Geophysical Research Abstracts, Vol. 7, 08943, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08943

Qualitative Assessment of Geohazard in Rječina Valley, Croatia

Č. Benac (1), V. Jurak (2), M. Oštrić (3)

(1) University of Rijeka, Faculty of Civil Engineering, Croatia, (2) University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Croatia, (3) Croatian Waters, Department of Rijeka, Croatia (benac@gradri.hr / Phone: +385-51-352-103 / Fax: +385-51-332-816 / Adress: V.Cara Emina 5, 51000 Rijeka, Croatia)

INTRODUCTION

Rječina watercourse is 18.7 km long. Its spring is placed in the foot of Gorski Kotar mountains, and its rivermouth in the center of the city Rijeka. Rječina river valley extends through three distinctive geomorphological units. The upstream part of the river is in relatively wide valley, formed in the Paleogene flysch rocks. The central part of the watercourse is in a narrow flysch valley, which is a part of a karst plateau, composed of the Upper Cretaceous and the Paleogene limestones. Downstream part of the watercourse flows throught deep canyon cutted into the Cretaceous and Paleogene limestone rocks.

The central part of the watercourse, between the Valići dam and the beginning of the canyon part close to Pašac, is 1.8 km long, and 0.8 to 1.1 km wide between the opposite slopes. This is the most unstable part of the wide area of Rijeka, with the high degree of geohazard. Mass movements are mostly occurring on the contact of fractured, and karstified carbonates with flysch rock complex. In the above mentioned, central part of the valley, that is in its south-western part, two large rockfalls of limestones were recorded. In the northeast part of the valley, a complex landslide is active. Different types of movements can be distinguished in it: sliding of slope deposits over the flysch bedrock, toppling of limestone blocks and rockfalls from cliffs.

GEOLOGY OF RIVER VALLEY

Tectonic structure which includes the investigated part of the Rječina valley is part of a dominant geomorphological unit which strikes in the direction: Rječina valley -

Sušačka draga valley - Bakar Bay - Vinodol valley. The structure was considered as a flysch sinkline skirted by faults.

Due to the analogy with a tectonic style of the Vinodol valley, which represents the continuation of Rječina valley structures, it was possible to apply an interpretation of tectonic relations by a process of continental subduction, on the basis of the model of joined subductions. "The main zone of shallow subduction" of Adriatic carbonate platform under Dinaric on the northest, is assumed to be placed in a wide area of the Rječina valley and the Vinodol valley (Blašković, 1999).

Kinematics of structural elements of the entire tectonic unit Rječina valley- Bakar Bay - Vinodol valley, is based on the relation of relatively rigid (carbonate rocks) and relatively plastic (flysch) material during the simultaneous deformations. This case also refers to the already mentioned structure in Rječina valley. The Cretaceous and the Paleogene limestones are situated on the top of the slope, while the Paleogene flysch is situated lower on the slope, including the bottom of the valley. Flysch rock complex represents a squeezed block between the limestone rock blocks on the northestern and southwestern side. The effects of deforming are the most distinctive on the contact between carbonate and flysch rock complex. That is the reason why relatively rigid limestone rock mass are pushed in a more ductile flysch rock, which had different resistence due to its complex geological composition. In such a way, a former straight line tectonic contact, could took a present appearence.

Neotectonic and recent movements , induced by the subduction of the Adriatic plate under the Dinaric, probably caused irregular subsidence of the valley bottom of the squeezed sincline and the uplifting of surrounding terrain (Blašković, 1999). Due to that, limestone rock mass was repeatedly faulted and fractured. This tectonic movements enabled separation of limestone rock blocks and fragments and its gravitational sliding over the flysch bedrock, disintegration of rock mass, as well as the accumulation of talus in the foot of rock cliffs.

Energy of the relief in the described part of Rječina valley was changing due to the neotectonic movements, climatic changes during the Quaternary and changes of local erosion base, that is, the position of the Rječina riverbed. That was a reason why the intensity of the erosion was frequently changed. The above mentioned morphogenetic development was probably not continuous, but there were periods of higher or lower intensity of accumulation of slope formations (Benac et al., 1999, Benac et al., 2000).

