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Characterisation and engineering properties of tectonically undisturbed but lithologically varied sedimentary rock masses

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Abstract

Tectonically undisturbed sedimentary rocks deposited in a quiescent shallow marine environment often include a sequence of strata that may present significant lithological variety at the scale of an engineering structure. Such rock masses exhibit engineering properties that are significantly different from tectonically disturbed rock masses of similar composition. For example, molasse consists of a series of tectonically undisturbed sediments of sandstones, conglomerates, siltstones and marls, produced by the erosion of mountain ranges after the final phase of an orogeny. They behave quite differently from flysch which has the same composition but which was tectonically disturbed during the orogeny. The molasses behave as continuous rock masses when they are confined at depth and the bedding planes do not appear as clearly defined discontinuity surfaces. Close to the surface the layering of the formations is discernible and only then similarities may exist with the structure of some types of flysch. Therefore extreme care is necessary in the use of geotechnical classification systems for the selection of design parameters, in order to avoid penalizing the rock mass unnecessarily. A discussion on the use of the geological strength index (GSI) for the characterisation of such rock masses is presented. Two GSI charts are proposed for estimating the mechanical properties of these masses: one mainly for tunnels; and the second for surface excavations. An example is given to illustrate the process of tunnel design in molassic rocks.

Keywords: Sedimentary rocks; Molasse; Air slaking; Brittle failure; GSI charts; Tunnel design

1. Introduction

In many mountainous regions a sequence of alternations of clastic and pelitic sediments were deposited during a quiescent period after the main orogenesis. The behaviour of these deposits, known as molasses in Europe, is quite different from that of flysch, a sequence of strata of similar composition associated with the same orogenesis. Although the cases on which this discussion is based come from the molassic formation of Northern Greece, we believe that the proposed characterisation can be of general application to sedimentary rocks deposited in a quiescent shallow marine environment and not associated with significant tectonic disturbance.

2. General geological setting

Molasse comes from a provincial Swiss name originally given to soft sandstone associated with marl and conglomerates belonging to the Miocene Tertiary period, extensively developed in the low country of Switzerland and composed of Alpine detritus. The term is now applied to all orogenic deposits of similar genesis, e.g. to describe sediments produced by the erosion of mountain ranges after the final phase of an orogeny.

The molasse consist of an almost undisturbed sequence of great overall thickness of sandstones and

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siltstones, mudstones or marls. These rocks can alternate in layers of tens of centimetres or they can be present as massive strata (mainly sandstones with occasional siltstone intercalations). Conglomerates occur rather commonly, forming thick bands in some cases. Rather restricted limestone horizons may also be present. Due to the fact that the sedimentation of the detritus material took place close to the sea shore line and the ongoing subsidence of the newly formed basin, an alternation of sea, lacustrine and terrestrial deposits, may characterise the molasses together with lateral transitions from one lithological type of layer to the other. A stratigraphic column and a geologic profile of molassic formations from Greece are presented in Figs. 1 and 2.

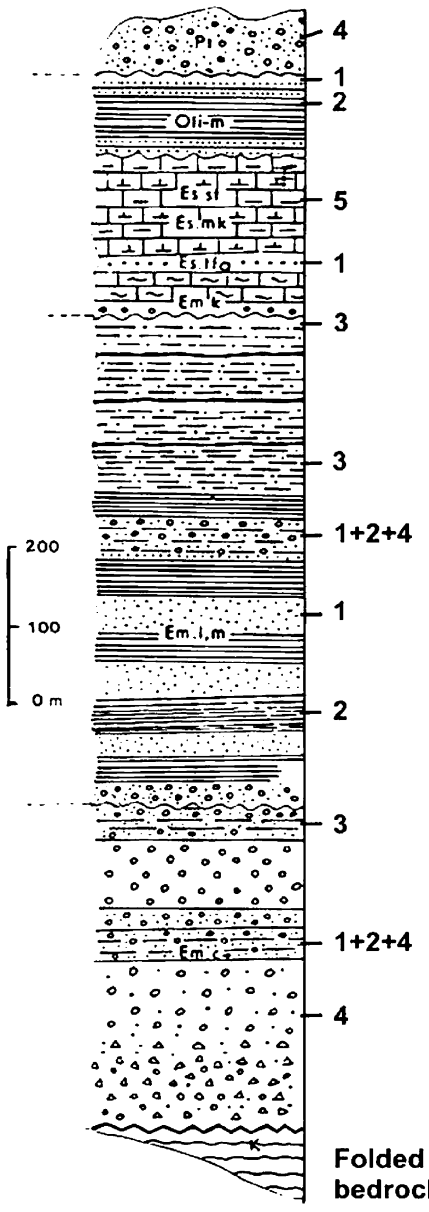

Fig. 1. Schematic column of the mollassic formations in the Rhodope basin, NE Greece: 1. sandstones, 2. clay shales or siltstones, 3. sandstones with siltstones or clayey sandstones, 4. conglomerates, 5. limestones, marly limestones or marles (from the Geolgical map of Greece, 1:50,000, IGME, 1980).

In some cases sandstones are very weak and can be assimilated with sands; in such weak molasses, clays and silts are also present and the material can be treated as soil. These types of molasses are not considered in this paper.

As the molasse characterise a series of sediments that were formed and developed after the main orogenesis, they have not suffered from compression or shear. They are thus unfolded or contain mild gravity folds or flexures. Inclination of strata is generally low and cases with dips of more than 30° are infrequent or local. Gravity faults are present, as in all post-tectonic basins but their impact on the deterioration of the quality of the rock is limited. In certain ranges molassic formations may be deformed and overthrust by the final advance of tectonic nappes. Again the decrease of their quality is localised.

3. Molasse vs flysch

In contrast to molasses, the term flysch is used to describe sediments produced early in the mountain building process by the erosion of uprising and developing fold structures. These are subsequently deformed during later stages in the development of the same fold structures. Flysch is thus produced in front of the advancing orogenesis, folded with the other strata or even overthrust by the advancing mountain belt. On the other hand, molasses in the basins behind the already formed mountain belt remain over the folded belt and are undisturbed by the mountain building process.

Flysch, in contrast to molasses, has more rhythmic and thinner alternations of sandstone and pelitic layers.

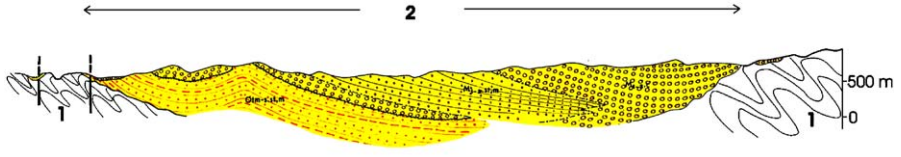

Fig. 2. Geologic section in a molassic country, NW Greece (from the Geological map of Greece, sheet Ayiofillo, 1:50,000, IGME, 1979, slightly modified). 1. Bed rock of the already formed mountain belt, 2. molassic country: alternation of sandstones, conglomerates, siltstones and marls.