LAND SUBSIDENCE HAZARD DUE TO KARST IN VIETNAM AND MITIGATION MEASURES

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ABSTRACT: In Vietnam karst caused land subsidence is serious problem, especially when it is occurring in limestone rocks covered by upper soil layer with the thickness of 30-40m. The deformation of the ground is dominantly resulted in colapsed depression or hole with circle shape on the ground surface. The diameters vary from 2 to 5m, reaching upto 5-10m in some places. Although funnel type of the subsidence is less common, it has widely impacting diameter. The main factors causing this type of hazard are the water table drawdown due to drought and groundwater overextraction, mining exploitation…. This paper studies the land subsidence hazard related to karst topography in some areas in Vietnam and suggests the preventive measures for reducing this type of disaster. The preventive solutions are relocating population from dangerous areas, strictly control the exploitation regulations and procedures, maintaining rational water use in the regions of karst topography. The question how to improve kart surveying is also disscused.

INTRODUCTION

Karst is a common geo-hazard in the area distributed carbonate, dolomite and general in the easy dissolved rocks. In Vietnam, rocks that contain the carbonate component located in large area and present in almost province in the north, north – central area, even though it express to earth surface in the low to and high mountains. In the lowland of delta, it was covered by the sedimentary. With the geological condition, accompanies with the complex hydro-geological and climate condition, the kart operating in Vietnam is promoted and led to cause the related geo-hazard that became the serious problem to human living and other society activities.

There were some previous researches studied on the kart hazard, however those researches only mentioned on to describe, demonstrate the reasons based on geological, terrain condition but there was not the field data or detail analysis. The purpose of this research is synthesis literature kart catastrophe in Vietnam to have an overview on the mechanism, the type and scale of disasters, mainly land subsidence, which offer solutions prevent. In addition to material derived from other studies, the authors have examined in some disaster areas, implementation of methods to locate the field scale, cave, geological, hydrogeological, geological conditions. A number of preventive solutions to reduce risks caused by kart also are proposed in this study.

Summary of Karst Risks in Vietnam

Karst subsidence problem is the formation of sinkholes, subsidence funnel surface topography of activities related to karst. This problem often causes the broken of houses, public works, roads collapsed, threatening human life. The phenomenon of land subsidence due to the kart limestone always has been happening annually. However, most cases occur "silently" in the hills, so it was not detected by many peoples. Only until the subsidence phenomenon known well by its effects to people's life, then that phenomena will be recorded, investigated. This paper synthesized a number of land subsidence places that has been a great influence on people's lives where they had to evacuated, displaced, this study also shown the severely hazards have been occurred in recently years, attracted the attention of the levels of local government, and scientists.

Land Subsidence in Cam Tuyen commune, Cam Lo district, Quang Tri Province

During 2006, at Tan Hiep village, Cam Tuyen commune, Cam Lo, Quang Tri province has been continuously occurring large-scale land subsidence at residential homes crowded. In just a short time, the village appeared tens of sinkholes, 4-5m wide, 1.5 to 3 m deep, distributed and displayed on the land surface, concrete roads, residential home gardens, water wells and even the floor, causing collapse led to surface land subsidence, cracks more than 60 houses and buildings. Land subsidence in Tan Hiep

was detected at 21clook on 18/02/2006 and had appeared scattered in the following days. Up to 03/03/2006, Tan Hiep village has identified 52 landslides, large and small holes, distributed in a strip with a width of 150-200 m, length 300 m. The holes are mostly round, offer size, maximum diameter 25 m, 0.2 m minimum, and average 4-5 m. The sink holes have the shape in typical funnel expanding in the bottom expand and link together to form a set of karst funnel causing the groundwater flow when water be supported. Landslides in Tan Hiep cause very serious damage to buildings and people's life. There were total 178 households in commune, while 122 households affected by karst hazard in different levels, including the seven floor houses collapsed, the wall collapsed, causing damage to the head completely. Dozens of other houses collapsed or partially sunk cracked causing insecurity. (Nguyen Duy Tieu et. all, 2007); (Doan Van Tuyen, Vu Cao Minh, 2008).

Figure 1 Sink holes Land subsidence in Tan Hiep commune, Cam Lo district, Quang Tri province (February, 2006).

Figure 2 Land subsidence in Quoc Oai district, Ha Noi (November 2008)

Land subsidence in Quoc Oai district, Hanoi

From 2006 to now, in the former province of Ha Tay (now belongs to Hanoi), there were three ground craking incidents breaking houses (Fig. 2). All these regional problems occurred when people digging wells to extract ground water. November 2008, at Quoc Oai Town, has serious incidents stem from domestic wells for household. Subsidence wide radius to 70 - 80m, the deepest collapse was measured about 1.4 m and tended to spread to the

provincial highway No.419 where was cracked about 20m long, wide cracks from 4 - 5cm.

