Ground Conditions for Construction Plant
a brief guide

STRATEGIC FORUM FOR CONSTRUCTION
PLANT SAFETY GROUP

If you are a construction client, contractor, plant supplier or operator with mobile plant on site then this document is aimed at you.

The Strategic Forum for Construction Plant Safety Group has produced guidance to assist with the planning, organising and operation of construction sites, to ensure that plant can operate safely without risk of overloading the ground or any structure on which it needs to stand, travel over or work on. This document is a brief guide only, introducing the detailed guidance in ***Ground Conditions for Construction Plant - A Good Practice Guide*** which is available for free download from the CPA website at www.cpa.uk.net :

If you operate plant on a construction site you need to check with the site management that the ground or structure (including site access routes) is able to support your plant while it is being positioned, standing, moving or operating.

Failure to fully assess the changing ground conditions on this site allowed the excavator to overload a barrel vaulted brick structure which collapsed causing the machine to fall through.

Photo: Courtesy of HSE

Introduction

A large number of construction plant accidents have resulted from the failure of ground or structures where the person planning the route and operating location of the plant overestimated the adequacy of the ground and/or underestimated the loads imposed by the plant.

Ground engineering is a complex topic. Where there is insufficient information already available about the load bearing capacity of the ground on which plant is to be routed, positioned, stood, moved or operated, those planning the construction work should obtain expert geotechnical and/or structural engineering advice.

This document is a brief summary of the detailed information contained in the publication ***Ground Conditions for Construction Plant - Good Practice Guide.*** The Good Practice Guide will help you through the process by providing an easy to read explanation of the theory involved and the pitfalls of getting it wrong. It will help you understand the terminology, principles and options behind complex areas including geotechnical surveys, analysis and assessment of soils data; the use of safety factors based on the level of confidence in the data; and the use of risk management principles. It will help you avoid mistakes which could lead to injury, damage, delay and unnecessary cost.

What is the best way to plan the work?

Construction sites come in all shapes and sizes and work may involve demolition, extension of existing structures, refurbishment or new build. The ground may be flat or steeply sloping and access onto site may be tight. The site layout, including access points, haul routes, compounds, lay-down areas and working areas needs to be planned. This planning needs to take into account all significant hazards and the condition of the ground is a fundamental consideration. Decisions at this stage may determine the type and largest size of mobile plant that can work on site and this in turn can dictate the cost of haul route and working area ground improvements.

Soil type and condition is a major element determining the load capacity of the ground. Surface features and substructures also affect how the work is carried out. Gradients, natural or assisted drainage or water courses, and current or planned excavations should also influence decision making.

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It is important to know what is under the ground, as well as at the surface. The following hazards may not be readily apparent, but their existence can lead to sudden ground failure:

- Hardcore or thin paving overlaying soft weaker material;
- Backfilled excavations and service trenches;
- Shallow pipes, culverts and other services;
- Covered shafts and manholes;
- Voids under old concrete foundations;
- Cellars and basements;
- Hidden geological features such as sink holes, other voids and fissures;
- Poor ground adjacent to slopes sensitive to slip failure.

If plant is to operate on top of structural frames, slabs, jetties or bridge decks etc, a structural analysis will be needed to ensure that these structures are capable of supporting the imposed load from the plant.

Water tends to reduce the strength of soils and this should be considered, especially if the area is in a tidal or floodwater area or if the work will be carried out in a wet season. Current ground water levels may be observed from open excavations, test pits or bore holes; but may change before work starts and during construction.

Decisions about build sequence, timescale and method of construction affect selection of plant. Scale of plant and the type of plant operation affect the ground bearing capacity that is required. It takes a high degree of skill to plan the optimal balance of these aspects, whilst ensuring the site is both safe and cost efficient.

What site information do you have or need?

You may have information such as:-

- Site survey information such as borehole and trial pit results;
- Undisturbed samples taken from a range of depths and tested for soil strength;
- Results presented in soil and ground reports;
- Reliable information about existing structures and previous use of the site;
- Survey confirmation of the presence of cellars, culverts, drains, manholes, other voids and weak areas including geological, structural and manmade features.

If this is the case, you may already have enough information to be able to work out the load bearing capacity of the ground at various locations on your site. Converting raw data into bearing capacity often needs the expertise of a competent geotechnical (ground) engineer. Talk to your site engineer or engineering consultant to check out the best way to proceed, as total costs can be reduced by planning ahead. Even if you already have information about the capacity of existing roads and other structures on site - such as bridges, ramps and floor slabs, it is important to be sure the information is ready for use. For example, you need to be clear about whether the data includes a suitable safety factor, and whether change or deterioration has occurred since it was collected or analysed.

Soil surveys are often commissioned to assist in the design of the building. The permanent works designer is normally interested in the characteristics of the soil to depths of several metres. For the movement and operation of mobile plant however, the upper soil levels are of more interest. Shallower samples taken and assessed or tested at the time of the original soils survey can avoid the need for further survey costs.

The responsibility for providing information on the bearing capacity of the ground or a structure rests with the person or organisation in charge of the site. The only exception to this is where plant is being used on domestic premises, in which case the person or organisation using the plant is responsible.

The ***Good Practice Guide*** provides practical guidance on obtaining and using the information listed above. The text guides you through the process to allow you to optimise both access and working areas, and the scale of plant brought to site.

