SYNOPSIS

The clear understanding of the mechanical behaviour and failure phenomenon is a prime requirement for the analysis and design of structures constituted of rock. Owing to the complexity in the structure of the rock the approaches based on classical concepts do not yield rational and realistic solution to boundary value problems in rock mechanics. It calls for independent approach which incorporates the inherent imperfections in rock at microscopic and submicroscopic levels. The process of differential thermal changes during the formation of the rock necessarily locks the stresses in the flaws which when nullified by external stresses triggers the failure as a consequence of release of stored elastic energy.

The first concepts on failure mechanics are associated with the names of Galileo (1400), Hooke (1678), Coulomb (1776), Saint Venant (1855) and Mohr (1900). These concepts initiated extensive studies on deformation properties of solids and led to the development of various failure critera termed as strength theories. These theories state that failure starts at a moment when at a certain point in a body, a particular combination of parameters such as stress, strain reaches a definite critical value. In recent years the new concepts in strength analysis evolved as a result of the works of Griffith (1921), Taylor (1940), Orawan (1951), Irwin (1957) and others. The new concepts suggest to include the influence of defects existing in a body and their propagation during loading.

Theoretical developments for the present investigation stem from the roots of classical Griffith theory for brittle materials. Failure criteria for rock materials as reviewed by Hoek (1980) are the extensions of Griffith with an attempt to verify against experiments. One of the principal lacuna in these extensions is the non-consideration of the value of 'locked stresses' in a rock material.

Theoretical models should stand against experimental verifications. A critical review of various experimental techniques utilised for investigating the failure in rock materials by number of research workers most notably Hondros (1959), Fairhurst (1964), Addinal and Hackett (1964), Hobbs (1965), Colback (1966), Jaeger and Hoskin (1966), Hudson (1969), Mellor and Hawkes (1971), Lajtai (1972) emphasise that the method of testing must necessarily be interpretable. Among the various experimental setups Brazil tests on disc and annuli are not only simple but also interpretable against theoretical derivations. The only important requirement for the validity of the test is the application of uniform line load. This will necessarily require development of test specimen grip which can produce theoretical loading on the specimen.

The scope of the present investigation is to explore theoretically and verify experimentally the mechanism of failure with a goal to contribute towards the mathematical framework for analysis of structures constituted in rock materials. To accomplish the objectives of the research a physical model conceptualised from origin and formation of rock material has been exploited to evolve a theoretical relations for failure criterion and constitutive law for rock materials. To test the integrity and validity of the theory of fracture in rock materials, experimental investigations have been conducted on discs and rings of two varieties of basalt from Narmada Dam site under diametral line loading employing specially developed grips.

The outcome of the present investigation is summarized as below:

I Igneous rocks are the consequence of pressure temperature cycles which leaves residual stress locked in the inherent structure comprised of submicroscopic flaws. When an external stress is applied to a rock material there occurs a storage of elastic energy until the nullification of locked stresses, the release of which triggers the failure at the submicroscopic flaws whence the critical stress conditions initiates the crack propagating throughout the material.

II Whence the ratio of stress difference (between excess compressive stress and pre-stress) to maximum tensile stress reaches a critical value at any critically oriented flaw the failure occurs which if expressed on Mohr diagram generates a mathematical equation for failure in rock materials. The failure equation is a general parabola which degenerates in to Griffith parabolic failure criterion for no pre-stress in the material.

III The constitutive relationship between stress ratio and strain at any point has been established from the mechanism of failure of hyperbolic form convenient for a mathematical scheme to solve the boundary value problems in rock mechanics.

IV Pre-stress is defined as the stress locked in to the structure of rock during the process of cooling of hot lava which gets manifested as concave portion in a load displacement curve. The geometrical linearlization of load displacement curve determines the value of pre-stress. A one to one correspondence exists with the value of pre-stress obtained from derived general failure criterion.

V Tensile strength in the rock is the value of maximum tensile stress at the point of failure represented as a vertex of the failure parabola on a Mohr plot. This value corresponds to the maximum tensile stress value calculated from elastic analysis of disc subjected to diametral line loading.

VI Failure in rock material occurs when the ratio of stress difference between the excess compressive stress and pre-stress to tensile stress approaches a critical value. The critical value at no pre-stress is 8 corresponding to Griffith critical ratio. When there is a pre-stress the critical value exceeds 8 depending on the magnitude of the pre-stress.

VII Brazil test on Nx size discs and rings has been found to be valid if load is distributed along the arc of a circle substending at 10°. The primary fracture initiates near the centre of the disc or near the centre hole of the ring and tend to coincide with the plane of the loaded diameter.

VIII Disc exhibit mild pulsating pattern approximating to a straight line signifying no appreciable change in the ultimate value of the failure load with loading rate ranging between 0.48 μ to 6100 μ. Annuli with radii ratios .055, .074 and .0925 show no appreciable effect on the failure load ofcourse there is a slight decreasing trend as the radii ratio increases.

IX The primary crack is initiated along the loaded diameter as could be expected in a disc or a ring of an elastic isotropic material with instantaneous transfer of the maximum failure stress conditions to the pre-existing flaws whether it is situated along, across or at any orientation manifested as secondary or tertiary cracks.

X The steel loading jaws designed and developed for disc shaped rock samples consisting of diametrically opposed surface over an arc of a contact of approximately 10° performed as per theoretical requirements of stress distribution initating the primary fracture along the loaded diameter for the majority of 44 specimens tested during the present investigation.

XI Specimens to exact diamensions conforming to theoretical requirements could be prepared through a sequence of controlled slicing, finishing and polishing by means of specially developed appliances whose tolerances stood against the profilometer observations.

XII A 30 speed conventional strain controlled 5 Tonne loading frame with proving ring dial gauge systems performed satisfactorily to produce data and observations for analysing the behaviour under the theoretical frame work developed during the present investigation.

The expositions from the present investigation should contribute towards the basic understanding of failure phenomenon in a typical igneous basalt rock material. It is suggested that postulations and formulations may by subjected to rigourous investigations on other varieties of igneous rocks and further extended to sedimentary and metamorphic classes of rocks. To accomplish the vividity in to the entire process of failure a sophisticated stiff load frame with micrographic attachments is essential so as to acquisise the record of all the significant instances from crack initiation to ultimate fracture through the sequence of crack propagation.