

SOME GEOLOGICAL AND GEOTECHNICAL ASPECTS OF WIND-BLOWN AND COASTAL DEPOSITS OF A SEMI-ARID REGION – A TURKMENISTAN CASE HISTORY

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Abstract: The geological and geotechnical aspects of wind-blown and coastal deposits of a semi-arid region are significantly different compared to deposits of a tropical country like Malaysia. These are mainly due to differences in the weathering process and also its mode of deposition. In this paper, some geological and geotechnical aspects of wind-blown and coastal deposits of a semi-arid country, Turkmenistan is presented. Some comparisons with deposits commonly found in Malaysia are made in order to illustrate the differences.

INTRODUCTION

Turkmenistan is part of the former Soviet Union which gained independence in the year 1991 after the collapse of the Soviet Union. It is a Central Asia country bordering the Caspian Sea between Iran and Kazakhstan.

In this paper, the information obtained is for the Turkmenbashy area, which is a port town situated approximately 535km from its capital, Ashgabat as shown in Figure 1 below. The proposed site at Turkmenbashy area experiences semi-arid weather condition with absolute minimum temperature reaching -22°C and the absolute maximum temperature

reaching +45°C. Average monthly relative air humidity at 1 o'clock ranges from 71% (coldest month) to 39% (hottest month). The atmospheric precipitation within a year is only 136mm. The site also experiences dust storms with frequency in the order of 20 days within a year.

