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Effects of weathering and lithology on the quality of aggregates in the alluvial fans of Northeast Rivand, Sabzevar, Iran

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ABSTRACT

Alluvial fans as depositional landforms can be considered as potential sources of aggregates. As the age of alluvial fans increases, their constituent sediments are exposed to longer periods of weathering and increased mineral alteration, resulting in a decrease in aggregate quality. In this study, physical properties and point load tests were used to assess the aggregate quality on three alluvial fan surfaces (relict, old and young) in the northeastern part of Rivand village in west of Sabzevar, Northeast Iran. Differentiating young from old and relict fans was carried out based on geomorphic criteria such as weathering features, fan surface morphology and drainage pattern. The young alluvial fan is characterized by sub-rounded and unvarnished clasts, distributary drainage patterns and a relatively flat surface, whereas old and relict fans are characterized by incised and rough surfaces, tributary drainage pattern and highly weathered and varnished clasts due to their long-term exposure to weathering. Due to a range of rock types occurring across each fan surface, lithological studies were performed to eliminate the effect of lithology on aggregate quality. A total of 18 rock types comprising comparable lithologies were sampled from each of the three alluvial fans. Results show that, in almost all 18 rock types, the point load test values increases from relict to young fans whereas porosity and percentage of water absorption decrease, implying that aggregate quality decreases with time as a function of duration of exposure to weathering. Also, the strength of aggregates in all three fans decreases from the fan apex to the fan toe. Data show that micaceous, intrusive igneous rocks, tuffs with high porosity and fine-grained extrusive igneous rocks with some porosity are more sensitive to physical weathering, and therefore have lower strength, particularly on the relict and old fans. Overall, variations in aggregate strength on these fans can be attributed to the relative ages of fans, with relict and old fans containing lower quality aggregates due to the longer-term exposure to weathering.

1. Introduction

Alluvial fans develop where confined mountain streams open up into valleys or onto plains (Benito, 2013). They include large boulders, gravel, sand, silt and clay, with particle size exhibiting a general decrease in the downstream direction. Although alluvial fans are subject to natural hazards such as flooding and debris flows (NRC, 1996; House, 2005; Pelletier et al., 2005; Khan et al., 2013) they are good sources for aggregate exploitation (Lindsey and Melick, 2002; Langer et al., 2004). Nevertheless, the difference in the degree of weathering between old and young alluvial fan surfaces plays an important role in the quality of associated aggregates. For example, long-term exposure to chemical and physical weathering can result in the degradation of the fan surface, reducing the quality of aggregates. In contrast, a younger alluvial fan that has experienced less weathering generally contains higher quality aggregates.

Aggregates consist of resistant materials such as sand, gravel and crushed rocks which can be mixed with a cementing material to form concrete, mortar or plaster that can be used in a wide range of construction projects. Aggregates can also be used in road or railroad construction (Tshwenyego and Poulin, 1997). However, the main value of aggregates is in making concrete, comprising about ¾ of the volume. Therefore their characteristics exert an important effect on concrete properties. Strength, particularly in response to compression and tension, is the most significant characteristic of concrete. In resistant types of concrete, the strength of aggregates and their cohesion with mortar are key factors in the strength of the produced concrete (ACI Committee 221, 2001).

Although some researchers have evaluated the physical and mechanical characteristics of aggregate and their relations to concrete properties (Fookes, 1980; Irfan, 1994; Wu et al., 2001; Al-Oraimi et al., 2006; Torgal and Castro-Gomes, 2006; Meddah et al., 2010; Yılmaz

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and Tugrul, 2012; Duan et al., 2013), only a limited number of studies have addressed the geomorphological controls on the aggregate quality and distribution (Thomas, 1988; Panizza, 1996; Smith and Collis, 2001; Langer et al., 2004; Bell, 2007; Kennedy and Froese, 2008). Geomorphological processes such as physical and chemical weathering, erosion and deposition, as well as tectonic activity are important controlling factors in the formation and quality of the aggregates used as construction materials. Among these factors, weathering is of particular importance in determining variations in aggregate quality (Smith and Collis, 2001). Weathering is the alteration and breakdown of rocks at or near the earth's surface, mainly by reaction with water and air, to form clay, iron oxides and other weathering products (Ollier, 1991). All the weathering processes can affect the quality of building stones and aggregates (Smith, 1999). The longer the rock is exposed to weathering, the more it is altered, resulting in poorer aggregate quality. Generally, the suitability of aggregates for a particular construction application usually depends on the degree of weathering. For example, highly weathered materials are not suitable for aggregate, but may be suitable for lower parts of the road pavement and hardcore (Fookes, 1980).

As alluvial fan surfaces age, they are exposed to progressively greater degrees of weathering, leading to decrease of aggregate quality. However, among studies associated with the geomorphological controls on aggregate distribution and quality (Thomas, 1988; Smith, 1999; Smith and Collis, 2001; Langer et al., 2004; Bell, 2007; Fookes et al., 2007; Kennedy and Froese, 2008), only a few have focused on alluvial fans as a source of aggregate exploitation (Bryan et al., 2000; Gondal et al., 2008). Bryan et al. (2000) showed that material in older alluvial fans includes more decomposed rock because of longer exposure to weathering, and the highest quality gravels are the youngest alluvial deposits associated with the Truckee, Carson and Walker rivers in Nevada. According to Gondal et al. (2008), aggregates deposited in alluvial fans of ephemeral streams like Kaha/Khalgari, Pitok and Zungi in Pakistan have sufficient quality for the road sub-base and base course. Bahrami et al. (2012) evaluated the resistance to abrasion (Los Angeles test), uniaxial compressive strength and impact value of aggregates for old and new river beds, taluses, old and new alluvial fans in Khoramabad Catchment in west Iran. Their results revealed that, although each of these landforms contained aggregates with appropriate quality, aggregate strength diminished in old alluvial fans due to the influence of weathering duration.

