Chapter -05 . Literature survey for three dimensional excavation using finite element method

A Number of published materials are available where in finite element method has been successfully employed in the analysis of excavation .Most of these concern three dimensional excavation tunnel excavation using finite element method ,while one interesting published materials gave understanding of three dimensional effects in excavation using model tests and numerical simulations was reported in 2011 .

The finite element analysis of earth retaining structure problems in non linear partially saturated soil was reported by Dr Hassanein F. Hassan, Saif M. Jawad in the year of 2012 .The presentation was made for the finite element formulation of the incremental Biot’s theory of consolidation .This formulation was extended to represent the non linear time dependent behavior of the earth retaining structures in partially saturated soil. The concept of thin layer element was incorporated to saturated soil. The concept of thin layer element was incorporated to simulate the behavior at the interfaces between the soil and retaining structure .The result obtained were comparable to the observed field results .Based on the above analysis, the present case study was in coorporated to the formulation as well as the finite element modeling .The stability of the vertical excavation might be achieved ,If the critical excavation was modeled based on the thin layer element concept. The larger or thicker element layer were applied at the far end ,but the excavated surface of the vertical cut was subjected to the thin layer which gave an exact approach for the analysis ,was the modern approach.

The earth pressure in trench rescue shoring system was reported by La Baws ,Aggour M in the year of 2012. The study showed that most significant effect on earth pressure was the strut loading .It was found that the magnitude and distribution of the soil pressure on shallow trench bracing was significantly different from that determines by the currently accepted one used for braced deep excavation .A method for calculating earth pressures on shallow trench bracing was developed that determined the earth pressure as a function of struts loading. It could be used to determine.

Three dimensional effects in excavation problems of model tests and numerical simulations was reported by Teruo Nakai, Hossain Md. Shahin, Naoyuki Iwata, Eunsu Sung and Masaya Hinokio in the year of 2011. In order to investigate the fundamental mechanisms of the generation of earth pressure and the ground movement in excavation problems such as tunneling and open excavation, two dimensional and three dimensional model tests and the corresponding elastoplastic finite element analyses were carried out. It was experimentally shown that the earth pressure and the ground movement were very much influenced by three dimensional effects including excavation sequence. In tunneling problems, not only the arching effect in transverse direction to tunnel axis but also the arching in excavation direction should be considered for proper predictions. In retaining wall problems, the earth pressure on the wall in three dimensional condition was much smaller.
than that in two dimensional (plane strain) condition, and the surface settlement at the backfill in three dimensional condition occurs more locally than that in two dimensional condition. These differences between three dimensional and two dimensional were simulated quantitatively as well as qualitatively by the analyses using an elastoplastic constitutive model which could describe typical stress. These models were used for analyzing the present problems and understanding the constitutive model.

Three dimension modelling of a tunnel re-excavation in soft ground was reported by M. Hilar, in the year of 2011. The construction of the shallow tunnel at Brezno started using the Pre-Vault Method. The tunnel excavation, uncomplicated geological conditions, led to many difficulties which finally resulted in a collapse, when a significant part of the temporary tunnel lining collapsed gave an understanding the excavation in complicated geological condition. Various options for re-excavating the tunnel were evaluated prior to further construction. Finally a decision was made to separate the collapsed area into sections 9 m in length using 16 m-wide, transversally oriented pile walls, to improve the stability of the collapsed ground. The walls were constructed from the surface prior to excavation. It was also decided to re-excavate a collapsed area using the sprayed concrete lining method. Due to problematic soft ground conditions, which had been made even worse by the collapse, some additional support measures had to be considered prior to re-excavation (ground improvement, micropile umbrellas embedded into the pile walls, etc.).

This paper describes numerical modelling of the tunnel re-excavation through the collapsed area. Initial calculations of the tunnel re-excavation were made using a 2D finite element method. Subsequently, further calculations to evaluate the rock mass behaviour in the collapsed area were provided in three dimension. The two dimension calculations were used to provide sensitivity studies of the current study of three dimensional excavation using finite element method, while three dimensional modelling was mainly used for evaluating the tunnel face stability (impact of the pile walls, impact of ground improvement) together with other factors (length of advances, moment of the temporary invert closure, etc.). The results of the modelling were compared with the monitoring results. The paper also briefly described the construction experience gave the understanding of technical problems, performance of various support measures, etc.

