Theme-1: Engineering Geological Mapping

Paper No: 2

Contour mapping and terrain analysis using SRTM data: a case study of dam area, Dibang Multipurpose Project, Arunachal Pradesh, India

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Present study deals with the problem of generation of contour map for planning of civil engineering construction of hydroelectric project from Shuttle Radar Topography Mission (SRTM) data. Further, SRTM data have also been utilized for terrain analysis (neotectonic study, aspect map & slope map analysis and 3D modeling) over the study area. In steep rugged terrain/ deep narrow valley/ deep river some small data patches are not fully depicted. To supersede this problem a needful correction has been carried out on the SRTM data using ENVI 3.6 (Environment for Visualizing Images 3.6) by creating prediction surface from available 3 arc second (90 meter spatial resolution) SRTM-DEM. The corrected 3arc second SRTM DEM data has been resampled to 10 meter spatial resolution DEM. Various interpolation methods, viz., Inverse Distance Weighted (IDW), Spline and Ordinary Kriging method have been carried out for resampling to higher resolution DEM generation. However, the results of Ordinary Kriging method have been found to be most suitable in the present study. Comparative analysis and accuracy assessment of SRTM DEM data and the DEM generated from Topographic contour plan (1:250,000) have been carried out. The result shows that SRTM data is more useful for terrain analysis and generation of contour map over the study area.

Paper No: 26

Seismic Slope Instability Assessment using RS & GIS Techniques: A Case study from Garhwal Himalaya

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Landslides are one of the most damaging collateral hazards associated with earthquakes. Seismically triggered landslides damages and destroy homes and other structures, block roads, and stream drainages. Predicting where and in what shaking conditions earthquakes are likely to trigger landslides is a key element in regional Seismic Slope Instability Assessment. In the present study an attempt has been made to derive information on causative parameters and preparation of seismic slope instability assessment map using Newmark's method in the seismically active zone of Garhwal Himalaya. The study area is lying in between Latitude 30°41′13.54″ N to 30°47′58.38″ N and Longitude 78°22′47.55″ E to 78°33′12.50″ E., from Matli to Maneri and covers approximately 1260 sq km and lies in SOI Toposheet Nos: 53 J/5, 53, J/6, 53 J/9 and 53

J/10. In Newmark's model a landslide behave as a rigid friction block that slides on an inclined plane. The block has a known critical (or yield) acceleration, which is simply the threshold base acceleration required to overcome basal shear resistance and initiate sliding. The analysis calculates the cumulative permanent displacement of the block relative to its base as it is subjected to the effects of an earthquake acceleration-time history. Spatial data sets such as geological map (1:25,000 scale), slope gradient, strong-motion records of the main shock and aftershock, geotechnical properties such as cohesion, friction, unit weight and seismic parameters were integrated using Newmark's method. All of these data sets have been digitized and rasterized at 20-m grid in the ARC GIS environment. Combining these data sets in a dynamic model based on Newmark's permanent-deformation (sliding-block) analysis yields estimates of coseismic landslide displacement in each grid cell from the Uttarkashi earthquake. The modeled displacements are then compared with the inventory of landslides triggered by the Uttarkashi earthquake to compare with the result of analysis. The final factor of safety map has been reclassified in to three classes such a stable, critical and unstable slope condition based on cumulative cutoff. The result shows around 72.89% of known landslides including the Uttarkashi landslide is in the unstable slope condition. The seismic data and the role of seismic activity have been analyzed for initiation of landslide. The results showed that using Newmark's method to model the dynamic behaviour of landslides on natural slopes yields reasonable and useful results. Final result anticipate that this seismic slope instability maps can be used to assist in emergency preparedness planning and in making decisions regarding development activity such as construction of Hydro Power Project and other development activity in areas susceptible to seismic slope failure.

Paper No: 31

Challenges in Geo-engineering

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The code for conducting the engineering geological investigations needs a drastic change on account of uninterrupted signals transmitted by the mother earth in the form of lowering of the ground water level, unusual trembling sound relayed from the crust of the earth while fracturing the ground and suction of ground water, heavy amount of toxicity developed and spread in the land-water-air system, conversion of prized agriculture land into barren zone by unscientific use of additives in the soil ,untreated disposal of industrial effluents; urban refuse and animal carcass in the pristine river water system and unplanned spurt in the urbano-industrial complex. It has compounded the problem for a healthy growth of society which was well thought of by our ancestors but due to its unawareness by the planners and executors, deaf ears have been paid to them. The science of engineering geology has; therefore, to formulate the guidelines for the planned development of the geo-engineering structures /mega cities in a phased manner so that the lost glory of mother earth is regained to maintain the pristine ecosystem for the sustainable development. Water is one and the foremost among them which needs suitable sites for storage and second in priority comes the shelter which calls for the suitable measures for the stable and durable design, and the last and more important attention is to be paid to reduce the surface load of the commuters through subways and short communication tunnels. A thorough search for suitable construction and building materials is to be made and a data bank established to get the ready made information. In the words of Henry Clues geology is the music of the mother earth. If it holds true, it is the geo-engineering community with the help and assistance of engineering geologists may formulate a programme and modalities to forsee, warning of the consequences and suggest preventive measures for the pace of developmental programmes in the 21st century .May be for reviving the groundwater regime, removing the toxicity in the surface water for irrigation and drinking, town planning for mega cities at a safer place on the river flank at the confluence of trunk river with its tributary to allow the natural cleansing of the river water and providing a good infrastructure for supporting the needs for human civilization . There is no dearth of land for horizontal expansion and modalities for mega cities, metro tube railways industrial sites for refineries and other ancillary units on the derelict and barren land without any damage paid to the prized agriculture land may be worked out. It may be projected on the thematic maps generated by the engineering geologists.Of late, the trends of learning the informative technology for better job opportunities has reduced the entry into civil engineering courses which has put the geo-technology into recycled bin. It has to be revived for the geo-engineering activities. The menace created by the anthropogenic activity, if not reduced to nil, may at least minimize the ill effects of the anthropogenic soil masking the natural earth resources which are the playground for the food chain and building material. The paper deals the various aspects of these phenomena which ISEG may highlight through seminars, symposia and workshops as a programme of mass awareness. A revised code for engineering geological mapping by standardizing the values of various parameters of rock and soil of Indian landmass may be attempted to for determining the values of “Q”and geo-mechanical properties of the soil along with the reaction of lechets. It may slightly improve the soil stabilization measures recommended by Terzhagi.The recent advances in video filmimg of one tunnel wall may have better appreciation of the site conditions after evaluating the causes of failure, if any.

Paper No: 35

Rock Mass Characterisation for Engineering Design

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In situ rock mass, a geological material, is discontinuous, anisotropic, non- homogeneous and often pre-stress. It’s strength and modulus responses depend primarily on the joints system, i.e. joint frequency, joint orientation , joint material and in situ confining stress. Any hydraulic structure, like rigid water retaining structure (masonry or concrete) , tunnel , underground chamber and reservoir periphery, need appropriate assessment of rock mass parameters for realistic, safe and economical design. The approaches which have been in vogue based on RMR , Q values and GSI do not provide realistic values of

strength , modulus and modulus ratio of rock mass and they have not been verified by any laboratory or field studies. A weakness coefficient of rock mass called Joint Factor based on the combined influence of joint frequency , joint strength and the critical joint orientation, has been evolved and linked to strength , modulus and modulus ratio based on vast experimental data. These relationships have been applied to solve some field problems of deep excavation to predict failure zone , deformations of large underground power chambers. The joint factor has been applied to estimate safe bearing capacity of foundation , shaft resistance of pile / pier, stand up time in tunnel excavation , ground reaction curve for circular tunnel and to predict the penetration rate of TBM.

Paper No: 57

Remote Sensing Based Generalized Analytical Model for Estimating Soil Properties

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In recent years the parallel developments in computing facilities and high resolution remote sensing sensors have revolutionized the data processing analysis and information extraction capabilities. At present the satellite data are being widely used for delineation of soil boundaries, land use, geological investigations, and geomorphologic mapping. Soils are characterized by a complex system. Applications of remote sensing techniques to finer levels of identifying and quantifying the soil characteristics are lacking. Evaluation of soil characteristics involves decision-making and modeling multiple interwoven criteria (Bauman, 1986; Cristopher, 1992; Carle & Fog 1996). Generally, soil data required for a scientific planning is either not available or not sufficient. Collection, storage, and processing of required data is difficult, costly, and time consuming (Goovaerts 1997, Lunetta et.al. 1998). Remotely sensed data has proven capability in providing many, above surface, surface and sub surface characteristics of a land unit. Synergistic use of remote sensing and ancillary data can be made for the development of the database required for estimating the soil characteristics. It is expected that synergistic use of remote sensing, ancillary data can help in solving many existing problems related to the evaluation of soil characteristics (Bhumgardner et al, 1970; Hoffer and Johansen, 1971; Gerberman and Nehr, 1979; Dubey, 1991; Brown et al.2002). In this study an attempt has been made to represent this system by Generalized Additive Model (GAM). The GAM involved decomposing a system in to a number of simpler components forming a cascade. The decision process moves from one cascade to another to arrive at the final decision. Generally remote sensing data are collected in different wave length regions commonly known as bands. GAM has been used to develop a model for weighting data of a particular set of remotely sensed data observed over a region of EMR. GAM was developed and calibrated for assessing the soil grain size analysis using historical database. The database was subjected to generalized analysis. The correlation matrix was developed and decomposed spectrally in to components. The first component accounts about 90 % variation in the data. The vector corresponding to this component represents the weights to different land characteristic that were considered influencing the decision. The GAM is mathematically sound but pair wise comparison is highly subjective. In order to get optimal results with minimum subjectivity the GAM was further modified to accommodate multi criteria. The developed GAM was validated and then tested for a part of rural areas in alluvial plains. The soil of the study area is generally coarse grained and aquifers are water table type. The area receives about 1000 mm annual rainfall; vegetation density is highly variable in spatial and temporal domain. It varies from 0 % to 95 %. Ground elevation varies from 215 m to 400 m; land slope varies from 0.6 % to 6 %, depth of groundwater table ranges from 0.9 m to 18 m. The database for the study was generated through the integrated used of remote sensing and conventional techniques. The model efficiency was tested by carrying out field surveys and found to above 80 percent. The model can be used for evaluating the soil grain size in an area after calibration.

Paper No: 76

Tectonic and environmental control in shaping the layout of the Jakhol Sankri HE Project, District Uttarkashi, Uttarakhand

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The 48 MW Jakhol Sankri HE Project across the Supin river, a major tributary of the Tons river, is another revelation of the geotechnical and environmental constraints in projects located in the mighty Himalayas. It has had its share of gnawing teething troubles in the PFR (Pre Feasibility Report) investigations itself and has landed up facing two important tectonic features- the Main Central Thrust and the Purola Thrust- across its water conductor system, besides the tightrope walking in adjusting the layout so that it stays clear of the widespread wildlife sanctuary area. The environmental restrictions imposed have gone a bit too far as even the deep seated subsurface structures like the HRT are not allowed even to be aligned through the restricted wildlife sanctuary area. Located largely within the Lesser Himalaya, this run-of-the-river scheme transgresses into the Great Himalaya as the diversion structure (barrage/raised trench weir) is proposed about 300m beyond the MCT, within Central Crystallines. The underground powerhouse near Sankri is proposed within interbedded quartzite and schist of the Jaunsar Group, separated by the Purola Crystallines with a thrusted contact (Purola Thrust) just upstream. The HRT, therefore, cuts across both the MCT and the Purola Thrust. Owing to the wildlife sanctuary stipulations, tectonic setting and optimization of power generation, the project layout has been drastically modified at the PFR stage. The diversion structure site has been shifted ~2.5 km upstream. The new site, proved to be an excellent location for the structure, but as it fell in wildlife sanctuary, it had to be relocated 300m downstream. The TRT outfall needed to be kept clear of the wildlife sanctuary and has been shifted upstream marginally, alongwith the underground powerhouse site. The powerhouse complex has also been proposed to be relocated within Purola Crystallines as the pressure shaft intersects the Purola Thrust. The thrust would now be negotiated in the TRT. The HRT alignment may also undergo slight changes in view of the changes brought about in the citing of other project components. The paper deals with the role of the detailed geological investigations in arriving at the optimal layout of the project and advocates a relook at the environmental restrictions so that both the nature as well as the developmental projects of national interest flourish side by side.

Paper No: 77

Compressive stress and thrust faulting deformation analysis in the Himalayan fold-thrust belt

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The Himalayas represent one of the few places on earth where continental crust is attempting to underthrust continental crust. As the Indian plate underthrusts the Himalaya, it warps down in response to an advancing orogenic load and keeps the entire Himalayan mountain arc seismically active. Even today the Himalayas continue to develop and change the structures by the movement between Indian and the Eurasian plate. From this viewpoint, a two-dimensional finite element model is generated to investigate most common structural pattern thrust fault and compressive stress in the Himalayas. It is beyond the scope of the present work to show whether the slip occurs on such a simulated fault or not. The numerical study has been performed considering the present convergence rate of Indian plate and rock layer properties of central Himalayan profile. Results show that the compressive stress and normal faults have primarily developed in the deeper region of Tethys Himalaya, Lesser Himalaya and Sub-Himalayan sequences whereas with increasing boundary displacement and changing layer properties, thrust faults have developed in the shallower depth in the respective layers and finally having a tendency to highly concentrate in southern part of the model. Thus the thrust faults predicted by the numerical model show the similar tendencies with the sequence of southward thrust development found in the Himalayan orogenic belt. Moreover, the simulated faults along the frontal part of Himalayas are the most common faults in field which influenced the present neo-tectonics of the region.

Paper No: 85

Geological Challenges for Hydropower Development in Bhagirathi Valley, Garhwal Himalaya Uttarakhand

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Bhagirathi river emerges from the Gaumukh snout, the terminus of Gangotri and Raktavarna group of glaciers (~4000m); after its confluence with Alaknanda river at Devprayag (~442m), ~185km d/s of Gaumukh, the river is known as Ganga or Ganges. About 5300 MW of hydropower potential has been estimated in the Bhagirathi valley, out of which only 26% (1396.2MW) has been harnessed through 4 large & small hydropower projects so far. Presently 10 large and small hydropower projects of 2731.5 MW are under construction stage and about 32 hydropower projects of about 1221.6 MW

are under investigations. These projects are located in complexly folded-faulted, seismo-tectonically sensitive and geoenvironmentally fragile middle & higher Himalayan terrain falling within Seismic Zone-IV & V of the Seismic Zonation Map of India. The Bhagirathi Valley exposes a myriad of lithologies belonging to Jaunsar, Garhwal and Central Crystalline Group of rocks. Presence of seismogenic major tectonic dislocations viz. the North Almora Thrust (NAT)/Srinagar Thrust (ST), the Main Central Thrust (MCT) with associated criss-crossing lineaments; epicenter clusters, geothermal signatures, rugged topography, rapid mass wasting, heavy bed load, active tectonics signatures, river blockades, high level terraces etc. are the main generic adverse geotechnical infirmities in the valley. The geological and geotechnical infirmities increase from south to north and particularly proximal to and north of MCT. Meso to micro scale manifestations of these geological challenges are required to be adequately understood and investigated during PFR, FR & bankable DPR stages of investigations for safe & economic design of the project layout and to reduce geological surprises to minimum at the construction as well as post construction stages with minimum down time. GSI has been associated with all the major projects in different stages right from identification, thus making immense contribution in promoting the hydel projects and braving the Himalayan odds. This paper brings out the present scenario of the hydropower development in the valley with special emphasis on the Himalayan geological challenges.

Paper No: 113

Cartosat-i and landsat imageries in the geotechnical Studies of Birahi-Ganga small hydel schemes, Chamoli district, Uttarakhand

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Landsat imageries provide synoptic view of the terrain and are in use for the interpretation of geomorphology, geology, hydrogeology, geotechnics and related fields o for last two decades. In the Birahi Ganga Small Hydel Scheme, which is inaccessible with steep hills and deep valleys and covered with thick forests, recourse has been taken to the interpretation of Landsat Imagery in combination with Cartsat-I for the preparation of maps on the above aspects. The Cartsat-I launched on May 5th, 2005 is yet another tool which provides track stereo data from which an accurate Digital Elevation Model (DEM) can be generated. The derivatives of DEM are contours, slope, aspect etc having vital role in wide range of applications. The other important product dependent on DEM is Ortho-image, which is free from distortions. The ortho-image can be used as maps to make measurements and establish accurate geographic locations of features, which can be displayed and worked in CAD and GIS environment. Cartosat-I in combination with Landsat Imagery has been made use of probably for the first time to generate accurate contour maps, geomorphological, geological, and hydrogeological maps for use in the geotechnical evaluation of Birahi Ganga Small Hydal Scheme.

Paper No: 115

Engineering Geological Maps – Introducing a Components Check List for Uniformity

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Detailed engineering geological maps form the backbone of any investigation. Lithology and geological structure, including joint data, have formed the basic data on these maps since the time engineering geology discipline got recognition. With the advent of Rockmass Classification approach, and introduction of mechanized tunneling, the maps became more and more advanced, particularly with respect to data on discontinuities. The Bureau of Indian Standards Recommendations for preparation of Geological and Geoechnical Maps for River Valley Projects (IS 15686:2006; Superseding IS 6065 (Part 1):1985) emphasise uniformity in the preparation and presentation of geological maps and guide the field geologist in preparing geological drawings that may be readily understood by the user. In practice, however, the map products may be in variance with the BIS Code due to project and site specific objectives and, hence, such uniformity is conspicuous by its absence. The present day boom in hydropower development, with attendant diversification and outsourcing of geotechnical investigations, has added greater disparity in engineering geological maps. The maps are found to defer from site to site, organization to organization and, surprisingly, even within the organizations. Along with the guidelines, therefore, it may be prudent to adopt well defined check list of map components and sample Engineering Geological maps. Besides the executing and designing agencies, this may be a great help to the outsourcing agencies as well. The paper discusses various aspects of engineering geological maps and introduces a 'Check List' of map components that have been categorized into 'Common', 'Need Based', 'Obligatory' and 'Desirable'.

Paper No: 116

Intricate problems faced in finalising the layout for augmenting the capacity of Pallivasal Hydroelectric Project, Idukki district, Kerala

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The Pallivasal Powerhouse with an installed capacity of 37.5 MW was commissioned between 1940 and 1952 in stages. Kundale and Madupatty reservoirs located at the upper reaches of Mudirapuzha river, a tributary of Periyar river provide the storage. The discharges are diverted into a 3.1 km long power tunnel at R.A. head works at Munnar. Other components include, a surge shaft, four number of penstocks and a surface powerhouse. The Project was constructed when the hydro-power development in the country was in its infancy. The water conductor system of the Project is facing certain problems. The water cushion available at the intake of power tunnel is very low and at times it is risky to operate. There was scope for having an additional powerhouse of 60

MW as surplus water was available. However, there is no possibility of raising the height of the weir as the site is surrounded by private lands, hotels and National Highway. Hence, an alternative water conductor system with tunnel intake at lower level for feeding both old and new powerhouses was planned. When a new water conductor system was designed, no problem was faced in finalising the power tunnel alignment but, penstocks was a challenging task. The existing penstocks faced problems in 1944 between anchor-3 and 4 due to soil creep when only two pipes were there. In 1961, after the monsoon, the penstocks were found deflected horizontally by about 23.5 cm from centre line. Further disturbance was noticed in 1964 and since then no movement was reported. Geological investigations carried out in the distressed zone indicated that fresh migmatitic gneiss is available only at deeper levels of 23 m and 28 m at anchor- 3 and 4 locations respectively. The overburden consists of clayey soil, scree and hill out-wash material and boulders. The slope is gentle and the affected zone forms shoulder portion of the ridge. The investigations revealed that mass movement of the overburden due to creep might have caused the distress. No major remedial measures were undertaken as advised by the experts and the powerhouse is functioning with the penstocks in the same condition. Under the circumstances, laying of additional pipes to feed the new powerhouse by the side of the existing penstocks was considered risky due to instability of the ground. The narrow strip of KSEB land that accommodates the penstocks is surrounded by private tea estates. Investigations were carried out for alignments away from the risky zone through tea estates and found to be favourable. But, anticipated problems in land acquisition forced the KSEB to seek alternatives. Underground pressure shaft for the entire length would be uneconomical as the horizontal limb would be too long. At this stage GSI was approached for resolving the vexed problem. When the project area was thoroughly examined, it was found that KSEB owns a sizable land at Mincut Colony located midway of the penstock route which is suitable for locating the exit portal of pressure shaft. A break in slope at the Colony created a favourable topography for providing the cover for tunneling. Finally, an underground pressure shaft for crossing the unstable reach and penstock for rest of the length was proposed by GSI. This worked out to a 355 m long pressure shaft inclined at 45° followed by a 495 m long pressure tunnel and the surface penstock for 1.5 km. The project layout was finalised on the same lines by KSEB and construction in the name of 'Pallivasal Extension Scheme' is in progress.

Paper No: 129

Geological mapping and planning for bore hole locations for Cherlopalli balancing reservoir, Handri Niva Sujala Sravanti scheme, Anantapur district, Andhra Pradesh.

J.Sri Hari and G.J.S.Prasad
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Handri Niva Sujala Sravanti Scheme is intended to provide water for irrigation and drinking purpose in the draught prone areas of Kurnool, Kadapa, Anantapur and Chittoor districts of Andhra Pradesh. The proposed Cherlopalli reservoir is a part of punganoor branch canal of Handri Niva Sujala Sravanti scheme. An earth dam having a length of 4.225 km, maximum height of 28.109m would form the reservoir of capacity of 1.609

TMC. Fine to medium grained gray colored granite with intrusions of dolerite dykes and quartz veins and pegmatite veins of Archean age are exposed in the area. Dolerite dykes are dark grey in color, fine grained and are intruding along the NE – SW trending joints. Electrical resistivity survey carried out in the area earlier tentatively delineated bedrock. Presently, boreholes were planned based on electrical resistivity survey, topography and ground examination to arrive at depth of foundation grade.

Paper No: 130

Geology of proposed weir foundations of Ashwaraopally tank, Godavari lift irrigation project, Warangal district. Andhra Pradesh.

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Ashwaraopally tank envisages formation of a 1.500 km long earth dam having a capacity of 0.500 TMC, which is an up gradation of existing Pangidi cheruvu (Reservoir). The bund is located on dolerite dyke, which is intrusive into grey granites of Peninsular Gneissic Complex of Archean age along with a 48m long weir. Geotechnical studies helped to delineate and to assess the foundation medium. Fresh and hard dark gray fine grained dolerite is exposed as foundation media. Joints are tight, discontinuous and are closely to moderately closely spaced. Some of the joints are filled with Quartz – calcite veins. A thin shear fracture zone is mapped in the body wall trending N65oW ~ S65oE from u/s to d/s. Logging of bore hole core, which is falling on the shear fracture zone is showing severely/highly broken core and permeability values ranging between 70 and 90 lugeons. Removal of loose material and grouting was carried out to control the seepage of water. Proper benching was recommended to dress the steep slopes.

Paper No: 131

Geology of Ghanpur tank, J.Chokka Rao Godavari lift irrigation project (Phase II), Warangal district, A.P

J.Sri Hari
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Ghanpur Reservoir is an up-gradation and linking of existing old tanks situated at Ghanpur and Rajavaram in Warangal district of Andhra Pradesh. The upgraded earth dam has a length of 8.06km, maximum height of 15m with a capacity of 1.5 T.M.C. The existing bunds are formed by joining the scattered out crops of dolerite dyke and the dolerite dyke is trending in N-S direction, has a length of about 8.0km and fragmented outcrops of the same are seen all along the proposed bund. Fine grained dark grey dolerite and light grey medium grained foliated granite are exposed in the area. Other litho-units exposed include lueco granite, pink and white, coarse grained pegmatite and quartz veins. Based on geological mapping it was recommended to locate the weir between Ch.4510 and ch.4670 to take advantage of better foundation. The bore hole data

indicated fresh and hard leuco gneiss at a depth of 2.5m from ground level. Geotechnical studies also helped to delineate the foundation grades for another weir located at Rajavaram, where the design was suitably modified to meet the ground conditions.

Paper No: 132

Geotechnical investigation of earth dam pertaining to Bhandarugudem reservoir, Indirasagar Lift Irrigation Scheme under Polavaram project, Khammam District, Andhra Pradesh.

G. J. S. Prasad
GSI, Hyderbad

The Indirasagar Lift Irrigation Scheme involves, laying of pressure mains from Peddavagu project to Bhandarugudem tank including surge protection against transient, formation of a reservoir at Bhandarugudem and out fall structure and construction of distributory system for irrigation. Medium to coarse grained ferruginous sandstones with cherty siltstones and pebbly beds form the main rock types belongs to Upper Kamthi formation of Lower Gondwana Group of Upper Permian to Lower Triassic age. The general attitude of beds is N45o to 55oW ~ S45o to 55oE with gentle dips varies from 5o to 10o towards Southwest direction. Structurally controlled drainage pattern has been observed. Small streams arising from the hilly region in a dendritic pattern forms Alivagu stream which joins Gumdeti vagu further to Kalperu vagu which is a small tributary of the river Godavari. Scanty out crops of sand stone are exposed in the stream bed of the Alivagu. Mostly the bed rock is covered under thick alluvial and gravely soil. A regional geological map indicates that a fault trending N50o to 55oE ~ S50o to 55oW cut across the proposed earth dam on the right flank. The impact of this fault needs to be assessed after opening the cut off trench of the earth dam. As the overburden soil is pervious in nature and the underlying weathered sand stone is very friable and pervious, it requires the excavation to be extended up to relatively hard rock.

Paper: 133

Study of lineaments in Polavaram Dam Project area, Khammam, East and West Godavari districts, Andhra Pradesh

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Mapping of structural lineaments in an area of 5,000 sq km around the Polavaram Dam Project, led to identification of several major faults/ shear zones. The objective of the study was to aid the geotechnical investigations of the Polavaram multi-purpose project carried out by the Geotechnical and Special Investigations Division, Southern Region, Geological Survey of India. For this purpose, remote sensing studies comprising LANDSAT MSS and TM FCC imagery of 1:2,50,000 scale and black and white aerial photographs on 1:60,000/ 30,000 scale were used. Field check traverses were undertaken

for ground validation of the 73 lineaments demarcated ranging in length from 10 km to 90 km. The major lineaments in the area trend ENE-WSW to NE-SW. On the basis of remote sensing studies and field evidences, the lineaments are classified into faults, shear zones, fractures, master joints and lineaments (unclassified). A number of faults/ shears identified by photo interpretation were observed and confirmed in the field, based on evidences such as, alignment of drainage, abrupt change in landforms and/ or lithology on either side of lineament, truncation and dragging of beds, intense brecciation, pulverization, silicification, ferruginisation and emplacement of quartzo-feldspathic veins. The E-W trending Srinivasapuram-Ramanujapuram fault is encountered 3 km north of Zangareddigudem and 1 km south of Srininvasapuram. The fault demarcates the boundary between the Precambrians in the north and Gondwanas in the south which was upthrown and tilted to form a spectacular E-W scarp facing north. The ENE-WSW trending Jagannadhapuram-Bhimolu-Ragholapalli fault shows evidences of dragging of beds and attitudinal changes in the Gondwanas and gneisses, silicification, brecciation, ferruginisation and slicken sides, etc. Another ENE-WSW trending fault/ shear passes alongside Kannapuram-Pragadapalli section. Evidences of shearing and pulverization are observed along a zone comprising clayey material for a stretch of 25-30 m in a nala, south of Kovvada kalva near Dondapudi. The slightly arcuate NE-SW trending fault passes along Velagapalli-Gangapalli section. It shows intense fracturing and silicification. A few faults were delineated in the vicinity of the dam site, such as, the major arcuate fault situated on the left bank of the river, 12 km northeast of the dam site; ENE-WSW fault across the Godavari River, 3 km north of the dam site and NNW-SSE fault, east of Devipatnam. Faults were also delineated around Bhadrachalam, Ashwaraopet etc, some of which mark the contact between the basement gneisses and Gondwanas. The NE-SW trending Sabari lineament possibly represents a deep seated crustal fracture as evidenced by emplacements of plutons of syenite and nepheline syenite. Proximity of Bhadrachalam temple town known for seismic activity and also presence of significant morphostructures in the Godavari delta, call for further study of Quaternary geology around the Project. Thus the evaluation of lineaments in terms of their status and neotectonic significance would prove useful for the purpose of planning and safe designing of the multi-purpose Polavaram project.

Paper No. 142

Geotechnical Challenges in MountainousTerrain of Himalaya

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In India twentyth century has witnessed commissioning of many dams /tunnels/ power houses and multipurpose irrigation schemes on diverse geological environment but the experience gained in one project can not be utilized on others due to changes in climatic conditions and their effect on physico-mechanical properties of the rock types. It, therefore, points out the peculiarities of the various earth features of the mountainous terra in which offer challenges to the geotechnical engineers. To overcome these problems each segment of the mountainous belts is governed by certain dictum which may or may not be inducted in others due to variations in their setting, lithological assemblage, geomechanical properties of the material, altitudinal behaviour and seismicity of the belt. It would therefore be prudent for a competent engineering geologist to formulate a suitable line of action before launching any geotechnical project. Paper deals the challenges posed by the mountainous terrain of Himalaya particularly in the north-western segment.

Theme-2: River Valley Storage and Diversion Structures

Paper No: 9

Some infirmities and non-homogeneity of foundation rocks help stability of gravity dams

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Existence of poor rocks, faults and joints in foundations rock mass below gravity dams are considered as a source of scare and worry for the safety of the structure. All efforts are made to treat, consolidate and grout such infirmities to obtail as sound and hard rock as is practicable. This naturally involves sometimes huge expenditure. Contrary to such apprehensions, research has shown that infirmities like anisotropy, joints, layers and faults can help to the safety of the dam, when such infirmities are in certain locations at the dam base and have certain orientations. Such conditions improve stress pattern in rock foundations and stress distribution in the dam body. Some such cases, as a result of extensive research work done by the author are presented, which would give confidence to the design engineers.

Paper No: 37

Integrated approach for rockmas characterization and designing of support system for 12.5 km long tunnel of Dewas-II Project, Udaipur district, Rajasthan

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Udaipur city, known as the ‘City of Lakes’ is one of the most important tourist place of India and is also a center of mineral based industries. Due to increasing demand and decreasing trend of rain fall in the catchments areas, these lakes are unable to cope with the water demand of the city. To meet the ever increasing demand, a four stage inter basin water transfer scheme has been contemplated. The Dewas-II stage under construction, envisages construction of two dams and tunnels of 12.5 km cumulative length ; about 1 km long Madri link tunnel and 11.5 km long Akodara tunnel. The tunnel is to pass through monotonous flysh metasediments comprising mainly phyllites and schists with bands of quartzites and minor calcareous and talc-serpentinite rocks belonging to Jharol Group of Aravalli Supergroup of rocks. The rocks have under gone polyphase deformation and exhibit progressive increase in the grade of metamorphism from low green schist facies in the east to low amphibolites facies in the west. The rocks are trending parallel to the tunnel alignment in Madri link tunnel and across the alignment in Akodara tunnel. 3D geological logging of the both the tunnels revealed that a number of shear zones, mostly thin with clay fillings, running parallel to the foliation in schistose rocks as well as cutting across it at different angles are the most important geotechnical features requiring attention besides very low RQD of the schistose rocks. In

this paper an attempt has been made to use the integrated approach utilizing the most widely accepted Rock Tunneling Quality Index ('Q')of Barton et al (1974), Geomechanics Classification or Rock Mass Rating (RMR) of Bieniawski (1989) and Terzaghi's (1946) rock load classification and their modified versions by different workers and their correlation is discussed for determining the rock mass characteristics and tunnel support requirement.