The purpose of this study is to evaluate the effect of weathering and lithology on the quality of aggregates formed on the relict, old and young alluvial fans in the Northeast Rivand, Sabzevar.

2. Study area

Geologically, the study area occupies part of Sabzevar ophiolitic belt which consists of a mixture of ophiolitic and volcano-sedimentary rocks. The Sabzevar ophiolitic belt marks the boundary between the CIM (central Iranian microcontinent) and the Turan plate (Forster, 1978). This ophiolitic complex is located north and west of Sabzevar along the northern boundary of the central Iranian microcontinent, and is one of the internal Iranian groups of ophiolites and colored mélanges (Rahmati and Niazi, 1986; Shojaat et al., 2003). Iranian ophiolites, linking the east European ophiolites of Greece and Turkey to the west Asian ophiolites of Pakistan and India, are parts of the Neo-Tethyan belt in the Middle East that formed during the Jurassic–Late Cretaceous time (Khalatbari Jafari et al., 2013). The Sabzevar ophiolite is considered to represent a part of the northern branch of the Neo-Tethys ocean (i.e. the Sabzevar ocean) that opened and closed during the late Cretaceous and may be related to the ophiolites of the Lesser Caucasus (Lensch, 1980; Sengor, 1990). Although the ophiolite stratigraphy in this area is largely dismembered, it contains all the rocks that are representative of an ophiolitic suite (Shojaat et al., 2003). Petrologically the Sabzevar ophiolite sequence consists mainly of ultrabasic to gabbroic rocks, predominantly tectonite-harzburgite (Rahmati and Niazi, 1986). Lensch et al. (1977) distinguished eight main units in the ophiolite belt: harzburgite, intrusive rocks, sheeted complex, volcanic sedimentary sequences, mélange, metamorphic rocks, Tertiary series, and Quaternary sediments.

As Fig. 1 shows, the lithologic units in the catchment for the alluvial fans under examination include amphibolites, amphibo-schist (Am), sheet dike complexes (Cs), dacite, dacitic andesite, quartz and trachyandesite (Da), diabase (Db), gabbro (Gb), harzburgite (Hz), pillow lavas and deep marine sediments (Kvl), kream, pink gypsum bearing marls (Mm), red, brown conglomerate with intercalations of marl (Plc), pale grey unconsolidated, poor sorted conglomerate (PlQc), alluvial fans with young and low terraces (Qt2) and soldalite, analcime-bearing latitic andesite (Sa).

The tectonically active Sabzevar ophiolitic zone is composed of some imbricate sheets (Fig. 2). The Sabzevar thrust is the major identifiable active fault in the region (Fattahi et al., 2006). The northward-dipping

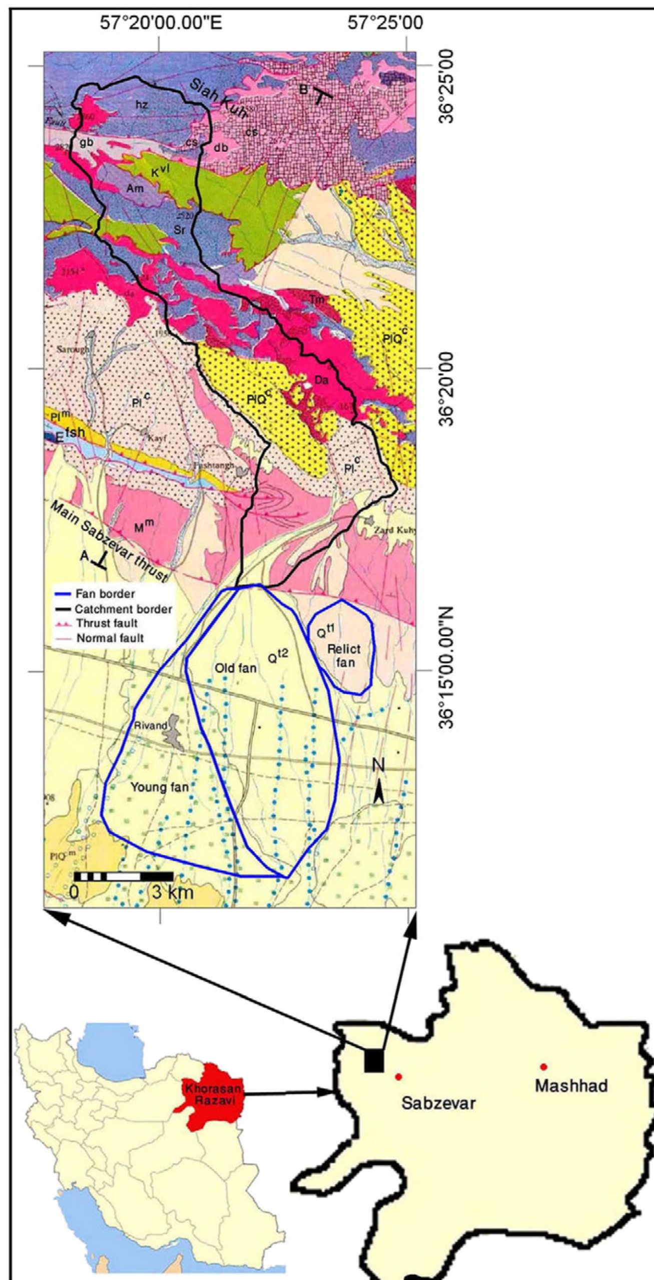

Fig. 1. Location map and geology of studied alluvial fans and catchment. The lithological units are described in the text.