A METHOD OF DESIGN OF ROCK SLOPES SUBJECTED TO STRONG GROUND MOTION

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The stability of a rock slope is controlled by the strength characteristics of the rock material and degree and extent of rock defects present in the rock mass. The rock material in the common rock types (except soils and pelitic rocks) possess good strength, and if no rock defects are encountered steep rock slopes and large underground openings do not pose any major design or construction problems. Intercallation of weak or altered rock material, bedding, joints, cleavage, schistocity and other discontinuity surfaces and partings, faults, fractures and shear zones, and openings along fracture surfaces or solution cavities are the common type of rock defects encountered in rock masses; and movements along them due to strong ground motion during major earthquakes leads to landslides. As all such discontinuity surfaces and weak zones in general occur as sets of inclined planes, intersecting with each other as well as with the slope surface, the stability and equilibrium of the rock volume bounded by these planes has to be evaluated for the design of the slope. This requires a three dimensional analysis of the various forces acting on the rock volume (block) and its bounding surfaces.

The first step in carrying out the study is to collect all geomechnical data from field investigations and geological mapping, and analyse it and determine the rock volume bounded by the discontinuity surfaces and the rock slope or excavation surface, which under the action of the operative forces can separate and move out of the rock mass. The forces acting on the rock volume and on each of its bounding surfaces are determined. The weight of the rock volume (including weight of any structure resting on the same), hydraulic thrust on the bounding surfaces, thrust of any structure (e.g. arch dam), seismic forces (expressed as a pseudo static force), and any other static or dynamic force acting on the rock volume has to be taken into account in the analysis. These forces are resolved into three orthogonal forces acting on the rock volume. The direction of the resultant of these three orthogonal forces give the probable direction of movement of the rock volume along the particular bounding surface(s). In order to compute the factor of safety for design, the resultant force on bounding surfaces along which movement will occur are determined and normal and shear components (along the direction of movement of the rock volume) are evaluated. Fig. 1 gives the data and the results of analysis of a rock slope as an example. The analysis assumes that rock material is competent and movements occur by translation along the bounding surfaces. The procedure gives a conservative estimate of the factor of safety, and the assumptions made can be accepted provided that the geological data are carefully examined and a judiceous selection of the set of discontinuity surfaces is made to determine the shape of the rock volume likely to move from a geotechnical point of view. The analysis also provides data on forces to be sustained by restraining and retaining devices and supports.

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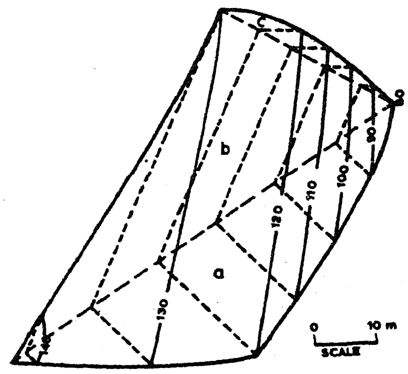
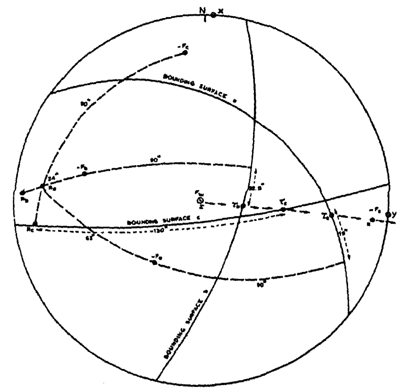


ROCK VOLUME CONSIDERED IN THE ANALYSIS



BOUNDING SURFACES AND DIRECTION OF FORCES PLOTTED ON STEOROGRAPHIC PROJECTION (LOWER HEMI SPHERE)

FIG. 1 - Example of Stability Analysis

GEOLOGICAL DATA

BOUNDING SURFACE	AREA	DIP	C	Ø
'a' SHEAR ZONE	557 m^2	45° TOWARDS N 35°	-	35°
'b' BEDDING	1230 m^2	65° TOWARDS N102°	70 ton/m^2	40°
'c' JOINT	135 m^2	78° TOWARDS N172°	70 "	45°

FORCES ACTING ON ROCK VOLUME

F_w	WEIGHT OF ROCK VOLUME	18402	TON VERTICAL DOWN		
F_a	WATER THRUST ON 'a'	18266	" 45° UP	TOWARDS	N 35°
F_b	WATER THRUST ON 'b'	48423	" 25° UP	"	N 102°
F_c	WATER THRUST ON 'c'	3753	" 12° UP	"	N 172°
F_s	EARTHQUAKE FORCE (HORIZONTAL SEISMIC COEFFICIENT 0.12g)	2208	" HORIZONTAL	"	N 92°

FORCES RESOLVED ALONG ORTHOGONAL AXES

X =-884 TON, Y = 26426 TON, Z = 2008 TON

RESULTANT R = 26515 ton PLUNGING AT 4° DOWN TOWARDS N 92°
ROCK VOLUME LIKELY TO SEPARATE ALONG 'C' AND SLIDE OUT

R_a RESULTANT FORCE ON 'a' 10435 PLUNGING AT 8° TOWARDS N 276°

R_b RESULTANT FORCE ON 'b' 23766 PLUNGING AT 2° TOWARDS N 274°

R_c RESULTANT FORCE ON 'c' 4684 PLUNGING AT 6° TOWARDS N 261°

$S = 10435 \times \cos 62^\circ \times \tan 35^\circ + 23766 \times \cos 24^\circ \times \tan 40^\circ + 70 \times 1230 = 107828$ ton

$\tau = 10435 \times \cos 152 \times \cos 19^\circ + 23766 \times \cos 144^\circ \times \cos 22.5^\circ + 4684 \times \cos 130^\circ = 20653$ ton

FACTOR OF SAFETY = 5.22

IF COHESION (C) IS LOST ON WEATHERING FACTOR OF SAFETY = 1.05