

GOOD PRACTICE GUIDE

# Ground Conditions for Construction Plant



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## Strategic Forum for Construction Good Practice Guide



Reference No. CPA 1402

First Published: October 2014

Published by:

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## Foreword

Construction plant is a vital part of the construction process. Plant stability often depends on the integrity of the ground on which it stands. If the ground fails, plant can overturn or collapse. In the past such incidents have led to a significant number of serious accidents, some tragically fatal. Not only do these accidents have a terrible cost in terms of human suffering, they also have a significant financial cost for all concerned. Consequently there is a very strong business case for improving safety performance.

Effective assessment of ground conditions is essential to assist with safe installation, setting up and operation of construction plant.

The purpose of this guidance is to help those involved with planning and carrying out plant operations to achieve a better awareness of ground conditions and how plant selection and use can affect the ground.

This guidance will also help those carrying out ground assessment to be aware of their own limitations - ground engineering can be a complex topic. It will help with planning simple operations and help site staff to work more effectively with experts. It is essential that all involved in planning plant operations know when to stop and seek advice from a structural or geotechnical engineer.

This guidance has been developed by a working group representing all parts of the industry. It provides clarity on the assessment of ground conditions and will help construction plant suppliers and users improve health and safety standards. The guidance addresses planning, ground assessment, plant selection and measures to ensure ground stability. The advice in this document is straightforward, comprehensive and easy to adopt. This guidance may go further than the minimum you need to do to comply with the law.

I thank those who have been involved in its preparation and commend the guidance to anyone who owns, supplies or controls the operation of construction plant. Please read the publication and turn the advice into action.



### **Philip White**

HM Chief Inspector of Construction

Chair of the Health and Safety Executive's Construction Industry Advisory Committee (CONIAC).

## 1.0 Introduction and Scope

Failure of the ground on which construction plant stands and moves is a frequent cause of minor incidents and near misses on sites, together with a significant number of serious injuries and fatalities. In addition to the impact on the lives of those involved, these events can lead to delays in construction programmes and significant commercial loss such as unrecoverable management time, loss of reputation and effect on future workloads. An HSE publication on the cost of accidents estimated that for each £1 of accident cost recoverable through insurance, a further £8 to £36 was unrecoverable and had to be borne by the employer.

From this it can be seen that adequate assessment of ground to establish its ability to support plant, is essential if these incidents are to be avoided.



*A building was being demolished using an excavator standing on the first floor. The floor collapsed bringing down the building. The excavator fell into the basement and was partially buried by rubble, trapping the operator in the cab. Unfortunately by the time rescuers reached the operator he had died.*

The aim of this document is to provide clear guidance on the assessment of ground conditions and the measures that can be taken to both improve ground and reduce loads imposed on the ground. Ground engineering can be a complex topic and part of the purpose of this guidance is to enable construction personnel to decide when they need to consult an expert geotechnical or structural engineer.

**It is essential that those carrying out ground assessment are aware of their own limitations and know when to stop and consult those expert in the field.**

This document is aimed at all those with an interest in the stability of plant including:

- Clients
- Designers
- Contractors of all sizes
- Plant hire companies
- Builder's merchants
- Plant manufacturers
- Training organisations
- Utilities

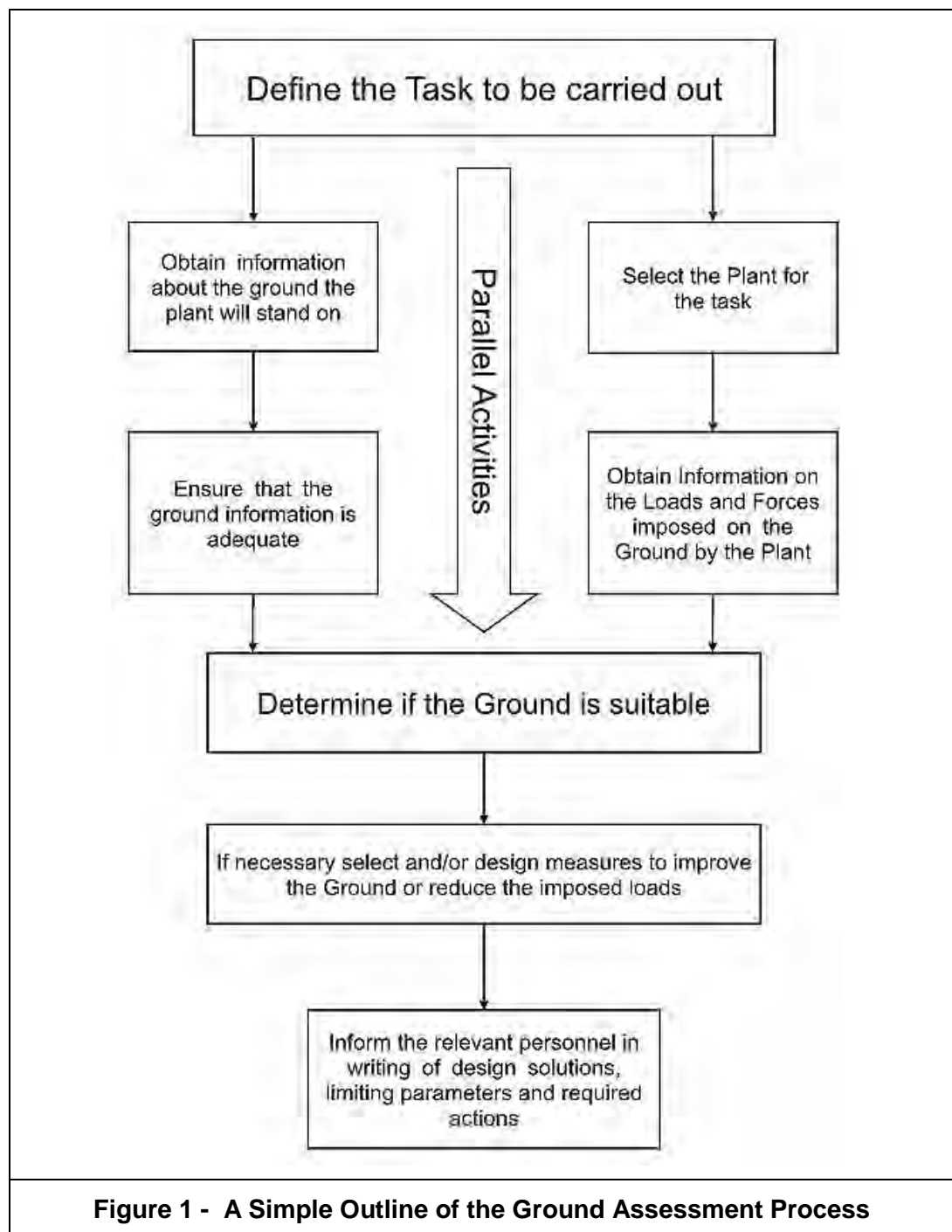
The types of construction plant covered by this document include:

- Mobile cranes (wheeled and crawler)
- Mobile self erecting tower cranes
- Self erecting tower cranes
- Top slew tower cranes
- Mobile Elevating Work Platforms
- Lorry loaders
- Piling rigs
- Telehandlers
- Ground improvement plant
- Vertical Mast fork trucks
- Dumpers and dumptrucks
- Loading shovels
- Pipe laying equipment
- Rollers and compaction equipment
- Dozers
- Concrete pumps and booms
- Excavators
- Demolition equipment
- Drilling rigs
- Road going vehicles including delivery vehicles, tippers and concrete truck mixers
- Jacking, winching and lifting equipment
- Tractors
- Specialist landscaping equipment

The scope of this document excludes:

- Waterborne and marine plant
- Jack up barges
- Work at sea
- Underground plant
- Non mechanical plant (scaffolding, formwork, ground support etc)
- Construction hoists, mast climbing work platforms and transport platforms
- Services above ground

The basic process of ground assessment is shown in **Figure 1** below. A more detailed flow chart of the process is shown in **Figure 2**.



## **2.0 Definitions of terms applying to this document**

### ***competent person***

person with sufficient knowledge of the specific tasks to be undertaken and the risks which the work will entail, and with sufficient experience and ability to enable them to carry out their duties in relation to the works, to recognize their limitations, know where to obtain further authoritative advice and to take appropriate action in order to prevent harm to those carrying out construction work, or those affected by the work

*NOTE: Modified from HSE CDM2007.*

### ***appointed person for lifting operations***

a competent person appointed by the employing organisation carrying out a lifting operation, to have overall control of the lifting operation and ensure that it is planned and carried out safely

### ***CDM***

#### ***The Construction (Design and Management) Regulations 2007 (CDM 2007)***

CDM 2007 is construction specific legislation that requires duty holders including clients, designers and contractors to plan, manage and monitor health, safety and welfare aspects of construction projects. This includes coordination of each stage of the process and sharing of information. Preconstruction information must be made available to assist contractors to tender. Upon completion, project information must be passed to the client to assist with planning maintenance and further work at the site.

*NOTE: The CDM 2007 Regulations are currently under review and this document will be revised to reflect any changes once new regulations are in force*

### ***CDM co-ordinator***

An entity (person or organisation) which provides clients with a key project advisor in respect of construction health and safety risk management matters. Their main purpose is to help clients to carry out their duties; to co-ordinate health and safety aspects of the design work and to prepare the health and safety file.

### ***client (non domestic)***

person or organisation who is having construction or building work carried out, unless they are a domestic client.

### ***client (domestic)***

person who lives, or will live, in the premises where the work is carried out. The premises must not relate to any trade, business or other undertaking.

### ***construction plant***

machinery used in the construction process, including lifting equipment, referred to in this document as “plant”

### ***crane supervisor***

person who controls the lifting operation, and ensures that it is carried out in accordance with the appointed person’s safe system of work

### ***designer***

competent person who carries out the assessment of ground suitability and the selection and/or design of measures to ensure ground suitability and/or measures to reduce imposed loads

**engineered structure**

designed, constructed and maintained man made structure,

*NOTE: This may include roads, jetties, bridges, buildings, earthworks (including fill) and temporary structures*

**Eurocodes**

a set of harmonized technical rules developed by the European Committee for Standardization (CEN) for the structural design of construction works in the European Union

**ground**

material supporting construction plant

*NOTE: This may include soil, rock, peat, stockpiled materials, made ground and engineered structures*

**ground assessment**

process of assessment of the suitability of a specific area of ground to support specific items of construction plant

**ground information assessment**

determination of reliability and sufficiency of ground information in relation to the task to be undertaken and the plant and equipment being considered

**ground investigation**

engineering processes and techniques used to obtain technical information that may be required to determine ground bearing capacity and validate the suitability of the underlying ground

**method statement**

document describing a safe system of work using text, images, drawings etc.

**outrigger**

extensible structure attached to the plant chassis to relieve the weight of the plant from its wheels or tracks and increase stability

**party in control of a site**

person or organisation who occupies and controls a workplace

**plant**

see construction plant

**plant operator**

person who is operating an item of construction plant

**proprietary support equipment**

“off-the-shelf” transportable equipment of a specified capacity which transfers and spreads load from construction plant to the ground

*NOTE: Examples include spreader plates, trackway, bog mats, but not equipment designed specifically for the specific task to be undertaken e.g, grillage*

**risk assessment**

a systematic process of identifying the hazards, evaluating the potential risks arising and identifying the necessary measures required to eliminate or reduce those risks to an acceptable level.



***safe system of work***

a method of working designed to eliminate, if possible, or otherwise reduce risks to health and safety

***stabiliser***

extensible structure attached to the plant chassis to extend the tipping line and increase stability

***temporary works*** (See BS5975)

an engineered solution that allows or enables construction of, protection, support or provide access to, the permanent works and which might or might not remain in place at the completion of the works

*NOTE: Examples include granular platforms, steel grillages and ground of assessed capacity.*

***temporary works co-ordinator***

TWC

competent person with responsibility for the co-ordination of all activities related to the temporary works

***temporary works supervisor***

TWS

competent person who is responsible to and assists the temporary works co-ordinator

***temporary works designer***

TWD

competent person who carries out the design of temporary works

***temporary works design checker***

TWDC

competent person, independent from the design process, who carries out a check of the temporary works design

## 3.0 Legal Duties

### 3.1 General

The Health and Safety at Work, etc. Act 1974 (HSWA) and associated regulations require employers and self employed persons to ensure the safety of employees and others not in their employ (including members of the public). Part of that duty is ensuring the stability of construction plant on site by assessing and managing the ground on which it stands. Those with duties include

- Clients
- Designers
- Management Contractors
- Principal Contractors
- Main Contractors
- Sub-contractors
- Other Employers
- Self Employed
- Employees
- Plant Manufacturers
- Dealers
- Rental Companies (Plant Owners)

In addition, plant manufacturers, plant dealers and rental companies have a duty under both HSWA (Section 6) and the Supply of Machinery (Safety) Regulations to provide adequate information to enable a piece of construction plant to be used safely. This will include the loads imposed by the machine on the ground in all possible configurations.

**Annex I** lists the main sets of regulations made under HSWA which apply to the management of plant operations, including ground conditions and stability issues.

**NOTE:** Northern Ireland has its own set of regulations which tend to mirror those in Great Britain, but may have minor differences. Employers should ensure that they are aware of the regulations in the jurisdiction in which they are working.

## **4.0 Roles and Responsibilities**

### **4.1 General**

As with all activities on construction sites, the effective management of ground conditions, including adequate ground assessment, can only succeed if all parties involved are clear about their roles and responsibilities, and able to communicate effectively.

It is essential for all persons undertaking these roles to be competent, having relevant up-to-date training and the qualifications and experience appropriate to the operations for which they are responsible.

The responsibilities for undertaking the various activities involved in ground assessment are set out in **Table 1**.

The roles outlined in **4.2**, **4.3** and **4.8** fulfil statutory duties whilst those in **4.4** to **4.7** reflect good practice.

### **4.2 Party in Control of the Site**

The party in control of the site has overall responsibility for the safety of all personnel on site. They should ensure that where plant is being used to carry out a task, adequate steps have been taken to ensure the stability of the plant on site during - transport onto site, set up, use, movement, maintenance, dismantling and removal from site.

### **4.3 Appointed Persons - Lifting Operations**

The appointed person in control of a lifting operation is responsible for all aspects of planning, supervision and execution of the lifting operation, including ensuring that the ground or structure on which equipment stands will take the loads imposed by the plant. This does not mean that the appointed person has to be an expert in ground assessment, they must however take reasonable steps to satisfy themselves that the information provided by the person in control of the site is relevant and appropriate. The appointed person should have the necessary confidence and authority to carry out their duties effectively.

Where doubt exists as to the accuracy or sufficiency of the information provided it is the responsibility of the appointed person to ensure that the lifting operation does not proceed until the doubt has been satisfactorily resolved.

### **4.4 Temporary Works Designer (TWD)**

The Temporary Works Designer carries out the design of the temporary works to a design brief provided by the Temporary Work Co-ordinator.

### **4.5 Temporary Works Design Checker**

The Temporary Works Design Checker carries out a check of the temporary works design for concept, adequacy, correctness and compliance with the requirements of the design brief. They should be independent from those responsible for the design. The degree of independence required will depend on the category of check required. See **12.3**

### **4.6 Temporary Works Co-ordinator (TWC)**

For a given site, the main or principal contractor should appoint a temporary works co-ordinator who is responsible for the implementation of their organization's temporary works procedures and coordination with all other contractors who are directly or indirectly in their employ.

When work is being carried out by different organizations on site it is common for one organization to prepare and provide the foundations upon which another subsequently erects the main temporary works structure. This physical interface is particularly critical,

but in all cases it is important that physical constraints and interface conditions are clearly defined and the work procedures adopted are able to take effective account of such matters.

The temporary works co-ordinator should manage these interfaces and retain an overview of the whole scheme to ensure each step of the procedure is completed and does not adversely affect the scheme.

It is essential for the TWC to be competent, having relevant up-to-date training and both the qualifications and the experience appropriate to the complexity of the project. The appointment of the TWC should be made known to all concerned.

#### **4.7 Temporary Works Supervisor (TWS)**

The temporary works supervisor (TWS) may be employed by the principal contractor, or by the specialist subcontractor who will be carrying out the work. Each TWS will need to have experience of the work in question and the TWC should be involved in the selection of suitable individuals. On very large or complex jobs the TWS may need to be an experienced and qualified engineer. On small or simple jobs the TWC may also act as the TWS.

On large construction sites where temporary works operations are carried out by various subcontractors, the Principal Contractor's TWC should ensure that a TWS is appointed to oversee the temporary works of each of the subcontractors.

#### **4.8 CDM Co-ordinator**

The CDM Co-ordinator must ensure that there is appropriate communication between permanent works and temporary works designers and, where both parties are involved concurrently, appropriate co-ordination.

***NOTE:** The CDM 2007 Regulations are currently under review and this document will be revised to reflect any changes, once new regulations are in force*

**It is essential that those carrying out ground assessment are aware of their own limitations and know when to stop and consult those expert in the field.**

Activity/Element	Responsibility	Comment
Define each task to be undertaken and its limitations considering static and travelling situations (including access and egress) and environmental conditions. Any changes to task or equipment must be considered	This will fall to the party responsible for the task, e.g. <ul style="list-style-type: none"> <li>Principal/Main Contractor for the design and provision of an access road and plant platform</li> <li>Sub-contractor implementing a lift, carrying out piling, tracking plant.</li> <li>Delivery firm when delivering to a householder's private address when a contractor is not involved</li> </ul>	It is important that contractually it is clear which party is responsible. Statutory responsibility may fall to more than one party e.g. Principal Contractor and the Sub-Contractor (the split depending upon the circumstances) and will not necessarily match contractual divisions.  The Main/Principal Contractor may need to feed information into this action to inform the party responsible of site-wide risk or restrictions.
Select appropriate plant for the task with assistance from manufacturer/supplier	The party carrying out the site operation*.  (On occasions it may be the separate party designing the access/platform etc. in which case the assumptions made, and any restrictions, must be conveyed to the party carrying out the site operation, and to the Main/Principal Contractor)	It may be necessary to consult with the permanent works designer, or Others, if the plant affects the permanent works or third parties.
Establish Obtain loads/forces imposed on the ground/structure by the plant (See Section 9.0)	The party carrying out the site operation has a duty to obtain this information*.  The party supplying the plant has a duty to provide this information.	This may be delegated on occasions to those who are competent to determine these loads  If delegated it is still the responsibility of the party carrying out the operation to ensure it is done by competent persons
Assess the bearing capacity of ground or supporting structure, defining limits of area considered and taking account of both static and travelling conditions (as applicable)	The party carrying out the site operation*.  This may be delegated on occasions to those who are competent to determine these loads	If delegated it is still the responsibility of the party carrying out the operation to ensure it is done by competent persons.  It may be necessary to consult with the permanent works designer if the plant affects the permanent works e.g. loads behind retaining walls.  A suitable check should be included here to guard against error.
Analysis taking account of imposed loads, ground/structure capacity, uncertainty and appropriate factors of safety	As above	As above
Review of adequacy	As above	As above
Design ground/structure improvements/bearing pressure reduction measures	The party determined by the contract.  This may be carried out by others who are competent to determine these loads and may include: <ul style="list-style-type: none"> <li>The Main/Principal Contractor</li> <li>The Permanent and/or Temporary Works Designer</li> <li>The TWC (or TWS)</li> </ul>	It must be clear <b>contractually</b> which party is responsible. Note that <b>statutorily</b> a number of parties may share responsibility e.g. the party undertaking the task and the Temporary Works Designer, the Main/Principal Contractor.  A suitable check should be included here to guard against error.  The TWC will want to be satisfied that this review has taken place and that significant information has been conveyed in writing to all interested parties.
Improve capacity of ground or structure or reduce bearing pressure	As above	As above
Post improvement check	As above	As above
Issue documentation and authorisation	This will vary, it will always include the party undertaking the task, but may also include: <ul style="list-style-type: none"> <li>The Main/Principal Contractor</li> <li>The Permanent and/or Temporary Works Designer</li> <li>The TWC (or TWS)</li> </ul>	For significant tasks the TWC will have a lead co-ordinating role and will authorise the activity e.g. a lift or loading of falsework.
Proceed with task	Party responsible for task	A known person within the organisation carrying out the task will have responsibility.
Monitor task and ground	As above with others as necessary e.g. <ul style="list-style-type: none"> <li>The Main/Principal Contractor</li> <li>The Permanent and/or Temporary Works Designer</li> <li>Person carrying out the task</li> </ul>	All tasks should be monitored, even if informally. For those with greater potential for adverse impact then the monitoring will require formalisation. The monitoring may concentrate on the equipment, lift, ground, adjacent structures etc. as appropriate.
<p><i>*The TWC will have an overarching co-ordination role in respect of much of the above activities, supported as necessary by TWS's. The AP will play a similarly important role with regard to lifting operations.</i></p> <p><i>It is important that in respect of these, and all roles, the duties are defined in writing and made known to all</i></p>		
<b>Table 1 - Planning Activities and Responsibilities</b>		

## 5.0 Principles of Task Planning

**Poor planning is one of the major causes of accidents arising from the use of construction plant. All operations on construction sites should be planned to ensure that they are carried out safely and that all foreseeable risks have been taken into account.**

### 5.1 *General*

The following sets out the principles of planning tasks involving the use of plant on construction sites. Planning applies to sites of all sizes and durations, and may cover a single operation or a whole series of operations requiring effective co-ordination.

