Modelling Studies for Tunnel Design

Designing tunnels is a difficult task since the rock mass behaviour tends to be unpredictable due to heterogenity of rock mass and geological discontinuties. Field experience provides some idea of rock mass behaviour. Many theories have been proposed for assessment of the rock mass behaviour, but no theory has been yet able to provide all the design parameters. The missing paameters are either assumed by experience or their effect is neglected. Therefore a detailed study of tunnels was initiated by the Central Mining Research Institute (CMRI), Roorkee Cell and C-MMACS to fill some of the gaps in the understanding of rock mass behaviour. Selected tunnels were instrumented by installing load cells and closure meters at different locations during face advance of tunnels. These instruments were to be monitored on a long-term basis so as to study the long time behaviour. To initiate the study for long-term solutions, field data of load cells and closure were collected from five different projects. The field data were processed by using statistical methods. This information provided a basis for the analysis of the deformation behaviour. The stress state surrounding the rock medium of tunnels was delineated by using the theory of elasticity and elasto-plasticity. The extent of broken zone was also predicted. This prediction has been helpful in predicting the load on the supports. For comparative analysis, the load on supports has also been predicted by the block theory with the help of geological information and mechanical characteristics of rock to determine the correlative factors. These factors are useful in refining the design parameters. *(A K Dube*, V V R Prasad*, A K Soni*, A Swarup*, Sridevi Jade, * CMRI, Roorkee)*

Thermosolutal Convection

Double-diffusive or thermosolutal convection, found in nature as well as in man-made systems, exhibits a great variety and richness of structure due to the inherent nonlinearity. Also, large differences in the diffusivities of heat and mass and the fact that thermal and species buoyancies can either aid or oppose each other depending on the molecular weight of the diffusing species can greatly complicate multi-component convection. Salt fingers, salt fountains and sharp diffusive interfaces offer some examples of the way the nonlinearities manifest themselves in these systems.

The class of confined buoyant flows has served as a test case for studying transititon and the onset of turbulence for over a decade, as the flow exhibits only a few degrees of freedom, and hence could be modelled as a low dimensional system. While there are many investigations of instablity and flow bifurcations in single component convection, there are only a few on double diffusive convection. Therefore the problem of combined convec-

