C H A P T E R - VIII

SUMMARY OF FINDINGS

The shearing behaviour of jointed rocks has been recognized as complex one and calls for rigorous theoretical developments and meticulous experimental investigations. The critical apprisal of the various investigations to study the influence of joint orientation, gouge material characteristics and stress fields culminate into identification of unique phenomenon well known as dilatancy which governs the mechanical behaviour of jointed rocks. The need is therefore to separate the total frictional behaviour from dilatancy effects so as not to disturb the theoratical edifice built around the classical model of basic friction after Coulomb. Starting from the fundamental conception of friction between the two bodies, the Coulomb's expression for failure stresses has been derived in general terms so as to separate the dilatancy effect from the basic friction. Experimental observations from varieties of tests confirm the theoretical model and the findings of various workers in the area of shearing behaviour of jointed rocks. The versatility, the integrity and the capability to sense and record the fine responses has been seen to exsit in the ultra modern version of closed loop servo controlled MTS setup. The implication of the present investigation interms of stability analysis for jointed rocks is the necessity to modify the conventional methods to include the factor for dilatancy.

The summary of major findings from the present investigation are stated below:

* The classical model of friction after Coulomb is potential enough to produce a failure criterion for jointed rocks from energy considerations.

* The energy dissipated in the basic friction is that involved in sliding at a critical orientation $45+\phi_{\mu}/2$ to the major principal plane and the excess energy towards the dilatancy is in the process of sliding at an orientation deviating from the critical orientation.

* The phenomenological parameter of dilatancy is the ratio of tangents of joint orientation to the critical orientation which is equivalent to the ratio of lateral strains to the axial strains at the point of failure.

* Dilatancy parameter calculated on the basis of joint orientation and basic friction angle stand in agreement with the values of dilatancy parameter from actual observations of the volume change.

* The failure stress in a jointed rock is a straight line relationship with slope as an angle of basic friction and intercept as cohesion quantity inclussive of the dilatancy depending on the gouge material characteristics and joint orientation.

* The derived failure criterion for jointed rock is

the Mohr-Coulomb criterion in which the stresses have been modified for dilatancy.

* The derived failure criterion is expressible in terms of stress invariants and reducible to the form of a circular cone on applying Drucker-Prager approximation to Mohr-Coulomb failure surface.

* The mechanistic picture of deformation is conceivable where in energy is stored elastically on the compression of contacts which activates plastic sliding at an orientation deviating from the critical orientation whence the critical combination of shear stress and normal stress is reached.

* The nature of most of the stress strain curves is typical with a concave downward in the early stages while slight concave upwards just near the peak signifying variable modulii throughout the process of deformation.

* The failure has been observed to be intantaneous and associated with the characteristics thud noise.

* The volume change is very low initially and increasing slightly till peak but just near and/or after peak stress a phenomenal increase in volume change is observed.

* After the peak a sudden drop in the stress is noticed which stabilize thereafter indicating the sliding in classical manner.

* The characteristic concave downdard nature in the initial part of loading is persistent even under loading and unloading cycles.

* The hysterisis loop is clearly observable and appears to remain almost constant during consecutive repeated loading

and unloading cycles.

* The stress-strain-volume change characteristics appear similar under triangular as well as sinusoidal loading events.

* On consideration of dilatancy it bears out that the effect of joint orientation is only on the cohesion parameter while the friction parameter remains equivalent to the basic friction angle irrespective of joint orientation.

* For softer material Drucker-Prager approximation circumscribing the Mohr-Coulomb criterion holds good while for harder material inscribing condition appears to be applicable.

* For a scale ratio of 2:1 in diameters corresponding to 3:1 in contact areas there is a perceptible change in failure values as well as in the trajectory of stress-strain curves.

The findings that have been listed above are the outcome of the 58 experiments grouped in three catagories one, in which three orientations viz. 54.8°, 45° and 30° to the horizontal, gouge material as cement:sand of proportions viz. 1:2, 1:3 and 1:4, second, in which N_x (5.4 cm) and A_x (2.86 cm) sizes of specimens jointed at 54.8° to the horizontal filled with gouge material as cement:bentonite with proportions viz. 50:50, 40:60 and 30:70 and third, in which three stress fields viz. monotonic, triangular and sinusoidalwhen analysed against the theoretical model developed during the present investigations.

The most significant point bears out from the present investigation is that it is possible to exploit the theoretical model under the umbrella of theory of plasticity if rigorous treatment is invested in the discovery of a flow rule. The starting point may be Drucker-Prager associative and non associative flow rules applied in conjunction with Drucker-Prager approximated Mohr-Coulomb criterion to derive an incremental stress strain relationships. It has been amply demonstrated during the present investigation that the servo controlled closed loop MTS setup has a promise in obtaining the insight into the phenomena governing the mechanical behaviour of the materials. It is possible to test the validity of various concepts by subjecting the carefully prepared specimens to any specific static or dynamic stress fields. It would be interesting to investigate the concave downdard nature as depicted in the initial part of the loading and phenomenal volume change near the peak and the residual shear stress in a post peak region. In order to investigate the appropriatness of theoretical model it is essential to verify against the results of model and prototype structures.