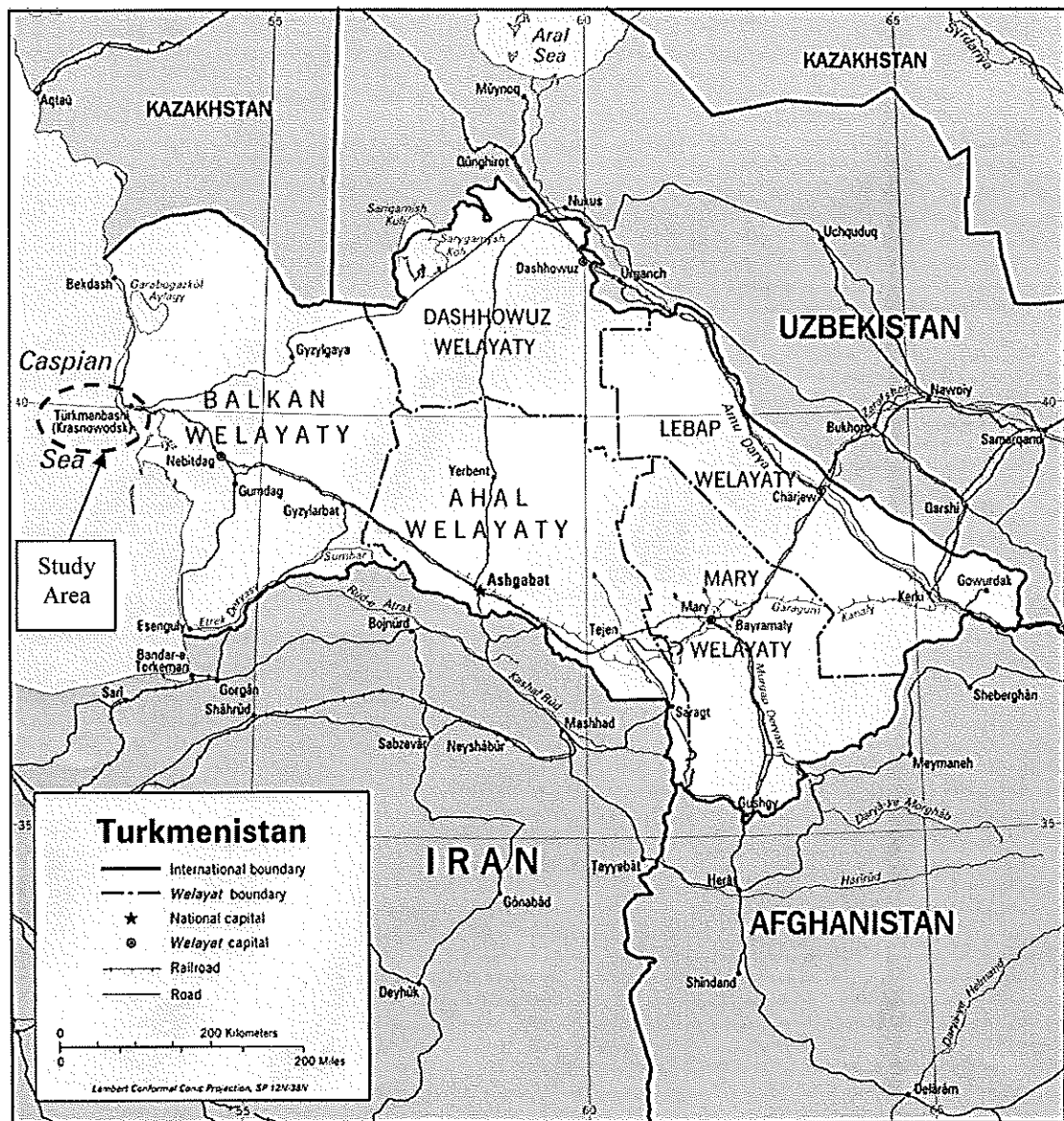


Figure 1: Map of Turkmenistan
(Source: <http://www.lib.utexas.edu/maps/turkmenistan.html>)

GEOLOGICAL AND GEOTECHNICAL ASPECTS OF THE TURKMENBASHYAREA

Inselbergs

A notable feature which is common with arid and wind-swept landscapes are residual peaks of hard rock left upstanding and wind polished above the general level (Blyth & de Freitas, 1984). These features are termed inselbergs (or 'island mounts'). An example of inselbergs in the Turkmenbashy area is shown in Figure 2. Due to its dry climate, vegetation is scarce and therefore, any soil deposits are easily eroded by wind. This is in contrast to features in Malaysia where dense vegetation and heavy rainfall results in very deep zones of residual soil and weathered rock as shown in Figures 3 and 4.