Stability charts for three dimensional failures of steep slopes subjected to seismic excitation was reported by Radoslaw L. Michalowski and Tabetha Martel J. Geotech. Geoenviron, J. Geotech. Geoenviron in the year of 2011. Design of slopes and analysis of existing slopes were carried out routinely using approximations of plane strain and substitution of quasi-static load for the seismic excitation. A three-dimensional analysis of slopes was used here, based on the kinematic theorem of limit analysis. A three dimensional rotational mechanism with a failure surface passing through the slope toe was developed, applicable to steep slopes. A quasi-static approach was used and an example of charts for the assessment of the factor of safety for slopes with predefined width of the failure mechanism was taken for understanding of failure mechanism developed during steeper slope of the
excavated slope. Critical acceleration was also calculated for three dimensional slopes, and a sliding block analysis was carried out to develop a solution for displacements of slopes subjected to seismic excitation.

Three dimensional settlement analyses of the tower of Pisa was reported by Klettke, A. and L. Edgers in the year of 2011. This paper compares and evaluates settlement analyses of the tower of Pisa by two dimensional and three dimensional computer models. The tower of pisa had been an important settlement case study for more than a century, previously modeled using one dimensional consolidation and more recently two dimensional and three dimensional finite element analysis. The structure was symmetrical, but was subjected to non-symmetrical loading, because of its inclination. The tower's symmetry allows a two dimensional plane strain analysis to model its tilt, but the magnitude of the settlement must be calibrated for the difference between plane strain and axisymmetric loading. The results of the calibrated two dimensional and three dimensional analysis showed excellent agreement and both agree reasonably well with the estimated actual settlements and tilts. However the three dimensional analyses require longer execution times and greater amounts of execution time than the two dimensional analyses. Based on the study the matrix sizes for the analysis might be reduced by adopting the element numbering. The better understanding for analyzing the complicated design of the bandwidth in analysis to avoid the delay in computation.

Use of a line of piles to prevent damages induced by tunnel excavation was reported by Emilio Bilotta and Gianpiero Russo J. Geotech. In the year 2011. Buildings founded in proximity to shallow tunnels under construction may be damaged by the ground displacements induced by tunneling. This was a matter of concern for design, and a variety of protective interventions were currently adopted to prevent such damages. Among these, rows of piles or jet-grouting columns were widely diffused. In this paper, the effectiveness of a simple row of piles was computed by means of three-dimensional (3D) finite-element (FE) analyses, thus allowing the investigation of the relationship between performance and some simple geometrical parameters, such as the spacing among the piles. The results of centrifuge tests were reported and used as a benchmark. The potential damage had been quantified in this work, taking into account both the settlement profile and the horizontal strain induced at the ground surface by tunneling. It was shown that although the settlement reduction was significant only for very small spacing ($s = 2–3$ pile diameters), even largely spaced piles ($s = 5–6$ pile diameters) were useful to prevent damage to buildings because of the significant reduction of the average horizontal strain.

Limit analysis and stability charts for three dimension slope failures was reported by 2010. The kinematic approach of limit analysis was explored in three-dimensional stability analysis of slopes. A formal derivation was first shown indicating that, in a general case, the approach yields an upper bound to the critical height of the slope or an upper bound on the safety factor. A three dimension failure mechanism was used to produce stability charts for
slopes. The slope safety factor could be read from the charts without the need for iterations. While two-dimensional analyses of uniform slopes lead to lower safety factors than three dimension analyses do, a three dimension calculation was justified in cases where the width of the collapse mechanism had physical limitations, for instance, in the case of excavation slopes, or when the analysis was carried out to back-calculate the properties of the soil from three dimension failure case histories. Also, a three dimension failure could be triggered by a load on a portion of the surface area of the slope. Calculations indicate that for the three dimension safety factor of the loaded slope to become lower than the two dimension factor for the same slope, the load had to be very significant and equal to the weight of a soil column.

The finite element analysis of an offshore wind turbine was reported by Hearn, E. N. and L. Edgers in the year of 2010. The interesting technical paper for understanding of large diameter monopile foundations for offshore wind turbines were subject to large horizontal loads and overturning moments. These foundations had diameters ranging from four to seven meters with the potential to become larger with the development of larger wind turbines. They were often analyzed by means of the p-y method to characterize the pile-soil interaction. While the method was theoretically rigorous, the input p-y curves, for example those recommended by the American Petroleum Institute (API) were based upon very limited field data. This paper described some analyses of a large diameter monopile in dense sand. The pile characteristics were representative of the foundations for a 3 to 5 MW wind turbine. The soil characteristics were representative of dense sandy soils that might be encountered at wind farm sites in the southern North sea and offshore the Northeast United States. The pile was modeled by the p-y method and also by three dimensional finite element analysis (FEA). The paper gave understanding the details of the FEA model development, important in minimizing numerical inaccuracies in three dimensional analyses. Equivalent p-y curves, back-calculated from the three dimensional FEA, might be useful for p-y analyses, which were simpler than three dimensional FEA. The results suggested that the API method over predicts soil resistance and under predicts pile deflection for large diameter monopiles subjected to lateral load and in stiff soils.

