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# Investigation of the Distributions and Causes of Landslides in Central Alborz, Iran

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**Abstract:** The study of landslides in central Alborz mountainous range revealed that frequency and type of failure mechanisms are strongly controlled by weathering processes. Slides on low angle occur most frequently near to faults, where the failures usually are rotational slides and mudflows. But in steep slopes avalanche and planar slides are dominant. Shallow slides are usually located near roads and rivers and in places in which vegetation coverage has been removed. Earthquakes and road construction are the main triggering factors in this area.

**Key words:** Landslide . alborz . weathering . earthquake . rainfall

## INTRODUCTION

From structural and geological points of view, the Iranian mountainous ranges known as part of Alpine-Himalayan system in western part of Asia, between the Arabian shield in southwest and plate of Turan in the northwest. This system is one of the major belts of neotectonic and seismic activity. The mountainous terrain such as Alborz and Zagros active belts characterised by steep slops, high relative relief weathered, fractured, faulted and folded rocks (Fig. 1). Figure 1 shows the distributions of landslides in Iran.

In this paper landslides in central Alborz are presented and the results of field investigation for some landslides in the Central Alborz are discussed. Landslides are common features in the Alborz Mountains of Iran. Due to geological location, geomorphology, topography, climatic, active tectonics, vegetation and dense population, the area suffers a number of natural hazards of different types, including all kinds of mass movement.

The landslide hazard is used as an umbrella term for wide range of complex slide. Different threats are posed by different type of slope movement [1]. Landslide triggered casualties and economic losses are greater in many countries than is commonly recognized [1-4]. There are many classification of landslide, which to some extent is due to the complexity of slope movement [5, 6]. Varner classified landslides according to the type of movement on the one hand and the type of material involved, on the other.

Reference is made below to different types of landslides using this classification. Landslides, debris slides, debris flows and rock falls cause extensive damage to forests, roads and highways, residential areas, gas and oil pipelines, water supplies, irrigation channels and occasionally result in loss of life. Damage to property and people are particularly great during earthquakes and after intense rainfall. For example, in the Manjil earthquake of magnitude Ms = 7.3 in 1990, a few hundred slides were triggered and more than 200 people were directly killed by landslides. In the recent earthquake of Baladeh in May 2004, of magnitude Ms = 6.3, numerous landslides occurred in the epicentre area, especially along the Chalous-Karaj road. This road was closed for a long time and eighteen people were killed by rock falls and rockslides. Also in October 1996 after three days of intense rainfall many landslides occurred in the hilly slopes of Mazanderan and Gilan Provinces in north of Iran. Damage was caused to forestland, roads, gardens, farms and residential areas. In this paper the characteristics of landslides in five different areas in central Alborz folded belts are introduced (Fig. 2).

**General geology and climatic of alborz mountainous range:** The Alborz mountain range in northern part of Iran, extending for about 2000 km from Armenia and Azarbaijan country in the North West to the north of Afghanistan to the east. This mountainous range has been created by collision of Turan and Iranian plates. This area is one of the most active seismo-tectonic provinces in Iran. The mountain belt is part of Alps-Himalayas mountain chain with similar seismic activity, which is a direct consequence of its tectonic setting. The Alborz mountain belt consists of different

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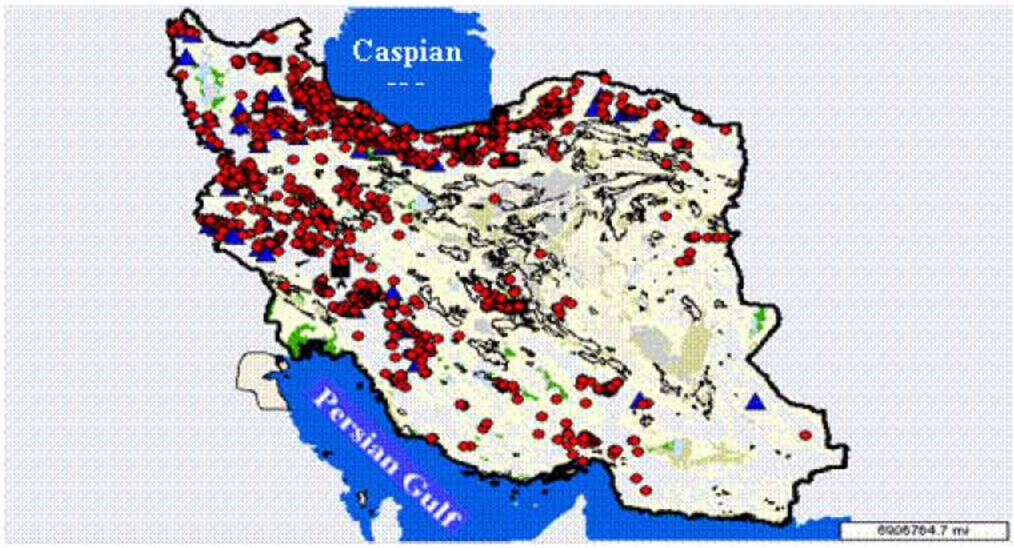