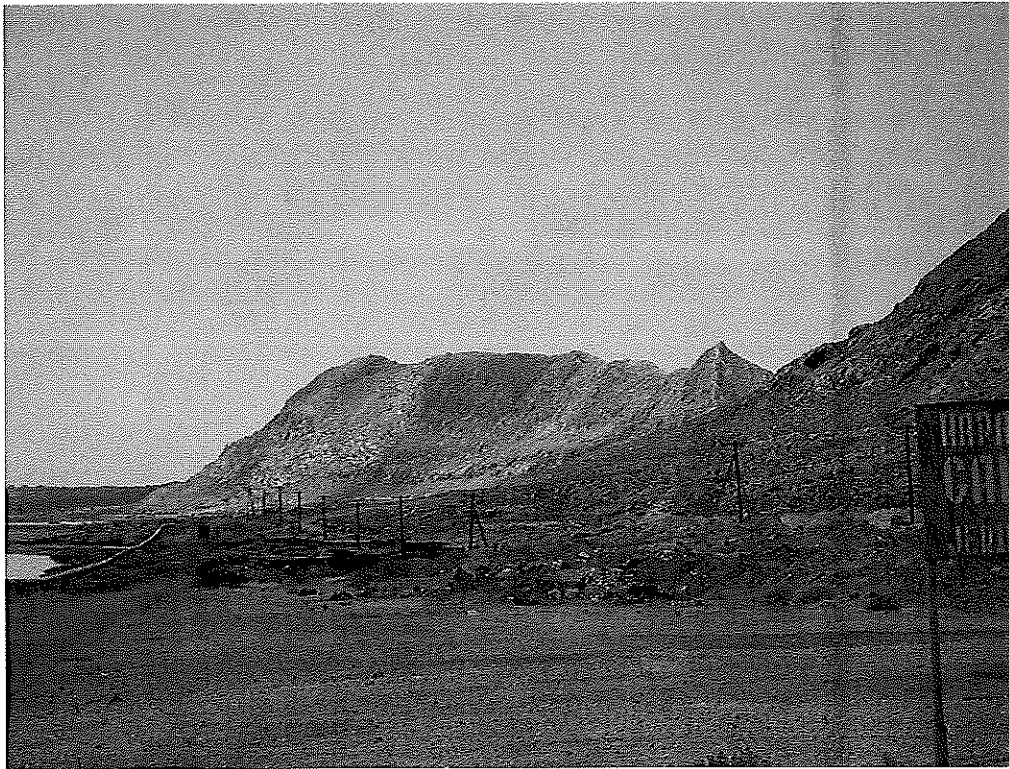


Figure 2: Inselbergs at Turkmenbashy

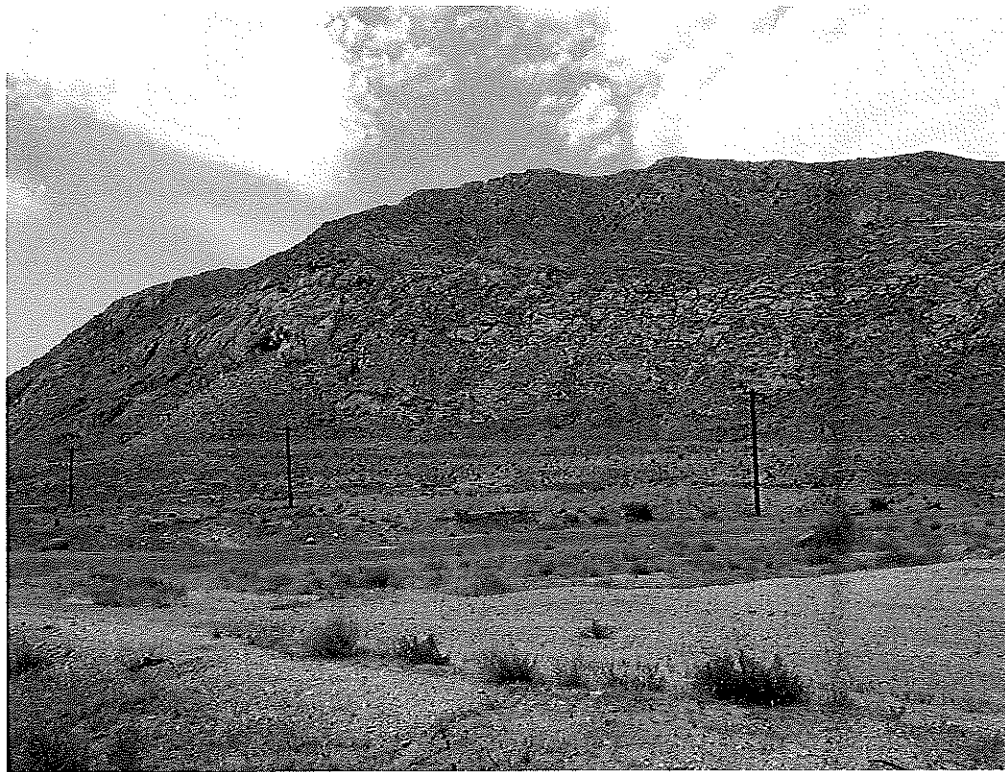


Figure 3: Inselbergs at Turkmenbashy



Figure 4: Residual soils in Cameron Highlands



Figure 5: Residual soils in Cameron Highlands

As such, the challenges posed to geotechnical engineers are completely different due to the different geological settings of Malaysia and Turkmenistan with regards to slope stability. In Malaysia, geotechnical engineers are essentially dealing with “soil” slopes whereas in Turkmenistan, rock slope stability governs. However, the situation is very complicated due to the different degrees of weathering of the parent bedrock in residual soils of Malaysia. Therefore, geological features such as bedding, faults, etc. is still an important consideration together with other features of residual soils such as very heterogeneous, high permeability, soil bonding, etc. For a more detailed discussion on slope stability in tropical residual soils, refer to Tan & Chow, 2004.

Wind-blown Sand or Eolian Sand

The weathering process in regions of hot and dry climate is predominantly governed by the action of wind. Wind-blown sand (or eolian sand) grains, dominantly composed of quartz, become worn down to well-rounded, nearly spherical forms with frosted surfaces. The grains are poorly graded, i.e. of

nearly uniform size, since wind of a given velocity cannot move particles larger than a certain diameter (Blyth & de Freitas, 1984). This characteristic is observed in the results of particle size distribution carried out from soil samples obtained from the site and shown in Figure 6.

