SLOPE STABILITY ANALYSIS AT ALTERNATE SANDSTONE, CLAYSTONE/SILTSTONE BEDS OF DHOK PATHAN FORMATION AT PIR PEHAI AREA DISTRICT MIANWALI, PAKISTAN

BY

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Abstract: *Slope stability analysis was undertaken on alternate sandstone, claystone/ siltstone beds, of Dhok Pathan Formation, exposed at Pir Pehai area. Studies were carried out to determine the geotechnical behaviour of the sequence with respect to excavation of cut slopes in the area. Investigation involved the evaluation of slope stability parameters using wedge method of analysis. Bedding shears were encountered in the claystone/siltstone beds, which are considered the potential failure surfaces. Based upon the studies various angles are proposed for stable cut slopes in these rocks.*

INTRODUCTION

Slope stability analysis was carried out on the alternate sandstone, claystone/ siltstone beds of Dhok Pathan Formation at Pir Pehai area, district Mianwali, Pakistan (Fig 1). The project area lies in sedimentary rocks dating from Pre-Cambrian to Recent (Shah, 1977). Regionally it spreads over three separate geological provinces (Taseer et. el. 1989) Surghar Range, Salt Range and Potwar-Kohat Plateau (Fig 2). Geological sequence in the area is comprised of Dhok Pathan Formation, river channel deposits, stream deposits, and terrace deposits. Dhok Pathan Formation is the main unit present which consists of alternate sandstone, claystone/siltstone beds with occasional lenses of gravels. Sandstone is hard, well cemented to very soft and poorly cemented having thickness from few meters to more than 90 meters. While claystones are hard dark grey, greenish grey or brown overconsolidated silty clays (Malik & Farooq, 1988), laminated at places containing some calcium carbonate. The claystone beds are variable in thickness and composition and contain siltstone layers at places. The thickness of claystone/siltstone sequence between sandstone beds varies from 0.5 to 30 meters. The siltstones are commonly found either at the base of the sandstone or within a claystone sequence. It is hard, yellowish brown to brown clayey and sandy silts with calcium carbonate. The thickness varies from 0.5 to 11 meters. For detailed engineering geological investigations Kalabagh Consultants (1984) have distinguished sandstones in to nine beds from highest to lowest in the sequence. Claystone/siltstone units between two sandstone units are described by the number of the overlying sandstone with the addition of negative sign. Brief description is given in table -1.

Dhok Pathan Formation is widely exposed in Potwar area of Pakistan (Shah, 1977). These rocks have geotechnical importance due to the presence of Mangla and proposed Kalabagh dams. Most of the small dam projects are also being considered in similar rocks. The claystone/siltstone beds present in the area need special attention because of their problematic nature (William, 2002b). Shear zones are encountered in claystone/siltstone beds. Exploratory adits and trenches have been used to explore the fresh surfaces for the demarcation of shear zones present in claystone/ siltstone beds. The shear zones seriously affect the geotechnical behaviour of these rocks. The presence of shear zones in claystones/siltstone renders a great difference in the intact and residual strength parameters (Malik & Farooq, 1988). Considering the importance of these rocks for future geotechnical projects, slope stability analysis has been carried out. Results of the studies can be applied in the geotechnical evaluation of the engineering projects of the area.

Table-1
Lithological details of the Dhok Pathan Formation at Pir Pehai area

Unit Number	Thickness (meters)	Description
1	53	Contains lenses of Claystone/siltstone
-1	12	Bedding shear is present
2	6	Sandstone bed
-2	6-8	Claystone/siltstone bed
3a	9	Sandstone
-3a	15-17	Claystone/siltstone
3b	27-30	Sandstone
-3b	5	Claystone/siltstone
4a	8	Sandstone
-4a	3	Claystone/siltstone
4b	6-9	Sandstone
-4b	3-9	Having sandstone lenses in some areas
5&6		Merges in to a single sandstone unit.
-6	15-27	Alternation of Claystone, siltstone & thin sst..
7	32-40	Sandstone
-7	21	Alternation of siltstone/Claystone
8	12-15	Sandstone
-8	11-12	Claystone/siltstone
9	14-17	Sandstone
-9	27-30	Claystone/siltstone

MATERIALS AND METHODS

Sandstone, claystone/siltstone beds of Dhok Pathan Formation are dipping at an angle of 4 to 5 degree. Investigated area is underlain by sandstone # 4 to 9 and associated claystone/ siltstone beds. Shear zones have been identified in claystone beds.

