UNLOCKING THE POTENTIAL OF 3D GEOLOGY

KATHERINE ROYSE, BRITISH GEOLOGICAL SURVEY, OFFERS AN EXAMPLE FROM THE LOWER LEA VALLEY OLYMPIC SITE, FOR THE NEEDS OF THE GEOTECHNICAL COMMUNITY.

The Lower Lea Valley, Olympic site will be situated in the East End of London. Most of the major development projects will necessitate construction on ground that would be classed as 'difficult' in engineering terms. Compressible soils, high groundwater levels and contaminated brownfield sites are typical of the problems that will be faced. The Institution of Civil Engineers estimate that about 50% of cost and time over-runs on civil engineering projects are caused by 'unforeseen ground conditions.' This is due, in part, because too little is understood of the three-dimensional (3D) geology.

Geological modelling in 3D can provide a detailed definition of subsurface conditions. Such modelling requires the extension of traditional GIS methods to handle the volumetric representations. Over the past two decades, a series of sophisticated 3D modelling technologies have been developed to address this need. However, the adoption of these techniques in the UK geotechnical industry has lagged behind technological advances. Recent changes to UK legislation, in conjunction with modifications to the way that 3D geological information is presented, have unlocked the potential of 3D geological models to the geotechnical community.

It was decided that the best location to showcase these new technologies would be within the Lower Lea Valley, Olympic site. This article will discuss how the 3D model can be used to predict potentially difficult engineering ground conditions by assessing the thickness, geometry and properties of individual geological units.

Applied Geological Map

In the UK, studies commissioned by the then Department of the Environment in the early 1980s, suggested that much of the information contained within the traditional geological map was not being incorporated into planning and development decisions. This led to the development of the applied geological map; the function of this new type of map was to supply interpreted earth science information to planners.

More than 50 studies were undertaken to promote the use of these maps in identifying the principal geological factors which should be taken into account during the planning process. The main limitation of these applied 2D geological maps was their inability to convey information clearly in 3D. Some depth information was included, such as: the thickness of the superficial deposits, depth to bedrock, and thickness of specific formations. However in trying to portray 3D information using different colour patterns these maps become very complex in appearance and sometimes difficult to interpret. Nevertheless, the main short-coming was their inability to portray superficial materials present between the ground surface and the bedrock. This limitation restricted the use of these maps in areas where complex assemblages of superficial deposits exist, such as beneath many towns and cities, notably London.

3D geological framework

The key developments necessary for 3D models to be taken up widely lie in improvements in 3D modelling capabilities, which, in turn, depend on the availability of digital data and on improvements in 3D modelling software. Critically, it is the ability to build and visualise 3D models on a standard desktop PC without the need for expensive and operationally complex computer software that, will encourage the regular use of 3D models.

The Lower Lea Valley 3D Model was constructed using proprietary software GSI3D (Geological Surveying and Investigations in 3D); produced by Insight. One reason why many professionals do not use 3D modelling routinely is because many modelling packages are too complex. GSI3D addresses this issue by using traditional techniques of cross-sections and fence diagrams, together with a generalised vertical section. Once the model is constructed it is possible to add property attributes such as hardness, plasticity and shear strength into the model, the process by which this is done is described in detail in the side bar on below.

Applications and uses of the Attributed 3D Geological Model

Engineers and geologists can use the attributed geological model to assist in the recognition and identification of problematic ground conditions, to help design more appropriate ground investigations and contribute to the most efficient foundation design. The model can be used to provide information on the depth to founding material, its properties and the variability of these properties. For instance the depth to the top of the gravel formations and Chalk beneath the alluvium can be exported from the 3D model and displayed as depth or thickness (isopac) contour plots in a GIS. It is then possible to combine the 3D surfaces with other spatially rectified data (be that geotechnical, geochemical, or geographical etc) which, when combined together, provides a way of assessing the suitability of sites for a variety of construction techniques.

The attributed 3D model can be used to generate synthetic geological cross-sections and borehole logs along a specified route enabling an interpretation of the subsurface geology beneath the route to be formulated. For example a linear route such as a railway track, road or flood defence barrier can be generated. The engineering classification is then applied to the synthetic geological cross-section and an engineering geological section is easily produced. A simple visual inspection allows regions of potentially difficult ground conditions to be immediately identified. Such attributed sections could become a key tool in strategic infrastructure maintenance and network expansion plans (e.g. pipelines, roads and railways).

