eJSE International

EJSE Special Issue:
Selected Key Note papers from MDCMS 1 1st International Conference on Modern Design, Construction and Maintenance of Structures - Hanoi, Vietnam, December 2007

Typhoons and technical solutions recommended for existing and new houses in the cyclonic regions in Vietnam

T. Cao Duy, C. Nguyen Xuan, M. Nguyen Dai, H. Nguyen Huu and C. Bui Tat

Vietnam Institute for Building Science and Technology (IBST)
Nghia Tan, Cau Giay, Hanoi, Vietnam

ABSTRACT: Typhoons are considered as the most destructive natural disaster in Vietnam. Typhoons that have the intensity scale greater than 10 or 11 (Beaufort scale) cause sever damages to houses and buildings on their paths. Typhoons associated with inundation can also create short- and long-term damages to national socio-economy and have negative impacts on the country's economic development. The typhoon affected area can be from hundreds to thousands of kilometres depending on the landfall of the typhoon. In Vietnam, the typhoon season is normally from June to October (occasionally to November or December), and is the most intense in September and October. This paper hence provides the information on typhoons in Vietnam. The paper also introduces the technical solutions recommended for existing and new houses located in the tropical cyclonic areas. The technical solutions presented in this paper are based on the Vietnamese traditional constructions, the results of the research projects conducted by IBST and other Vietnamese institutions as well as the international construction experiences regarding to natural disasters prevention and mitigations.

Keywords: Disaster mitigation; technical solutions; tropical cyclones; typhoons; and wind disasters.

1 INTRODUCTION

In 1995, a design code TCVN 2737:1995 Loads and actions – norms for design [1] was issued for analysis and design of buildings and structures in Vietnam. This code provides the wind-pressure map for construction for the whole territory of the country. The effects of the typhoons (or tropical cyclones) are also considered in this map. During recent 20 years, some research were conducted with objectives to provide the guidelines for construction (including planning) in the cyclonic and flooding areas in our country [2-5]. However, due to the global warming effects, damages caused by typhoons are still considerable. In October 2006, typhoon No.6 (the international name: typhoon Xangsane), with intensity greater than 12 (Beaufort scale [6]), hit Da Nang city, Thua Thien-Hue and Quang Nam provinces (the Middle part of Vietnam) causing extreme lost to these regions. Investigations showed that more than 19,000 houses collapsed and nearly 270,000 houses were heavily damaged with the roofs blown-off [7]. In December 2006, typhoon No. 9 (typhoon Durian) made the landfall to the Southern part of Vietnam. Although the intensity of this typhoon was 10, only in Vung Tau area (close to Ho Chi Minh city) it was indicated that more than 9,000 houses collapsed and about 60,000 houses with their roofs blown-off [7]. These examples show only the part of the economic lost caused by typhoons. Actually, there were many people died or injured due to buildings collapsed during the typhoons and nothing could compensate for human loss. This paper therefore provides the information on the typhoons in Vietnam as well as to introduce the technical solutions recommended for existing and new houses to limit the damages caused by the tropical cyclones. The technical solutions presented in this paper are based on the Vietnamese traditional construction, the results of the research conducted by IBST and other Vietnamese institutions as well as the international experiences regarding to natural disaster construction.

2 TYPHOONS IN VIETNAM

2.1 *Tropical typhoons and tropical depressures*

Tropical typhoons and tropical depressures are cyclonic wind-gust areas formed in tropical seas with its diameter up to hundreds of kilometers; in these areas, wind flows into the centre following counter-clockwise direction in the North hemisphere and

clockwise direction in the South hemisphere [8]. In Vietnam, the tropical typhoons and tropical depressures are classified based on the maximum wind speed (vmax) measured near the centre of a cyclonic flow. The intensities of the typhoon based on Beaufort scale are given in Table 1.

A tropical depressure is a tropical cyclonic flow with the intensity of 6-7 according to Beaufort scale. A typhoon is a tropical cyclonic flow with intensity of 8-9 scale while a strong typhoon has the intensity of 10-11 scale. A very strong typhoon is a tropical cyclonic flow with the intensity of 12 and 13. A tropical cyclonic flow with the intensity higher than 14 is called a super typhoon.

2.2 *Typhoon seasons*

Typhoons are considered as the most destructive natural disaster in Vietnam [2]. The Vietnamese territory (including the continental shelf) is located in the directly-affected zone of North-Western Pacific Ocean typhoon centre. The East Sea (the international name: the South China Sea) is also a region where many strong typhoons are originated.
In Vietnam, the typhoon season normally extends from June to October (occasionally to November and December) with a tendency of moving from the North to the South of the country.
The landfall directions of typhoons are:

- From June to September, typhoons mostly approaching the coastline of the Northern part of Vietnam;
- From September, typhoons move to the North of the Middle part of Vietnam;
- From October to November (occasionally to December), typhoons majorly affect the Middle part of Vietnam; in this period there are almost no typhoons approaching the Northern part;
- From November, typhoons mostly affect the Southern regions of Middle part and the Southern part of
- Vietnam and many of the typhoons dissipate before their eyes reaching the coastline.

The number of typhoons with the intensity greater than 12 (Beaufort scale) that go to inland is about 25% of the total number of the typhoons hitting Vietnam. The coastal areas most suffering from the typhoons are from the South of the Middle-part to the North of Vietnam.

2.3 *Typhoon-affected regions*

The inland regions adversely affected by typhoons are the plains and the coastal areas from Khanh Hoa to Quang Ninh province. In the Red River Delta, the most affected area extends to the west approximately 100 to 150 km from the coastline. The coastal areas of 20 to 40 km from the coastline in Quang Ninh province and the Middle part provinces are also under threat of typhoons. In the East Sea, the most affected area is the northern section extending down to the south at northern parallel of latitudes from 7o to 10o. The territory of Vietnam is divided into 5 regions for typhoon impacts as follows [3,5]:

Northern Coastal Region:
This region is above northern parallel 20 extending from Quang Ninh to Ninh Binh province.

The typhoon season lasts from June to September. The average number of typhoons hit the region annually is between 1 and 2. However, the density of typhoons (a term describing the number of typhoons over a coastline distance of 100km) is of 43% of the total number of very strong typhoons hitting the country with wind speed of above scale 12 with return period of 20 years.