DESCRIPTION OF INSTABILITIES

Almost entire southwestern slope of the valley, composed of flysch bedrock, is covered by predominantly coarse soils of limestone composition. Crown of instability is clearly marked by cliffs formed in limestone rocks. The crown represents the rim of the karst plateau. On the northeastern slope, slope deposits are mostly a mixture of clayey silt that was formed by weathering of flysh bedrock and fragments to blocks of limestone originating from the cliffs on the top of the slope. Only in area of the active complex landslide, coarse grained slope deposits, like those from southwestern slope, can be found. On both slopes, different types of instabilities, according to type of movement, type of material involved and state of activity, can be found (Cruden and Varnes, 1996). Limestone cliff from the top of the southwestern slope is very disintegrated and recenty opened fractures are visible. Rockfalls are permanently occurring and debris slides are formed of predominantly coarse soils. There are no visible boundaries between the instabilities.

However, two phenomenon on the southwestern slope can be distinguished:

1) Debris avalanche on SW slope: The crown of the recent instability phenomenon is clearly skirted by limestone cliffs, while the toe reaches the regional road. Moved slide mass is composed of coarse fragments to blocks larger than 10 m^3. Slip plane is probably predisponed by flysch bedrock morphology. Excavation of rock materials caused rock avalanche that buried the regional road in 1979. It was estimated that the mass movement had a volume over 170 000 m^3. Estimated dimensions and geometry of this instability phenomenon are described according to WP/WLI Suggested Nomenclature for Landslides (IAEG, 1990):

-total length: $L = 110$ m;

-width of the displaced mass: $W_d = 150$ m;

-depth of the displaced mass: $D_d = 10$ m.

2) Debris avalanche and rock slide on SW slope: Slide material is composed of coarse fragments to blocks up to 50 m^3 large. Slip plane is probably predisponed by morphology of flysch bedrock. It was recorded that in this area in 1908. debris avalanche buried village Grohovo and partialy dammed Rječina River. It was estimated that the mass movement had a volume of 1 650000 m^3. Estimated dimensions and geometry of this instability phenomenon are:

-total length: $L = 450$ m;

-width of the displaced mass: $W_d = 300$ m;

-depth of the displaced mass: $D_d = 10$ m.

The crown of the instability phenomenon reaches the foot of a rocky block, which is 450 m wide and 150 m long. Limestone rock mass in the block is disintegrated.

Recent velocity of movements is very slow and it can be considered as an inactive, dormant landslide. However, movements in reactivation period were very rapid. A large limestone block separated from the karst plateau can be considered as a separate phenomenon. It can be considered as an inactive, dormant rock slide.

On the northeastern slope debris avalanche and a complex landslide can be distinguished.

The crown of slope instability is clearly marked by carbonate cliffs formed on the rim of the karst plateau. Like in other instabilities slip plane is predisponed by flysch bedrock. Limestone rock mass is very disintegrated and recently opened fractures are visible. That caused a formation of rockfalls and rocktoplles. In the foot of the limestone cliffs coarse grained slope deposits can be found and debris slides formed. In the lower part of the slope fine grained material prevails and consequently earth slides are formed. Dimensions and geometry of this instability phenomenon are:

-total length: L = 425 m;

-width of the displaced mass: W$_d$ = 200 m;

-depth of the displaced mass: D$_d$ = 6-20 m;

This landslide is not a recent phenomenon, because the data concerning mass movements has been registered during the entire 20th century. On December 1996 approximately 850.000 m^3 of material moved. That caused movement of isolated limestone blocks and opening of new fractures in a rock megablock on the top of the slope. Results of geodetic surveys indicated the largest displacements on the top of the slope, displacements of isolated blocks as well as the limestone megablock that is separated from the karst plateau. The larger part of landslide body is saturated by underground water penetrating through the covering zone in contact with flysch bedrock. Unlike the limestone, flysch rock mass is more subject to weathering. That caused a formation of a clayey weathering zone on the flysch bedrock (Benac et al., 2002). According to accepted classifications, the described instabilities have characteristic of retrogressive landslide that started to develop from toe to the top of the slope. The reason has been undercutting by river flow erosion. Movements of predominantly coarse slope deposits have characteristics of debris avalanches, according to velocity of movements. Due to the fact that the position of the slip plane was predisponed by geological composition, the landslide can also be considered as a consequent translational (Cruden and Varens, 1996).