Slope stability analysis

The area is comprised of alternate sandstone, claystone/siltstone beds with persistent shears. Therefore Wedge method of analysis has been employed to carry out slope stability studies of these rocks. The method is useful to analysis of rock slopes in layered strata, where a discontinuity locates the failure surface (Bowles, 1984). This method is particularly appropriate to those slope situations where potential shears surfaces are constrained by the presence of bedding plane structural features (Attewell et. el 1976). Claystone/siltstone bed (-6) with persistent bedding shear, having low value of Φ, (KC, 1984) is exposed in the area. Therefore, it has been considered, during analysis, the potential failure surface. For convenience sides of the excavation are named A & B and accordingly both the cases are delt separately for each angle (Figs. 3a, 4a, 5a and 6a). The sides A and B are further, subdivided in to Active and Passive Wedge (Bowles, 1984). The analysis consists of four angles 30^o, 38^o, 45^o and 60^o and three trial factors of safety are assumed for each angle. The resultant earth forces acting at the vertical boundaries of the passive and active wedges are determined by constructing force polygons. So, the force polygons are made for both the wedges and calculated the values of E_A, the earth force of the active wedge and E_P, the earth force of the passive wedge. The magnitude of resultant forces, E_A and E_P depend upon the trial factor of safety. The notations W_A W_P and F_A F_P used in the figures (Figs. 3b, 4b, 5b and 6b) for force polygons show the weights and frictional forces for the Active and Passive Wedge respectively.

The values of cohesion, angle of internal friction and density are taken from the report of Kalabagh Consultants (1984).