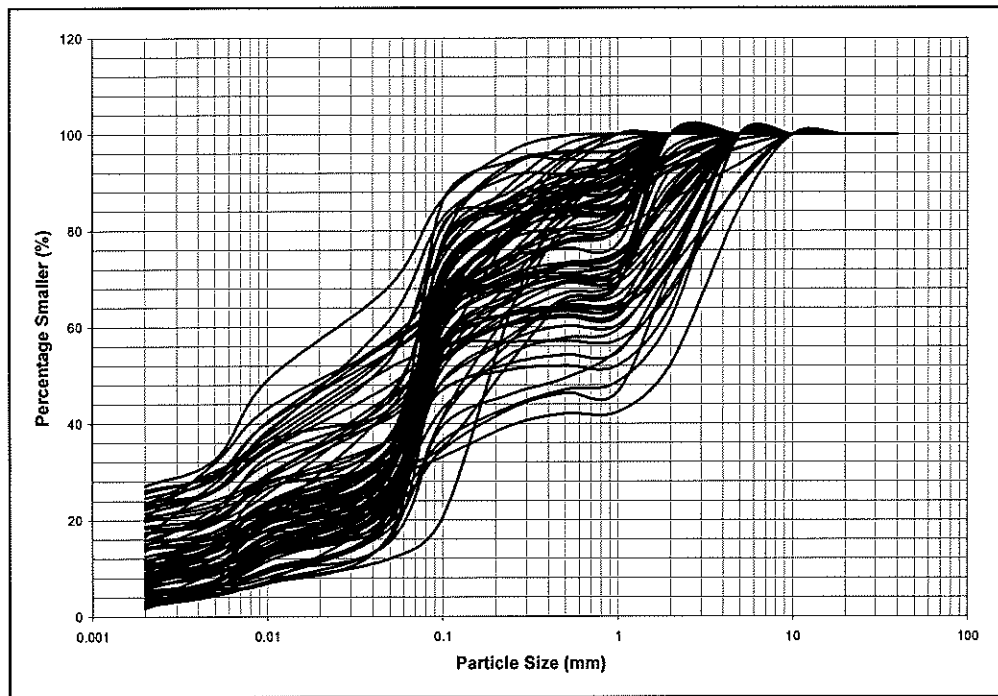


Figure 6: Particle size distribution of wind-blown sand from Turkmenbashy area

As shown in Figure 6, the grains are poorly graded and predominantly consist of grain size with diameter in the range of 0.05mm to 0.1mm. Typical landscape of the Turkmenbashy area is shown in Figure 7.

In the absence of downward leaching (e.g. from rain), surface deposits become contaminated with precipitated salts, particularly sulphates and chlorides (Bell, 2000). This is also confirmed from the preliminary geotechnical investigation carried out at the site and summary of the chemical test results are presented in Table 1.



Figure 7: Typical landscape of Turkmenbashy area during summer

As can be seen from Table 1, the soil is very aggressive towards concrete made with ordinary Portland cement as its sulphate content is consistently more than 2280mg/l (expressed in SO_4^{2-}). This is in accordance with BS8110: Part 1 where concrete exposed to soil with sulphate content more than 2280mg/l (expressed in SO_4^{2-}) or 1900mg/l (expressed in SO_3) but less than 3700mg/l (expressed in SO_4^{2-}) or 3100mg/l (expressed in SO_3) is categorized as Class 3 where ordinary Portland cement with pfa or ggbfs, sulphate resistant cement (SRPC) or super sulphated cement (SSC) shall be used.

Due to the close proximity of the site to the sea, the groundwater level is also at shallow depth. As Turkmenbashy area is situated in an earthquake of Magnitude 9 zone (MSK-scale), liquefaction potential of the soil should be carefully assessed due to the presence of the shallow groundwater level and the lack of clay content in the soil.