Paper: 41

Water Resources through low dams in Kandi Area of Punjab

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Kandi zone is formed by the outwash which has been deposited by numerous small ephemeral rivers (choes) which originate in the Shivalik hills and merge with Indus Plains. Govt of Punjab took an ambitious plan of developing this region. A series of low dams in the upper reaches. The implementation of this network of low dams is eco friendly. For the attenuation of the floods and for the development of irrigation facilities for about 22000 hectares 31 prospective dams have been identified. Presently twelve low dams have been completed and functioning well. Geotechnical evaluation, hydrology and research activity on geotechnical problems; design measures have been handled reviewed by team of eminent experts. It is a unique model of development and a standing example of cost effective regional development of rural regions of our country. My paper will furnish full details and latest evaluation of benefits.

Paper: 42

Challenges In Engineering Geology, Deccan Trap Terrain -Maharashtra state

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Engineering geological studies have Important role in identifying the problems and suggesting suitable corrective measures for safe execution and functioning of the projects. Though the problems appear simple, the cost involving for corrective measures maybe quite high as compared with the total cost of the project. Yet the problems can not be ignored as they concern the stability of structure, competency of structure etc. Engineering geology deals with the applications of geology in different Engineering projects. It is concerned with the mapping and characterizing all the materials proximately to a project. Geofogy supplies information about the type of rocks, their structure, their age, history and origin. In Engineering Geology the aim is not to elucidate origin of rocks but to describe their characteristics quantitatively which have direct bearing on stability and durability of Engineering structures constructed on them. The Deccan traps cover about 85% of the area of the Maharashtra state and the older rocks, the Dharwars, the Kaladgis, the vindhyans and the Gondawanas cover comparatively small area. Hence Engineering Geological problems faced and tackled in various structures such as earthel' and masonry dam foundation, tunnels and underground excavation etc. iff som e of the projects In Deccan Traps *of* Maharashtra are presented in this paper. The foundation *for* dam sites In Deccan Trap terrain consists of varieties *of* basalts i.e. compact basalt, porphyritic basalt, amygdaloidal basalt, volcanic breccias, tachylytes and lateritic deposits. Deccan trap terrain considered to provide good foundation generally. However the occurance of varieties of volcanic breccias, tachylytes, laterite and alluvial deposits have created problems during construction. Deep weathering, spheroidal weathering, weathered flow contacts, vertical, horizontal and sheet jointing, fractures and dykes etc. are also unfavourable characteristics in dam construction, underground excavation in Deccan trap region. Experiences have belled the belief that basalts are hard and massive and can safely house the underground structures. Basalts are not that problem free as they appear outwardly.

Paper No: 43

Geotechnical Appraisal of Dam Foundation of Adavinainarkoil Reservoir Project, Tirunelvelli district, Tamil Nadu

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The Adavinainarkoil reservior project envisages, the construction of a 47.20 m high and 670 m long masonary dam with an uncontrolled central spillway of 100m length, across the river Hanuman nadhi, which is a tributary of Chittar river in the Tambraprani basin. The dam is located near Mekkarai village in Sengottai taluk of Tirunelvelli district, Tamil Nadu.The main objective of this scheme is to store a part of seasonal flood water, which goes to the sea unutilised. By forming a reservior the flows can be regulated to stabilize the existing ayacut areas in the downstream through an already existing network of tanks and for irrigation of new ayacut areas. Detailed geotechnical investigation has been carried out for the assessment of the foundation medium of both the abutments and stilling basin areas. Charnockite gneiss with associated linear bands and stringers of pyroxene granulite and granite gneiss are the prominent rock types present in the mapped areas. The general foliation direction is N 55º to 70º W –S 55º to 70º E; with 50º to 70º dip towards down stream side. It is disposed parallel to sub parallel to dam axis. The joints system is generally prominent and closely disposed and more open towards left abutment, river course dam blocks and in the stilling basin areas. That is not the case in the right abutment, their frequency is less and they are generally tight in nature. Extensive shearing effect along, the pyroxene granulite bands were observed also along the prominent joints sets in the left abutment and stilling basin areas are also affected, due to the symphathetic effect of Achankoil limament or shear zone, which is possing 3 Km south of the dam location. This has resulted to increase the depth of excavation to reach the acceptable foundation media, leading to consequential increase in height and base width of the structure. In the weak zones, removal of sheared weathered materials up to fresh rock level were not possible, hence it is recommended to excavate up to a depth, double their width and to fill the weak zone with rich martor to surmout the foundation

problem .In addition to this remedial measures such as foundation rock-bolting, modification in the direction of consolidation grout holes to intercept the maximum number of joints sets and close-space grout holes to some selected reaches and extension of base width to abut the dam toe infresh rock beyond the weathered or shear zones were recommended.

Paper No: 46

Geotechnics of Birahi Ganga Small hydel project, Chamoli district, Uttarakhand

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The paper evaluates the geotchnics of the Birahi-Ganga Small Hydel Project which envisages to generate 32.7 MW in two stages as the run-of-the –river schemes utilising gross head of 367 m with 11 cusecs of water. The structures and tunnelling media mainly lie within the limestones/dolomitic limestones with minor bands of shale belonging to Pipalkoti formation of Garhwal Group. The rocks have been subjected to three phases of folding and faulting. The limestones of Pipalkoti formation are thrown into antiforms and synforms. Major faults are however not known in the area of the project although the surrounding area is dissected by major thrusts like Main Central Thrust (MCT) and a number major transverse faults. Based on the geological mapping, geological sections are prepared depicting that fairly compact and hard limestones at depths of 2 to 10 m would form the foundations of all the structures (1) Diversion dams, (2) Intake structures, (3) Power houses and other appurtenant structures. Geological sections are prepared for tunnels of the Original project and alternative alignments and the tunnelling media has been evaluated and classified. The tunnelling media classified according to Rock Mass Rating of Bieniawski and Rock Quality Tunnelling Index "Q" of Barton et al falls in Good and Fair classes with minor stretches falling under Poor class. These studies have shown that the major portion of tunnelling media do not require supports. Spot bolting/ systematic bolting are however required and these are to be carried out wherever tunnelling conditions warrant. Based on the seismic studies, horizontal seismic coefficient of 0.24 g and the vertical seismic coefficient of 0.12 g are recommended to be adopted in the design of structures. These studies have thus established that the project is feasible and that the geological conditions are quite favourable for the project.

Paper No: 54

The Engıneerıng Geologıcal Investıgatıons on the Çoruh-Yusufelı dam sıte and ıts reservoır, Turkey

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The most important river of the northeastern Turkey is Çoruh which has a potential of 9x109 KWh energy. In order to use the energy potential of the Çoruh River, a series of dams have been designed (usptream to downstream); Laleli, Kilicci, Ispir, Gullubag, Cetinbogaz, Uzumlu, Yusufeli, Inanli, Artvin(Deriner), Borcka and Muratli. The construction of Borcka and Muratli is completed and Artvin(Deriner) is on the way. The average discharge is 33 m3/sec at Laleli dam site and 205.45 m3/sec at Muratli dam site. Lias is represented by the Yusufeli formation which is composed of serpentinizated gabro, amphibolite at the bottom; spilite, metalava and green schist at the middle; and graywacke, slate and phyllite at the top. The Berta formation which consists of alternations of basaltic-dacitic and sedimentary rocks is seen in Upper Cretaceous. The Pugey formation starting with basal conglomerate overlies a granitic bedrock in southwest. This formation is continuous from Lias to Upper Cretaceous. The extension of the Pugey formation towards Oltu Brook starts with basal conglomerate in Malm and continues with flysch facies until the end of Lower Cretaceous; between these two, a volcanic intrusion composing of basaltic and rhyolitic agglomerates took place in Neocomian. Eocene is represented by Borcka volcanics which are composed of lithic tuffs at the bottom and andesitic lavas and agglomerates at the top. All the rocks are occasionally cut by granites. At Yusufeli damsite, the thalweg elevation is 500 m, the maximum water level is 720 m, and the average discharge is 125 m3/sec. Yusufeli damsite was located over Ikizdere magmatites and the reservoir area consists of Berta formation, Yusufeli formation, Ikizdere magmatics along Çoruh River and Pugey formation along Oltu and Tortum creeks. The watertightness of the damsite can be succeeded by grouting. In the reservorir area, the Berta formation is impervious. The dacitic tuffs locating in this formation, which were hydrothermally altered and lavas, agglomerates, show tendency of downward sliding between east of Çevreli village and Yusufeli County. The most significant one of these slides occured northeast of Yusufeli and named as Vecaket landslide. In the spring of 1968, just after a heavy rain, this mass which covers 2 sq-km area in the left bank of Barhal creek, slided down the slope, plugged the creek bed and formed a temporary lake and two workers, who had been working for the road construction, have lost their lives. After this disaster, Yusufeli County was evacuated for a short period. Meanwhile, the material in the river bed had been washed away by the creek. Today the remnants of that material can be observed on the right bank. The type of the movement was avalanche and mudflow. This landslide covers a large area at the upper parts while it follows much narrower path towards down the Burhal Creek. It is assumed that the thickness of the sliding mass changes between 100-250 m. After the construction of Yusufeli dam, the impounding of the reservoir would accelerate the slides (draw down) It is not expected that the Vecaket landslide would affect the feasibility of Yusufeli dam since the landslide area is very for from Yusufeli damsite. However, it would fill the dead storage partly and reduce the life of the dam. The lanslides locating around Gorgulu village by Tortum Creek are also active. At this location, the soil formed due to the weathering of Yusufeli formation slides (just like mud) down the bank towards the Tortum Creek. The moisture content of the material, which changes seasonally, affects the type and velocity of the movement: rotational slide and mudflow. The slope is gentle, so it reduces the velocity of movement. This area locates at the end of Yusufeli reservoir, therefore a probable slide mass will only fill a part of the dead stroge while it will not create any risk for Yusufeli dam. Yusufeli and

Berta formations in Yusufeli reservoir area are impervious. Along Oltu Creek, the limestone levels of Pugey formation do not show any excessive solution traces. It is considered that no leakage will occur through Pugey formation. In addition, there are no other basins by this path where the water would leak into.

Paper No: 56

Foundation problems & remedial measures power house & four diversion tunnels left bank Gangrel hydro electric dam project across Mahanadi, Distt-Dhamtari, State - Chattisgarh

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The left bank 2.5 * 4 MW hydel project has been constructed down stream of the existing Gangrel dams across Mahanadi River. The foundations of the power house and the diversion tunnels are located in the quartzitic sandstone. The contact of the sandstone and the underlying the pink Granite gneiss has been established below the power house foundations.The power house having 13.5 meter and 36 meters dimension ns have been completed. Artsian flowing water conditions were observed during the excavation of the power house site. Anchor have been provided grouting was recommended to seal the opening and make the foundation impermeable and monolithic. Four diversion tunnels for the total length of 182.4 m were studied and examined. The fresh Rock has been encountered in all the tunnels except some minor seepage problems both at the inlet and outlet portals. The rock mass properties of the tunnels fall in class I & II and RMR classification is very good > 80% to good > 60%. Rock bolts 3 m depth 2m center to center, resin coated have been provided. Short creted with wire mesh for smooth flow of waters suggested and has since been implemented.The project was completed before schedule time frame work.Remedial measures and treatment of the power house , tunnels, upstream and downstream portals have been done.The details have been discussed in the paper.

Paper No: 67

A Joint Strategic Approach for Hydropower Development in Alaknanda and Bhagirathi Valleys, Garhwal Himalaya, Uttarakhand

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India needs to add 12,000MW of power every year to meet its growing demand for power to sustain a GDP growth rate of 8-10% per annum. Estimated hydropower potential of Uttarakhand State is ~20,000MW and only ~16% is tapped (commissioned) so far albeit with huge time and cost overruns. In Uttarakhand and U.P. per capita power consumption stands to about 175kWh against all India average of 354kWh, an index of appalling power situation and under development. Many of the already identified hydropower

schemes in the Ganga and Yamuna Valleys are plagued with long gestation period between identification of the schemes and its conversion to a power generating project. Studies carried out for different hydropower projects by the authors in Garhwal Himalaya evolved a strategy that can cut down gestation period and time & cost overruns. Based on their studies in Alaknanda-Bhagirathi Valleys, the authors in the present paper advocate that instead of promoting isolated or stand alone hydro power schemes in Himalayan terrain emphasis should be to adopt Total Integrated Watershed Development on micro watershed basis with preference for clean development mechanism (CDM) compatible run of river (ROR) hydropower schemes over storage based schemes.Hydropower projects are inherently constrained by limited sitting options. Geological inputs at the identification stage enables sequential best practice for PFR, FR and bankable DPR stages of geotechnical investigations thereby minimizing geological surprises at the construction stage. Inadequate and/or intermittent geotechnical investigations have been identified to be one of the biggest impediments in hydropower development in Himalayan terrain. On such sequential best practices 1-2% of project cost can be incurred, examples abound where down sizing of geological/geotechnical investigations have resulted in hold ups during construction stage and consequential time & cost overruns. The new strategy seamless merges an engineering geologist with the sponsor right from the identification stage itself thereby addressing various issues related to sitting & size of the project vis-à-vis expected geological/geotechnical infirmities. By adopting the new strategy, the state with its huge hydropower resource can play a power leader role by bridging the power deficit and become a major and model hydropower generator for the nation through accelerated hydropower development.

Paper No: 72

Gundlakamma Reservoir Project, Prakasam Dt. A.P.

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The Gundlakamma Reservoir Project owing to its location in a complex geomorphic, geological and seismotectonic set-up posed some typical problems during preliminary/feasibility, pre-construction and construction stage geotechnical investigations. The construction of this 17.43m high and 6.9 km long major irrigation river valley storage project intended to irrigate 24281 Ha of land and to provide drinking water facility to the needy ongole town is nearing completion. Originally, a 420 m long concrete gravity dam comprising a 160 m long spillway in the main gorge with 130 m long N.O.F. sections on either side of it were proposed in the riverbed. Owing to the presence of 13 to 15 m thick riverine overburden, deep scouring of the bed rock below MSL and structural complexity of the terrain it was suggested to locate the spillway on the exposed charnockite outcrop of the Easternghat Complex, limited in its aerial extent on the left bank and to construct an earthen dam in the main river course. Consequently, a 240m long gravity dam, comprising 16 spillway blocks and appurtenant structures are concreted and the super structure is almost completed. Two major shear fracture zones which are the sympathetic features of the close by neotectonic Gundlakamma fault,

daylighted in the foundations, close to the left bank edge and in the central blocks have been treated. Earthen dams,1.7 km long as proposed in the left flank and 420m long as suggested in the main river course have been raised to the TBL with the cut-off taken 2 m into the moderately weathered to fairly fresh charnockite. The depth to cut-off in the 4 km long right earth dam, covered by thick alluvium has been decided based on the analysis from 31 boreholes and corresponding permeability data and also logging of 20 to 25 m deep trenches excavated along the alignment. The cut-off trench in the reaches of the right earth dam from Ch.0/0 to 0.115 km and Ch.3.90 to 4 km has been taken down to a depth of 2 m into fairly fresh and hard charnockite and was suggested to be grouted down to a depth of 6 m for rendering the strata water tight. In the reach of the earth dam between Ch.0.115 and 1.200 km, the borehole data revealed the presence of a wide buried valley of old Gundlakamma river course comprising thick pile of alluvial material of sand, pebbles, silt and heterogeneous clay of several flood cycles, underlain by fairly fresh and hard charnockite at 18 to 20 m depth, i.e., at R.L. +1 to -2m below the ground level. The stretch between Ch.1.2 to 3.9 km, the sub-surface is occupied by a thick pile of brownish and grey clayey soil, down to a depth of 15 to 19 m in general, underlain by highly weathered charnockite. The 20 to 25 m deep trenches excavated along the alignment revealed that the most vulnerable zone of seepage is confined to the reach between Ch.0.115 to 1.2 km. Therefore, a twin diaphragm wall, 0.8m thick of clay-concrete core going up to at least 1 m into impervious charnockite was designed for the contemplated structure. However, based on the realistic technical considerations, a single diaphragm wall was finalized to serve the purpose and is executed to erect a positive cut-off, with 100 m long transition zones on either side. The cut-off trench between Ch.1300 and 3.900 km has been excavated down to 3 m depth below the ground level and a grout curtain was erected going into fresh charnockite passing through the highly weathered

Paper No: 79

Geotechnical evaluation of Dibang Multipurpose Project, Lower Dibang Valley District, Arunachal Pradesh.

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Dibang Multipurpose Project envisages construction of a 270 m high rock fill dam across Dibang river, a tributary of Brahmaputra at Munli (28020'15": 95046'15", 82 P/15) with 150 m wide chute spillway, 6 headrace tunnels and an underground powerhouse on the right bank for generating 3200 MW of hydroelectric power. Earlier dam axis was suggested at 450 m downstream of Munli (Axis-I), where gneissic rock had been met at both the banks of the river. Subsequently the dam axis has been shifted further upstream of Munli to accommodate spillway intake (Axis-II). But due to presence of about 70 m thick overburden on left bank (DDH-13), as evidenced from drill data, axis-II has been again shifted at about 500 m downstream of Munli (Axis-III). The present dam axis III under consideration has been mapped geologically and subsurface exploration in the form of drilling and drifting was also carried out to assess the feasibility of the scheme. The project is located over litho-assemblage comprising quartzo-feldspathic gneiss, amphibole gneiss and granite gneiss belonging to Ithun Formation and bears imprints of low-grade metamorphism and multiple deformation. A major asymmetrical plunging anticline (450 towards NW) is interpreted along the Dibang river, where left abutment falls over normal limb and right abutment over the overturned limb. Thinly to thickly foliated quartzo-feldspathic gneiss will be the foundation rock for dam and its appurtenant structures. However, thin bands of granitic gneiss, amphibole gneiss and pegmatitic gneiss are also present. Thickness of overburden are 25 m in riverbed, 3-4 m in left abutment and few cm to 13.5 m in right abutment. Stripping limit of left and right abutment will vary between 12 m – 20 m and 12 m –30 m respectively. Joint frequency in bedrock of both abutments are J4 and J5. Permeability varies between 1.5 lugeon and 25.32 lugeon indicating mixed flow to turbulent flow condition. Several free flow zones characterised by presence of brecciation, shearing, pulverized / shattered zone and high joint frequency are recorded. The proposed rock fill dam is 270 m high, thus a central core will be advantageous and it will provide higher pressure at the contact between core and foundation reducing possibility of leakage and piping. Fresh rock should be exposed at the core contact area. Positive cut-off upto 1 m depth in fresh rock is to be provided. It has also been suggested to extend the cut-off in abutments upto top of fresh rock. Slopes of both the abutments are to be excavated from top to form moderate slopes by providing berms in order to get good contact between core and fresh rock and also to minimise the effects of cross valley load transfer. Curtain grouting below cut-off trench will be required for arresting seepage though cracks, joints and sheared rockmass. Conventional dental treatment is to be provided for shear zone of <2 m width and for shear zone for >2 m width , concrete plug may be preferred. A 150 m wide chute spillway has been planned on right abutment at the dam body earlier – for which huge rock excavation would be required. Stabilisation of the cut face on both the sides in that case is a big problem. Presences of foliation shears and cross shears are also big threat in terms of seepage and erosion along spillway. So it has been suggested to consider shifting of spillway from dam body by about 160 m towards N 350 W from junction of dam axis and planned spillway and to pass the spillway through the saddle zone – which will minimise rock cutting of order of 35 m to 40 m. Thickness of overburden is 9 m and joint frequency in bedrock is ‘J5’. Permeability value ranges between 2.31 and 5.18 lugeon. Adequate measures should be taken to dissipate the energy of the discharge channeled through spillway, as it is located over highly fractured rock. The earlier proposed surface powerhouse (at 8 km d/s from Munli) is located on the river terraces near Nizamghat. Tipam group of rocks are exposed to the south of the project area – overlain tectonically by Miri Formation along Mishmi Thrust. In the case of surface powerhouse, a 7.2 km. long HRT through fractured / sheared rocks was required. Dam toe powerhouse was also not feasible due to fluctuating periodic discharge of Dibang river, uncertain flood character and rapid change in many course. Later it has been decided to construct underground powerhouse at 1.5 km downstream from Munli at the right bank of Dibang river in view of the high Seismotectonic activity. Rock cover above the powerhouse cavern is about 400 m. For assessing the rock mass condition to be encountered at the proposed powerhouse location, 270 m long S 800E-N800W trending drift has been geotechnically assessed. The drift makes an angle of 750-800 with foliation strike. Presence of three sets of joints and shears in quartzo feldspathic gneiss and amphibolite have rendered the area vulnerable to failure due to formation of wedges. RMR varies between 30 and 7 1 (Class II and IV) and 'Q' value ranges between 0.17 and 6.6 indicating very poor to fair categories of rocks. Wedge analysis indicates that the rock failure may take place due to wedging – if angle of friction (300) and slope (400) is disturbed. Excavation parallel to steep dipping foliation (NW-SE strike with 560-700 dip towards NE) are expected to have higher rock pressure with very limited bridging action. To avoid the excavations parallel to foliation joints and expected collapse along the wedges, it is suggested to shift the powerhouse alignment in, N 640W-S 640E direction from originally N 800W-S 800E direction. N 300W-S 300E trending and southwesterly dipping shear zone located at 500m upstream of this proposed powerhouse may be intersected at the proposed transformer hall drift.

Paper No: 80

Geotechnical appraisal of Lakroh Minihydel Project, Jaintia Hills District, Meghalaya

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Lakroh Mini Hydel Project envisages construction of about 5 m high masonry weir across Lakroh river, a tributary of Umngot river near Lakroh village (25008':92014', 83 C/A) at E.L. 248 m. The water will be conducted through 808 m long rectangular power channel with 1.15 cumec design discharge to the powerhouse through forebay and 340 m long penstock for generating 1.5 MW of power using 165 m head. The project area is located at the fringe of Meghalaya plateau close to Bangladesh plains. Archaean granitic rock and metabasic rocks intruded by pegmatite and vein quartz rocks unconformably overlain by Tertiary sandstone and interbedded conglomerate are the rock types of the surrounding areas of the Project site. At the proposed weir site, 25 m wide Lakroh river flows towards S 300E and the weir alignment is N 650E-S 650W. Right bank slope (600-650) is steeper than left bank slope (450-500). Slightly weathered to fresh, hard quartzitic sandstone are expend at the weir site and continues from river bed upto 10 m above. The rock shows E-W strike with 50 to 80 dip towards south and have been dissected by three sets of joints. So the weir can be constructed over bedrock itself. The proposed 880 m long openpower channel will pass through mainly slopewash debri material comprising subangular gravels / boulders/pebbles of conglomerate and sandstone with some intermittent exposures of sandstone and conglomerate. Maximum cutting for the power channel will be around 5 m to 6 m and average is 3 m to 4 m. Excavation of debri material surcharged with water and jointed sandstone may cause slope failure. Moderation of slope alongwith provision of cross drainage across power channel are to be considered. The proposed forebay site shows presence of slopewash debri material consisting of boulders and pebbles of sandstone set in dark grey coloured silty matrix. For providing platform for constructing forebay, excavation of hill slope will be necessary. For stability of the excavated hill slope, it is suggested to provide suitable slope with 3 m wide berms at suitable height intervals – with proper drainage arrangements. Shotcreting of slope face is to be considered. One penstock pipe 340 m long and 0.75 m dia will carry the water running through hillslope. This part of hill slope appears to be stable. Anchor blocks of penstock pipe are to be laid over weathered rock and at places soil. Since bedrock is not available at reasonable depth. Provision of raft foundation is to be kept for anchor blocks to be found on soil. The site for the proposed surface powerhouse is devoid of any rock exposure and occupied by soil mixed with slopewash debri and boulders / pebbles of sandstone. Heavy cutting (say 30 m) will be required for creating platform for powerhouse and its ancillary structures – which can cause slope failure. So for arresting slope failure, shotcreting of excavated faces, provision of benches at suitable interval and retaining wall in back slope and drainage arrangements are to be considered. The area belongs to seismic zone V and the active Dawki Fault is located very near to the project site. Proper seismic coefficient may be incorporated in design.

Paper No: 88

Treatment of a highly deformed rock mass zone in the control gate shaft area Tehri dam project, district Tehri Garhwal, Uttarakhand

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This prestigious multipurpose mega-hydroelectric project envisages generation of 2000 MW of hydroelectricity, in two stages, by constructing a 246.2m high (from deepest foundation at El.593.30m) earth and rock fill dam, at Tehri, across river Bhagirathi in Uttarakhnd. This project is the first storage dam in the Ganga valley and the mammoth reservoir along Bhagirathi and Bhilangana valleys will impound the surplus monsoon flows which shall then be utilised in a regulated manner for irrigation and power benefits. The construction of four control gate shafts viz., CGS-1, CGS-2, CGS-3 and CGS-4 was taken up from the platform (at El840m) on the left bank. These 110m deep shafts of excavated dia of 13m between El 840m and El 830m and 11m below El 830m are connected to the four head race tunnel (HRT) at El 729m. The shafts 1, 2 & 3 were excavated without encountering major geotechnical problem and they encountered bands of phyllitic quartzite massive (PQM) and phyllitic quartzite thinly bedded (PQT) rocks, dipping 52-600/205-225. The stabilization of these shafts, in general, was done by means of rock bolting (L-4m; dia 25mm; @ 1.5m c/c) and shotcreting. During the course of geological investigations a 35m wide and extensive deformed/tectonised zone was delineated, which occupied a huge structural wedge confined within two major shears one longitudinal (L-11)shear and one diagonal (D-3) shear between El±910m - El±835m on the cut slope and on the platform at El 840m (CGS area). The zone is extended from the upstream of HRT2 and d/s of HRT4 alignment with its maximum depth (+40m) anticipated at the location of HRT3 shaft, based on the rock mass condition encountered during excavation of the pilot shaft from HRT3. During the course of excavation of CGS 3&4, there was movement in the deformed rock mass (formed by the intersection of D-3 & L-11 shears), which lead to formation of a big cavity and damaged the rib support in shaft number 4. The D-3 shear (in the form of two nearly crushed seams of 1.5-2m) was encountered at El± 750m in CGS-4. Due to the collapse of material, this shaft (CGS-4) was filled with muck up to El± 761m. Stabilisation of this mass was crucial as the slopes on the upstream side were coming in the draw down level of the reservoir and the two control gate shafts were to be excavated through the deformed zone. The slopes occupied by deformed rock mass, between El± 745m and El± 840m, have been provided with concrete cladding on the surface. A number of pile shafts were sunk at different levels between El± 790m and El± 840m and in the process the deformed mass was replaced by high strength concrete. The excavation of CGS-4 was undertaken by making lateral multiple drifts in the deformed zone and backfilling them with high strength concrete.

Paper No: 89

Excavation and stabilisation of right bank shaft spillways, Tehri dam project, district Tehri Garhwal, Uttarakhand

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Two vertical shafts, each of 12.2m finished diameter, were constructed on the right bank and they were connected with the right bank diversion tunnels T-3 and T-4 respectively so as to function as shaft spillways, after the initial requirement of diversion was over. Shaft spillways were planned to join the diversion tunnels at 450 chainage. The crest of these 230m deep ungated shafts had been provided at El 830.2m and they have been designed to operate automatically as soon as the reservoir level reaches El 830.2m. The intake of these shaft spillways is funnels shaped structure with uncontrolled circular weir of 34.0m dia. Vertical shafts join eccentrically (by 6m) with the tunnels at lower level, through a swirling device, which imparts a swirling motion to the flow in the tunnels for energy dissipation. Each shaft spillway on the right bank can pass a rated discharge of 1950 cumecs. These shafts were provided with the 9m diameter de-aeration ducts to release the air separated from the air-water mix. The de-aeration ducts were joined with the main shafts with the reverse curve. At 160m below the surface nearly 26m long and 11m deep separation chambers were constructed ahead of the de-aeration ducts. Different bands phyllitic quartzite massive (PQM) and phyllitic quartzite thinly bedded (PQT) were delineated in the two shafts. In T-3 shaft a 60m wide zone of sheared and puckered phyllite traversed by multiple shear seams was encountered between El 690m – El 630m. The poor geological conditions (with rock mass of Q value as low as 1.33, encountered in T-3 shaft) and the intricate design of the structure posed a stiff challenge during the full widening of these shafts. Wedge failures were noticed at number of locations. The junction of the main shafts with the de-aeration ducts was the area of high stress concentration and failures were more frequent in this zone throughout the length of the shafts. Another critical area was the lowest portion i.e. the swirling device area where the slant profile in the rock created overhang areas. Similarly the junctions of Intermediate Level Outlet (ILO), for T-3 shaft and that of construction adit, for T-4 shaft were also vulnerable. The excavation of all these complex structures was accomplished by devising appropriate support systems for different critical reaches. Pattern rock bolting and chain link shotcreting (in two layers) were provided as the general support measure whereas in critical zones steel rib support was provided. Spot bolting was resorted in the areas of overbreaks. The junction of the shafts and ducts was supported by horizontal and cross struts till the final lining was provided.

Paper No: 90

A glimpse through hydroelectric projects of North-eastern India

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Recently special emphasis is given in development of sustainable renewable ecofriendly energy resources in the form of hydroelectric power. North-Eastern India, with immense water resource potential for generating of hydel power – possesses 40% of the total potential of the country. The main source, Brahmaputra River originating from the Himalayas and its tributaries (Kameng, Subansiri, Dibang, Dibang and Lohit) flowing through Arunachal Pradesh has tremendous power potential. In southern part, Barak is the main river draining Manipur, Mizoram and parts of Assam.. Only 2% of hydel resources have been utilised so far. Recently – there is an urgent need for developing the vast hydel potential. Thus a large number of hydel projects are coming up in recent times. Though Northeastern part of India is blessed with huge water resource, most of the region is covered by soft sedimentary rocks of Tertiaries. The sites are characterised by geotechnically complex geological settings showing several episodes of folding, faulting and thrusting. Numerous shear and thrust zones are conspicuous throughout the region. Main Frontal Thrust, Main Boundary Fault, Main Central Thrusts are conspicuous throughout the area. Other notable faults and thrusts are Dauki Fault, Naga Thrust and Disang Thrusts. Continued movement of the Indian Plate causes accumulation of stress and subsequent release through earthquakes of high magnitude in this region. Two major earthquakes with magnitude more than 8.5 have been recorded in this region. Great Indian Earthquake of 1897 (8.7) occurred in Meghalaya massif. Great Assam Earthquake of 1950 was recorded in Mishmi Block. The areas lie in the region of collision tectonics – demonstrated by N-S compression stress field. Major earthquakes are related to northerly dipping detachment surface. In view of high seismicity, the highest hazard Zone V has been assigned to this area. Severely structurally disturbed rocks are the main barrier for searching a suitable site for concrete dam. Foundation grade rocks are available at higher depth leading to selection of rock fill dam in place of concrete dam. Water Conductor System in the form of head race tunnels are passing mainly through soft shale, siltstone and sandstones with a granitic/gneissic rocks for a short stretch. Tunnelling through such soft rocks with heavy seepage belonging to Class IV & V is highly problematic and requires heavy concurrent support along with proper drainage system. Locating surge shaft, penstock pipe and powerhouse either surface or underground in a suitable safe and techno-economically feasible site is a serious challenge. In northeastern India, .landslide is a major hazard. Heavy rainfall, soft, weak and fragile lithology and unfavourable structural disposition are the main contributing factors of landslides. So slope protection for arresting the natural landslides and induced landslides due to heavy excavation of rock mass is required. Geological Survey of India have made immens contribution in promoting the hydel projects by identifying suitable and tecnoeconomically feasible sites for locating dams, tunnel alignments and powerhouse braving the hostile terrain and remoteness of sites. Due to such constraints, a lot of problems are being faced during construction. A few problems faced during construction of some hydel projects are given in this abstract. In Ranganadi Hydel Project Stage-I of Arunachal Pradesh presence of highly pervious riverine material and slope wash debri in right abutment of concrete dam, formation of several cavities and overbreaks with seepage along the thrusted and sheared contacts of different groups of rock in head race tunnel and absence of fresh rock at reasonable depth in powerhouse sites are the main problem. In Kameng Hydel Project of Arunachal Pradesh, presence of thick terrace deposits in Bichom and Tenga Dams; several thrusted contacts between lithounits encountered in Bichom-Tenga and Tenga-Kirni headrace tunnel are the main problem. Location of surge shaft and power house near the thrusted contacts between Gondwanas and Siwaliks is also a real threat to this project. In Loktak Hydel Project of Manipur, flowing ground condition, roof collapse, squeezing of support and occurrences of methane entrapped in fissures in rocks in head race tunnel have been faced. Severe slope failures in sandstone-shale sequence along the power channel of Gumti Multipurpose Project of Tripura were encountered during construction. In Kopili Hydroelectric Project of Assam, limestones in reservoir area constituting about 67.7% have undergone extensive karstification and thus it was apprehended that after reservoir impounding there might be sub-terranean flow from Kopili Reservoir to adjacent lower valleys of Umrong and Diyung lying in east. Seepage from the right abutment through a nala cutting in downstream of dam axis, slope stability problem due to heavy excavation in chute spillway site, presence of swelling clay in mudstone are the main problem of Doyang Hydroelectric Project of Mizoram. In Tuirial Hydroelectric Project of Mizoram, construction of diversion tunnel and paucity of suitable coarse aggregates are the main problem. Presence of a NE-SW trending subvertical fault in Umram Stage-I Hydroelectric Project was the main problem.

