. Because when considering the damage of high winds and storms, the floor principle will be transferred to the sub-beam, from the secondary beam to the main girder, the main beam will be transferred to the column. In which the column has the largest role, so in the three options choose the option of both the internal force of the column and the small main beam, so option 1 is the best.

IV. CONCLUSION

To increase the resilience of rural houses in mountainous areas of Thai Nguyen province, Vietnam. The article has identified three options: building vertical walls across the house, adding slant struts along the house, building reinforced walls on both sides of the column. Then modeling the structural system of the alternatives shows that the case of building vertical walls across the house is the most optimal for bearing in the first and second column of the second floor beam. Then determine the best improvement solution to enhance the resilience to wind and storms of rural areas in Thai Nguyen province in Vietnam.

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