The Northern Coastal Region is subdivided into two sub-regions:

Quang Ninh Sub-region:
This sub-region has the highest density of typhoons in Vietnam. Storms also happen frequently due to the topography that mountains extend to the ocean causing wind speed sharply reduces in the lowsea level areas. In the valleys of Binh Lieu and Ba Che, effects of typhoons are almost insignificant. In areas of high altitude, open or valley areas parallel to the direction of wind, effects of typhoons may stretch up to Lang Son and Bac Giang provinces.

Red River Delta Sub-region:
Although the number of typhoons directly hit this sub-region is less than that of the Quang Ninh sub-region, the number of recorded strong typhoons is higher. Impacts of typhoons are more severe and stretching deeper inland causing enormous damages to the national economy and the society. The maximum wind speed measured in a typhoon event may exceed scale 12 (with return period of 20 years) when it is from 4 to 50 km from the coastline, and exceed scale 10 as it is at 100 km west of the coastline. Winds acting on this sub-region are generated from strong typhoons directly approaching the coastline between Hai Phong and Ninh Binh, the coastline of Thanh Hoa and the southern coastline of Quang Ninh.

Middle Part Coastal Region:
This region lies between parallels 20 and 16, stretching from Thanh Hoa to Thua Thien – Hue with 500 km of coastline.

The typhoon season is from July to October (occasionally to November), and is the most intense in September and October. The density of typhoon is ranked the second nationwide with 2 to 3 typhoons hitting the region per year. The number of strong typhoons occupies 29% of the total number of typhoons landing on the country.

This region is a narrow coastal area where many sections of Truong Son Mountain Range (the mountain located along the boundary between Vietnam and Laos) progress to the sea. This rough topographical feature makes the approaching typhoons to dissipate quickly but their intensities remain significant. The coastline in this region is in the Northwest-Southeast direction, which coincides with the path of the cyclonic flows. Therefore, many typhoons after hitting the region had moved along the coastline extending the affected area.

In this region, Nghe An and Ha Tinh provinces are the most-severely affected by typhoons with the highest storm surges. The wind speed during an typhoon event may exceed scale 12 with a return period of 20 years.

South Middle-part Coastal Region:
This region is located between the parallels 16 and 12, from Quang Nam to Khanh Hoa.

The typhoon season is between September and November, and is the most intense in October and November. There are 1 to 2 typhoons hitting the region in a year. The typhoon density and the percentage of strong typhoons are less than those of the Northern Coastal Region and Middle-part Coastal Region.

The most severely affected area by typhoons is of Quang Ngai and Binh Dinh provinces.

South-eastern coastal region:
This region lies under the parallel 12 from Ninh Thuan to Ca Mau with the coastline longer than 600 km.

There is on average only 1 typhoon hitting the regions in every 5 years, mainly in November. The typhoon density is equal to only 5% of that in the Northern Coastal Region. This region is mainly affected by low pressure circulations, which mostly dissipate before reaching the inland causing heavy rains. The wind speed at a return period of 20 years is normally of less than 17.2 m/s. The impacts of typhoons and low pressure circulations on civil structures are insignificant.

2.4 *Impacts of typhoons on buildings and structures*

Typhoons that have intensity greater than 10 and 11 cause sever damages to residential houses on their paths. In Vietnam, residential houses can be classified into three types: solid (stable and sustainable), semi-solid and temporary. Solid houses are commonly found in cities and towns. These houses are able to resist most of typhoons in Vietnam. The semi-solid houses commonly constructed in the countryside areas by owners' experience with no quality control are the most vulnerable to damages caused by typhoons. Therefore, it is of utmost importance to have proper structural solutions against typhoon impacts such as multi-directional wind pressures and gust wind.

Typhoons and low pressure circulations associated with inundation have caused short-term and long-term damages to national socio-economy and have negative impacts on the country's economic development. The typhoon affected area can be from hundreds to thousands of kilometres depending on the landfall of the typhoons. The total rainfall in a typhoon event ranges from 300 to 500 mm, and occasionally exceeds 1,000 mm causing inundation which in turn results in the long-term damages to the crops and the environment. In summary, typhoons and inundation are one of the many factors causing hunger and poverty hindering the socio-economic development of Vietnam. Therefore, planning and construction of houses and buildings against typhoons and flooding impacts is the solution for the country's sustainable development.

2.5 *Wind pressure map of Vietnam*

The updated wind pressure zone map of Vietnam is given in Fig 1. This map is recommended for the revised version of TCVN 2737:1995 (see [9]). The wind pressure zone map covers both the inland and the continental shelf. The coequal contours on the map were established based on the topographical maps, meteorological stations map and the administrative map of Vietnam scale 1:1,000,000.

3 TECHNICAL SOLUTIONS RECOMMENDED FOR HOUSES IN TYPHOONIC AREAS IN VIETNAM

The technical solutions presented in this section can be applied to dwelling houses in the tropical cyclonic areas with purposes to limit damages caused by typhoons. The technical solutions consist of planning, architectural and structural solutions of the new houses in terms of the typhoon resistance as