Paper No: 95

Geological Challenges & Foundation Treatment of Concrete Gravity Dam – A case study of Uri-II HE Project under construction

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The Himalayan geo-complexity, difficult site/weather condition, immediate on-site appraisal vis-à-vis geological mapping & rock mass characterization, treatment of weak features, coping rightbank landslide, chasing scheduled time frame of concrete pouring etc. without hampering the progress of work gives an opportunity towards engineering the geological challenges at Uri-II Project. This paper is a case study of 240 MW, Uri-II HE Project with its 52m high concrete gravity dam presently under construction across Jhelum River at Salamabad, 120km west of Srinagar, J&K. the project area falls on the eastern part of Kashmir Syntaxial bend of NW Himalaya, occupied by upper Murree formation comprising of alternate sequence of Strong to Medium strong Siltstone (45%), very Strong Sandstone (35%), weak to extremely weak Shale (25%)-mostly splintery in nature. The exposed foundation witnessed numerous bedding & cross shears running along the spillway sections. This primarily owes to the proximity to a major lineament

Murree Thrust and vertical-open joints attributed to the u/s plunging anticlinal structure in which the dam site lies. A varied degree of approach for rock mass characterization was adopted depending upon the in-situ site specific geological condition especially while treating 2 major shear zones running across the dam axis along spillway blocks (S1&S4). An unprecedented right bank slide that originated from El.1454M, much beyond Dam top (El.1242M) has caused damage to dam concreting works. This would require an elaborate treatment from the top, which is presently under progress, looking to the overall stability of the abutment and dam life. Furthermore, removal of large boulders with low charge blasting in the near vicinity of concreted blocks, step cutting of rock slope against dip-depth excavation, step lifts for steep dipping shear zones against reinforcement, very close spaced consolidation grouting etc. makes Uri-II project an example of good engineering of geological inputs.

Paper No: 97

Geotechnical appraisal of Sri Narasimharaya Sagar (Gorakallu balancing reservoir) project under construction in Kurnool district, Andhra Pradesh (June, 2008)

Raju, K.C.C, K. Ravindranath
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This paper deals with the reservoir competency of the Gorakallu Balancing Reservoir and detailed preconstruction stage geotechnical appraisal including the on-going construction. Under this project, it is envisaged to construct a 48-metre-high and 3626-metre-long composite dam across Gurralamadugu stream to store waters of 12.44 TMC drawn from the foreshore of Srisailam Reservoir. Koilkuntla Limestones, Paniam Quartzites and Narji Limestones form foundations of the composite dam consisting of concrete dam of 1721m in the initial reach and 1905 m of earth dam thereafter. The right reservoir rim is formed of Narji Limestones capped by Paniam Quartzites. Detailed geological studies and explorations especially in the right reservoir rim showed that there are no caves and caverns of concern and that insitu chemical weathering of selected zones of shearing and fracturing has only rendered certain stretches into impervious clay. It was also established that the main dam area with the normal remedial measures would be water-tight thus establishing the competency of the reservoir. Hard and massive Panyam quartzites exposed in the left flank from Ch(-) 240 to Ch. 1400 m would form the foundations. The reach from Ch.1400 m to Ch.3240 m is covered with dark grey silty-clayey soils. Panyam quartzites extend below the overburden up to Ch.1700 ; thereafter Koilkuntla limestones are known to occur from Ch.1700 m to Ch.2820 m. Two step faults cut across between Ch. 2820 m and Ch. 2900 m. Narji limestones are found to occur below overburden up to Ch.3100 m and exposed later in the left abutment. The foundations when excavated showed to be much better than what was established during detailed investigations. The paper deals with the assessment of foundations and the treatment as required for the construction of the composite dam and also discuss construction stage studies and remedial measures recommended with those adopted.

Paper No: 98

Preconstruction stage geotechnical appraisal of Sravarasagar earth dam of GNSS project, Cuddapah district, Andhra Pradesh.

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A 22.538-metre-high and 5.435-kilometre-long earth dam with a saddle dam of 600 m with surplus channel at the right end with a storage capacity of 3.10 TMC to irrigate 25,000 acres of land known as Sarvarajasagar Dam is in an advanced stage of construction. This paper deals with the preconstruction stage and construction stage geotechnical appraisal. The dam site area and is formed of dolerite sill with subordinate quartzite-shale sequence and dolomites. This area including the reservoir is covered with 0.5 to 1.5 m thick dark grey to black clayey soil expect for the hillocks on either end and in the river bed. The study of excavated cut-off trenches from Ch.0.50 to Ch.2.400 km on the left side and from Ch.5.180 to Ch.5.300 km on the right side have shown that the dolerite sills, dolomites and shales are moderately weathered in the top 2 to 4 m. The dolerite sills are profusely kankarised and are moderately fresh from depths of 4 to 6.5m. Cyclic permeability tests have shown that the permeabilities of the formations are in the range of 5 to 32 lugeons (5x10-5 to 3.2x10-4 cm/sec) up to full FRL depth. The remaining reach from Ch. 2.400 to Ch.5.300 km could not be studied. It is however surmised that geotechnical parameters will be similar and the same type of remedial treatment could be accorded. Two alternative remedial measures were suggested with preference to the second recommendation for implementations. This recommendation is to fill the cut-off trenches with clay puddle up to depths already excavated and then provide grout curtain to full FRL depth with primary grout holes spaced at 12 m intervals in the reaches where the permeabilities less than 5 lugeons and 6 m apart in the reaches with permeablities above 5 lugeons.

Paper No: 100

Pre-construction and construction stage geotechnical appraisal of sunkesula dam of veligonda project, Prakasam district, Andhra Pradesh.

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Sunkesula dam is one of the dams proposed under Veligonda Project to fill on of the three gaps in the Nallamala Hill range. This dam will be 63 m high in the ultimate stage and this is in an advanced stage of construction. The geological studies have shown that quartzites interbedded/intercalated with phyllites belonging to Cuddapah Super Group would form the foundations. These formations run nearly parallel to the axis and dip at 450 towards downstream. The foundations of central blocks Nos.6,7 and 8 extending from Ch.150 m to Ch.240 m after excavation up to foundation grade appear as minor ridges and depressions due the alternating sequence of the two categories namely (i)

Predominantly quartzite with laminae of phyllites and (ii) Thin phyllite bands intercalated with quartzite respectively. The abutment blocks also have similar geological setting and during progressive excavations the nature of rocks to be studied and a decision on the foundation grade level. The laboratory tests on rock cores indicate that the foundation rocks possess adequate compressive strength. As the weakest rock in the foundations has given 1920 t/m2, which is 13 times the expected stresses imposed by the structure. Consolidation grouting of the foundations to depths of 6 to 8 m is considered quite adequate and recommended. Single line grout curtain with primary holes spaced at 6 m intervals to depths as per I.S.Code are recommended with secondary and tertiary as required according to normal practice. Horizontal seismic coefficient of 0.06 is recommended to be adopted in the design of the dam.

Paper No: 101

Geotechnics Of left earth dam of Thotapalli barrage, Vizianagaram district, Andhra Pradesh

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Thotapalli Project across Nagavalli river is an earth dam of 20.28 m height and 8.800 km long with central spillway of 117 m length with storage capacity of 71.05 cumecs (2.509 T.M.C) to stabilize the ayacut of 64,000 acres under Thotapalli Regulator and providing irrigation for 1,20,000 acres(ID). The right earth dam and spillway are completed. This paper discusses geotechnics of Left Earth Dam (Ch.0.600 km to Ch.4.10 km) and Right dyke (Ch.8.200 km to Ch.8.720 km). The area encompassing dam site is mainly occupied by rocks of the Eastern Migmatite zone and at places by Central Khondalite zone. Porphyro-blastic migmatite occurs in Rallavagu stream and on right flank of Nagavalli River. The remaining stretch of the dam site is occupied by the flood plain deposits mostly consisting of silty clay, clayey sand and silty sands. Detailed explorations established three layer sequence of silty clay, clayey sand and sand up to depths of 7.50 m to 27.00 m below which weathered to fairly fresh and hard khondalite and migmatite are encountered. The geotechnical explorations established the impervious nature of the overburden and the bedrock to depths of 8 to 33 m explored. The permeability values in the top 9 m are in the range of 6.31 x 10-5 to 9.48 x 10-8 cm/sec. In the deeper levels, the permeabilities are well with in permissible limits. The cut-off trench is therefore suggested uniformly at a depth of 2.00 m in the reach from Ch.1.900 km to Ch.4.100 km, where the ground level is below FRL. In the remaining reach from Ch.0.600 km to Ch.1.900 km, one metre deep key trench has been recommended. For the Right dyke, 1.5-metre-deep cut-off trench in the central portion where water column is less than a metre and key trench in the remaining stretches.

Paper No: 102

Preconstruction stage geotechnical appraisal of twin reservoir schemes of Kumaradhara and Pasupudhara, Tirumala, Chittor district, Andhra Pradesh

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To cater to the ever increasing needs of water supply to the pilgrims visiting the abode of Lord Venkateswara, two concrete gravity dams of Kumaradhara and Pasupudhara of 60 m and 30 m height respectively are under advanced stage of construction. The twin reservoirs will have a combined storage capacity of 2.38 M.Cum. The geotechnical studies established that the quartzites and shales belonging to the Nagari quartzites would form foundations of both the dams. The river bed blocks of Kumaradhara would have quartzites as foundations while abutment blocks rest on shales. The 60- metre-long spillway in the riverbed of Pasupudhara would be founded on quartzites and the abutment blocks would rest on shales. The foundation grades of both the dams would be available at depths of 0.50 to1.2 m in quartzites and 1.85 to 4.00 m in shales. The quartzites of both the dams are moderate to fairly tight with permeability values in the range of 3 to 6 lugeons. The shales in the top 9 m have given highly permeable values with permeabilities of the order of 5 to 35 lugeons. Consolidation grouting to depths of 8 to 10 m in the case of Kumadhara dam and 6 to 8 m in the case of Pasupudhara dam are suggested. Curtain grouting of single row to depths as per I.S specifications are recommended. Based on the seismicity of the area, the incorporation of horizontal seismic coefficient of 0.12 g in the designs of all structures is recommended to be provided. The paper also discusses the Rock Mechanics data of the foundation rocks, blasting techniques to be used in the excavation of foundations, selection quarries of construction materials and the reservoir competency. The project is in an advanced stage of construction and geotechnical problems of the construction stage are briefly discussed.

Paper No: 108

Preconstruction stage and construction stage geotechnical appraisal of Pulichintala dam, Andhra Pradesh

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A 42.34-metre-high and 1289-metre-long composite dam across the Krishna River to impound 1296 M.C.M of water to irrigate 4, 87,640 hectares is under construction. Slaty phyllites, phyllitic slates and intercalated quartzites belonging to Cumbum Slates would form the foundations. The general foliation of the formations is in a N500E-S500W with dips of the order of 200 to 350 towards S400E i.e. towards the right abutment. The results of the boreholes and permeability tests carried are studied and analysed. Based on the depth of overburden and the thickness weathering, the layout is modified with the Left earth dam extending up to C.444.00 m. The depths to foundation grade were worked out and depths of consolidation grouting and curtain grouting were suggested. As there was the possibility of encountering moderately fresh and hard phyllites suitable as foundations at higher levels in the Non-overflow and Power dam blocks, it was advised to study the progressive excavations and select the acceptable foundation levels. The

paper also discusses the geological setting and attendant geotechnical aspects of the spillway and right abutment. The competency of the reservoir and the seismicity are also discussed.

Paper No: 109

Construction stage geotechnical studies of Pulichintala left earth dam, Andhra Pradesh

Raju, K.C.C
GSI, Hyderabad

A composite dam of 42.34-metre-high and 1289-metre-long Pulichintala Dam is under construction across the Krishna River to store 1296 M.C.M of water to irrigate 4.8764 lakh hectares. This paper deals with the Left earth dam extending from Ch.0.00 m to Ch.444 m. Slaty phyllites, phyllitic slates and intercalated quartzites belonging to Cumbum Slates would form the foundations. The general foliation of the formations is in a N500E-S500W with dips of the order of 200 to 350 towards S400E i.e. towards the right abutment. The Project Authorities had proposed the left earth dam from Ch.0.00m to Ch.355 m. As the weathering was established to be deep, it was advised to extend the left earth dam up to Ch.444 m and it was accepted. Drilling and test grouting in the left earth dam reach established highly impervious nature of the phyllites indicating curtain grouting is not required at all. This paper deals with detailed studied carried out and the analysis of permeability tests and test grouting data which established very impervious and water-tight nature of phyllites forming the base of the earth dam and curtain is not warranted.

Paper No: 112

Preonstruction and construction stage geotechnical appraisal of right earth dam and of Gundlakamma reservoir project, Prakasam district, Andhra Pradesh.

Raju, K.C.C, K. Ravindranath
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Gundlakamma Reservoir Project now completed has a gross storage capacity of 92.27 m. cu. m with potential to irrigate 80,060 acres and providing drinking water to 2.56 lakh people of Ongole town and 43 other villages. Granite gneisses and charnockites form the country rock. The Right earth dam area is completely covered with silty clays and silty sands except for the initial reach of 100m forming slope of hillock and at Ch.4.00 km, where charnockite occurs. The reach from Ch.0.115 km to 1.00 km is almost aligned parallel to the river course running 200 to 300 m from the river. Due to the suspected old river course, one metre thick concrete diaphragm has been provided in the reach from Ch.0.115 km to Ch.1.200 km to a maximum depth of 20.25 m to end in one metre of bedrock. As the reach from Ch.1.200 km to Ch.3.385 km is covered with 9 to 12 m with maximum water column about 4 m, a 2-meter-deep cut-off trench is recommended to be

provided. In the river bed cut-off trench up to one metre to fairly fresh charnockite is provided. The paper also discusses the construction stage geotechnical aspects.

Paper No: 125

Foundation problems vis-à-vis geological set up – a few examples from Andhra Pradesh

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Safety of the structures depends on the strength of the foundation media for which geological set up provides basic base. No two sites will be identical in nature so also geological problems. Andhra Pradesh with three major river basins namely Godavari, Krishna and Pennerur, is occupied by geological formations extending from Archaean age to Quaternary. Irrigation in Andhra Pradesh dates back to 700 A.C and Srisailam, Nagarjuna Sagar, Sriramasagar, Priyadarshini Jurala and Telugu Ganga are the major projects constructed in recent past apart from number of medium irrigation and umpteen number of minor irrigation tanks. Linking of river basins is under progress through canal/tunnel arteries under Jalayagnam. This paper presents different foundation problems, which can be identified with specific lithological variant, Geomorphic or structural set up, in particular reference to Priyadarshini Jurala project, Telugu Ganga projects, Yogivemana project and S.R.B.C.

Paper No: 126

Solution features in Narji limestones of Cuddapah Super Group and their bearing on the geohydrological set up and competancy of water bodies

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Limestone especially cement grade, is in much in demand in recent years because of skyrocketing activity of construction of superstructures. However, when they form the foundations they are least preferred because of apprehension of solution features, cavities or karstification. Andhra Pradesh is rich in such limestone resources, especially Narji Limestones of Cuddapah super group and Koilkuntla limestone of Kurnool group. Some of the variants of these limestones have developed solution features, cavities depending on their physical and chemical nature and geochemical environment. The geometry and magnitude of such features and their influence on geohydrological set up or competency of reservoirs/tanks like Bangampally tank and owk reservoir constructed over them are discussed.

Paper No. 140

A Massive Chute Spillway, partly resting on terrace material - A case study.

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The chute spillway of Koldam HEPP was originally designed to rest completely on rock foundation. However, during excavation, it was found that a paleo channel was passing through the spillway area, which was missed during the preconstruction investigation and as a result, the rock level was present at lower levels in a stretch of about 150 meter of the spillway chute. The Project Consultant suggested a conservative solution of removing the entire terrace material and replacing it with concrete, which would have resulted in considerable cost overrun as well as time overrun of about at least one working season. After detailed analysis, the owner NTPC found that the terrace material also is having adequate strength to withstand the forces expected from the spillway operation and hence overruled the advice of Consultant and founded the spillway chute partly on the terrace material, with some confidence building measures such as confinement with curtain grouting and consolidation by area grouting.

Paper No. 141

Morphometric analysis for the neotectonic evaluation of the Pein River Basin, Lower Subansiri district, Arunachal Pradesh

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The Pein River, in the Lesser Himalaya of Arunanchal Pradesh, is a six order stream indicating strong tectonic control. The morphometric analysis of the Pein River basin has been carried out using IRS I-D, LISS III, PAN images and topographical maps of the area. Lineament analysis indicates the two prominent directions *viz.* NE-SW and NNW-SSE. Slope and relief aspects of the area have been studied by Digital Elevation Models using ARC VIEW 3.2 and ERDAS 8.5. The morphometric analyses of the basin points out that the basin drainage configuration is conspicuously controlled by tectonic grain. The study indicates that elongated shape of the basin, high bifurcation ratio, parallel drainage and high drainage texture are the result of geomorphic adjustment of river channels against ongoing tectonic activity along the thrusts and faults of the Himalaya. The drainage also shows straight stream segments, right angle offsetting, triangular facets and asymmetrical terraces indicating evidences of neotectonic activities. It is postulated that the activity in the region is related to its close proximity with the NE Himalayan Syntaxial bend.

Paper No. 144

Geological and geotechnical setup of dam projects, African Rift Valley, Ethiopia.

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The project areas forming a part of Ethiopia lies geologically between the African and Arabian plates, morphologically formed by the East African system. The area is marked by physio-graphic units, the Ethiopian plateau, Ogaden Plateau, and Rift Valley widening to the north into Afar Triangle material of sea floor spreading as a result of constant separation of Arabia and Africa plates during Tertiary times & Uplifted sea floors. The Awash river forma an important river system in the Central part of Ethiopia . and has a long course after originating from the Highlands of Addis Ababa, the capital city of Ethiopia. The river flow has been utilized for development of irrigation systems and hydropower development. by a number of agencies Foreign and Indian from a long time. The authors were associated with two major schemes in the Awash valley namely Tendaho and Kesem projects which are actively under construction. Tendaho area exposes Volcanics (Paleocene-Miocene), younger silica rich volcanics (Miocene-Pleistocene) and Afar group volcanics (Pliocene- Holocene) of rocks are also well exposed. Tendaho dam site acroos R.Awash is located within area known as the "Tendaho Graben" which forms the center of Afar Triangle. The dam envisaged is a composite on 55m high to facilitate sugarcane cultivation over an area of 60, 000 hectares. The Kesem Dam & Irrigation Project envisages construction of a 90m high dam across River Kesem a tributary to Awash river. The dam under construction is a central earth core rock fill dam. The scope of the project is to facilitate cultivation of sugarcane crop over an area of 20,000 hectares. The geological setups of these projects along with the tectonics and geotechnical problems at the dam sites are highlighted in the paper.

Theme-3: Underground and Deep Excavations

Paper No: 1

Failure of pressure tunnel constructed in soft media – a case study focused on possible cause

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Failure of a low pressure tunnel constructed though highly weathered granite gneiss at Umium – Umtru Stage IV Hydroelectric Project (U.U. IV HEP) in Meghalaya despite provided with adequate support has puzzled the engineers and geologists associated with the project. In the paper the author who carried out the investigation of the tunnel failure discusses, the possible causes of failure and remedial measures.

Paper No: 4

Geo technical Assessment of Diversion Tunnels of Lower Subansiri Hydel Project, Assam.

Choudhury, Dr. A.K Biswajit Das
GSI

Five tunnels each of 9.5 m diameter and 600 m average length have been constructed through the left abutment of proposed 132 m high concrete dam across Subansiri river for the purpose of diverting water during construction. In view of the close proximity of tunnels to each other, road headers have been used for excavation, instead of conventional drilling and blasting. Shotcreting and rock bolting have been executed as tunnel support. Tunneling has been done from inlet side towards exit end.Medium to coarse grained Middle Siwalik Sandstone, dipping steeply towards downstream, constitutes the tunneling media, traversed by four sets of joints. The intersection of these joints has caused roof failure in the form of wedge at the kink portions of each tunnel. The overall tunneling condition was "Fair to Good "having RMR values 50 to 70 and Q values 5.5 to 37.5. Close assessment of geo technical condition led to the successful completion of the tunnel in stipulated time frame and diversion of water in December,2007. The present paper presents detail geo technical parameters of these tunnels and the associated construction problems, including inlet and outlet portals.

Paper No: 5

Tunneling in Soft Rock

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The 2000MW Subansiri Lower HE Project is under construction at the border of Assam and Arunachal Pradesh on Subansiri River, a major tributary of Brahmaputra River. For construction of dam the river has been diverted by constructing five diversion tunnels of 9.5m diameter. The rock type in the project area comprised of weak sandstone of Middle Siwalik. The project is located in fragile Outer Himalaya and bounded in the north by Main Boundary

Fault and to the south lies Main Frontal Fault. The rock has UCS value of 15 to 20 Mpa in dry condition and its values drop to 4 - 7 Mpa in saturated condition. The diversion tunnels have been negotiated through soft rock. Because of soft nature of rock, non blasting method of excavation by using roads header and twin cutter mounted on excavator bases are used. The cutting rates of the twin cutter and road header are significantly lower than the predicted rates by manufacturers. Low cutting rate is mainly attributed to massive nature and devoid of fissility in rock. Presence of higher percentage of fine gained matrix in rock leads to generation of large quantity of dust as the cutter head grinds the rock. Use of water for dust suppression have detrimental effect as it lead to formation of slush and make it difficult to handle muck generated. For engineering classification of rock mass in the tunnel both RMR and Q – system have been adopted. Both the system gives significantly higher value for the rock. Further, massive and weak nature of rock limits the use of these systems for classification of rock mass. Though the tunnels have moderate (200m) superincumbent cover, spalling has been observed in the underground opening at number of places.

Paper No: 18

Accelerated approach in construction of hrt of Maneri Bhali H.E. Project (Stage II) using swellex rockbolts – A case study

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Tunnels and underground excavations are obligatory in any hydroelectric project, especially in the Himalayas. Apart from various geotechnical challenges, now a day’s, completion of the project within time frame is a big task. Therefore, the advancement and introduction of modern tunneling techniques have attracted the geoscientists for speedy and safer construction. Rockbolting is an important requirement in tunneling to provide immediate ground support to the surrounding rockmass. This paper highlights the importance of accelerated approach in the excavation of Head Race Tunnel (HRT) as in the case of Maneri Bhali H.E. Project (Stage – II), district Uttarkashi, Uttarakhand, India, where utilization of Swellex rockbolts instead of conventional rockbolts helped in reducing the cycle time considerably, thus enhancing HRT excavation. Swellex is a friction – type rock bolt, which adjusts itself in the irregularities of the hole and permits very small movements in rock without adverse effects. Installation of this rock bolt is very fast (2 min/rockbolt), simple and safe as compared to the conventional rockbolts. The comparative study of conventional Vs Swellex types of rock bolt has been discussed in detail in this paper.

Paper No: 20

Geological consideration on backslope failure in diversion tunnel inlet area of Parbati Hydroelectric Project, Stage-III: a case study.

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The Parbati HE Project Satge III is located in district Kullu, one km downstream of Sainj and Jiwa Nala confluence. The area is seismically active and falls within zone V of seismic zonation map of India. The paper explains the nature of failure taken place and procedure adopted for the treatment of the failure zone during the excavation of backslope of Diversion

Tunnel Inlet Portals of Parbati Hydroelectric Project, Stage-III. The diversion tunnel backslope excavation was carried out at 1:5 slope from El ± 1344 M to ±1326 M and 1:4 slope below El ±1326 M. The design supports consisting of 25 mm dia 5m long rock bolts with 100mm thick shotcrete and wiremesh were being provided regularly. Exposed rock was slightly to moderately weathered, fractured to blocky, strong to weak metavolcanics and thinly foliated chlorite schist. A slope failure started around El ±1333 M above the upstream side of the diversion tunnel -1 portal (point P1) on 22nd May 2006, around 1700 hrs. The study of the slide area indicated that the rock mass has failed due to a combined effect of a shear seam of 20-50cm thickness running along the foliation plane (060o/65o) mapped from El 1332m down to El 1320m and another clay-filled joint with attitude 310o/80o. The resultant failure took place as block (visually estimated as a dimension of 20m x 10m x 8m approximated to ±1600m3) along the failed shear plane. The portal face of DT-I is partially blocked due to the slided debris. The immediate stability measures undertaken was removal of muck from DT portal and erection of ribs with complete backfill before further advancement of tunnel face, providing additional longer rock anchors 32mm dia, 9m long rock anchors at 1.5m c/c on and above the failure portion, removal of the detached rock mass and providing of top catch water drain above the slope area. The Case study elaborates the failure of the backslope of Diversion Tunnel Inlets of Parbati HE Project, Stage-III and its geological consideration and subsequent treatment measures undertaken to prevent the damage to the inlet portals and slope treatment.

Paper No: 23

Prognostication of unconfirmity intersection at tunnel grade for 43.93km long tunnel by geoelectrical survey

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A 43.93Km long tunnel T1 with a finished diameter of 9.2m is being constructed by two tunnel boring machines (TBM) as part of the SLBC project(AMRP). During detailed mapping along the alignment in the preconstruction stage, the unconformity between the Archaean basement granites and quartzites of the Srisailam formation was identified for further investigation to prognosticate its intersection at tunnel grade of T1. Accordingly, Geoelectrical survey comprising of deep vertical electrical sounding (VES) of 250m depth was conducted at 200m interval for a length of 1km between Ch.28.1Km and Ch.29.1km along the alignment. The study showed that the dip of the unconformity is 2.4o which is close to the formation dip in the area and the unconformity is prognosticated to intersect at tunnel grade at Ch.21.358Km. In this scenario, the tunnel T1 will be driven 48.62 % of its length in quartzites from inlet end and the remaining reach of 51.38% in granites from exit end.

Paper No: 24

Geotechnical prognostication and assessment of tunnel grade for 7.121 km long tunnel of Srisailam left bank canal project (A MRP)

Ramakrishna,D., Anil A.Kamat
Jaiprakash Associates Ltd.

A 7.121 Km long tunnel is being constructed by the Drill –Blast-Muck method as part of the SLBC project (AMRP). During detailed investigation, Core drilling was carried out along the alignment of the tunnel at four locations to assess the tunnel grade of the rock mass. Laboratory tests were done on both Core samples and irregular lump samples after start of tunneling, to assess the geomechanical properties. The Core samples gave a maximum unconfined compressive strength of 159.94 Mpa and a minimum of 14 Mpa while the lump samples gave a maximum of 295.36 Mpa and a minimum of 247.19 Mpa. The study shows that the granites have medium to very high compressive strengths at tunnel grade with some samples showing low strength due to fracturing of the rock mass. Accordingly, the tunnel grade is prognosticated to be fair to very good class of rock mass with few reaches of poor rock mass class.

Paper No: 25

Leakage in Head Race Tunnel and Surge Shaft and its remedial measures-A case study of Ranganadi Hydro Electric Project

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All out efforts have been made in recent times to harness the hydro power potential of Arunachal Pradesh. However, scanty data available on engineering and geological problems faced during execution and post commissioning of Hydro Projects in the region characterized by geotechnically complex and poor ground conditions has become one of the major hindrances in planning and developing the proposed Projects. Problems and remedial measures of tunneling in sub-Himalayan regions of Arunachal Pradesh both during construction and post construction situation will be eye opener for present developer and planner of the Projects. Ranganadi HE Project is situated in Lower Subansiri District, Arunachal Pradesh. The Project has been developed with creation of a pondage by constructing a concrete gravity dam along Ranganadi River near Yazali and the pondage so created is diverted to Dikrong River through a tunnel.Thus, the project comprises of 67m high concrete gravity Dam having effective storage capacity of 5.70 Mcum, 10.27km long, 6.80m dia Tunnel and a surface power house with the installation of 3 units of 135 MW each operating under design head of 300m. The Project has been commissioned in 2001. The HRT passes through Precambrian Schist, Precambrian Gneiss, sand stone and carbonaceous shale with coal seams, volcanic and metabasics belonging to Gondowana Group, soft friable sandstone with bands of clay shale and streaks of coal belonging to Siwalik upper group. Main Boundary Fault (MBF) is the tectonic contact between Gondowana Group and Tertiary Sandstone. The Project faced a setback after commissioning due to leakage problem in Head Race Tunnel and Surge Shaft surrounded by weak fragmented rock with high permeability belonging to Siwalik upper group. During October/November, 2006, the leakage of water more than 2500 LPS from Adit-III was observed and considering the extent and trend of the leakage, the Plant was shutdown and detailed remedial measures were undertaken. The remedial measures undertaken in 2006 with extensive drilling & cement grouting works in weak fragmented sandstone surrounding the Surge Shaft and part of Head Race Tunnel improved the permeability condition of the surrounding rock mass and thereby eliminated the problem of seepage. The problem of leakage and its rectification with necessary geological backdrop has been briefly discussed in the paper.

Paper No: 58

Geotechnical considerations for design and construction of highway tunnels through weak rocks of north Cachar hills, Assam.

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Construction of two highway tunnels one about 1050m long and the other about 250m in the Nagabasti hills between Jatinga and Maibang is envisaged on the existing single lane road between Lumding and Jatinga / Haflong. These highway tunnels form part of rehabilitation and upgrading the existing road in ruined condition to 4-lane highway in North Cachar hill district of Assam. The alignment of the tunnels passes through Tertiary Group of rocks comprising moisture sensitive and low dipping sandstone, siltstone, shales, carbonaceous shales, mudstone etc. The sedimentary sequence of rocks show wide variation in strength and deformability characteristics due to varying grades of weathering and being affected by major tectonic activity in the area like Haflong-Disang thrust. The paper presents estimates of the strength parameters of rock mass constituting tunnelling media. Based on the field and laboratory test data, rock mass classification parameters of the tunnelling media and the geotechnical oriented design and construction problem's are also outlined in the paper. The rock mass behaviour shows the need of providing appropriate support system and construction methodology for anticipated poor, very poor and exceptionally poor rock zones. Different types of support system including pipe roofing / umbrella arch, steel sets, self drilling rock bolts, plain and fibre reinforced shotcrete, grout injection depending upon the stand up time may be required. The design of support system may have to be separated into two principal components 1) provision of an initial support system keeping in view the anticipated stand-up time of the strata & 2) selection of secondary permanent support system to meet the design life of the project. During construction phase, systematic monitoring of the ground behaviour and its comparison with predictions is deemed necessary for checking the adequacy of the design.