Part of this planning process is the assessment of the ground which will support the plant during transport onto site, set up, use, movement, maintenance, dismantling and removal from site. The process of carrying out the assessment and undertaking any remedial measures required is described in **Section 6**.

Even a simple task cannot be carried out without some preparation. More complex tasks need to be planned ahead so that all necessary arrangements have been made by the start date. Planning a task to ensure it can be carried out safely and efficiently involves the following actions:

- Identify task or outcome to be achieved;
- Set out budget and commercial restrictions;
- List hazards associated with the activity;
- Consider options that could completely avoid (remove) the most serious hazards;
- Propose measures to control the remaining hazards (including e.g. information gathering, physical protection, special procedures);
- Review the situation and consider whether the preferred control measure(s) create any new hazards or difficulties;
- If the overall risk of an incident will now be low enough - arrange the work. If the risk of incident is still too high the control measure/s need to be reviewed. If acceptable control measures cannot be found then the task or outcome will need to be reconsidered;
- Arranging the work includes fully briefing the team who will carry it out.

### 5.2 *Responsibility for planning*

Planning and organising the work needs to be coordinated by the Main or Principal contractor. Detailed planning of tasks is usually carried out by the employer who is undertaking the task. The contractor should ensure that they identify a person who is competent to undertake the planning and give them that duty. Where several parties are involved it may be possible to allocate certain tasks to each party. This should be by agreement and recorded. It is particularly important that there is no scope for confusion about who is doing what.

### 5.3 *Identifying the task to be undertaken*

As the first stage in the planning process, the task to be undertaken should be clearly identified, together with the location and sequence. For a simple task there may be limited opportunity for flexibility - e.g. delivery by lorry loader crane - but even at this level the unit could vary from van sized, through rigid body to articulated dependant on site restrictions and nature of load. For more complex tasks it can help to set out the outcome to be achieved as the starting point. This allows a wider range of options to be considered and may prevent early decisions proving too costly or difficult to implement.

## 5.4 Risk Management

We all automatically use the principles of risk management in everyday life. Recognising this allows us to use the process more effectively by breaking it down into a series of steps. In reality it is necessary to go through the process several times during planning of a task as each change tends to have a knock-on effect. Managing the hazards associated with the task involves the following steps:



### 5.4.1 Identifying the hazards associated with the task




The hazards associated with the task should be identified. These might be due to the location and environment where the work is to be carried out; the type of plant being used; the type of task being carried out; the travel route or the people associated with the task or located in the vicinity. This process should also consider the effect of other operations being carried out in the vicinity and the need for co-ordination.

**NOTE:** Assessment of the implications of language skills and prevailing or anticipated weather conditions should form part of all hazard evaluation carried out as part of the planning process for the safe use and maintenance of plant.

### 5.4.2 Eliminate hazards where possible

It may be possible to remove some of the hazards completely. To achieve this, earlier assumptions about sequencing the work or choice of plant may need to be reconsidered.

<b>Examples of hazard elimination</b>	
<p><i>Haul route layout should be designed to keep plant away from open edges or deep water</i></p>	
<p><i>Undisturbed soil samples are often needed in order to assess ground conditions. The photograph shows soil samples being collected by hand from a deep excavation. The trench will only be open for a few minutes and the completely unacceptable temptation is to save time by not shoring the sides. Most excavations will require shoring or battering back unless a site specific risk assessment indicates otherwise. Core samples can also be collected by use of a drilling rig.</i></p>	 
<p><i>Access roads should be wide enough to avoid heavy equipment travelling near soft verges</i></p>	

<p><i>Long boom excavator standing on the berm or bench was selected to avoid working from the slope</i></p>		
<p><i>A Trackway road was laid over a soft grassed area to avoid the machine becoming bogged down</i></p>		

### 5.4.3 Evaluating the remaining hazards

Having eliminated as many of the identified hazards as possible, the next step is to select or develop control measures that can be applied to the remaining hazards. It is useful to be aware of:

- who could be harmed; and
- the consequences of any harm (ie the number of potential casualties; the extent of possible damage; the nature of the injuries - minor or severe; and the complexity of any clear-up operation).

This information helps to direct selection of control measures. For example one highly trained and experienced person doing short duration high hazard work is likely to need fewer physical control measures than a situation where a number of people, such as members of the public, could be exposed to a similar hazard.

### 5.4.4 Identifying control measures

Once the hazard evaluation has highlighted those parts of the task that need control measures to be applied, the procedures and measures required to control each aspect should be identified. This will include consideration of the suitability of plant that is already available for the task to be undertaken, or whether another more suitable type of plant should be used.

*Example - Where materials need to be moved around site and lifted to height a telescopic material handler can perform a variety of lifting operations and be fitted with a range of lifting attachments. The use of a telehandler is a versatile control measure that can remove the hazards involved in repetitious manual handling and dropped material when carrying materials up ladders, using gin wheels and wheel barrows etc.*

*However the use of a large heavy item of plant with visibility issues introduces new hazards requiring control. These control measures include the use of competent operators to avoid contact with pedestrians, other plant and structures. The whole site may have been assessed and a maximum working capacity allocated to the ground. The telehandler may be restricted to travelling on specified routes that have been assessed for bearing capacity, and lifting only while on designated, designed areas. Operators should be provided with information that makes clear which operations are allowed in which areas. This may need to involve briefing documents (including a plan) and reminder signage set out in working areas.*

*Control of the collision hazard will include route segregation to keep vehicles and pedestrians separated. Plant should be fitted with appropriate visibility aids for site conditions such as mirrors and possibly CCTV camera/monitors. As a last resort a competent banksman standing in a safe position may be needed to guide the operator.*

*In summary - control is only achieved by a combination of measures to deal with the original task and hazards and any new hazards that the control measure/s may introduce. Where it is not possible to reduce the risk arising from all these hazards to an acceptable level alternative equipment/working methods may need to be considered.*



**Annex C** shows a range of control measures that allow local plant loadings on the ground to be reduced.

#### **5.4.5** Evaluation of the adequacy of control measures

Having identified control measures that appear to be suitable, they should be assessed to ensure that they are adequate. This includes checking that one control measure will not conflict with another, or introduce fresh hazards. When the overall mix of control measures means that an incident is unlikely to occur the 'risk' of an incident becomes acceptable or tolerable.

If at any time in the assessment process the risk appears too high, then alternative or additional control measures should be considered. Where an acceptable risk cannot be achieved using control measures, the task itself should be reconsidered. This may result in a range of hazards that are easier to control. In some circumstances it may be beneficial to change the build sequence or even the design.

The conclusions of the assessment should be recorded. This is often called the '*risk assessment*' but is in fact just one stage in carrying out a risk assessment. (Recording the conclusions is a legal requirement unless the employer has less than 5 employees). For general construction activity the written assessment should not need to get any more complicated than outlining which measures (physical controls and procedures) have been selected to deal with the significant hazards. The level of remaining risk should be recorded as well as the control measures.

If all the measures taken to reduce the risk to an acceptable or tolerable level leave a residual risk that is still significant, the risk assessment should recognise this and site management should be made aware that continuous supervision and monitoring of the activity is required to ensure it is carried out safely.

#### **5.5** *Developing the method to be used*

Having identified the hazards and worked out the control measures required to carry out the task safely, the information should be developed into a coherent plan. Especially for unusual or non-routine tasks this should include consultation with those who will be undertaking or be affected by the task. Any limitations, contingency measures and emergency procedures should be included in the plan.

#### **5.6** *Recording the planning in a Method Statement*

Once the plan has been developed it should be recorded in a Method Statement. The length and detail of this document depends on the nature and complexity of the task to be undertaken, the skills and experience of the workforce involved and on the level of risk involved. Where it helps, the conclusions of the risk assessment can be recorded in the method statement as a single document. The title needs to reflect this. Many companies now use the term RAMS (Risk Assessment Method Statement) to show that the briefing package comprises both items.

Where a company uses generic procedures for certain tasks, these must be reviewed and modified before use on each site. This is to ensure the procedure is definitely suitable for the site in question. For large, lengthy or complex jobs the review should be planned ahead. For short, simple tasks, the review may be carried out by site personnel in the form of a dynamic assessment - e.g. a routine fork lift or lorry loader crane unloading operation.

Many companies now find that the most effective way of preparing a method statement is to include step-by-step instructions including, or based on, sketch diagrams (or photos from a similar job). These can be labelled and show the current site, the intended sequence and the equipment list more readily than long, wordy documents.

Only the simplest and most repetitive tasks involving an experienced workforce are suitable for verbal only task briefing.

### **5.7      *Communicating the planned safe system of work to all persons involved***

One of the most important aspects of successful planning is to ensure that the contents of the planned safe system of work are communicated effectively to, and between, all parties involved. This needs to take account of language differences. Arrangements should be made to ensure that up to date copies of any method statements are given and explained to the appropriate people, including the Principal Contractor, and that others involved in the job are fully briefed.

Supervisors in particular, need to be clear about how the task will be carried out. They, in turn, need to ensure that the gang has understood the procedure and the sequence of the task. It is also important that those working nearby have been informed of any activity that could affect them. If anyone raises any concern or provides new information, this should be considered and action taken before the work starts.

### **5.8      *Reviewing the plan before the job starts***

There may be a lag between planning and the work getting underway. Many incidents occur because site conditions have changed or the equipment or materials provided are not quite as expected. Immediately before a job starts the specified method should be checked to see if any aspect of the job has changed and the effect that these changes could have on the safety of the operation. If any significant modifications to the plan are required these may need to be considered by the designers. The person responsible for the activity should amend the Method Statement and sign off any significant changes. Any changes should be explained to all those involved.

A check should be made to ensure that all the steps shown in Figure 2 have been carried out and that responsibilities have been allocated.

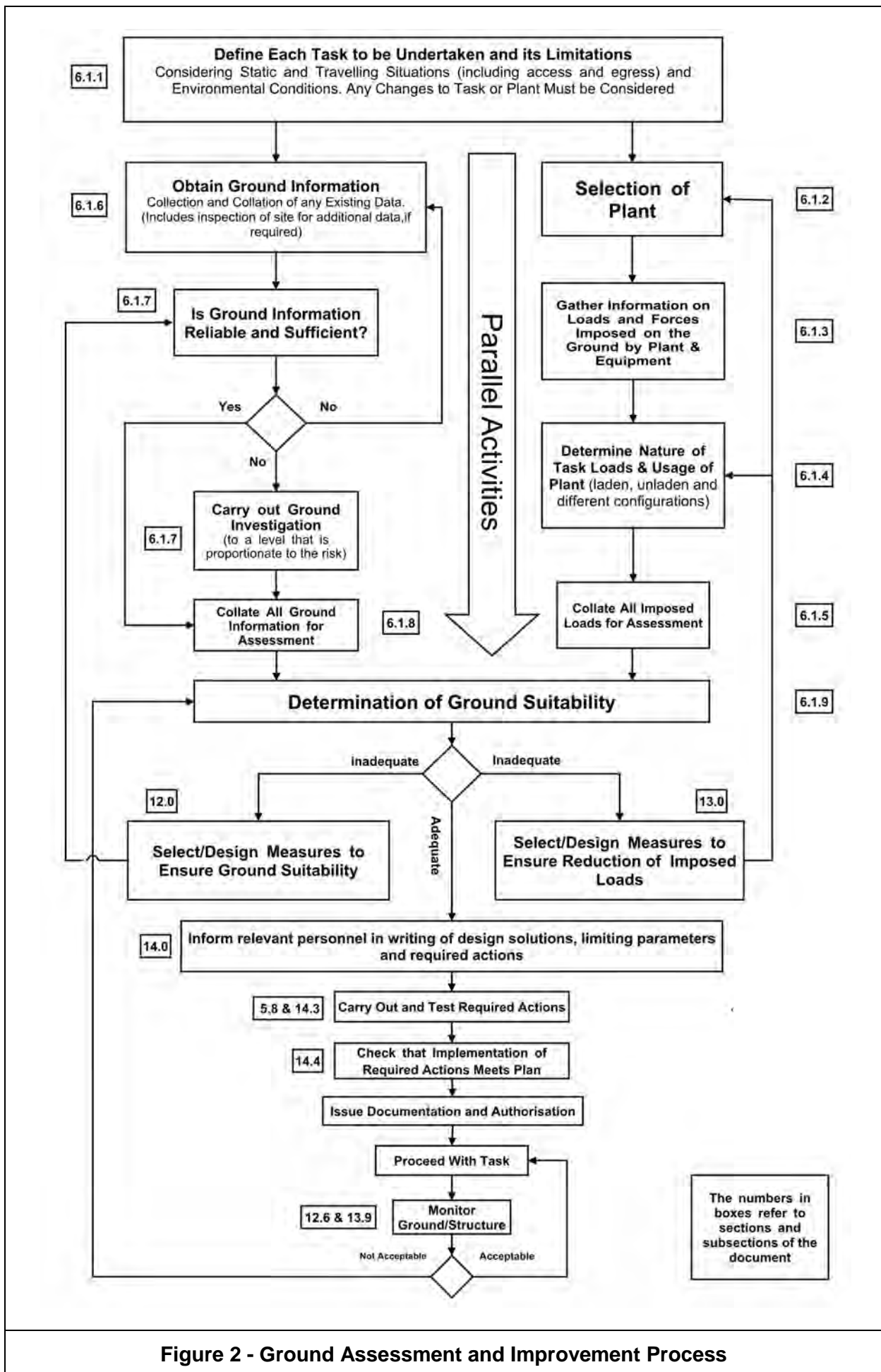


Figure 2 - Ground Assessment and Improvement Process

## 6.0 The Ground Assessment Process

The assessment of the ground on which construction plant is to stand must be carried out in a logical manner, ensuring that all relevant factors are identified and evaluated. Where load reduction or ground improvement measures are required these must be designed by a competent person.

### 6.1 *The Process Step by Step*

**Figure 2** shows the complete ground assessment process which consists of the following steps:

#### 6.1.1 Define each task to be undertaken and its limitations

This should include all circumstances related to the task including:

- delivery of plant to site;
- setting up/erection;
- in service including travelling;
- and out of service including travelling;
- maintenance;
- stowing/dismantling;
- removal from site.

Any changes to the task or the plant will result in a redefinition of the task (See **7.0**).

#### 6.1.2 Selection of plant

Select the item(s) of plant required to carry out the task (See **8.0**).

#### 6.1.3 Gather Information on the Loads and Forces Imposed on the Ground by the Plant

This may include vertical loads such as weight, horizontal loads such as wind or slewing and the resulting forces such as ground pressure under tracks or point loads from outriggers (See **6.0**).

#### 6.1.4 Determine the Nature of the Task Loads and the Use of the Plant

This may include laden, unladen conditions and different configurations (See **9.0**).

#### 6.1.5 Collate Imposed Loads for Assessment

The outcome of this process is a set of imposed loads for the determination of ground suitability (See **9.0**).

**The processes of selecting plant and obtaining ground information are generally carried out at the same time**

#### **6.1.6** Obtaining Ground information

This involves the collection and collation of any existing data for the ground on which the plant will stand and over which it will travel during access to and egress from the site. This includes, if required, inspection of the site for additional data and investigation (See **10.0**).

#### **6.1.7** Assessment

Once the information has been gathered it must be assessed to ensure that it is reliable and sufficient for the purpose of assessment (See **10.0**). If it is not there are two options:

- Attempting to gather more information from various sources;
- Carrying out a ground investigation to a level that is proportional to the consequences of failure of the ground supporting the item of plant.

#### **6.1.8** Ground Information for Assessment

The outcome of this process is information on the ground for the determination of ground suitability (See **10.0**).

#### **6.1.9** Determination of Ground Suitability

Before a determination of ground suitability can be carried out the plant has to be selected and information on the ground collected. These activities can be carried out in parallel.

Once the loads and forces imposed by the plant on the ground and adequate information on the ground are known an assessment of ground suitability is carried out. If the result of this is satisfactory, the results of the assessment must be communicated to those responsible for setting up and using the item of plant (See **11.0**).

If however the assessment indicates that the ground will not be able to bear the loads and forces imposed upon it two measures can be taken to rectify the situation:

- The selection/design of measures to ensure that the ground is suitable such as the provision of a granular working platform, ground stabilisation or the use of a piled foundation (See **12.0**);
- The selection/design of measures to reduce the load imposed on the ground such as reselection of the plant, reduction of task loads or the use of proprietary support equipment (See **13.0**).

Once either or both of these measures have been employed, the assessment of ground suitability is repeated until a satisfactory outcome is achieved.

#### **6.1.10** Communication

Once it has been determined that the ground is suitable to bear the loads imposed by the plant this must be communicated effectively in writing to those responsible for setting up and using the item of plant, together with any requirements for ground improvement or load reduction (See **14.0**).

**It is essential that those carrying out ground assessment are aware of their own limitations and know when to stop and consult those expert in the field.**

## 7.0 Definition of the Task to be Undertaken

### 7.1 Introduction

Before making any assessment of ground conditions it is essential that the task to be undertaken and the plant to be used are carefully defined to avoid confusion.

