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Assessment of Rockfall Risk along Kakia scala road, Greece

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Introduction - Objective

Rockfall phenomena often occur at highway road cuts in mountainous terrain. It's a common type of fast-moving landslide and represents a major hazard in mountain areas worldwide. They can cause human lives' loss and extensive damage to the human structures (especially roadways and houses). Rockfalls are dependent on the site conditions (both topographic and geological structure), climate, tectonic, human activities as well as seismic loading (Hoek and Bray, 1981; Koukis et al., 1994; Guzzetti et al., 1996; Marinos and Tsiambaos, 2002). As far as Greece is concerned, Rockfall is considered as the most frequent (55%) landslide type (Koukis et al., 1994; Marinos and Tsiambaos, 2002) and usually occurs after heavy rainfalls or earthquake events.

The main objective of the research is the rockfall risk assessment in the "Kakia Scala" region using Rockfall Hazard Rating System (R.H.R.S). The study area is a typical example with high impact of rockfalls. It is part of the *"Patra–Athens–Thessaloniki-Evzoni (P.A.TH.E.)"* motorway one of the most major highways in Greece and for this reason the importance of a reliable rockfall risk assessment is crucial. Eight representative sites (A-H) were examined, and the Rockfall Hazard Rating System was calculated according to Pierson et al. (1990).

Geology-Tectonics-Seismicity

"Kakia Skala" area mainly consists of Alpine formations that belong to the Sub-Pelagonian geotectonic unit. A carbonate (limestone and dolomitic limestone) sequence of Middle-Upper Triassic age constitutes the basement of this area (Gaitanakis et al., 1984). A transgressive sequence of Cretaceous limestones – marly limestones overlies them. Finally, this sequence passes upward to post-alpine formations (Late Pleistocene screes and cone - shaped screes, talus cones, alluvial Deposits, marls, clays, Fig 1). The present research focusses on the limestones because rockfalls occur only on them.

The study area is mostly affected by normal faults which have an East–West to ENE-WSW direction while the inclination fluctuates from 45° to 75° (sometimes until 85° or seldom 90°). On the other hand a smaller number of secondary faults with NE–SW direction are met (Mettos et al., 1988). This great fault zone mostly occurs in limestone and dolomitic limestone of the Middle-Upper Triassic. Many faults go through the fault zone, but the "Kakia Skala" main fault can easily be recognized. This happens because it has been activated many times in the past and its plane has become much more smooth and impressive. Although "Kakia Skala" is not considered to be highly seismic, the high seismicity of the eastern "Corinthian gulf" (next to it) has a great influence on it. Some researchers (Mettos et al., 1988; Rondoyanni and Papadakis, 1992; Makris et al., 2004) mentioned that the "Kakia Skala" fault is of great importance and possible to be approximately related with an earthquake of Ms=6.5 Richter. Earthquakes of this size are likely to cause a significant movement along the crack and cause rockfalls.

Methods - Results

In order to assess the exposition to the risk associated with Rockfalls and the remediation works, many classification systems were designed for highway slopes. One of the most widely used methods is the Rockfall Hazard Rating System (RHRS, by Pierson et al., 1990). It is an approach that leads to an immediate and relatively user-friendly way of scoring the hazard level of the examined rock slope. In the scoring procedure, several critical parameters concerning the geological and the geometrical features are evaluated (slope height, the ditch effectiveness, average vehicle risk, percent of decision sight distance, roadway width, structural condition, friction, difference in erosion rates, block size, volume of rockfall per event, climate and presence of water on slope, rockfall history). Each parameter contributes to the overall hazard associated to a score of 3, 9, 27 or 81 following an exponential increase in the form of $y=3^x$. According to the literature data, slopes with a rating of less than 300 can be considered as slopes with low risk while slopes with a rating greater than 500 are identified for urgent remedial action (slopes of high hazard level). In this study eight representative sites (A-H, Fig 1) were examined and the Rockfall Hazard Rating System values were calculated for each section. As it was listed in Table 1, the Rockfall Hazard Rating System (R.H.R.S) gives values between 378 and 603. Along the study area, the most dangerous sites are F (603) and G (504). Both of them present high risk and so measurements must be taken. The best site is H (378) and it is characterised as moderate.

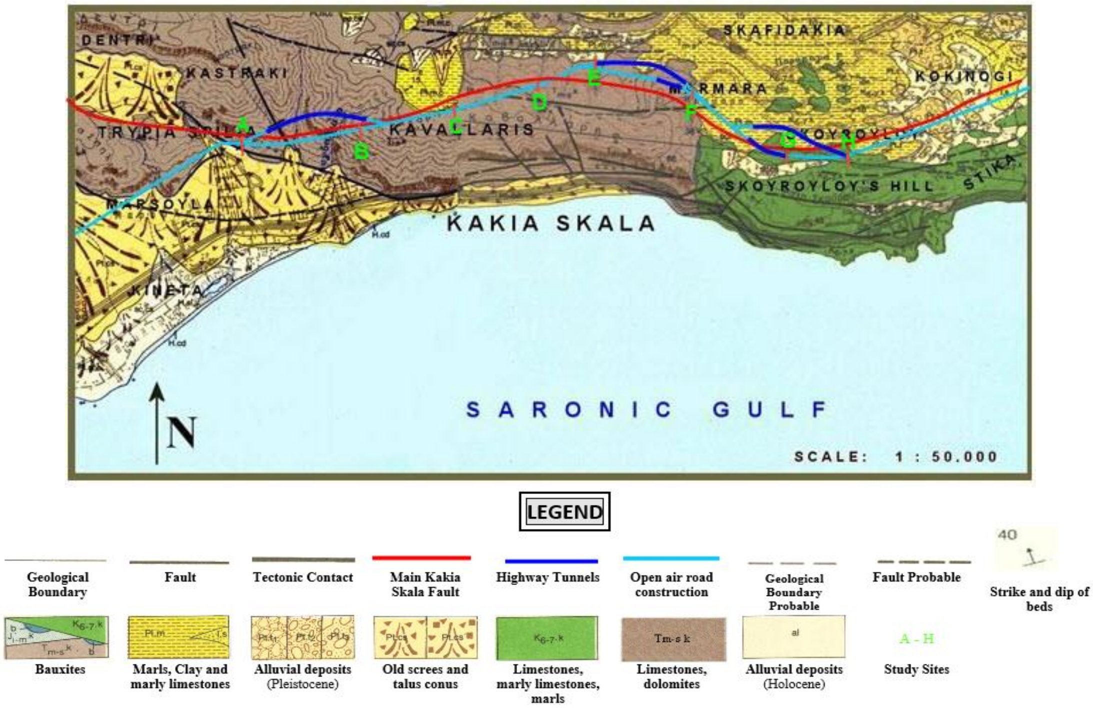

Figure 1. Geological Map of the "Kakia Skala" area (Geological mapping: I.G.M.E. 1976)

Table 1. The rating of each site and their classification according to RHRS

Site	Rating	Classification
A	423	Moderate
B	459	Moderate
C	486	Moderate
D	477	Moderate
E	441	Moderate
F	603	High
G	504	High
H	378	Moderate

Conclusions

To sum up, this research mainly attempts to study the assessment of Rockfall Risk in the "Kakia Skala" area, which is part of the one of the most major highways in Greece. For this reason, the Rockfall Hazard Rating System (R.H.R.S) values were calculated for eight sites. The study demonstrates that the R.H.R.S fluctuates between 378 and 603 and the most dangerous sites are F (603) and G (504). Both of them present high risk and so urgent remedial actions must be taken. The best site is H (378) and it is identified as moderate.

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