The Value of an Attributed 3D Model

The value in having large quantities of geoscientific information, is not in the possession of it, but in the interpretation and presentation of that data to those that need it most. One way of achieving this is by adopting a modelling system such as described here, whereby not only are detailed and regional 3D models produced but models attributed with physical, chemical or hydrogeological parameters. Once the attributed model has been created, it is possible to generate a large number of customised geoscientific outputs with little extra computation.

The Key Development

Since Rosenbaum listed his concerns (see below) the development of the 3D attributed geological model of the shallow subsurface has moved a significant step forward towards reaching his goals.

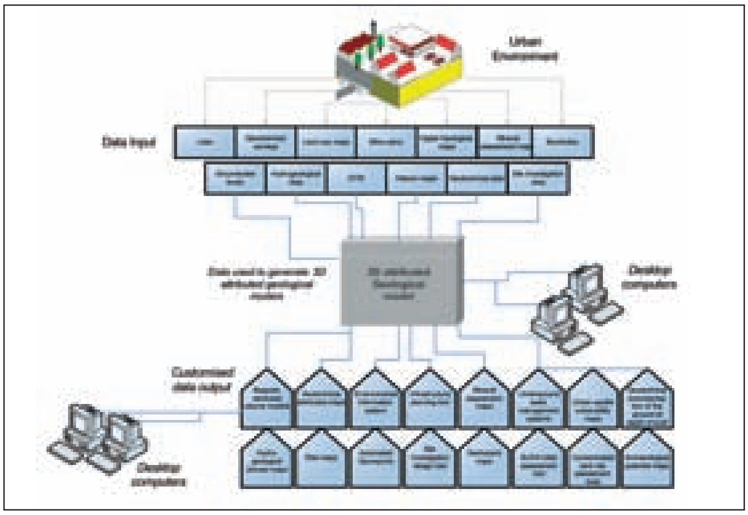
The key development necessary for models of the shallow subsurface to be used routinely in planning and site investigation design lies in the ability to build and visualise 3D models on a standard desktop PC without the need for expensive and operationally complex computer software. Not only can the modelling system used here (GSI3D) be used on a standard desktop PC but also the 3D model is built by using traditional geological techniques which are familiar to geologists, engineering geologists and hydrogeologists, negating the need for specialist operators.

The attributed 3D model provides a platform whereby the integration and visualisation of data from many different sub-disciplines can be achieved. This allows the model to portray some of the natural hetero-

ATTRIBUTED 3D GEOLOGICAL MODELS

Once the 3D geological framework has been constructed, the physical attributes of the modelled geological units (3D polygons) can be described. This is achieved by developing an engineering geological classification scheme. In this case the geological units were primarily divided in terms of engineering 'rocks' and 'soils'. These primary divisions were further subdivided into coarse grained (sand and gravel) fine-grained (clay and silt), organic soil (peats) and mixed soils. Secondary subdivisions further classify the modelled units on the basis of general strength or density. These subdivisions are based on log descriptions, undrained shear strength and standard penetration tests, plus any other appropriate parameters included in site investigation reports.

This attributed geological model is now able to encapsulate, at least in part, some of the natural variability of real geological systems. Rosenbaum (2003) considered this to be one of the four major impediments to 3D modelling not being widely used within the geotechnical industry. The method of attribution described above is not able to take into account the heterogeneity within a modelled geological unit (Group, Formation, Member or Bed) but rather it provides the user with bulk attributes for a given unit. This has been done for two reasons: firstly, working with manageable file sizes; the process of discretisation (whereby each modelled unit is split into a series of 'volume' elements, often cubes) results in very large data files being generated, which are difficult to handle, making data manipulation on a standard desktop PC unworkable. Secondly, lack of



sufficient data for detailed variability modelling; to model property variation within a geological unit without an unfeasibly high level of uncertainty, it is essential that geoscientific data is of a high density and quality throughout the modelled area. Nevertheless, heterogeneity within a modelled unit can be visualised by using a variety of graphical techniques.