Paper: 66

Tunneling through Reasi Thrust Zone, Katra – Reasi railway line section (J&K)

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KRCL,Reasi, J&K

The construction of Jammu – Udhampur – Srinagar – Baramulla rail link project has been taken up as a National Project with a total length of about 341 Kms. The break up of the proposed rail link is, from Jammu to Udhampur – 54 Kms, Udhampur to Katra – 30 Kms, Katra to Loale – 90 Kms, Loale to Qazigund – 47 Kms, and Qazigund to Baramulla – 120 Kms. The Jammu – Udhampur railway line section consisting of 21 tunnels and 5 major bridges has been completed and commissioned during the year 2006. The Udhampur railway line section consisting of 10 tunnels and 22 bridges is nearing completion. Katra – Qazigund railway line section consisting 65 tunnels and 70 bridges besides two special bridges is under construction partly by Konkan Railway Corporation Ltd. (Km 30 – Km 100) and partly by Ircon Ltd. (Km 100 – Km 167). The railway line between Katra and Reasi is mostly located either within thrust zone or near/along the thrust. The width of the Reasi thrust in the area varies from 300m to 450m. Reasi thrust has affected more Sirban dolomite as compared to Siwalik rocks which are soft. Thrust zone is made up of crushed dolomite with clay gouge. At places crushed and caught up Muree rocks are recovered. Crushed dolomite when charged

with water starts flowing and creates cavities. Tunneling through crushed dolomite/thrust zone is costly, time consuming and difficult. Frequent cavity formation has been taken place in both the tunnels. Besides formation of cavities, at places water seepage is so high that work remained suspended for more than a year. In view of the above problems, it is recommended that as far as possible tunneling should be kept away from thrust/fault zone area. The Problems encountered during the tunneling through this zone have been described in this paper.

Paper No: 68

Geotechnical problems and their tackle in the Gondwana section of the HRT, Ranganadi H.E. Project, lower Subansiri district,Arunachal Pradesh- A case study

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Ranganadi hydroelectric project is the first major hydropower scheme in the Himalayan terrain in Arunachal Pradesh. Its 10.2 km long Head Race Tunnel passes through the schist and gneisses of the Bomdila Group, the Bichom Group of the Gondwana and the sedimentary rocks of the Siwalik Group separated by two major thrusts.. It has encountered various problems during excavation, especially while passing through the Gondwana portion. Cavity formation, squeezing, profuse seepage are some of the adverse condition that were face apart from methane gas. This paper deals in some of such aspects.

Paper No: 70

Geotechnical appraisal of powerhouse cavern, KotliBhel HE Projects, Stage-II

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The excavation of an underground powerhouse cavern of size 338m long, 25m wide & 45.5m high is an arduous task particularly in Himalayan terrain where reaches are difficult, rugged topography with complex geology and covered with overburden. The Kotli Bhel H.E.Project, stage-II is proposed on left bank of river Ganga for installation of eight no of units having capacity of 66.25MW each to generate 530MW of power near village Kaudiyala on NH-58 in Tehri-Garhwal district. The present paper deals with various aspects of survey and investigation involved in geotechnical appraisal of powerhouse cavern for smooth opening in Himalayan terrain without time and cost overrun.

Paper No: 84

Luhri Hydro-electric Project -A case for Planning of Geo-technically viable and Cost - effective Hydro Power Projects in the Himalayas

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For Planning a hydro power project, it is very important to asses optimum and full utilization of the available potential in a river valley. Stage wise development and identification of sites for schemes should be dealt with a prudent approach. Integrated approach of hydrological,

geological and design parameters should be viewed in totality. Hasty and wrong decisions, if taken in the preliminary stage would not only force undesired layouts but would incur recurring power and financial losses. Geological constraints for want of availability of sound foundation for safe design of dam, incomplete comprehension of hydro-logical data and structural designs, restricting heights of dams- at times due to environmental constraints,or in an attempt to reduce the initial cost of major civil structure, such as a diversion, or a desilting structures or impractical approach for tunnels, etc. may pose problems of cost overruns or operations in the long run. Should these be given importance?!, Remains a basic question to be answered. A case study for evatuation of the layout of the Luhri H.E.Project, by way of five alternative layouts studied in Satluj basin,involving problems related to a burried channel at Kepu dam, presence of shallow rock cover of crossing a 29 km long HRT across Satluj at Nathan; two alternative proposals involving a 38 km long HRT crossing major thrust zones with a dam located at Neerth, has been discussed in the paper, to have a foresight in adopting the best possible option.A two stage development of the scheme with dam at Neerth -power house at Luhri (Stage-I) and a dam at Nathan having powerhouse at Morola (Stage-II) reducing the aggregate length of HRTs to only 25 km, also has been dicussed for a cost effective and geotechnically viable proposition.

Paper No: 87

Tunnelling through weak zones using dress methodology in Himalaya - A case study

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Tunnelling through major weak zones, especially charged with ground water, has always been a great problem particularly in the Himalayan geoenviorment. There are number of cases where tunnelling activity had to be suspended for several days or even months. For such conditions, DRESS (drainage, reinforcement, excavation and support solution) Methodology appears to be the appropriate solution. In India, this methodology was first adopted at a mega power project, the Nathpa-Jhakri Project, in western Himalaya to tunnel through a very thick sheared rock zone, Daj Shear, along the 27.4 km long 10.15m finished diameter head race tunnel (HRT). Tunnelling for a length of about 380m has been done using this method though the main shear zone was expected to be 120m thick excluding the fracturing effect to the surrounding rock mass and small sympathetic shears. The paper deals with the tunnelling conditions predicted and encountered. The excavation and support procedure adopted in negotiating the Daj shear has also been discussed in detail. This method of tunnel construction has also been used successfully to cross extremely poor and water charged tunnelling media along HRT of Tala Hydroelectric Project, Bhutan, and currently it is being used at Katra-Srinagar-Baramula Railway Project in Jammu and Kashmir.

Paper No: 92

A Sculpture in Rock to Convey Water

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Rajiv (Bheema) Lift Irrigation Project – Lift-2 envisages conveying water horizontally, while lifting it. The project is laid out in two stages. The first stage caters to a horizontal

conveyance of 2414m with a vertical lift of 38m. Water conveyed to the starting point of the above scheme is first led through a tunnel and into a surge pool. Four draft tubes emanate from the pool into the pump house acting as the intake point for the pumps. The delivery side of the pump consists of mains of 2800mm diameter. These mains are taken through granite rock at an angle of 45o and discharge into a cistern. Energy dissipation arrangements are provided inside the cistern. Water at low velocity is then led into the next stage through a gravity canal. The discharge of the system is 63.72 cumecs. Three pumps with a motor rating 12mw is to be installed for the lift. Stage-2 of the scheme caters to a less quantity as part of the water is laterally diverted. Discharge of this portion is only 32.38 cumecs. The initial conveyance is through a gravity canal which discharges into the surge pool directly. In this case also, four draft tubes lead water to the pumps. The delivery is through mains of diameter 2000mm, lifting water to 22m. Pumps with a motor rating of 4mw perform the conveyance.

Paper No: 93

Hydraulic modeling of Mahatma Gandhi (Kalvakurthy) Lift Irrigation Scheme Stage-2

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‘Models save millions’ is a meaningful saying. This has been proved right many a time. This refers to hydraulic modeling. The flow of water and its interaction with the containing boundaries is a highly complex phenomenon. The shape of a full scale structure once built cannot be altered. So, it is all the more important that trials are taken in a small model where the shape and size are subjects of experiments and varied without much difficulty.. But before experiments are conducted in the model, it has to be ensured that the model behaves similar to the full scale structure. The principle underlined in hydraulic modeling is to simulate the flow parameters involved in the actual scenario. Hydraulic modeling needs expertise and experience. Normally this is being done in specialized organizations. But in this instant case, a hydraulic model was constructed and run by Navayuga Engineering Company Ltd. The flow in a lift irrigation project is open to atmosphere at the intake, at the surge pool and at the discharge point. So, Froude law was taken as the basis of modeling. Based on the space available and operational convenience, a linear scalar ratio of 30 was used. Based on this ratio, time ratio worked out to be 5.477. Velocity ratio also came to 5.477. Ratio of discharges was 4929.5. Ratio of areas came to 900. With all these ratios, the velocity in the model tunnel came to 0.927m/s against a prototype velocity of 5.078m/s. The discharge through the model tunnel came to 22.984litre/s against the prototype discharge of 113.3 cumecs. The model was run for various operating parameters and the results were recorded.

Paper No: 96

Geotechnical evaluation of design parameters for use in the tunnel boring machines of left bank tunnel with the help of satelite imageries and travrses, Srisailam project, Mahabbobnagar district, Andhra Pradesh.

Raju, K.C.C
GSI, Hyderabad

The Government of Andhra Pradesh has taken up a bold decision to implement the Srisailam Left Bank Canal Scheme under which it is envisaged to irrigate 3.00 lakh acres in the

chronically draught affected areas of Nalgonda district and also provide drinking water to Nalgonda town and fluoride affected villages enroute by drawing 113.28 cumecs (4000 cusecs) of water from Srisailam Reservoir. This paper deals with the geotechnical evaluation with the help of Satellite Imageries and geological data studied from limited traverses and computing of the parameters required for the tunneling of this 45.164 km long and 9.2 m dia tunnel by the Tunnel Boring Machines available due to environmental restrictions imposed. This Tunnel is aligned in an almost N-S direction up to outlet portal from where water will be led into the proposed Dindi Balancing Reservoir. The geological studies have established that Kakletvagu quartzites of Srisailam Quartzites of Cuddapah Super group will be the tunneling media from entrance portal to Ch. 27.175 km. In the remaining stretch from Ch.27.175 to Ch. 45.164 km, granites belonging to the Archaeans will be tunneling media. The geotechnical evaluation of this tunnel with attendant problems is discussed based on the geology and Rock Mass Classification. The tunnel reaches of the tunnel are grouped under three classes – Class-I- Very Good, Class-II-Good and Class III- Fair and the problems likely to be encountered and support system required has been worked out and provided. Based on the rock properties worked out from the laboratory testing of the rock samples of both quartzites and granites, the cutters of required strength for the TBMs have been designed. The tunneling media is however grouped into two classes for ease of construction and the prefabricated and pre-stressed concrete lining segments are thus designed.

Paper No: 99

Preconstruction stage geotechnical appraisal of the tunnel no.II of the Srisailam left bank canal scheme, Nalgonde-Mahaboobnagar districts, Andhra Pradesh.

Raju, K.C.C
GSI, Hyderabad

The tunnel No.II of Srisailam Left Bank Canal Scheme of 9.00 m dia and 7.25 km length will have its inlet portal in the fore-shore of proposed Dindi Reservoir. The geotechnical studies have been carried out using the satellite Imageries and limited traverses due inaccessibility and time constraint. These studies have shown that pink coloured and coarse to porphyritic granite would be the tunneling media expect for dolerite dykes of 25 to 75 m width aggregating to a length of 175 m and on quartz reef of 75 m width. The granite appears to be massive with a few sheared and fracture zones. The granite which forms the tunneling media is expected to be very good with dry conditions. Therefore, it is grouped and placed under Class II -Good to Class-I- Very Good. These stretches grouped under Class I and II may not need any support system. However, provision may be made for rock bolting of 5 % of the tunnel length if zones of intense fracturing are encountered during the construction phase of tunneling. The geomorphological and hydro-geological studies also indicate that the tunneling will be in dry condition for a major part of the tunnel. Wet and dripping conditions would be encountered in a very few stretches. Moist to dripping conditions are expected in the fracture zones and these stretches are relegated to Class III of RMR, which may need immediate support, rock bolting and shotcreting.

Paper No: 103

Preconstruction stage geotechnical evaluation of Veligonda tunnel, Kurnool and Prakasham districts, Andhra Pradesh

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GSI, Hyderabad

The Stage-I of the Veligonda Project envisages drawl of about 10.70 T.M.C. of water from Srisailam reservoir through 18.80 km long and a 7 m diameter tunnel to provide irrigation facilities to 4.38 lakh acres (I.D.Crops) and to provide drinking water to about 15 lakh people in the districts of Prakasam, Nellore and Cuddapah districts spreading over 29 mandals. The Veligonda Tunnel is located entirely in the Rajiv Gandhi Wild Life Sanctuary and therefore not accessible for any detailed geotechnical investigations. Geological mapping of the area by conventional method has also not been possible. Latest Satellite imageries of the area have therefore been interpreted using all the geological information available from Published and unpublished geological reports and maps with limited geological traverses and ground checks. The geotechnical studies have indicated that the Cumbum quartzite, shales and phyllites will be the tunneling media mostly except in the inlet portal and short stretches, where Kollamu Vagu shales and quartzites are expected. The formations are folded and faulted. These formations, however strike in N 600 W-S 600 E direction with dips of the order of 350 towards S300W. There are two sets of major joints with one random joint. The tunneling is almost at right angles to the strike of the formations is considered to be very good. The dip of 350 towards inlet portal i.e. towards S300W is also considered favourable especially so with wide spaced joints. A number of faults are likely to be encountered in tunneling. The chainages where they are likely to be encountered and their widths and effect on tunneling are dealt with. The rock mechanics properties and the RMR classification are discussed. These studies indicate that the tunneling will be good to satisfactory with standup time 0f one year for a span of 10 m.

Paper No: 110

Implementation of a Long Tunnel without any Mishap- Case Of Bansagar Tunnel, Madhya Pradesh.

Srivastava Mridul, Yogendra Deva
GSI, Lucknow

A 5.0 m dia and 2.045km long horse shoe shaped, lined tunnel has been constructed at the end of 68.860km long bansagar Feeder Channel across flat topped Kaimur Range in Sidhi District M.P. The scheme envisages diversion of 46.46-cumec water from Bansagar Reservoir to Adh Nala, a natural carrier to Mirzapur for further distribution of water for irrigation in Allahabad District through Meja Reservoir. The tunnel has been excavated in rocks of Kaimur Group of Vindhyan Supergroup. Jointed sandstones dominate the tunnel alignment. Shale and thinly interbedded sandstone and shale are limited to some sections. The strata dip N320°-355°/04°-07° i.e. along the tunnel alignment. The rock is traversed by three joint sets plus random. Few thin shears and fault zones not exceeding 50cm thickness have been intersected. The Q-Value for the rockmass ranges between 0.8 and 73.88. The design support includes 25ϕ 1.75m rock bolts centre to centre, staggered both ways above spring level with 50mm thick shotcrete. The geological investigations indicated problems of crown collapse due to the major basal set of bedding joints. This has been contained by way of systematic rock bolting in crown region, immediately after excavation, irrespective of rockmass class. The measure proved effective and the entire tunnel has been excavated without any mishap. This long tunnel may even be considered to be one of the rarest major underground structures completed without any problem. The paper provides details of

geological investigations, excavation, support etc. and highlights the preventive measures for containing tunnel instability in crown region due to basal joints.

Paper No: 111

Geotechnical appraisal of lft-ii stage i &ii ofrajiv lift irrigation scheme, mahabbobnagar district, Andhra Pradesh

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GSI, Hyderabad

The Stage I & II of Rajiv Lift Irrigation Scheme nearing completion envisages the diversion of Krishna water by lifting to the balancing reservoir to irrigate 2.03 lakh acres of land and supplying drinking water to 250 villages of draught prone areas in Mahaboobnagar District. The major components of Stage I are (i) Tunnel of 1.655 km of 5 m dia, Surge pool, Pump house, Cistern and Gravity canal. The Stage II consists of Approach Channel, Surge pool, Draft tube tunnels, Pump house and Cistern. Study of Satellite Imageries and detailed geological mapping has revealed that granites and migmatites of Peninsular gneissic complex are the country rocks with sporadic outcrops, but generally covered with thin sandy soils. Geophysical explorations followed by details explorations of drilling of bores have helped to select the best possible layout of the project. For selecting the Surge Pool and Pump house innovative method of determining the depth to fresh rock, by fast drilling DTH boring machines adopted successfully. Forecast geology of the tunnel media, tunneling conditions with the computation of Rock Mass Classification and seismicity of the area are discussed in the paper. Detailed geological mapping of the excavated tunnel and recommendation tunnel lining are also dealt with.

Paper No: 114

Art of Producing 3-D Geological Logs While Driving Highly Mechanised Tunnels

Yogendra Deva, Harsh Gupta
GSI

Till recently, the 3-D Geological Logs of tunnels remained the most important geological record for river valley development projects. Besides being the basis for designing permanent support systems, these logs served as permanent records for the upkeep of tunnels. The changing scenario of project implementation and use of state-of-the-art technology, however, are leading to serious deviations from this age old practice of data collection. For example, use of double shield TBMs, such as at Parbati HE Project in Himachal Pradesh and at Srisailam Left Bank Canal in Andhra Pradesh, hinders geological data collection during tunnelling and, consequently, prevents preparation of 3-D geological logs. Accelerated tunnelling using NATM, such as in Delhi Metro and the Banihal Railway Tunnel, on the other hand, is an example where time for geological data collection is limited and subsurface geological maps are produced as records. However, considering that the 3-D geological log is the only graphical form of data presentation that provides geological and other details for the entire surface of the tunnel, it is irreplaceable as a record and it would be prudent to keep it for future reference. The reproduction of a 3-D geological log involves extraction of information on planar attitude of discontinuities from face logs, subsurface maps, slit window logs, etc, and plotting of special features that fall outside the reaches covered by such records.

The discontinuity reproduction, that normally involves mathematical computations of dip and tunnel dimension/shape, may also be possible through simple projections. The paper discusses the theory of 3-D geological log and provides easy methodologies of its projection from regular face logs and subsurface maps of a tunnel, or, from the limited geological data collected from the slit windows adjacent to grippers in double shield TBMs.

Paper No: 134

Planning and phasing of Detailed Geotechnical Investigations for underground structures

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Geo-technical Investigations plays a dominant role in deciding design parameters, construction methodology including cost assessment for underground structures such as tunnels, power house cavern during preparation of Detailed Project Report (DPR). As every project has got unique engineering components, a detailed understanding of Geological and Geomorphological features including stress field conditions of the area surrounding the proposed project site are of utmost importance rather than adopting a cook book approach. It is experienced in past that geological surprises encountered during construction, causes delays and disputes during and after construction. A well-planned explorations if undertaken at investigation and design stage is always helpful in evaluating feasibility, safety, design and economics of the project in more systematic and reliable manner. In the engineering project areas located in complex geological set up like Himalayas the cost and feasibility parameters are being dominated by Geological factors. To overcome this challenge a comprehensive knowledge of regional geology including structural geology of the area and its inter-relationship with cavern axis must be known. There must be adequate Geological / Geo-technical information including "Stress Field Conditions" to support the preparation of the "Geo-technical Design Summary Report (GDSR) forming the part of Contract Document. In order to fore cast anticipated geological problems a detailed sub-surface exploration programme including drilling of boreholes and Geo-physical survey is to be worked out on the basis of detailed Geological walk over survey and maps prepared with help of satellite imageries. On the basis of the results obtained from surface / sub-surface explorations, the Rock Mass Quality (RMQ) is determined. Based on this a suitable geological model is prepared depicting distribution of reach wise Rock Mass Quality (RMQ) of anticipated rock types, ground water conditions and proposed method of excavations including ground support system. The final Geo-technical report that supports the Contract document has received considerable attention in recent past because of its legal significance to construction contract document. This is due to the fact the sudden occurrence of fault / shear zones requiring complete change in excavation method, support system, results in delay in project schedule and cost escalation, leading to a legal complications on later date.

Paper No: 137

Surface subsidence prediction in Barapukuria coal mine, Dinajpur, Bangladesh

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As a part of the evaluation of long wall caving mechanism of the 1101 coal face of the Barapukuria coal mine (BCMC), Barapukuria, Parbatipur, Dinajpur district, Bangladesh. Analysis of horizontal strain and subsidence that would be expected at the ground surface over long wall coal face was performed. To extract coal from Barapukuria Coal Mining Company (BCMC) using the method of Inclined Slicing Roof Caving Long Wall Mining along the Strike, and the sequence of slices mining from top to bottom order. Mining of 1101 coal face initiates caving from the lowest strata in the immediate roof and propagates upward into the Gondwana Formation and up to the base of lower Dupi Tila and finally reaches up to the surface. NBC (England, 1975) method, it is estimated that at around 0.75 m ground subsidence may occur for the mining of 1st slice, and successively for the mining of 5th slice the ground subsidence may 2.25 m occur, of which is relatively difficult to control the ground response and a violent interaction effects may anticipated. Filling process can not eliminate subsidence but reduce it if the operation is carried out to a higher standard and to allow an increase in the percentage of recovery of the coal over the caving mining methods. Again, such a high risk mining methods must be avoided because its failure would seriously jeopardize any future mining prospects in the country. Incorporation of this research work to the mine authority will facilitate guideline and provide an integrated tool for future long wall planning and design of the mine.

Theme-4: Construction Materials

Paper No: 15

Prospecting of concrete aggregates for river valley projects-some specific problems and case studies

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A thorough and systematic investigation of construction materials is essential to optimize techno-economic aspects of any major project. The effect on durability and economical feasibility are two major considerations during investigation for finalizing the source of materials. The suitability of an aggregate deposit from all aspects should be assessed by considering geological and other factors during prospecting. Most factors pertaining to suitability of aggregate deposits are related to the geological history of the region. A detailed study including geological origin, size, shape and location of the deposit, thickness and character of overburden, type and condition of rocks, grading, rounding and degree of uniformity of aggregate particles etc. are required to be under taken at the time of prospecting the aggregate. Further studies in laboratory are conducted to assess the suitability of aggregate source for use in concrete. Petrographic and chemical tests are also required for assessing the reactivity and durability of aggregate in concrete. A systematic approach to include all these studies and to study various parameters for arriving at a judgment regarding suitability with remedial measures etc., if any, is discussed in the paper. Typical case studies of a few important construction materials investigation projects have been brought out to illustrate problems encountered and the remedial measures suggested for effective utilization of available aggregates. Certain chemical constituents of rocks which may cause possible durability problems had been encountered in a few cases and the same have been discussed in the paper.

Paper No: 55

Construction material resources and planned investigations - A review

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Aggregate Construction material is very important and useful requirement in the building of major multipurpose dams Hydel & Thermal Projects , Bridges ,Communication tunnels and etc. and all civil structures . It therefore needs systematic studies for location of suitable quarries sites. The paper deals with the lack of investigation for construction material during investigation and preconstruction stage resulting in relocation of the quarries. Studies have revealed that in Major River Valley projects , the cost of construction material has escalated by 1 to 2.5%. Some major projects located in the states of Madhya Pradesh & Maharashtra have been delayed as well as escalated the cost of construction . It is therefore suggested that the planned and systematic studies of the quarry sites where suitable construction materials are available . The cost of the projects due to relocation of new quarries for construction material viz. Bansagar , Tawa Hydel Project , Bargi Project , M.P and Ghosikhurd , Chandrapur - Thermal Station (Maharashtra) has increased. The engineering parameters Rock/Soil characteristics should be determined. The estimation of the quantities of quarry material for use as construction material identified. It is

suggested that Engineering Geology Division G.S.I NHAI , state PWD (B & R) , WRD (Irrigation) . Engineering colleges may prepare suitable quarry maps and published for the users Agencies. This aspect has been stressed in the paper.

Paper No: 104

Major problem at micro level: Alkali-aggregate reaction - its effect on Srisailam Dam, Andhra Pradesh, India.

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A possible chemical reaction takes place between alkali content in the Portland cement and part of reactive silica present in aggregate, popularly known as alkali-silica reaction, gained its importance because serious damages occurred to many concrete structures were attributed to this phenomenon. An expanding silica gel is resultant product of the reaction, causes increase in volume and thereby development of high stresses in concrete which ultimately result as cracks in concrete. Reaction takes place in no definite period and time, contributing factors are ascribed to many parameters like mineral content, strained quartz, amorphous silica and sulphates present in aggregate, ph condition of soaking water, temperature etc. The problem is discussed with particular reference to the 25 year old Srisailam Dam in Andhra Pradesh, India. The Petrographic study of aggregate and concrete samples collected from the Srisailam dam indicate the presence of requirements which can create potential alkali-aggregate reaction. But no deleterious effects, such as formation of reaction haloes are noticed in Petrographic study of concrete samples. It is attributed that the reaction is not commenced in the concrete despite the fact that the presence of deleterious materials and time period of about 25 years after construction of dam. However, as there is no time limit to initiate the reaction, it can happen at any time.

Theme-5: Communication Projects

Paper No: 3

Slope stability analysis of Narayanbagar landslide on Karnaprayag - Gwaldam road, Uttarakhand Himalaya

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Landslides are one of the major natural disasters in the fragile Himalayan ecosystem and pose serious threats to both life and properties. The present study deals with the Narayanbagar landslide on the left bank of Pinder river, along Karnaprayag - Gwaldam road in Chamoli district of Uttarakhand state. This landslide is located in the middle of Narayanbagar town, along the road stretch. This slide poses problems related to traffic disruption every year especially during rainy season. The hill slopes within the landslide have an average angle of 420 towards west i.e. towards valley. Since a part of the overlying debris material was removed during sliding, the rock exposures are visible at many places on the flanks as well as on the upper levels above crown. The debris are mainly seen in the central portion of the slide. In view of thin debris cover (≈ 3m) above the rocks, the slope may be dominantly affected by Planar debris slide (Talus slide) affecting the overburden with movement occurring at the in-situ rock and debris contact. The geological map of the slide was prepared on 1:1000 scale with a cross section passing through the middle portion of landslide. Detailed Engineering Geological investigations incorporating relevant geotechnical parameters were carried out for this landslide. Samples were collected from the slide zone and direct shear tests were conducted in laboratory to estimate shear strength parameters. To assess the status of stability, the Factor of Safety (F) has been calculated along the section, by limiting equilibrium method under static condition using the method for Talus slide analysis (Anbalagan et al., 2007). The detailed investigations helped to know the status of stability of the slide and to arrive at suitable control measures for stabilizing the slope.

Paper No: 6

Highly damaging tiny landslides of Noth East India

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Fifteen percent of the Indian landmass is prone to landslide, out of which 1/5th are located in northeastern states of India. Many areas of Assam, Manipur, Meghalaya, Mizoram and Nagaland are prone to landslides. With the increasing occurrences of landslides in the inhabited areas during the recent past, it is becoming a problem of concern to the society. Moreover, it is known that, human interference in the form of developmental activities is one of the most important causal factors for landslides. In other words, landslides and development goes hand in hand. From societal point of view,

landslides can be classified into two groups viz. landslides that do not have an impact to the society and landslides that give an impact to the society. The second category can be further classified into two viz. large/major landslides and tiny/minor landslides based on dimension of the slide. Among the large/major landslides of recent past, mention can be made of Mao Songsong, Sajouba and Tadubi landslides of Manipur, Soapur and Umtang landslides of Meghalaya, Zubja landslide of Nagaland, Kalapahar and Dhirenpara landslides of Assam and Bilkhwathlir and Rengtekawn landslides of Mizoram. Every year northeast India is experiencing number of tiny/small landslides during monsoon. Among the very recent ones, mention can be made of Tura and Nongrimba landslides of Meghalaya, Tamenglong landslides of Manipur, Makokchung landslides of Nagaland, Noonmati, Kamakhya Ganesh Mandir, Fatasil Ambari Durgasarovar Jyotikachi landslides of Assam. Even in the year 2007, the authors attended more than 25 landslide incidences that claimed around 20 lives apart from damaging properties. In most of the cases, the large landslides of northeast India give indirect impact to the society in the form of blockade of roads and partly damaging the properties. However, the tiny landslides have direct impact to the society killing number of people and damaging properties. The large landslides do get attention from the public, govt., academic and scientific organisations, but it is not same in the case of tiny landslides. They remain unattended and neglected in spite of their highly damaging nature. The present paper deals with the comparative study on the impacts of large and tiny landslides. It also gives emphasis to understand the causes and mechanism of failure of the tiny landslides of this region. The paper concludes with the statement that construction of engineering structures as one likes and where he likes has to be regulated.

Paper No: 7

Geological Investigation of the landslide hazard prone hill slope in Mizoram

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Especially during the monsoon the landslide activity in Mizoram not only creates frequent disturbances to the moving vehicles by damaging the National Highway NH-54, but also causes huge loss of properties like damage of buildings, bridges, culverts, road, wide spread cultivated and non-cultivated slope surfaces adjacent to the highways etc. Since 1996 a portion of the National Highway at km. 209.00 has been facing continuous problem of sinking, creep and sliding. In the year 2003 about 150m stretch of the highway was severely damaged by landslide and sinking. It not only created problems to the moving vehicles but also enhanced risk and further instability of the hill slope in that area. Immediate investigation therefore became necessary to avoid further damage to cause a total stop of supply of essential materials to the Indian army settled in the border areas of India and Myanmar through this one and only connecting National Highway. Hence a detailed landslide investigation was carried out by a team of scientists of CRRI from both geological and geotechnical aspects so as to understand the exact causes and mechanism of slope failures. The major role of geological properties to create landslide hazard in this area has been highlighted in this present paper. For detailed geological and geotechnical investigations various samples and field data were also collected from different locations of the landslide affected area. Based on detailed analyses of both field and laboratory data, the best remedial measures suitable to the existing geo-environmental condition were recommended to restore hill slope stability and maintain a steady flow of vehicles on the National Highway.

Paper No: 8

Slope stability measures adopted in Kimi powerhouse - A case study of Kameng H. E. Project

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Kameng hydro electric project (600 MW) is under construction in Arunachal Pradesh, India. The proposed semi underground powerhouse is being constructed in Kimi. The power house area of Kameng HE Project is located on Gondwana Supergroup overlain by thick overburden of about 25 m comprising river terrace deposit followed by colluvium deposit. The Gondwana Supergroup comprises alternate sequence of gray sand stone, carbonaceous shale and carbonaceous siltstone with layers of coal partings. The rock mass is highly folded, jointed and crushed thus making the slopes unstable if not protected in a systematic way. The surface excavation of powerhouse is in progress. The slopes were protected by Shotcreting with wiremesh and anchoring. Even after protecting the slopes, it failed by toppling and subsidence. The previous slopes had to be regraded after slope failure at some stretches. The new slopes have been treated as per the insitu rock mass characteristics and are stable since then. For excavating further down the slope to the foundation level, some more protection measures have been proposed by the consultants and executed partly. This paper describes the protection measures applied before and after the slope failure along with a critical analysis of the geotechnical aspects.

Paper No: 14

Causes of instability of slopes formed of Plioquartar sediments presented on a landslide nearby Croatian capitol-Zagreb

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Area of Vukomericke gorice situated in the south peripheral region of the Croatian capitol Zagreb, from the geological aspects is formed of plioquartar sediments. These sediments consist of sands, moulds, clays and gravel and layers interchange between themselves, while in some parts, are characterized by limonite concretions. In clays, remains of coal and peat are also found. These materials occur in a form of thin layers. This litofacial differentiation implies to the conclusion that the coarse-grained sediments have been deposited within the boundary parts of the sedimentary basin, in form of banks on the shore or directly by the waterside, while finer particles are deposited deeper in the

sedimentary basin. Engieneering-geologial, hydrogeological and morphological factors, in combination with mechanical characteristics and permeability characteristics of soil layers, and structural-tectonic correlations represent the medium very submissive to the instability occurrences. Described region is characterized by a series of landslides and land creeping areas. In the article, authors will give a description of the geotechnical medium, methods of investigation works and applicable methods of improvement.