Fig. 1: The distribution of landslides in Iran

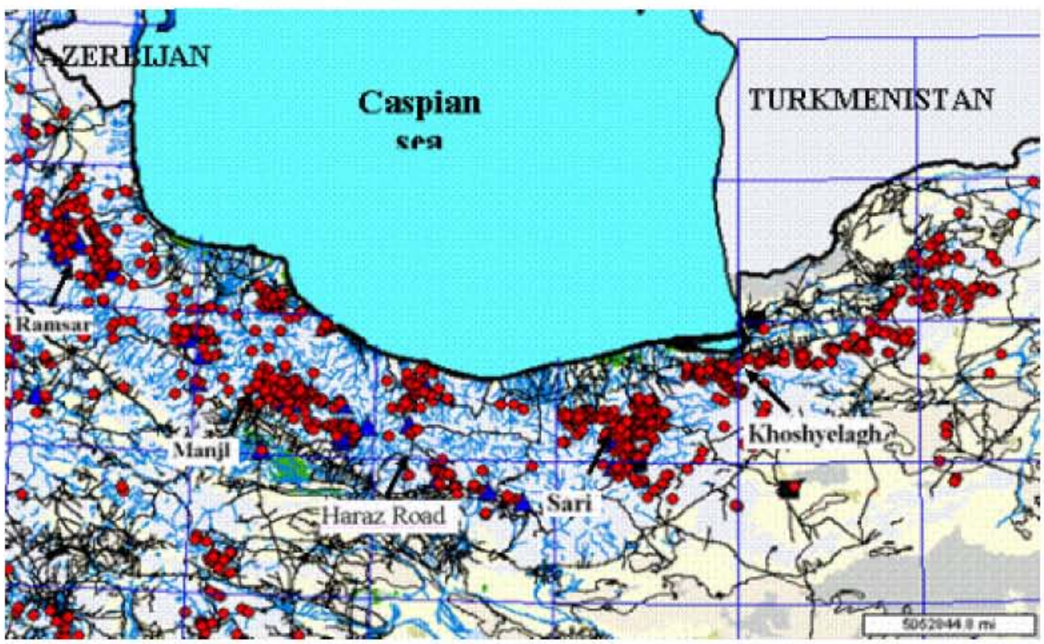


Fig. 2: The distribution of landslides in central Alborz in North of Iran

sedimentary, metamorphic and igneous rocks aging from the Precambrian to the Quaternary [7]. The geomorphologic features of the range are strictly related to the morpho-structural and selective erosion processes, which have led to rugged topography. The slopes are near vertical at the margin of strong rocks and main reverse faults. Inclined and undulating strata occur in outcrops of clay-rich weak rocks such as marl, shale and tuff. The The outer Alborz terrain in the north overlooking to Caspian Sea having a semi-Mediterranean climate with an average of precipitation from 700mm in mountains and up to 2000mm in the coastal plain and has thick vegetative cover due to the soft sedimentary rocks present there. The action of reverse fault of Khazar in north boundary of Alborz range causes the 2000 meter relative elevation between the Alborz Mountain and Khzare coastal plain. This high relative elevation resulted the high river erosion and under cutting of slopes that caused many landslides in bank of rivers. In this area the slopes usually consist of thick debris deposit and residual soils.

**Common causes of landslides:** Investigations reveal that in the Alborz folded belt lithology (such as marl, shale and tuff), steep slopes, high weathering, tectonic fissuring, active seismicity, rainfall, river undercutting and the human activities are the important susceptible parameters and the earthquakes, intense rainfall and road construction are the main factors triggering instability. The earthquake also makes the slope susceptible for future landsliding The human effects includes road, Gas and oil pipe line construction, the change of landuse(such as converted the forests to the farm).

