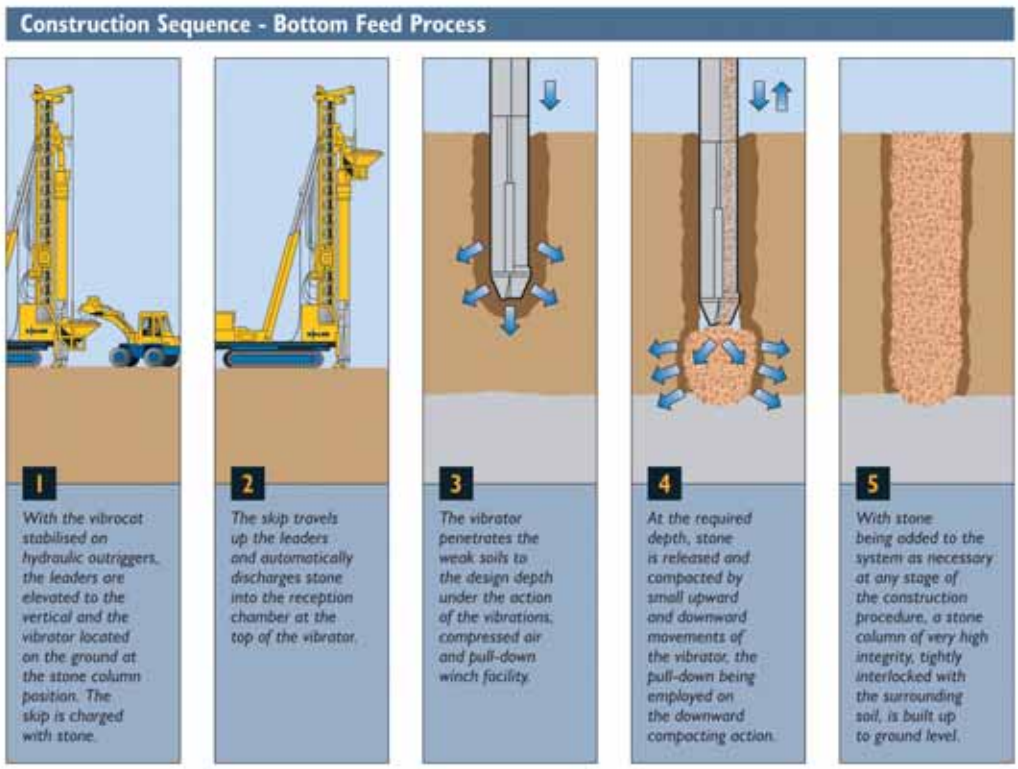

Vibro-techniques for ground improvement in Ireland

Bryan McCabe and James McNeill explore the use of vibro-compaction and vibro-replacement techniques in ground improvement.

There are a number of 'ground improvement' systems which can provide a geotechnical performance intermediate to those of shallow foundations (constructed on unimproved ground) and piled solutions, and there are a large number of applications which fall into this intermediate category. Ground improvement schemes work with the existing ground rather than bypassing it. They can be tailored to meet specific bearing capacity and/or settlement requirements and are generally much more cost-effective than piling. This article presents some general information on Vibro-Compaction and Vibro-Replacement techniques, which have been used in the UK with great success for over 50 years, and in Ireland for over 30 years. A new piling system called Vibro Concrete Columns is also introduced.

Vibro-compaction

Essentially, Vibro-Compaction is achieved by inserting a vibrating poker into the ground (typical range of diameters 450-800mm). The poker penetrates under the action of its own vibrations, assisted with the pull-down facility of the rig as necessary. The vibrations are predominantly horizontal and tend to increase the density of materials having sufficient granular (sand and/or gravel) content (usually 90% or more). Clays and silts are not improved using Vibro-Compaction on its own. Where clay, silt, made ground or mixed ground conditions are present, stone aggregate can be inserted down the hole formed by the vibrating poker to form a stone column. This process is known as Vibro-Replacement or Vibro Stone Columns.