Paper: 16

Temporal Probability for Landslide Hazard along communication routes

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Communication routes such as railways or roads in hilly terrain are often prone to slope failure and in due course of time they often retrograde into landslides of larger dimension. Quantitative landslide hazard and risk assessment along such corridors requires detailed information on the temporal and spatial probability of slope failures. A study was carried out along a 19 km long section of road and railway routes, constructed through the slopes of the Nilgiri hills of Southern India, to quantify temporal probability of landslide hazard. Geologically, the routes sectors are constructed in Charnockite Group of rocks overlain by lateritic soil, with a thickness up to10 meters, as observed along cut section. A landslide inventory was prepared, along the rail and road corridor, from technical documents of the road and railway maintenance organizations for the period from 1987 to 2007. Out of a total of 783 landslides, the majorities (96%) are shallow debris slides associated with cut slopes. Their volume ranges from two to 3600 m3. Within this period, 94 individual landslide events were recognized of which 40 events resulted into 1 slide, 37 with 2 to 10 slides, 8 with 11 to 20 slides, 10 with 21 to 45 slides and 2 events with more than 50 slides. Out of the 94 events, 75% of them occurred during October to December and 25% during January to September. Based on the average rate of occurrences of landslide events, in the time period considered, the temporal probability using landslide frequency estimates through determination of exceedance probability of one or more landslide annually as well as in 3, 5, 15 and 30 years time were made. The probability indicates that during 1-year period, only seven kilometer length of the rail route (37%) have a 70% or larger probability of experiencing at least one damaging landslide event. These figures increase to 18 (94%) and 19 (100%) kilometer length for a 3 and 5 year period, respectively. During 15 years, 12 km route length or 63% of the total track will have a 100% probability of experiencing one or more landslide event. For the road sector, during the one year period, entire road section will have below 20% probability of getting one or more landslide event and during five years time, only seven kms of road will have 50 to 69% probability of experiencing at least one event. By 30 years time, almost 70% of the road will have 90% or more chance of getting landslide event that can cause one or more landslides. The statistics indicates that even by 30 years time, the 100% probability of experiencing one or more landslide event is minimal. Each landslide event, mentioned above, has a capability of causing one or more landslides.

Paper No: 17

Landslide hazard zonation & evaluation of Lunglei town, Mizoram - its utility in planning and development

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With the increasing need for sustainable development, particularly in unstable hilly areas like Lunglei, importance of Landslide Hazard Zonation map is to identify and delineate hazard prone areas. A landslide hazard zonation map divides the land surface into zones of varying degrees of stability, based on the significance of causative factors inducing instability. If such multi-purpose terrain evaluation maps are used in planning of the development schemes, it will help to select geo-environmentally sound sites, which may pose minimum hazards of instability. Even if, the hazardous areas cannot be avoidable altogether, their recognition in the initial stages of planning can help to adopt suitable precautionary measures, thus mitigating possible loss to life and property. The landslide hazard zonation map of the area has been prepared based on the modified form of BIS, 1998 guideline. Ten geo-environmental parameters viz. slope morphometry, relative relief, landuse, landcover, lithology, structure, hydrogeological condition, rainfall, landslide incidence and slope erosion have been taken into consideration. Facet map as well as different thematic maps has been prepared and sub-categories of each geo-environmental parameter have been awarded rating values according to their influence on slope stability. The facet map has been superimposed over the different thematic maps and the total estimated hazard of each facet has been calculated by adding the rating values of different sub-categories of each geo-environmental parameter. LHZ map of the Lunglei town reveals that 10.84% of the area falls under very low hazard zone, 79.17% of the area falls under low hazard zone, 6.94% of the area falls under moderate hazard zone, 2.44% of the area falls under high hazard zone, and only 0.61 of the area falls under very high hazard zone. The very high hazard zone area and high hazard zone area should be avoided for any future developmental works as these areas are more prone to landslide. Moderate hazard zone area may be taken for developmental work with adequate slope stability measures. Whereas, very low hazard zone and low hazard zone areas are most suitable for undertaking developmental works. Need based detailed LHZ mapping may be carried out to evaluate the nature of instabilities.

Paper No: 21

Geological and Geotechnical Evaluation of cut slope of Diversion Channel of Nimoo Bazgo Hydroelectric Project

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The Nimoo Bazgo Hydroelectric project (45MW), a run of river scheme is located near village Alchi in the northern side of greater Himalaya (Ladakh Himalaya), in Leh district of Jammu and Kashmir on the river Indus. Geologically the project is located in the thick pile of monotonous, syntectonics sedimentaries, namely Sandstone and Shale, constituting the Indus flysch of Ladakh region belonging to Cretaceous age. The major components comprises of a 278m long Diversion Channel on the left bank, 57m height concrete gravity Dam, three independent intakes directly from the dam block and a surface Power House on right bank. As per the detailed project report, prepared during the investigation stage, a Diversion Channel was proposed on the left bank in moderately jointed bedrock of Sandstone and Shale. The discontinuities classified as per field occurrence were as 1) S1: 223/56 (Bedding), 2) S2: 105/62 (Joint), 3) S3: 025/56 (Joint), 4) S4: 350/58 (Joint). As per the anticipated structural stability of the cut slope for Diversion Channel, S1 joint strike sub parallel to the Diversion Channel alignment and is hill dipping, hence possibility of this set leading to structural instability is lesser. However the valley dipping joint S3 requires to be treated suitably to avoid unstable block on the left bank. Based on the detailed field mapping, during the construction stage it was found that rock mass is dissected by four sets of discontinuities as 1) S1: 260/55 (Bedding), 2) S2: 120/68 (Joint), 3) S3: 010/55 (Joint), 4) S4: 355/60 (Joint). The discontinuities have a significant role on the strength and deformability of rock mass. Joints parameters collected during the progressive excavation such as 1) Discontinuity length, 2) Aperture, 3) Roughness, 4) Infilling, 5) Spacing of discontinuity, 6) Weathering, plays an important role in the analysis of the cut slope. Several uncertainties exist in the analysis of the stability condition of a cut slope (Giami 1992). Basically slope stability analysis involves three steps (Pathak and Nilsen 2003) 1) Definition of the potential stability problem, 2) Quantification of the input parameters, 3) Calculation and interpretation of results. The present paper deals with the following aspects 1) Geological and Geotechnical evaluation of rock mass of the cut slope of the Diversion Channel, 2) Geotechnical aspects in extreme weather conditions with special emphasis on limitation of man and machines.

Paper No: 28

Occurrence of landslide and their impact on environments in parts of lesser Himalaya

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Every year during winter months in the show bound areas of the mighty Himalayan ranges, especially in northwestern states of India (J&K, HP and Uttaranchal), avalanches are one of the major natural calamities. They occur regularly with devastating effects in terms of human lives, properties, highways and other structures. Life gets paralysed due to extreme cold and snow conditions and communication network are thrown in disarray. Jammu-Srinagar National Highway-1A, the most important link between Kashmir valley and rest of the country, is severely affected by avalanche activity around Jawahar tunnel near Banihal where it crosses the mighty Pir-Panjal range. A large volume of the traffic

passes through this highway for carrying needs of Kashmir valley. This highway gets blocked between Naugam (180 km) due to frequent, recurring landslide and avalanches during winter months. Closure of this stretch is a major inconvenience to the traffic on this highway. The landslides occurrences have caused several accidents in the past and have taken a heavy toll of human lives and properties. Past records show that on this highway more than 100 fatalities have occurred in a span of 10 years. The north portal of the Jawahar tunnel gets blocked frequently (3 to 4 times in a winter) by avalanche debris from D-10 avalanche site. The Batote-Banihal sector along the NH 1A has become most vulnerable to landslides/slope failures during the past few years. Many slope failures occur every year, during or immediately after a short spell of heavy rains or prolonged drizzle, causing disruption of transport routes and damage to property and life. The slopes, having a thin soil cover and sparse ground vegetation, allow the rain water to flow quickly and cause severe soil erosion. About 40 landslides/slope failure sites have been recorded and mapped. The most problematic ones are Nashri, Pira, Fagla, Makerkote and Badwan. The number of vulnerable spots, which are in the course of their development, is much more. In spite of adopting the principles and practices of Mountain Risk Engineering (MRE) by the Beacon Organization and various other agencies in this sector, the landslide/slope failure problem has eluded a lasting solution. The whole area represents a badland topography with slopes ranging from generally very steep/vertical topography with slopes ranging from generally very steep/vertical (45o and in some cases reaching upto 85^{o}C) to steep (25^{o}-45^{o}). These slopes are highly dissected and incised by numerous channels in the form of rills and gullies. The spatial distribution of landslide/slope failure zones along the highway in this sector reveal that their frequency per km is highest (0.31) along the slope belt followed by 0.26 in the thrust belt and 0.25 in the valley belt. Among them the deep slope failures per km in the slope belt is highest (0.31) followed by 0.12 in the thrust belt and 0.05 in the valley belt. The surface slope failures are confined only to valley and thrust belts with an average of 0.15/km and 0.12/km respectively. Rockfall zones are also confined to these two belts with an average of 0.05/km and 0.02/km respectively. Some geomorphic processes like surface sliding, under cutting and back cutting become functional once a slide/slope failure initiates. These processes function either individually or collectively and accentuate the process of degradation beyond human control in all the segments of the highway.

Paper No: 32

Quaterneries- A ground reality in the proposed Lucknow metro track

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The thick pile of 630m Quaternary sediments widespread over a geographical area of 2528sq km in Lucknow district comprises Older and Newer Alluvium brought out by Pre Ganga and Central Ganga Drainage System since Middle Pleistocene. The Older Alluvium comprises polycyclic sequence of sand, silt and clay with frequent kankar concretions. Newer Alluvium is further divisible into (a) Gomati Terrace Alluvium comprising cyclic interstratified sequence of non oxidized grey, micaceous, sand, silt and clay, and (b) Gomati Channel Alluvium comprising grey micaceous point / channel bar/ lateral bar sand and over bank silt. The lithological and geomorphological units of these alluvial sediments have a great bearing on the civil engineering structures placed over it and proposed to be set-up as a part of the phased developmental work of Lucknow. The proposed Lucknow metro track comprising 4 corridors one each from Amausi to Kursi road, Bada Imambara to Sultanpur road, SGPGI to Charbagh via Rajajipuram and Hazaratgang to Faizabad road would involve a deep cutting in the Older and Newer Alluvial sediments which are characterized by different geomorphological setup. The alignment of these corridors would be passing through (i) Lucknow Older Alluvial Plain (110 to 123 m above msl) (ii) Gomati Older Flood Plain (105 to 110 m above msl) and (iii) Gomati Active Flood Plain (105 m above msl). The individual geomorphological units equipped with tals and palaeo channels in Older Alluvial Plain, abundant channels, meander cut off and oxbow lakes in Older Flood Plain and point bars, channel bars, and lateral bars in Active Flood Plain would follow their own dictums and may pose problems of bank collapse, squeezing ground and having water in rush from the surface water bodies identified in the Older Alluvium. The sub surface geology inferred from the drill records of CGWB, UP Irrigation, and UP Jal Nigam reveals that there is lot of facies variation in sandy, clayey and silty loams. The soil of Lucknow district has been found to contain ML (silty), CL (clayey), CL-ML (silty clay) and SM (silty sand). Out of these 4 types only silty clay is plastic and rest are non plastic types. The paper highlights the various aspects of geomechanical properties of the alluvial sediments and their impact on construction. The experience gained in the construction of Kolkata and Delhi tube railways suggest that the problems may be compounded while excavations on account of deep bed rock configurations, presence of Lucknow fault and possibility of its mobilization during any seismic activity in the vicinity of the area. The stability of sky scrapers and their safety on the land surface may be considered to minimize the cracking of wall plaster and changes likely to crop up in the ground water regime.

Paper No: 34

Ganga Expressway and Ecosystem

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The proposed Ganga Express having 1047 km access-controlled with eight line expressway from Ballia to Greater Noida(155 m wide)to fascilitate smooth traffic for carrying the agriculture products and improving the transport system of the State is no doubt a remarkable boost in trade and marketing of regional products, but ground reality of the track passing through the Gangetic Alluvium amalgamated with the tributary sediments enroute needs critical examination of its impact on the structures and their consequences on ecosystem after commissioning. The prized agriculture land all along the banks of Ganga is enriched with monocrop(Kheera, Tarbuj, Water lemon, Kakri and other vegetable products) which are the summer food for consumers to combat the scorching heat.These products if converted into multicrop may not only reduce the monocrop items but may inject the toxic elements in the multicrop and monocrop

produce released from vehicular emissions passing through the expressway.Lead is one among them which is carcinogenic.Moreover, new shops would emerge for the repairs of tyres and tubes and burning of unused old tyres below the road would fill the atmosphere with cadmium which is another toxic element.Needless to say that the food chain grown on the surrounding fields would aggravate the health hazards.Mushrooming of the hotels/dhabas/rainbaseras along the roadside may discharge untreated urban refuse/pollutants inthe river water regime thus endangering the aquatic life and health of the populace. It has been reported(Times of India 7th March 2008) that 3.40 lakh land would be saved from the flood furry by constructing embankments.River piracy is a boon in the development of agricultureland and floods besides engulfying the land also bring lot of nutrients for enriching the soil fertility. The lengthy embankments (1047km) along the river flanks would spoil the aesthetics and give a look of monotonous canal.The groundwater regime of the area may drastically change after creating an artificial barrier. Geologically, the expressway would be laid on Varanasi Older Alluvial Plain(VOAP) which is equipped with stringers of tals/ponds and palaeochannels (old river course).After the construction of the expressway tals and ponds may disappear thus reducing the recharge of groundwater and reactivate the palaeochannels during monsoon.It may develop waterlogging conditions in the area.The expressway route from Ballia to Greate Noida may need many culverts/bridges/causeways to negotiate the mighty rivers Kosi,Chhota Sarju, Gomati, Sai and many smaller rainfed nalas. The expressway would be falling in Zone-IVfrom Ballia to Ghazipur and thereafter through Zone-III upto Badayun and again in Zone-IV upto Greater Noida in the Seismic Zoning Map of India.The suitable safety factor may be incorporated in thr design of the expressway .It would not be without any significance to add here that tremor shocks were felt in thr area during the recent Bihar earthquake and Uttarkashi earthquake(1995).

Paper No: 38

Safety evaluations of Rajshahi City Protection Embankment at several locations, Rajshahi, Bangladesh

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Stability analyses using different slope stability methods including finite element method at 4 different locations along the Rajshahi City Protection Embankment (RCPE) revealed that the embankment is safe against sliding, but the presence of cracks, toe erosion and significant rise of water level at River Padma may cause failure. The factor of safety at Talaimari, Shashanghat, Dargahpara and police line areas ranges from 1.35 to 1.48 with river water below the danger level (<18.5m). Rise of river water exceeding the danger level and appearance of tension cracks at the top of embankment can reduce the factor of safety significantly at these locations. Again, the analyses considering softening phenomenon showed that the embankment could be failed if 40%-60% reduction of shear strength occurred. A method of Progressive failure analysis, PgFan, Finite element method developed by Wright (1999) and Morgenstern-Price method were used for these analyses. A number of cracks near the top of the embankment at Talaimari and

Shasanghat and several toe erosion cavities at Talaimari, Dargahpara and Police line areas were critically developed during 2002-2004 rainy seasons. This study suggests immediate repair works have to be done in the areas of Shasanghat, Dargahpara and specially Talamari parts of the RCPE.

Paper No: 39

Landslide hazard mapping of Chittagong City Area, Bangladesh

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Landslide is regarded as one of the most damaging hazards in Chittagong area of Bangladesh. In order to make safe mitigation programs and proper planning for the urban development, it is necessary to identify the landslide prone areas of this city. The landslide hazard zoning of the Chittagong urban area has been done using the weighting-rating system of landslide causing factors. The slope lithology, slope angle, height, slope cover and slope aspect were selected as landslide causing factors for the area. A data base was developed from different sources including geological map, topographical map, satellite image and field visit. The causing factors were assigned numerical attributes according to their contribution to landslide. The four zones of hazard were identified based on the collective effects of these attributes. These zones are termed as High hazard, Medium hazard, Low hazard and No hazard. About 39% of the total study area is found to be landslide prone. The high hazard zone is comprised of about 3% of the total area, medium hazard zone covers about 14% and about 22% of the total area is in the low hazard zone. This hazard zoning map shows that the some parts of Khulshi, Pahartali, Panchlaish and Bayazid Bostami area are categorized as high risk zone. Special attention relating to the landslide problems in Khulshi and Pahartali areas should be given since the urbanization in these areas is growing rapidly.

Paper No: 40

Preliminary analysis of intensity of landslide hazard in the country for the period between April 2007 and March 2008

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Different parts of our country are vulnerable to different natural hazards like earthquakes, floods, landslides, cyclones, tsunamis, floods, draughts, cloudbursts etc. Some of the areas are vulnerable to more than one hazard and can be affected by different hazards at a time. It is estimated that about 60% of landmass of the country is vulnerable to earthquakes of different magnitudes, about 8% of total area is prone to cyclone hazard, about 68% of the area is draught prone, 12% of area is susceptible to floods and 49 million hectares or 15% of total area of the country suffers due to occurrence of

landslides. In recent years a rising trend in both natural as well as man made disasters has been observed. This is due to existence of geo-dynamically active locales in the vicinity, unique climatic pattern, brisk urbanization and rapidly growing population encroaching geo-environmentally sensitive areas. All of these factors in various combinations lead to regular occurrence of different natural disasters related to floods, earthquakes, draught, cyclones and landslides in different parts of the country. The severity of natural disasters in the country is indicated by the estimate of the Ministry of Home Affairs which states that in the decade 1990-2000, an average of about 4344 people lost their lives and about 30 million people were affected by the disasters annually. The severity is apparent from the data which indicates that during 1994-1998 period approximately 120 million people were affected by the natural disasters and the consequent economic losses from same were estimated to be Rs. 2,86,780 million. These figures climbed to 560 million and Rs. 4,74,640 million during the period 1998 to 2003. It has also been observed that the extent to which population is affected by a calamity, besides its location in physical realm of vulnerability, also relates to prevailing socio-economic and psycho- social conditions and their consequent effect on human activities. Landslides, as processes within geo-systems pose a threat to those elements of the social system exposed or indirectly affected. Understanding the behavior of a geo-system requires the knowledge of history of the system as factors controlling the instability can change with time. Once an area is affected by landsliding, it might become source of hazard for a very long time (Crozier and Glade, 1999; Reimer, 1995). The risk arising from a specific hazard can be managed through the process of Disaster Management. This would require assessment of status of hazard and processes responsible for it. Landslide hazard is one of the most significant hazards that affect different parts of the country every year during the rainy season. It has been observed that 21 States and Union Territory of Pudducherry, located in hilly tracts of Himalayas, N.E. India, Nilgiris, Eastern Ghats, and Western Ghats, are affected by this hazard every year and suffer heavy losses in terms of life, infrastructure and property. The fact that this natural hazard affects different parts of the country severely is apparent from the data collected about the landslide incidences that occurred during the period April 2007 to March 2008. The development of data bases depicting the spatial and temporal distribution of hazardous events is considered an essential input for assessing the status of hazard and managing the risk arising from it. Keeping this in view, an attempt has been made in the paper to analyse the landslide activity that occurred around the country in one annual cycle, during the period from April 2007 to March 2008. Information on 436 landslide incidences has been assembled. The data was collected through various sources such as media reports, some state government agencies and some websites. However, it may stated here in clear terms that major contribution in collecting the information was made by various Regional Offices of Geological Survey of India, the Nodal Agency for Landslide Hazard Mitigation in the country. The data collected through above sources is incomplete due to gaps in data collection network and a standardised data transmission system. The data also does not follow any standard format though extensive attempts have been made for circulating it widely. However attempts have been made in the paper to analyse the data available to get some trends. The paper discusses the intensity of landslide hazard in different parts of the country, the density of casualties resulting due to landslides, sequence of occurrence of landslide activity in different parts of the country and also attempts the correlation of landslide activity with progression of monsoons. The distribution and trends helps in identifying gap areas of information inflow and it can also be inferred that the impact of the hazard is much more severe than indicated by the available data. It is felt that it is necessary to develop a systematic network involving various stakeholders so that the data is communicated to designated data storage center on real time basis in a standard format so that the situation of hazard is analysed and monitored regularly during critical period and disastrous situations are managed effectively. This would also help in reconstructing the history of hazard in different parts of the country. The efforts to establish a network to capture the information about the occurrence of landslide events in different parts of the country on real time basis, its limitations and suggestions to make it really effective have also been discussed.

Paper: 44

Land slide of 17th July 2004 and its causative factors at km 67, Roing-Hunli road, Lower Dibang valley district, Arunachal Pradesh

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Arunachal Pradesh with its varied lithology enacted upon by Main Frontal Thrust, Main Boundary Fault, Main Central Thrust and innumerable number of other localized faults, folds shears and sutures becomes more susceptible to complex structural disturbances at the two major plate junction. Falling in seismic zone V, the entire state is vulnerable to frequent earthquakes that have rendered the state prone to frequent rock/land slides and formation of undeterred sinking zones, throughout the state. The eastern part of Arunachal Pradesh comprising of Lower & Upper Dibang Valley, Lohit and Anjaw districts in particular have been facing immense slide/sinking zone problems. Roing-Hunli-Anini road is the only artery that connects the interior parts of Lower Dibang Valley district in Arunachal Pradesh is of strategic importance being the defence link to the borders of China very near to Anini. Thus landslides or road breach in these crucial links deserves/require special attention.

Paper No: 51

Evaluation of hazards along Calicut- Kasargod coast, Kerala – A Geoenvironmental approach.

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The Northern Kerala coast trending NNW-SSE, is most dynamic and youngest of the coastal areas. This densely populated coast exhibits a complex geomorphic set up consisting of narrow active beaches, beach ridges, mudflats, mud banks , swales, rocky promontories laterite ledges and wave cut benches. The coastal area consists of mainly gneisses followed by Warkala sediments comprising sand stone and clays flowed by

laterites. The Quaternary formations represented by of sands, black clays, silt occupy the narrow coastal tract. The foliation of gneisses trends NNW-SSE and NW-SE. The IRS 1D LISS III image reveals a set of fracture and lineaments of the rocks which extends to the younger sediments indicating neo-tectonic activity and reactivation of several basement faults. The analysis of imagery and the field data reveals that the coast is tectonically active and has a history of several earthquakes and tremors in the past. The area falls in the zone III of seismic zonation map of India. The other hazards are severe coastal erosion, salt water contamination of the fresh ground water aquifers, sand mining and quarrying, siltation of estuaries and destruction of natural mangroves. Based on the studies, suitable remedial measures are suggested for mitigation of various hazards.

Paper No: 52

2007- An year of landslides in Kerala

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In the year 2007, Kerala state witnessed the maximum number of rainwater triggered landslides. 53 such landslides have been studied and reports suggesting mitigative measures to be adopted were submitted to the respective revenue authorities of the state. As per the records of IMD, the State received 30% extra rain in the year 2007, during the Southwest monsoon alone. 8 out of 14 districts of Kerala have been reported with several types of landslide occurrences. The affected districts are; Kannur, Kozhikode, Wayanad, Palakkad, Malappuram, Thrissur, Idukki and Kottayam. 13 precious lives were lost, 10 were injured, 29 houses were either destroyed or damaged and 0.67 sq km area of agricultural and forest land were lost. Most of the victims of landslides in Kerala are from the underprivileged and low income group of society. Rapid urbanization has caused rising up of the land value so dearly, forcing the migration of groups of economically weaker sections towards high ranges and hilly terrains, for survival. This has totally changed the scenario of landuse and landcover in most parts of the state. The excessive anthropogenic activities in such areas have further aggravated the incidence of landslides. A multidisciplinary approach is warranted to ensure stability of high slopes by optimizing terrain response factors vis-à-vis anomalous climatic conditions.

Paper No: 53

Causes and mechanism of reactivation of Kallala 102/800 slump, Vazhikkadavu area, Nilambur taluk, Malappuram district, Kerala

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A rainwater triggered slump with sudden development of deep cracks and fissures parallel to the median line, causing extensive damages to an arterial highway was reported on the 4th September 2008 at Kallala point 102/800 on the Vazhikkadavu-

Gudalur road (SH-28). Traffic along the road was disrupted for days together causing inconvenience and hardship to the local populace. The slump site is located about 12 km east of Vazhikkadavu town, Vazhikkadavu village, Nilambur taluk, Malappuram district on the western slope of the Nadugani Betta (1042Δ above MSL) at the point defined by the latitude 110 25’53.5’’N and longitude 760 23’20.5’’E, represented in the SOI toposheet No.58A/7. Observations revealed that the slump occurred due to reactivation of a pre-existing slide whose scar is evident along the higher reaches of the slope. Widening of the gaps of the fissures day by day and progressive deterioration in the condition of the road were also evident. The mass movements across the fissures were measured and monitored. A detailed survey was conducted on 1: 1000 scale and the thickness of the overburden was estimated by geophysical methods. The rainfall data for the years 1997 to 2007, were analyzed. The study area is part of the southern Precambrian shield characterized by hornblende-biotite gneiss and gneissic charnockite with small lenticular and thin bands of garnetiferous pyroxene granulite and magnetite quartzite. Geomorphologically, the area is a linear NE-SW trending ridge strewn with loose boulders of various sizes in its shoulder covered by a thin layer of slope materials. The general trend of foliation in the rocks ranges from N500E - S500W, 600SE to N750E - S750W, 600SE and the joints are N200 W- S200E, 300NE; N650E- S650W, 580NE; N600 W- S600E, 200SW and N150W- S150E, 620NW. About 34,000 m2 area of evergreen forest land was adversely affected by the landslip/slump. As a result of the incessant heavy rain fall during the southwest monsoon, the slumped area got saturated with water and became water-logged, and the drain along the road side directed the water-flows towards the southern rupture plane. The breast and retaining walls present on either margin of the road also obstructed the free flow of ground water. The supporting pillar of the culvert, which was positioned right above the southern end of the rupture plane, also helped the water-flow to be directed towards the rupture plane. The heavy rainfall for a continuous period of two days increased the shear stress which triggered reactivation of a larger pre-existing slide/slump and ultimately there was movement along the whole slumped material. On the 28th September 2007, the area experienced a debris flow on the western side of the toe. The failure evidently got triggered at the head region and was retrograded very slowly. This was a rotational slide triggered by heavy rainfall and aggravated by excess pore water pressure. There are ground signatures to suggest that the slide/slump might get reactivated and cause more problems under similar condition of precipitation if suitable reinforcement measures are not initiated at the appropriate time.

Paper No: 60

Macro-scale Landslide Susceptibility Mapping in Kurseong –Mangpu area of Darjeeling Himalaya

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Macro scale (1:50,000) Landslide susceptibility map (LSM) of 315.76 Sq km in parts of Kurseong –Mangpu area of Darjeeling District was prepared by facet-wise integration

of six causative factors (lithology, structure, slope morphometry, relative relief, landuse & land cover and hydrogeology) using GIS techniques (ARC/INFO 9.1 software) following the guidelines of Bureau of Indian Standards (BIS). The prepared LSM shows spatial distribution of five zones of increasing landslide susceptibility. The thematic maps with landslide incidences, prepared through detailed field studies and augmentation of available database, indicate the spatial distribution of thematic parameters vis-à-vis landslide incidence of the area. Analysis of the LSM database reveals that about 38.51% of the studied area comes under high (HSZ) and very high susceptibility (VHSZ) zone. The moderately susceptibility zone (MSZ) covers 36.17% and low & very low susceptibility zones (LSZ&VLSZ) together constitute 25.32% of the study area. The prepared LSM when validated with the landslide incidence map of the area indicates a) no landslide incidence in VLSZ, b) a progressive increase in the relative abundance values of landslide for successive higher categories of susceptibility zones and c) a very high value (72.03) for HSZ & VHSZ together. It is recommended that a) VLSZ&LSZ areas, which covers about 25.32% of the total area can be taken up for large scale future developmental work, b) Identification of suitable areas for developmental work within MSZ by Meso scale (1:10,000 /1:5,000) LSM and c) HSZ&VHSZ areas should be avoided for any large-scale development. Identification of suitable sites, if essential, within HSZ&VHSZ, has to be done by meso scale (1:10,000 /1:5,000) and micro scale (<1:5,000) landslide susceptibility and risk mapping. Re-evaluation of the prepared macro scale susceptibility maps at regular intervals is recommended after major earthquake (> 5.0 on Richter scale), cloud-burst and large scale anthropogenic changes.

Paper No: 61

Landslides in Goa: An overview

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Goa known for its beaches and mountains has been affected by one of the natural disasters i.e. landslides. Physiographically Goa is divided from west to east as western ghat (700-1000m above msl), foot hills region of western ghat (300 to 700m above msl), undulatory terrain (10 to300m above msl) and coastal plains. The landslide affected areas in Goa are Anmod Ghat (NH 4A), NH-17, SH connecting Pernem –Morjim- Mapusa and Altino hill. Most of the landslides are shallow with <2m depth and are debris slides. The debris consisting of boulders, rock fragments and colluvial deposits. The geology of the area comprises of granite, gneisses and schist. The study reveals that the main triggering factors of slides are land use i.e. construction of road and human settlements. Factors like slope morphometry and relative relief are not significant triggering factors and no slide has occurred without any anthropogenic activity. Cutslope angle and height plays a mojor role in all the slides.The depth of overburden varies from 3-10m. The hill slopes vary from 25-30°. Height of the Cut slope was included as a factor found to be the major cause of the slides as the sliding events crown and toe are restricted between the cutslopes.The failed cut slope height is >2m with 75° to vertical slope. The convex slopes were found to be more prone /susceptible to sliding than the concave and irregular

slopes. The main causes of landslides in Goa state are toe cutting of hill slope for construction of road, modification for human settlement, highly weathered rock mass and frequent rain. The ubiquitous presence of water is favorable for intense weathering of rocks causing appreciable drop in their shearing resistance. The area receives an average rainfall of 100mm.The surface runoffs causes extremely rapid soil erosion. Heavy infiltration causes excess saturation of slope material which results in increased pore pressure and decreased shear strength. Dashing of sea water against the hills, cutting toe part of the slopes and loading of the slopes due to construction also triggers landslides. Besides, improper construction of houses at hill slopes without giving proper remedial measures at the toe also causes landslides in Goa. Several settlements in the area near Vasco are facing imminent danger from unstable slope and precariously hanging boulders. Identification of such slopes by carrying out detail survey and taking preventive measures are considered of priority requisite.

Paper No: 62

The causes and trigerring mechanism of Biligeri creep, Somwarpet taluk, Coorg district, Karnataka

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During the monsoon of 2005, the incessant rain for 11days in Somwarpet taluk, Coorg district caused the development of ground cracks all along the slope of hill trending ENE-WSW near Basavaneswar temple, Biligeri village for nearly 200m along the S10°W facing slope damaged two houses in the slope. Cracks on ground and in civil structures were noticed by the local people on 27th July 2005. Local residents heard loud subterranean sound on the mid night of 26th July. The information in the print media describing it as a fissure on the ground caused due to seismicity created panic and anxiety among the residents. The frequent slope failures during rainy season year after year have been a concern for the public and the administration. The load/pressure on the slopes of the Western Ghats has increased with time to sustain and accommodate the increase in density of population. The unscientific modification of the slopes (slopes being graded into small localized flatland) to bring more areas under plantation and creating more space for constructing new civil structures (for housing, processing plants for economic activity, roads for communication) without any consideration to the slope stability has increased the risk for the inhabitants and the property in these stretches. The creep is bounded by the coarse grained, light grey, foliated granite gneiss with gneissosity varying from N21°W to N10°E direction with dipping from 42° towards south to vertical. The gneisses are exposed all along the stream section in the left flank and central part of the toe region near the right flank. Fine to medium grained, dark green dolerite dyke are exposed in the head and the mid slope zone. Layers of unconsolidated rock fragments (gravel, cobble and boulder sized), sand, silt and clay covering bedrock, and formed by the in situ, or nearly in situ, weathered bedrock was observed near the NE corner of the area. Removal of slope support, modification of slope geometry, increased loading of the crest and slope and transient effects (due to the major road in the mid slope) are found to be the main causes of the creep. Heavy rainfall was the trigger for the creep for which may be operating either to increase the shear stress or to decrease the shearing resistance of the material for the slope to fail /slope to move.

Paper No: 63

The geotechnical evaluation of foundation rocks of pier/ abutments and unstable downstream slope of bridge no.69, Londa-Vasco railway line, south western railway, Karnataka.