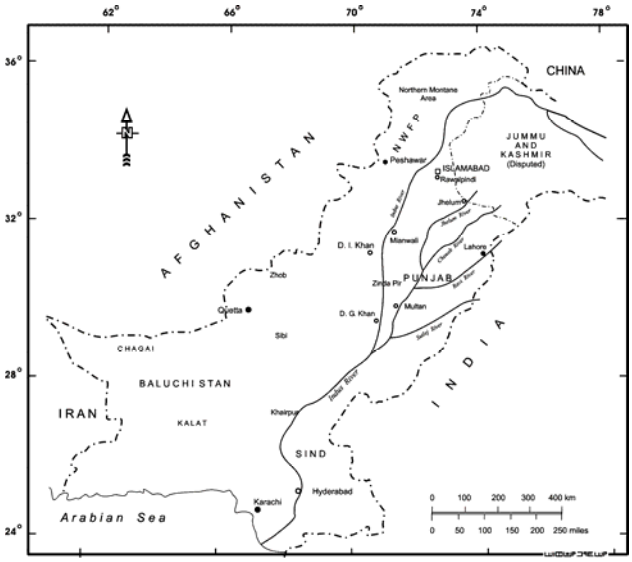

Fig. 1: Map of Pakistan

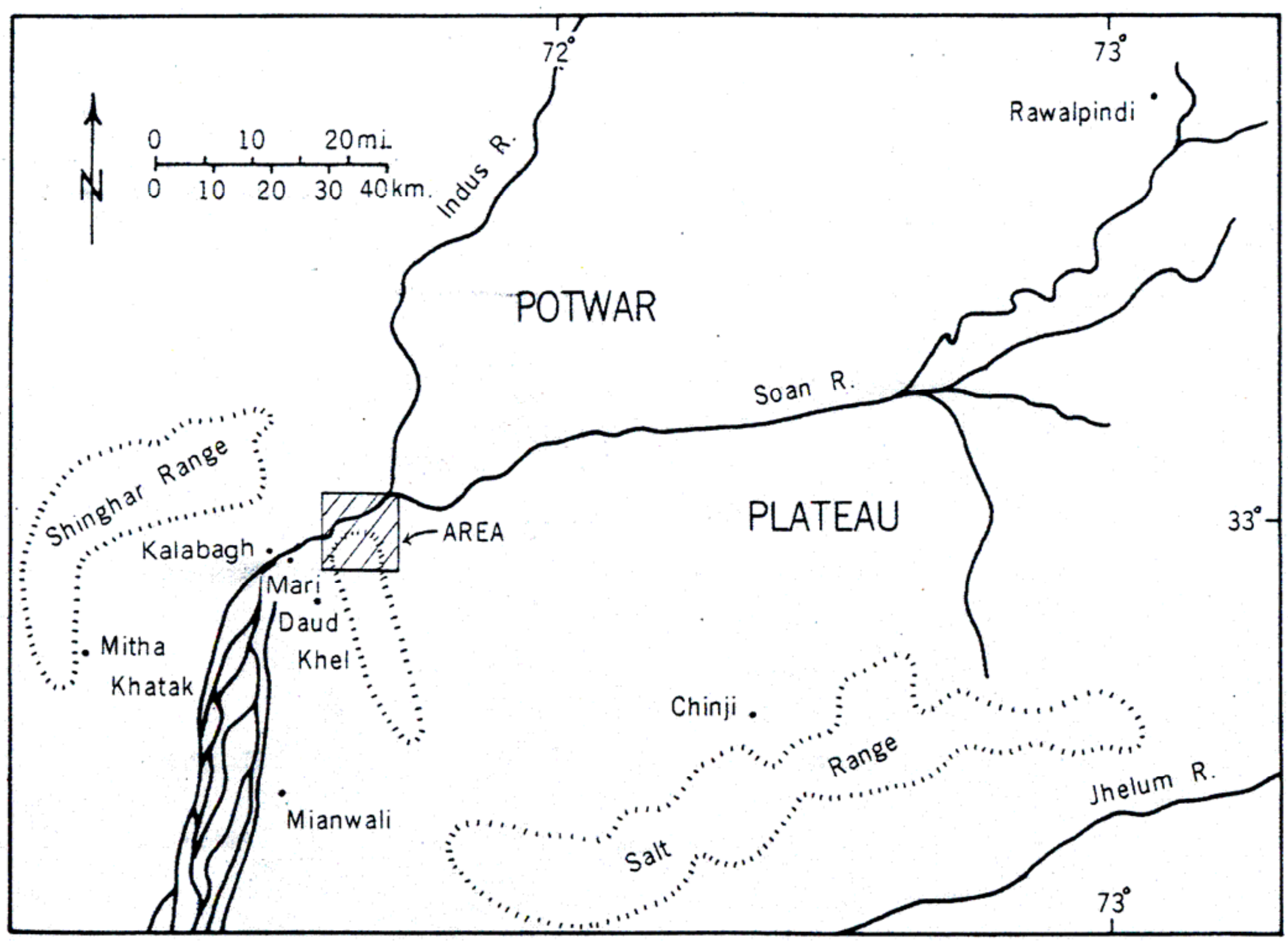

Fig. 2: Location map showing the project area

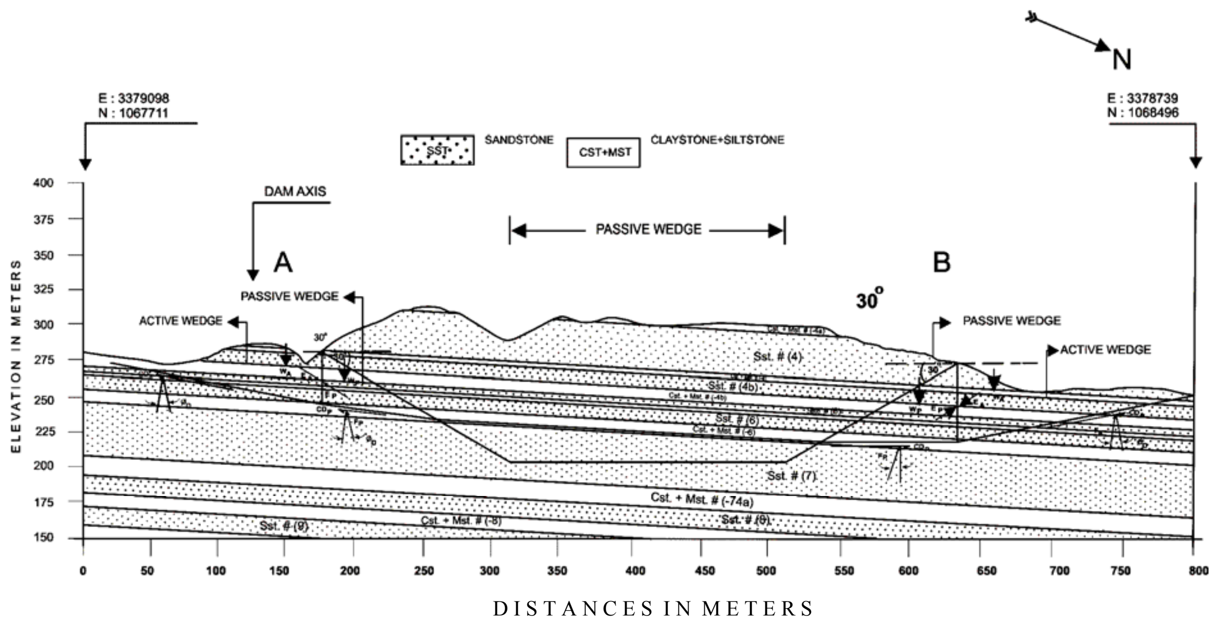

Fig. 3a: Cross-section showing lithological details of the Dhok Pathan Formation at Pir Pehai area. Active and Passive Wedges are also shown