Table 1: Results of chemical tests on soil samples

BOREHOLE	DEPTH (m)	CONTENT (mg/l)	
		Cl ⁻	SO ₄ ²⁻
BH-1	1.0	208.80	2514.40
BH-2	0.5	475.60	1547.20
	1.0	336.40	2639.40
	2.0	406.00	2533.70
BH-5	1.0	353.80	2471.20
	5.0	336.40	2903.80
BH-6	1.0	411.80	2615.40
	2.0	359.60	2985.60
BH-9	0.5	359.60	2370.20
	1.0	226.20	2896.90
BH-10	1.0	400.00	2962.80

In summary, based on a preliminary geological study of the site, important features of ground conditions of a semi-arid region can be deduced as follows:

- Soil deposits are poorly graded, i.e. of uniform size
- High possibility of contamination with precipitated salts, particularly chlorides and sulphates
- Liquefaction potential shall be assessed for areas in earthquake zone due to shallow groundwater level and lack of clay content in the soil

Calcareous Deposits

Calcareous deposits in the form coquina are also encountered at the spit area of the site as shown in Figure 8. Such deposits are formed in shallow marine environments within protected sea areas which are conducive for cementation to take place. In addition, the lithification that takes place requires that the sediment is exposed above sea level, or to supersaturated (warm and shallow) water.



Figure 8: Coquina at spit area

Note:

Spit – a sandy ridge formed by the longshore drift, extending out into open water from a bend in the coast as at the mouth of a river or bay or from the leeward side of a headland (Blyth & de Freitas, 1984).

Coquina – a coarse-grained, porous, easily crumbled variety of limestone composed principally of mollusk shell and coral fragments cemented together as rock (McGraw-Hill, 2003).

The formation of such calcareous deposits depends on the carbonate concentration in the sea water which in turn is a function of temperature and pressure. Therefore, the higher the temperature and the lower the pressure, the higher the carbonate concentration which means that the highest rate of deposition of calcareous deposits is potentially in shallow water near the equator (Jewell, 1993). As such, it is interesting to note that the presence of calcareous deposits in Malaysia is not well-documented even though the coastal areas of Malaysia fulfill the requirements of shallow water near the equator.

This is because the calcareous deposits are potentially being covered by thick deposits of silicate detritus provided by the sediment-supplying rivers (Jewell, 1993). As such, the presence of calcareous deposits are not detected at shallow depths in Malaysian waters as it is most likely being covered by thick layers of sediments composed primarily of sands and clays of terrigenous origin supplied by the extensive network of rivers in Malaysia. However, the presence of calcareous sediments cannot be completely ruled out as studies carried out by Jewell, 1993 and Davis et al., 1976 have indicated the potential occurrence of such deposits of the coast of Sabah as shown in Figure 9.