Panduranga,R., R. Dharuman, A.K. Mishra
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The downstream slope of Bridge no-69 has been experiencing extensive bed erosion/scouring and formation of gullies due to excessive surface and sub surface water action. This resulted in deep cuts in the channel bed along with land slips at the proximity of right abutment as well as removal of shoulder support to Gabion in the central part. This phenomenon has caused serious concern to scouring of the slope beds in general and removal of lateral support to the foundation of pier/ abutments of the bridge no-69 in particular. As a part of Geotechnical investigation, sub surface geological conditions of the foundation rocks at Bridge site was explored by drilling and stability problems of downstream slope of Bridge no-69 has been geotechnically evaluated for providing effective slope reinforcement and stabilization measures. The investigation revealed that the bed rock at the bridge site is dominated by multilayered sequence of variegated phyllite, ferruginous phyllite with intercalation of ferruginous quartzite, ferruginous quartzite with intercalation of thin bands of phyllite and thickly bedded quartzite with intercalation of thin bands of phyllite. This litho unit trends NNW-SSE with 10o dip towards ENE, and intersected by two sets of sub vertical to vertical joints tending NW-SE and NE-SW direction. The geotechnical investigations clearly indicate the need for stabilizing the slope. In the absence of effective method of stabilization and poor maintenance of surface drainages the slope undergoes further deterioration particularly during monsoons. Recommendations comprise mainly easing/grading of slope, adequate drainage measures and construction of retaining structures to restraining the slope were suggested. In addition to the ensuing stability of slope in general the civil structures like gabion walls, geotextile and natural turfing of the slope to be provided to stabilize the unstable mass along the stream bed downstream of the existing bridge no. Feasibility of other alternative proposals like elimination of bridge pier, providing a new bridge of wider span and shifting of the track alignments which are suggested by SWR authorities were evaluated on the geotechnical conditions.

Paper No: 64

Geotechnical evaluvation of the unstable slopes of Cabohill, adjacent to Rajbhavan, Panaji, Goa

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GSI, Bangalore

Raj Bhavan, the official residence of His Excellency, the Governor of Goa, situated atop the Cabo hill promontory (El.40m) is over 400 years old. This NW-SE trending promontory is confined by Mandavi River in the North, and Zuari River in the South, both rivers flowing towards west and joining the Arabian Sea. The western and the north western slopes of this promontory adjacent to Raj Bhavan, facing the Arabian Sea have been experiencing continued distress since a few decades. Cracks have been developed on the pavements, floor of the verandah and also extending head ward retrogressively intercepting the corners of the back portion of the building of Raj Bhavan. The Geotechnical evaluation of instability of slopes of Cabo hill, adjacent to Raj Bhavan, Goa includes the detailed investigation conducted at this site which includes surface geotechnical studies, geophysical surveys, subsurface exploration by drilling, insitu testing of the sub soil, testing of soil/ rock samples in various laboratories for determination of their properties, and finally suggesting various long term and short term remedial measures to stabilize the slopes in general and safeguarding the structure of Raj Bhavan in particular. The cabo hill area comprises mostly the laterites and lateritic soil. The parent rock is not traceable due to deep weathering. Thickness of weathering is as high as 60m. The hard laterites (duricrusts) occupy the topmost part of Cabo hill and vary in thickness from 10 to 13.5 m. About 10 m wide medium grained dolerite dyke trending in NW-SE direction is exposed at the sea level. To ascertain the probable character of the slope failure, the position of the critical circle the detail sub surface exploration was conducted by drilling. During the course of drilling, insitu testing were conducted by SPT methods and undisturbed samples were collected from the bore holes at sub surface levels representing different soil units for determination of their grain size distribution, specific gravity, bulk density, natural moisture content, porosity, compressive strength, C and Ø values etc. The critical slip circle of the distressed slopes adjoining the Raj Bhavan has been constructed on the basis of the existing geotechnical conditions and the engineering properties of the subsoil. Total stress field, which includes the magnitude of shear strength within the sub soil units with respect to effective shear stresses were determined and contours of probable factor of safety for the distressed slope were drawn. The study shows the relative improvement in shear resistance (mechanical properties) of sub soil units with depth. Keeping in mind the position of the slip circle, slope morphometry and the type, nature and the properties of the slope forming material, number of remedial measures to stabilize the distressed slope and suggestions for monitoring the slopes are recommended.

Paper No: 65

Composite slide at km 67, Roing-Hunli road, lower Dibang valley district, Arunachal Pradesh

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Arunachal Pradesh with its varied lithology enacted upon by Main Frontal Thrust, Main Boundary Fault, Main Central Thrust and innumerous number of other localized faults, fold shears and suture becomes more susceptible to complex structural disturbances at the two major plate junction. Ascertained to seismic zone V, the entire state is vulnerable to frequent earthquake that has rendered the state prone to frequent rock/land slides and formation of undeterred sinking zones, throughout the state. The eastern part of Arunachal Pradesh comprising of Lower & Upper Dibang Valley, Lohit and Anjaw districts in particular have been facing immense slide/sinking zone problems. The area forms the mountainous part of the northeastern Arunachal Pradesh, between Mayudia and Hunli (Lower Dibang Valley district). Monsoonal rain starts from May and continue upto end of August and the highest precipitation of 1456mm was recorded in a span of 21 days in July 2004. The slope failure followed thereafter. Roing-Hunli-Anini road is the only artery that connects the interior parts of Arunachal Pradesh and is of strategic importance being the defense link to the borders of China very near to Anini. Thus landslides or road breach in these crucial links deserves special attention.

Paper No: 74

Landslide hazard and risk mapping procedures: case study from parts of Ravi catchment, Himachal Pradesh

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Landslide Hazard and Risk Mapping (LHRM) is multivariate and complex problem in mountainous environment. Landslide Hazard mapping has been significantly developed over past decades but framework for risk mapping are rarely available. The process of landslide risk estimation integrates the hazard levels with specific element or set of elements at risk. The paper evolves a procedure of a qualitative hazard and risk mapping in mountainous environment. Identification of potential hazard zones, nature of the hazard, projected velocity and run-out distance are the primary steps involved in the LHRM. The quantification of the hazard may be obtained by either numerical weightings or by calculation of posterior probability while the quantification of consequences associating with the degree of losses (life, property and infrastructure etc.), though difficult, can be evaluated in general terms. Three sets of elements of risks have been outlined for the purpose, viz, Risk to life (Grade-1), Social risk such as lifeline features (Grade-2) and Infrastructure like road, bridges etc. (Grade-3). For each grade a numerical adjustment rating (1 to zero) has been assigned. Thereafter, the elements or set of elements at risk have been assessed with reference to a particular surface area subject to land sliding. This varies depending upon land use and slope morphological characters of the terrain. The risk levels are determined by expressing hazard frequencies(Numerical ratings or probability values) multiplied with an assigned value of elements of risk in order to qualitatively classify the area with varying categories of risk levels such as Very High, High, Moderate, Low and Very Low, depending on the range of values. A case study of LHRM has been presented based on the evolved approach to classify the terrain into five risk levels due to the threat of landslides. The LHRM may be of immense use

for making quantitative or alternative decisions for the management of the landslide hazard and infrastructural planning for suitable growth.

Paper No: 75

Slope stability- problems and remedies in river valley projects of NW Himalayas, India. A review

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The paper deals with the slope instability problems and remedial measures adopted for stabilizing the hill slopes and cut slopes at various river valley projects of NW Himalayas. Geologically the area is represented by the formations ranging from Recent to Sub-Recent Quaternary sediments, soft and friable Siwalik sand-rock and clay-shale in the foothill zone to Central Crystalline Rocks of Archean age in the higher reaches. Due to repeated folding, faulting and thrusting the rock condition has considerably deteriorated, particularly near the tectonic contacts. The entire Himalayan belt is located in high seismic zone hence the area experiences frequent earthquakes of high magnitude. The author has reviewed the case histories of some of the river valley projects located in NW Himalayas. He has come to the conclusion that in most of the cases slope failures have been due to the presence of adversely oriented planes of discontinuities, loss of cohesion and angle of internal friction on saturation, removal of toe support and poor rock strength due to crushing near the tectonic contacts.

Paper No: 81

Geomorphological and lineament framework of Holi- Brahmaur area, Chamba district, Himachal Pradesh with special reference to Holi slide.

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Geomorphologically the Chamba catchment forms a part of the wide longitudinal valley that lies between Zanskar and Dhauladhar ranges in the north and south respectively. The valley trends NW-SE and is considered to be of tectonic origin. The stratigraphic sequence in the Chamba-Brahmaur syncline, a part of the Chamba nappe belongs to Precambrian-Upper Palaeozoic age and is thrust over the lesser Himalayan formations to the south along the Vaikrata thrust. The rock type exposed in the area belongs to Chamba and Morang formations of Vaikrata Group and Manjir,Katarigali formations of Palaeozoic age. The Vaikrata Group is intruded by Dallhouse Granitoids. The rocks are regionally folded into the south verging Chamba and Barhmaur syncline with a NW-SE trending axial trace. The general trend of rocks in the area is NW-SE with low to moderately dipping in NE direction besides vertical at places. The area has suffered poly-phase deformation. The Quaternary deposits in the area are represented by four level of terraces and two levels of fans. The terraces are both fluvial and fluvio- glacial in nature.

The Satellite data of IRSP6 LISS 3 GEOCODED FCC(Band432) were used for the preparation of geomorphological, lineament and landslide incidences map of the area on 1:50,000 scale. The interpretation of data covering Holi-Brahmaur area of Chamba district in Ravi Basin of HP were carried out with an objective to prepare thematic maps of lineament fabric, slope facet, lithological and structural elements, land use, land cover, drainage network, and landslide incidences, which are useful in demarcating various landslide potential zones., The area show three main trends of lineament i.e. NE-SW, NW-SE, and N-S. The NE-SW lineaments are most dominant and youngest and cut across all other lineaments and the strike of the major geological formation. The majority of the slides are restricted along these lineament. Landslide incidences and slope facets within the particular geological formation have been taken as an important parameter for evaluating landslide prone zones in the area. These variables were interpreted on probability analysis for demarcating slide in similar facets in a particular formation. Instability pattern is generally controlled by lithology and major structural elements, faults, axis of major folds, toe portion undercutting by the river or by man made activities etc. in the area.Land cover/ land use map of the area shows 53% area is barren, 5 % area is glaciated, 16% is sparsely vegetated areas, 9% area falls in the a moderately vegetated category, 8% area falls in the a thickly vegetated category, 9 % area constitutes in agricultural land or urbanized areas. Out of total 671 slope facets 664 (99.6%) fall in the high relief (>300meter) while only 7 (0.4%) slope facets fall in the moderate relief (300-100 meter) slope category. The Ravi river in the area flows along a major lineament trending in NW-SE direction from Banun to Dhog for nearly 30 km. The Holi slide,a major slide near Holi village, is the result of rock falls from the right bank of Ravi river and has blocked the flow of the Ravi river for nearly two days during rainy season of 2001and made a artificial lake. The river cut through the blockage in the left bank direction. The shifting of river course disturbed the toe portion of debris of the left bank and overburden mass of the left bank moved downward causing major land subsidence's and sinking of the road and village land. The NE-SW trending lineament controls this slide. This slide is a good example of wedge failure, rock falls, toppling and debris flow. The strikes of the lithologies are trending in NW-SE and dip northwards. The joints plane trending in the same direction, dipping southward, forms a wedge plunging in the SW direction and is responsible for the rock falls and wedge failure in the area. The three slip surfaces trending in NW-SE directions and dipping in the NE direction are the major slip surfaces of this debris slide along which the land subsidence and sliding are taking place. The metalled road of this bank has gone down nearly 100 meter below the present level due to toe cutting by river. The rock types of Holi slide mainly consist of slate-shale and arenite of the Katarigali Formation The rockslides and debris slides are maximum in Katarigali Formation followed by Manjir Formation. The back slopes are more vulnerable for the rock slide due to steep ness of the slope and planar failure whereas the dip slope are prone for the debris slide .The NE-SW lineament control most of the landslide incidences. It has been concluded that the most of the high hazard zones are restricted in the valley portion whereas the toe portions of slope are disturbed by the river undercutting or by the man made activities i.e. road cutting or by some engineering projects. The Holi slide can be stabilised by removing load from the crown portion and putting extra load in the toe portion and making proper drainage network so that no water seepage take place through the slip surfaces.

Paper No: 83

Landslide hazard zonation mapping of Holi- Brahmaur area, Chamba district, Himachal Pradesh

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The landslide Hazard Zonation mapping (LHS) of Holi-Bharmaur area of Chamba district of HP was carried out with an objective to demarcate the different hazard zones. The different thematic maps i.e. slope morphometry, slope facet, lithological and structural elements, land use, land cover, relative relief, hydrogeology, drainage network, slope forming material-cum-landslide incidences have been prepared which are useful in demarcating various landslide potential zones. Landslide incidences and slope facets within the particular geological formation has been taken as an important parameter for evaluating landslide prone zones in the area on the basis of probability analysis. The area lies in a WNW-ESE wide Chamba valley .The rock types exposed in the area belongs to Chamba and Morang formations of Proterozoic age and Manjir,Katarigali formations of Palaeozoic age. The Dallhouse Granitoids are intrusive in Chamba and Morang formations.. The general trend of rocks in the area is NW-SE with low to moderately dipping in NE direction besides vertical at places. The area has been divided into 671 slope facets of which 88% lie on bedrock and remaining 12% on overburden. The Katarigali Formation has the maximum facet (488), Manjir Formation has 82 facets, 66 facets falls in the Chamba Formation, 25 facets fall in the Dollhouse granitoids and 10 facets fall in the Morang Formation. Land cover/ land use map of the area shows that out of total 671 slope facets, 53% fall in the barren areas, 5 % fall in glaciated areas, 16% fall in sparsely vegetated areas, 9% fall in the a moderately vegetated areas, 8% fall in thickly vegetated areas and 9% fall in agricultural land or local urbanisation areas. Out of total 671 slope facets 664 (99.6%) fall in the high relief while only 7 (0.4%) slope facets fall in the medium relief slope category. The result indicates that out of 425 sq.km, 55.07 sq.km. area falls in the high hazard, 16.50 sq..km.. in moderate and remaining 346.00sq.km falls in the low hazard zones. Higher vulnerability of slopes was recorded in ortho-catacline and orthocline slopes of Manjir Formation and Katarigali Formation while the lowest vulnerability was recorded in Morang Formation. The Holi slide is a major slide which is the result of rock falls from the right bank of Ravi river and caused major land subsidence's and sinking of the road and agriculture land for about 500 meter. This slide is a good example of wedge failure, rock falls and debris flow. It has been concluded that the most of the high hazard zones are restricted in the valley portion where the toe portion of slope is disturbed by the river undercutting or by the man made activities i.e. road cutting or by excavations for some engineering projects. The rock and debris slides are maximum in Katarigali Formation followed by Manjir Formation. The back slopes are more vulnerable for the rockslide due to steepness of the slope and wedge formation whereas the dip slopes are prone for the debris slide.

Paper No: 86

Geotechnical evaluation for stability of slope in renovation work of fort Mutrah and Mirani, Muscat, Sultanate of Oman

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The paper covers a detailed geotechnical investigation for restoration work in northern slope of the Mutrah fort and for the entire area around the Al Mirani fort, Muscat, Sultanate of Oman. The area around Mutrah fort is 1.2 hectare and around Mirani fort is 1.8 hectare. Mutrah Fort and Al Mirani Fort located on the rocky mountain, situated in the capital city of Muscat, Sultanate of Oman on the southern shore line of the east-west extending Gulf of Oman. These are very important defense cum archeological structure and have great historic as well as strategic significance. As per the information gathered, a significant restoration work had earlier been done in case of the Mutrah fort's engineering structure from geological as well as geotechnical engineering perspective by M/s Atkins International. Zone-wise measures in the form of doweling, rock bolting, grouting, surface dressing and provision for structural support had been considered. Based on that, protection work for the Mutrah fort close to the base has already been done by M/S Al Manar International LLC of Muscat, Sultanate of Oman. Objective of the present investigation at the instance of the Royal Estates of Oman was to review the surface condition of the slope by a detailed engineering geological mapping followed by determination of geotechnical properties of rock with a view to evaluating a realistic assessment of the rock strata and prediction of the probable hazards likely to be encountered. This paper consists of slope stability analysis and suggested remedial measures for the rock slopes at Muthra and Mirani Forts. The earlier recommendations in case of Mutrah fort have also been selectively incorporated. Further information is expected from the results of drilling and geotechnical investigation being arranged by the client. Based on this additional information a detailed analysis will have to be carried out and proposal outlined here may have to be suitably adjusted and modified subsequently.

Paper: 105

Morphometric analysis ofSeul Nal watershed, Chamba district, Himachal Pradesh and its significance in landslide study with special reference to neotectonic activity

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Landslides are one of the most dynamic natural process very common in hilly region. The present study discusses the relationship between the drainage morphometry and the landslide hazard with special reference to the neotectonic activity, as it also influences the landslide occurrences in the area. The study area is approximately 213.22 sq. km in and around Pringul, Kinar and Mera area. The area comprises of recent alluvium to lower Proterozoic group of rocks. All the bed rocks are folded along the NW- SE direction. The major tectonic feature presented in the area is Chamba syncline and its trend is NNW-

SSE. The area has high drainage density, high bifurcation ratio and high ruggedness number which indicate that the drainage is mainly structurally controlled and the area is tectonically active. Low circulatory ratio indicates the semicircular to elongated nature of the basin. Length of overland flow and constant channel maintenance indicate that basin has been under the influence of high structural disturbance. Low permeability, steep to very steep slopes and high surface runoff and provide little scope for ground water recharge. The main stream of Seul Nal flow is SSE direction i.e. trend of Chamba Syncline. 19 landslide incidences are marked in the left bank of the watershed while right bank of the watershed shows only 7 landslide incidences. The asymmetry factor of the watershed is 34% i.e. less than 50% and the length of the tributaries of the left bank is more than the right bank (facing downstream), which means that the tectonic rotation or tilting is down to the right bank and tilting is upward in the left bank. Major landslide incidences occur in the up-lifted side of the basin, which shows that slopes are more prone to fail in the uplifted block of the basin compared to the downside of the basin.

Paper No: 118

Geotechnical assessment of November 2006 landslides in the Nilgiris Tamil Nadu.

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Consequent upon continuous heavy rains in the NIlgiri Hills, numerous landslides were reported to have occurred at the early hours on 14.11.2006 killing one and injuring three persons and disrupting traffic in NH - 67 and blocking of Mountain Rail track between Mettuppalayam and Coonoor. Complete damage and washing away of a rail and a road bridge, washing away of a truck and partial damages to many culverts are the other effects of the landslides. The area forms northern flank of the deeply dissected part of Coonoor River valley of Nilgiri plateau which stand out prominently and rise to a height of about 2500 m above mean sea level. The Nilgiri massif is occupied by high grade metamorphic rocks comprising charnockite, banded garnetiferous biotite gneiss. Laterite, insitu transformed soil, rock detritus and alluvial/ colluvial deposit material are the capping materials over the bedrock. A total of 28 landslides of medium to large size occurred on 14th November 2006 along NH-67 between Kallar and Pudukkadu villages and along Mountain Railway track between Adderley and Barliyar stations. An important slide in terms of size and location that has taken place between hairpin bends 1 and 2 of Mettuppalayam - Conoor stretch of NH-67 near Kallar village was studied in detail by carrying out of large scale geological mapping and preparation of geological section and the rest were inventoried. The depletion part of the Kallar slide lies above the upper arm and the accumulation part extends just downside of the lower arm of the road bend -2. The run out zone was observed to cross the lower arm of hairpin bend -1, west of Kallar village. The slide has taken place on 30º to 35º slope between NH-67 road and E and°railway tack from elevation+637m to +408m in the direction towards S 50 caused partial damages and total blocking of two arms of the road, uprooting of numerous trees and plants and accumulation of silt and debris in plantation areas. About 11,550 cu.m of debris material has been moved out exposing fresh bedrock. The landslide is of Debris flow type and was climatically triggered. The failure is rotational cum translational, started as a slip circle rupture and moved along the plane of contact between bedrock and overburden . Steep slope, movement of ground water and particulate removal by eluviation process at the contact between the rock and overburden and increase in soil water content due to antecedent continuous rain fall are considered to be the preparatory factors. Sudden increment of pore/cleft water pressure due to heavy rain in a short duration is inferred to be the triggering factor. Stabilization, control and corrective measures recommended. Most of the other landslides that have occurred adjacent to the road NH-67, Railway Track and at the top levels of the slope are located within the two convergent slope facets that have retreated by palaeo slides. The Soil/regolith strippings have taken place on 35º - 55º slope causing partial/complete damage to road/rails, culverts and bridges and depletion in forest cover by uprooting many trees and plants. The thickness of soil/regolith/debris varies from 1m to 3.5m. In general, slope failures occurred close to communication corridors have caused only blockade and minor damages to the road/railway track, where as the runout debris is responsible for choking, partial and complete damages of culverts and bridges. The slides are generally shallow sheet debris slides occurred along the bedrock – overburden contact. Steep slope, removal of lateral support and changes in water content due to continuous heavy rainfall are identified to be the causative factors for the near road/track and top level slides. Some slope failures/slides observed along the streams are stream bank failures caused by the instantaneous erosion and removal of toe support by the fluid debris runout from the upper level slides.Cleaning of the culverts/ bridges choked with debris and periodical maintenance will minimize the damages. Increasing the bay width and height of the culverts may be thought of for existing culverts/ bridges, if not at least where ever new structures are planned. At least three landslide prone stretches are present along the important communication corridors (Both road and railway line) connecting the hill station Ootacamund with the plains, where landslides/soil slips have occurred frequently. Two of the stretches are falling in zone II and III of Landslide macro zonation map by D.N. Seshagiri et al (1982) and the third one falls in zone ‘V’. Hence it is necessary to carry out a comprehensive meso/micro zonation studies applying the methods in vogue for the entire stretch of the slope from Kallar to Coonoor. Monitoring of the slopes by installing instruments may also be taken up for the critical stretches. As a long term measure, constructing a tunnel from right slope of the Kallar stream to Barliyar and from Barliyar to Conoor is suggested.

Paper: 120

The distressed railway bridge no 144 near Lailak-Mamalkha railway station, on Sahebganj loop of eastern railway Bhagalpur district, Bihar

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The more than hundred year old Railway Bridge over Sadonia River between railway stations Sabour and Lailak-Mamalkha, on Shahebganj Loop, Eastern Railway, was severely affected through settlement and subsidence of its right abutment (A 1 abutment) and on of its four piers (P4) from November'2007 resulting suspension of the Railway Traffic movement on this line from December'2007. Study of the exploration data of this area showed that the abutments and piers of the bridge have been founded on a 10 to 11m thick silty clays layer having low competency (N value ranging from 4 to 9) horizon. This impervious silty-clay horizon is underlained by a thick saturated very high to high competent sandy horizon having N value ranging from 15 to 40. Presence of deep widening cracks encircling the distressed abutment, subsidence cracks in two to three steps along both the banks of the river, sand boiling in the D/S of the bridge, seepage of water from the river bank etc. were noticed. Distressing of a bridge abutment and pier can be caused by several factors such as a) scouring below the foundation level, b) plastic deformation of the foundation material, c) effect of swelling pressure of the foundation material, d) neotectonic activity/ earthquake/ any other man made ground tremor resulting liquefaction of the founding soil, e) piping action below the abutment/pier foundations etc. After considering all pros and cons of each of the probable causes of failure it has been concluded that the development of quick condition and piping through the foundation soil under high hydraulic gradient and development of high pore water pressure resulting from the submergence of the area by the flood water of the nearby flowing River Ganges almost every year during the monsoon period is the most plausible cause of distressing of the bridge abutment and the pier. The manifestation of the quick condition is the occurrences of a number of sand boils and extensive bank subsidence along both the banks of Sadonia river covering a long stretch. To restrict/confine settlement and lateral movement of the distressed A 1 abutment Railway authority has initiated sheet piling encircling it. It has been indicated that selective sheet piling may cause destabilization of the rest of the piers and the abutment as the obstructed underground seepage force may find its path below the foundation of the rest of the unprotected structures. It has also been recommended that the sheet piles must go at least 3 to 4m into the underlying sand bed. Hence, to relieve off hydrostatic pressure it has been suggested to sink a number of large

Paper No: 122

Site specific studies of Sonapur landslide, Jaintia hills district, Meghalaya

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The Sonapur landslide is an old, active rock cum debris slide on NH-44, which disrupts traffic movement seriously every year during monsoon due to accumulation of slide debris and slurry. The Sonapur landslide zone is located at the cross-junction of three lineaments trending WNW-ESE (Dauki fault), NE-SW and NW-SE. The Sonapur landslide area falls under the highest seismic zone (zone-v) in the seismic map of India. An area 0.3 sq km has been covered by large-scale geological mapping on 1: 1,000 scale with 10 m contour interval. The length of slide from crown to toe is 870 m with a vertical height of 400 m and the breadth varies from 40 to 220 m. The area consists of medium-grained sandstone with interbedded siltstone and gray splintery shales. The strike of the formation varies betweenN80^{0}E – S80^{0}W and N75^{0}W - S75^{0}E, dipping 30^0 to 45^0 due south. Comparatively the influence of toppling of the rock slope failure is more prominent than the wedge failure in the right flank scarp of the slide. In Sonapur area when the monthly rainfall is more than 2000 mm the landslide is likely to occur. The main factors causing the landslide in the area are weak geological formation, discontinuity of joints, fractures and faults, steep slope of the hill and heavy rainfall. Ground improvement methods like bally benching; construction of retaining walls and drainage diversion channel and benching of slope are proposed for mitigating the landslide.

Paper: 124

Slope failures in the Western Deccan Basalt Province of Maharashtra: An introduction

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Slope failures are among the most important natural disasters faced by the geo-environmentally sensitive western part of Maharashtra. They frequently damage communication links as well as property and at times result in loss of life. Besides, they also have long lasting impact on the livelihood of the people. Geomorphically, the landslide prone part of Maharashtra lies along the crest line of nearly NNW-SSE trending Western Ghats and immediately west of it. Geologically, the vulnerable slopes comprise basaltic lava flows with simple or compound flow morphologies, laterite, residual soil and/or colluvium. The overall landscape presents a youthful relief with rugged topography and fast erosion. The annual average rainfall of this region is about 4000 mm, restricted almost entirely to monsoon season of four months. The slope failures are also restricted to rainy season thereby highlighting the dominant role of rainfall in landsliding. Slope failures observed in western Maharashtra mostly in vicinity of communication routes or habitations are debris slides (most common), soil slumps, failures in the highly weathered rock mass, debris flows, rock slides and rock falls (least frequent). In cases of debris and weathered rock, their interfaces with sound bed rock are the most critical surfaces for failure. In rock failures, the nature as well as extent of joints in the rock mass coupled with loss of support governs the locales and size of failures. The prime causes of failures include 1) saturation of residual soils by rain water, 2) fabric damage by water seepages in colluvial deposits, 3) uncontrolled surface drainage over vulnerable slopes, 4) toe erosion, 5) presence of adverse discontinuities especially destressing joints in the rock mass, 6) differential erosion in the lava flows and 7) modifications in natural slope and drainage. The GSI has recently initiated systematic study of landslides in western Maharashtra, mainly involving post-disaster studies and long term studies aimed at ascertaining the landslide hazard on a regional scale. These efforts have underlined the need for more interaction between the societal and scientific cultures and for developing a more appropriate rating system for parameters that govern the slope failures in this geo-environment. However, much more remains to be done to reduce the risk posed by the landslide hazard to this area.

Paper No: 128

Occurrence of Landslides in Araku Valley and its Environs,Vishakapatnam District, Andhra Pradesh

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Landslides are one of the natural disasters in the fragile ecosystem and creating serious threat to the lives and its environment. The present paper deals with the occurrence of Landslides in the mandals of Araku valley, Dumbriguda, Paderu ,Peddabayalu and G.Madugla of Vishakapatnam district of Andhra Pradesh. The reported landslide occurrence during the first week of August 2006 caused loss of 18 precious lives in one single instance at Kodipunjavalasa Village and host of damages in other parts of the above mandals. Also the slide leads other problems related to dwelling units,part of communication corridors and drainage systems. The slides occurred in the areas located in a rugged hilly terrain,part of Eastern Ghats Mobile belt.The slides reported are of varying dimensions predominantly debris slides and have occurred in khondalitic country. The slides have occurred in slopes of the order of 30° in a media made up of scree,soil and weathered rock. The predominant cause of the slope failure because of toe erosion, debris accumulation resulting blockade ,overtopping and changing the course of streams and most of the slides occurred the day when heavy rainfall showered the terrain due to cyclonic storm. Several corrective and control measures recommended include,clearing of accumulated bed load for clear waterway to enhance accommodation of flood discharge, river training works, protection of banks from erosion by construction of gabions,boulder crates with wire mesh,masonry pitching etc.,The investigation carried out as per priority of district administration covering the entire gamut of assessment of damages due to slides,causative factors, triggering mechanisms and control and corrective measures.Besides, the area still on threat due to future possibility of impact of landslides so further zonation of slides and risk assessment is needed.

Theme-6: Geo-hazards (Earthquakes, Floods, Geo-environment and Tsunami)

Paper No: 11

Seismic Hazard Analysis for Tamil Nadu State – A Deterministic Approach

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Tamil Nadu State with an area of 130, 058sq.km is located in the southern most part of the Peninsular India is selected for the present study on seismic hazard assessment. The part of northern and western Tamil Nadu State and its capital city Chennai have been categorized under Moderate Seismic Hazard (Zone III) areas, by Bureau of Indian Standard (BIS) in 2001. A catalog of historical/instrumental earthquakes/earth tremors in the state is prepared and used in this paper. The earthquakes/ earth tremors having magnitude of greater than 3.0 has been considered for the present study. The seismic sources have been identified using remote sensing images with limited ground truth verification. Seven near potential seismic sources in the region delineated as area sources for seismic hazard assessment based on geological, seismological and geophysical information. Shortest distance from the each seismic source to the major cities of Tamil Nadu measured and the Peak Ground Acceleration (PGA) at bed rock level is calculated for the seven sources with their maximum credible earthquake events using available attenuation relationship formula applicable to Peninsular India. The maximum magnitude associated with these potential seismic sources is in the range of 6.0 to 5.0 in Richter scale and the estimated of Peak Ground Acceleration at the source is 0.212 to 0.078g. The PGA values are estimated from the closest potential source for major cities of Tamil Nadu viz., Chennai, Coimbatore, Salem, Madurai and Trichirappalli cities, which have PGA of 0.107g, 0.133g, 0.012g, 0.077g & 0.113g respectively. The result of the present study reveals that the seismic hazard in northeastern and western part of the state is closely matching with the Seismic Zonation map published by the BIS. However the east southeastern part of the state shows higher value because of the adequate earthquake data used for the present study for the years 1800 to 2004. The southern part of state shows comparatively low seismic hazard than the other parts of the Tamil Nadu state.

Paper No: 82

Considerations in the design and construction of fill dams in earthquake zones

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In addition to general considerations that enter into the design and construction of embankment dams, there are several special considerations that are very important in the design and construction of embankment dams in areas classified as seismically active. The paper lists and discusses these special considerations and furnishes coverage on the

design and construction of the 260m high Tehri Dam in an area classified as of high intensity seismic activity.

Paper: 107

Neotectonic activity and seismic hazard assessment of the Hima.layan Frontal Belt around Ramnagar, Kumaun Himalaya, India.

