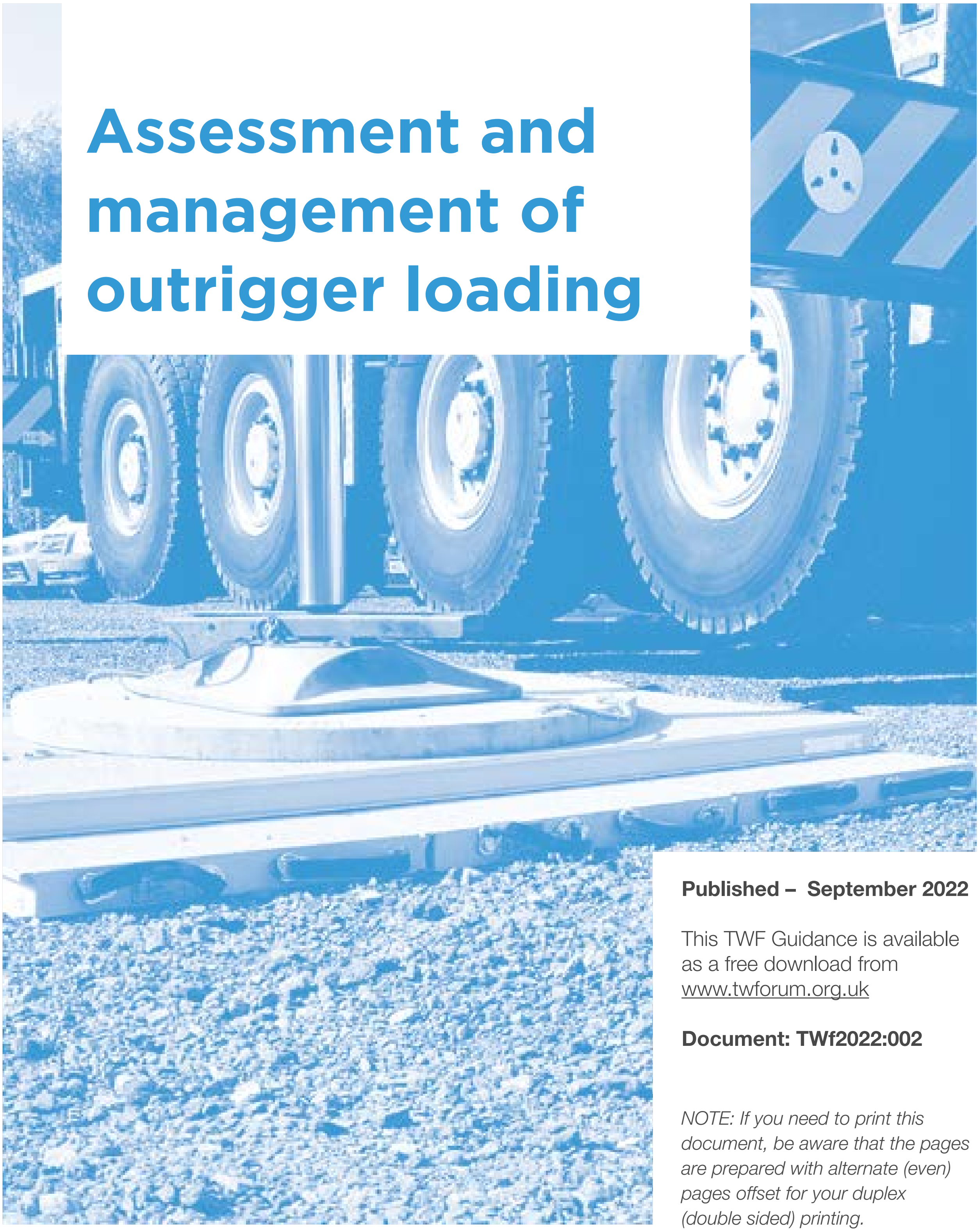
# Assessment and management of outrigger loading



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Temporary Works forum

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Classification of temporary works: 2.0.12 (Lifting)


## Synopsis

Outriggers (or stabilisers) maintain the stability of many types of construction plant such as mobile telescopic cranes, concrete pumps, lorry loaders and mobile elevating working platforms (MEWPs) during setup and when in use. The outrigger (or stabiliser) foot typically applies a vertical load to the ground, often via a spreader mat (commonly known as an outrigger mat) to reduce the bearing pressure.