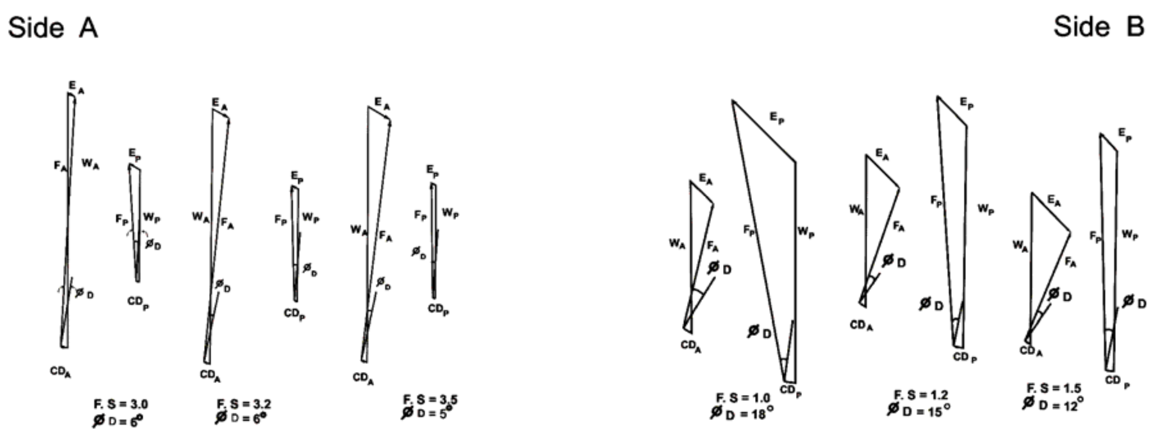

Fig. 3b: Force polygons for slope angle 30º showing the weights and the frictional forces of Active and Passive Wedges

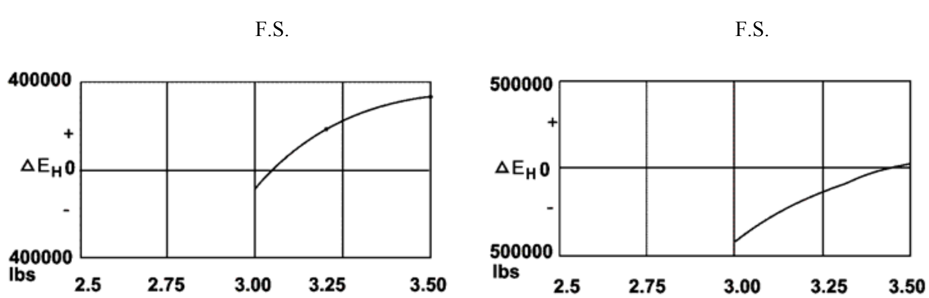

Fig. 3c: Trial Factor of Safety (F.S.) versus Net Effective Force (ΔE_H) to obtain the value at which ΔE_H=0