The mechanism and location of slides are usually related to type and degree of weathering. The effects of weathering in slope instability in this area could be described as follows:

- Disintegration of rock mass
- Decrease of the shear strength of rock mass and discontinuities
- Increase the porosity and water absorption by decomposed material

In strong jointed rocks, weathering begins from discontinuities and increases the susceptibility of the rock mass to rock falls and planar and block slides. In weak rock masses (such as marl, tuff and shale), the weathering proceeds homogenously in rock material rather along fractures and usually result in slumps, rotational failure, mudflows and shallow and deep translation slides. The contact surface between fresh and highly weathered material that is usually parallel to slope surface has an important role in controlling instability of slopes in the weaker rocks. Also deep weathering in the toes of low angled slopes decreases their stability and may result in deep rotational slides. In following sections the causes of slope instability in five different area of central Alborz ranges are discussed.

**Landslides in Manjil area:** Manjil area is located in central-west part of the Alborz range. The various rocks such as tuff, shale, sandstone, schist, phylite, limestone, dolomite andesite, loess and Quaternary deposits occur in the area. The Manjil earthquake of magnitude Ms=7.3 in 1990 triggered a few hundred slides around the hilly and woody epicenter area. Landslides affected large areas and blocked all the roads in this mountainous region, thus disaster relief efforts were impeded and this increased the death toll. During this earthquake a large landslide buried the village of Fatalak with about 180 inhabitants. All kind of slides such as rock falls, rockslides, planar slides, rotational slides, mudflows and rock avalanches occurred during the earthquake [8]. The landslides were mainly located near the earthquake fault, ancient faults and the banks of rivers. Figure 3 shows the relationship between landslide occurrence and distance from main faults. As shown, more than 40 percent of landslides triggered by earthquakes are located less than 1km from main faults. The following characteristics are main reasons for this phenomenon:

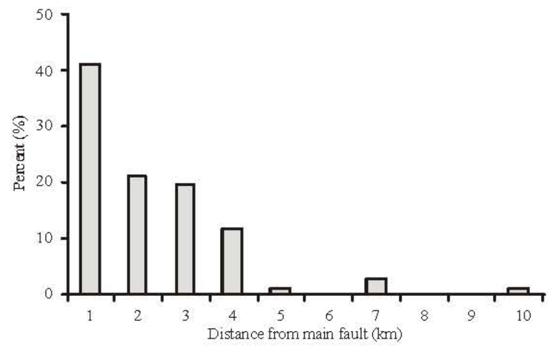


Fig. 3: Relationship between percent of landslide vs. distance from main faults in Manjil area

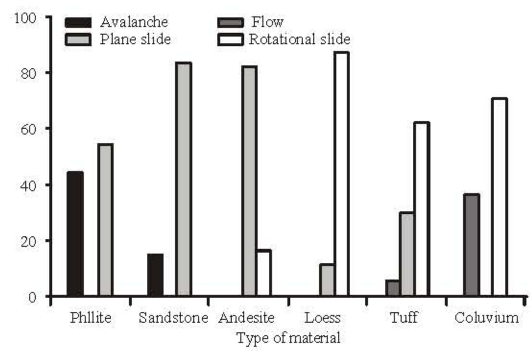


Fig. 4: Relationship between type of material and failure mechanism in Manjil area

- Closely spaced jointing and deep weathering near to faults
- High accumulation of debris deposits in foot area of faults
- High elevation difference

It was also noted that the type of lithology and geological conditions have great influence on the erodability potential and failure mechanism (Fig. 4). In weak rocks such as tuff and loess which are more, susceptible to weathering, the rotational slides and mudflows are more common, but in strong rocks such as andesite and sandstone it is usually rockslides that are dominant. The failure surface of planar slides in both weak and strong rocks usually lie at the contact between fresh and weathered rock.