Land subsidence in Bac Kan province

The phenomenon of land subsidence and collapse in Bac Kan has happened many times and many places, such as in the case of land subsidence in Luong Thuong, Na Ri district in late 2006 and Ngoc Phai, Cho Don district in early 2008.

In Cho Don district date from 7/1-9/1 in 2008, has appeared many cracks and ground subsidence, making the cracks long and the funnel with the depth up to 6m . Cracks appeared in two rural areas: Na Tum and Coc Thu, Ngoc Phai commune. The floor of the 10 households appeared cracks around 2-3 cm. In particularly, on 8 January 2008, in Na Tum field region, there were two land subsidence holes suddenly appeared with distance between them of about 100meters, the depth from 5 - 6m, and 7m in diameter. Na Ri district, the phenomenon of land subsidence and cracks appeared in Giang hamlet, Luong Thuong. Firstly, the kart operating begun and expressed in small cracks in the dry fields on 31/12/2006. Then, the cracks gradually grew, and created large sinkholes up to 4-5m deep.

Land subsidence in Tuyen Quang province

This area frequent occurrence of karst subsidence hazard, particularly in the year 2004 - 2005 many sinkholes have appeared in the Tan Thanh village, Tan Quang township, Ham Yen district, and the village of La-Y, An Tuong, Luong Son in Yen Son district. (Figure 3). Since 2009, land subsidence occurred seriously due karsts at highway No.2, at Tuyen Quang township (Tuyen Quang province), while the widest hole has the diameter of 3-4m and the depth of about 5m, causing many traffic accidents on this road. Based on the results of geo-physical, geotechnical investigation, the reason caused surface land subsidence is the collapsing of karsts hole in the underground and these hole had been filled by the soft soil as mud and sand cause the mud lenses with the thickness of 5-7m.

Land subsidence hole in Tan Thanh

Land subsidence hole in An Tuong

Figure 3 Land subsidence in Tuyen Quang

Figure 4 Ground craks and land subsidence at Trai Cau, Dong Hy, Thai Nguyen province

Land subsidence in Thai Nguyen province

The area that has been identified the land subsidence related to underground kart are in Trai Cau, Dong Hy district and Can hamlet, Ky Phu commune, Dai Tu district.

In 5 years recently, the land subsidence appeared and extended in the large area in the Trai Cau town, Dong Hy district (Figure 4). To July 2010, it was found nearly 10 sinkholes with sizes up to 5-7m and many cracks in the ground surface. More than 100 households are affected, while nearly 10 houses were damaged.

In Dai Tu district, the phenomenon of cracking in the house and at the road or land subsidence of surface ground was detected on 01/15/2010 at the Can hamlet, Ky Phu commune. Firstly, a numbers of racks appeared at about 30 meters long, about 2 to 3 cm wide, and one other cracks in arc shape stem from a family's garden and then spread to two other families' area. Few days later these cracks forming the border of a drop funnel with the wing cracks down to 2 to 3 cm.

Land subsidence in Long Tho district, Hue city

In Long Tho, Hue City, the subsidence area that has been determined the cause of phenomena relating to underground karst, was not large scale with the shape in circle, class size, the diameter of 8 m and 2 m depth. In the same time, at the edge of the mining exploited limestone at a depth of 22m, appearing a muddy stream flows into the mining. The flow was estimated from 200m3 to 3400m3/ngay, shown there was large hole in underground.

According to initial survey results of the Department of Natural Resources and Environment in conjunction with Department of Geography and Geology, University of Science, Hue University, regional subsidence on clay sediments, belong to Holocene clay formation, caused thin layer covering upper the limestone rocks of the Co Bai formation. The geological structures companied with the morphology of the subsidence area help to predict the reason caused by dome collapse of kart caves in the limestone area.

Land subsidence in Hoa Binh province

Hoa Binh province is the wide distribution of limestone and often occurs land subsidence due to karsts phenomenon, however the data recording was until very limited. Recently, the subsidence in kart areas was evaluated for the developing and planning land use in the Dam Vi, Phu Lao, Lac Thuy district. The phenomenon of land subsidence was begun investigated from 2005. According to the survey results by questionnaires in communities shows that the land subsidence has appeared since 1995 with the large sinkholes in shape of oval hole 15 meters long, wide 7-8m. In 2005, new sinkholes have appeared next to that old hole with a diameter more than 5 meters, breaking a piece of irrigation canals. In addition the survey also recorded two other sinkholes 7-10m diameter in the previous year.