Numerical modelling of borehole water-inflow tests in the foundation of the Alqueva arch dam was reported by M. L.B. Farinha, J. V. Lemos, E. Maranha das Neves in the year 2010. Borehole water-inflow tests allow to understand of measurement of discharges and water pressures in isolated sections of drains and piezometric boreholes. A series of water-inflow tests and water electrical conductivity analyses were carried out in an area of the foundation of an arch dam. Detailed three-dimensional numerical models developed for the analyses of the test data in two foundation areas were presented. Results of rock mass permeability tests and areas where seepage paths cross each drain, identified with both water-inflow tests and water electrical conductivity analyses, were taken into account. Models were validated against flow rates and water pressures recorded in situ. By examining water-inflow tests using numerical models, the main flow processes are identified and quantified. Test results and conclusions drawn from the detailed three-
dimensional models were used to elaborate a global model of the foundation. The present study showed that borehole water-inflow tests add valuable information to the usual monitoring data, which improved our ability to analyse the behaviour of concrete dam foundations. It was also concluded that although discontinuum models provide a more natural representation of flow in jointed rock masses, equivalent continuum models can still be used successfully to study both global and local hydraulic behaviour of dam foundations.

The three-dimensional numerical modeling of a piled embankment was reported by Orianne Jenck, Daniel Dias, and Richard Kastner in the year 2009. The case study provided the understanding of a soft ground mass improved by vertical stiff piles, using a finite-difference continuum approach for three dimension. Arching occurs in the embankment granular material, leading to load transfer onto the piles and surface settlement reduction and homogenization. The embankment, the piles, and the soft ground were explicitly taken into account in the proposed numerical model. First, a unit cell from the pile grid was considered. Two sorts of soft clay deposits and two embankment materials were successively modeled. The soft soil behavior was simulated by the modified Cam Clay model and the embankment material behavior was successively simulated by an elastic perfectly plastic model with a Mohr–Coulomb failure criterion and then by an isotropic hardening elastoplastic model, the CJS2 model, in order to approach the real system behavior. The calculations were performed in drained conditions, simulating the long-term behavior. The impact of the soft soil deposit compressibility and of the embankment material characteristics were underlined. The academic case of a current embankment section including lateral slopes was then simulated. The embankment was 5 m high and 44 m wide and the lateral slopes had inclination of 26°. The piles were now subjected to horizontal movements.

Two and three dimensional analysis of a slope failure in a lignite mine was reported Levent Tutluoglu, Ibrahim Ferid Oge, Celal Karpuz in the year 2010. The understanding of field investigations, laboratory testing and back analyses were vital instruments for the input parameters. This study presents the results of slope stability analysis via finite difference code and a limit equilibrium software for the soil slopes of the Elbistan–Collor lignite mine. The basic input parameters, cohesion and friction angle were determined in the soil mechanics laboratory. By back analyses of a large scale slope failure, mobilized friction angles for a critical weak clay layer under the lignite seam were determined accurately by using the two dimension limit equilibrium method and three dimension finite difference models. Results of the friction angles were compared in order to check the effectiveness of commonly used two dimension approaches in handling the slope problems. Differences in the results of the mobilized friction angles for the weak clay layer were more than 30%. The three dimension models indicated that the mobilized friction angle during the major slope failure was substantially lower than the friction angle generated by the two dimension limit equilibrium method.
Analysis of capacity of suction anchors in clay by three dimensional element analysis was reported by Edgers L.L. Andersen and H.P. Josted in the year 2009. This paper gave understanding of the use of three dimensional finite element analysis (FEA) to compute the undrained capacity of a suction anchor in clay. A particular issue that this study focused on was use of interface elements to model the possibly reduced strength and slippage along the soil-structure contact surface. The suction was first analysed as plane strain problem followed by full three dimensional analyses of a 5m diameter suction anchor. The studies included an evaluation of the effect of the wall interface strength and comparison with approximate calculation. The paper gave an understanding of strategic use of mesh refinement procedures, interface elements and symmetry greatly reduce the discretization errors associated with finite element analysis. Isoparametric interface elements were required to accurately model the soil–anchor.

Application of large three-dimensional finite element analyses to practical problems was reported by F. H. Lee in the year of 2008. This paper provides understanding of the usefulness and feasibility of three-dimensional finite element analysis in geotechnical engineering practice. The usefulness of three-dimensional analysis was illustrated through two examples. The feasibility of such analyses was then understood by reviewing some recent numerical developments, which allow large-scale analyses to be conducted using relatively modest computational means. The understanding of finite element analyses had been assuming an increasingly important role in the geotechnical consultant’s office. However, to date, most of the analyses conducted in geotechnical engineering practice were still restricted largely to two-dimensional analyses. Many practical geotechnical problems were inherently three dimensional. This paper discussed the usefulness as well as the feasibility of three-dimensional analyses in geotechnical engineering practice. By means of several case histories, the usefulness of three-dimensional analysis would first be demonstrated. The feasibility of bringing large three-dimensional analyses within the reach of practising geotechnical engineer was then explored by considering some advances in numerical technology which allows relatively large three-dimensional problems to be solved using desktop personal computers (PCs) within reasonable turnaround time.