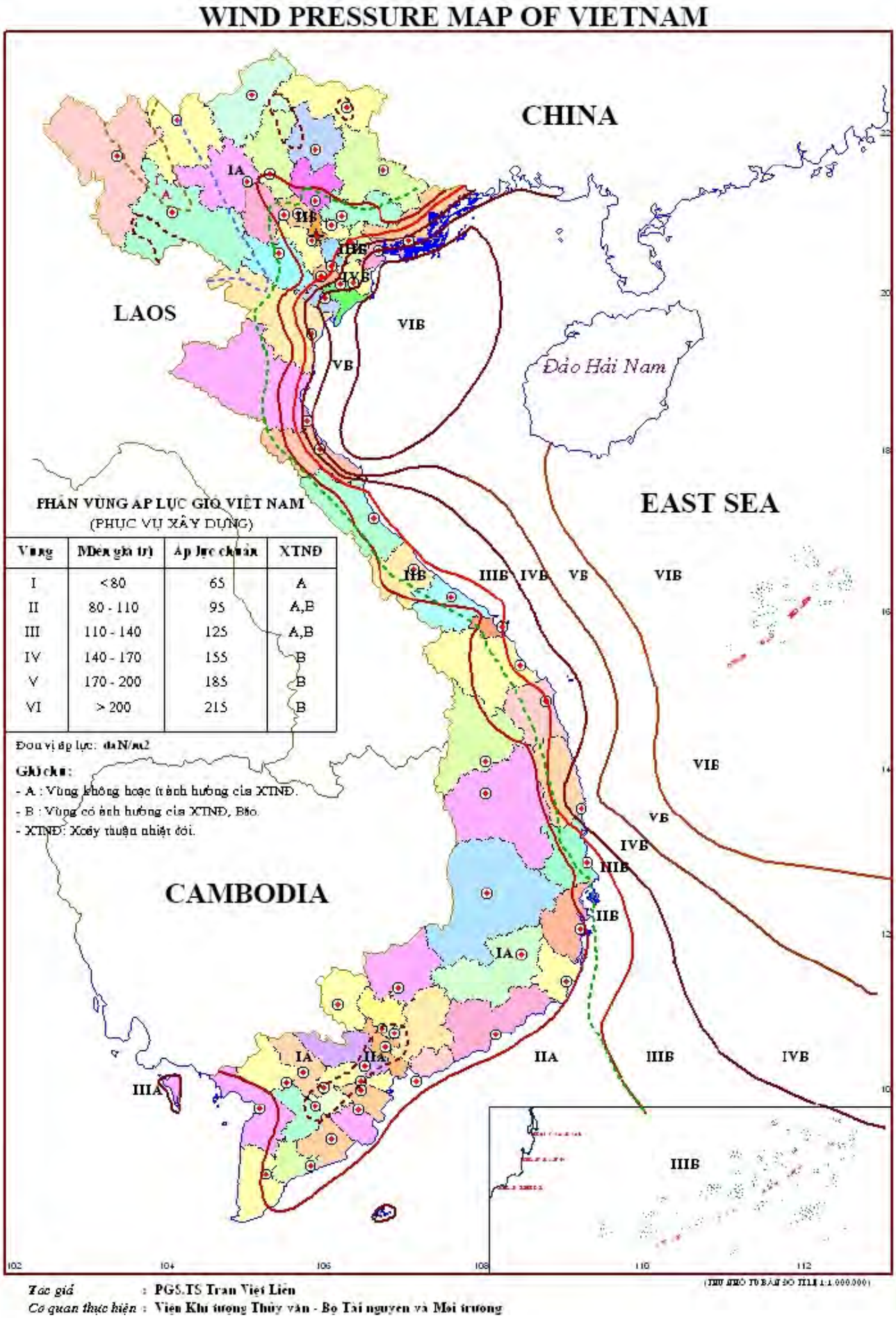

Fig. 1 The revised version of the wind-pressure zone map for construction for the whole territory of Vietnam (recommended for new loading code), A – not influenced by typhoons, B – influenced by typhoons.

well as strengthening of the existing houses before the tropical cyclones coming.

3.1 *Planning solution*

a. Should do (Fig 2a): When selecting the location to build the house, the good terrains regarding to wind resistance (try to avoid exposed open terrains) should be chosen to protect the houses from storms or typhoons. Dwelling houses should be built in a group. Houses in a group should also be unequally arranged in the plan in the way that can reduce the effects of typhoons and storms (on the houses).

b. Should not do (Fig 2b): Dwelling houses should not be built in the exposed open terrains with few or no scattered obstructions, in the open countryside, along the river sides, in the coastal area, on high exposed hills or in the mountain corridors. Dwelling houses should neither be arranged in a straight line, which is likely to face dangerous wind suction or cyclones.

