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Influence of Reservoir Load on a Neighbouring Reverse Fault: A Simulation

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ABSTRACT

The simulation of reservoir induced seismicity indicates that a finite reservoir situated on the footwall of a reverse fault can induce a tendency towards instability.

INTRODUCTION

The problem of reservoir induced seismicity (RIS) in the Himalaya is little understood as yet. The past experience of large reservoirs in the Himalaya not withstanding (Gupta and Rajendran 1986, Srivastava 1990), it would be prudent to assess the risk due to this hazard for each individual future site of a large reservoir in these mountains. Numerical simulation of RIS has a role to play in this aspect of site investigations. Several articles, notably, by Gough and Gough (1970), Snow (1972), Bell and Nur (1978) and Roeloffs (1988) have covered considerable ground from simple beginnings. In this paper we combine aspects of the first and last of these works to seek through simulation an answer to a question pertinent to the Himalaya, namely, stability of reverse faults under reservoir loading. The analysis of the stability of such a fault is prompted by the observation that many of the so called thrusts in the Himalaya are reverse faults in the strict sense. (Gansser 1964, Valdia 1981 and Mehdi et al. 1972).

MODEL AND THEORY

The model taken up for consideration here is a relatively simple one. Following Gough and Gough (1970) we have mainly considered the effects of reservoir loads. The length of the reservoir is assumed to be much greater than its width, so that, it could be approximated as a line load. For quantitative purposes the reservoir is assumed to be an inverted infinite prism of right triangular, vertically symmetric, crossection with the base of the triangle oriented horizontally at the top. The water load due to the entire section is assumed to be concentrated at the lower apex. We assume the earth to be flat, homogeneous, isotropic and perfectly elastic, so that the well known results of Boussinesq (Jaeger and Cook 1969) could be used to estimate analytically the stability changes on a plane of the same orientation and location relative to the reservoir as the anticipated fault. The fault is taken to be of the reverse type with a dip of 60^0 and strike parallel to the length of the reservoir.

QUANTITATIVE APPROACH

Roeloffs (1988) following Bell and Nur (1978) used the following quantitative definition of change in fault stability due to reservoir effects,

$$\Delta S = \mu(\Delta\sigma - \Delta\rho) \pm \Delta\tau \quad \text{..........} \ (1)$$

where,

ΔS: Reservoir induced instability

μ: Coefficient of friction

$\Delta\sigma$: Normal stress on the fault plane due to the water load.

Δp: Pore pressure change induced by the water load.

$\Delta\tau$: Magnitude of shear stress on the fault plan due to the water load.

Compressive normal stress is taken to be positive. The positive sign before $\Delta\tau$ is to be used if the sense of the shear stress induced by the reservoir load is opposite to the sense of shear stress along the fault under ambient stresses. The effect of reservoir impoundment will be to drive the fault towards instability if ΔS has a negative sign.

RESULTS

Calculated changes in the stability of the reverse fault are shown graphically in Fig. 1. The point P represents the idealized reservoir line load of $662\text{x}10^6$

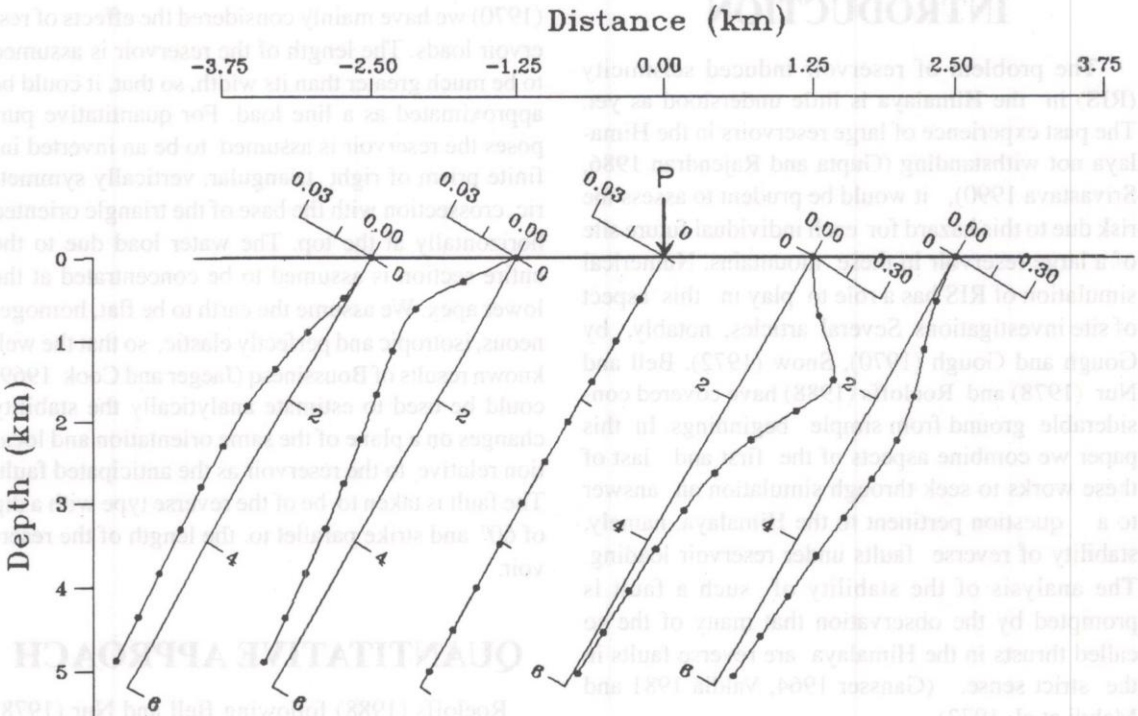

Fig. 1 Display of the reservoir indeced changes in stability of reverse fault as a function of position of the fault relative to reservoir and of the position on the fault (see text for further details).

N/m commensurate with a reservoir depth of 260 m. For all the calculations the value of   is taken to be 0.75. The vertical and horizontal scales of distances relative to the load are shown. The five straight lines sloping down to the left represent five different positions of the fault relative to the axis of the reservoir. In each case, left side of the fault is expected to have a tendency to move up relative to the right side under ambient stresses. Each curve shows variation of S with distance measured along the fault from an origin at the surface. The unit of the scale of ΔS is MPa.

We infer from Fig.1 that the finite reservoir does not have uniform effect on the entire fault. The nature of this variation also depends on precise location of the fault relative to the reservoirs. A fault is driven towards instability when the reservoir is located in the footwall of a reverse fault.

DISCUSSION

Inspite of the idealized nature of the above model it has implications at the time of the initial filling of the reservoir when the water load at the site increases for the first time. It has also implications for changes of water level during subsequent operations of the reservoir.

An obvious short-coming of the above calculations is that the role of pore pressure is not explicitly considered. Work on this aspect is already underway. Still, we note from the equation (1) that the increase in pore water pressure will decrease stability by an amount equal to Δp at the point in question and vice-versa.

CONCLUSIONS

1. The effect of a finite reservoir on the stability of a fault is not uniform in space.

2. The load of an idealized reservoir of the above type impounded on the footwall of a reverse fault will induce a net tendency towards instability and failure of the fault and vice-versa.

3. Whether a given fault at a given point will be driven to induced failure actually will depend on whether or not the initial stability (S) of the fault under ambient stresses can be nullified by the net reservoir induced instability (ΔS) at that point.

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