Research into three-dimensional geotechnical finite element analysis started several decades ago. One of the first applications was understood in building excavations. This stems from the recognition that, in reality, many excavations especially those constructed for building basements, were three-dimensional in geometry, and significant three-dimensional effects might arise from lateral arching of the retained soil and lateral flexure of the wall-waler systems between corners. In the last fifteen years or so, three-dimensional analyses relating to corner effects in basement excavations had been increasingly explored in research and high-value engineering projects was reported. Finno and Harahap, in the year of 1991, Wong and Patron, in the year of 1993, Ou and Chiou, in the year of 1993, Lee et al., in the year of 1995, Lee et al., in the year 1998. All of the above interesting studied to understand building basements and many relate in some ways to corner effects. Apart from the above, three-dimensional effects had also been reported in other situations. The soldier-piled excavations were understood for analyses using two dimensional finite element analyses with properties that were averaged over a certain span of the wall. Hong
et al. (2003) noted that such an approach could give rise to modelling errors in several ways. Firstly, by modelling the discrete soldier piles as a wall, a two dimensional analysis tends to over-predict the coupling to pile to the soil below excavation level, thereby under estimating soldier pile deflection. Secondly, the deflection of the timber lagging was reported and better understanding which was usually larger than that of the soldier piles, was often underestimated. The understanding of a two dimensional analysis could not replicate the softening of the soil face just behind the timber lagging. In instances where the timber lagging was insufficient or its installation delayed, this softening could give rise to local collapse, which might exacerbate the ground loss and therefore ground movement. Increasing the inter-pile spacing would tend to accentuate the effects of these modelling errors. Another instance was tunnel headings, which had been recognized for a long time to be a three-dimensional problem. Simulation using two dimensional analysis often required artificial measures to limit tunnel wall movement was one of the interesting analyses. The above explanation provide better understanding of three-dimensional effects could manifest themselves in a wide variety of problems. Indeed, one might wonder, if most problems were not only essentially three-dimensional but do have significant three-dimensional effects.

Effect of grain size and thermo-mechanical properties of minerals on strength reduction of binary ores subjected to microwave radiation was reported by Ali, A. Y., and S. M. Bradshaw, in the year 2008. The finite element analysis could run in two dimensional or three dimensional was used for geotechnical applications in determination of tunnels, deep foundations, slope stability, seepage analysis, soil structural analysis and capacity for earth retaining structures. The finite layer analysis of consolidation founds application in determination of settlement behavior of material as a function of time subject to either uniform torque or rectangular forces that act on a surface. The numerical analysis using finite layer analysis of consolidation results into determination of stress, level of displacement or pore pressure subject to user specific points and times. Thus finite layer analysis of consolidation was a function of time and specific point. The finite layer analysis of consolidation three dimension had capacity to contribute into simulation of sufficient strain behavior on a structure that was supported by the soil or a continuous plastic material that could exhibit plastic properties when the material attained yield limit. Thus finite layer analysis of consolidation found application in determination of geomechanical properties of continuum problems and involved tasks like excavations, backfilling and loading. The finite layer analysis of consolidation had been determined a fast lagrangian algorithm Code that made use of finite difference technique to determine geomechanical problems subject to time and specific point of stress on a surface of continuum material that exhibit.

This paper presents the shoreline slope stability analyses performed as part of seismic vulnerability studies for the San Francisco transition structure (SFTS) of the bay area rapid transit system trans bay tube (TBT) system was reported. Wei-Yu Chen, Jacob Chacko,
ESTIMATION OF STRESSES DURING VERTICAL EXCVATION USING FINITE ELEMENT METHOD

Shahriar Vahdani, and Tom Lee in year of 2008. This paper gave an understanding of the shoreline slope stability analyses performed as part of seismic vulnerability studies for the San Francisco transition structure (SFTS) of the bay area rapid transit system and trans bay tube (TBT) system. The SFTS connects the TBT to the east with Bored Tunnels to the west via multiple degree-of-freedom seismic joints. For these analyses factor of safety and yield acceleration were evaluated by state-of-the-art 3-D finite difference model (FLAC3D) that incorporate both the 3-D variations in stratigraphy and the interactions with adjacent structures. Those analyses also provided critical insights into the mechanism of interaction between slope movement and the various buried structures. The project criteria required consideration of extremely high shaking levels associated with an approximately 1,000-year return period event. The slope deformations were calculated by a decoupled approach consisting of a 2-D equivalent linear site response analyses (Quad4m) and newmark-type analyses, fully-coupled two dimension nonlinear finite element (Plaxis) and finite difference (Flac) analyses. The results of the analyses were used to develop inputs for a project global analyses and helped guide the selection/rejection of retrofit measures for the project.