CONCLUSION

A clear distinction in morphology of the opposite slopes of the valley, as well as the difference in granulometric composition of their deposits, can be noticed. The northwestern side is almost entirely covered by coarse grained, uncemented tallus material, where blocks larger then 10 m^3 are frequent. Tops of the slopes are clearly divided from the karst plateau by carbonate cliffs. Measurements of displacements, as well as visible instability phenomenon on the southwestern slope, are indicating relief of distinctive geodynamics. Described instabilities are atypical for karstified carbonate and flysch complex contact in wide area of Rijeka. Those types of instabilities are more frequent in Alps (Moser, 2002).

Only in the above mentioned part of Rječina valley, instabilities on both slopes are formed. Basic geohazard event could be movement of slope deposits towards the channel of Rječina. This could cause two secondary effects: damming of Rječina and formation of lakes; and formation of flooding wave due to destruction of natural dam, and consequently flooding of some parts of the city. (Erismann and Abele, 2001)

Since both slopes are at the edge of a stabile equilibrium state, preparatory factors already exist. Heavy precipitation or earthquakes may be efficient triggers of rockfalls and rockslides. Daily precipitation higher then 100 mm is frequent in this area. Rječina valley is a part of Rijeka's epicentral seismic area, in which earthquakes with magnitude higher then M= 6 where recorded during the last two millennia (Herak 1996).

In further investigations of mass movements on slopes, quantitative geohazard assessment will be needed. A monitoring system for the observation of further events on both slopes of the valley should be set.

REFERENCES

Benac, Č., Arbanas, Ž., Jardas, B., Kasapović, S. and Jurak, V. (1999): Complex Landslide in the Rječina River Valley. Rudarsko-geološko-naftni zbornik 11, 81-90. (in Croatian)

Benac, Č., Arbanas, Ž., Jurak, V., Kasapović, S., Dujmić, D., Jardas, B. and Pavletić, Lj. (2000): Lanslide Grohovo-Complex Landsliding in the Valley of the Rječina River. In: Procedings of 2^{nd} Croatian Geological Congress, Cavtat, Croatia, 517-523. (in Croatian)

Benac, Č., Arbanas, Ž., Jardas, B. Jurak, V and Kovačević, S.M. (2002): Complex Landslide in the Rječina River valley (Croatia): Results and Monitoring. In: Landslides (J. Ribar, J. Stemberk and P. Wagner, eds.) Proceedings of the 1^{th} European Conference on Landslides, Prague, Chech Republic, 487-492. A.A. Balkema Publishers, Lisse-Abingdon-Exton-Tokyo.

Blašković, I., (1999): Tectonics of Part of the Vinodol Valley Within the Model of the Continental Crust Subduction. Geologia Croatica 52(2), 153-189.

Cruden, D.M. and Varnes, D.J. (1996): Landslide type and Proceses. -In: Landslides: Investigation and Mitingation (Turner, A.K. and Schuster, R.L. eds.). Special report 247, 36-75, National Academy Press, Washington, D.C.

Erismann, T.H. and Abele, G. (2001): Dyamics of Rockslides and Rockfalls. Springer-Vrelag, 307 p.p., Berlin-Heidelberg -New York.

Herak; M., Herak, D. and Markušić, S. (1996): Revision of the Earthquake Catalogue and Seismicity of Croatia, 1902-1992. Terra Nova, 8, 86-94.

IAEG (1990): Suggested Nomenclature for Lanslides. Bulletin IAEG, 41: 13-16.

Moser, M. (2002): Geotechnical Aspects of Ladslides in the Alps. In: Landslides (J. Ribar, J. Stemberk and P. Wagner, eds.) Proceedings of the 1^{th} European Conference on Landslides, Prague, Chech Republic, 23-43. A.A. Balkema Publishers, Lisse-Abingdon-Exton-Tokyo.