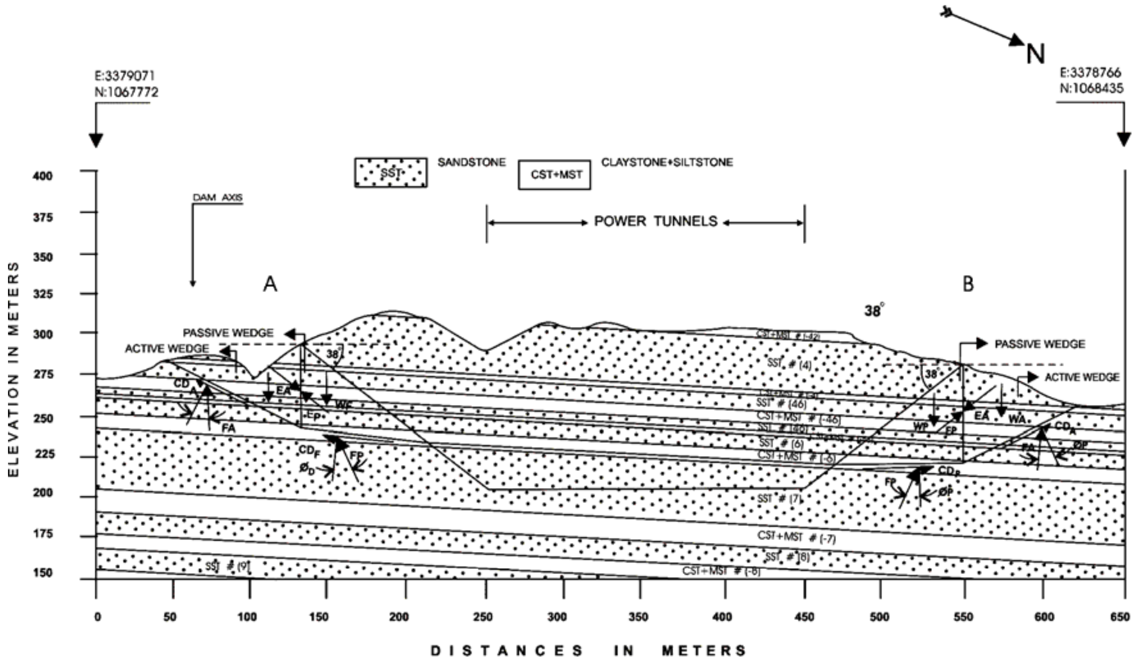

Fig. 4a: Cross-section showing lithological details of the Dhok Pathan Formation at Pir Pehai area. Active and Passive Wedges are also shown

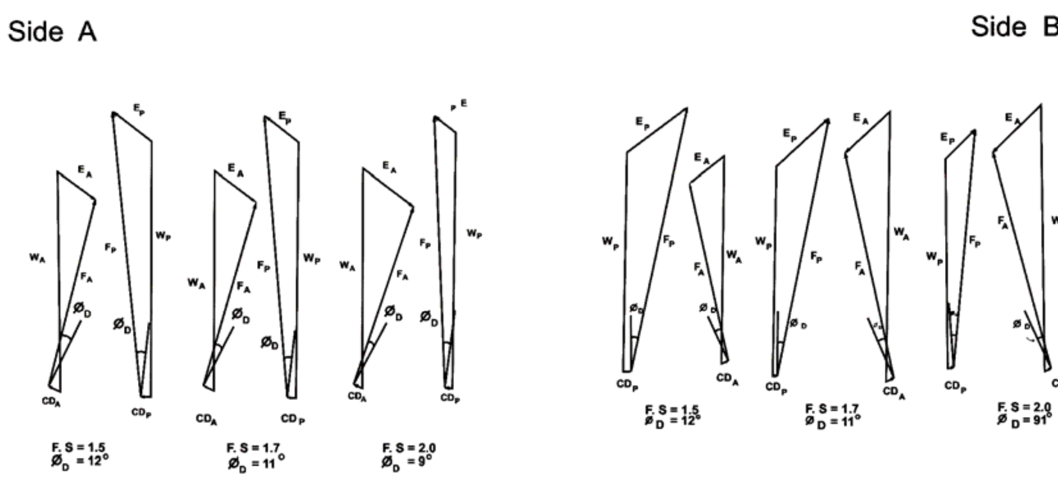

Fig. 4b: Force polygons for slope angle 38º showing the weights and the frictional forces of Active and Passive Wedges

Fig. 4c: Trial Factor of Safety (F.S.) versus Net Effective Force (ΔE_H) to obtain the value at which ΔE_H=0