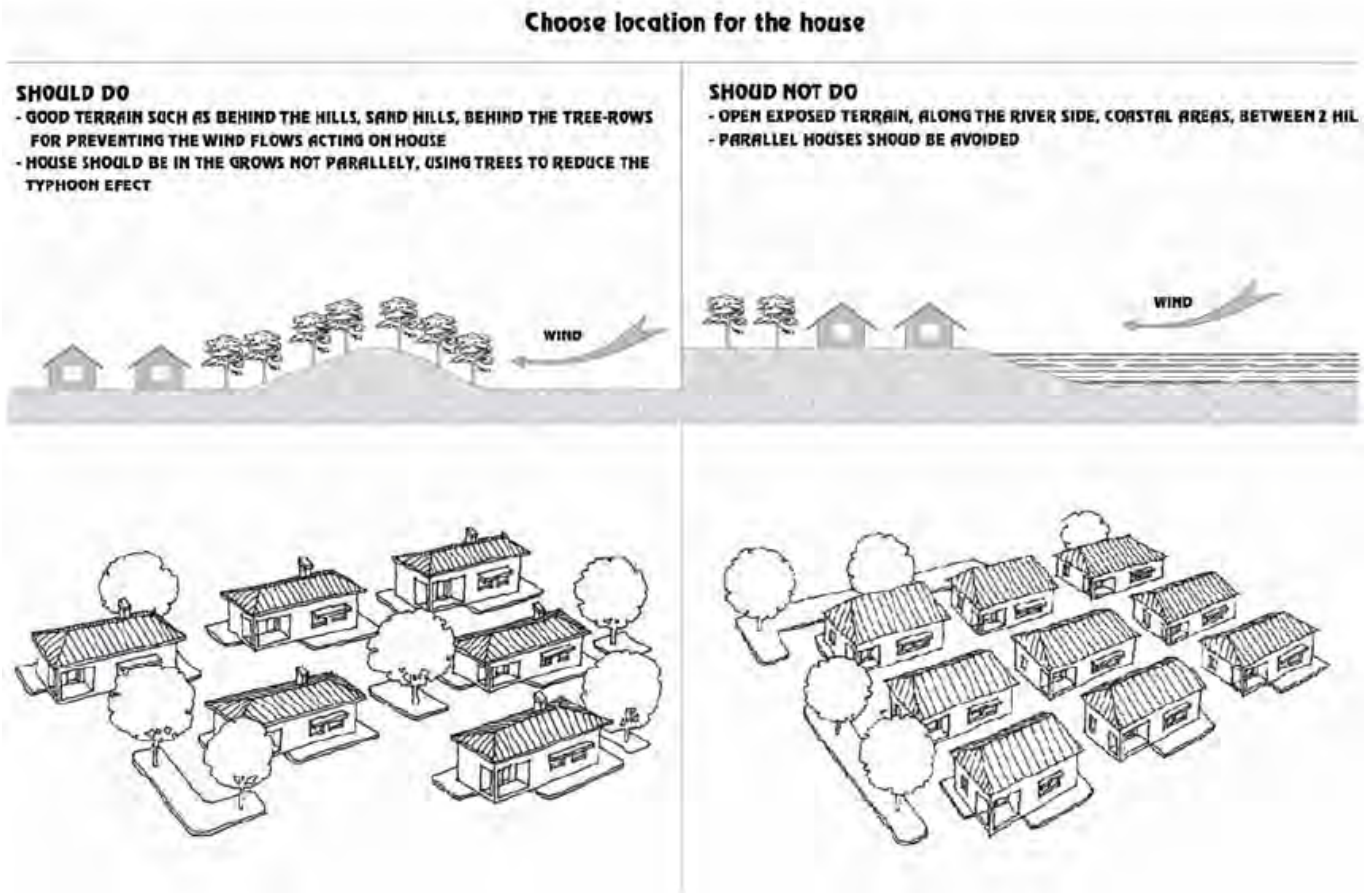

Fig. 2 Planning solution.

3.2 *Architectural solution*

a. Dimensions (in plan) of the house must be well selected considering the wind resistance. Houses that are very long and thin should be avoided. Simple plans such as square and rectangular plans with ratio between the length and the width smaller than 2.5 are very good in terms of wind resistance.

b. Structural components of the house should be well arranged to resist the wind loads. Houses with the L-, T- and U-shaped plan should be avoided because these plans can easily create the wind suction locations during typhoons.

c. Roof's types that may result local turbulent flows should also be avoided. Separate eaves should be used, and do not build the roofs with long canopies.

d. The important room (in the house) be properly strengthened because this is a safe place for shelter during typhoon.

3.3 *Structural solutions*

a. General principles

Tropical wind loads on a house act predominantly upwards and horizontal. A house must have a structural system that will remain intact these loads and

transmit the wind forces to the foundation through its structural members, connections and cladding without failure of these members [4]. Therefore, in general, a tight and continuous concrete bracing system (including the concrete columns) needs to be applied to the house so that the roof and the super structures are well anchored to the foundation and the structure can be stiff in the horizontal directions.
A structural system consisting of bracing-columns-walls that can form a 3-D rigid system is preferred. Vertical supporting columns should be used inside the house an in the extended areas. Long spans and cantilevers should be evaluated under the wind loads.

b. Specific requirements

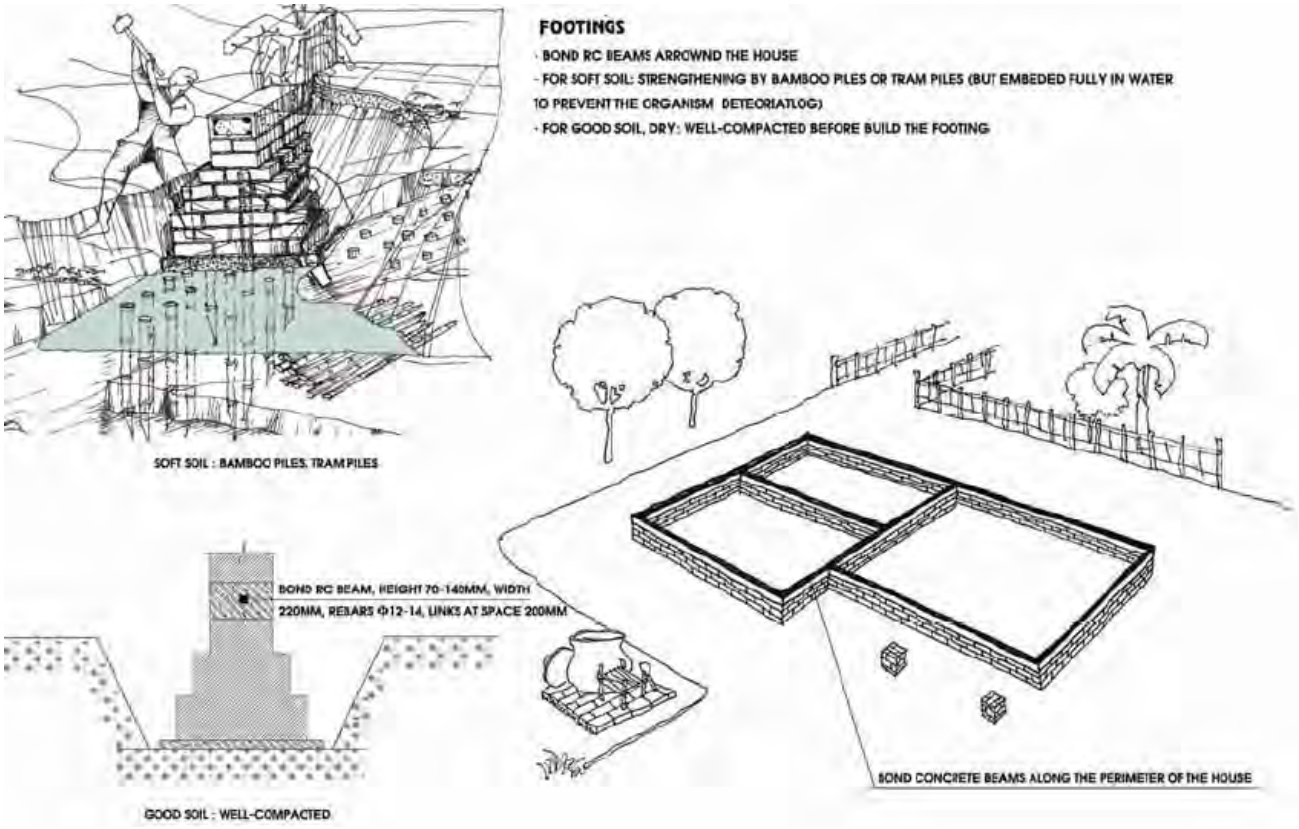

Fig. 3 Footing.