Three dimensional versus two dimensional liquification analysis of hydraulic fill earth dam was reported by F.G. Ma, J. LaVassar, and Z.-L. Wang, in the year 2008. This project was a 200-foot-long, 63-foot-high earthfill dam that stored water on a seasonal basis. Deformations of the dam induced by strong ground motion and localized liquefaction were analyzed using two and three dimension numerical models. The two and three dimension analyses were conducted using the programs FLAC2D and FLAC3D with the User Defined Model option, respectively. Since the dam spans a relative narrow valley, a three dimension analysis was considered more representative than the 2D plane strain formulation. In both the two and three dimension analyses, soil behaviors were simulated using a bounding surface plasticity model. This constitutive model simulates the shear induced contractive and dilative behaviors of sandy soils in an integrated way. The model was rewritten from the original fortran in C++ and then compiled as a user defined model to achieve acceptable run times. In this case the deformation prediction of the 3D model was considerably less than of the 2D analysis, consistent with expectations.

Three-dimensional asymmetrical slope stability analysis extension was reported by of Bishop, Janbu, and Morgenster, Y. M. Cheng and C. J. Yip in the year 2007. Most existing three-dimensional slope stability analysis methods were based on simple extensions of corresponding two-dimensional methods of analysis and a plane of symmetry or direction of slide was implicitly assumed. In this paper, three dimension asymmetric slope stability models based on extensions of Bishop’s simplified, Janbu’s simplified, and Morgenstern–Price’s methods were developed. Under these new formulations, the direction of slide was unique and was determined from 3D force/moment equilibrium. Results from the new formulations were similar to the classical methods in normal cases but were numerically stable under transverse load. Further, the writers demonstrated that the present formulation was actually equivalent to the axes rotation formulation by Jiang and Yamagami.
but was much more convenient to be used for general problems. The gave understanding to
discovere some inherent limitations of three dimension limit equilibrium analysis which
were absent in the corresponding two dimension analysis.

Numerical analyses of masjed-e-soleiman powerhouse cavern was reported Ahmadi, M. K.
Goshtasbi and R. Ashjari in the year of 2007. The interesting technical paper for
Underground excavations were of immense interest to mining engineers worldwide.Underground projects were often complex in nature where geological features, geomechanical parameters of rock mass and stress play important role. The present research had conducted two dimensional, quasi-three dimensional and three dimensional continuum analyses of the underground excavation of the extension phase at the Masjed-e-
Solaiman hydroelectric project in Iran’s southwestern province of Khuzestan. The effects of weak zones and the formation of multiple openings in the inhomogeneous rock mass have, in particular, had been taken into account during those analyses. This study revealed that two dimensional was more deformed than the other models, whereas three dimensional analysis yields the best results comparable with in-situ measurements.

Slope stability analysis with Flac in two dimension and three dimension in numerical
modeling, was reported by Cala, M., J. Flisiak and A. Tajdus in the year 2006. Topics include
grid generation procedures and guidelines for creating two and three dimension models, overview and example applications of structural element support in two dimension and three dimension, advanced topics in dynamic analysis, and new options in Flac-3D to facilitate model creation and solution.

Development of the retaining wall concept for backfilled stope using finite difference codes was reported by Antonov in the year of 2006. The effect of microwave treatment on the processing of mineral ores was investigated through simulations of microwave heating, thermal damage and confined particle bed breakage test on bonded-particle models. The simulations were undertaken on two-phase mineral ore consisting of a microwave-absorbing mineral in a non-absorbing matrix. The microwave heating was simulated by dissipating a volumetric heat source in the absorbent phase. The progeny size distribution and degree of liberation for the untreated and microwave treated ores after breakage tests were determined by undertaking image analysis of the model outputs. It was shown that microwave treatment at high power density considerably changed the progeny size distribution and enhanced the degree of liberation in confined particle bed breakage tests. It was also found that crushing velocity has a significant effect on both progeny size distribution and liberation, particularly for the ore treated at high power density.

