Getting a grip on SHRINK-and swell

Allowing for the natural effect of ground movement as sub-surface excavations take place can be a tricky and expensive business for those seeking to make the most of London's underground space. Lee Jones, Kathryn Lee and Andrew Hulbert present a new 3D dataset that will prove a valuable aid in locating, identifying and quantifying the risk

With space at a premium on the surface, the number and diversity of structures being built underground is steadily increasing. But space is tight here, too, constrained not only by the current infrastructure (pipes, cables, tunnels, foundations), but also by co-existing natural geological hazards.

One of these hazards is the volume change potential, or shrink-swell, of clay and clay-rich lithologies. These can vary from lithology to lithology and also within a lithology or rock type. Once uncovered or disturbed by excavation, any changes (e.g. weather, groundwater) affecting the lithology could cause new or exacerbate existing shrink-swell hazards.

New 3D data insight

The British Geological Survey's (BGS) Hazard & Resilience Modelling Team has developed a new shrink-swell 3D dataset, called BGS GeoSure Shrink–Swell 3D that delivers a unique insight into the properties of the sub-surface.

The shrink–swell 3D data is a regional hazard susceptibility map that identifies areas of potential shrink–swell hazard, in three-dimensional space, at intervals down to 20m in the London and Thames Valley area (Figure 1). The data is classified on an A–E range of hazard susceptibility. The data have been produced by geologists, geotechnical specialists and information developers at the BGS, and are derived from the London geological model[1].

Using data, knowledge and expertise, it combines geological data from boreholes, 3D models and laboratory test results of plasticity to interpret the Volume Change Potential (VCP) of all rocks and deposits.

The dataset contains the following information at each 50m x 50m cell: Depth (0m-20m), Formation (a BGS Lexicon Code), Dominant Value (A-E), and Range Value (A-E).

This new data product is designed to assist in the preparation of tenders, the planning of groundworks and the compilation of ground investigation desk studies. In particular, the dataset is highly relevant to the utility, engineering works, and tunnelling industry in terms of route planning, installation and network management.

Shrink-swell hazards

Swelling clays can change volume due to variation in moisture. This can cause ground movement, particularly in the upper two metres of the ground or, where excavated and exposed, that may affect many foundations or underground services. Ground moisture variations may be related to a number of factors, including weather variations, vegetation effects (particularly growth or removal of trees) and the activities of people that might cause changes to the water content and, hence, the ground conditions.

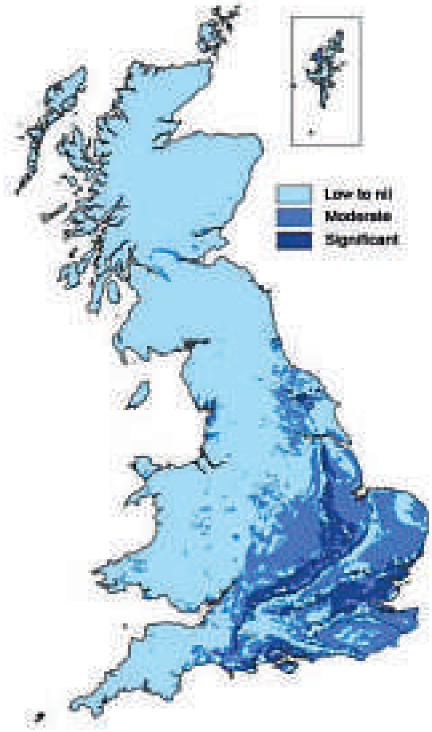

Fig.1: Shrink-swell potential across the nation is highest in London and the South-East

Properties of earth materials are important for all engineering projects and the classification of shrink-swell potential provided by this dataset can be used in all ground developments to give a generic assessment informing engineers and planners at the pre-tender and desk study stage of likely ground conditions at their site or along their route. This allows for a far more efficient tender preparation, planning and execution of subsequent ground investigations.

Key data resource

The dataset is a key data resource for all assets and infrastructure developments and maintenance. Natural ground stability hazards may lead to financial loss for anyone involved in the ownership or management of assets, including developers, construction or local government if suitable measures are not taken. These costs could include increased reinsurance and/or additional engineering works to stabilise land or developments. These hazards may also impact on anyone involved in the construction of large structures (deep foundations, basements), infrastructure networks (road or rail) or utility companies.

The 3D properties of these materials can be used to identify potential problems at the surface, in the shallow sub-surface, or deeper underground (e.g. tunnels). Armed with knowledge about potential hazards, preventative steps can be put in place to alleviate the impact of the hazard to people, property and infrastructure. The cost of such prevention may be very low, and is often many times lower than the repair bill following ground movement.