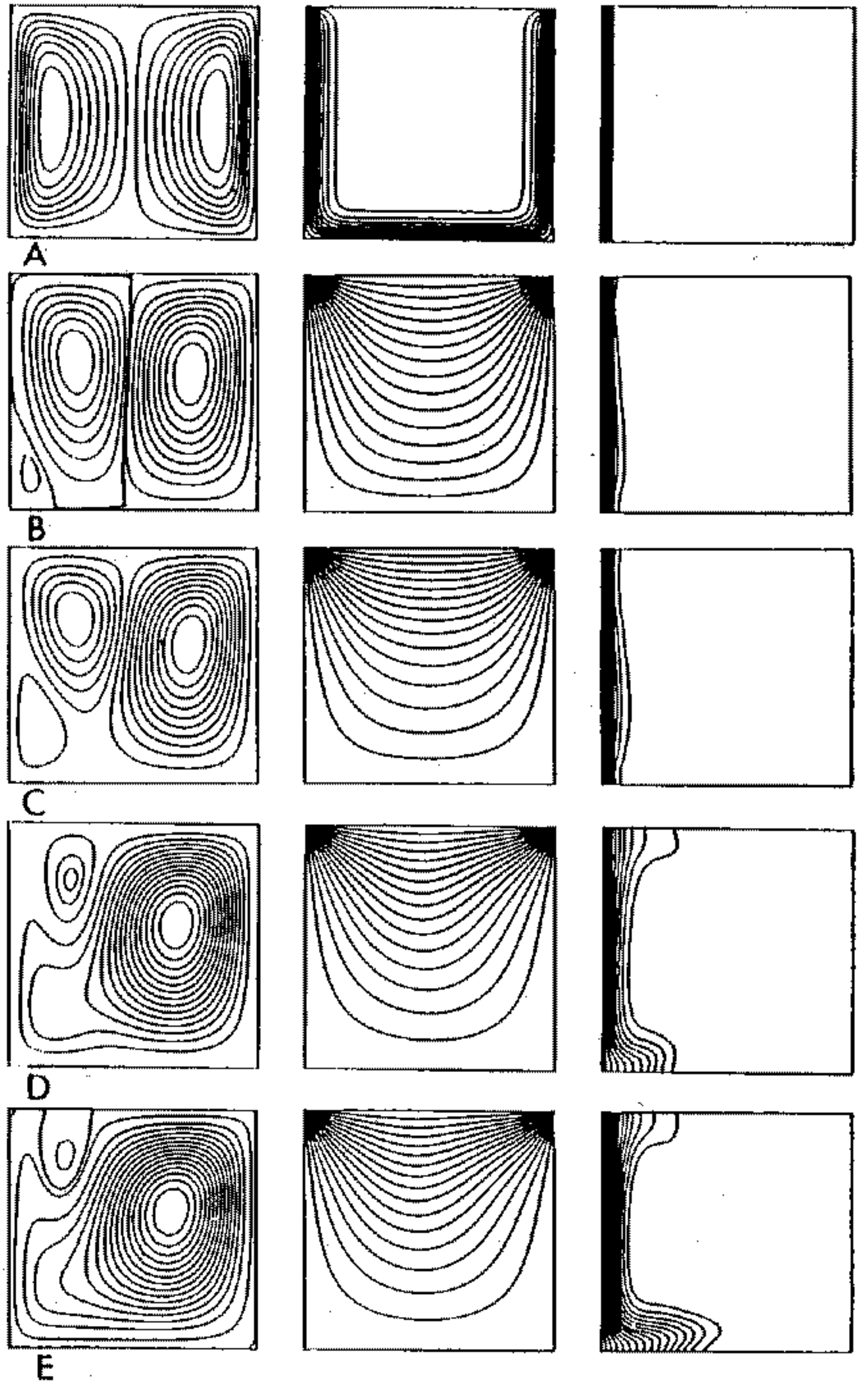

Figure 13: Time evolution of the velocity, temperature and concentration fields for different dimensionless times (A) 0.0001 (B) 0.5 (C) 2.5 (D) 3.5 (E) 5.0 Notice that the initial phase of convection is dominated by thermal effects (two cell structures)

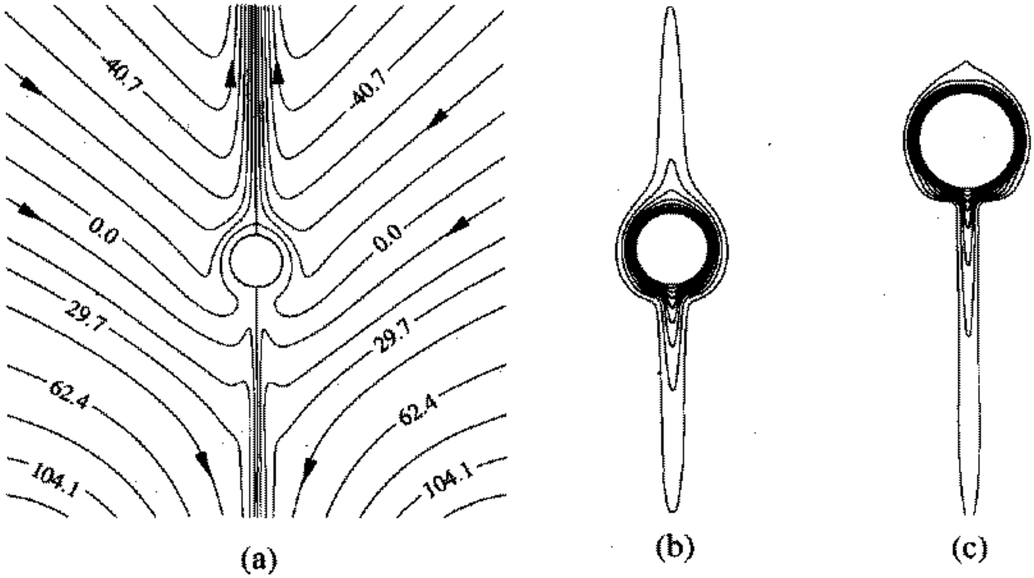

Figure 14: "Bi-plume" solution for thermosolutal convection over a horizontal isothermal circular cylinder for one set of control parameters. Streamlines are shown in (a), isotherms in (b) and lines of constant concentration in (c).

tion in a confined enclosure was studied at C-MMACS for a configuration that is important not only from technological but also geophysical point of view. The focus is on elucidating the mechanism of instability with the help of appropriate mathematical models and numerical schemes. Fig. 13 shows the time evolution of the velocity, temperature and concentration fields for one set of control parameters. For the problem considered, the top corner cell on the left wall, formed as a result of the interaction between the unsteady solutal and thermal boundary layers is found to give rise to instability. The problem of combined solutal and thermal convection over a horizontal isothermal circular cylinder is of fundamental importance in a variety of application areas such as the manufacture of cables, control of surface temperature using transpiration cooling etc. Surprisingly a full Navier-Stokes solution of the problem which gives details of the flow fields and the nature of interaction between the buoyancy forces for this important problem was not available till to date. This problem has been solved at C-MMACS by carrying out a full Navier-Stokes simulation using efficient numerical methods. For mildly opposing flows (when thermal and species buoyancies act in opposite directions) an interesting 'biplume' behaviour has been observed in which the flow over the cylinder is divided into an upward thermally driven flow and a downward solutally driven flow. Fig. 14 shows the velocity, temperature and concentration fields for one typical case. *(M S Phanikumar)*