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Ongoing convergence of Indian Plate into Eurasian Plate at a rate of 40- 50 mm!yr has been attributed as the cause of three major earthquakes of magnitude >7.7 magnitude in the Frontal Belt. The strain release has been manifested in the development and growth of anticline and coseismic surface rupture/ fault in the Frontal Belt. The Siwalik rocks exposed along the Himalayan Frontal Belt in- between ESE-WNW trending Main Boundary Thrust (MBT) in north and the Himalayan Frontal Thrust (HFT) in south, show broad south verging anticline along the southernmost, north dipping HFT. Most of the lithounits exposed around Ramnagar, Nainital district, Uttarakhand, comprise a litho-sequence of sandstone, shale, claystone and pebbly conglomerate, which have been thrown into homoclinal strata of backlimb with gentle to moderate (10°-55°) northerly dips. The forelimb of the WNW-ESE trending, broad Siwalik anticline shows steeper, southerly dips (30°-80°). The Upper Siwalik rocks comprising pebbly conglomerate, clay and soft sandstone as well as overlying Quaternary alluvium and river terraces show gentle (10°- 30°) northerly dips to the east of Kosi and Dabka rivers. The fluvial sediments of the Kotadun occupy longitudinal, intermontane valley fill within the Siwalik hills. In Ramnagar- Mohan- Kotabag- Kamola area, the MBT demarcates the boundary between Siwalik rocks in the south and pre- Tertiaries (Krol- Infra Krol and Chandpur phyllites) in the north. It passes through Kosi river north of Ukhaldhunga village and crosses Dabka river north of Kotabag. The HFT makes the boundary of the Siwaliks and piedmont zone towards west of Dabka and Kosi rivers. In south and southeast of Dabka river, it shows right stepping and forms scarps (5-10 m) of Upper Siwalik rocks, which is overlain by alluvium river terraces against the relatively low lying piedmont zone on southern side. These scarps along the HFT are well noticed in the LISS-III+PAN merged satellite imagery, aerial photographs and online Google imagery. The southern boundary of Kotadun in between Kotabag in the east and Kosi river in the west, is marked by right stepping WNW-ESE trending back faults. The northern boundary of the Kotadun is marked by a thrust, which brings the Lower Siwalik rocks from northern side into contact with Dun sediments in Kotabag area and the Upper Siwaliks in Garjia area. Besides these longitudinal major tectonic planes, few transverse faults/ lineaments are also observed within the Himalayan Frontal Belt of this region. A NNE- SSW trending cross fault tectonic lineament is observed extending from Himmatpur in south to south of Garjia. It is a wrench type cross fault where the eastern, apparently down thrown block covered with Quaternary terraces of Kosi river shows gradually more throw laterally towards south. Monoclinal folds along with crushing and shattering of Siwalik sediments are observed along this cross fault near Himmatpur. A N-S trending tectonic lineament with

appreciable linear geomorphic and lithological break is identified in the eastern vicinity of Ramnagar along left bank of Kosi river. A N-S trending, high angle, neotectonic, normal fault along with rotation and crushing of pebbles has been observed within pebbly piedmont deposits along a road cut section near Kamola village, crossing the surface trace of the HFT. The morphotectonic study and geological field work indicate signatures of neotectonic activities/ active tectonics in the area, in the form of faults and lineaments cutting the Quaternary sediments of the Upper Siwaliks, Kotadun and overlying alluvium, trending both, parallel as well as transverse to the Himalayan trend. The involvement of young sediments of river terraces, piedmont alluvium along with the Upper Siwalik rocks in the co-seismic ruptures/ faults along and across the HFT are the geological signatures of neotectonics/ active tectonics and inherent seismic hazard in the area. The northward gentle tilting of beds of terrace deposits of Kosi river near Ramnagar, crushing and shattering of sub vertical beds along with fault propagation, tight folds of the Siwaliks and the overlying Quaternary sediments within the forelimb of south verging growth anticline are observed in Swaldeh and Karkat nalas along the emergent segments of the HFT. The growth of the anticline and episodic movements along the HFT have caused rise of different levels of river terraces and induced river incision along with 'V' shaped river valleys within the Upper Siwaliks and overlying younger sediments as observed near Ramnagar in Kosi river, Powalgarh in Oabka river and along Karkat nala towards further south. The unpaired terraces of Oabka river and its northward migration near Kotabag and unpaired terraces of Baur river and its eastward migration, indicate that the part of the Kotadun sediments lying between Kotabag and Rurki village has risen during geologically Recent time. An antecedent, Khichari nadi river originated across the MBT irr north, crossing through low lying the Kotadun valley and the Upper Siwalik ridge towards further south indicate rise of the frontal Siwalik ridge due to movement along the HFT and back faults. Shutter ridge and radial drainage pattern observed south of Oabka river/ Powalgarh village within the alluvium indicate rise of topography in the geologically recent time. Back tilting of unpaired river terraces are also observed at the northern margin of the Kotadun valley. The almost straight fault scarps involving unpaired river terraces and piedmont alluvium along the HFT indicate seismogenic character of this emergent fault segment as formed by coseismic rupturing in the geologically recent past. These seismogenic events along the HFT have seismic reccurrence value in the future by reactivation of the faults or generation of new faults nearby to release the accumulated strain energy of on going active tectonics in the region. These neotectonic signatures indicate a hidden seismic threat to this region of the Himalayan Frontal Belt.

Paper No: 121

Seismicity in Central Kerala: Some Observations

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Last 15 years had witnessed 3 earthquake events of M>4.5 in parts of Kottayam-Idukki districts of Central Kerala. The twin earthquakes of 2000 and 2001 (M 5.0, 4.8) were a

rare phenominon in peninsular India. The damage pattern show that the two mesoseismal areas were separated by about 15 km and isoseismals of both the earthquakes oriented in NNW-SSE directiond. Literature survey had unearthed another set of twin events, slightly south of this area in 1953. This earthquake sequence had some similarities with the 2000-2001 earthquake sequence including the westward migration. Spatially, these events are associated with NNW-SSE lineaments, which are sympathetic to the west coast fault. Epicenters located by instruments for these events were well off from the felt area. Historically, a few more tremors were also reported in this region. Drainage morphometry analysis of this area show deviation from symmetry for the drainages bearing NNW-SSE lineaments. The occurence of tremors and geomorphic anomalies may be indicative of the NNW-SSE fractures (parallel to west coast fault) experiencing adjustment under the present regional stress regime.

Paper No. 143

Site response studies under seismic hazard microzonation – A case study from Visakhapatnam urban agglomeration, Andhra Pradesh.

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This paper presents the Site response characteristics in form of amplification factors for seismic microzonation of Visakhapatnam Urban Agglomeration. The general methodology adopted in this investigation is noise survey carried out for site response parameters to determine & evaluate the predominant frequencies and the amplification of the ground motion in and around Visakhapatnam. Basically, these studies have been aimed to delineate susceptible zones of damage during an earthquake. The principal rocks units in the area are Khondalites, Charnockites and granite gneisses, which form the bedrock besides, river alluvia, soil and beach deposits of recent times. The site response studies indicated various vulnerable zones of damage when affected by earthquake. Processing of the data obtained from noise survey at various sites in Visakhapatnam Urban Agglomeration show variations of peak frequency in the range of 1 to 10 Hz and peak amplification from 1 to 8. It also indicates frequent lateral variations in the subsurface characteristics especially of the overburden. Maps showing relationship between maximum amplification and peak frequency and average amplification at different frequency ranges are useful for a variety of end user communities, including geotechnical engineers, building planners and general public at large. The maps presented in this paper are preliminary in nature and qualitative by analysed.

Paper No. 145

Geotechnical application of Free Vibration Testing of A Steel Frame

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Free vibration of a steel frame with varying mass at top has been carried out using Ranger Seismometers. A Single storied one bay frame is used in this study to compare its analytical and experimental fundamental time periods. Free vibration is carried out by hammer hits at top with a wooden hammer. Mass is varied with the help of pre-cast Concrete Slabs. Free vibration records were obtained in both Longitudinal and Transverse direction of the frame. The predominant frequencies of vibration have been obtained with the help of FFT of the free vibration record in every direction. The Steel frame has also been modeled as a 3D space frame in STAAD Pro 2005 and Modal Analysis has been carried for both the longitudinal and transverse directions to obtain the natural frequencies and mode shapes of the structure. Time periods were observed in both the directions assuming a 2D shear frame and compared. Damping of the structure has also been obtained from the free vibration records of all cases and is compared. The observations made and findings in the study are applicable in the design of structures which are resistant to seismic events.

Paper No: 29

Flood devastation in "Kaval towns" Pilibhit and Lalitpur districts of Uttar Pradesh.

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Floods in Kaval towns, Pilibhit and Lalitpur districts of Uttar Pradesh are common features of rivers Ganga, Yamuna, Gomati , Sarda, Betwa, Shahzad, sajnam and jamni. The seasonal / periodical floods of these rivers are restricted to three morpho units (a) Active flood plain (To) (b) lower depositional terrace (t1) (c) older flood plain (t2). The flooding of the Active Flood Plain starts immediately after the onset of monsoon. The water of the rivers spread in the low lying areas causing water ponding around palaeochannels, ox -bo lakes, back swamps etc. The lower depositional terrace (t1) of the older flood plain of the rivers are also generally flooded annually. The older and higher terrace (t2) of the rivers are flooded periodically during high flood only. The Gomati river flood of 1971 in Lucknow had inundated several crowded localities of Trans-Gomati areas located on t1 terrace such as Gokhle Marg, Botanical Garden, sapru Marg etc. damaging houses and properties of the area. The Ganga river flood of 1982 in Varanasi invaded several crowded markets and colonies such as Goddoulia, prachi cinema area, Durga Kund, Assi area etc. disrupting normal life of the people. The Ganga and Yamuna floods of 2000 in Allahabad had crossed the danger mark of 84.73 m and reached to 86.73 m and 86.5 m respectively submerging low-lying areas of Allahabad town. The 1994 and 1997 floods in Allahbad area were caused by sudden discharge of water from Belan and Rewa dams respectively consequent to heavy rains in the reservoir areas. The Betwa river flood of 1999 in Lalitpur District damaged the road bridge connecting Lalitpur and Chanderi and also submerged cultivated fields. The flood of Jamni river in Lalitpur district had created havoc in the area submerging road bridge between Banpur and Mahrauni at Putlighat . In Pilibhit district Deoha valley flood in 1990 had inundated Pilibhit town causing extensive damage to the property. The flood in mighty river Sarda had caused collapse of river banks, soil erosion and submergence of

low-lying areas uprooting the people. The impact of floods on common people are severe and devastating due to loss crop and property.The state government has to bear the burden of rescue and rehabilitation work which involves unplanned expenditure of several crores . The mosquito breeding in certain low- lying areas due to water ponding causes Malaria and other diseases. The cattles had to face severe shortage of fodder in the aera. The menace of floods can not be totally eliminated but can be reduced by adopting suitable flood control measures such as construction of flood embankments along the left and right bank of the river wherever possible . The flood can also be controlled by constructing storage dams in upper reaches. The small scale irrigation strategy should be followed by constructing bundhi in the area. In the critical flood prone sections suitable techniques should be adopted such as use of sand bags and wire meshed boulders along the river banks to prevent bank erosion to a large extent. In the Geomorphic low areas drainage should be improved to avoid drainage congestion and flooding in the area.

Paper: 48

Coastal erosion at Uppada along Kakinada coast, Andhra Pradesh- A study from Remote Sensing

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Large scale coastal erosion often termed "long term coastal hazard" is prevalent along the 30 km long coast between Kakinada in the south and Antarvedipeta in the north. The worst affected locality being Uppada (170 04' 53": 820 20' 03") located 20 km north of Kakinada town. The impact of sea erosion at Uppada is so intense that the sea walls and groins erected south of it have proved ineffective in protecting the beach road which has suffered damage at several places. More than half of the village predominantly a fishermen's colony has gone in to sea. Study of temporal remote sensing data indicates that the coast line has eroded more than 370m over the last three decades. Historical evidences point towards loss of more than 600 acres of coastal land during the same period. Major geomorphic units found in the area having a relief difference of 7m include beach ridge, younger beach dune complex, older beach ridge, tidal marsh/mud flat and tidal creek. The most vulnerable geomorphic unit is the long and extensive beach ridge/younger beach dune complex for its proximity to shore and poor geologic formation. The long shore current has caused maximum erosion to the stable beach ridge and at the same time has widened the mouth of tidal inlets like Pedda Eru located north of Uppada. This, in turn, has accentuated inundation of more and more low-lying flats. Though long shore current and wave action seem to be responsible for such large scale sea erosion, the possibility of land subsidence vis-a-vis sea level rise can not be ruled out. The recurved spit extending from the mouth of river Goutami to Kakinada port in the north forms a bay and at the same time allows the longshore currents to deflect and cause erosion at Uppada.

Paper No: 117

Assessment of Tsunami impact on land forms of West coast between Kanyakumari and Kochi, India

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At 0628 hrs IST on 26th December 2004, an earthquake with focus at a depth of 30km, and a magnitude of 9.3 on the Richter scale occurred, with epicenter located off Sumatra, Indonesia. The earthquake's epicenter (3.298°N-95.779°E) was located at 257km SSE of Banda Aceh, Sumatra, Indonesia and 2028km SE of Chennai, India. As a consequence to this seismic activities, tsunami was generated which the different coasts of Indian main land, Andaman Nicobar and Ladshadweep Islands with devastating effects in terms of life and property. Though the west coast has not directly faced the epicenter, the waves got deflected by Srilanka, Ladshadweep, Somalia and Maldive and struck the west coast of India (GSI, Spl. publ-07). Heavy casualties were reported in Kanyakumari - Kolachal sector in Tamil Nadu and Alappad- Azhikkal sector in Kerala. Soon after the Tsunami, the Geological survey of India has launched a rapid survey at selected locations along the Indian coast from Chennai to Kochi, to assess, evaluate and record its impact on the coastal land forms and beach placers. The present paper deals with the west coast from Kanyakumari to Kochi, falling in Tamil Nadu and Kerala. During the course of post Tsunami rapid survey along the west coast, affected zones have been delineated and demarcated in terms of run-up elevation, inundation, devastation, causalities, etc.(Jayabalan et al.,GSI, Spl publ -07). For the detailed studies, section line measurements (Transacts) were carried out at selected locations by using total station on scale 1:2000 to evaluate the maximum run up elevation and inundation along the coastal stretches. From the observations, emergence of a new surface in the beach front, erosion of spits and breaching along the coastline were the major impacts recorded in the foreshore and back shore areas. The field data also depicts that the run up elevation is gradually reduced from south to north. It varies from 0.85m to 6.45m and the run up distance/inundation varies from 200-500m on land and more than 2000m were recorded on the open inlets (River, Kayal. Etc,.). Maximum run up elevation and inundation occurred along the natural course of closed and open inlets. Besides, different pulses of tsunamis were reported. For every pulses, sea water recession was reported for a distance of 250-400m. It was observed that wherever shoreline protective measures like rip-raps and wave breakers were provided, the damages were minimum. However, the loose boulders placed on the wave-breakers have been tossed up like canon balls by the surging waves causing sever damages to the adjacent human settlements while the toe of the rip raps supported by gabions could retain the rip raps intact. The havoc caused to the coastal settlements and the existing coastal defence systems has also been assessed. Casualties, destructions and devastations mostly depend on the coastal geomorphology, landforms, bathymetric, and socio-economic features. Other parameters such as tsunami intensity and magnitude have also been assessed. The beach placer deposits (heavy minerals) brought by tsunami especially on either side of the Kayangulam estuary in Kerala and Manavalakurichi in Tamil Nadu, were commented upon briefly. Besides, vulnerable zones have been delineated and the areas have also been identified for the protective measures. Control and corrective measures have also been suggested to protect the valuable life, coastal land and property.

Paper No: 119

Cross shore profiling and assessment of response of coastal landforms of Tamil Nadu to 26th december 2004 Tsunami.

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Subsequent to the surprise strike of Tsunami disaster on 26th December 2004, cross shore section measurements and geological studies were taken up along the east coast of Tamil Nadu from Pulicat Lake to Kanyakumari. The studies include measurement of run-up elevation and inundation distance, landform based classification of the coast and assessment of their response to the tsunami event along with recommendation of preparatory measures. The major part of coastal tract of Tamil Nadu is occupied by coastal sediments, wind blown sand, kankar, calctufa, lateritic and calcareous sandstone, limestone and river alluvium of Quaternary to Recent Period, sandstone, clay and laterite of Mio-Pliocene age (Cuddalore Formation), hard and compact sandstones, clay, shale, siltstone and shell limestone of Tertiary period. Splintery green shales and pebbly brown sandstone of Lower Gondwana age, Precambrian rocks of Migmatite, Charnockite and Khondalite Groups and intrusive dykes of dolerite, basalt are occurring in selected sectors. The coast from Pulicat to Vellar mouth (Portnova) is, in general, indented with two broad bays of North Chennai and Pondicherry with a cuspate outline. The coast is straight in NS direction from Vellar mouth to Point Calimere and swerves in an E-W direction upto Agniar. Further upto Kanyakumari, it is an embayment coast with two major bays – Palk Strait and Gulf of Mannar separated by Mandapam cuspate foreland / Pamban Island. A number of small bays with cuspate forelands are present within the two major bays. Older dune complex including teri, tidal flats, mangrove swamps, salt marshes, deltas, lagoons, chenniers, strandlines, younger dune complex, wave cut and abrasion platforms, wave cut terraces, beach, spits, tidal bars, tidal inlets, estuaries, offshore bars etc., are the landforms present along the coast. Based on the broad lithology and landforms the coast has been divided into six categories as 1.Tidal bar / Tidal bar island coast 2. Flat coast with low disfigured dunes 3.Coast with barrier dune / dune complex 4.Flat coast with residual dunes 5.Narrow flat coast with dunes and 6.Coast with rocky platform and dunes. Besides these coastal categories, the response of Tidal inlets and coasts of Pamban Island were assessed based on the extent and elevation of the landforms with reference to sea level, run-up elevation, inundation and damages during the tsunami surge. In order to arrive at extent and height of the coastal landforms, run-up elevation and inundation of the tsunami, a total of 45 shore cross profiles were measured by rapid tacheometric survey taking the sector wise mean sea level as the reference. The run-up elevation in general is highest near shore line i.e. the berm area and gradually reduces towards backshore area. In tidal bar islands the run-up elevation gradually reduces towards the central part and again increases towards the backwater bodies / water ways indicating water surge from all around. In general, near shoreline run-up is

comparatively more in the coastal stretch with steep berm followed by stretches with moderately sloping and gently sloping berms. The run up is maximum in the coastal stretches from Ponnaiyar river mouth to Point Calimere. Further south the water surge and damage are comparatively less could. The inundation is maximum (3-5 Km) along the tidal inlets and estuaries and minimum in the coasts with rocky platform and dunes varying from 10m to 142m followed by narrow coast with sand dunes varying from 18m to 78m. The inundation in the sectors of the coast with barrier dunes / dune complex varies from 66m to 562m. The inundation in this category was mainly restricted to beach and at places sea water entered and inundated shore parallel inter-dunal depressions by breaching near shore dune complex along cross shore inter-dunal depressions. The tidal bars islands - Devanampattinam and Sonangkuppam of Cuddalore, MGR Tittu near Portnovo and Akkaraipettai / Kechankuppam near Nagapattinam were thoroughly inundated from sea and other water bodies connected sea. The inundation distance through land is maximum which varies from 449m to1666m in the stretches of flat coast with low disfigured dunes and flat coast with residual dunes. The stretches from Ennore creek and Adyar mouth and Coleroon mouth to Nagapattinam fall in these category and bore the brunt of the tsunami. Based on the statistical analysis of the historical and recorded earthquake events along the nearest belts of seismogenic source and the resultant tsunamis and the source parameters like magnitude, type of rupture and focal depth of the the causative earthquake, the magnitude of the 26th December 2004 tsunami can be taken as maximum considered tsunami for the Tamil Nadu coast. Accordingly the inundation limit of this event with some cushion may be taken as "Set back line". The preparatory measures suggested to face such type of hazards include ban / restriction of new settlements within the set back line, relocation of the existing settlements well beyond the set back line, stabilisation of existing dunes particularly the recent dune complex, growing of sand dunes by artificial methods particularly in the stretches of low flat coast with or without isolated dunes, construction of curved sea walls and formation of stone revetment in conjunction with earth filling in select reaches.

Paper No: 22

Geo-environmental assessment for determining suitability of buildable land in context of a hill town

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Inappropriateness of the building and construction activities taking place in preferred locations in the lower Himalayan region is a cause of concern. Environmental degradation in form of increased occurrences of hill instability, soil erosion, reduction in vegetation cover, drying up of natural water sources and micro-climatic changes, is often witnessed along with increased construction activity in most of the popular hill towns of north India. Locational factors, such as accessibility, proximity to work centers and community facilities, land values and micro-climatic factors, often override the considerations of stability of hill slopes (which is considered to be most important) in deciding not only the preferred locations for development but also the type of buildings and their builtform in context of urban settlements in hills. Whereas, proper appraisal of hill slopes in and around hill towns is important for determining their suitability: it is equally important to consider the damage potential of the building type/use and the resulting builtform for ensuring development that is sustainable as well as pragmatic. After discussing the problems and issues related to construction of buildings and roads for urban development, this paper discusses the methodology for geo-environmental assessment of hill slopes for determining their suitability for building purposes, which can become a basis for planning for future urbanization in hill regions. This is demonstrated in context of Almora- a hill town in Uttarakhand that was the capital of Kumaun for three centuries and is witnessing rapid urban growth.

Paper No: 27

Interplay of civil engineering structures with Quaternary sediments

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Most comman civil engineering structures such as earth embankments to check the flood furry, pavements for highways, earth dams for storage of water and subways for diverting the commuters congestion underneath and highrise buildings are being placed on the Quaternary sediments due to availability of bed rock at a greater uneconomical depth The Quaternary sediments occupying the youngest status in the geological history of the earth ranging in age from Lower Pleistocene (1.18 Ma) to 0.00 Ma (measuring from 1950 A.D.) are ascribed in the form of alluvial deposits brought up by fluvial regime, sand dunes and desertification by aeolin regime, lacustrine deposits by standing water regime in lakes, ponds and reservoirs, tephra deposits, ash beds by volcanic regime, coastal beach sand and precipitates by marine regime and laterisation by weathering regime of the nature. The geomecanical properties of the above mentioned sediments such as atterberg limit, swelling index, moisture content, porosity, load bearing strength etc. and fluctuation of ground water table of the area in each regime exhibit different behaviour on loading and /or piercing the geoengineering structures underneath. Some of the problems met with in Siwalik Rocks are of dispersive nature while presence of buried channels/abandoned channels in Older Alluvium pose the problems of severe seepage. The excessive vertical permeability in aeolin sediments and saturation of loessic sediments give rise to subsidence and under flooding .The swelling of clay minerals in volcanic ash are characteristic features giving rise to sqeezing phenomenon.Coastal beach sands on account of high salt content do not find any use in building construction. Similarly weathered oxidized part of the basalt and metabasics producing saprolite are prone to destabilize the geostructures by differential settlement. The recent sediments of active river channel brought out in the form of riverine sand quite often do not posses the required fineness modulus making them unsuitable for mortar unless otherwise blended or upgraded. The plasticity in clays of Newer Alluvium and facies changes in the Gangetic Alluvium need a thorough probe before placing superstructure over them. The paper deals some of the case histories where intricacy of Quaternary sediments has

resulted in the collapse and sudden failure of the structure during liquefaction/swelling and of the poor bearing capacity of the strata.

Paper No: 33

Lessons from the geotechnical settings of water resources projects in Mirzapur and Sonebhdra districts, Uttar Pradesh

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A critical Geotechnical assessment of 49 surface water resources development projects made in Mirzapur and Sonebhadra districts of Uttar Pradesh reveal that future development of these resources in 3 different physiographic units of the districts would follow different dictums based on the experience gained in earlier construction. Mirzapur and Sonebhadra districts of U.P. are drought prone and planned development of surface water resources in these districts was initiated in 1909 by making bundhis, ponds, storage schemes, barrages, lift pump water schemes through canals and earth dams to combat the natural calamity for mitigating irrigation potentials of the area. Paper deals at length the geotechnical setting and characteristics of each physiographic units and proper treatment to be offered for different geo-engineering structures before seating them on foundation of complex geological terrain ranging in age from Precambrian to recent in age. The forthcoming projects in Unit-1, Gangetic Alluvium, may face the problem of bank erosion during floods and bed rock at greater depth. To remedy the situation project would require shifting of the site from the bank and river training. Second Unit, Robertsganj Plateau, is characteristically a combination of arenaceous and argillaceous bands dissected by 3 prominent discontinuties which have given rise to the problems of foundation leakage and dislodgement of blocks from the spillway and scouring of the softer bedrock members and their sliding. Most of the bundhis located in this unit have homogeneous section which has allowed seepage in downstream section of the structures . Arrangements for curtain grout and /or blanketing of the reservoir be made after evaluating the permeability of the rocks. To arrest upheaval of the rock blocks from the foundation anchoring is to judiciously practised on the competent rock member and a thick concrete pad spread over it or masonry flooring done. Projects falling in Son Valley Unit-iii, must investigate the solution channels in limestone country which is spread over an area of 280 sq km and pockets of deep weathering identified in granitic country. --- The dental treatment must be accorded in the weaker zones. Bundhis in this unit also need key trench to minimize the foundation leakage .Rock toe is felt to be an essential component in all the homogeneous earth embankments .

Paper: 49

Presence of burried channel as the cause of subsidence cracks at Priyanagar under Chakdah block, district Nadia, West Bengal

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An earth crack measuring 60m long (approx) and 2-4m wide has been reported on 26th September 2007 morning at a place called Priyanagar under Chakdah Block near Kalyani town of Nadia District (toposheet No. 79A/8). Besides badly damaging an old pucca house, this land subsidence has endangered the adjacent house and other structures, thus creating a panic among the locals in general and the occupants of the pucca house in particular. On the spot study of the earth crack was undertaken to find out the causes and assess the gravity of the incidence. The published geological map of the area shows presence of Quaternary Sediments, deposited by the Bhagirathi river which flows from north to south. The two major Quaternary Formations of the area are (i) Hoogly Formation (Late Holocene to Recent) consisting of fine sand, silt & clay and (ii) Chinsura Formation (Middle to Late Holocene) consisting of alternate layers of sand, silt & dark gray clay representing natural levee and flood basin zone. Sediments of both these formations are unconsolidated in nature. Nature of cracks: The 30-75 cm. deep crack trending N65^0-80^0 E-S65^0-80^0W direction is confined in between two man made ponds with an elevation difference of approximately 10 to 12m within a distance of 85-90m, having gradient towards west. The damaged house and the prominent subsidence zone lie in between these two ponds and falls along the crack alignment. The crack can be sub divided into three sectors from NE to SW; viz. crack on the ground, cracks in the house and the subsidence zone. Development of fissures and subsidence below ground surface and its impressions on the surface as ground cracks generally takes place due to the following four reasons either independently or as a combined effect. i) Seismic activity, ii) Over withdrawal of groundwater, iii) Mining activity, iv) Presence of buried channel . The paper deals in details about the nature and impact of each causes, before advocating for presence of buried channel as the only cause of the crack, at Priyanagar -the site investigated.

Paper No: 59

Medical Geology in Ancient Past

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Since the dawn of human civilization, our ancestors were seriously in a look out to find the path ways for healthy life and its longevity. They observed very curiously how the life stops and plant kingdom maintain their life without any consultation and dependency on others. During the course of such examinations our ancestors observed that most of the animals consume herbs for their ailments but they could reach on the conclusion that the herbs and other metallic extracts taken by the mammals in smaller parts may find their utility in human beings. They saw monkeys to licker the extracts of many metals released from granite gneiss during scorching sun for improving their life style. Such evidences gave birth to Ayurved Shastra dealing the use of herbs, plants, minerals and metals for healthy and longer life. Famous Vaidya Charak and Shushrut have dealt many such medicines in their treatise for curing unresolved ailments, however, little has been done on the Ras Shashtra which deals the role of minerals and metals in supplementing the loss of cellular energy in the development of human body. In Ayurvedic medicines ‘Dhatu’ (metals) is referred to gold, silver, copper, brass, zinc, lead and iron which are essential for keeping the body in proper functioning. ‘Ras’ or ‘Bhasm’ is the end product produced by various means from these metals for supplementing the deficiencies caused during the course of ailments in human body. Our saints and mahatmas noticed how the secretions of gold, silver, copper and iron from the rocks containing them are released from their surface in the form of a thin surficial layer on the rocky surface during the scorching sun which are being unhesitatingly licked by the animals for maintaining the vigour and vitality. They named this extract released from the rocks as ‘Shilajit’. The extract from gold was named as ‘Sauvarnya’ from silver as ‘Rajat’ from copper as ‘Tamra’ and from iron as ‘Ayas’. Depending upon type of ailment vaidyas were deciding the type of extract and their quantity to cure jaundice, stomach worms, diabetes, TB, piles,breathing problems and cleaning stool and stones. Among the dhatus the bhasm prepared from gold which becomes red on heating, white on cutting, showing streak like kesar, devoid of copper and silver and having high specific gravity was used for eye treatment, semen increase, potency, heart ailment, retentive power, glamour, longevity and speech purification. Similarly silver bhasm was used for maintaining bigger and vitality provided silver for medicinal use was heavy, soft, white in cutting and heating, malleable and exhibiting good lusture like a moon. In Hindu way of marriage bettels cover with silver foil is a customery to be offered to the bridegroom for maintaining youth. The rich and el lit group of our ancestors used to take dinner in silver pots for maintaining their potency. Copper in medicinal use, for healing the wound, jaundice, liver ailment, fever, cough, TB, acidity and worms should have dark red colour, soft, able to tolerate hammer and devoid of iron and lead. Brass is utilized for eye treatment, worms, jaundice and breathing problems. It gives power to organs. Hindus believe that in morning water contained in brass utencils gives relief to stomach but if the water is acidic it should not be kept in brass utencils. Zinc has found many uses in healing the bed sore, eye ailment and developing the resistance. In modern allopathy vitamin B capsuls are being mixed with zinc to increase the resistive power of the patients. Another metal lead increases apetite and makes man more potent and simultaneously increases the longevity. It is a killer to many deceases. Iron stablises the age, improve writing power and cures the ailment of spleen, eyes, liver and releases worms. It is given to anemic patients. The iron dust has similar properties and is obtained by heating the iron. Besides, metals or dhatus, there are many alloys or updhatus such as copper sulphate, brass, cinnabar which have medicinal values. Copper sulphate cures eye etching and stomach disorders while brass kills bile release from gall bladder and useful for eyes and cough. Some of the minerals such as sulpher and mica are also used for skin treatment and increasing longevity respectively. It has been established that black mica ‘biotite’ found in Himalaya has more medicinal value as compared to that of peninsular rocks. Hartal a compound of arsenic and lead is found very useful in mouth ailment, blood purification, etching and for healing. In Unani medicines serpentine is used to neutralize poisonous effects while in Ayurvedic medicines it finds its use for seditives. It is rightly said that every medicine is a poison and every poison is a medicine. It depends on their judicious use and proper selection of their potency which requires a detailed study in Ras Shashtra for extracting the metals from gneissic rocks.

Paper: 106

Application of vital energy for propitiation of Nature

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Government of Andhra Pradesh envisages irrigation of 8.08,000 Ha (20 lakh acres) command area in the state under the ambitious 'Jalayagnam' (water worship) about 50 major irrigation projects, several earth dams, concrete dams, canals, tunnels etc by the year 2008 at an aggregate cost of 500 billion rupees. For the construction of structures on such a large scale for harnessing irrigation potential it is necessary that the role of dynamics of nature should also be considered along with geotechnical inputs. German allopathic Dr Hahnemann, founded homoeopathy in 1810 for curing diseases by establishing symbiosis between ailing person and his environment. He was the first scientist who realized omini presence of spiritual vital force as energy, the activating power of the Universe. It has been observed that the mysterious vital force controls the planets in their courses and influences the rivers, winds and tides, influences the manner of growth of plants thus tying manifestation of life to the Universal energy. All the elements, and all forms of matter like water is capable of being moved, activated by vital energy, although they may not themselves possess this energy within themselves. The stat of discovered vital energy realms are represented by unsustainable growth of population, alarmingly rising scarcity of water and food grains, climate change due to pollution of atmosphere to tipping point of 385ppm with carbon di oxide etc. In fact for ---- parameter of nature with functional disorder, homoeopathy which is governed by laws that are Universal offer the greatest hope of regaining lost balance by replenishment of energy to surmount challenges in engineering geology. In the context of 'Jalayagnam' as water worship, management of vital force as energy therefore needs consideration along with geotechniques for irrigation, boosting food production and control of population to sustainable level with geosymbiotic harmony with every parameter of environment.