Slope Stability Analysis Using 2d and 3d Methods was reported by Albataineh, Nermeen in
the year 2006. The analysis and design of failing slopes and highway embankments required an in-depth understanding of the failure mechanism in order to choose the right slope stability analysis method. The main difference between the limit equilibrium analysis methods was the consideration of the interslice forces and the overall equilibrium of the
sliding mass. The effectiveness of any slope failure remediation method depends on the
analysis method. The objectives to understand with this thesis were to Perform a literature
review to study the theoretical background of the most widely used 2D and 3D slope
stability methods, perform comparison between 2D and 3D analysis methods, evaluate the
effect of ignoring the side forces in 2D and 3D analysis methods, evaluate the effect of using
advanced slip surface searching techniques on the selection of the most critical slip surface.
Theoretical limitations of the slope stability methods were discussed. In addition, the
limitations were assessed using numerical examples. The studied slope stability methods
included 2D and 3D slope stability methods using limit as well as finite element analysis
methods. Based on the results, more rigorous limit equilibrium slope stability methods
should be used which should consider the side resistance of the sliding mass and the
searching technique for the most critical slip surface.

The assembled geotechnical data include stratigraphy, N-values, sieve analysis, ground
water depth, and sample descriptions was reported by Edgers, L. Sanayei, M. and J. Alonge
in the year of 2005. The till was the bearing material for most structures in the area. The
paper gave understanding of present results on characterizing the till layer using corrected
(N_i)_{60}. By using geostatistical interpolation to characterize the site and process of evaluating
confidence level of predictions. The paper gave an understanding of the confidence in
prediction. The confidence was greater, when using three dimensional characterization
than using two dimensional characterization.

Three-dimensional characterization and visualization of till in Boston was reported by
Massachusetts, Balfe, M.L. G. Baise, and L. Edgers in the year 2005. In order to understand
for evaluation of benefit of using three-dimensional geostatistical interpolation and
visualization methods over two-dimensional methods to characterize a site. It gave of
understanding in assembled a database of densely spaced geotechnical data in downtown
Boston. The study area included several high-rise buildings as well as a 300 m length
segment of the Central Artery/Tunnel (CA/T) project. The stratigraphy of the site includes
artificial fill, organic deposits, marine clay, till, and bedrock. The three-dimensional
characterization maintained the integrity of the vertical variability of the till without needing
to subset the data. Test boring data were grouped into three stages: 1) relevant test borings
completed prior to 1988 (including 79 borings, 2) CA/T test borings (including 33 borings),
and 3) the combined data set. The site was characterized separately for each stage
providing an opportunity to evaluate the effect of boring density and spacing for site
characterization. In three-dimensional was compared confidence volumes for different
stages to show that incorporating prior test borings in the general vicinity of the CA/T
alignment increased the confidence in the overall prediction. Using the CA/T test borings
alone resulted in a predicted model with high variance and therefore low confidence. The
interpolation of corrected (N_i)_{60} values reflects the inherent variability in the test data and
results in a prediction with low confidence levels.

Three-dimensional base stability of rectangular excavations in soft soils using finite element
method was reported by Hamdy Faheem, Fei Cai, Keizo Ugai in the year of 2004. The three-
dimensional base stability of rectangular excavations in soft soils was evaluated using the
finite element method with reduced shear strength for understanding and assessment to
ESTIMATION OF STRESSES DURING VERTICAL EXCAVATION USING FINITE ELEMENT METHOD

implement the case study to present problem. Numerical results indicate that the base stability of excavations was significantly influenced by the following factors: the depth to width ratio, the thickness of the soft soil layer between the excavation base and the hard stratum, the depth of walls inserted below the excavation base, the stiffness of walls, and the length to width ratio of the excavation. The three-dimensional effect could be neglected at the length to width ratio larger than six. Terzaghi's equation for base stability could be used to evaluate the three-dimensional base stability of rectangular excavations after modification.

Study on integration of an analysis of three-dimensional ground movements was reported by Wang Chunxiang, Bai Shiwei in the year of 2004. Three-dimensional strata information system (3DSIS) was a system for storing, managing, checking, manipulating and displaying data which were spatially referenced to the underground strata. But the grids for visualization in 3DSIS were triangular prisms and could not be directly used in finite element method. Based on the principle of mesh generation in finite element method, the reasons were given that the visualization grids in 3DSIS could not be used in finite element method.

A local-whole (L-W) model which was suited to three dimensional visualization and finite element method was put forward. Using the L-W model, the grids were easily changed into the meshes of finite element. The understanding of key points that control the stratum shape were obtained by the topological analysis and then lines and areas were defined and solid model features were generated from the bottom up and then new grids were regenerated. An integration system of 3DSIS and FEM was developed by the method of mixed-language programming using Fortran and Visual C++. The integrated modelling system based on the fortran and c++ was understood for the analysing the present problems.