Vibro Stone Columns

The hole created by the poker is filled with inert crushed stone or gravel, and compacted in stages from the base of the hole upwards. The performance of the stone column depends largely on the lateral resistance of the soil around it. In this regard, the poker acts as an investigating tool, and will match the quantity of stone supplied to the consistency of the soil layer encountered. When using a standard Vibroflot the stone column is typically 500-600mm in diameter. There are two different approaches that may be used to construct the stone column. The stone may be tipped in controlled amounts from the ground surface and compacted in layers through penetration and withdrawal of the poker; this system is referred to as 'Top Feed'. Alternatively, the stone may be fed from a hopper through a delivery tube along the side of the poker, exiting adjacent to the poker tip. This is known as 'Bottom Feed' and is preferred when hole collapse is likely, such as when there is a high water table or running sand conditions.

Stone columns are normally spaced at centres varying from 1.2-

2.0m under strips and footings, up to 3.0m under floor slabs, and to depths of up to 10m depending upon the combination of loading and ground conditions. The Vibro Stone Column system can be used in granular soils, in mixed fills, and in cohesive soils with undrained shear strength (cu) not less than 15kN/m^2. In these materials, improved bearing pressures of 100-200kN/m^2 are typically achievable.

Settlements are also reduced, with improvement factors of 1.5-3.0 achieved on most projects over the depth of significant stress. Improvement factors may be calculated using the method of Priebe (1995). Peat is generally unable to confine the stone adequately, so the process is unsuitable for all but very thin peat layers.

In addition to reducing total settlements, stone columns installed in a uniform grid pattern at a site will help 'homogenize' whatever natural variability exists, thereby reducing differential settlement potential. Stone columns serve a secondary function of acting as vertical drains, and accelerate the dissipation of excess pore pressures and associated settlement generated from loading, allowing a foundation/floor slab to be brought into service at an early stage. In addition to the savings per metre length that stone columns offer over piles, this 'soft' solution enables ground-bearing slabs to be constructed, representing further significant savings over the ground beams and suspended slabs associated with piled solutions. Key publications which illustrate the Vibro-Compaction and Replacement techniques, the importance of good construction practice, and some interesting case histories, are Sondermann and Wehr (2004), Bell (2004) and Slocombe *et al* (2000).

Where the ground conditions are unsuitable for Vibro Stone columns, then a new piling system known as Vibro Concrete Columns could be considered.

Vibro Concrete Columns

The Bottom Feed Vibro Stone Column Rig can be easily converted to construct Vibro Concrete Columns (VCCs); with concrete now passed through the delivery tube as opposed to stone.

The poker penetrates to the founding layer (inducing compaction if granular) before concrete is pumped from the base of the delivery tube. After lifting by up to 1 metre, the poker re-enters the concrete shaft, displacing it into a bulb until a set resistance is achieved.

Once the bulb end is formed, the poker is withdrawn at a controlled rate while concrete continues to be pumped out at positive pressure. When completed the columns can be trimmed and reinforcement placed as required. Where an enlarged head is required (up to 900mm diameter), for instance to support a suspended concrete floor slab or a Load Transfer Platform beneath a road embankment, this can be formed integral with the VCC shaft.

This is much more cost-effective and quicker than using a separate pile cap. VCCs are ideal for weak alluvial soils such as peats and very soft clays (which are unsuitable for Stone Columns) overlying a competent founding stratum of sands, gravels or rock.

Working loads of up 1000kN may be supported. The main advantages of VCCs over other piling types include (a) the bulb end enables high working loads to be developed at much shallower depths than alternative piling systems, thereby generally providing a far more economical solution, (b) installation rates can exceed 1000m of concrete column per rig week, and (c) the system is quiet compared with driven systems.

The system has already been successfully used to support a number of retail and industrial units across the country and a road embankment for a major new road into Shannon Airport.

Impact for Ireland

The Irish construction industry has been slower than many of its European counterparts to realise the technical and economic advantages that Vibro Stone Columns and Vibro Concrete Columns can provide. Ireland has an abundance of soft alluvial and estuarine soils and many of these may be improved sufficiently by Vibro techniques to allow standard foundations to be constructed at shallow depth, without the need to resort to deep piling.

Where ground conditions are suitable, the Vibro Stone Column system has been shown to be more cost effective than foundations requiring trenchfill in excess of 2m. While other ground improvement techniques, such as surcharging and band drains, can seriously delay a contract programme, Vibro- techniques generally do not provide such a stumbling block.

As with all construction projects, a good site investigation is necessary, with information on compressibility and strength of the soils being particularly important for ground improvement design.

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