Masonry Footing (Fig 3):

- There shall be the reinforced concrete (RC) bond beam (or the foundation bracing) above the brick footing (at the ground level) continuously running around the perimeter of the house. The depth of the bond beam is from 70 to 140 mm, the width is 220 mm. The reinforcing bars are D12-14, the links are D4-6 at 200 mm spacing.
- For the soft soil: the soil shall be improved by bamboo piles or tràm piles (the tràm tree can be found in the South of Vietnam, similar to bamboo). Theses piles must fully be in the underground-water level to avoid the quickly degradation of the piles.
- For the good soil: the soil should be well compacted.

Masonry-Walls (Fig 4):

- The wall with thickness of 200-220 mm (or the double wall) should be used. The single wall (the brick wall with the thickness of 100-110 mm) can also be used but strengthened with pillars at the distance of 2.5m in order to increase the stability and stiffness of the single wall.
- The RC bond beam (the width equals to the thickness of the wall, the thickness is from 150 to 200 mm) should be placed at the level above the windows and door (to be replaced the lintel) in the brick wall and continuously run around the house.
- The starting rebars should be arranged at the location where the roof-trusses are located from the reinforced concrete bracing to the roof-trusses to anchor the roof under the uplift forces.

Roofs (Fig 5):

- The best type of the roof is reinforced concrete slab-roof.
- If it is a slope roof, the roof should be provided with a ceiling. The roof slope should be in the range of 20o to 30o. Rafters to support the roof should be made of timber classified as the group 1 or 2 (Vietnamese Building Code 1997 [5]), bonded with solid mortises. Bracings in both vertical and horizontal directions should be provided between the roof elements. Purlins and battens must be firmly fixed to the roof's structure and gable walls. Diagonal bracings should be provided at roof's corners.
- Roof sheeting must be firmly fixed to the roof

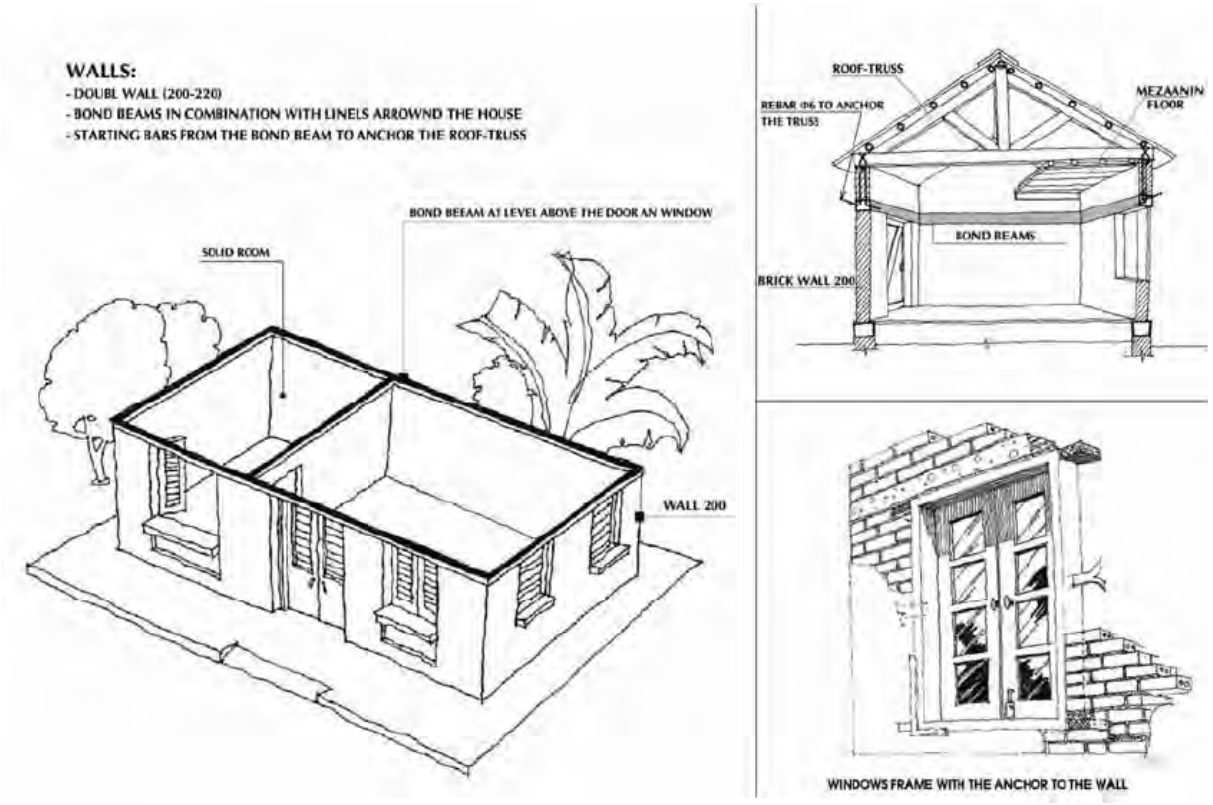

Fig. 4 Walls and windows.