The management of outrigger loading is a specific part of the wider management of this type of construction plant operation. It is a potentially complex area of temporary works, which must consider the interface between the outrigger, outrigger mat and the underlying ground. It can require coordination between several different designers, construction personnel and plant/equipment suppliers, often remotely from one another and frequently at short notice.

This guidance sets out best practice for the assessment and management of outrigger loading. It aims to align with (and signpost to) existing good guidance on the wider management of construction plant operations and temporary works. It seeks only to complement existing guidance and good practice relating to the calculation of maximum outrigger load and minimum required bearing area.

The primary aim of the guidance is to provide clarity regarding the selection of a suitable outrigger mat or mat arrangement with sufficient capacity to spread the maximum outrigger load to the minimum required bearing area. Assessment of the capacity of outrigger mats or mat arrangements has been identified as an area of particular weakness in existing guidance. Specifically, the Temporary Works Forum (TWf) highlighted concerns regarding the stated capacity of some outrigger mats/systems in a safety bulletin [1.]. This guide makes specific recommendations with the aim of addressing these concerns, and more general recommendations regarding the assessment of outrigger mats in all materials.




## Abbreviations

| | |
|---|---|
| AP | Appointed Person (Lifting) |
| TWC | Temporary Works Coordinator |
| TWD | Temporary Works Designer |
| TWf | Temporary Works Forum |

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## Introduction

**1.** Overall responsibility for the management of outrigger loading on construction sites typically rests with two individuals:

(a) the Appointed Person (AP), who is responsible for planning and having overall control of lifting operations in accordance with BS 7121 [2.] (or an equivalent person for non-lifting operations);

(b) the Temporary Works Coordinator (TWC), who is responsible for coordinating all temporary works associated with the operation (including coordination of associated temporary works designs) in accordance with BS 5975 [3.].

**2.** Discharging these responsibilities can be complicated by the following:

(a) crane lifts and other plant operations are often part of a sub-contract package and/or delivered via 'contract lift', whilst the TWC is typically employed by the main contractor;

(b) outrigger mats are often supplied by the plant supplier or other construction equipment supplier (typically, without adopting design liability);

(c) there are a wide range of proprietary outrigger mat products available in the market that stand up to varying degrees of engineering scrutiny;

(d) it is not uncommon for the AP (or equivalent person) to propose the required outrigger mat area in some 'low' or 'very low' risk situations [3.], without the involvement of a Temporary Works Designer (TWD), e.g. based on published permissible ground bearing pressures [3.] [4.] [5.], via the use of online calculator tools [6.], or using a single value for permissible ground bearing pressure provided by the project structural engineer;

(e) in higher-risk situations, responsibility for determining the required outrigger mat area is usually delegated to an appointed TWD, who may also specify ground improvement such as soil stabilisation or the installation of a granular working platform [7.] [8.] to increase the permissible ground bearing pressure.

**3.** In particular, two main areas of concern have been identified:

(a) Many APs and TWCs lack the necessary appreciation of the interaction between the outrigger mat and the underlying ground or surface, and the need for both the ground and mat to be assessed in their own right (whether via two separate assessments or as part of a single integrated assessment). This is a particular concern in situations where the AP (or equivalent person) proposes the required outrigger mat area and/or size and type of outrigger mat without the involvement of a TWD.

Selecting an outrigger mat on the basis that it is larger than the required outrigger mat area overlooks the importance of ensuring the mat has adequate strength and stiffness to spread the applied outrigger load to the required area and does so in a way which maintains compatibility of load distribution and deflection with the ground beneath.

(b) There is no universally accepted method for verifying the capacity of outrigger mats or mat arrangements. The majority of existing guidance relating to the management of outrigger loading, or the wider management of related construction plant operations, does not focus on assessment of the outrigger mat itself (although some sources of guidance do exist, e.g. Duerr [9.]). TWDs who may routinely use the suite of Eurocodes to assess steel, timber, and aluminium structures [10.] [11.] [12.] have no equivalent code by which to assess the wide range of plastic proprietary mats now available on the market. Existing physical tests and complex software analyses (such as finite element analyses) have often been found to have incorrectly accounted for the complex interaction between mat and ground.

The correct verification of outrigger mat capacities is particularly important in the case of proprietary mats and common mat arrangements, since there are obvious benefits to the construction industry in being able to rely on published, pre-calculated capacities that allow them to be safely deployed hundreds or thousands of times without the need for a bespoke temporary works assessment each time.