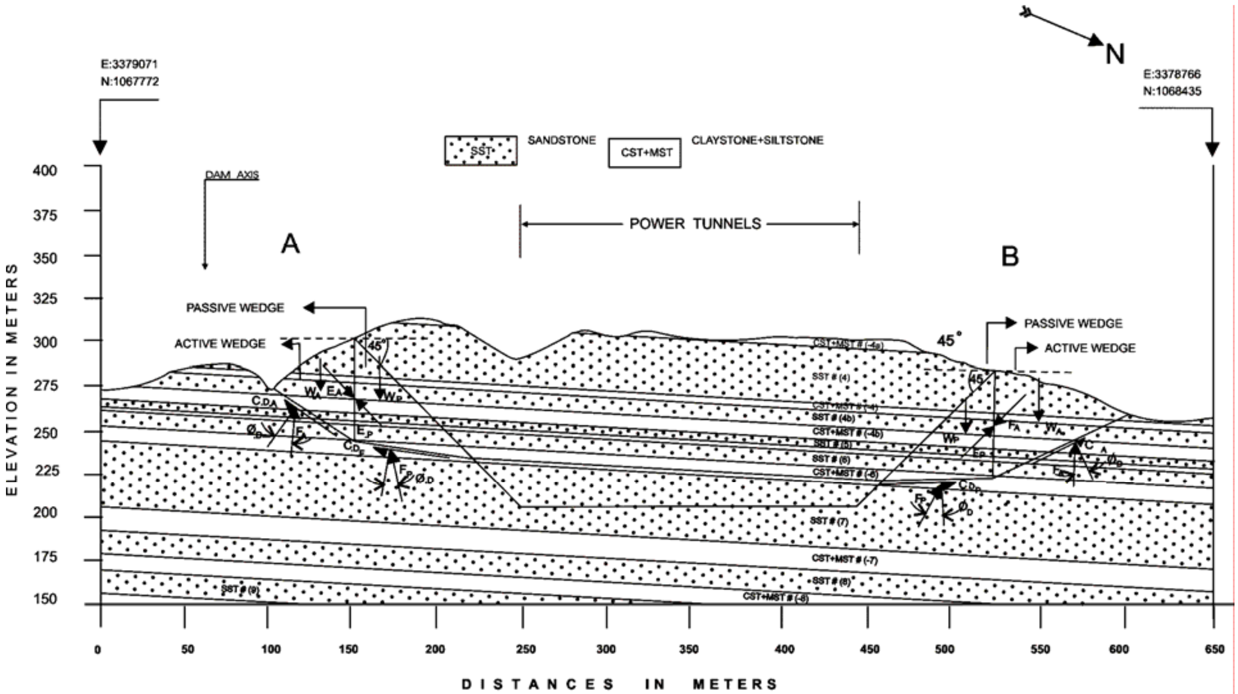

Fig. 5a: Cross-section showing lithological details of the Dhok Pathan Formation at Pir Pehai area. Active and Passive Wedges are also shown

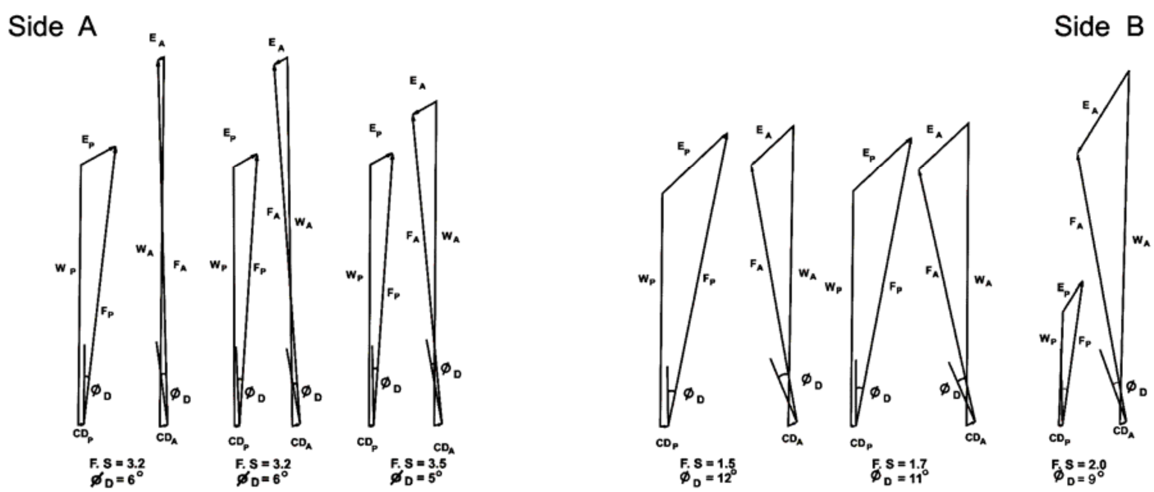

Fig. 5b: Force polygons for slope angle 45º showing the weights and the frictional forces of Active and Passive Wedges