SURVEYING KARST AREA BY GEOPHYSICAL METHODS

The survey results in Cam Lo district, Quang Tri province

Geological Institute, Vietnam Academy of Science and Technology has conducted survey in the field to determine the cause and scale of activity in Cam Lo Karst region in February 2006. The method that has been used to determine seismic fast tracking of the distribution area of limestone karst zone structure was the method of electrical resistance tomography electrical resistance tomography, seismic. The results (Figure 5) displayed in the electrical resistance tomography, seismic resolution, processing software analyzes the document on the field combined with the geotechnical survey in the field, show that this is a catastrophe typical kart subsidence. The karsts phenomenon has already occurred here before the processing of kart subsidence hazard, geological structure is a favorable prerequisite for subsidence processing (Figure 6).

The survey results in Tan Thanh district, Tuyen Quang province

In Figure 7 shows the result of a geophysical survey lines with resistance tomography technique through sinkholes in Tan Thanh village. The results display the structure and factors causing kart subsidence hazard. In subsidence funnel, the thickness distribution of sediments thicker than the two edges, and the subsidence funnel is just above the limestone kart processes caused by the influence of the zone of groundwater movement. This area continue suffered by karsts risks if there is any more factors of water discharge such as drilling extract ground water or any other factors that promote the movement of the water in the area of limestone.

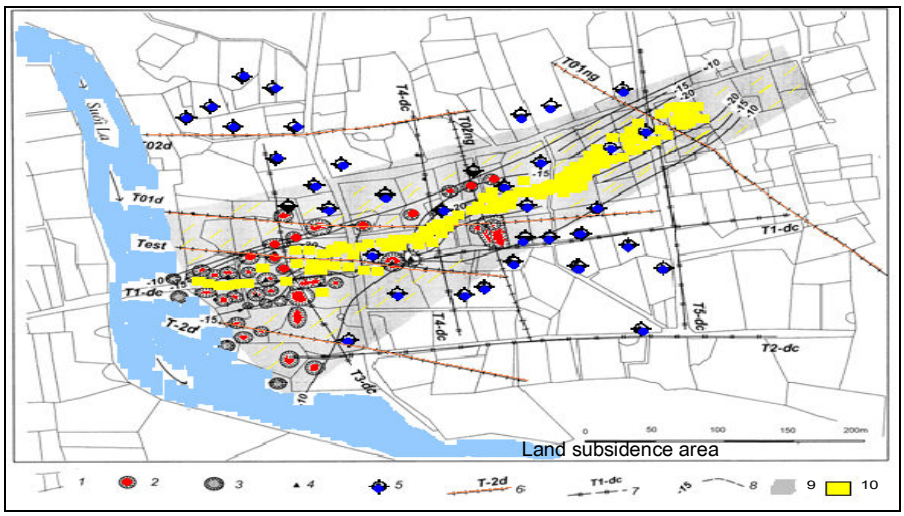

Figure 5 A map of the survey results and landslides locations in Tan Hiep village

Legend: 1 - field, garden, 2 - Dry sinkholes; 3 – Under water sinkhole; 4 - Location of sampling; 5 - Water wells, 6 – Electrical geophysical survey route; 7 – Seismic geophysical survey route; 8 - Thickness of overlaying limestone soil layer; 9 – Area of high risks of land subsidence; 10 - Deep limestone drop zone > 20 meters.

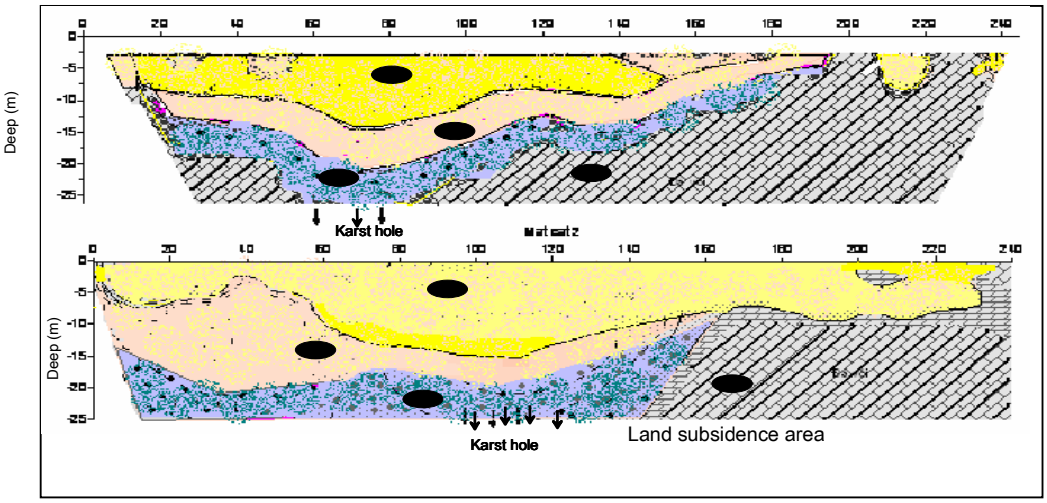

Figure 6 The cross-section showing soil and rock profile along T01d test route

Legend: 1- Low cohesion Clay; 2- Saturated Sand;