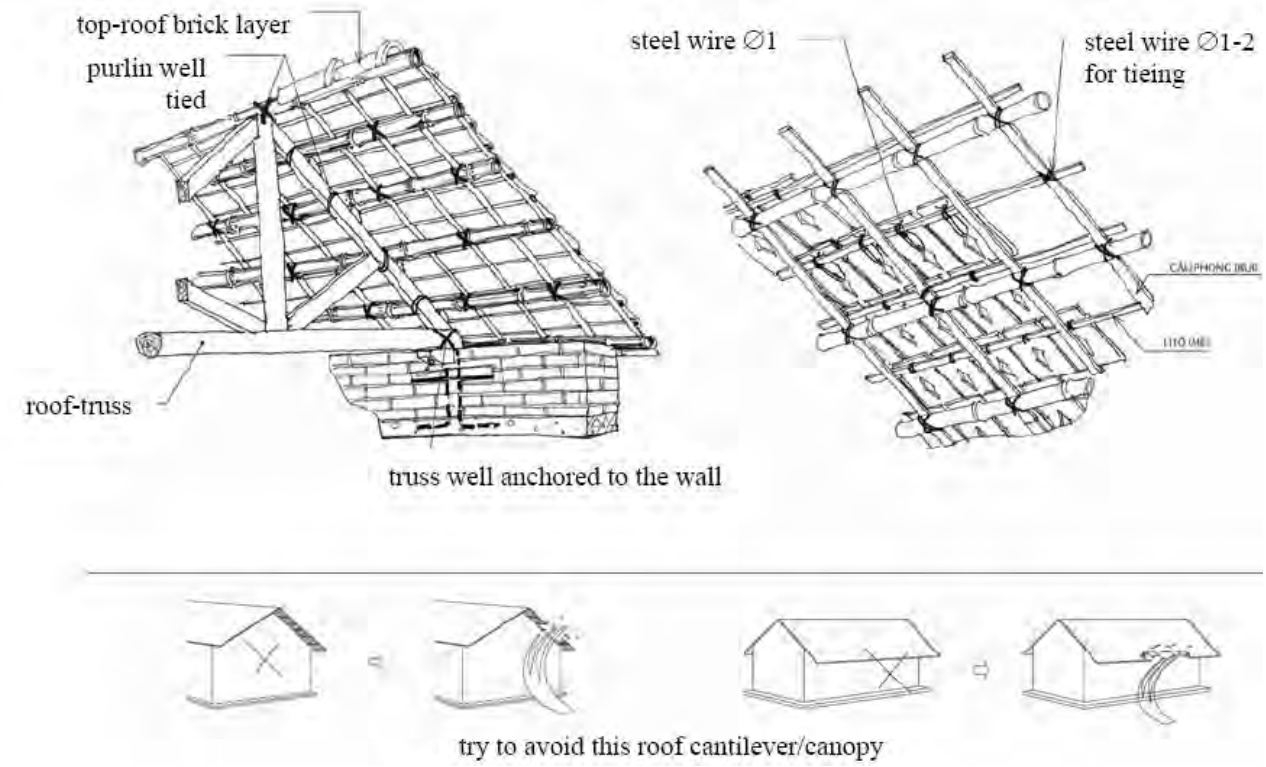

Fig. 5 Tiled roofs.

- structure. It is recommended to use the tiles with a hole for tieing them to the battens by steel wire 2. Purlins and rafters must be firmly fixed to each other for intergridity of the roof structure.
- Rafters and trusses must be well anchored down to the wall and the foundation.
- For houses with non-tied tiled roofs, cement motars should be added between the tiles to prevent the blown off of the roofs. Lay clay brick lines at the top (longitudinal) of the roof and following the roof's slope with an interval of 0.9 to 1.2m to enhance the stiffness of the roof under the upward winds. The roof's ridge should be covered with ridge tiles or clay bricks, well filled with cement mortar of grade 50.

Doors and windows:

- The doors and windows must be well closed during typhoon. Sliding doors may also be used for easily closing and opening.
- Door and window frames must be provided with steel nails for firmly fixing into the wall (Fig 4).
- Doors and windows that are made of bamboo mats or timber planks (without frames) should be strengthened with Z-shaped rods or be carefully nailed.

3.4 *Strengthening of the existing houses before typhoons coming*

Before typhoon coming, people living in the cyclonic regions usually ask the authorities for the ways to strengthen their houses (existing). Therefore, the following are the solutions recommended for the existing houses in terms of typhoon resistances.

a. Limitation of the roof from blown-off

During the typhoon if the roof is blown-off, the house is very easy to be collapsed. Limitation of the roof from blown-off is very important to keep the house stand. The below are some recommended techniques to strengthen the roofs.

Using sandy bags (Fig 6):

Sandy bags (or other similar bags) with the weight of 15 to 20 kg put on the top of the steel sheet roofs or the fibro-cement curve panel (FCCP) roofs can prevent or reduce the roof or part of the roof from blown-off under typhoon winds. Sandy bags can be up-loaded on the roof as follows: (i) Put the sandy bags in the edges or the overlaps of the roof sheets; (ii) distance between the sandy bags is about 1.5 m at the central area of the roof and about 1.0m at the edges of the roof; (iii) sandy bags shall be connected together by good wires or strong rope to avoid sliding.
Fig 3 shows people using sandy bags to prevent their roof from blown-off.

- Using steel member to tie the roof sheets to the purlins:

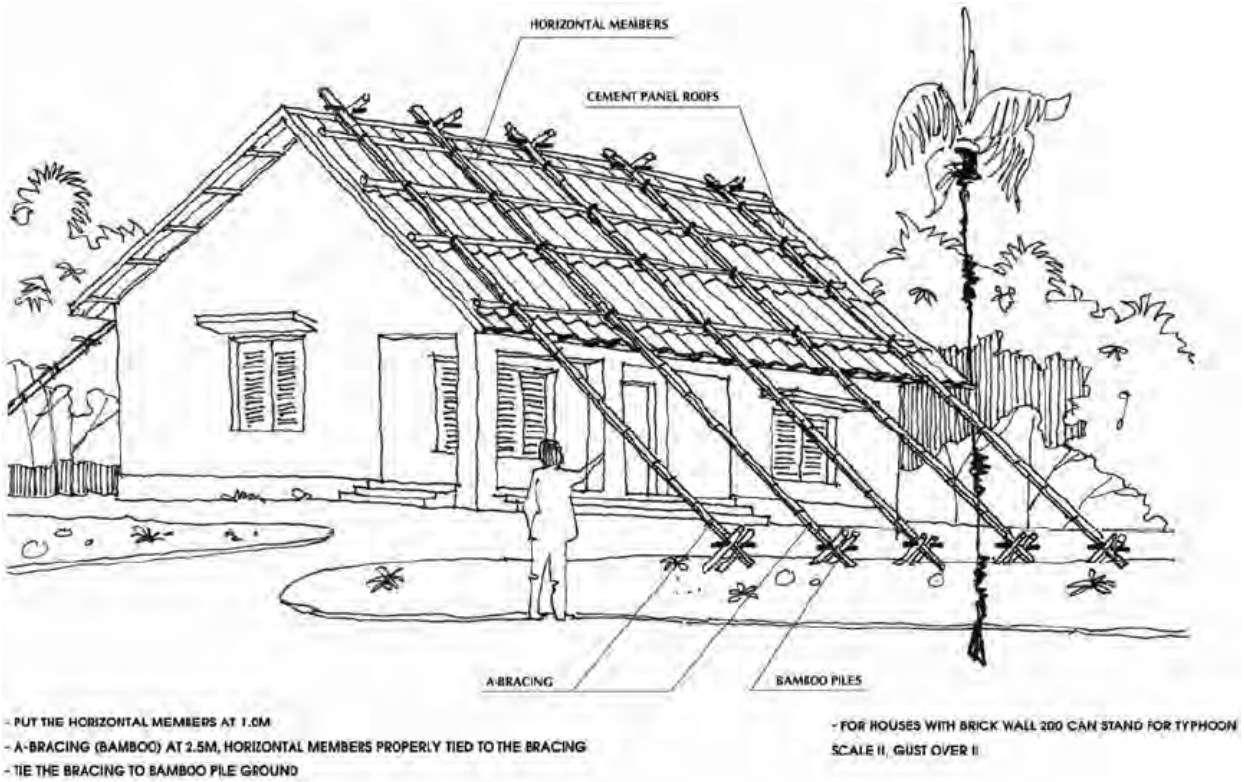

Fig. 6 Limitation blown-off of the roof by sandy bags.

Steel members can be rebars >=D14, long steel plate with the width greater than 50 mm, thickness of 1.5 to 2.0 mm and L-section members. Wooden or bamboos can be used as a strengthening member depending on the local conditions. Strengthening members shall be put on the roof with the distance between each other from 1.2 to 1.5 m for steel-sheet roofs and from 1.5 to 2.0 m for FCCP roofs. Then, using the high-strength screws or steel wires D2 to tie these members to the purlins. The distance between two screws or two wires is about 0.6 or 0.7 m. This solution will be applied for houses with stable bearing walls, rafters and truss systems.