**4.** In response to these concerns, and with a desire to improve this area of temporary works, the TWf convened a Working Group (WG36), which has prepared this guidance.

**5.** The guidance is split into two parts:

**Part A**

This describes the assessment process which should be overseen by the AP and/or TWC to determine the maximum outrigger load and then ensure both the outrigger mat and underlying ground have adequate capacity to resist that load. A large volume of good information and advice exists already to determine the maximum outrigger load and the minimum required bearing area. Such sources are summarised in the References and Bibliography (at the end of this guidance and signposted accordingly throughout). More detailed guidance is included on the selection of a suitable outrigger mat or mat arrangement.

**Part B**

This contains guidance for TWDs, including those acting on behalf of the manufacturers or suppliers of proprietary outrigger mats, on the capacity assessment of the outrigger mat or mat arrangement itself. It seeks primarily to address the complex nature of the interaction between the mat and the underlying ground which, if not considered appropriately, can lead to incompatibility between the two and over-estimation of the capacity of the outrigger mat. It provides a 'lower bound' approach which enables the capacity of proprietary outrigger mats to be pre-calculated without foreknowledge of the ground conditions on which they will be deployed.

## Part A: The assessment process

### Overview

**6.** The recommended assessment process comprises three steps (see Figure 1):

- **Step 1:** Determine the maximum outrigger load.
- **Step 2:** Determine the minimum required bearing area so as not to overload the underlying ground.
- **Step 3:** Select a suitable outrigger mat or mat arrangement, with the strength and stiffness to spread the maximum outrigger load to the required bearing area whilst deflecting within allowable tolerances.

**7.** Whilst it is possible to undertake Step 3 before Step 2 [13.], by assessing the three steps in this recommended order the limiting capacity of the ground is considered before the selection of a suitable outrigger mat. This reflects the fact that ground conditions are typically unchangeable for a given location, whereas there is a wide choice of potential outrigger mats or mat arrangements.

**8.** Where appropriate, the TWD may wish to combine Option 2A and Option 3A into a single analysis. This option is described in Para. 53 et seq.

### Step 1: Determining the maximum outrigger load

**9.** The maximum outrigger load(s) generated by a proposed lifting operation is usually calculated by, or under the supervision of, the AP (or equivalent for non-lifting operations) [5.] [14.] [15.].

**10.** Calculation of the maximum outrigger load(s) should be checked [3.].

**11.** The maximum outrigger load value(s) should be stated within the 'Lift Plan' or other equivalent 'Safe System of Work' documentation (such as a Risk Assessment – Method Statement, or RAMS) [2.], from where they can also be stated within the Temporary Works Design Brief(s) associated with Step 2 and Step 3 of this process [3.].

**12.** Outrigger loads are typically stated as 'characteristic' or 'unfactored' values [16.] (i.e. they may make allowance for dynamic or wind loading effects but require the application of suitable partial or global factors in Step 2 and Step 3) and should be treated as such unless specifically stated otherwise.

**13.** The maximum outrigger load is typically determined by specific calculation (see Option 1A) or estimated using a recognised rule-of-thumb or manufacturer's published value (see Option 1B).

### Option 1A: Specific calculation

**14.** Specific outrigger loads can be calculated based on the weight of each element of the plant and load, and its corresponding distance from the centroid of the machine. Vertical and rotational forces are balanced, from which the reaction under each outrigger can be calculated.

**15.** Calculation of specific outrigger loads can be undertaken by hand, although it is typically carried out using assessment software or calculation tools developed by the crane manufacturer or other provider. Examples include manufacturer-specific software such as LICCON (Liebherr) and LiftPlanner (Terex, Demag, Tadano), generic software such as Cranimax, and online tools such as those made available by ALLMI, Kobelco and Hitachi-Sumitomo.