### 7.2 Task to be Undertaken

The task to be undertaken should be specified as part of the planning process. The brief should include:

- What is to be done e.g. carrying out a piling operation or lifting a specific load with a mobile crane;
- Where it is to be done e.g. location;
- Time limitations.

#### 7.2.1 What is to be done

A brief description of the task to be carried out, such as - install 14No. 800mm diameter x 6m long bored piles or lift 3No. 20m long precast beams into position. The description should include weights and dimensions.

#### 7.2.2 Where it is to be done

A description of the location of the task and should include the access and egress to and from the location for both materials and plant. The description should include brief details of the ground conditions where they are known and any limitations on access, egress, working positions and travelling on site.

**Example** - A large crawler crane was being used for the erection of wind turbines on a wind farm. Once the erection of a wind turbine was completed the crane was travelled fully rigged to the site of the next turbine to be erected. This involved a journey of three-quarters of a mile along site roads. During the journey the edge of the road collapsed causing the crane to overturn.

The crane operator had not been briefed on the importance of keeping the crane in the centre of the road and the road cross slope (camber) at the edge was greater than permitted, increasing the pressure under the track on that side.

**Example** - A 250 tonne mobile crane was being used on a concrete slab supported by columns, but with inadequate back propping. The slab suffered from localised collapse due to the loads imposed by the crane outriggers, allowing the crane to fall through the slab



### 7.2.3 Time limitations.

A description of when the task has to be started, how long it is expected to take and any restrictions, such as limited working hours or the need to complete within a railway possession or a road closure.

**Example** - *A school extension project needed several months build time which could not be shortened into the summer break. Using existing access via the main entrance driveway would have involved construction and delivery vehicles working in close proximity to the public. It would also have effectively stopped deliveries and plant movement during school arrival and departure times including lunchtimes.*

*Playing fields to the rear backed onto a quiet road. The contractor arranged for a fully fenced and gated temporary haul route to be built from the quiet road directly into the site. This involved ground investigation to enable an efficient design to be prepared. At no overall increase in cost the new arrangement benefited the client and the public and removed pressure from the contractor who could be more flexible with scheduling the work and was able to provide better contractor parking, unloading, turning and storage areas.*

## 8.0 Selection of Plant

### 8.1 Introduction

Once the task has been defined the plant required to carry out the task should be selected taking into account the following factors:

- Plant characteristics (See **Annex G**)
- Availability of plant;
- Access to site;
- Egress from site;
- Time constraints;
- Production requirements.

It may well be that some of the requirements are incompatible and several repetitions of the plant selection process will be required to ensure that the most effective solution in terms of cost and efficiency, is found.

### 8.2 Availability of Plant

If the item of plant is to be provided from a contractor's own resources the choice may be limited which may result in the item of plant being larger or heavier than required. Whilst this may appear to make good economic sense, the equipment may impose greater loads on the ground, which may in turn increase the cost of load spreading or ground improvement measures.

On the other hand if the plant is to be hired in from a plant hire company it should be possible to obtain the correctly sized piece of plant for the task. It is often false economy to use an item of plant which is not of the optimum capacity, as productivity will be affected. Sometimes where the correct piece of plant is not available the plant supplier will substitute a machine with a larger capacity. Care should be taken to ensure that this does not compromise safety as the substituted machine may have a different specification such as a greater weight, wider outrigger spread etc.

**Example** - Foundations for wind turbine generators required the use of driven precast concrete piles to transfer the permanent works loads through weak alluvial soils overlying dense gravel and into the underlying chalk. The foundation design required the piles to found in the chalk at depths of between 34 and 35 metres. This meant that piles had to penetrate up to 10 metres of dense gravel. To facilitate this, the piling specialist brought in a rig from its parent company in Denmark equipped with a 9 tonne hydraulic hammer. This was successful in ensuring that all piles penetrated to the chalk.

A further benefit of using this machine was that it was able to handle and pitch the piles in two segments of 17 to 18 metres in length, whereas generally available UK piling plant is limited to 15 metres which would have meant three segments per pile. This gave savings in both time and cost

Since two of the foundation locations were adjacent to the dock perimeter road, the risk of lifting operations adjacent to areas used by third parties was reduced by 1/3, i.e. two lifts per pile instead of three.

### 8.3 Access to Site

A significant constraint on the selection of plant may well be access to the site in terms of width, height, bend radii and ground bearing capacity. This may limit the size of machine which can access the site and if a larger piece of plant is required to carry out the task, it may be necessary to either modify the access route to increase its capacity, dismantle the plant for transport onto site and reassemble at the task location or reconfigure the task so that a smaller machine can be used.



## 8.4 Egress from Site

When selecting plant for a task it should always be born in mind that access routes change over the life on a construction project and that the access route that a piece of plant came into site on may not be adequate when the time comes to leave site.

*A self erecting tower crane (SETC) was being used for lifting on a refurbishment project in a town centre. The crane stood in a courtyard for the duration of the project and the only way in to the courtyard was through a single archway, which was just high enough to allow the folded SETC to pass below. During construction a beam was inserted at the top of the arch to support a wall being constructed above. When it was time to remove the crane from site it was found that the headroom had been reduced to such an extent that the crane could not pass through the archway. The only way to remove the crane was to dismantle it at considerable cost and inconvenience to the site.*

## 8.5 Time Constraints

The time constraints on a task will also have an effect on the selection of plant. For example - if a bridge deck is to be lifted into position over a railway line with a 24 hour possession over a week end, this will probably have to be completed in one lift using a large capacity mobile crane. On the other hand if a bridge is being constructed over a road that is also under construction the bridge deck may be constructed in situ over a longer time, requiring a much smaller capacity crane.

Where small amounts of material have to be excavated, time constraints may mean that it is more effective to use a large 360° excavator that is already on site, rather than to wait for a smaller machine to be delivered, even though the ground loads are greater.

**Example** - *The facade of a building in an inner city location required a structural inspection which had to be completed during a Saturday night and Sunday all day road closure. Access was provided using a 61m working height truck mounted MEWP as the machine was able to be set up rapidly and could cover the whole facade from two set up positions, reducing downtime for repositioning the machine. This allowed the inspection to be completed within the time limit of the road closure.*

**Example** - *A pre-stressed concrete bridge carrying two rail tracks over a road had to be removed and replaced with a new steel bridge deck over a weekend rail possession. Utilising a 1000 tonne capacity mobile crane and purpose designed lifting accessories, the bridge replacement was completed in time to allow rail traffic to resume on Monday morning.. The large capacity crane required a costly, purpose built foundation to accept the loads imposed by the crane's outriggers.*

*If the contractor had not been given a limited amount of time to complete the operation it would have been possible to have carried out the work by demolishing the old bridge and constructing the new bridge in situ. As a consequence a much smaller crane could have been used and the foundation costs would have been greatly reduced.*

## 8.6 Production Requirements

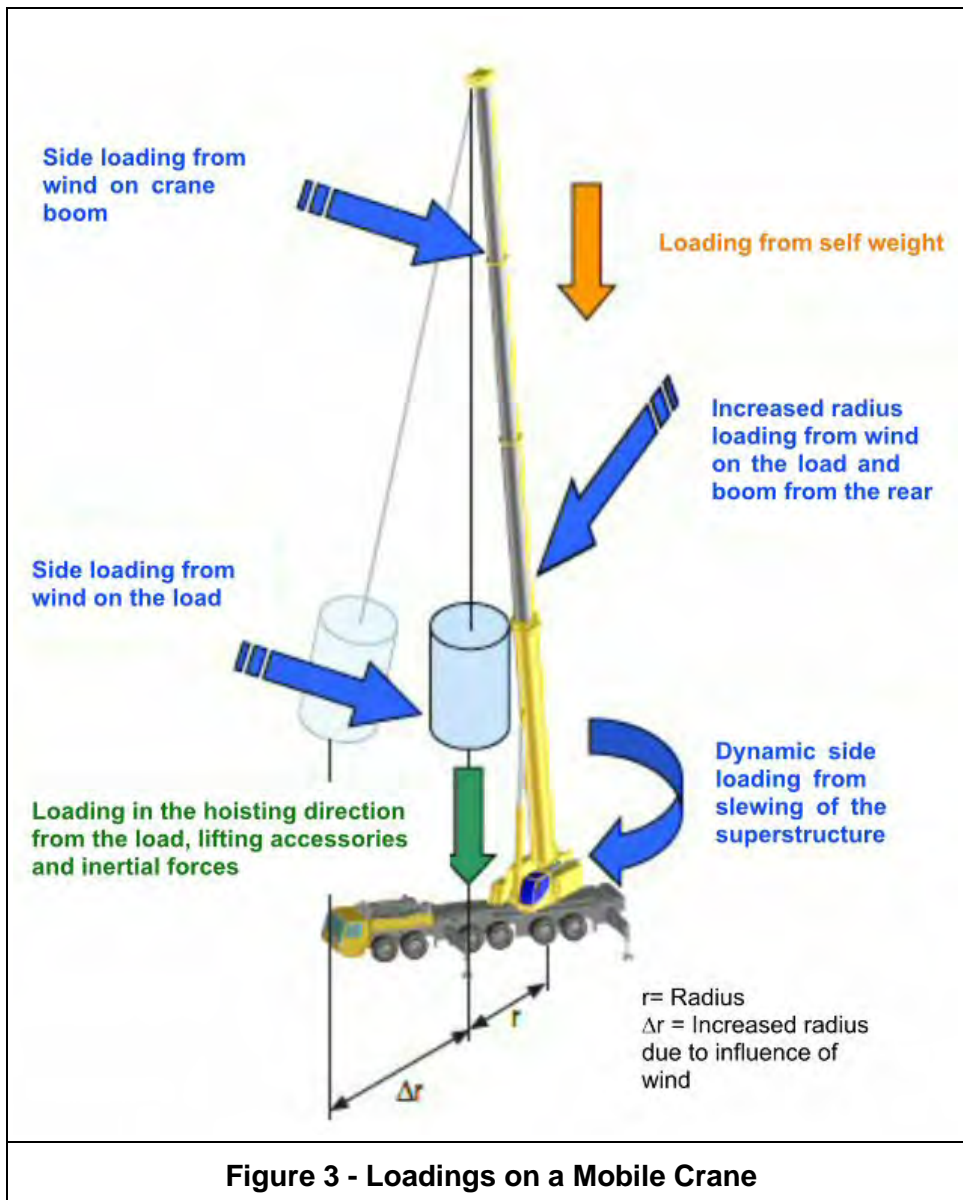
Production requirements will also have an impact on the selection of plant for a task. The construction programme may well require a specific output such as a specific volume of earth excavated each day or a specific number of piles driven and the plant selected will have to be capable of meeting this requirement.

**Example** - *During flood defence work in a harbour on the coast of East Anglia large quantities of sand had to be moved each day to maintain the construction programme. The haul route involved several significant inclines, soft areas and difficult going. The distances involved were too long to allow temporary levelling and construction of a designed temporary roadway structure. Although the route was passable and safe for wheeled dumpers to use, it was recognised that it would be susceptible to delays and impassable during and following wet weather. The contractor priced the job to use tracked dumpers which were ideal for the conditions and able to achieve the required output in both dry and wet weather.*

## 9.0 Plant Loads and Forces

### 9.1 Introduction

Having selected the plant required to carry out the task an assessment of the loads and forces it will impose on the ground should be made. These will be made up of loads imposed by the item of plant itself due its self weight and configuration and additional loads due to the mass of any object or material being handled or lifted by the item of plant. These loads will be affected by wind both in and out of service. This may significantly increase the loads. **Figure 3** shows the effect of wind on a mobile crane and it's load.



### 9.2 Information Sources

#### 9.2.1 Plant Loads and Forces

Plant loads and forces may be obtained from a number of sources including:

- The plant manufacturer;
- The plant supplier;
- By calculation (See **Annex A**);
- By measurement (using load cells to measure the imposed loads).

Care should be taken to use the most accurate source of information as this will influence the cost of any ground improvement measures required, if those loads are over estimated. Conversely a collapse could occur if they are underestimated

**NOTE:** Both plant manufacturers and plant suppliers have a duty to provide this information under Section 6 of the Health and Safety at Work etc Act 1974 and the Supply of Machinery (Safety) Regulations 2008. Further information on this legislation is given in **Annex I**.

The information provided by the plant manufacturer and suppliers will vary depending on the type of plant. Examples of loading information for various types of plant are given in **Annex G**.

**When obtaining loading information for plant it is essential to ensure that the information is for the exact configuration of plant to be used. Some manufacturer's data sheets give weights for a base machine to which the weight of jibs, booms, buckets, wide tracks etc must be added.**

Although the manufacturer or supplier of the plant has a duty to provide information that will allow it to be used safely, it is however, essential that the user advises the manufacturer or supplier of the task to be carried out i.e. extracting or driving piles, and the exact configuration of the item of plant, so that the correct information can be supplied. The task being under taken and the configuration of the plant may both have a significant effect on loads imposed on the ground.

It is ultimately the responsibility of the user to ensure that they have obtained accurate information and have interpreted it correctly.

*A large mobile crane was being used to lift a small piling rig out of an excavated area. The crane was set up on the piled edge of the excavation and the appointed person decided that to achieve the required load radius the outriggers would have to be short rigged (the outrigger beams not extended to their full extent). With a reduced distance between the tipping line and the centre of gravity of the crane and load, the outrigger loads were greater than anticipated, the ground failed and the crane overturned into the excavated area.*



In some cases, particularly with older items of plant, the manufacturer may no longer be in business. In this case the owner, supplier or in certain circumstance, the user, should consult a suitably qualified and experienced engineer who should, after carrying out an assessment, be able to provide the required load information.

A brief assessment which involves making a number of assumptions will provide data with a low certainty and require the use of a large factor of safety, resulting in a conservative, and possibly expensive, foundation. On the other hand a detailed assessment will be quite costly, but will result in data with a higher level of certainty and allow a lower factor of safety to be used, resulting in a less costly foundation. It is important to consider these factors to ensure the lowest outturn cost. (See also **9.5**)

It may also be more efficient to use alternative plant with readily available data.

### 9.2.2 Duty or Service Loads

Duty or service loads include anything imposed by the use of the plant and may include prefabricated units, bulk materials, people, driving/extracting forces etc.

Object or material loads may be obtained from a number of sources including:

- The manufacturer of the object or material;
- The supplier of the object or material;
- By calculation (based on standard criteria);
- By measurement (e.g. weighing).

Again care should be taken to use the most accurate source of information as this will influence the accuracy of the ground assessment and the cost of any ground improvement measures required.

**NOTE:** Both manufacturers and suppliers have a duty to provide this information under Section 6 of the Health and Safety at Work etc Act 1974. Further information on this legislation is given in **Annex I**.

The information provided by manufacturers and suppliers of objects and materials will vary depending on the type of object or material but will include some or all of the following:

- Weight;
- Density;
- Overall dimensions;
- Location of centres of gravity;
- Wind sail areas and centre of pressure.

#### **Wind on Suspended Loads**

Wind can have a significant effect on suspended loads as shown in **Figure 3** leading to an increase in the load radius or side loadings on jibs. The load due to the wind depends on:

- the aerodynamic drag on the load
- the area and weight of the load.

Mobile cranes are designed with a standard drag factor of 1.2 and a wind area/weight of 1.2 m<sup>2</sup>/tonne. This means that certain types of loads will produce higher side loads on the crane than it is designed to take.

. The area/weight and drag factor for some typical loads are:

<b>Load</b>	<b>Area/Weight</b>	<b>Drag Factor <math>c_w</math></b>
Standard values from EN13000	1.2 m <sup>2</sup> /tonne	1.2
12m Container Cabin	14 m <sup>2</sup> /tonne	1.55
System Shutter Panel 3m high x 1.9m wide	42 m <sup>2</sup> /tonne	1.4
Wind Turbine Rotor	5 - 10 m <sup>2</sup> /tonne	1.5 to 1.8

Further guidance on this issue can be found in the Liebherr publication "*Influence of Wind on Crane Operation*" See **Annex K**

### 9.3 **Plant Configuration**

Before obtaining the plant loads and forces, the plant configuration must be established. Many items of construction plant can be configured for a large number of duties and each configuration and/or mode of use will give rise to differing ground loads. As an example the information for a mobile crane will include:

- Crane make and model;
- Outrigger spread;
- Boom extension;
- Length and offset of any fly jib;
- Hook block and number of falls of hoist rope;
- Quantity of counter weight fitted to the crane;
- Maximum radius the load will be taken to during the lift together with the pick-up and lay down radii;
- Mass of and centre of gravity of the load to be lifted;
- Slew arc for the lifting operations.

Further examples for other type of plant are shown in **(Annex G)**.

### 9.4 **Travelling, Set up and Operating Conditions**

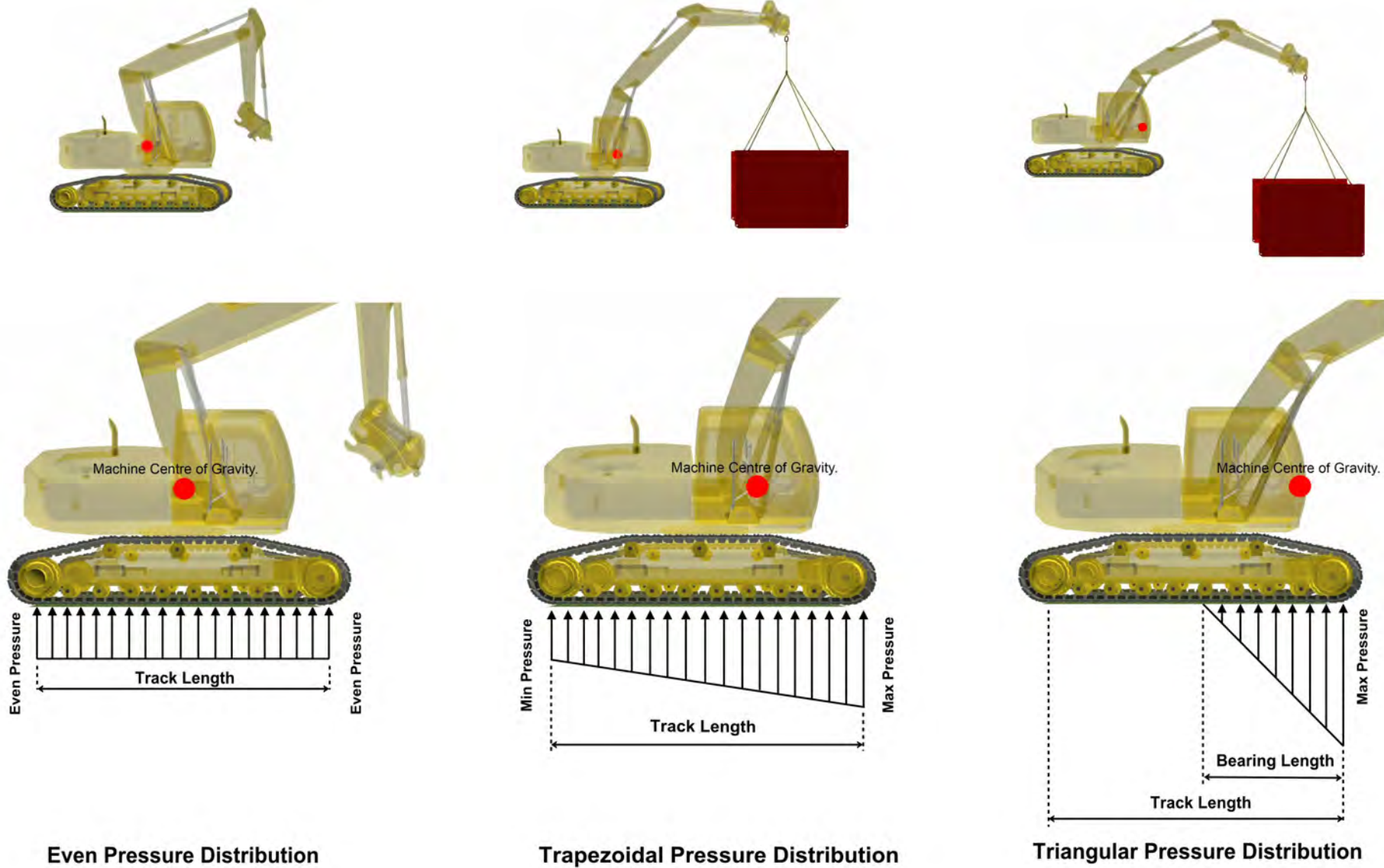
When establishing the loads and forces imposed by the plant on the supporting surface it is important to ensure that all conditions are considered including:

- Access/Egress (travelling);
- Set up/erection/maintenance;
- Operating - fully laden (static and/or travelling);
- Operating – unladen (static and/or travelling);
- Out of service (not in use).