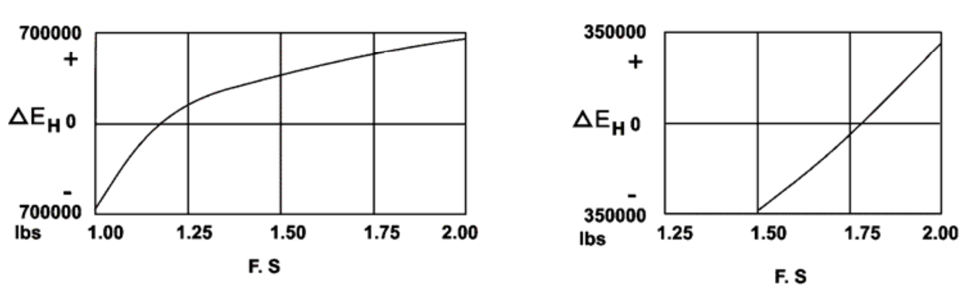

Fig. 5c: Trial Factor of Safety (F.S.) versus Net Effective Force (ΔE_H) to obtain the value at which ΔE_H=0

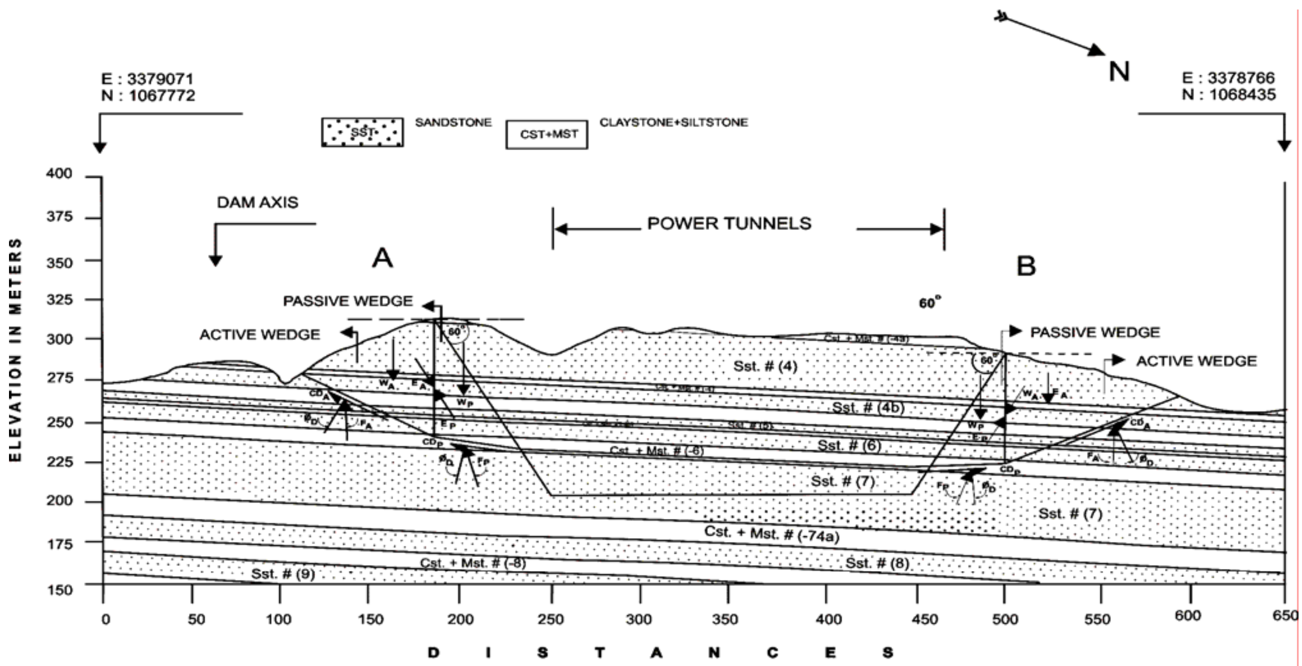

Fig. 6a: Cross-section showing lithological details of the Dhok Pathan Formation at Pir Pehai area. Active and Passive Wedges are also shown