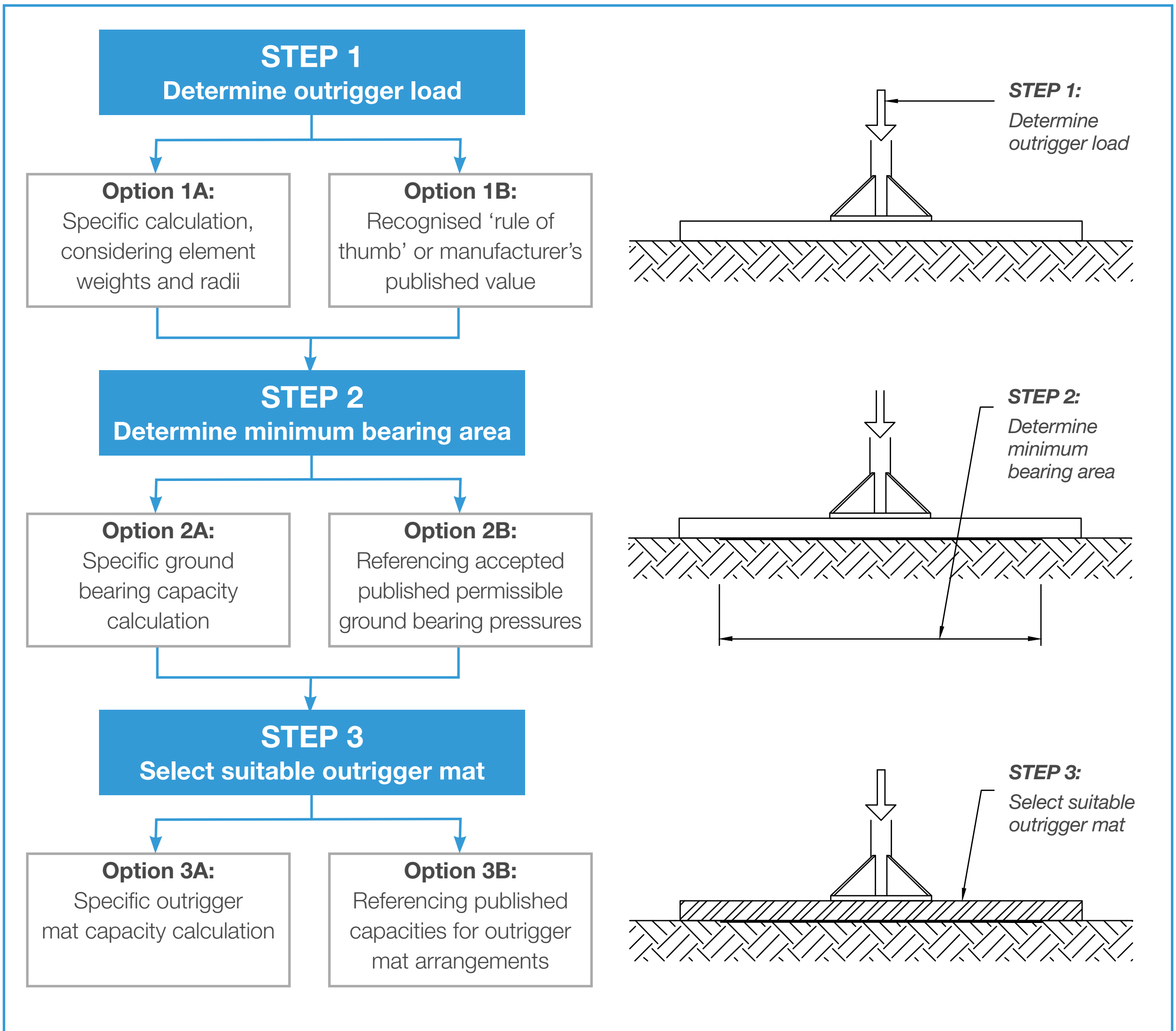



*Figure 1: Assessment process flowchart and diagram*

**16.** For each operation, the maximum load on each outrigger must be identified. This should be achieved by considering each stage of the whole operation. Scenarios which should be considered include (but are not limited to):

- rigging and 'test slew' arrangements (which can, under certain circumstances, generate more onerous outrigger loads than the main operation);
- maximum planned load, and corresponding radius;
- maximum planned radius, and corresponding load (if different);
- minimum radius and zero load conditions (which can generate the most onerous outrigger loads under the counterweight);
- 360-degree slew (unless robust slew restriction is to be in place during the operation);
- In some instances, it may be appropriate to also consider load/radius combinations corresponding to the maximum operating capacity of the plant.

**17.** Each scenario that has been considered, and the corresponding calculated outrigger load(s), should be clearly stated within the 'Lift Plan' and/or other documented 'Safe System of Work' [2.]. The plant operator can ensure that the maximum calculated outrigger load(s) is not exceeded by remaining within the constraints of the scenarios listed and/or by monitoring actual outrigger loads (where on-board software permits).