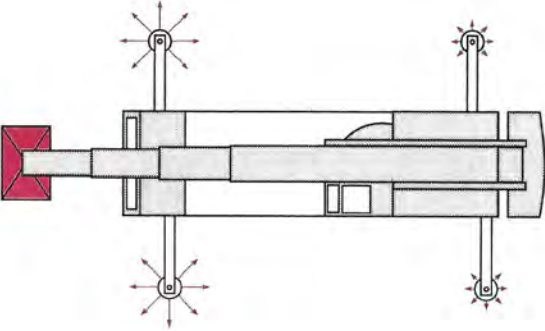
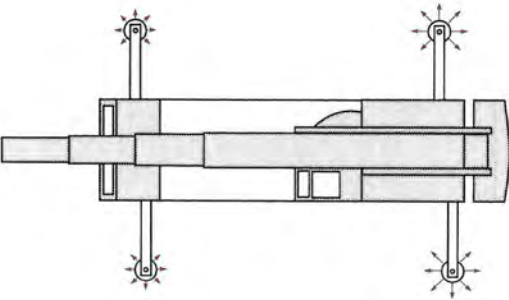
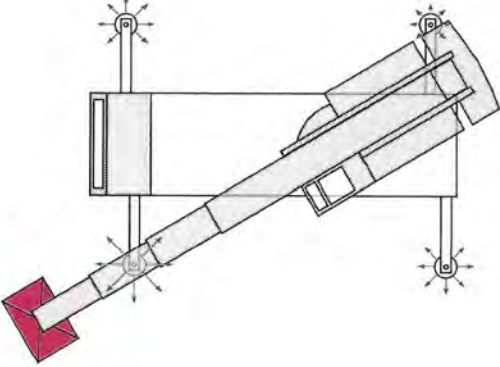
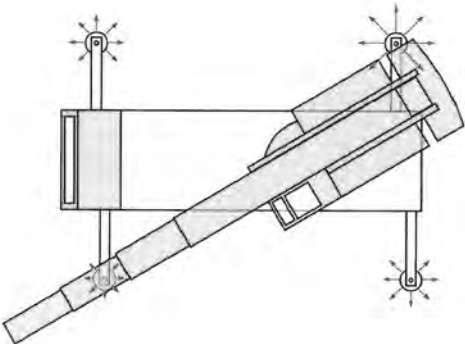
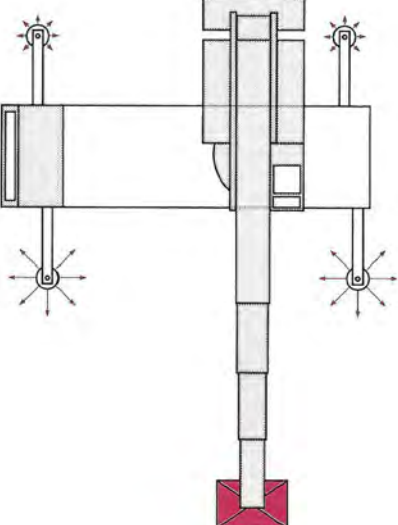
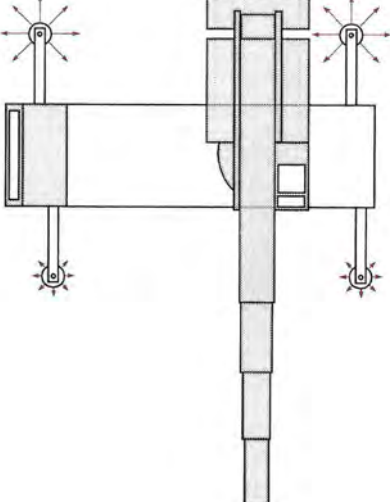
It is often assumed that maximum loads and forces will occur during operation at maximum capacity. This is not always the case - for example, on some 360° excavators, travelling with an empty bucket and the main boom and dipper at minimum radius will result in maximum ground pressures under the rear of the tracks (See **Figure 4**).

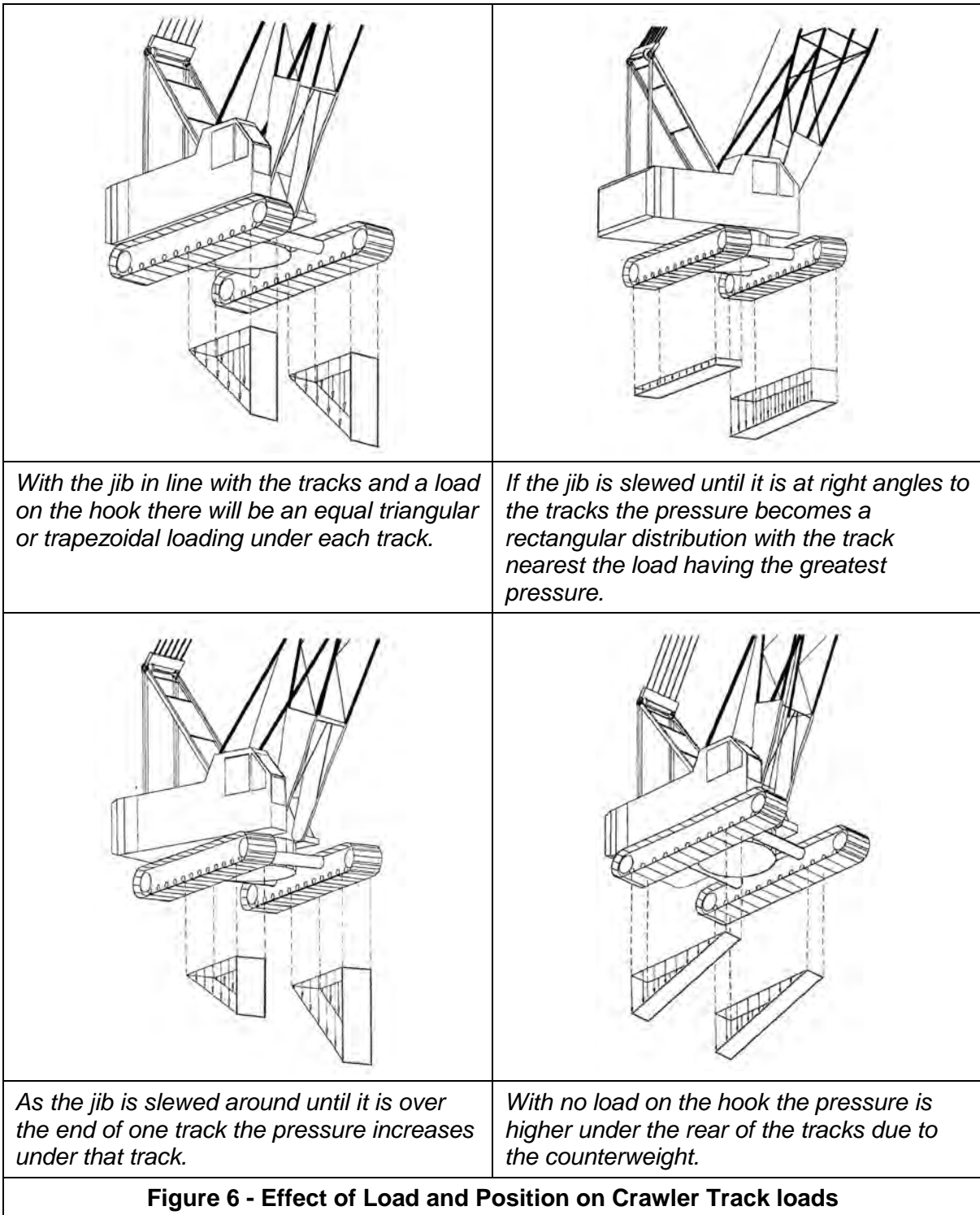
The same is true for a mobile crane where the outrigger loads may well be higher without any load on the hook at minimum radius, due to the backward moment from the counterweight, than when lifting loads at maximum radius. (See **Figure 5** for cranes on outriggers and **Figure 6** for crawler cranes).

**NOTE:** *Outrigger loads for mobile cranes may not include the effects of wind loads on the crane structure. The manufacturer should be contacted to seek clarification.*



**Figure 4 - Crawler Track Pressure Distribution**

Load on Hook	No Load on Hook
	
<i>Highest loads on front outriggers</i>	<i>Highest loads on rear outriggers</i>
	
<i>Highest load on outrigger under jib</i>	<i>Highest load on outrigger under c/weight</i>
	
<i>Highest loads on outriggers nearest load</i>	<i>Highest loads on outriggers under c/weight</i>
<b>Figure 5 - Effect of Load and Position on Outrigger loads</b>	





## 9.5 Safety Factors for Plant Loads

It would obviously be unacceptable for a structure to fail as soon as it experienced the full load it was designed to carry. In order to prevent failure the structure needs to be designed so that it has some extra load carrying capacity – in other words a “margin of safety”. It should be noted that the presence of a safety margin does not mean that allowable (rated) loads can be exceeded - it is not spare capacity or overdesign that is available for intentional use

Information about, for example, the size of the load, the forces involved, the strength of the material, the ground bearing capacity, etc may be provided in one of two ways:

- Working loads or capacities (which include a factor of safety)

or

- Ultimate failure values (to which a factor of safety must be applied)

**It is essential that the user of this information clearly understands which approach has been adopted. If they have any reservations about the accuracy of the information or what factors (if any) have been applied they should seek clarification from the supplier or their manager before proceeding with the design.**

Therefore when obtaining the loads and forces imposed on the ground by construction plant it is vital to establish if these are factored or unfactored. If this is not established, additional factors may be applied to an already factored load, resulting in double application of safety factors and unnecessarily costly ground improvement measures. On the other hand, if safety factors are not applied to unfactored loads during ground bearing capacity calculations, this may result in ground bearing failure and plant overturn. It is essential that the designer carrying out the determination of ground suitability and the design of any remedial measures is made aware of the status of loads and forces i.e. are they factored or unfactored.

Factored loads or capacities include a safety factor that the supplier has usually taken from a national or international code. It is also important for the designer to be sure that a factor already applied is suitable for the situation being assessed.

*A lorry loader imposes a maximum load of 70kN (unfactored) on the foot of each outrigger. The outrigger foot stands on a 0.5m x 0.5m pad which gives a maximum ground bearing pressure of:*

$$\frac{70}{(0.5 \times 0.5)} = 280\text{kN/m}^2$$

*The ground on which the lorry loader is standing has an ultimate (unfactored) bearing capacity of 600kN/m<sup>2</sup>. A factor of safety of 2 is applied to the ultimate bearing capacity of the ground to give a maximum permissible bearing capacity of:*

$$\frac{600}{2} = 300\text{kN/m}^2$$

*The maximum ground bearing pressure imposed by the lorry loader on the ground is less than the maximum permissible bearing capacity of the ground and result is therefore acceptable.*

See **Annex H** for further information on factors of safety.

## 9.6 *Dynamic and Static Loads*

The loads imposed on the ground by an item of plant are frequently given as static loads calculated from masses and centres of gravity of the plant and its load. These may have to be multiplied by a factor to take account of dynamic effects due to

- Vibration due to motors or driving equipment
- Slewing
- Lurching, braking and acceleration during travel
- Acceleration/retardation of load during lifting operations
- Impact or sudden release of load
- Piling and extraction
- Digging

The dynamic factor is not the same as a factor of safety. It only converts the static load to a dynamic load. The factor of safety has to be applied separately.

Establishing values for all circumstances is beyond the scope of this document but there are numerous documents that indicate suitable values for dynamic factors, particularly for travelling vehicles and cranes. The values suggested vary greatly depending on the type of plant or vehicle being considered but are generally between 1.1 and 2.0.

The exact dynamic factor to be used should be selected by the designer based on the specific circumstances and giving due consideration to the following

- type of ground
- type of foundation
- maximum speed of travel / movement
- regularity and gradient of the travelling surface
- rates of acceleration/retardation
- smoothness of plant operation
- advice from the plant supplier (if necessary)

## **10.0 Ground Information**

### **10.1 Introduction**

Before the suitability of the ground can be determined information on the ground on which the plant will stand must be obtained. This can be obtained or compiled from a number of sources such as:

- Site inspection;
- A comprehensive ground investigation report for the site;
- A comprehensive ground investigation for the plant location;
- A blanket maximum permissible bearing pressure for the whole site or part of the site from a competent source;
- Records of demolition contractors on site reinstatement on brownfield sites;
- Highways authority;
- Owner of premises (Health and safety file);
- British Geological Survey records;
- Tender site investigations for locality;
- Coal authority reports;
- Utility location plans.

Once the information has been obtained it should be assessed to ensure that it is adequate to enable a determination of ground suitability to be made. If the information is not adequate it will be necessary to obtain more detailed information by either returning to the original sources of information or arranging for a ground investigation to be carried out.

The validity of the information should be verified by site inspection (See **10.3**)

### **10.2 Typical Ground Information**

Typical ground information required to determine ground suitability includes the following examples:

- Surface type:
  - Soft ground such as topsoil;
  - Unsurfaced ground;
  - Surfaced footpath;
  - Roadway - tarmac or concrete.
- Surface properties:
  - Potential for degradation, including wearing
  - Adverse weather effects;
  - Resistance to sliding;
- Topographical properties:
  - Gradient;
  - Cross slope;
  - Flatness
  - Major and minor obstacles;

- Make-up of Ground:
  - Soil strata;
  - Groundwater
  - Engineering properties
- Adjacent/underlying features:
  - Structures (adjacent and underground);
  - Buried or Surface Services;
  - Trees;
  - Embankments;
  - Retaining walls;
  - Excavations
  - Proximity of other plant.

### 10.3 **Site Inspection**

A site inspection should always be carried out as part of the planning process well in advance of the start of task. Where basic operations are being carried out in straightforward circumstances this may be undertaken on arrival of the plant on site.

**Example** - A large piling rig is needed to install piles to a depth of 35m on a congested site. The site inspection is required at an early stage to identify the need for any working platform and the viability of access routes.

**Example** - An excavator is being used on an open greenfield site to dig trial pits. In this case the ground conditions site inspection can take place when the machine arrives on site and before work starts.

The site inspection should include the identification of visual indicators such as:

- Topography;
- Distressed structures;
- Backfilled areas - e.g. cracking/differential settlement e.g. at junction with undisturbed ground;
- Water flow - e.g. streams, ditches, wet areas, land drain indicators;
- Rainfall - recent history or likely effect of fresh rainfall;
- Service duct access covers;
- Adjacent structures;
- Trees;
- Embankments;
- Retaining walls;
- Excavations;
- Proximity of other plant.

### 10.4 **Assessment of Information Adequacy**

The amount and detail of ground information required for plant carrying out a particular task will depend on a number of factors such as:

- The magnitude of the loads and forces imposed on the ground by the plant;
- The zone of influence of the loadings (See **Figure 7**);
- The risk of ground bearing failure;
- The consequences of ground bearing failure in terms of both injury/death of site personnel and the public, together with delays/cost to the project;
- Whether or not a large factor of safety can be applied without incurring large cost/space penalties.

If the ground information is found to be adequate this can be used to input to the determination of ground suitability. If it is not a ground investigation will need to be carried out.

## **10.5 Ground Investigation**

As with the assessment of adequacy of information in **7.4**, the nature and extent of any ground investigation will be determined by similar factors. Once these have been evaluated a suitable investigation should be carried out. The exact requirements for the investigation will depend on the nature of the loading and any proposals for an engineered solution. Detailed advice should be obtained from the designer and or the site investigation specialist to confirm exact requirements.

Requirements will include some or all of the following:

- The depth of the investigation will depend on the size of the foundations or loaded areas (See **Figure 7**);
- Identification of soils and groundwater (if present);
- Tests to determine both the engineering properties of soils
- Simple on-site tests to confirm the adequacy of the ground investigation during installation of the support measures and/or the plant.

**Table 2** gives basic soil descriptions and indicative SPT and Cu values. More detailed soil types and characteristics are given in **Annex B**

***NOTE** – Soil contamination and chemical properties should be considered separately from other environmental consideration where soil stabilisation techniques such as lime stabilisation are being evaluated.*

### **10.5.1 On-site tests**

Tests carried out on site may include:

- Digging of trial pits;
- Basic soakage tests;
- Penetrometer tests
- Hand vane tests to measure undrained shear strength;
- Plate bearing tests;
- Collection of soil samples by boring or other means.

### **10.5.2 Laboratory tests**

Tests carried out in a laboratory using samples collected on site may include:

- Classification;
- Compaction;
- Compressibility;
- Permeability;

- Durability;
- Hydraulic cell tests;
- Total Stress;
- Effective stress;
- Rock strength.

### 10.6 Final Assessment of Information Adequacy

Once the ground investigation has been completed the information obtained should be assessed to ensure that it is adequate to allow the determination of ground suitability to be carried out.

<b>GRANULAR MATERIAL (Gravels, sands etc)</b>	<b>COHESIVE MATERIAL (Clays)</b>
<b>Very loose</b> – SPT < 4 blows/300mm	<b>Very soft</b> – Cu < 20
<b>Loose</b> – SPT = 4-10 blows/300mm <i>Can be loosened with a spade easily</i>	<b>Soft</b> – Cu = 20-40 <i>Can be moulded easily by light finger pressure</i>
<b>Medium</b> – SPT = 10-30 blows/300mm <i>Can be excavated by spade with effort</i>	<b>Firm</b> – Cu = 40-75 <i>Can be moulded by strong finger pressure</i>
<b>Dense</b> – SPT = 30-50 blows/300mm <i>Requires pick for excavation; 50mm wooden peg hard to drive</i>	<b>Stiff</b> – Cu = 75-150 <i>Cannot be moulded by fingers; can be indented by thumb.</i>
<b>Very dense</b> – SPT - >50 <i>Steel pin hard to drive</i>	<b>Very stiff</b> – Cu >150 <i>Can be indented by thumb nail</i>
<b>Key</b> <b>SPT</b> = Standard Penetration Test <b>Cu</b> = Undrained immediate shear strength (kN/m <sup>2</sup> )	
<b>NOTE:</b> Where ground has be excavated and backfilled special care must be taken as the soil types can be mixed and the compaction may be variable. On backfilled ground a low compaction figure (loose - granular or soft - cohesive) should be assumed unless an actual compaction figure can be obtained from the site.	
<b>Table 2 - Soil Descriptions and Indicative SPT and Cu Values</b>	

## 11.0 Determination of Ground Suitability

### 11.1 Introduction

Once the loads and forces imposed by the plant and the information on the ground have been obtained, the suitability of the ground can be determined by analysis.