Paper No: 139

Hydro geological Studies of Chitoda Village From Yawal Taluka Of Jalgaon District, Maharashtra State.

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The aim of the study for the management of aquifer for meeting drinking water requirement on priority basis. The existing dug well are for mainly for Irrigation purposes. The shortage of groundwater in future may affect the cropping yield however in case of shortfall in surface water in future. The groundwater should be kept intact by way of AQMP and adoping various suggested measures under such circumstances. The groundwater recharge and draft need to be balanced by adopting various techniques recommended to keep the safe Environmental Intact.

Theme-7: Exploration, Instrumentation, In-situ and Lab Techniques

Paper No: 10

Geophysical Earth Resistivity measurement utility for Earthmat Design: A case study

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Proper and adequate earthing in substation and switchyards is extremely important for the safety of operating personnel as well as for proper system operation. By earthing we mean connecting the electrical equipment to the general mass of the earth, which has a very low resistance. One of the main parameters affecting the design of earthing mat is soil resistivity and the true resistivity of the sub surface of the location and accordingly the geophysical earth resistivity measurements technique provides the best and economical way to measure the earth resistivity. In general Geophysical Electrical Resistivity measurements used to be carried out at various structural locations of all hydroelectric projects sites for economical earth mat design. The conventional Wenner and Schlumberger configuration data interpretation using computer software, standard graph methodology is in good agreement with the empirical techniques like (σ Resistivity & 1/лR) cumulative and inverse slope method, which can be used at site locations for immediate decision making even by non geophysical person. A case study at Kotlibhel hydroelectric project, Uttarakhand, India.

Paper: 12

Geophysical investigation for delineating the MCT under cover across Kumaltigad HRT, Pala Maneri hydro–electric project, Uttarkashi, Uttaranchal

H.P.Mishra, Amar Singh, Mehadi Hassan
GSI, Shillong

Pala – Maneri Hydro-electric Project envisaged the construction of a 74 m high concrete gravity dam across river Bhagirathi near village Pala, a 12.7 km long head race tunnel and a power house at village Aungi to generate 416 Mw of power. Geophysical surveys employing magnetic (VF) and seismic refraction techniques were conducted across Kumaltigad HRT alignment for mapping the MCT under cover. The rocks of this area belong to the Garhawal group and the central crystalline, which are separated by the Main Central Thrust (MCT) traced along the Kumalti and Duggada gads near their confluence with the river Bhagirathi. This thrust is no where clearly exposed and is generally concealed by basic intrusion or terrace gravel. The MCT has been conspicuous by clear-cut 'bipolar' magnetic anomaly as shown in figure. Seismic profile, laid along the magnetic traverse T-1, has also depicted the thrust, showing parallel displacements in the time segment. The throw of the thrust suggest that the lateral extent of the MCT zone might be between 50m and 70m. The throw of the thrust have been found of the order of 20m. In this area the order of P-wave velocity is between 4000 and 4500 m/sec. The MCT zone depicted in seismic survey is corroborated by the second horizontal derivative of the magnetic profiles.

Paper No: 13

Geophysical studies for delineating bedrock topography and its competence along song dam axis and to congigure the palaeochannel of Song river, district Dehradun, Uttaranchal

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The water supply Scheme for Dehradun town envisages construction of a 100m high concrete gravity dam across Song River near village Sondana, district Dehradun, Uttaranchal. Sondana village is situated about 10 km upstream of Song river road head near village Maldevata along a Kachcha road. In the vicinity of Song dam site, fine to medium grained grayish to greenish Nagthat quartzites with quartz veins at places are exposed at both the bank of the river and the valley is filled with river borne material. Geophysical surveys were conducted employing electrical resistivity and shallow seismic refraction techniques along the proposed dam axis with an objective to configure the bedrock topography and for delineating the palaeochannel of Song River. Vertical electrical resistivity soundings were conducted using Schlumberger array of electrode configuration whereas the seismic refraction survey was carried out using hammer source single channel refraction seismograph with a maximum spread of 100m. Vertical electrical resistivity soundings (VES) have shown resistivity of the bedrock varying between 650 and 800 Ohm-m. Four to five layered subsurface configurations was depicted along dam axis. The thickness of the overburden varies between12.5 and 25m bgl. The P-wave velocity of the bedrock (Quartzites) was recorded in the range of 4500-5000 m/s, which is suggestive of the competent bedrock. The depth to the bedrock deciphered by geophysical surveys is in corroboration with the test drilling results. The result shows that the bedrock is deeper along left bank than the right which suggests that the river was flowing through left bank in the past which presently flows through right bank.

Paper No: 19

Geotechnical instrumention for monitoring the stability of surface and subsurface structures in Parbati H.E. Project, Stage-III.

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Parbati hydroelectric project, stage-III is located in the lesser Himalayan rocks which are highly fractured and thrusted. The area is seismically active as it falls within zone –V of seismic zonation map of India. The project involves about more than twenty kilometer of tunneling through diversion tunnels, head race tunnel and tail race tunnel beside excavation of very large caverns such as desilting chambers and power house cavern. The project also involves construction of a rock fill dam on river Sainj. The stability of various surface and underground excavations is an important aspect of the hydroelectric projects. Even the minor movements within the rock mass may result into large scale deformation and rock failure, if not detected and controlled at the proper time. Geotechnical instrumentation provides an effective tool to detect

slightest of movement within the rock mass on a continuous basis. In this project, a well planned geotechnical instrumentation program has been adopted to continuously monitor the stability of various underground structures and excavated dam abutments. The data from these instruments are collected regularly and interpreted to verify the stability of the associated rock mass. This paper describes layout plan of various geotechnical instruments installed in the project area along with the procedure adopted for effectively monitoring the movements of the rock mass by interpretation of geotechnical data collected regularly from these instruments and also suggesting remedial measures if any.

Paper No: 45

Two Dimensional Electrical Resistivity Imaging (ERI) for Identification of Site for Artificial Recharge of Groundwater in Residential Areas: -A Case study of J. Telaiya town of Koderma district, Jharkhand, India.

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The groundwater scenario of residential areas is very critical due to imbalances between recharge and exploitation. Built-up pattern of residential areas restrict rain water to percolate into sub-surface for recharging of groundwater. A large amount of rain water is lost through run off in dense populated areas due to absence of rain water harvesting structures at appropriate locations. Two dimension Electrical Resistivity imaging of sub-surface has emerged as a useful tool for various applications. Electrical Resistivity Imaging (ERI) of shallow sub surface has been carried out along southern and eastern margin of a commercial apartment (under construction) near Krishi Bazar Samatee in dense built up areas of Jhumari Telaiya town for identification of appropriate site of rain water harvesting structure. The ERI of both sites indicates that of fractured and weathered zones are present in sub-surface. The ERI reveals that resistivity of hard and compact rocks are more than 300 ohm-meter. Weathered or fractured rocks have resistivity lower than 300 ohm-meter. Geologically, quartzite occurs in and around study area. Eastern Margin is highly fractured and weathered in comparison to southern margin. Therefore, weathered and fractured part in ERI has been selected as ideal site for construction of recharge well to divert roof top rain water into sub surface for artificial recharge of groundwater.

Paper: 47

Significance of Instrumentation in Tunnels and Large Underground Openings

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Most of the hydroelectric projects in India are located in Himalayas which are characterized by a variety of rock types having varied strength and have often undergone structural deformation. The Himalayan are also traversed by many thrust and faults which are considered as zones of high stress concentration and influence the tunneling condition. Rock mass behavior plays a vital role in determining the stability of the underground structures. During excavation, the natural

state of stress of rock mass is disturbed. Consequently, the rock mass around the opening begins to deform and causes inward radial movement. This displacement or movement continuous till the rock mass reaches equilibrium with the new state of stress condition. The extent of such deformation depends primarily on the insitu strength of the rock mass and stress condition before and after the excavation. Implementation of Instrumentation arrays concurrent with the tunneling plays a significant role in understanding the rock mass behavior and its influence on tunnel excavation and large underground openings during and after the excavation. It also helps the designer to plan suitable support system for safety and stability of the structure in the given regime of stress condition around the openings. Various rock mass properties such as deformation behavior, rock loads, insitu state of stress, mechanical and shear strength parameters of the rock mass can be monitored by installing instruments during construction and post-construction stage. Instruments also playa key role in optimizing the support system, particularly when the tunneling is done under challenging geological environments such as 'High Stress Condition' or 'squeezing ground' condition. The present paper gives an overview on the need of instrumentation in tunnels and underground excavation with experiences gained at some of the NHPC projects.

Paper No: 78

Long wall stress distribution in 1101 coal face of the Barapukuria coal mine, Dinajpur, Bangladesh

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To extract coal from Barapukuria Coal Mine using the method of Inclined Slicing Roof Caving Long Wall Mining along the Strike, and the sequence of slices mining from top to bottom. Mining of 1101 coal face initiates caving from the lowest strata in the immediate roof and propagates upward into the Gondwana Formation, to the base of Lower Dupi Tila and as well finally up to the surface. The redistribution of stresses analyze by the Peng (1986) and Wilson (1981) method, and the result shows that the stresses are relatively large; and the magnitude of front and side abutment pressure ranges from 1.3 to 6.92 MPa and 2.6 to 22.75 Mpa, respectively and the side abutment pressure may affect the surrounding rock mass up to 147.04 m from the face line. As a consequence of stress redistribution surrounding the rib pillars may be started to deform, of which ultimately affect the gate road geometry and overall stability of the 1101 coalface. The process of caving that each of the strata sags downward as soon as it is under direct effect of 1101 coal face advanced. However it is recognized that this might eventually be necessary to control strata movements and reduce mining problems, which might arise from multi slicing mining conditions in the very thick seam like Barapukuria condition. It is mandatory for the mine authority to carry out a detail study for the gob forming process and expansion of the materials. As mining experiences is gained so far from the 1101 coal face operation, the mine planning and method of roof control should be modified and developed in the light of the experiences, because failure of the project would be totally unacceptable for economic, political and social grounds of the country.

Paper No: 94

The point load test in rock material characterization

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Standard laboratory tests to determine uniaxial compressive strength (UCS) of rocks require machined specimens. Therefore, tests where relatively unprepared specimens can be used are often considered for predicting UCS and the point load test has long been recognized as a useful tool in this regard. Although the point load test has also been used for other purposes by researchers, its potential has not yet been fully utilized in routine rock engineering environment. This article presents a comprehensive review of the point load test in rock material characterization. Starting with the background of the test, the review focuses on different issues such as correlations of point load strength index with UCS, response of the test to rock anisotropy, estimation of fracture toughness by the test and use of the test in categorizing weathering grades. The article also recommends a few salient points for plausible improvement of the test procedure in order to obtain more reliable and reproducible test results than that achieved by following ASTM and ISRM stipulations and thus to enhance the applicability of the test in rock engineering.

Paper No: 135

Petrographic studies of concrete aggregate in Engineering Geology Applications

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Two important constituents of the concrete that is commonly used in engineering constructions, are the portland cement and a silicious aggregates. Alkali aggregate reaction causes concrete cracking that results in significant damage to the concrete structures. There are two types of alkali aggregate reactions, the alkali-silica reaction and the alkali-carbonate reaction, depending on the presence of certain silicious or carbonate aggregates respectively, in concrete. The former is most common. Product of the reaction is a gel that absorbs water and increases in volume and the swelling pressure ruptures the aggregate particles and causings cracks. Some strained quartz may cause a deleterious alkali-silica reaction if present in sufficient amounts in concrete aggregate. Petrographic techniques help in study of deleterious constituents, including the strained quartz which is a constituent of many rock aggregates used in engineering constructions, and for identification of microscopic features indicating deformation and alteration.

Paper No: 136

A critique on the petrographic detection of potentially deleterious minerals in aggregates and its significance in Engineering Geological studies in the Indian Context

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Aggregate together with lime – alkali paste (cement) forms the fundamental framework of any concrete structure. Presence of certain minerals and their forms destabilizes the concrete structures over a period of time. The main deleterious materials are certain forms of silica. Dolomite can also be a major deleterious material in the aggregates. These materials deleterious in the sense, they react with alkali hydroxides of the cement and cause expansion and cracking over a period of time. Reactive minerals and their forms can be identified by petrographic examination. Petrographic detection of deleterious minerals in aggregates is cost effective; can be done with in a short time and can be performed as a first step to screen the aggregates for concretes before proceeding for elaborate tests.

Paper No: 138

Geophysical Investigation For Ground Water In Yawal Taluka Of Jalgoan District, Maharashtra.

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The present area under investigation of Yawal Taluka is located towards northeastern parts of Jalgaon district in Maharashtra State. The total geographical area under study is about 95435 hectares. The area is covered with undifferentiated Quaternary sediments and exhibits an undulating topography with southward gradient. The existing land use pattern of the area clearly shows that more than 60% of the area is utilized for agricultural sector. This area is famous for banana and sugarcane plantation. Ground water is the major source of irrigation and domestic purposes. A hydrological investigation was carried out with the help of the well inventory data and utilizing geophysical techniques. Data obtained from resistivity in Yawal Taluka of Jalgaon district in Maharashtra State, were interpreted by the Inverse-slope method of Sanker Naraan and Ramanujachari. Resistivity, values obtained showed a variation of between 0-3 ohm-m for clay/silt,3-5 ohm-m for medium grained sandy layer, 5-7 ohm-m for loose sand and gravel bed, 7-15 ohm-m for clay with pockets of sand ,15-25 ohm-m for clay with lenses of sand, 25-45 ohm-m for compacted clay with pebbles, cobbles,gravels,40-60 ohm-m for compacted clay beds, and over 60 ohm-m for hard and compacted litho logical units, sites were recommended for dug wells/bore wells, 90% of which proved to be successful.The litho logs from the dug wells were correlated with investigation data. The North-South cross-section of VES (Vertical Electronic Soundings) data indicates that typical behavior of alluvial, (i.e. clay beds are generally pinches out towards north direction) is discussed. The authors conclude the paper with the opinion that the geophysical studies play a vital role in the development of the area for better environment in future.

Theme-8: Post Construction Issues

Paper No: 127

Geotechnical appraisal of post construction problem of Vagetikona irrigation tank, Cuddaph district, Andhra Pradesh

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The paper deals with the post-construction problems for the 9.67 m high and 2.0 km long earth dam constructed across the Vagetikona river in Cuddapah district, A.P. to store 281 mcft of water which was not holding water since its commissioning. The studies revealed that the cut-off for the earth dam was not provided during the construction and an upstream auxiliary cut-off provided to a limited stretch rests on bouldery zone. The field investigations led to suggest mainly (1) to extend the upstream auxiliary cut off trench to be raised from the bed rock level up to the right flank hillock followed by grouting the bed rock. (2) to reestablish whether the already provided auxiliary cut off trench has been taken down to impervious bedrock or not (3) to remove the 1.20 m thick flood plain deposit formed above FRL in front of H.C. Weir, which is obstructing the surplussing arrangements and (4) to study whether the existing surplus arrangement is adequate for the anticipated flood.

Theme-9: Allied Issues (Reservoir Competency, Interlinking of River basins, Conservation of Heritage works and Dam safety)

Paper No: 71

On reservoir competency of lower Goi project, Khargone district (MP)

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The Lower Goi Project envisages the construction of a 2211.20 m long and 41.40 m high earthen dam across river Goi (21°54'30" : 74°55'30"), a tributary of river Narmada in Barwani Tehsil, Khargone district, M.P., for irrigation purpose (toposheet 46 K/13). Geotechnical investigation carried out in proposed submergence area of about 11 Sq km for the assessment of the reservoir competency has revealed the presence of 9 "Aa" type flows of Deccan basalt within the FRL (298.00 m) traversed frequently by basic dykes and overlain by river alluvium up to 25 m thick. The basalt flows comprising dark grey, fine grained, dense aphyric to moderately porphyritic, massive basalt and fragmentary top zone provide, by and large, a suitable lithology from reservoir lightness point of view. No interfluve pervious zone or water divide is present in the proposed submergence area. Flow junctions, red bole horizons, and localized faults are unlikely to cause any outlet for reservoir water in the adjacent basin/channel due to favourable topography. Of the seven sets of joints recorded in the area, ENE-WSW and NNW-SSE trending joints form the predominant and persistent fractures. The former is parallel to the Narmada mega lineament where as the latter cuts across it. These are mainly open joints spaced 6 cm to 2.5 m apart with an aperture of <1 mm to as much as 20 cm. They are sometimes filled with clay or chert, and opening are generally smooth to rough. These may facilitate some loss of water but are unlikely to pose any serious problem of reservoir seepage. Other joints tend to become tighter and gradually terminate in the depth. Except along a 20 m high vertical escarpment, a suspected fault escarpment, no other part is vulnerable to land slide. The water table as intersected in the dug wells is 3 m to 10 m deep below the general ground level, a depth shallower than river bed level. One spring present in the adjoining area drains towards the river. Fluviatile alluvium present in the adjoining part of the proposed submergence area will trigger off some siltation which could be augmented to some extent through seasonal nalas reeling down from the adjoining barren hill slopes. These slopes are under active pedeplanation and ploughing for cultivation by villagers in the catchment area. The reservoir area falls in zone III of the seismic zonation map of Inida. It is located about 20 km away from Narmada lineament, an active seismo-tectonic zone. In the light of the seismic history of the area, the possibility of the recurrence of the earthquake tremors of up to 6.5 magnitude is not ruled out in this part in the life time of the project. No known mineral deposits of strategic/economic importance have been reported from the proposed submergence area.

Paper No: 73

A mega lifeline project of Srisailam Right Branch Canal Scheme, Kurnool District, Andhra Pradesh. --- A case study on the Proterozoic limestone foundations with particular reference to the reservoir competency.

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GSI, Hyderabad

The Gorakallu project is a 48 m high and 3645m long composite dam, under construction, across Gurralamadugu stream by Government of Andhra Pradesh.,to create a balancing reservoir of 352.26 M C um (12.44 TMCG) capacity. The geological investigations of the scheme were initiated during the years 1978-79 and continued intermittently up to 1990-91. The detailed geotechnical investigations have been carried out during the years 1991 to 1995 and 1997 to 2000. The main purpose of the investigations was to evaluate the prospects of the reservoir leakage through the two limestone formations, viz., Koilkuntla limestone Formation and Narji Limestone Formation of the Kurnool Group of Proterozoic Age, covered by thick alluvium along the dam axis and to assess the competency of the reservoir with respect to the Narji limestone Formation exposed all along the right reservoir rim over a length of 5 km. Of the two, the Narjis are more cavernous in general, and are known for the presence of some caves in the southern part of the project area. It had been very difficult to quantify the extent of the site investigations in cavernous limestone terrain of this nature. Identification of underground solution features, unraveling the geometry and establishing inter connections are not, did constitute the most unpredictable objectives of such prolonged investigations. However, all out effort was made, direct or indirect, besides conventional subsurface explorations, for a comprehensive analysis of the terrain. Evaluation and analysis of the data obtained from published geological maps, survey of available literature, study of aerial photographs and land-sat imageries, several reconnoitry traverses, detailed geological mapping, hydrogeological and geophysical ,subsurface exploration and intensive local inquiry were made to assess the competency of the reservoir. The dam site is located across a broad E-W trending valley with a high land towards north and cuesta in the south. The valley floor, with a general elevation of 221m, is 1600m wide at the mouth and narrows down to 110 m upstream and is covered with colluvium and alluvium. A narrow, linear educational hillock made up of fractured quartzite is exposed in the middle of the valley. Low dipping Narji limestone Formation, Paniam quartizite Formation and Koilkuntla limestone Formation are present at the dam site in the order of superposition. The high land in the left rim is made up of quartzite while the cuesta in the right rim exposes 55m thick Narji limestone. The koilkuntla limestone is covered below the alluvium. The rock formations are subjected to tectonic activity, the Gorakallu valley has developed along NNE-SSW/N-E—S-W trending fault which is sympathetic to the major regional Gani-Kalwa fault, located at 9 km north of the dam site. The detailed mapping revealed five distinct horizons within the Narji limestone Formation exposed in the right rim. The solution features were more prominent in the II and IV horizons. No major cavities were discernible in the entire exposed stretch. Detailed subsurface exploratory programme by way of a number of deep boreholes and wide trenches revealed that the northern slopes of the right rim are affected by deep and selective chemical weathering , manifested by insitu marly clay, kankar and windows of unweathered limestone. The total thickness of the Narjis is +90m, of which 50m is exposed and 40m covered below the alluvium along the axis. A great variation in lithology, facies was distinct. The solution features are of small scale ,like small sinkholes, collapse zones, hemi spherical pits, anatomizing pipes and grikes and they are more pronounced along the sheared, fractured and fault zones. The occurrence and movement of ground water is confined to such zones in the bedrock. The most significant feature at the dam site is a major fault trending at right angles to the dam axis in the valley, separating the two major limestone formations. It is now established to be a reverse fault, with 30-40 dip towards left side and the Narji limestone Formation has been dragged up, the throw of the fault being +95m. The fault zone, about 300m wide, has greatly influenced the development of karstic/solution features of the terrain. The Government of Andhra Pradesh has taken up the construction of the project under the turn key E PC system during the year 2006 and it is now in advanced stage of construction, as majority of the geotechnical issues are resolved at a depth of 20 to 25 m below the valley floor. Although the investigations have been conclusive, the several riders put forth in the geotechnical reports, have led to a meticulous designing of the various components of the dam. A foundation gallery in the earth dam, at the bottom of the impervious cut-off and a depleting sluice are provided in the dam design to cater to the foundation treatment in case of any remote possibility during the operation of the reservoir. During the initial operations, some loss of water is anticipated through the right rim and the reservoir is expected to stabilize by a couple of filling seasons. As such, no treatment measures are envisaged for the exposed limestone strata, for the time being.

Paper No: 126

Solution features in Narji limestones of Cuddapah Super Group and their bearing on the geohydrological set up and competency of water bodies

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Limestone especially cement grade, is in much in demand in recent years because of skyrocketing activity of construction of superstructures. However, when they form the foundations they are least preferred because of apprehension of solution features, cavities or karstification. Andhra Pradesh is rich in such limestone resources, especially Narji Limestones of Cuddapah super group and Koilkuntla limestone of Kurnool group. Some of the variants of these limestones have developed solution features, cavities depending on their physical and chemical nature and geochemical environment. The geometry and magnitude of such features and their influence on geohydrological set up or competency of reservoirs/tanks like Bangampally tank and owk reservoir constructed over them are discussed.

Paper No: 91

Geotechnical appraisal of the river linking projects of Sankosh-Tista, Tista-Ganga link canal, West Bengal and Bihar

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The paper discusses the results of geotechnical investigations on the feasibility of transferring surplus water of the extra-peninsular Ganga-Brahmaputra basin to the peninsular southern and Western India for mitigating the water scarcity. The links envisage diversion of 43,208 MCM of water annually to Ganga. The 349km long Sankosh-Tista and Tista-Ganga (ST & TG) link canal is a part of the 457km long Manas-Sankosh-Tista-Ganga (MSTG) link project. The study includes geological mapping, geotechnical assessment of CD structures, high cutting and filling sections, fall points etc. in addition to preparation of map based on satellite imagery and study of geotechnical parameters of the soil samples and ground water. The proposed canal alignment is passing mostly through the Quaternary surfaces and partly through the Pliocene sediments. Keeping in view the far reaching effects of linking the trans-boundary rivers and their possible impact on scientific aspects in the long run have been critically studied. The data generated on geology and engineering properties of the foredeep sediments, over which the canal alignment is proposed, is analyzed and relevant conclusions drawn. The compiled post monsoon water table data surmises a general laminar flow towards south with some local variations. The sudden change of sinuosity pattern of the few present day river meanders indicate that the river morphology is subjected to neotectonic activity. The satellite imagery indicates that the major tributary rivers follow NW-SE trending mega lineaments and the major fracture system in adjoining West Bengal and Bihar trends ENE-WSW. The geotechnical parameters of UDS samples indicate that the soil to be within ML and MI group, which is sandy to silty with good porosity. The relevant aspects of the River Linking Project have been analyzed with due consideration to the environmental, engineering and neotectonic parameters and their impact on ground water recharge. Remedial measures on depletion of shallow and deep aquifers at downstream of the rivers have been discussed. Stress has been given on the aspects of ground water recharge in probable basins keeping in view of its depletion through the river linking project.

Paper: 123

Geotechnical feasibility study of inter basinal water transfer through link canal in respect of Chunar-Sone in parts of Kaimur & Roht as districts of Bihar

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The 148 km. long Chunar-Sone link canal envisages diversion of 5918 million cubic meters of water from the Ganga basin in Uttar Pradesh to the Sone basin in Bihar, to stabilize, intensify and extend irrigation in the regions lying to the South of Ganga and

West of Sone river and for the mutual benefit of the two neighboring states. This inter-basin and inter state water transfer will help in controlling flood in parts of U.P. on one hand and cater to the requirement of Sone barrage and fill the deficit of Sone at Kadhwan Dam in Bihar on the other hand. The proposed canal off-takes from the right bank of the river Ganga about 5 km SW of Chunar town at FSL 60.00 m and involves lifting of the water in four stages while traversing a distance of 148 km before out falling into the reservoir of the Sone barrage at FSL 108.44 m The studied area can be broadly classified into two distinct geological domains, viz. (i) Middle Proterozoic sedimentary sequence of the Vindhyan Supergroup and (ii) unconsolidated to semi-consolidated alluvial sequence of the late Pleistocene to late Holocene age. The execution of the proposed canal and its appurtenant structures will involve strata composed of clay, silt, sand and their hybrid variants. The study was conducted with the following objectives: a) Identification of spots where deep open excavations may cause or initiate slope failure and work out necessary protective measures for reaches where deep excavation is unavoidable. b) To avoid deep excavation in hard massive rocks for canal and explore the possibility of tunnelling through such rock mass as an alternative. c) Geotechnical evaluation of the sites of major and minor cross drainage (CD) structures. The paper incorporates the inputs from photo interpreted lineament study of the entire canal stretch, geological mapping on 1:50,000 scale, covering] km on either side of the proposed canal, detailed mapping on 1:1000 scale of most of the major CD structures, slope stability study of the areas where deep excavation will be required, collection of soil samples for determination of various geotechnical parameters, fixing of drill hole points for subsurface exploration for exploring the possibility of making a tunnel instead of deep excavation in hard rocks and assess groundwater behavior etc. On the basis of studies carried out so far, the link canal prima facie seems feasible from the geotechnical point of view.

Paper No: 36

Geotechnical aspect of heritage site and monument conservation

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Conservation of the invaluable remains of our cultural heritage in rock is complex in practice due to the wide variety of materials, construction, and technology used among monuments, as well as the stringent demands the conservation principles make on any intervention. Environmental effects and human actions, including pollution, have damaged the archaeological monuments. With growing interest in conservation of rapidly decaying monuments, many of the masterpieces have been declared 'World Heritage' by the UNESCO. Since materials and processes of the geoenvironment constitute, support and/or damage the monuments, geological study is basic and vital for their long-term conservation. The geotechnical aspect of monument conservation work, including the methods and techniques of study and ground improvement/protection, is no different from that of construction or mining activity, in principle. However, there are some differences mainly on account of their special features and needs, which make the conservation more complex and challenging than the normal geotechnical work.

Geotechnical conservation of rock monuments seems a less visited field in India. A beginning towards conservation of rock-cut monuments in our country was made with the multidisciplinary study of Ajanta and Ellora world heritage monuments, by the Geological Survey of India in 1998. Considering our archaeological wealth, creation of specialization and specific, intensive resources for detailed evaluation and conservation, is essential to meet the challenge of securing the future of the past.

Paper No: 30

Engineering geology in dam safety Vidharba region, Maharashtra

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Dams are playing an important role in the human and animal development .The Socio-economic benefits derived from dams are power, irrigation, municipal and industrial water supply, improved navigation, flood control, recreation and fisheries etc. Once constructed they tend to last for years and serve the purpose with full efficiency. More than hundred old, Major, Medium and Minor dams exists in Vidharba region of Maharashtra. The health of some of the dams has been checked. Deficiencies have been noticed in their functioning. Engineering Geological investigations for them is being carried out in three phases. Phase I, covers collection of data for preconstruction to construction stage of the project, including hydrology and seismicity. In Phase II, inspection of the site is done to assess the general condition of the dam, determine the need for any additional geological and engineering investigation. Phase III, consists of checking the functioning of the scheme after the implementation of the suggested corrective measures and also to observe the response of the dam to treatment measures. Deficiencies are observed in the dams located in the rock formation ranging from Archaen to Quaternary. The observed deficiencies are, chocking of foundation drains, wetting, seepage and leakages, undercutting, erosion, formation of pits and retrogration, subsidence collapse and washing out of the structure. Based on damages/deficiencies in the structures, they are categoried nominal to very severe and the treatment measures suggested on priority basis for implementation. On the basis of above studies, it is emphasized to make it mandatory to prepare and perverse the engineering geological data for all the engineering structures, also for protecting the dam structures use of latest and innovative techniques like geomembranes and new blended cement techniques are advocated in the paper.

Paper: 50

An appraisal of hydropower development and its constraints in North East India

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The pace of economic development of a country depends on the status of infrastructure, of which, power form an important component. Hydropower being cheap, eco-friendly and renewable source of energy has to be developed to the extent possible so as to have a sound infrastructural base. However, despite the fact that India is bestowed with vast hydropower potential, a considerable population of India, even in this modem era is still deprived of this basic necessity. As per estimates, the present hydro-thermal ratio in India is 25:75 against the ideal ratio of 40:60. The total identified hydroelectric potential of country upto March 2008, as per the reassessment study of Central Electricity Authority (CEA), Ministry of Power is 148701 MW which is envisaged to be harnessed through hydroelectric schemes. Out of this 148701 MW, a mega share of 40% (58971 MW through 145 identified projects of different installed capacity) alone is stored in the North Eastern Region of India comprising seven sister states. Against this gigantic capacity of 58971 MW in North East India, only 2.04% (1202.7 MW) has so far been developed and another 4.62 % (2724 MW) is in various stages of development. In addition, about 2000 MW installed capacity also exists in this region which can be tapped through micro, mini and small hydro schemes «25MW). In other words, although, North East India is blessed with huge hydropower potential, still 93.42 % (56955.3 MW) of its total installed capacity is yet to be tapped. This abysmally slow rate of development is attributed to various reasons, like; low internal demand due to economic backwardness, almost nil existence of infrastructural facilities and problems related to evacuation of power. All the 145 hydroelectric projects proposed in North East India (>25MW) during the reassessment study by CEA are located in the basins of Brahmaputra and Barak Rivers and are to be housed in diverse and complex geological domains. These domains including Himalayan Domain; Mishmi Block; Brahmaputra Plains; Shillong Plateau & Mikir Hills and Indo Burmese Arc with characteristic geological and geotechnical constraints and coupled with high seismicity (Seismic Zone V, as per map of India showing Seismic Zones (IS 1893 (Part I): 2002) pose a great challenge to the development of hydropower and therefore, in turn have greatly affected the rate of hydropower development in the country. The paper discusses the existing status of hydropower potential and its development in North East India and the various constraints likely to be encountered in different domains in North East region in developing hydroelectric projects in these regions. These include difficult geographic terrain and complex tectonics, geology, scarcity of suitable construction materials coupled with other factors like; inaccessibility of project sites, poor infrastructure facilities, difficulties in power evacuation, etc. Various geological, geotechnical and other constraints likely to be faced in each of the five geological domains mentioned above are discussed in details for constructing a dam, water conductor system, power house and its various other appurtenant structures.