Table 1: Geotechnical properties of Marl and weathered marl in North of Sari (downstream of Tajan dam)

| Type of material | Dry density (gr $cm^{-3}$) | Unconfined compressive strength (Mpa) | Water content (%) | Liquid limit | Plasticity limit |
|---|---|---|---|---|---|
| Marl | 2.1 | 0.8-0.9 | 5-6 | - | - |
| Weathered Marl | 1.7 | - | 20 | 45 | 25 |

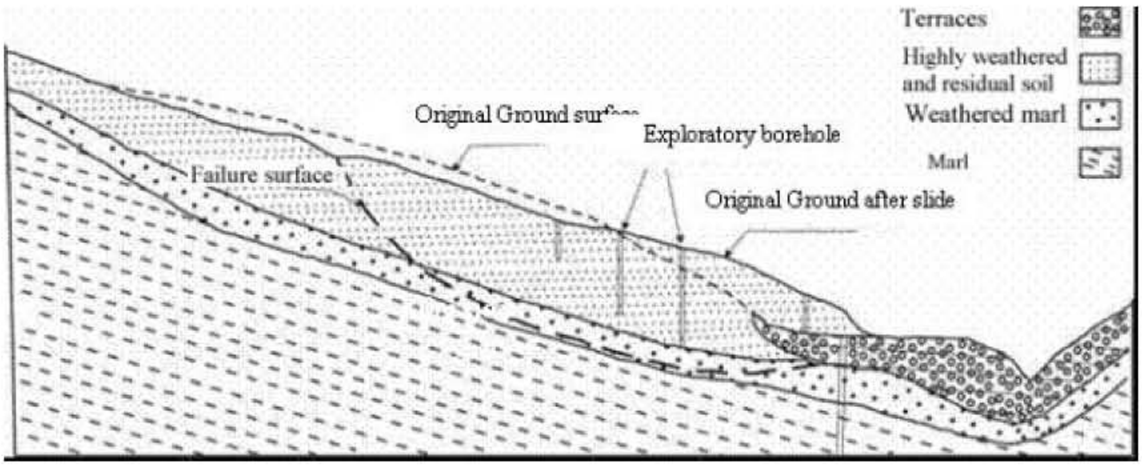


Fig. 5: The cross section of landslide in downstream of Tajan dam

Fig. 6: A view of landslide in downstream of Tajan dam

**Landslides in South of Sari:** Sari, the capital city of Mazanderan province, is located at the foot of the Alborz range near to the middle. The area consists of grey shale, sandstone, Shemshak formation and thinly-bedded limestone. The area is covered by dense forest. Weathering processes common in these formations change the soft sedimentary rocks, especially marls and shales, to unstable soils and result in frequent landsliding. The thickness of residual soil and highly weathered material in areas underlain by shale and marl are up to 40m, but in sandstone and limestone it is less than 5m. There are many ancient landslides in this area that become triggered by earthquakes and erosion of slope toes. The steeper slopes usually display evidence of creep failures. The construction of the Kiasar-Sari road in this area resulted in the reactivation of ancient landslides and the occurrence of about 150 new slides. Most are translational with a failure surface at the contact between fresh and weathered material. The great thickness of debris at the foot of slopes has an important role in the occurrence of landslides. Selective erosion leads to high relief where weak and strong rocks such as shale and limestone are present. The accumulation over time of debris material over decomposed shale results in landslides.

There are some large landslides downstream of the Tajan Dam. This structure is a 65m high concrete arch dam constructed in the Tajan river valley in Tangeh Soliman, North Sari. The bedrock downstream of the dam is marl and sandy marl. Landslides have occurred in both banks of the river with one about 200m from the dam axis. This 300 m long by 35m wide by 40m deep landslide is an ancient rotational slide that was reactivated during dam construction in 1996 and 1997.

It was not identified during the dam site study and the site selected for the power plant was in front of this slide. Reactivation was caused by building activities especially, the construction of the access road that entailed under cutting of slide toe. The storage of construction material was also responsible for the failure. Geophysical and geotechnical studies showed that the weathered marl is about 40m thick and that the failure surface is located at the contact of weathered with fresh marl. Figure 5 and 6 show the cross section and a view of the slide. The geotechnical properties of fresh and weathered marl are presented in Table 1.