### 11.2 Transmission and Distribution of Load into the Ground

There are a couple of important principles to understand about the way loads are transmitted into the ground. The first is the manner in which loads are distributed to the surface of the ground, especially for outrigger pads. The second is the way ground pressures are distributed through the underlying soils.

#### 11.2.1 Transmission of loads

To obtain maximum load bearing capacity and keep deformation to a reasonable limit, the load from the plant must be transmitted to the ground in an effective manner. This means ensuring that:

- Pads used under outriggers need to be both strong enough and stiff enough
- Outriggers are placed centrally on pads

It's important to understand that a pad may have enough strength but may not be stiff enough. If the pad isn't rigid enough, the load will be concentrated on a smaller area in the middle of the pad. This will result in increased ground pressure which will cause more deformation and may lead to collapse. (see **Figure 5(b)**)

The strength and stiffness of a pad will depend on the material and the thickness. Material strengths and stiffness are generally understood but it should be noted that plastics are stronger than timber but timber is stiffer than plastic, the order being as follows:

**Strength:** steel > aluminium alloy > nylon > polyethylene > hard wood > soft wood

**Stiffness:** steel > aluminium alloy > hard wood > soft wood > nylon > polyethylene

Because of this a timber pad may not be able to carry as much as a plastic pad but it will still be more effective at transmitting the load into the ground because it will spread the load more evenly over a larger effective area.

What is not generally understood is that the load carrying capacity and stiffness of a pad isn't proportionate to its thickness. For twice the thickness you actually get four times the strength! You also get eight times the stiffness!

Looking at this the other way round, people often assume that two pads, one on top of the other, will be as good as a pad of the same total thickness. However, the two thinner pads will only provide half the load capacity and would deflect twice as much. This is due to the two pads sliding over each other as they deflect, known as a "*lack of shear connection*".

#### Example

Consider an 18mm thick 1.2m x 2.4m steel road plate.

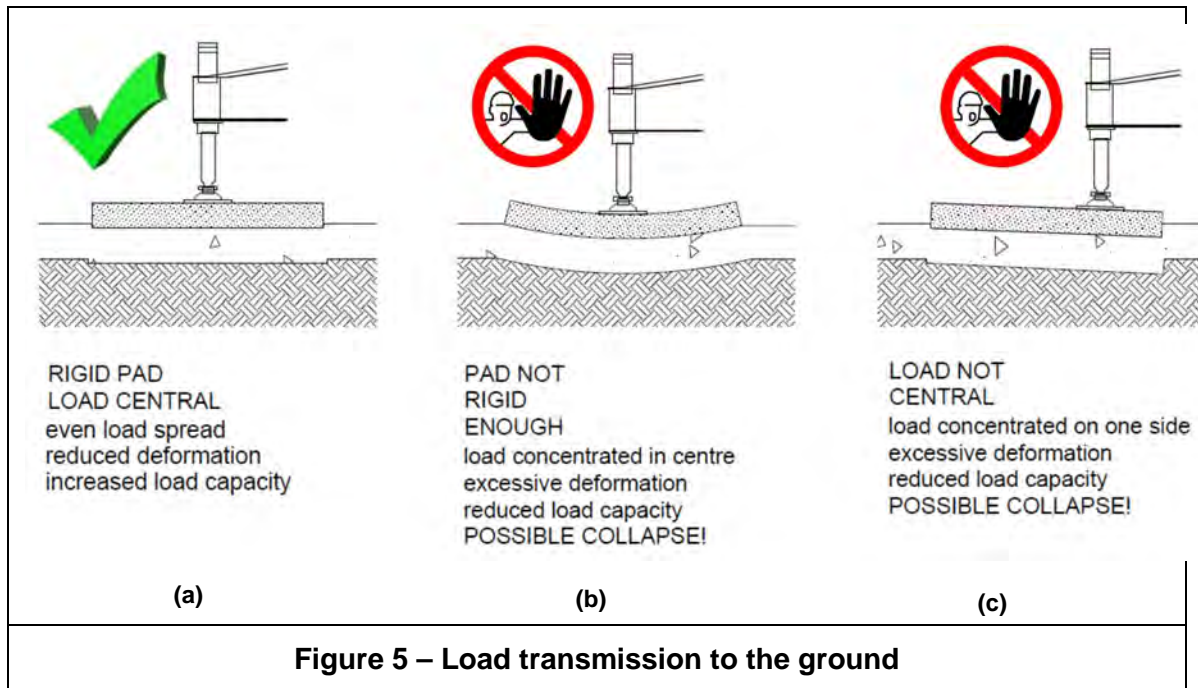
Its safe working load will be only about 4 tonnes, which would cause up to 30mm deformation.

Two of these plates would have a safe working load of about 8 tonnes, which would cause the same deflection.

A plate of the same size but twice as thick (36mm) would have a safe working load of about 16 tonnes, which would cause up to 15mm deformation – twice the capacity and half the deflection!

It's also important to understand that the load must be placed in the centre of the pad (concentric) and not toward the sides (eccentric). If the load is placed to one side it also

has the effect of concentrating the load on a smaller area, resulting in excessive deformation and possible collapse. (see **Figure 5(c)**)



### 11.2.2 Distribution of loads

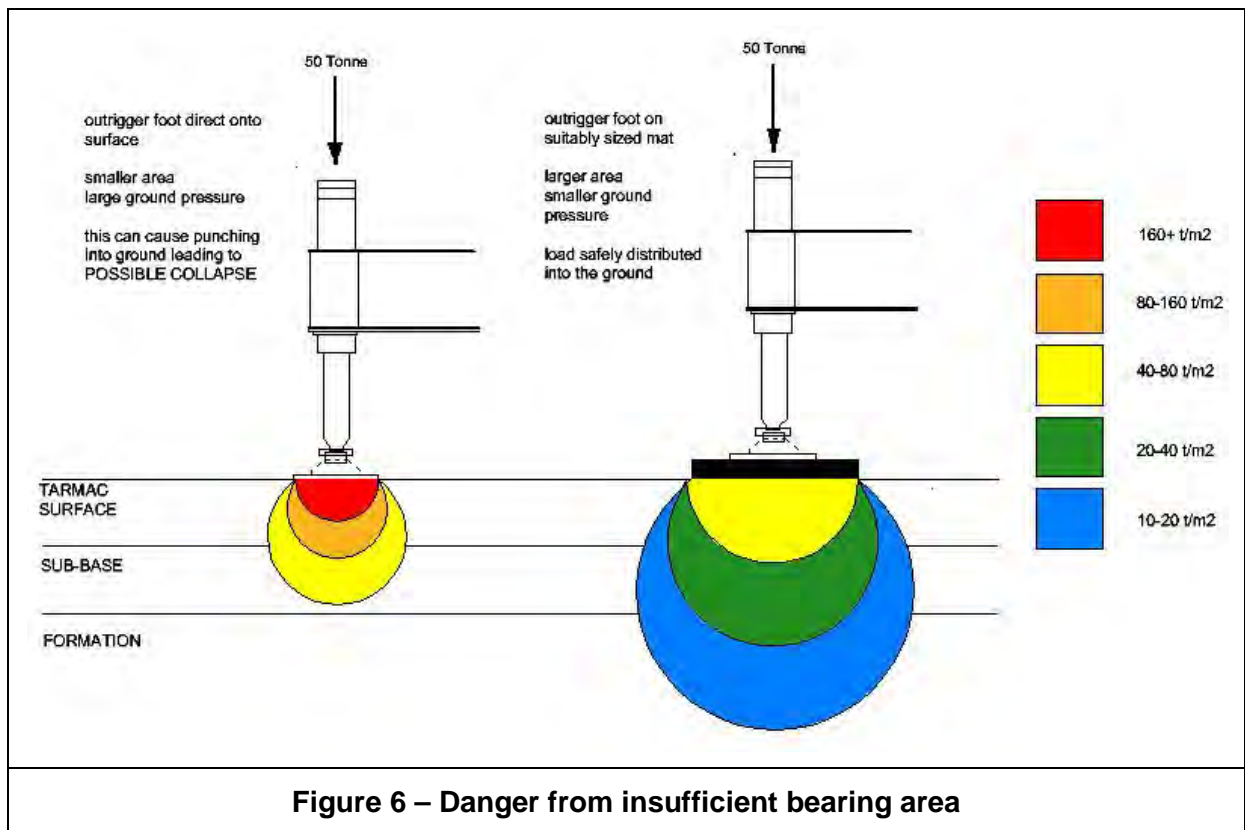
To avoid collapse due to failure of the ground it is important to ensure that:

- The contact area must be large enough to give a safe ground bearing pressure
- Stresses in the underlying ground must also be at a safe level

At the surface, it is important to make sure the loads are distributed over a large enough area to avoid “punching” into the surface. In other words, the ground bearing pressure must be kept within an acceptable level for the surface and/or underlying ground. If the bearing pressure imposed is too large, some means of spreading the load must be provided.

For example, an outrigger foot alone might cause too much pressure. If a pad is added then the load will be spread and the pressure reduced, avoiding damage to the surface and preventing possible collapse. (see **Figure 6**)

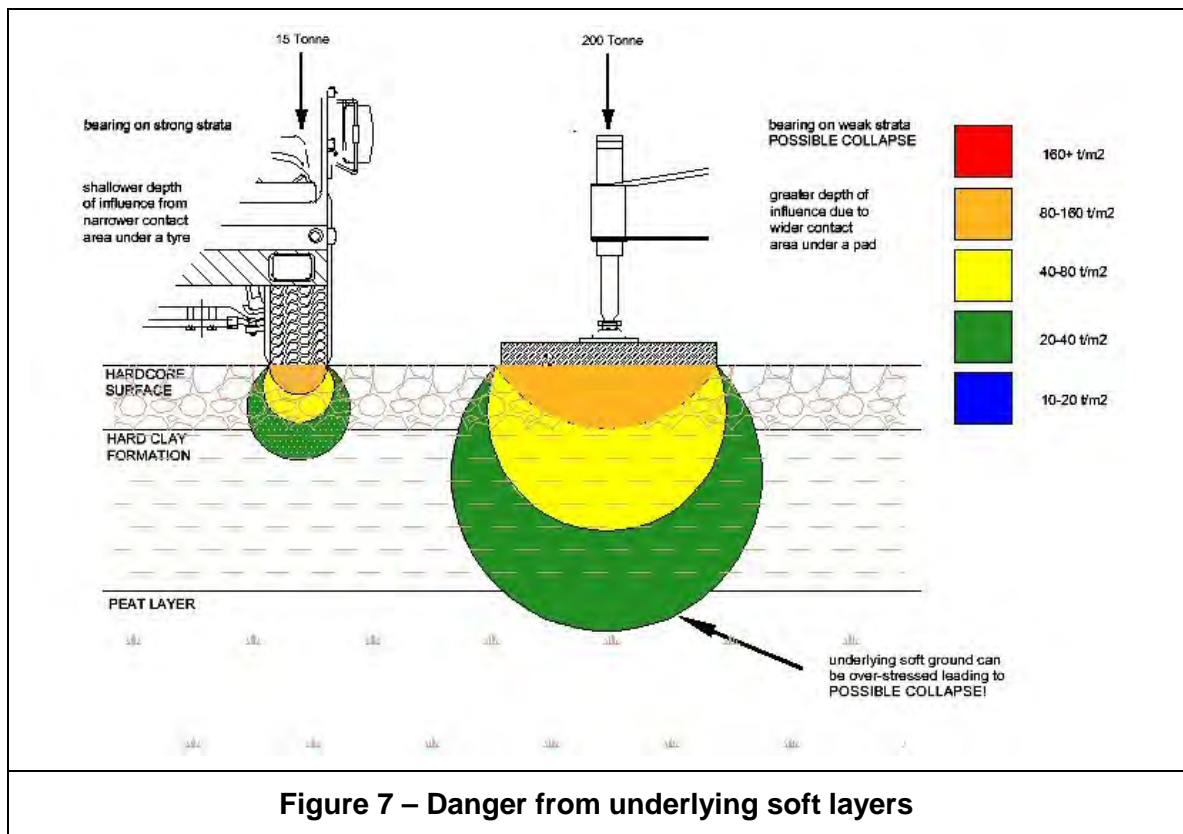




Below the surface, loads are distributed (dispersed) into the soil structure. The bearing pressure reduces with depth and the pressures within the ground can be described as a “pressure bulb”. The depth of this pressure bulb depends on the width of the contact area.

Normally the ground will increase in strength as you get deeper but it is important to understand that the ground can have weak layers below the surface. Sometimes, a weaker layer might not even be strong enough to carry the reduced pressure. Because of this, it is possible for a larger outrigger pad to cause un-acceptable loading of an underlying layer of weak or soft ground, possibly leading to a collapse. (see **Figure 7**)

**Don't assume a bigger pad will always provide a bigger load capacity! – you need to know if there are any underlying softer layers.**



**Figure 7 – Danger from underlying soft layers**

### 11.3 Analysis

The basic methods of analysis involve determination of :

- Equivalent rectangular patch load
- Bearing capacity
- Settlement
- Soil - structure interaction

Foundations are generally designed to either BS 8004:1986 or BS EN 1997-1:2004. BS 8004 uses a permissible stress approach and was superseded in 2010 by BS EN 1977-1 which, like all Eurocodes uses a limit state approach. Although BS 8004 has been withdrawn it still provides a useful method of designing simple foundations of the type frequently required for construction plant.

**It is essential that the designer clearly understands which approach is being adopted. If they have any reservations about the accuracy of the information or what factors (if any) have been applied they should seek clarification from the supplier or their manager before proceeding with the design.**

**Annex F** gives a simplified method of ground suitability assessment. This approach is **not** a full design - if any doubt exists about the underlying ground or, if the type of ground is not covered, further advice and/or a formal design should be obtained by consulting a suitably qualified engineer. Any design must be checked as specified in **12.3**.

### 11.4 Results of Analysis

Once the analysis has been completed the results should be reviewed to determine whether or not the ground is suitable to support the plant. If it is suitable the outcome of the assessment should be given to the relevant personnel in writing (See **Section 14**).

If the ground is not found to be suitable either of the following steps must be taken before proceeding with task:

- Design measures to ensure ground suitability (See **Section 12**)
- Design measures to reduce imposed loads (See **Section 13**)

*A contractor was carrying out stabilization work on a previously capped and grassed iron ore mineshaft in Cumbria when the ground around the top of the shaft collapsed and one of the contractor's drilling rigs fell into the hole. The rig operator was rescued by a local resident. The ground failure resulted in eight nearby properties being evacuated. (Whitehaven News) In some instances where risk of ground failure cannot be ruled out (eg due to lack of accurate records or survey data) remote (radio control) operation may be the only option using small plant with automated feed.*



## 12.0 Selection and Design of Measures to Ensure Ground Suitability

### 12.1 Introduction

If the final assessment of ground suitability indicates that the ground cannot safely bear the loads imposed on it by the plant one of the steps that can be taken is to modify the ground to improve its bearing capacity. Ground improvement should only be undertaken following consultation with a suitably qualified engineer.

### 12.2 Ground Improvement Measures

Techniques to improve the load bearing capacity of the ground on which plant is standing can include:

#### 12.2.1 Construction of a granular working platform

A working platform is an area of ground on which a platform has been constructed with sufficient strength to support an item of plant such as a piling rig, crane or other heavy equipment.

The design of working platforms is addressed in:

- BRE publication BR470 *Working platforms for tracked plant*;
- Temporary Works Forum - *Working Platforms - Design of granular working platforms for construction plant - A guide to good practice*

#### 12.2.2 Ground improvement

Ground improvement techniques to improve the bearing capacity of the ground include:

- Soil stabilization - the use of lime, cement or other binder materials to geotechnically improve areas of weak soil into a construction material that can safely withstand applied loads;
- Grouting - pressure grouting the ground with a high viscosity mortar in a pattern designed to suit the specific features of the site;
- Vibro compaction - the use of a vibroflot to increase the compaction of loose granular soils;
- Vibro stone columns - a bore hole created by a vibroflot is filled with stone and compacted by a vibrating poker to provide an adequate foundation;
- Dynamic compaction - a weight of between 5 and 20 tonnes is dropped from height by a crane to consolidate the ground;
- Rapid impact compaction - utilizes a hydraulic piling hammer fitted with a steel foot of 1m to 1.5m diameter which produces settlement. The settled area is then backfilled with granular material.

#### 12.2.3 Strengthening existing structures

Techniques for temporarily strengthening existing structures include:

- Back propping - propping installed at levels below the slab that supports the plant in order to distribute the load on the uppermost slab to suitable supports, such as lower slabs or the foundations
- Back filling - use of self compacting or rolled layers of material to temporarily fill or level an excavation, void or basement to allow plant movement or work;
- Shoring - the use of a proprietary or bespoke system to support the sides of an excavation or walls of a structure;
- Bracing - linking adjacent isolated columns or beams to enable them to work together with improved capacity;

- Buttrressing - low volume steelwork or high volume loose stone, bagged stone or gabion box structure to stiffen or stabilise a wall - eg a retaining wall - by increasing base width and adding resistance to overturning or buckling;
- Encasing - structural bolted steel frame to eg stiffen/strengthen columns;
- Bridging - installation of a load bearing deck resting on eg shear walls or building cores or behind excavation faces and spanning weaker areas to allow plant to move or stand.

In some instances it may be cost effective to permanently strengthen all or part of an existing structure to carry new temporary construction loads.

Assessment of the load capacity of the structure must take into account existing loadings plus the full range of forces added by the plant due to, for example, acceleration, braking, slewing, tool forces, vibration, and additional windage if exposed. Incidents and structural damage have occurred in the past where the full range of operations and loads have not been considered. For example additional local loading during attendance by a towed refuelling bowser; use of arisings (e.g. demolition or excavated material) to build a ramp to enable a small demolition excavator to track between floors; use of back props mid-span on a precast plank floor leading to hogging of the unladen half, tensile loading of the unreinforced face and failure.

In situations where plant load needs to be shared between an existing structure and the ground it can be particularly difficult to assess the likelihood of differential settlement. The potential for this should be considered and where plant would be sensitive to it monitoring may be needed. This problem can also arise where compacted fill materials level areas of varying depth or density or crossed by old structures.

*NOTE: Detailed advice on shoring is given in the CPA Good Practice Guide on Management of Shoring in Excavations*

#### **12.2.4 Construction of a mass or reinforced concrete foundation**

Concrete foundations are often used for tower cranes, large mobile cranes and batching plants. Such foundations require the design to be carried out by competent engineers in accordance with appropriate standards such as the Eurocodes.