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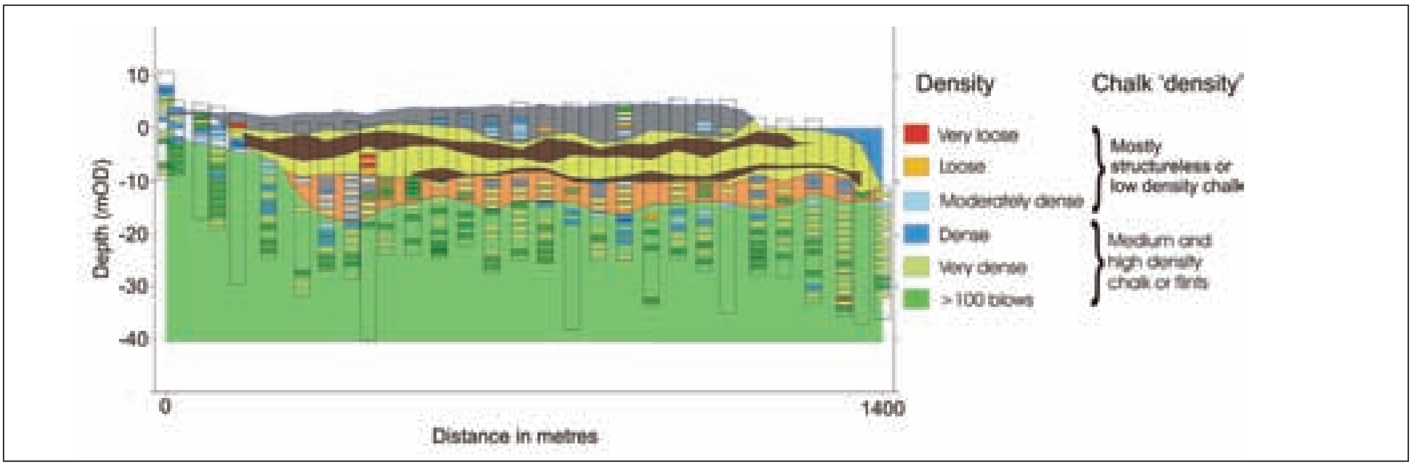
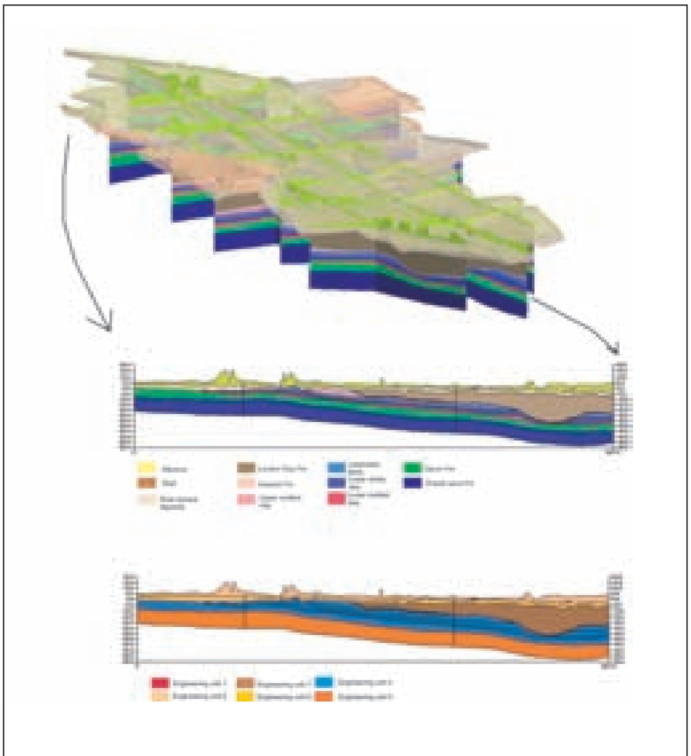


geneity of real geological systems. The level of geological detail contained within the model will always be dependent on the amount and quality of the digital data available. Nonetheless, a considerable amount can be accomplished by bulk attribution of a geological model, whereby an understanding can be gained about general geotechnical and geological ground conditions, such as the depth to good foundations. Further work is needed to model full heterogeneity; nevertheless, it is possible to portray intra-formational variability by using statistical plots or 'borehole-sticks' spatially registered within the model.



ROSENBAUM CONCERNS

Rosenbaum (2003) suggested that there were four reasons why 3D geological models of the shallow subsurface were not used routinely for site investigation design. These can be summarised as follows:

The lack of 3D and 4D mathematical, cognitive and statistical spatial tools.

The lack of modelling tools specifically designed for shallow subsurface modelling which are not too expensive and do not require specialist personnel to operate them

The inability of models to depict accurately the natural variability of geological systems or to represent uncertainty.

The worry that the investment in time and effort to produce 3D models would not result in significant improvements in knowledge or better science.

Conclusion

In Conclusion, 3D attributed geological models will transform the way geological maps are made and produced and change the way groundwater modelling and ground investigations are carried out. For example, site investigations will become more targeted, concentrating on areas where the engineering behaviour is known to be complex or where there is little data. As a result, the future where ground investigations will start by testing the validity of a 'real' geological model, is rapidly becoming a reality. Large-scale developments such as the 2012 Olympics provide geoscientists with the opportunity to showcase how new developments in 3D attributed geological modelling can be used in practice to provide answers to real world problems.

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