The Loadtest settlement prediction and analysis method for piles

It is common knowledge that piles carrying constant loads settle in accordance with time from loading. In consequence the final settlement at a given load is a function of the time. Some test loads, according to widely used specifications, are held for short periods, others for long periods. The result is that load settlement results as commonly presented, are erratic.

If one supposes that loads can be held fully constant at each stage and that the time deformation relationships can be accurately defined and projected to define its asymptote, then the final and unique load / settlement relationship can be established for a full range of loads.

This is what engineers seek to know, but such knowledge has not been obtainable in the past for practical reasons - namely insufficient loading times and inherent inaccuracies in both load and recorded deformation.

Loadtest overcome these difficulties with the use of three computer programs and a system for practical on-site load testing, which allows high grade testing and analysis to be carried out.

TIMESET can model the displacement behaviour of a pile under a constant load with great accuracy, allowing the final settlement at infinite time to be extrapolated. This permits the definition of unique behaviour of a pile under load in a way, which has not previously been possible. The method is described in detail in "*A Method of analysis of stress induced displacement in soils with respect to time*", England, M., Deep foundations on Bored and Auger Piles, BAPII Ghent, A.A.Balkema June 1993, p241-246.

CEMSET the name which has now become synonymous with the prediction program, is based on known or measured soil parameters or alternatively on comparison with other similar cases. CEMSET is based on and developed from the paper *"A new method for single pile settlement prediction and analysis", Fleming, W.G.K.,* published in Geotechnique 42, No 3, 411-425,1992.

CEMSOLVE the back analysis program has been proven to be an exceptional analysis and diagnostic tool. It can not only be used to derive soil parameters from tests much more reliably than was previously possible, given high quality data, but also it can be used to look in a detailed way at techniques of pile installation and their effectiveness.

LOADING SYSTEM Based on equipment and software developed specifically, is, not only an order of magnitude better in terms of accuracy but has very necessary safety features.

System evaluation

1. More informative pile tests

The pile design parameters for a given site and pile founding stratum can be determined from a suitable preliminary test. In situ strength, stiffness and reaction time of the founding strata and their effects on pile behaviour can be derived without the use of expensive load measuring devices within the pile body.

It is easy to discover inappropriate design parameters by appropriate site tests. This allows designs to be verified or made more economical and efficient.

Pile behaviour follows from installation practice as much as from SI conditions, the parameters that can be derived from load testing are one stage better in most cases than SI.

2. Piling Equipment Design.

Piling equipment design is an obvious candidate for investigation. Already new tools for cleaning bored pile bases have been developed and self-cleaning under-reaming tools to improve pile performance.

3. Pile construction technique improvement.

The relative merits of a variety of pile construction techniques can be explored. For example, the high efficiency of displacement piles is easily demonstrated in certain soils. The technique therefore has implications for pile selection and related job economy.

Unsuitable or inefficient construction techniques, such as may inadvertently cause loosening of soil around a bored pile shaft or the presence of soil debris on a pile base, can often be detected.

4. Advancement of pile design methods.

The ability to arrive at pile reaction parameters on a much broader basis than previously, means that, for example, bearing capacity coefficients and friction factors may be derived from real rather than theoretical considerations, and the range of natural variation to be expected with such methods in a variety of soils can be assessed.

5. Soil stiffness importance recognised.

The stiffnesses of soils are determined. This is an important parameter usually missing from site investigation findings. The behaviour of soils surrounding and below the pile under test after its installation can be characterised in time and under load.

Piles, which are of lesser diameter, but founding in the same stratum, can yield the required parameters, which may then be applied to any other pile size or sizes. This provides a better and more useful design assessment than can otherwise be achieved and can substantially reduce the cost of testing.

6. Settlement and time relationship made clear

The time relationships for any founding soil can be explored and it can be determined whether total or effective stress design methods are appropriate to any given case. Tests on piles may thus have applications beyond those, which one would normally expect.

The time model allows the duration of application of loads to be reviewed, so that the most economic test schedule can be defined.

7. Application to other foundation types.

The method can easily be applied to other foundation and similar problems with little modification; for example, surface foundations are even simpler to deal with than piles.

The method appears to have good potential for extension into the field of pile group behaviour, using a system of influence coefficients as presently used for the assessment of behaviour in 'elastic' soils.

8. Significance of the pile behaviour under load.

The method can be used to forecast or analyse the behaviour of piles, which have been base-grouted, and to demonstrate the mechanics of this method of construction and its effect very clearly.

9. Partial factoring methods.

The technique has profound implications for all factoring methods, which are used to derive acceptable performance from ultimate states. This applies to both conventional Factors of Safety and Partial Factors as they are now operated and it introduces soil stiffness as a parameter, which is as important as ultimate load.

10. Unique pile behaviour revealed.

Once the definitive pile behaviour can be determined, the merits of other pile testing methods may be assessed. Shortcomings of all other testing are critically exposed and the limitations in any situation become apparent.

11. Invaluable diagnostic tool.

When piles are carefully loaded and deflections measured much can be deduced if the performance of the pile is in some way anomalous. Poor end bearing or shaft friction capacity can be identified and even on occasions cracks or other concrete problems can be inferred.

A limitation that should be emphasised is that in order to derive accurate parameters from pile tests, settlement must be carried to a stage where virtually all shaft friction and a reasonable proportion of base resistance has been mobilised. Likewise it is fundamental that loads in Maintained Load tests should be held constant at each stage.

Perhaps the most important aspect of this technique is that it has an important bearing on the general understanding of foundation behaviour. Multiple definitions of failure are no longer necessary and only cause confusion. The definition of failure reverts to the unique statement by Terzaghi to the effect that continuing indefinite settlement for no further increase of load represents failure. This is unequivocal.

The method equally applies to spread foundations and piles. It will become an important tool of site investigation yielding data which is really pertinent to foundation design, unlike present practice which often concentrates on strength testing for bearing capacity, in contrast to stiffness and deformations.