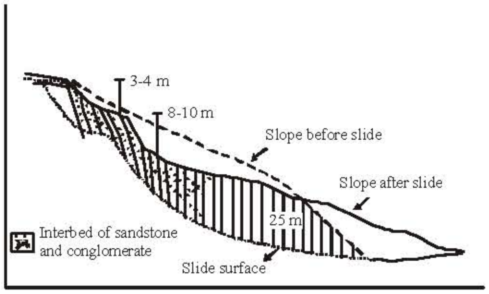


Fig. 7: Cross section of Sadat-Mahalleh slide in south of Ramsar

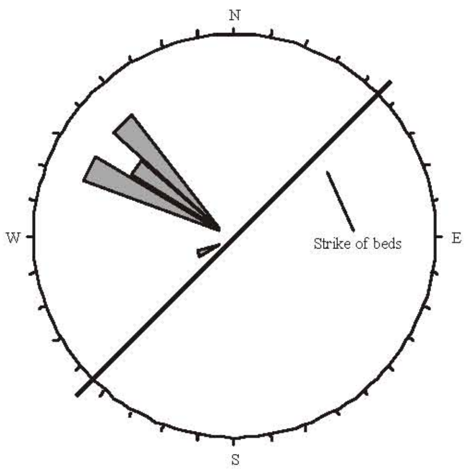


Fig. 8: Rosette diagrams of large slides directions respect to the strike of beds in Khosh-yelagh

**Landslides in North of Ramsar:** Ramsar is a beautiful city located at the foot of Alborz Mountains to the west of the Caspian coastal plain. The coastal plain in the Ramsar area is very narrow and the city extends on to the hilly terrain to the south. The bedrock in the latter area is alternations of shale and sandstone (Shemshak formation). The annual perception in this area is more than 1500 mm and the area covered by dense forests. The weak lithology, high rainfall, high degree of weathering and also human-activities such as deforestation, road construction, housing and agriculture have increased the potential for slope instability in this area.

In October 1996 after a few days of heavy rainfall many landslides occurred in the hilly parts of Ramsar City. These were mainly mudflows, shallow and deep rotational slides, many of which were in the bank of rivers and road sides. One particular notable landslides occurred in 1966 in sandstone in a location where forest trees had been replaced by fruit gardens. The seepage of surface and irrigation water in sandstones resulted in solution of calcite cement in the rock mass. The slide damaged a few homes and 3 people were killed in the Sadat-Mahalleh area. Figure 7 shows a vertical cross-section of the slide.

**Landslides in Khosh Yelagh area:** This area is located to the south of Azadshahr city in the central-eastern part of the Alborz mountainous range. The lithology of this area includes shale and sandstone with interbedded coal horizons. The strike and dip of beds are respectively N450 E and 40-500 towards the NW. Two groups of deep and shallow slides are present in this area. The deep landslides are usually controlled by geological structures and water absorption by the coal horizons and decomposed shale layers that give rise to very weak surfaces resulting in large planar slides. Figure 8, a rose diagram for the direction of large slides and the strike of the beds, shows the slide directions are usually normal to the bedding strike. Large planar failures result from increased intensity of weathering in zones of crushed rock. Secondary failures include mudflows and slumps. There are some active coal mines in this area and the construction of mining roads has triggered many new landslides and reactivated some ancient ones. The shallow slides are controlled by vegetation coverage. The averages of root extent and root penetration depth in this area are 4.5 and 1.5 m. respectively so the upper 1.5m of surface soils are reinforced. Shallow landslides mostly occur in areas of ancient slides, roads and man-made deforestation, especially where close proximity of villages has resulted in damaged root cover.

**Landslide along the Haraz road:** Haraz Road with 180km length is the shortest path joining the Tehran to the northern cities. This road cross the different rock units and geological structures of Central Alborz zone. Three large destructive landslides in this road are: Imamzadeh Hashem, Mobarak Abad and Lasem Valley Landslide. The Mobark Abad slide is located about 80 km far from Tehran in the south east of Damavand mountain. During last three decades it was activated several times. In 22 May 1988 after of a heavy rain the slide reactivated. Field investigation and structural analysis shows that geological conditions and structural discontinuities had significant role in the occurrence of the slide. The main damages of last activity of this slide were destruction of three shrines, three shops, several residential houses and blocked the Haraz road for more than one month.

## CONCLUSION

The landslides in Alborz Mountain range can be classified into two groups of deep and shallow slides. Investigations of these landslides have shown that lithology, geological structure, weathering and toe erosion of slopes are important factors that favor the occurrence of landslides whereas earthquakes, intense rainfall and road construction are the main triggers. Among these factors, weathering processes are very important. The locations and failure mechanisms of slides are strongly controlled by the degree and type of weathering. Shallow failures usually occur at the contact between fresh and weathered material and they are most prevalent where the forest cover has been degraded. On the other hand deep landslides are usually controlled by the geological structure, particularly the dip and dip direction of the bedding. Such landslides also give rise to conditions that favor the development of shallow slides.

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