**18.** If the planned operation has to be amended in any way (e.g. change in load or radius, modified rigging arrangement, etc.), the maximum outrigger load(s) should be recalculated and the 'Lift Plan' and/or other documented 'Safe System of Work' amended.

**Robust controls must be in place to ensure that the maximum outrigger load (against which the capacity of the ground and/or outrigger mat is assessed) is correctly calculated, adequately communicated and not exceeded on site.**

### Option 1B: Estimating the maximum outrigger load

**19.** The maximum outrigger load can be estimated based on a recognised rule-of-thumb or manufacturer's published values. Estimated or published values seek to reflect the maximum outrigger load that can be generated when plant is operating at maximum capacity and may be considerably more conservative than values determined by specific calculation (Option 1A). In choosing to determine the maximum outrigger load in this way, consideration should be given to the fact that it may result in the need for larger and stronger/stiffer outrigger mats.

**20.** Several manufacturers and industry bodies (such as ALLMI) publish maximum possible outrigger loads for different models of construction plant [17.]. This value may also be printed on the side of the machine. When not printed on the side of the machine, care should be taken to ensure the value used corresponds to the correct specific make and model.

**21.** In the UK, the most frequently used rule of thumb for all-terrain type mobile cranes is the '75% rule', which is taught on the CPCS "Appointed Persons: Lifting Operations" course (A61) [18.] and asserts that the maximum outrigger load will not exceed 75% of gross weight of rigged crane (including all counterweight) plus 100% of the hoisted load (including all accessories and hook block etc.). It is recommended that this rule is not used for cranes with a capacity in excess of 160 tonne.

**22.** For all-terrain type mobile cranes up to 160 tonne capacity, outrigger loads calculated using the 75% rule should be compared against the values listed in Section 2.5.1 of CIRIA C703 [4.]. Where rule-of-thumb values exceed the CIRIA values, maximum outrigger loads should be determined by specific calculation (Option 1A) to avoid an uneconomical solution. This is particularly likely if the crane is operating at a short radius.

**23.** Equivalent rules-of-thumb for other types of cranes and construction plant, e.g. lorry loaders, mobile elevating working platforms (MEWPs), concrete pumps, etc., are not as well developed or widely used and should be used only by competent TWDs with a detailed understanding of their derivation.

### Step 2: Determining the required bearing area

**24.** The minimum required bearing area must be determined, so as not to overload the underlying ground.

**25.** The minimum required bearing area will usually be determined by geotechnical assessment, undertaken by a suitably competent civil, structural or geotechnical engineer, taking into account the site-specific conditions encountered (see Option 2A).

**26.** In some 'low' or 'very low' risk situations [3.], the minimum required bearing area is sometimes determined by the AP or TWC, using published values for a given outrigger load and soil description / allowable bearing pressure (see Option 2B).

### Option 2A: Determining the required bearing area by geotechnical assessment

**27.** Geotechnical assessment typically involves applying the maximum outrigger load as a uniform pressure over a given area and assessing the ability of the modelled ground to provide adequate resistance against failure. This can be an iterative process, whereby the area is increased (and corresponding pressure decreased) until an acceptable margin is achieved between the applied load and available resistance.

**28.** Several different analysis methods and approaches are commonly adopted, including (but not limited to):

- limit state design, applying partial factors to both the load and resistance [16.] [19.];
- maintaining a global factor of safety between the load and resistance [20.];
- shallow foundation theory, using accepted equations for drained and undrained soil resistance [19.];
- use of more complex computational software, some of which rely on finite element or quasi-finite-element methods in two or three dimensions.

**29.** The geotechnical assessment should assume that the outrigger load is to be applied as a uniform bearing pressure over a given area, in order to maintain compatibility with a lower bound outrigger mat assessment described in Step 3. Refer to Part B for further detail. (The exception to this guidance is if Step 2 (Option 2A) and Step 3 (Option 3A) are combined into a single analysis, as described in Para. 53 et seq.)

**30.** Adequate consideration must be made of more complex geotechnical considerations, including (but not limited to):

- multi-layered soils, in particular those which contain weaker strata below the surface layer;
- sloping ground;
- presence of buried services or other underground assets (tunnels, basements, etc.);
- proximity to slopes (including the edge of working platforms), retaining walls, existing structures, etc;
- absolute or differential settlement.