Rainfall Induced slides of unsaturated slopes, landslides, evaluation and stabilization was reported by Edgers, L and F. Nadim, Rio de Janeiro in the year 2004. In order to evaluate the benefit of using three-dimensional geostatistical interpolation and visualization methods over two-dimensional methods to characterize a site and had assembled a database of densely spaced geotechnical data in downtown Boston. The site was characterized separately for each stage providing an opportunity to evaluate the effect of boring density and spacing for site characterization. The three-dimensional analyses compared confidence volumes for different stages to show that incorporating prior test borings in the general vicinity of the CA/T alignment increased the confidence in the overall prediction. Using the CA/T test borings alone resulted in a predicted model with high variance and therefore low confidence. The interpolation of corrected (N_s)_iso values reflects the inherent variability in the test data and results in a prediction with low confidence levels. The high variance gave an approach of lower confidence for the prediction of modelling. The above paper gave an understanding of proper prediction of modeling with high confidence.

The two dimension and three dimension finite element analysis of underground openings in rock mass reported by K.R. Dhawana, D.N. Singh, I.D. Gupta in the year of 2002. The finite element analysis of the underground openings excavated for Koyna hydroelectric project, Maharashtra, India, had been conducted. The two dimension and three dimension models had been developed assuming that the rock mass obeys Drucker–Prager failure criterion.
The computed deformations and the stress distribution, around these openings, had been compared with the in situ measurements. The study revealed that the two dimension elasto-plastic analysis underestimates the deformations. On the other hand, the three dimension elasto-plastic analysis yields results, which compared reasonably well with the in situ measurements. The effect of weak zones in the rock mass and creation of multiple cavities in the nonhomogeneous rock mass had also been considered in the analyses. Such a study was found to be very helpful for evaluating the stability of underground openings when extensive realistic input data is available for nonhomogeneous rock mass. 3D and 2D model test and numerical analysis of settlement and earth pressure due to tunnel excavation was reported by Nakal Akai, T Xu, L Yamazaki in the year of 1997. Three-dimensional (3D) and two-dimensional (2D) model tests of tunnel excavation problems with two different depths were carried out to confirm the analytical results obtained previously. 3D and 2D elastoplastic finite element analyses corresponding to the model tests were also performed. The model test results were compared with the results obtained from numerical analyses. Through comparison supported by the model tests and numerical analyses, it was determined that a clay foundation results in a large surface settlement and a much wider surface settlement curve than a sand foundation with the same displacement. It was also shown that the settlements were different whether or not the construction procedure was taken into account (3D or 2D) even if the displacements imposed were the same at the end of excavation. In addition, the earth pressures were predicted through numerical analyses. It was concluded that the distribution of earth pressures in the sandy subsoil near the bottom of lowering basement was influenced considerably by the smoothness of basement, dilatancy characteristic and the magnitude of the prescribed displacement.

Study on modeling of three dimensional multi-layer was reported by Mang chunxiang, Bai Shiwei, He Huaijian in the year of 2002. Stratum three dimensional modeling and visualization technology was one of key and hot issues about three dimensional geological simulation research field. Borehole data was the main way to obtain required information about three dimensional stratum modeling. According to drilling data, the method of three dimensional stratum modeling based on multi-layer DEM was proposed. The method determined the sorting of stratum according to arrangement position of boundary stratum point in stratum drilling information and cross division of multi-layer DEM according to stratum lithology, thus form a three dimensional stratum framework that divided by lithology as element in three dimensional space. Considering that the layers of interpolation and fitting might occur pinch point phenomenon, because the layers intersect, the sampling point detection algorithm was proposed and using the fourth-generation language visualization IDL implements a three dimension stratum visualization system software. The above technical paper dealt with the stratum lithology as element in the three dimensional space, gave a fourth generation language visualization and detection of algorithm.

The three dimensional deep excavation using finite element method was reported by Chang–yu ou, chang chiou, Tzong–shiann wu in the year of 1996. The accuracy of the computer program was assessed by analyzing the deep excavation using finite element method. The series of convergency studied were performed to minimize the number of
element and nodes were one of the interesting technical paper for understanding and analyzing the present problem of three dimensional excavation using finite element method. The results of analyses showed the close agreement with field measurements. The understanding of the wall deflection was reported during the excavation using finite element method.

An analysis of three-dimensional ground movements using finite-element analysis was reported Mingfei Li, Atsushi Nakamura, Fei Cai and Keizo Ugai in the year 1991. The advance of a tunnelling shield and the associated ground losses resulting from the tunnelling process was used to calculate the deformations caused by the excavation of the Thunder Bay sewer tunnel. The soil parameters adopted in the analysis were based on the results determined from stress-dependent triaxial tests. The results of this analysis were compared with the measured soil displacements. The reasonable agreement between the calculated and observed An analysis of three-dimensional ground movements settlement distribution and horizontal displacements at different distances from the tunnel face was reported. This overall agreement for displacements under an analysis of three-dimensional conditions suggested that the method of analysis might be applicable to design problems involving tunnelling in soft clays similar to that at the Thunder Bay sewer tunnel provided that the soil parameters were reliably determined. The above technical paper gave an understanding of determination of the soil parameters below the ground surface. The techniques used were three dimensional using finite elements in tunnel excavation.