*NOTE: Detailed advice on the design of concrete foundations for tower cranes is given in Tower Crane Stability, 2006. CIRIA C654. Construction Industry Research and Information Association.*

#### **12.2.5 Construction of a piled foundation**

Where ground conditions are particularly poor and the imposed loads are large, a piled foundation is often the only solution.

#### **12.2.6 Steel or timber grillages**

A grillage consists of a number of substantial steel or timber members which are laid out on the ground and connected together to spread the loads from an item of plant into the ground.

Steel grillages connected to the permanent works are sometimes used to support tower cranes without base ballast. In such cases the designer must ensure that all loads and forces applied to the grillage by the crane are taken into account in the design.

### **12.3 Design Check**

Once a design solution has been determined the design should be checked in accordance with Table 1 of BS 5975 for concept, adequacy, correctness and compliance with the requirements of the design brief. This check should be carried out by a competent person who is generally independent from those responsible for the design. The ability of the checker and his remoteness or independence from the

temporary works designer should be greater where new ideas are incorporated or the temporary works are complex. Table 1 of BS 5975 allocates four categories requiring different levels of independence which are related to the risk and consequences of failure of the design.

As large scale and complex designs take a significant amount of time to carry out, it should be born in mind that the checking process will also be time consuming.

#### **12.4     *Determination of Ground Suitability***

Once the design and design check have been completed, the results should be reviewed to determine whether or not the ground is suitable to support the plant. If it is suitable the outcome of the assessment should be given to the relevant personnel in writing (See **Section 14**).

If the ground is not found to be suitable, additional measures must be taken before proceeding with task. These may include design measures to reduce imposed loads (See **Section 13**).

#### **12.5     *Post Construction Inspection***

Following construction or installation of the ground improvement measures an inspection should be carried out to ensure that they have been constructed to the design specification. The results of the inspection should be recorded in writing and kept in a "*Technical File*" containing appropriate design and construction details for the measures, including photographs taken during construction.

#### **12.6     *Maintenance***

Although most items of plant are in position for a relatively short period of time the designer should consider the need for inspection and maintenance of the foundation and ensure that where it is required the requirements and intervals for inspection and maintenance are specified. Those responsible for the construction and use of the foundation should ensure that these instructions are followed.

## **13.0 Selection and Design of Measures to Reduce Imposed Loads**

### **13.1 Introduction**

If the final assessment of ground suitability indicates that the ground cannot safely bear the loads imposed on it by the plant one of the steps that can be taken is to reduce the loads imposed on the ground by the plant. This can include measures such as:

- Re-selection of the plant;
- Re-siting of the plant
- Reduction of task loads (e.g. splitting of loads);
- The use of proprietary support equipment.

### **13.2 Reselection of the Plant**

Loads imposed on the ground by plant can sometimes be reduced by changing the model or type of plant selected. For example a wheeled mobile crane with outriggers may impose higher loads on the ground than a crawler mounted crane of similar capacity.

### **13.3 Re-siting of the Plant**

Ground bearing loads can sometimes be reduced if the plant can be re-sited to reduce the load radius and hence the load moment. This will depend on the geometry of the site.

### **13.4 Reduction of Task Loads**

Reduction of the task load by, for example splitting the load into lighter parts, may have two benefits. Firstly it may reduce the loads imposed by the selected plant or it may enable a smaller machine to be used.

### **13.5 Use of Proprietary Support Equipment**

The loads imposed on the ground by an item of plant can often be significantly reduced by the use of proprietary support equipment. Some examples are given in **Annex C**.

***NOTE:** Care should be taken to ensure that proprietary support equipment is stiff enough to ensure that the load is spread effectively.*

### **13.6 Design Check**

Once a design solution has been determined the design should be checked in accordance with **12.3**

### **13.7 Determination of Ground Suitability**

Once the design and design check have been completed, the results should be reviewed to determine whether or not the ground is suitable to support the plant. If it is suitable the outcome of the assessment should be given to the relevant personnel in writing (see **Section 14**).

If the ground is not found to be suitable, additional measures must be taken before proceeding with task. These may include design measures to ensure ground suitability (See **Section 12**) or reduce loads.

### **13.8 Post Installation Checks**

Following construction or installation of the load reduction measures an inspection should be carried out to ensure that they have been provided and installed in line with the design specification. The results of the inspection should be recorded in writing.

### **13.9    *Maintenance***

Although most items of plant are in position for a relatively short period of time the designer should consider the need for maintenance of the load reduction measures and ensure that where it is required the requirements and intervals for maintenance are specified. Those responsible for the implementation and use of the load reduction measures should ensure that these instructions are followed.



## 14.0 Communication

### 14.1 Introduction

As with all parts of the construction process, effective communication is vital to ensure that ground supported plant can operate safely and efficiently. Once the ground suitability assessment and the design of any necessary ground improvement or load reduction measures have been completed, the relevant personnel must be informed, in writing, of the design solutions, limiting parameters and required actions. At this stage it is essential that the recipient's understanding of the information is assessed. If their understanding of the process is not clear steps must be taken to remedy this before any work is started.

### 14.2 Information

Information should be provided in a clear, concise form which is specific to the particular task and not padded out with unnecessary generic data. Notes on drawings are particularly helpful. All written information should have a date of issue and revision status.

### 14.3 Briefing and Feedback

Those responsible for implementing any ground improvement or load reduction measures must ensure that the people carrying out the work are properly briefed and supervised, and that any difficulties in understanding or carrying out the designers instructions are immediately fed back, so that appropriate amendments may be made.

### 14.4 Changes

It is essential that any changes that occur, such as to the plant, task or ground, are communicated to the relevant personnel so that appropriate action can be taken in line with a formal change process. The personnel involved may include designers, appointed persons (lifting), temporary works coordinators. In any event the person supervising the operation must be notified. The use of a formal change process will ensure that all parties are working with the latest information and that any changes have been authorised.

**Example** - A working platform for a piling rig was constructed, using a geotextile membrane, on marshy ground alongside a live railway line. To remove an obstruction the contractor dug a trench in the platform, which damaged the critical geotextile membrane. The trench was then poorly backfilled. When the rig crossed the trench the ground settled under one side causing the piling rig to overturn across the live railway lines, bringing down a 25,000 volt overhead catenary. Fortunately no one was injured but the railway line was closed for three days.



*Whilst senior construction managers knew how critical the piling platform was and expected junior managers to tell the engineering department about the need for repairs. The HSE investigation found that junior site managers were not aware of this procedure and did not understand how critical the design was. HSE said that "Better communications, including explanation of safety critical parts of the job and better monitoring of the work would have prevented this incident."*

**Uncontrolled changes are a major cause of accidents involving ground failure**

## Annex A – Calculation of Plant Loads and Forces

The loads and forces imposed on the ground by an item of plant are due to some or all of the following factors:

- the dead weight of the plant
- the position of the centre of gravity of the plant
- the dead weight of the load (if any)
- the position of the centre of gravity of the load (if any)
- the magnitude of wind loads
- the position of the centre of pressure
- the position of supporting structures (e.g. crawler tracks, wheels, outriggers)
- the position of the tipping line
- dynamic factors

The reactions at the supports (wheels, tracks, outriggers etc) can be calculated if the weights of components and their centres of gravity are known, by moment calculations taken about the supports. Figure A1 shows an example of the calculation of the wheel reactions of a boom type MEWP.

Examples of calculation methods for outrigger loads on loader cranes and track bearing pressures for piling rigs are available as follows:

**Lorry Loaders** (Association of Lorry Loader Manufacturers and Importers)

ALLMI Guidance Note GN013 *Stabilizer Forces*

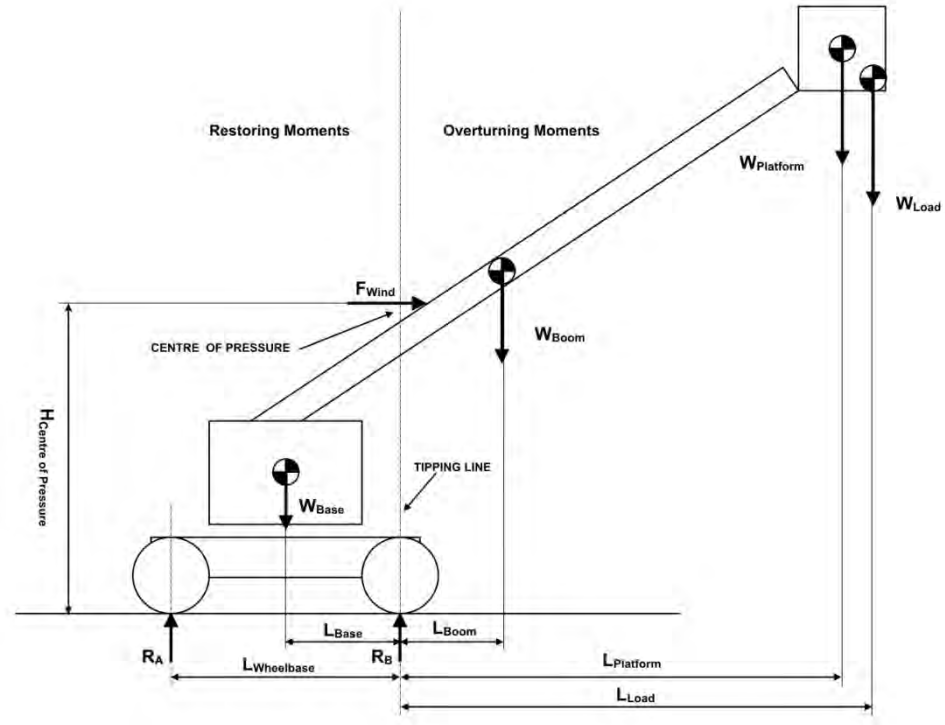
<http://www.allmi.com>

**Piling Rigs** (Federation of Piling Specialists)

*Calculation of Track Bearing Pressures for Platform Design*

*Rig Loading Spreadsheet*

[http://www.fps.org.uk/fps/guidance/platforms/platforms\\_trackpressurecalc.php](http://www.fps.org.uk/fps/guidance/platforms/platforms_trackpressurecalc.php)



Take moments about  $R_B$

$$W_{Base} \times L_{Base} = R_A \times L_{Wheelbase} + F_{Wind} \times H_{Centre\ of\ Pressure} + W_{Boom} \times L_{Boom} + W_{Platform} \times L_{Platform} + W_{Load} \times L_{Load}$$

$$R_A = \frac{W_{Base} \times L_{Base} - (F_{Wind} \times H_{Centre\ of\ Pressure} + W_{Boom} \times L_{Boom} + W_{Platform} \times L_{Platform} + W_{Load} \times L_{Load})}{L_{Wheelbase}}$$

Take moments about  $R_A$

$$R_B \times L_{Wheelbase} = W_{Base} \times (L_{Wheelbase} - L_{Base}) + F_{Wind} \times H_{Centre\ of\ Pressure} + W_{Boom} \times (L_{Boom} + L_{Wheelbase}) + W_{Platform} \times (L_{Platform} + L_{Wheelbase}) + W_{Load} \times (L_{Load} + L_{Wheelbase})$$

$$R_B = \frac{W_{Base} \times (L_{Wheelbase} - L_{Base}) + F_{Wind} \times H_{Centre\ of\ Pressure} + W_{Boom} \times (L_{Boom} + L_{Wheelbase}) + W_{Platform} \times (L_{Platform} + L_{Wheelbase}) + W_{Load} \times (L_{Load} + L_{Wheelbase})}{L_{Wheelbase}}$$

**Figure A1 - Example of Calculation of Wheel Reactions for a Boom Type MEWP**

## Annex B - Soil Types and Characteristics

Category	Types of rocks and soils	Investigation Description	SPT Value	Cu Value	Presumed allowable bearing value kN/m <sup>2</sup>
<b>Rocks</b>	Strong igneous and gneissic rocks in sound condition		N/A	N/A	10,000
	Strong limestones and strong sandstones		N/A	N/A	4,000
	Schists and slates		N/A	N/A	3,000
	Strong shales, strong mudstones and strong siltstones		N/A	N/A	2,000
<b>Non-cohesive soils</b> (Sand and Gravel)	Dense gravel, or dense sand and gravel	Steel pin hard to drive (not to be used in areas with underground services)	>50	N/A	>600
	Medium dense gravel or medium dense sand and gravel	Can be excavated with a spade with effort	10 - 30	N/A	< 200 to 600
	Loose gravel or loose sand and gravel	Can be loosened with spade easily ; 50mm wooden peg can be easily driven	4 - 10	N/A	< 200
	Compact sand	Requires pick for excavation; 50mm peg hard to drive	30 - 50	N/A	> 300
	Medium dense sand	Can be excavated with a spade with effort	10 - 30	N/A	100 to 300
	Loose sand	Can be loosened with spade easily ; 50mm wooden peg can be easily driven	4 - 10	N/A	< 100
<b>Cohesive soils</b> (Clays and Silt)	Very stiff boulder clays and hard clays	Can be indented by thumb nail; cannot be moulded, crumbles	N/A	>150	300 to 600
	Stiff clays	Can be indented subjectively slightly by thumb; crumbles in rolling thread; remoulds	N/A	70 - 150	150 to 300
	Firm clays	Thumb makes impression easily; cannot be moulded by fingers; rolls to thread	N/A	40 - 75	75 to 150
	Soft clays and silts	Finger pushed in up to 10 mm; moulded by light finger pressure	N/A	20 - 40	<75
	Very soft clays and silts	Finger easily pushed in up to 25 mm; exudes between fingers	N/A	<20	Nil
<b>Peat and organic soils</b>	Firm organic material/Medieval fill	Can be indented by thumbnail.	N/A	N/A	20 to 40
<b>Made ground or fill</b>	Unidentifiable made ground	Bearing values depend on the likelihood of voids and the compressibility of the made ground	N/A	N/A	25 to 50
	Engineered Fill	Consult the designer	N/A	N/A	Variable

**Table B1 - Presumed allowable bearing values under static loading**

### NOTES

- Cu = undrained cohesion or the resistance due to the forces tending to bond or hold the soil particles together in a solid mass.
- SPT (Standard Penetration Test) is a dynamic, in situ penetration test used for providing information on geotechnical engineering properties of soil. This test procedure is described in and regulated by the British Standard BS1377 – 9:1990 and Eurocode 7.  
The test takes place inside a borehole, using a sample tube. The sample tube is driven from the bottom of the borehole into the ground using a hammer, which is dropped freely. The test results are deduced through the number of blows needed to drive the tube each 75mm into the ground. The “standard penetration resistance” or “N-value” is calculated by the sum of the number of blows required for the last four 75mm increments of penetration, to a maximum of 50 blows.  
An SPT is particularly used to indicate relative density of granular deposits.
- Approximate conversion factors 100 kN/m<sup>2</sup> = 1 tonf/ft<sup>2</sup>. = 10 ton/m<sup>2</sup>.
- Data Sources – BS 5930:1999, BS 8004:1986 and Structural Engineer’s Pocket Book:2004

## Annex C - Typical Equipment Used to Spread Loads

### C.1 Timber Mats

Timber mats, often known as bog mats or navy mats consist of hardwood beams bolted together to form mats of various sizes (see Table D1). They are generally made from European Oak or tropical hardwoods such as Ekki, Dabema, Mora or Cumaru. These species give a durable mat with high resistance to wear.

**Table C1** gives a typical range of mat sizes, whilst bespoke mats are available from most suppliers. Mats can be hired or purchased.

5m x 1m x 70mm
5m x 1m x 100mm
5m x 1m x 150mm
5m x 1m x 200mm
4m x 1m x 70mm
3m x 1m x 100mm
3m x 1m x 150mm
<b>Table C1 - Typical Mat Sizes</b>



**Positioning of Timber Mats**

### C.2 Trackway

Trackway is a generic term for aluminium or polypropylene roadway systems consisting of panels of various sizes and thicknesses which can be joined together to form temporary roadways, ground protection and pedestrian walkways. They are generally used for access and have limited ability to spread large concentrated loads.

Trackway can be purchased or hired with or without an installation service.



**Trackway Installation**



**MEWP on Trackway**

### C.3 Proprietary Systems

Proprietary aluminium mat system made up of interlocking sections which can be combined to produce a mat with an area of 3.0 m<sup>2</sup> or 1.3m<sup>2</sup>.



**3.0m<sup>2</sup> Mat**



**Layered Configuration**

#### C.4 *Outrigger Pads*

There are a number of proprietary outrigger pads available, made from plywood and various type of plastic such as nylon, polyethylene or polypropylene. They are supplied in a range of sizes from 800mm to 1500mm in diameter and 400mm square to 1200mm square in thicknesses up to 100mm. Pads carried on cranes, MEWPs and concrete pumps tend to be limited in area to sizes which can be manually handled.

As these pads tend to have a smooth surface, care should be taken to ensure that outrigger feet do not slip off the pads in wet or icy conditions. Some pads are manufactured with a recess to locate the outrigger feet. Where pads are placed onto surfaces such as crushed concrete or other large granular material - a blinding layer may be needed to avoid point loading and pad damage. For longer term use a blinding material should be used that will not wash out.



**Plywood Pad**



**Plastic Pad with Recess**



**Telehandler Outriggers on Round Pads**



**MEWP Outriggers on Pads and Timbers**

#### C.5 *Bespoke Spreader Pads*

Bespoke spreader pads can be fabricated in both aluminium and steel and are generally of cellular construction to provide stiffness with minimum weight.



**Steel Pad after Fabrication**



**Steel Pad in Use**

## Annex D - Precautions When Using Outrigger Pads

Where the ground is not strong enough to support the pressure exerted by plant outrigger feet, pads or mats are frequently used to reduce the pressure imposed on the ground by the machine. The size of pad required may be determined using the simplified method of ground assessment detailed in **Annex E**.

The following notes set out the limitations for using **Annex E** information. They are based on sensible principles for the safe use of pads. They also set out simple limits for the location where pads can readily be used. In essence the flatter, more consistent and firmer the ground, the more likely it will be that pads offer an effective solution to ensuring plant stability. The examples given cannot cover all situations and additional geotechnical advice may be needed. In particular, use on waterlogged or soft or loose ground will not be possible without additional work.

### D.1 Proximity to Slopes and Excavations

Plant should not be positioned near to the edge of trenches and other excavations as these are likely to collapse without warning. If the machine needs to be used close to the edge of a slope or excavation, with the outriggers or wheels in the "danger area", an engineering assessment must be carried out by a competent geotechnical engineer before the machine is set up and operated.