Planning ahead and getting the planning right prevents accidents, keeps temporary works costs under control and avoids costly delays due to recovery of stuck or damaged plant or worse. Planning should take account of the potentially serious consequences of any failure of the ground or structure.

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What load will a machine or operation place on the ground?

The ***Good Practice Guide*** will help you work out what plant you can use on which ground, and the operations that can be carried out. Most plant applies an uneven distribution of load onto the ground - some wheels or stabiliser/s or some parts of the track may apply considerably higher loading onto the ground than others. This is obviously the case where a crane, telehandler or lorry loader crane booms or derricks out to place a load at a distance from the centre of the machine. You will need manufacturers/suppliers data or engineering expertise or both to work out the worst case plant bearing pressure.

The ***Good Practice Guide*** explains that the supplier or manufacturer of plant is legally obliged to provide core information. You will need it in a written format, generally as a drawing with tabular data. Typically the information provided will include maximum and minimum point loadings in tonnes or kilonewtons (kN) for each track, wheel or outrigger. Prevent error by providing the serial number, exact model and configuration of the plant to be used. The information may be available from the manufacturer's website, or from proprietary software packages. Care must be taken to ensure that the correct make, model and configuration of plant has been selected. If you add attachments from other manufacturers or modify standard plant, this will also need to be taken into account by your site or consulting engineer.

> ***Rule of thumb methods should only be used as a last resort. For example, one method for mobile cranes is to assume that highest load on any one outrigger will be 75% of the sum of the total weight of the plant, plus additional counterbalance, plus lifting accessories plus the load. All rule of thumb methods can give very different loadings (which may be much larger) than actual figures obtained from the plant supplier.***

How should a Ground Assessment be carried out?

The ability of ground to sustain applied loadings is typically expressed in two ways:

- **Ultimate bearing capacity** is the loading at which the ground will **fail**. This is the unfactored capacity of the ground calculated from the results of ground testing. This is always a much higher value than the permissible bearing capacity and **must not** be used without applying a factor of safety.
- **Permissible bearing capacity** includes a factor of safety and may be supplied by the ground engineer where this has been specifically requested. If you require the soil investigation specialist to provide interpreted test results eg presented as permissible bearing capacities then this must be specified from the start as it is likely to increase the cost of the service.

Where plant is to be placed on the new structure, the designer of the permanent works should be able to provide information on the loading limits for the permanent structure. This will be provided as either permissible maximum point loadings in kN and/or permissible bearing capacity in kN/m2. Where the plant is to be placed on or could affect temporary works or an existing structure, the temporary works designer or structural engineer must allow for the imposed loadings of the plant.

A brown field or partially completed new site may already have been levelled, back filled, stoned and compacted to a ground bearing specification. This may be expressed in different terms such as California Bearing Ratio (CBR), applied compaction pressure or ground bearing capacity. Those planning the site need to understand what this means.

> ***It is vital that un-factored data is not mistakenly used to indicate a safe working or permissible load.***

In the absence of either a plant site specific ground test, or adequate information from the site, the competent person (eg site or consultant engineer) may choose to carry out the ground assessment using a combination of visual and physical techniques. Further advice on these methods which involve digging a pit to assess the dominant soil type and its condition is given in the ***Good Practice Guide***.

> ***Remember - in all cases where the accuracy of the ground bearing pressure assessment is less certain, then a larger factor of safety will need to be applied.***

Decision Time - Ground improvement and other options

Where you have good ground data and good machine data you need to decide whether the ground is good enough. The ***Good Practice Guide*** will help you understand how to assess whether the ground is already

suitable for some operations - eg those involving small plant, and especially plant with a low centre of gravity. However a lot of plant operations need thorough checks before they can go ahead. In particular operations that impose high localised loadings; or use of plant that has a high centre of gravity can be very sensitive to slight settlement or gradients. Where the ground is borderline or offers insufficient bearing capacity the following three main options are discussed in detail in the Good Practice Guide:

- **Pads / Mats -** where plant will be rigged in a static operating position it may be possible to spread the load using a rigid pad under each support point. This is a common method for mobile cranes and other plant that use stabilisers to remove all or most of the load from the wheels. For mobile plant such as crawler cranes or for plant crossing soft ground for access it may be possible to use large timber, steel, plastic or aluminium mats to spread the load into the ground. ***Note that these are properly designed mats - not just a few old boards!***
- **Ground improvement** - this involves strengthening the ground and is often used where plant needs to operate over a wide area. It is most commonly done by removing soft material and laying a compacted layer of stone, often incorporating a structural membrane (geogrid or geotextile) within the stone layers. Typical uses are for crawler crane and piling rig working platforms. Other common options include remixing the ground in-situ by adding stone or cement or lime to a designed depth; or placing these materials at depth; or simply compacting the ground and capping with stone.
- **Plant or operation reduction** - this involves either selecting a replacement machine that imposes a lower load on the ground, or reducing the load that needs to be carried or lifted. It could involve simply using a tracked rather than a wheeled machine; or using a smaller machine. This option includes breaking a load down to require more journeys with less carried each trip or each lift. It is important to know what the ground bearing capacity is and the highest ground pressure the machine or the operation will place on the ground.

The following flow chart summarises the process outlined above. Much more detail is available in the publication ***Ground Conditions for Construction Plant - Good Practice Guide*** which is available for free download from the CPA website at www.cpa.uk.net