Approach to automatic hexahedron mesh generation for rock-mass with complex structure based on three dimensional geological modeling was reported by WU Ying-zhou, JI. The understanding of three dimensional modeling and numerical simulation of geotechnique and using the advantage in modeling geological characteristics, precise geological models were provided for numerical simulation software. An approach to three dimensional geological modeling, automatic hexahedron mesh generation was formed based on the section model method. Accordingly a technique for automatic hexahedron mesh of rock-mass with complex structure was realized using multiply mapping mesh. This technique was used successfully on the feasibility analysis of mining under the left bank of Xifei River in Yangcun coal mine. The current method and technology was used in the above problem which elaborate the section model method and multiply mapping mesh.

Three-dimensional modelling of rotational slope failures was reported by Martin Mergili, Wolfgang Fellin. On the other hand, less sophisticated infinite slope stability models were used in combination with Geographic Information Systems (GIS) in order to cover larger areas. The present paper describes an attempt to combine these two philosophies and to come up with a spatially distributed, three-dimensional model for slope stability going beyond the widely used infinite slope stability concept. Both model types were compared using artificial topographies in order to compare the outcomes of different slip surface assumptions and to benchmark the validity of the infinite slope stability model. It was found
out that the resulting factor of safety is highly sensitive to the type of model used and to the slip surface geometry. In complex terrain, the performance of the infinite slope stability model strongly depended on the specific situation, particularly on slope curvature.

Prediction of surface subsidence due to inclined very shallow coal seam mining using FDM, was reported by Kourosh Shahriar, Sina Amoushahi and Mohammad Arabzadeh. The subsidence as an inevitable consequence of underground mining could cause problems for the environment and surface structures. Subsidence due to mining two shallow panels from an inclined coal seam C1 of the Parvadeh (Tabas) coalfield, located in the eastern part of Iran, was predicted by finite difference method (FDM) using FLAC3D software. The predicted subsidence profiles were compared favourably with both the measured values as well as the profile functions method. Using the parametric analysis, the position of maximum subsidence area was predicted over the panel rise side, which was completely in contrast with deep coal seam mining. The range of critical width to depth ratio (W/H) for both panels was determined between 1.0 and 1.4.

Three dimensional analysis of the influence of primary support stiffness on the surface movements during tunnel construction was reported by Jakob Likar. The usage of underground structures was increasing which was the reason that in many cases construction took place in heavy and difficult geological geotechnical conditions. The main understanding of the technical paper to reduce surface settlement on the minimum was connected with stiffness of the primary lining and effective protection excavation face against deformation process realized in rock pillar ahead the excavation. The construction process was modelled with Plaxis three dimensional tunnel program. Input parameters were determined by three dimension back analyses with soft-soil-creep (SSC) constitutive material model, which took into account rheological phenomena. The three dimension development of stress-strain fields during the tunnel excavation was performed to show major stress-strain changes in the surrounding rocks and support elements. The calculations showed that during excavation of the top heading substantial deformations were developed ahead of the top heading. Influence of the support stiffness had strong connection with amount of surface movements above the tunnel.

Establishing the fundamentals of the theory of stability of mine workings was reported by A. N. Guz. The fundamentals of the theory of stability of mine workings were analyzed. The theory for understanding was based on the linearized three-dimensional theory of stability of deformable bodies. Some results on horizontal and vertical mine workings and on underground closed cavities were analyzed underground mine workings - three-dimensional theory - stability - closed cavities.

Numerical modelling of a tunnel turecky was reported by Jan Pruska & Michal Sejnoha. The current railway line went round the massif of the Turecky. The region of the Turecky was listed as a protected landscape area. Several variants of the new railway line design were studied due to the straightened alignment and environmental reasons. The variant of a
tunnel with double-rails was then selected. Complicated geological conditions promoted the NATM. The paper for understanding was concerned with the modelling of actual tunnel excavation using the Geo finite element method program. The analysis was carried out in two dimension, while generally three dimension character of deformation in the vicinity of a tunnel face was taken into account by employing the convergence confinement method. Two ways of excavation were studied particularly in view of the stability of the overall system. In this regard, the stabilizing effect of an anchorage system was also examined. Outside of the tunnel, the system of reinforcing elements was introduced through a region with improved strength parameters of the original soil. Within the buttress, the reinforcing elements were modeled individually using anchors with excluded compression. The present analysis demonstrated the applicability of the chosen software.