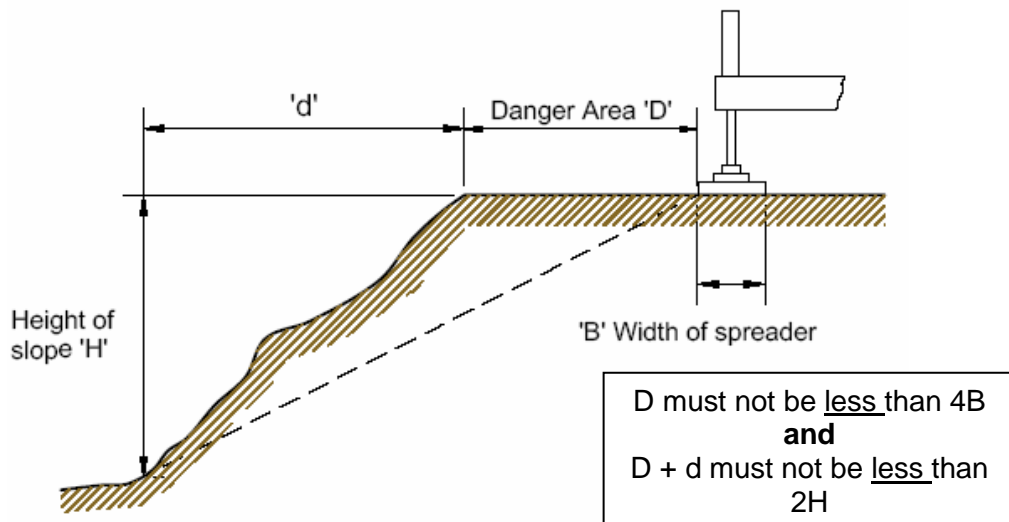


Figure D1 - Proximity to Slopes and Excavations

### D.2 Outrigger Pad Stiffness

It is essential that outrigger pads are sufficiently stiff to ensure that load is spread over the area of the pad. If the pad isn't rigid enough, the load will be concentrated on a smaller area in the middle of the pad. This will result in increased ground pressure which will cause more deformation and possibly lead to collapse. (see **11.2.1** and **Figure D2**)

### D.3 Positioning of Outrigger Pad and the Outrigger on the Pad

If the outrigger pad is not located on level ground and the outrigger foot is not located centrally on the pad the load will not be spread evenly and will create increased local ground pressure which may well lead to collapse (see **Figure D3**).

Examples of good and bad practice are shown in **Figure D4**.

**NOTE:** Where pads are made up of a number of elements, such as individual timbers, these elements must be fastened securely to ensure the integrity of the pad under load.



**Figure D2 - Examples of Outrigger Pads with Insufficient Stiffness**



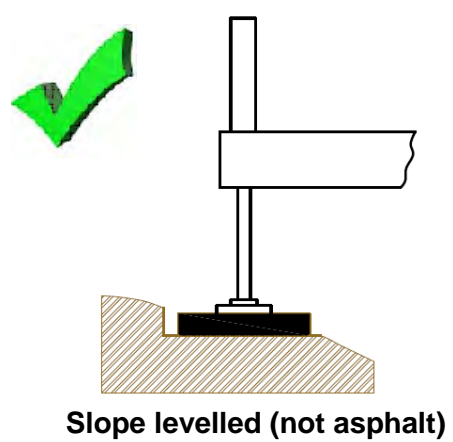
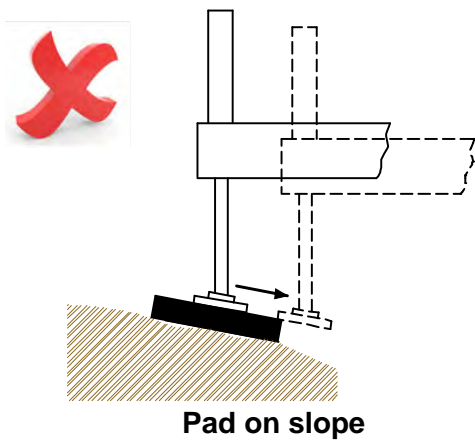
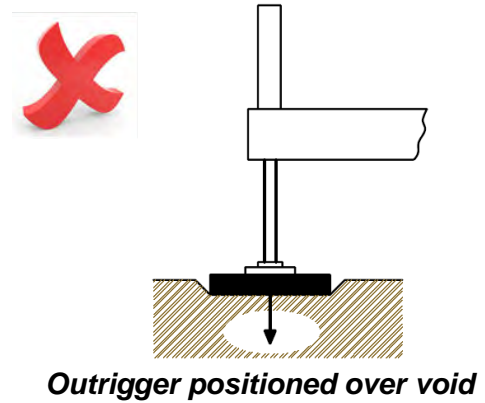
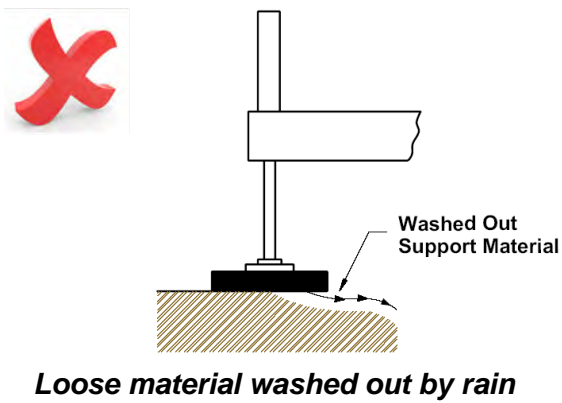
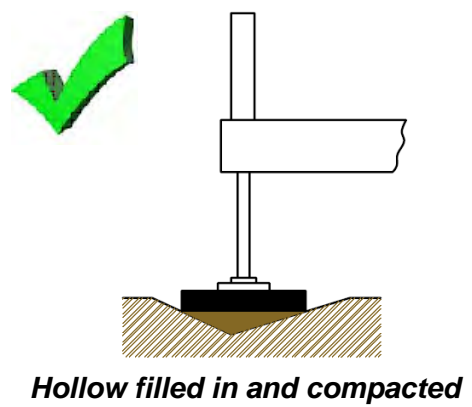
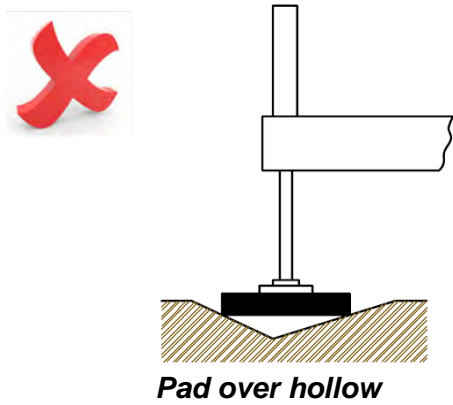
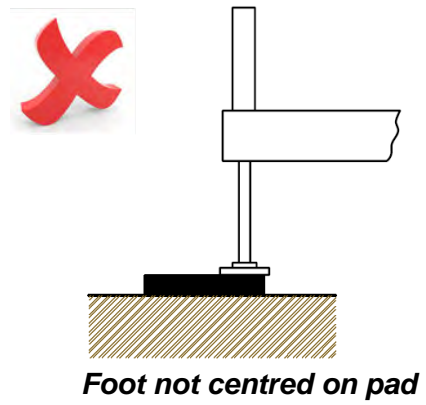
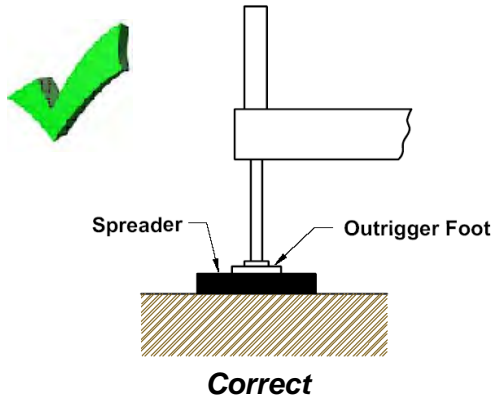
**Offset outrigger  
causes pad to tilt**



**Load concentrated  
on one edge of the  
pad causing  
failure of the  
ground**

**Figure D3 - Example of the Effect of an Offset Outrigger on a Pad**





**Figure D4 - Examples of Good and Bad Practice**

## Annex E - Ground Capacity for Outrigger Pads - Simplified Method

The following section provides a general indication of the safe working load capacity of various soils and surfaces depending on the size of the loaded area and the type of soil or surface. **Annex D** should be read before using the information in this annex.

The maximum outrigger load is limited to 25 tonnes, if larger outrigger loads are to be applied, a formal design will be needed.

**This is not a full design - if any doubt exists about the underlying ground or, if the type of ground is not covered, further advice and/or a formal design should be obtained.**

Important things to check are:

- Is the groundwater table less than B below the surface?
- Are there any underlying soft layers, man-made structures or natural voids less than 3 x B below the surface?

**CAUTION!** even if the underlying ground is strong enough, other things to remember are:

- If the pad is too small the surfacing could crack or you could cause a depression;
- Topsoil will compress until the pad 'finds' more solid underlying ground – ideally pads should be placed directly on the underlying firm soils;
- If you are near to a retaining wall or top of embankment, a formal engineering assessment will still be needed (See **Figure D1**).

If all the above are OK then the safe working load (SWL) can be found by the following steps:

1. Determine the nature of the ground by inspecting the surface, carrying out simple tests and/or requesting suitable information from those who are likely to have it;
2. Find out what the outrigger load will be;  
*NOTE: The load on an outrigger can be a substantial proportion of the combined gross vehicle weight and any load being carried or lifted.*
3. Select a pad and find out the safe working load the pad has been designed to carry;
4. Look up the safe working load for the pad shape/size and ground/surface type in the table;
5. Use the lower value out of the SWL for the pad and the SWL for the ground/surface.

**Annex F** gives some examples of the application of this method.




Pad Shape	width/diameter B (m)	Length L (m)	Safe Working Loads (tonnes)						
			car parks, minor public & private roads	major public roads	soft clay, silt and peat	firm/stiff clay	very stiff clay	loose made ground	naturally occurring compacted sand/gravel
circle	0.3	-	2.1	4.0	0.0	1.2	3.9	0.1	0.1
	0.45	-	4.0	6.4	0.0	2.7	8.9	0.2	0.5
	0.6	-	6.4	9.5	0.0	4.7	15.7	0.5	1.1
	0.75	-	9.5	13.1	0.0	7.4	24.6	1.0	2.1
	0.9	-	13.1	17.3	0.0	10.6	<b>25.0</b>	1.7	3.7
	1.2	-	22.2	<b>25.0</b>	0.0	18.9	<b>25.0</b>	4.1	8.7
	1.5	-	<b>25.0</b>	<b>25.0</b>	0.0	<b>25.0</b>	<b>25.0</b>	7.9	17.0
square	0.3	0.3	2.7	5.1	0.0	1.5	5.0	0.1	0.2
	0.45	0.45	5.1	8.2	0.0	3.4	11.3	0.4	0.8
	0.6	0.6	8.2	12.1	0.0	6.0	20.0	0.9	1.8
	0.75	0.75	12.1	16.7	0.0	9.4	<b>25.0</b>	1.7	3.6
	0.9	0.9	16.7	22.1	0.0	13.5	<b>25.0</b>	2.9	6.2
	1.2	1.2	<b>25.0</b>	<b>25.0</b>	0.0	24.1	<b>25.0</b>	6.9	14.7
	1.5	1.5	<b>25.0</b>	<b>25.0</b>	0.0	<b>25.0</b>	<b>25.0</b>	13.5	<b>25.0</b>
rectangle	1.2	0.6	12.9	17.4	0.0	10.2	25.0	3.5	7.4
	2.4	1.2	<b>25.0</b>	<b>25.0</b>	0.0	<b>25.0</b>	<b>25.0</b>	<b>25.0</b>	<b>25.0</b>

**NOTES:**





1. An overall factor of safety of 3 has been applied throughout
2. Values in **bold** italics have been restricted to the nominal maximum of 25T
3. Generally in accordance with BS8004 with bearing capacities calculated using Brinch-Hanson as per Tomlinson
4. For public roads in the table the formation is assumed to be "firm clay" and loads are taken to be dispersed at 2v:1h through a total 250mm surfacing + sub-base
5. For car parks and private roads the formation is assumed to be "firm clay" and loads are taken to be dispersed at 2v:1h through a total 100mm surfacing + sub-base





**Table E1 - Safe Working Loads for Differing Ground Conditions and Mat Sizes**





## Annex F - Examples of the Application of Annex E





<b>Machine type</b>	<b>Lorry Loader</b>	<b>MEWP</b>	<b>Concrete Boom</b>
<b>Description of the task</b>	Delivery of building materials to a domestic property.	High level maintenance on a block of flats	Placing of concrete on a construction site
<b>Plant selected</b>	12 tonne-metre lorry loader, with a brick grab attachment.	13 metre working height tracked MEWP with "spider" type outriggers.	36m vertical reach vehicle mounted concrete placing boom.
<b>Example</b>			
<b>Assessment of the loads and forces.</b>	Using the figure stated in the manufacturer's handbook the corresponding manufacturer's figure is 70kN (7.14 tonnes) under each stabilizer foot.	Using the figure stated in the manufacturer handbook the corresponding manufacturer's figure is 12.5kN (1.27 tonnes) under each outrigger.	Using the figure stated in the manufacturer handbook the corresponding manufacturer's figure is 190kN (19.37 tonnes) under each outrigger.
<b>Description of the ground, assessment of the load bearing capacity and required size of outrigger/stabilizer pad.</b>	A 0.6m x 0.6m x 0.030m HDPE pad has a rated capacity of 13 tonnes, therefore OK. The delivery site is a private road. Looking at the "Car parks, minor public and private roads" column in <b>Table E1</b> in <b>Annex E</b> , a 0.6m x 0.6m pad gives a maximum allowable imposed load of 8.2 tonnes, therefore OK.	A 0.3m x 0.3m x 0.030 HDPE pad has a rated capacity of 5 tonnes, therefore OK. The machine is to be set up on a grassed area. Investigation of soil under turf indicates a firm clay which can be moulded by strong finger pressure (see <b>10.5 Table 2</b> ). Looking at "Firm/Stiff clay" column in <b>Table E1</b> in <b>Annex E</b> , a 0.3m x 0.3m pad gives a maximum allowable imposed load of 1.5 tonnes, therefore OK.	A 1.5m x 1.5m x 0.1m HDPE pad has a rated capacity of 200 tonnes, therefore OK. The machine is to be set up on soil. Investigation of ground on site indicates a medium dense sand/gravel which can be excavated using a spade with effort (see <b>10.5 Table 2</b> ). Looking at the "naturally occurring compacted sand/gravel" column in <b>Table E1</b> of <b>Annex E</b> , a 1.5m x 1.5m pad gives a maximum allowable imposed load of 25.0 tonnes, therefore OK.

## Annex G - Examples of Typical Configuration and Loading Information

	<i>Machine Type</i>			
	<b>Telehandler</b>	<b>Piling Rig</b>	<b>360°Excavator - Wheeled</b>	<b>360°Excavator - Tracked</b>
<b>Typical Example</b>				
<b>Configuration Information for Loading Information Requests</b>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Fork length</li> <li>• Attachments (if any)</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Jib configuration</li> <li>• Counter ballast</li> <li>• Track spread</li> <li>• Load mass</li> <li>• Load radius</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Bucket size</li> <li>• Dipper length</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Bucket size</li> <li>• Dipper length</li> </ul>
<b>Typical Loading Information</b>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Location of centres of gravity;</li> <li>• Wheel loads;</li> <li>• Track and wheelbase dimensions;</li> <li>• Outrigger loads;</li> <li>• Outrigger pad sizes;</li> <li>• Outrigger centres;</li> <li>• Moments.</li> <li>• Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Track pressures;</li> <li>• Track dimensions;</li> <li>• Track centres;</li> <li>• Limiting in-service wind speed</li> <li>• Dynamic load effects.</li> </ul> <p><i>NOTE: Working platform design is covered in detail in BRE 470 "Working platforms for tracked plant"</i></p>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Location of centres of gravity;</li> <li>• Outrigger loads;</li> <li>• Wheel loads</li> <li>• Wheel pressures</li> <li>• Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Location of centres of gravity;</li> <li>• Crawler track pressures;</li> <li>• Crawler track length, width and centres;</li> <li>• Dynamic load effects.</li> </ul>

	<b>Machine Type</b>			
	<b>Wheeled Mobile Crane</b>	<b>Crawler Mobile Crane</b>	<b>Tower Crane</b>	<b>Lorry Loader</b>
<b>Typical Example</b>				
<b>Configuration Information for Loading Information Requests</b>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Jib configuration</li> <li>• Counter ballast</li> <li>• Outrigger spread</li> <li>• Load mass</li> <li>• Load radius</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Jib configuration</li> <li>• Counter ballast</li> <li>• Track spread</li> <li>• Load mass</li> <li>• Load radius</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Height under hook</li> <li>• Jib length</li> <li>• Rated capacity</li> <li>• Counter ballast</li> <li>• Base type</li> </ul>	<ul style="list-style-type: none"> <li>• Machine make and model</li> <li>• Boom system C of G</li> <li>• Stabilizer beam spread</li> <li>• Load mass</li> <li>• Load radius</li> <li>• Column offset</li> </ul>
<b>Typical Loading Information</b>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Outrigger loads;</li> <li>• Outrigger foot dimensions;</li> <li>• Outrigger centres;</li> <li>• Limiting in-service wind speed;</li> <li>• Dynamic load effects;</li> <li>• Wheel and axle loads when travelling.</li> </ul>	<ul style="list-style-type: none"> <li>• Machine weight - laden and unladen;</li> <li>• Overall dimensions;</li> <li>• Track pressures;</li> <li>• Track dimensions;</li> <li>• Track centres;</li> <li>• Limiting in-service wind speed</li> <li>• Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>• Vertical forces;</li> <li>• Horizontal forces;</li> <li>• Torsional Forces;</li> <li>• Moments;</li> <li>• Limiting in-service wind speed</li> <li>• Dynamic load effects.</li> </ul> <p><i>NOTE: Tower crane base design is covered in detail in CIRIA C654 Tower Crane Stability</i></p>	<ul style="list-style-type: none"> <li>• Lorry weight and payload;</li> <li>• Overall footprint area;</li> <li>• Stabilizer loads;</li> <li>• Stabilizer beam spread;</li> <li>• Stabilizer foot dimensions;</li> <li>• Limiting in-service wind speed</li> <li>• Dynamic load effects.</li> </ul>

	<b>Machine Type</b>			
	<b>Vehicle Mounted MEWP</b>	<b>Self Propelled Boom MEWP</b>	<b>Scissor MEWP</b>	<b>Spider MEWP</b>
<b>Typical Example</b>				
<b>Configuration Information for Loading Information Requests</b>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>
<b>Typical Loading Information</b>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Outrigger loads;</li> <li>Outrigger foot dimensions;</li> <li>Outrigger centres;</li> <li>Wheel loads (if applicable)</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Wheel loads</li> <li>Wheel bearing pressures;</li> <li>Wheel centres;</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Wheel loads</li> <li>Wheel bearing pressures;</li> <li>Wheel centres;</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Track pressures;</li> <li>Track dimensions;</li> <li>Track centres;</li> <li>Outrigger loads;</li> <li>Outrigger foot dimensions;</li> <li>Outrigger centres;</li> <li>Dynamic load effects.</li> </ul>

	<b>Machine Type</b>			
	<b>Dumper</b>	<b>Skid Steer Loader</b>	<b>Tipper Truck</b>	<b>Concrete Boom</b>
<b>Typical Example</b>				
<b>Configuration Information for Loading Information Requests</b>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> </ul>	<ul style="list-style-type: none"> <li>Machine make and model</li> <li>Jib configuration</li> <li>Outrigger spread</li> </ul>
<b>Typical Loading Information</b>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Location of centres of gravity;</li> <li>Wheel loads;</li> <li>Track and wheelbase dimensions;</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Wheel loads</li> <li>Wheel pressures;</li> <li>Wheel centres;</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Wheel loads (travelling &amp; tipping);</li> <li>Wheel pressures (travelling &amp; tipping);</li> <li>Wheel centres;</li> <li>Dynamic load effects.</li> </ul>	<ul style="list-style-type: none"> <li>Machine weight - laden and unladen;</li> <li>Overall dimensions;</li> <li>Outrigger loads;</li> <li>Outrigger foot dimensions;</li> <li>Outrigger centres;</li> <li>Limiting in-service wind speed</li> <li>Dynamic load effects.</li> </ul>



## Annex H - Factors of Safety

### H.1 Global Factor of Safety

The margin of safety is traditionally represented by a Factor of Safety (FoS). The FoS is the extra capacity available in the system so that if the design information is slightly inaccurate it does not mean that collapse will always occur. Good design practice allows the extra capacity to be reduced where the designer is confident that the information they are working from is accurate. Conversely, where the information is less detailed or contains more assumptions the FoS needs to be increased. The FoS might be more correctly called a "factor of uncertainty".