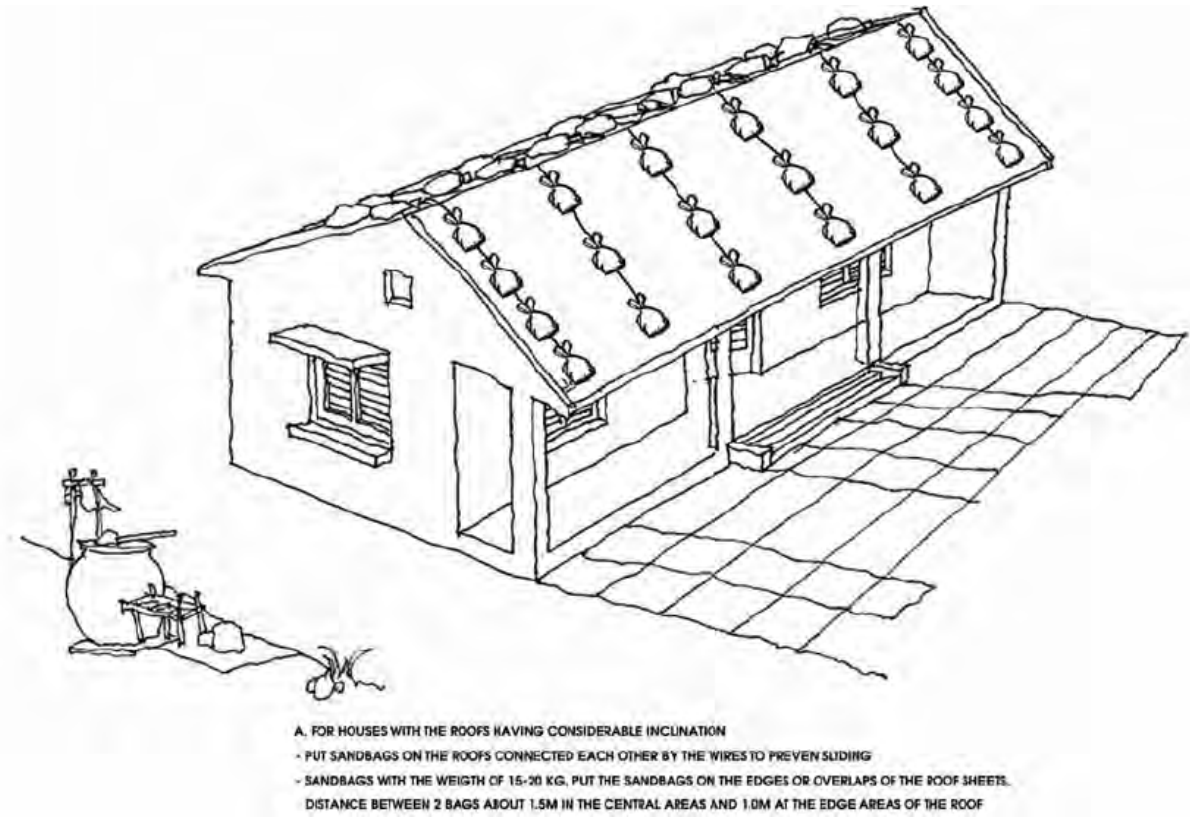

Fig. 7 Strengthening of existing house using A-bracing

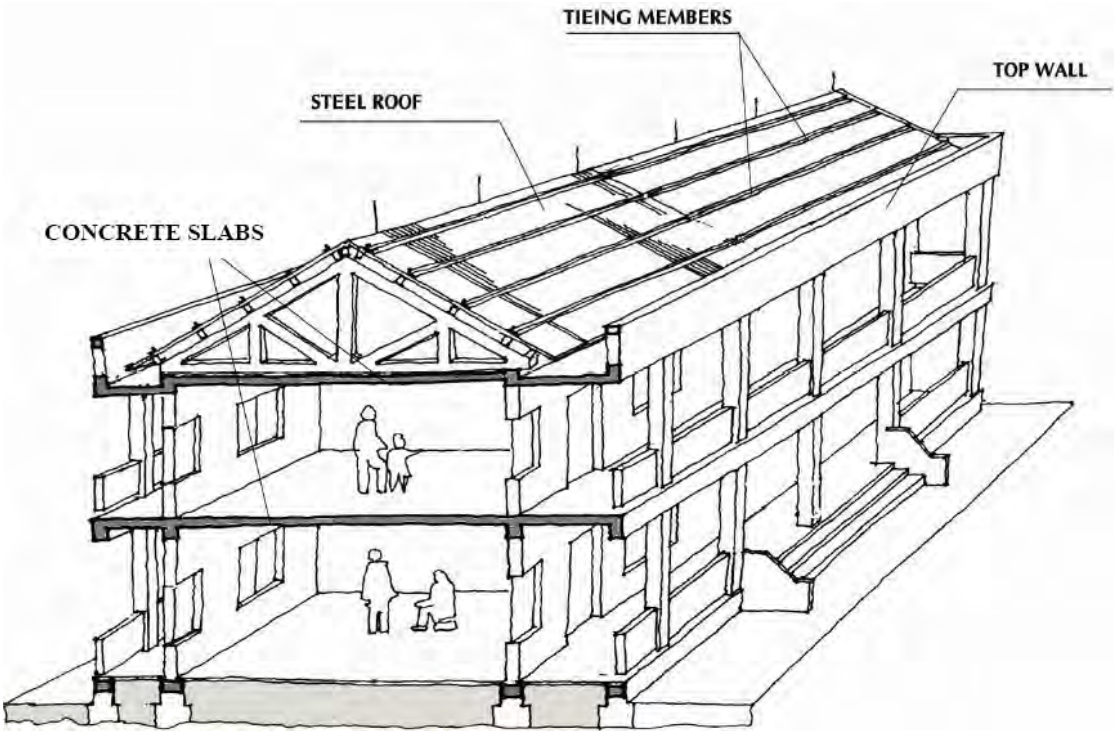

Fig. 8 Typical evacuating building made by RC frames and slabs.

- Limitation of the ties-roof from blown-off:
With regard to existing houses that are roofed with non-tied tiles, add mortar above the upper part of a tile to raise the lower part of the tile lying above it at the roof's edgings, at 3 to 4 lines (of tiles) next to the ridge and the gable edges. Add brick lines following the roof's slope with the distance about 1.0 m to reduce the possibility of lifting-up the roof.

b. Using the A-bracing to prevent the house collapsed during typhoon

A-bracing in combination with strong wires to tie the roof and the house to the foundation is an effective solution to strengthen the existing house under the typhoon attack (Fig 7). This solution can be applied for the houses in the suburban areas or country sides.

c. Close and tie all doors, windows and other holes properly before typhoon coming.

3.5 *Evacuating people to strong and stable buildings when very strong typhoons coming*

When very strong or super typhoons coming, the strong and stable buildings such as the government offices, schools and medical centers etc. shall be used for evacuating people. Strong and stable buildings must well be constructed based on the specifications of the building codes and standards considering the wind loads caused by typhoons that are expected for the site. RC frame buildings with concrete floors and the RC roof are preferred for such kind houses (Fig 8). In case, the evacuating building is quite far from the house, it is advised to prepare the underground space strengthened by sandy bags and bamboos (in or near by this house) for hiding during the typhoon.

4 CONCLUSION

This paper has provided the information about the typhoons in Vietnam and the technical solutions recommended for existing and new houses in the tropical cyclonic areas considering the local conditions. Houses in the typhoon affected areas must be constructed considered the wind forces caused by typhoons. Typhoon winds can uplift the roofs, blow-off the windows and doors of the houses. The gust-wind in the very strong typhoons can fully damage the houses or structural parts of the houses. Therefore, understanding the typhoons and typhoon wind pressures as well as the simple typhoon resistance construction techniques can significantly reduce the damages of the houses for people living in the cyclonic areas. The general principle is that the roof and the house shall be well tied and anchored to the foundation. However, the roofs should be evaluated under the uplift loads during the typhoon. Windows and doors must be well closed and properly tied to avoid breaking up for aged people and children. Traditional experiences should be referred and the experiences of professional architects and engineers can be asked when building the houses in the typhoonic regions.

5 ACKNOWLEDGEMENT

The supports from the UNDP Project VIE/01/014 Capacity Building for Natural Disaster Mitigations and Ministry of Construction of Vietnam are highly acknowledged.

6 HYPERINK TO OTHER MATERIAL

A wide range of submission file formats is supported, including: Word, TIFF, GIF, JPEG, Excel and Powerpoint, MPEG and AVI files. The individual file size should be less than 3 Megabytes (Zip files are highly recommended for reducing the size), otherwise please contact the Webmaster for instructions to upload documents using Ftp. Upon publication of the documents, hyperlinks will be provided in the main documents to read these files.

7 REFERENCES

- *[1] TCVN 2737:1995 Loads and actions – Norms for design, Construction Publishing house, Hanoi, Vietnam, 2005 (in Vietnamese).*
- *[2] NguyÔn TiÕn C−êng, TrÇn Chñng, Cao Duy TiÕn, Phạm M·o, NguyÔn Xu©n ChÝnh et. al. Study the technical solution for typhoon and flooding prevention for buildings and houses, Research project report, State Scientific program, Hanoi, Vietnam, 1992 (in Vietnamese).*
- *[3] IBST Guidelines for constructions in natural disaster affected regions, a component of the UNDP Project VIE/01/014, Hanoi, Vietnam, 2007.*
- *[4] Macks K. J. The A.B.C. of Cyclone Rehabilitation, © UNESCO 1996. Vietnamese version, Construction Publishing house, Hanoi, Vietnam, 1997.*
- *[5] Ministry of Construction Vietnam Building Code, Vol. I, II and III. Construction Publishing house, Hanoi, Vietnam (in Vietnamese).*

– *[6] Scott, H. Defining the wind: The Beaufort scale, and how a 19th-Century admiral turned science into poetry. Crown, ISBN 1400048842, 2004.*
– *[7] Nguyen Xuan Chinh, Nguyen Huu Hung and others Investigations on the damages of houses and buildings caused by typhoons Xangsane and Durian, Internal report, IBST, Hanoi, Vietnam (in Vietnamese).*
– *[8] UNDP Project VIE/97/002 Strategic Study for Natural Disaster Mitigation and Management in Vietnam, in CDroom, Disaster Management Unit, Ngoc Ha, Ba Dinh, Hanoi, Vietnam, 2001.*
– *[9] Nguyễn Đăng Bích and Trần Việt Liễn Explanation report on the wind zoning map for construction, Institute of Meteorology and Hydrology, Hanoi, Vietnam (in Vietnamese).*