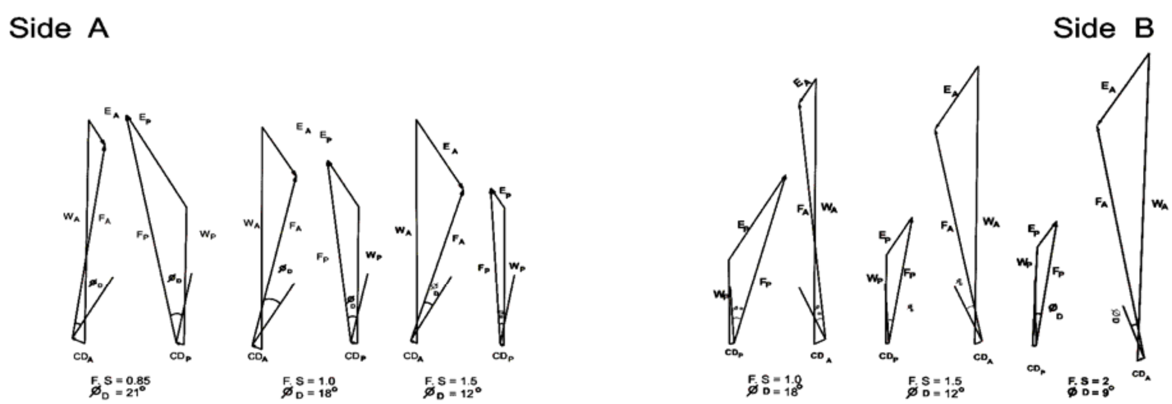

Fig. 6b: Force polygons for slope angle 60º showing the weights and the frictional forces of Active and Passive Wedges

Fig. 6c: Trial Factor of Safety (F.S.) versus Net Effective Force (ΔE_H) to obtain the value at which ΔE_H=0

Cohesion of the material = C = 600 Psf

Angle of internal friction for sheared claystone-siltstone = $\Phi = 18^o$

Density of the material = ρ= 120 lbs/ft^3

The developed value of cohesion and angle of internal friction along the failure surface are controlled by the assumed values of factor of safety, F.S. (Department of the Army Office, U.S.A, 1970) which can be computed as

The developed value of cohesion = C_D = C/F.S.

The developed angle of internal friction

$\Phi_D = \tan^{-1}[\underline{\tan \Phi}]$ [F.S]

The net effective force, ΔE_H, is determined for each case using the values of E_A and E_P. The positive or negative sign of the ΔE_H, shows either $E_A > E_P$ or $E_P > E_A$. ΔE_H is plotted versus trial factors of safety to obtain the value at which ΔE_H is zero (Figs. 3c, 4c, 5c and 6c). This is the factor of safety required to balance the forces, E_A and E_P for sliding surface being analyzed. Results are presented in the table 2.

Table-2
Comparison of slope angle and the factor of safety at Pir Pehai area

Slope angle	Factor of Safety	
	Side A	Side B
30º	3.05	3.45
38º	1.57	1.95
45º	1.17	1.79
60º	0.99	1.30

CONCLUSION

In the sequence of alternate beds of sandstone, claystone/siltstone of Dhok Pathan Formation, claystone/siltstone bed (-6) with persistent bedding shears and low value of Φ represents the potential failure surface. The results of slope stability analysis are presented in table-2 showing factors of safety for side A and B against different slope angles. The table indicates that values of factors of safety are gradually decreasing as the slope angle is getting higher. This effect is more pronounced for side A due to down dip direction as compared with side B which is relatively more stable at higher angle due to up dip direction. However, at slope angle of thirty eight degree, the factor of safety is 1.57 and 1.95 for side A and B respectively. Considering the factors of safety for both sides, this seems to be most appropriate angle for the stability of the excavation in the area. So, the angle of thirty eight degree is recommended for stable cut slopes in these rocks.

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