There are two ways a FoS is normally used.

1. The maximum capacity of a structure is divided by the maximum load to be imposed to give the FoS and this is checked against an acceptable minimum FoS.

*Example: If the minimum FoS is 2, A crane pad is sized to take 100 tonne and the load is 80 tonne, then the  $FoS = 100/80 = 1.25$ . The FoS is less than the minimum, so the crane pad is too small. If the crane pad is resized to carry 200 tonne, then  $FoS = 200/80 = 2.5$ ; FoS is now greater than the minimum, so the larger pad is acceptable.*

2. The maximum capacity of a structure is divided by a fixed acceptable FoS to give an allowable working capacity

*Example: If the maximum capacity of a crane pad is 200 tonne and the accepted FoS is 2, the allowable working capacity is  $200/2 = 100$  tonne.*

The magnitude of the FoS is related to the accuracy of the predicted loads and capacity of the supporting structure. The more unsure the designer is about the accuracy of any aspect of the design, such as load information, ground bearing information and calculation methods, the larger is the FoS that should be used.

**Low Certainty  
needs a high  
Factor of Safety**

**High Certainty  
allows a lower  
Factor of Safety**

**Figures H1 & H2** show that if the uncertainty of the design is high, a large safety factor is used giving a lower safe working load. On the other hand, if the designer is confident that the uncertainty is low (i.e. the accuracy is high) a smaller safety factor may be used, giving a higher safe working load.

The CIRIA publication *Crane Stability on Site* gives an example of a 30 tonne capacity mobile crane operating on outriggers on dense to very dense sandy gravel. For a maximum outrigger load of 33 tonne the required area of outrigger pad is 1.4m<sup>2</sup> with a safety factor of 3. Where a full geotechnical investigation of the specific location of the crane has been carried out, the CIRIA document suggests that the safety factor may be reduced to 1.5 giving an outrigger pad area of 0.7m<sup>2</sup> (i.e. half the original).

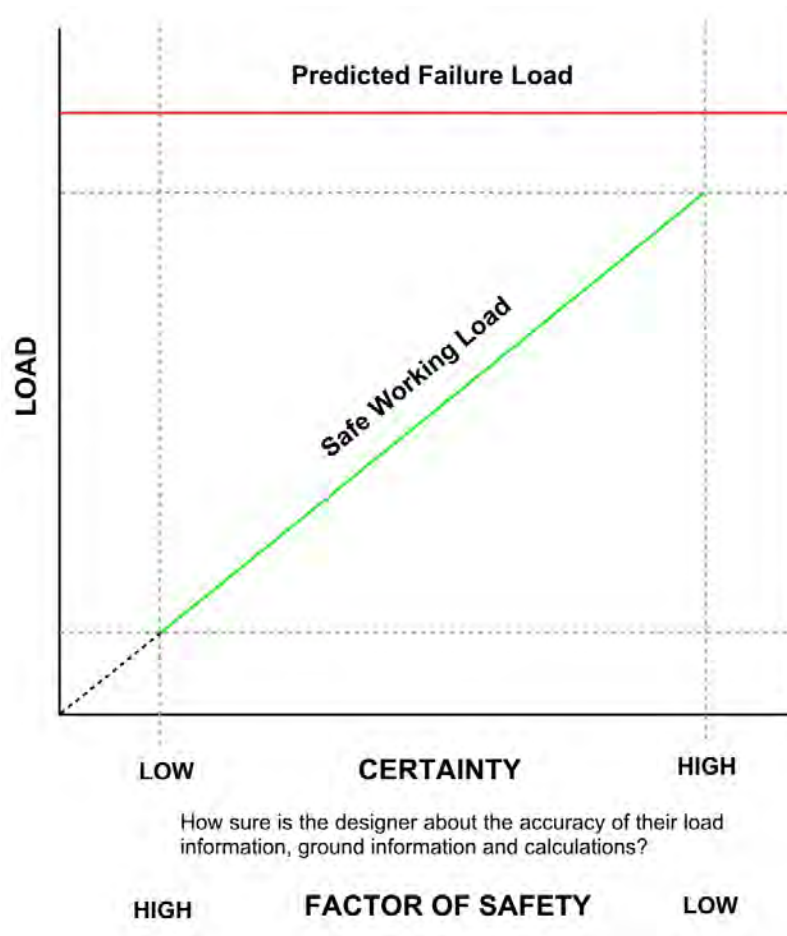
Whilst reducing the size of a mobile crane outrigger pad may not be of great significance, if a significant amount of work is required to prepare the ground for plant the magnitude of the safety factor will have a considerable effect on cost. It may well be that spending a relatively small amount of money on a ground investigation and a formal design will enable a lower safety factor to be used, giving significant savings in the cost of ground preparation.

The choice of FoS is the responsibility of the designer and is generally based on Standards or other design codes, taking account of the quality of the ground and loading information.

### H.2 Partial Factors

A new approach introduced by the Eurocodes is the use of partial factors where loads are split into three categories: permanent, variable and accidental and different factors are applied to each category. The magnitude of each factor reflects the probability of an unfavourable deviation from the characteristic value, inaccuracies in the calculation method and the consequences of failure. The outcome is a more accurate prediction of the performance of a structure (including ground) than the application of a single factor of safety.

**NOTE:** When using limit state design codes such as the Eurocodes it may be beneficial to request loads which are split (permanent, variable and accidental), so that partial factors may be applied.



**Figure H1 - Explanation of Safety Factors**

<b>Accuracy of Ground Assessment</b>	<b>Low</b>	<b>Higher FoS Needed</b>	<b>Higher FoS</b>	<b>Higher FoS</b>
	<b>Medium</b>	<b>Intermediate FoS</b>	<b>Intermediate FoS</b>	<b>Higher FoS</b>
	<b>High</b>	<b>Lower FoS Needed</b>	<b>Intermediate FoS</b>	<b>Higher FoS</b>
		<i>High</i>	<i>Medium</i>	<i>Low</i>
		<b>Accuracy of Plant Information</b>		

**Figure H2 - Safety Factors Depend on Accuracy of Information and Assessment**

## **Annex I - Legal Framework**

### **I.1 Introduction**

The law places duties on persons concerned with the setting up and use of construction plant on construction sites. This Section outlines those legal duties and points the reader towards further relevant guidance material.

***NOTE:** Northern Ireland has its own set of regulations which tend to mirror those in Great Britain, but may have minor differences. Employers should ensure that they are aware of the regulations in the jurisdiction in which they are working.*

### **I.2 The Law Outlined**

**Legislation relating to the use of construction plant at work includes the:**

- Health & Safety at Work etc Act 1974
- The Construction (Design and Management) Regulations 2007/SI320
- Management of Health & Safety at Work Regulations 1999/SI3242
- Provision & Use of Work Equipment Regulations 1998/SI2306
- Lifting Operations & Lifting Equipment Regulations 1998/SI2307
- Supply of Machinery (Safety) Regulations 2008/SI1597

### **I.3 Health & Safety at Work etc Act 1974 (HSWA)**

HSWA places a duty on employers to ensure the health and safety of employees and others who may be affected by their work activities. Similar duties are placed on the self-employed and persons in control of premises. Employees, managers and directors also have responsibilities. The HSWA also places a duty on construction plant owners and users, where their work activity involves plant being used where it could affect the general public.

### **I.4 The Construction (Design and Management) Regulations 2007 (CDM)**

The Construction (Design and Management) Regulations place duties on duty holders including clients, designers and contractors for the planning, management and monitoring of health, safety and welfare in construction projects and of the co-ordination of the performance of these duties by duty holders. These include a duty on every person working under the control of another to report anything that he is aware is likely to endanger health or safety. The Regulations impose additional duties on clients, designers and contractors where the project is notifiable, defined as likely to involve more than 30 days or 500 person days of construction work. These include the duty of the client to appoint a CDM coordinator and a Principal Contractor.

***NOTE:** The CDM 2007 Regulations are currently under review and this document will be revised to reflect any changes once new regulations are in force*

### **I.5 Management of Health & Safety at Work Regulations 1999 (MHSWR)**

Under MHSWR, employers and self-employed people are required to assess risks to health and safety from their undertaking. This includes risks from the setting up and use of construction plant on their premises. The risk assessment should identify what measures are needed to comply with health and safety requirements and control risk. The duty holder should then put in place the organisation and arrangements to ensure that those measures are properly implemented. MHSWR also requires employers on multi occupancy sites to co-operate with each other to ensure that all statutory provisions are complied with.

### **I.6 The Provision & Use of Work Equipment Regulations 1998 (PUWER)**

PUWER is concerned with such matters as selection of appropriate work equipment, safeguarding of dangerous parts of machinery, provision of appropriate controls, and maintenance of work equipment including construction plant.

PUWER places duties on any person who has control to any extent of:

- work equipment;

- a person at work who uses, supervises or manages the use of work equipment or
- the way in which work equipment is used at work (including maintenance).

PUWER applies to employers in respect of work equipment provided for, or used by, their employees, self-employed persons in respect of work equipment they use and other persons, e.g. visitors.

### **I.7 The Lifting Operations & Lifting Equipment Regulations 1998 (LOLER)**

LOLER deals with the specific risks arising from the use of work equipment (including lifting accessories) to lift loads. It builds upon PUWER and applies to the same groups of people. LOLER also introduces particular requirements for lifting equipment which is used to lift people, and a requirement for the thorough examination and reporting of thorough examination of lifting equipment.

### **I.8 Supply of Machinery (Safety) Regulations 2008 (SMSR)**

The Supply of Machinery (Safety) Regulations are the UK's implementation of European Union Directive 2006/42/EC, the "*Machinery Directive*" which requires that all machinery (including lifting accessories) supplied into the European Union, meets the Essential Health and Safety Requirements detailed in Schedule 2 Part 1 of the Regulations. This include the provision of information for use, including loads imposed on the ground. Each machine must be accompanied at time of supply by an "*EC Declaration of Conformity*" declaring that the machinery fulfils all the relevant provisions of the Regulations.

### **I.9 British, European and ISO Standards**

Standards do not generally have the force of law: the application of a standard is almost always voluntary, although standards are very often used in support of legislation, and compliance with a standard is sometimes quoted in legislation as offering a route to discharging legal obligations. Good examples of this are the references to the BS 7121 series in the Guidance to LOLER.

British standards are generally restricted to Codes of Practice for safe use of equipment e.g. BS7121-3:2000 *Safe use of mobile cranes*, whilst European (EN) standards cover requirements for basic principles (Type A), common product requirements (Type B) and specific product requirements (Type C) e.g. *EN13000:2004 Mobile cranes*.

International Standards (ISO) cover both the safe use and specification of mobile cranes and components. They do not have any legal status by themselves but are often taken as good practice and when cited as normative references in some EN product standards have the same force as EN standards.

## Annex J – Environment Agency Guidance

The Environment Agency has prepared two documents for the use of machine mats, particularly on the banks of rivers, canals and lakes. These can be downloaded from their website at <https://s3-eu-west-1.amazonaws.com/ea-oi/MISC/Use+of+Machine+Mats+in+the+Environment+Agency.pdf>

The documents contain the following guidance for the use of machine mats. This is an example of core procedures that an organisation can insist are used as the basis for planning work where a particular control measure is likely to be used.

*"When preparing a specialist plan and undertaking the work on site the following 'golden rules' must be applied:*

- *When working near a watercourse the machine mats must not slope towards the watercourse.*
- *The minimum distance between the machine mats and the top edge of the bank or the bank of any water body should be determined by risk assessment. However, unless the specialist plan has identified other methods of preventing the machine sliding off the mats then the minimum distance should be no less than two metres.*
- *The machine mats shall be laid either way up, butted up against each other on their long side and laid on a geotextile membrane.*
- *There must be sufficient mats laid to provide an escape route of at least two machine lengths to allow the machine to return back in the event of an emergency.*
- *Working on machine mats is not permitted during icy conditions or in conditions that may cause operational risks.*
- *When lifting the machine mats they must not be dragged, or immersed into water in order to clean them.*
- *Lone working when using machine mats is not permitted."*

## **Annex K - Further Information and Guidance**

### **Legislation**

Health and Safety at Work etc. Act 1974. London: The Stationery Office;

The Management of Health and Safety at Work Regulations 1999 as amended (MHSWR);

The Provision & Use of Work Equipment Regulations 1998/SI2306

L22 *Safe use of work equipment*, HSE Books

The Lifting Operations & Lifting Equipment Regulations 1998/SI2307

L113 *Safe use of lifting equipment*, HSE Books

The Construction (Design and Management) Regulations 2007 (CDM);

L144 *Managing health and safety in construction*, HSE Books

### **Other Publications**

BS 5975:2008 + A1:2011 - *Code of practice for temporary works procedures and the permissible stress design of falsework*

BS 6031:2009, *Code of practice for earthworks*

BS 7121-1:2006, *Code of practice for safe use of cranes — Part 1: General*

BS 7121-3:2000, *Code of practice for safe use of cranes — Part 3: Mobile cranes*

BS 7121-4:2010, *Code of practice for safe use of cranes — Part 4: Lorry loaders*

BS 8004:1986, *Code of practice for foundations*

BS 8460:2005, *Safe use of MEWPs - Code of practice*

BS EN 1997-1:2004, *Eurocode 7. Geotechnical design. General rules*

*Working Platforms for Tracked Plant*, 2004, BR 470, BRE Bookshop

*Working Platforms - Design of granular working platforms for construction plant*  
*A guide to good practice*, Temporary Works Forum (expected 2015)

Joint PFF/BCSA/HSE *Crane Planning Safety Bulletin*

Environment Agency guidance on the use of bog and tracking mats

*Crane Stability on Site*, 2003. CIRIA C703. Construction Industry Research and Information Association

*Tower Crane Stability*, 2006. CIRIA C654. Construction Industry Research and Information Association.

*Influence of Wind on Crane Operation*, 2012. Liebherr-Werk Ehingen GmbH. Download from [http://www.liebherr.com/AT/en-GB/default\\_at.wfw/measure-metric/tab-94354](http://www.liebherr.com/AT/en-GB/default_at.wfw/measure-metric/tab-94354)

*Management of Shoring in Excavations*, Construction Plant-hire Association

*Calculation of Track Bearing Pressures for Platform Design*, Federation of Piling Specialists

*CFA Piling: Preventing ground & rig instability through over-flighting*, Federation of Piling Specialists

### **Useful Websites**

Association of Lorry Loader Manufacturers and Importers	<a href="http://www.allmi.com">www.allmi.com</a>
British Constructional Steelwork Association	<a href="http://www.steelconstruction.org">www.steelconstruction.org</a>
British Drilling Association	<a href="http://www.britishdrillingassociation.co.uk">www.britishdrillingassociation.co.uk</a>
British Geological Survey	<a href="http://www.bgs.ac.uk">www.bgs.ac.uk</a>
Construction Plant-hire Association	<a href="http://www.cpa.uk.net">www.cpa.uk.net</a>
Construction Industry Training Board	<a href="http://www.citb.co.uk">www.citb.co.uk</a>
Federation of Piling Specialists	<a href="http://www.fps.org.uk">www.fps.org.uk</a>
Health and Safety Executive	<a href="http://www.hse.gov.uk">www.hse.gov.uk</a>
International Powered Access Federation	<a href="http://www.ipaf.org">www.ipaf.org</a>
Strategic Forum for Construction	<a href="http://www.strategicforum.org.uk">www.strategicforum.org.uk</a>
Temporary Works Forum	<a href="http://twforum.org.uk/pubs.html">http://twforum.org.uk/pubs.html</a>
UK Contractors Group	<a href="http://www.ukcg.org.uk">www.ukcg.org.uk</a>

## Annex L - Project Group Membership

### Chairman:

K Minton Construction Plant-hire Association

### Members:

<b>Name</b>	<b>Employer</b>	<b>Representing</b>	<b>PG</b>	<b>SC</b>	<b>WG1</b>	<b>WG2</b>
M Allanson	Universal Crane Mats	Universal Crane Mats	M			
S Appleyard	Select Plant Hire	CPA - TCIG	M			
M Banasik	Allianz Engineering	SAFed	M			
J Carpenter	TWF	TWF	M			
B Bolton	HSE	HSE	M		M	M
M Davies	Barhale	CECA	M	M		M
T Downs	NCC	CSkills	M			
J Dunne	Balfour Beatty	UKCG	M			
T Faithfull	CEA	CEA	M			
J Gregory	Carillion	UKCG	M			
R Handley	Aarsleff Piling	FPS	M	M		M
R Hare-Winton	BAM Construct	UKCG	M			
S Hesketh	MGF	CPA - STIG	M			M
E Hudson	Liebherr	CPA - CIG	M	M		M
V Hutson	JCB	CEA	M	M	M	
A Johnson	ALLMI	ALLMI	M	M	M	
P Markham	RNP Associates	UKCG/TWF	M			
B Murphy	Camfaud	CPA - BCPG	M			
A Newell	NCC	CSkills	M			
M O'Connor	HSE	HSE	M	M	M	
I Simpson	HSE	HSE	M	M		M
R Storey	BSP	FPA	M			
D Tees	Lend Lease	UKCG	M			M
D Thomas	William Hare	BCSA	M			
J Underwood	HSE	HSE	M		M	M
S Vickers	Hewlett CE	Hewlett CE	M			
P Walker	BCSA	BCSA	M	M	M	
S Whittam	Environment Agency	Environment Agency	M	M		M
I Wilson	Balfour Beatty	UKCG	M	M	M	
P Wilson	UCATT	UCATT	M			
C Wood	CPA	CPA - CIG	M	M	M	
C Wraith	IPAF	IPAF	M	M	M	

### Key

M = Group Member

PG = Project Group

SC = Steering Committee

WG1 = Working Group 1 - Management of ground conditions

WG2 = Working Group 2 - Assessment of ground conditions

### Secretary & Editor:

T P Watson Construction Plant-hire Association





Reference No. CPA 1402  
First Published: October 2014  
Published by:  
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