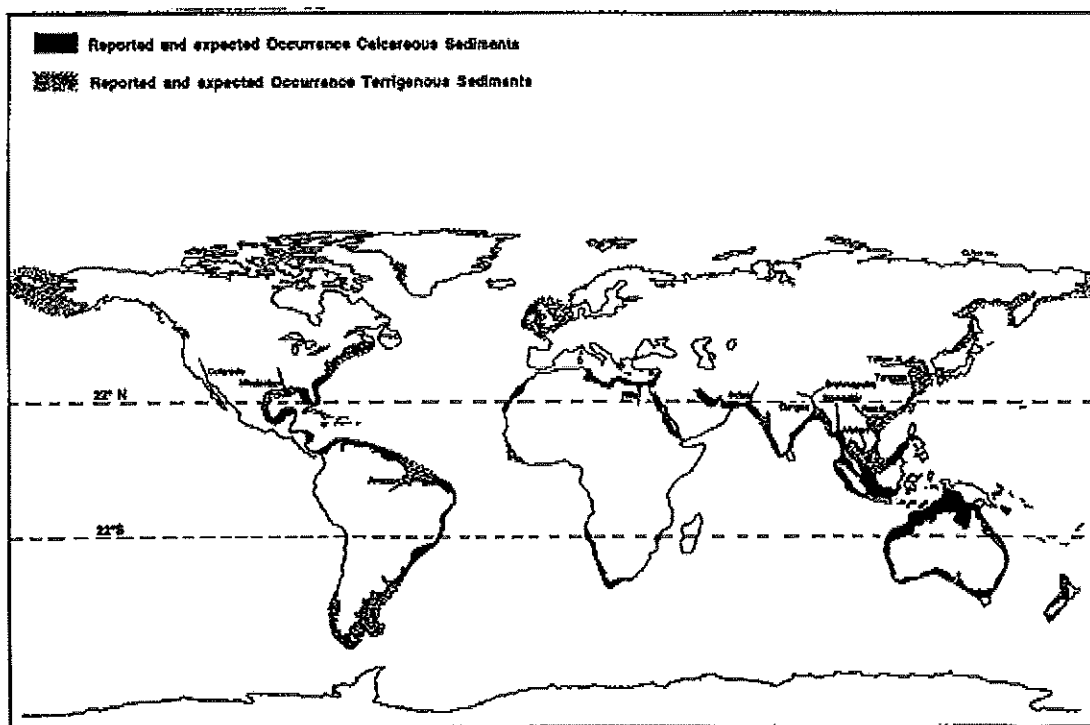


Figure 9: Known and anticipated distribution of modern sediments on continental shelves (from Jewell, 1993)

In deeper waters away from the spit and also at open sea areas, such high degree of cementation is not expected to occur and the occurrence of calcareous deposits is most likely in the form of lightly cemented sediments rather than lithified carbonate rocks such as those encountered in the spit areas (Figure 8).

The presence of calcareous deposits present new challenges to geotechnical engineers as problems associated with such deposits are well documented. Some of the potential problems are as follows (Jewell, 1993):

- a) Much lower than expected shaft friction developed for driven pile foundations based on conventional methods of calculation (e.g. API method).
- b) Individual grains are extremely angular and weak
- c) Cementation between the grains is highly variable
- d) The materials have a wide range of particle type and size distribution
- e) High void ratios
- f) Shear load carrying capacity of the weakly cemented sediments can degrade rapidly with cycles of load

As such, geotechnical works in areas with calcareous deposits require special considerations especially with regards to driven pile foundations. Alternatives to driven pile foundations such as bored piles and “driven-and-grouted” option as discussed by Randolph et al., 1993 can be explored in areas with calcareous deposits. However, its applicability and suitability to a particular project has to be carefully assessed in relations to ease of construction, economics and technical feasibility.

Summary

Some preliminary geological and geotechnical aspects of wind-blown and coastal deposits of a semi-arid region are presented. It is shown that a desk study on geology complemented by site visit is highly beneficial for geotechnical works in order to obtain a general picture of the ground conditions at the site especially in a foreign country. With such understanding, subsequent planning of detailed geotechnical investigations can be carried out with the specific aim of obtaining information relevant to the type of problems and challenges posed by the ground conditions.

This case history also serves to illustrate the significant differences of ground conditions at different regions and the importance of a good understanding of basic geology to complement geotechnical studies. The information in this paper is only based on preliminary information obtained at the time this paper is being prepared. A more detailed geotechnical description of the ground conditions will be prepared in the near future.

References

1. Bell, Fred G. (2000). *Engineering Properties of Soils and Rocks*. Fourth Edition. Blackwell Science, London.
2. Blyth, F.G.H. & de Freitas, M.H. (1984). *A Geology for Engineers*. Seventh Edition. Edward Arnold, London.
3. Davis, T.A. & Gorsline, D.S. (1976). Oceanic sediments and sedimentary processes. In: Riley, J.R. (Ed.). *Chemical Oceanography*. R. Chester Academic Press, London.
4. Jewell, Richard J. (1993). *An Introduction to Calcareous Sediments*. Research Report No. G1075. The University of Western Australia.
5. McGraw-Hill. (2003). *Dictionary of Geology & Mineralogy*. Second Edition. McGraw-Hill, New York.
6. Randolph, M.F., Finnie, I. & Joer, H. (1993). Performance of shallow and deep foundations on calcareous soil. *Symposium on Foundations in Difficult Soils*, Kagoshima, Japan.
7. Tan Yean-Chin & Chow Chee-Meng. (2004). Slope stability and stabilization. In: Bujang B.K. Huat, Gue See Sew & Faisal Hj. Ali (Eds.). *Tropical Residual Soils Engineering*. Taylor & Francis Group, London.