Shrink-swell 3D facts

Through development of this model, it has

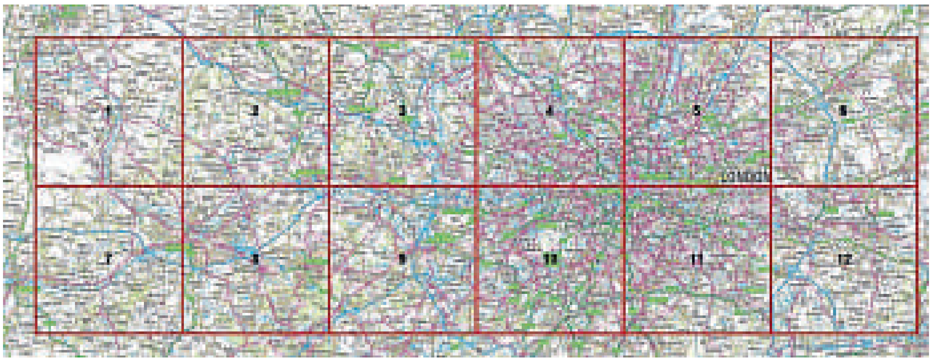

Fig.2: Coverage of the Shrink–Swell 3D dataset (copyright OS open data 1:250K)

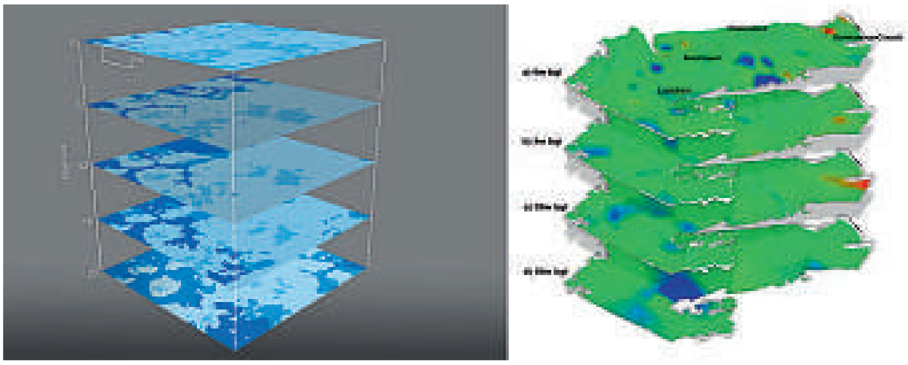

Fig.3: Left: Example of variation in Shrink-swell potential at different depths. Right: 3D volume change potential of the London Clay

Shrink-swell 3D Classification	Modified Plasticity Index (%)	Volume Change Potential
A	<1	Non Plastic
B	1-20	Low
C	20-40	Medium
D	40-60	High
E	>60	Very High

Table 1. Volume Change Potential Classification, modified from BRE Digest 240 (BRE 1993)

been found that, on average, some 42.5% of London and the Thames Valley is potentially susceptible to shrinkage and swelling (classes D and E) if exposed by development and construction works. In sum, the new dataset identifies and classifies some 10,000 different geological units

1. Each of the geological units was allocated a Volume Change Potential (VCP) classification based on its upper quartile value. These units were then converted and, in some cases, combined or broken apart so they could be allocated to one of the 10,000+ geological LEX-ROCK (Lexicon and lithology code system) codes in BGS Geology 50k.

2. The Modified Plasticity Index (IP') (Table 1) was calculated using the method proposed in BRE Digest 240 (1993)2. This method was used where the particle size data, specifically the fraction passing through a 425μm sieve, was known or could be assumed. Firstly, this method required the Plasticity Index (PI) values to be calculated from the Liquid Limit (LL) and Plastic Limit (PL) data, as follows:

$$PI = LL - PL$$

The Modified Plasticity Index (IP') could then be calculated from the PI and the amount of fines passing a 425μm sieve, as follows:

$$IP' = PI \times \frac{\text{percentage less than 425m}}{100}$$

The model was interrogated to determine the percentage presence of shrink-swell at the different depths shown in table 2. Approximately half (51%) of the surface coverage in the model area (London & Thames Valley) has a Class A rating, i.e. deposits are non-plastic, and only 25% of surface deposits are high or very high plasticity. However, with depth, this high-to-very high proportion increases considerably, with some 48% of deposits being susceptible to shrink-swell at 10m and 49% at 20m depth.

This highlights that, even across this relatively large region, there is much variation with depth that needs to be taken into account for any engineering project. An example of these changes in hazard potential is demonstrated in Fig.3.

Further information:

http://www.bgs.ac.uk/products/geoSure/geoSureLondon.html
email enquiries@bgs.ac.uk

References:

1. www.bgs.ac.uk/services/3Dgeology/lithoframe.html

2. Building Research Establishment. 1993. Low rise buildings on shrinkable clay soils: Part 1. BRE Digest 240

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Hazard Level	Interpretation	% present at 0m depth	% present at 5m depth	% present at 10m depth	% present at 15m depth	% present at 20m depth
A	Ground conditions predominantly non-plastic.	51	47	42	42	43.5
B	Ground conditions predominantly low plasticity.	14.9	5.5	5	5	5
C	Ground conditions predominantly medium plasticity.	9	8	5	3	2
D	Ground conditions predominantly high plasticity.	25	39	47.5	49.5	49
E	Ground conditions predominantly very high plasticity.	0.1	0.5	0.5	0.5	0.5

Table 2: percentage classifications of VCP at depth intervals calculated from the model