Particulate Flows

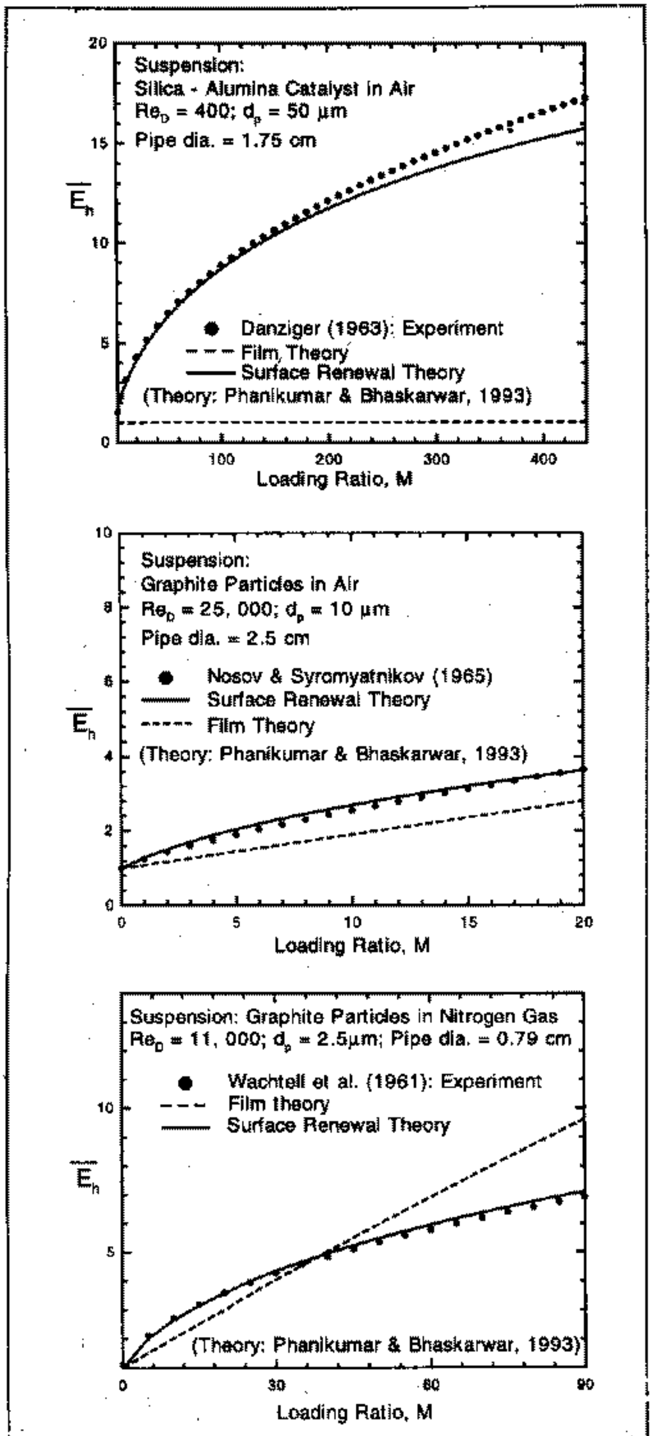

Figure 15: Comparison of theoretical predictions of enhancement in heat transfer with experimental data for turbulent flow of slurries in a pipe.

Dispersions of solid particles in fluid phases are encountered in several systems of scientific and engineering interest. Examples from application areas include extraction of heat from flue gases (laden with Al-Si catalyst particles) in the petroleum industry, the drying of wet grannular materials and suspensions (e.g. lotions, foods) and fluid flow vizualization using fine polystyrene or Aluminium particles. Even though there are situations in which particles are introduced deliberately to improve performance (e.g., to achieve higher mixing / heat transfer as in the Brayton power generation cycle), interest also lies in situations where particles are not introduced deliberately but appear as a by-product (e.g., as in combustion). An important question in these problems is related to the enhancement in heat transfer due to the presence of solid particles. A fairly general theory for predicting heat transfer augmentation in flows of slurries, gas-solid suspensions and flows with bubbles (e.g., nucleate flow boiling) has been proposed recently (M S Phanikumar & A N Bhaskarwar, Int. J. Heat Mass Transfer, vol. 36, No. 3, p. 735-741, 1993) using a surface renewal theory and the theory of Brownian motion of particles. Recent work (Bhaskarwar and Phanikumar, Trans. ASME, J. Heat Transfer, Vol. 117, No. 4, p. 1091 - 1094, 1995) carried out with the aim of establishing limits of applicability of the proposed theory shows that an excellent agreement is obtained between the predictions of the theory and a vast body of experimental data for turbulent flow of gas-solid suspensions in pipes. Figure 15 shows comparisons with data over a wide range of loading ratios. The proposed theory is found to work well for water suspensions of solid (slurries) as well as for flows involving mixtures of a liquid and gas (as in boiling). *(M S Phanikumar and A N Bhaskarwar*, *IIT, Delhi)*