3- Coarse sand and Gravel; 4- Limestone

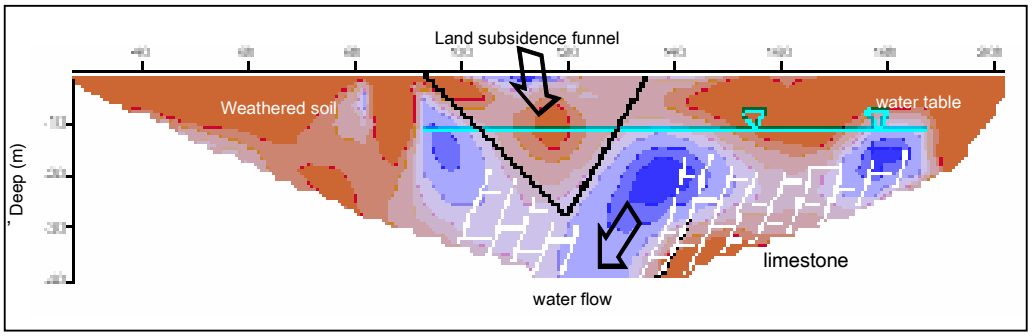

Figure 7 The geophysical cross-section in Tan Thanh, Tuyen Quang province

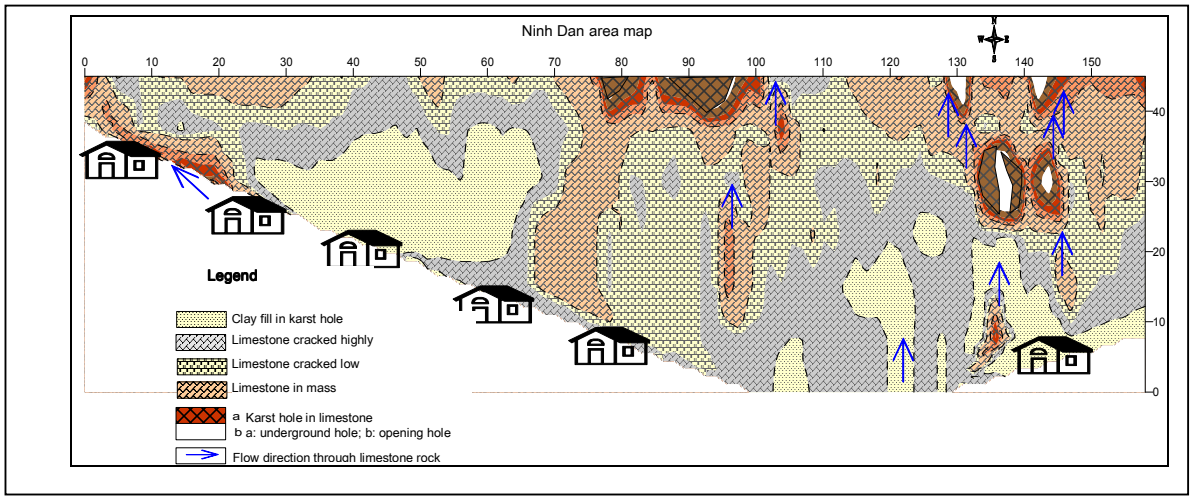

Figure 8 Map of karst structures in Ninh Dan commune, Thanh Ba district, Phu Tho province

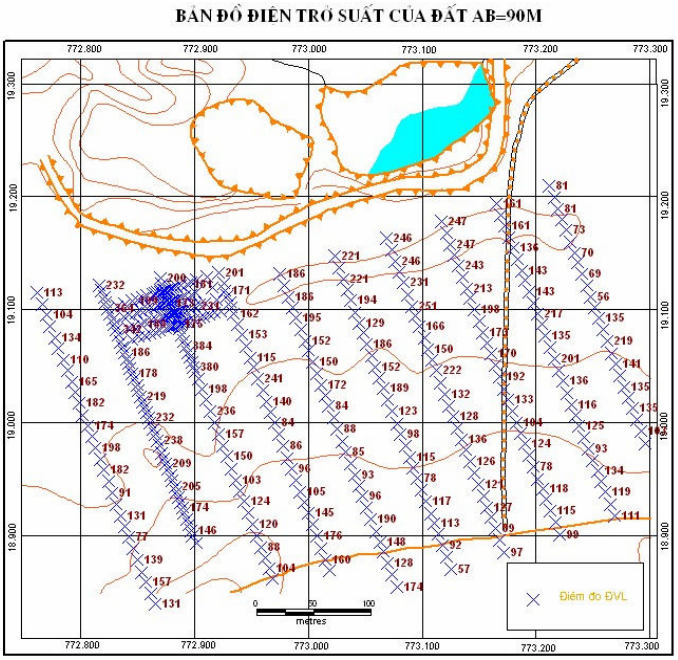

Figure 9 Map showing the locations of resistivity measured points in Long Tho district, Hue city

The survey results in Ninh Dan commune, Thanh Ba district, Phu Tho province

Figure 8 is the result from the application of handheld devices (ERA made in Russia) to map the current situation and forecast the underground karst cave near the church in Ninh Dan, where has high density of karsts sinkholes. Based on this map, the warning should be given to houses located in dangerous locations.

The survey results in Trung Thuong, Thuy Bieu, Hue city

In Trung Thuong village, Thuy Bieu, Hue city, objective research was the active karst sinkholes located in the south of Long Tho limestone mining pits. The research scope was limited to about 0.25 km2 (500m x 500m), the depth approximately 30 m, with karst sinkholes in the center. Areas with high risk of landslides from 20m^2 to 1000m^2, includes 18 holes positions with the shape quite offer size, extending in two lines parallel to the latitudinal. Areas with negative anomalies on the resistively may be the rocks broken then to be inserted in the fill material as clay, and

may be the karsts caves. The main cause is due to the corrosion and solution of underground limestone leads to thinner of caves edges and loss of bearing capacity of the above soil layer, then causing the surface collapse.

PREVENTIVE MEASURES FOR DISASTERS RELATED TO KARST

Kart activity is complex and varied, in order to avoid the risk of stroke Kart activity affects to the works and community life, the present study suggested the following solution measures:

1. Investment funding and specific knowledge to study and mapping the distribution of karsts risks area: Based on geological materials, tectonics, geomorphology determine the limestone formations given in the listed hazard risks. Next, identify and classify risk level when additional conditions on hydro-geological, engineering geological conditions, other human activities. To achieve high performance in research, must use a combination of methods such as methods of geological, geomorphological, hydrogeological, geological, modern geophysical methods. Production of research activities show clarify the current status of Kart region corresponding to the stage, the level, and scope of influence in space and time company with the predicted results development capabilities, and hazards potential.

2. Based on the results of the mapping on kart hazards zone, all levels of local government making orient for land use planning, building works away from dangerous areas or solution works efficiently, safely. Give early warning to the community and have specific and strict instructions on the use and exploitation of land and water for communities in the underground kart areas. Taking measures to provide drinking water to avoid exploitation of underground water that considered as one of the major causes of loss of balance and accelerating the process of karst hazards causing land subsidence. Strengthening management and building permits for homes and offices in the province according to regulations.

3. Increased use of modern methods such as geophysical methods to monitor, study the karst activities. Combined with other methods of geotechnical method to interpretive mechanism causing surface subsidence, then make oriented technical solutions for the prevention and treatment applied in the construction building.

CONCLUSIONS

Limestone is widely distributed in North and Northern Cental Vietnam so that the land subsidence due to karsts activities occur frequently causing greatly damage to the local communities. Human activities such as overexploitation underground water, construction and mining works also make these disasters stronger and widely occurred.

To prevent and mitigate hazards caused by the karsts, it is needed to carry out the following works: i) doing detail research and carrying out the mapping in the highly risk karst hazards zone; ii) using modern combined methods having no or little disturbances and negative impacts to the surrounding ground and surface and underground water environment such as Electrical receptivity and Radar penetration and tomography methods; iii) Using combined methods on site survey data interpretation to find out the causes as well as the mechanism of land subsidence and sink hole formation and finally iv) to affort construction projects and buiding houses in the high risk karst areas to follow strictly the safety regulations for the buildings in karst regions and finally v) the collaboration among scientists, local government and communities is needed in mitigating the karsts risks by inducing training programs on the awareness of the karst risks and explaining rules and regulations on groundwater extraction, exploiting mineral resources as well as other knowledge for sustainable management of the karst topography and landscape.

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