**31.** Where outrigger mats are located above or adjacent to buried services or other underground assets, a detailed geotechnical assessment must be undertaken, which accurately considers the load spread through the mat and the ground, and the anticipated load effect upon the buried services or underground assets.

**32.** Where there is the potential to temporarily alter the load upon third party assets, necessary permissions and/or consents should be sought in good time. Such permissions may require demonstration of compliance with relevant local and legal procedures and/or the submission of calculated pressure profiles or ground settlement [21.] [22.].

**33.** The completed geotechnical assessment should be recorded on a Temporary Works Design and Check Certificate [3.].

### Option 2B: Determining the required bearing area by use of published values

**34.** A number of sources of published values exist, which can be used to determine the required bearing area. However, they are necessarily simplified and do not account for more complex geotechnical considerations, as described under Option 2A.

**Determining the required bearing area by use of published values should only be undertaken in simple situations, where the AP or TWC is suitably competent and is confident that more complex geotechnical considerations do not exist which require assessment. If in any doubt, this method should not be used, and the advice of a suitably competent civil, structural or geotechnical engineer should be sought.**

**35.** The charts published in Section 2.5.2 of CIRIA C703, Crane stability on site [4.], provide indicative outrigger foundation areas on granular and cohesive soils for mobile cranes up to 160 tonne capacity. A factor of safety of 2.0 is adequate for most situations. These charts should not be used for larger cranes, special situations and where ground conditions are not straightforward (e.g. layered strata, paved areas, etc.). Guidance is provided on how to make allowance for groundwater/flooding and rectangular outrigger mats.

**36.** Table E1 of the Strategic Forum for Construction Plant Safety Group Good Practice Guide, Ground conditions for construction plant [5.], lists safe working loads for differing ground conditions and mat sizes, and can be used to determine required bearing areas for a given outrigger load on the described ground.

**37.** The IPAF Spreader pad calculator [6.] allows users to calculate the required bearing area for plant outriggers/stabilisers or wheel loads, based on either a maximum allowable ground pressure or simple description of the ground conditions.

**38.** Table 18 of BS 5975: 2019 [3.] is commonly used for presumed allowable bearing pressure under vertical static loading. However, Note 2 states, "The data in this table is for buried foundations. For surface foundations, use BRE 470 or other classic soil theories …". As such, this information is unsuitable for most outrigger loading assessments.

*NOTE: BRE 470 [8.] is likely also to be unsuitable as it specifically relates to tracked plant.*

**39.** In the majority of cases, published values (such as those described in Para. 35 et seq.) advise only on the required bearing area for outrigger loads on different types of ground. Unless explicitly stated otherwise, outrigger mat options are inferred and not assessed, and should not be selected without following the guidance described in Step 3.

**40.** The assessment should be checked and recorded on a Temporary Works Design and Check Certificate [3.].

### Step 3: Selecting a suitable outrigger mat

**41.** Unless the required b earing area is smaller than the outrigger foot itself, a suitable outrigger mat or mat arrangement must be selected with the strength and stiffness to spread the maximum outrigger load (determined in Step 1) to the minimum required bearing area (determined in Step 2).

**42.** It is incorrect to assume that an outrigger mat simply has to be large enough to satisfy the minimum required bearing area as determined in Step 2. As with any other temporary works item, the capacity of an outrigger mat must be determined and found to be adequate prior to use.

**43.** The misconception described in Para. 42. may be compounded by existing sources of information, such as [5.] and [6.], which do not always make it explicitly clear whether the capacity of the outrigger mat has been assessed or not. Outrigger mats should only be selected in accordance with Option 3A or Option 3B.

It is essential that the capacity of the mat itself has been assessed and found to be adequate to spread the maximum outrigger load (or greater) to the minimum required bearing area (or greater).

Particular care should be taken with existing sources of information, which may imply that a mat of a certain size is adequate, despite not having undergone a suitable assessment. In such circumstances, unless explicitly stated otherwise, it should be assumed that the capacity of the outrigger mat has not been verified.

**44.** The capacity of an outrigger mat or mat arrangement can be assessed for a specific application (see Option 3A). This is particularly suitable for bespoke mat arrangements such as layered timber sleepers, or to achieve a more efficient solution where the specific outrigger load and required bearing area are known.

**45.** Alternatively, an outrigger mat or mat arrangement can be selected for use based on a published pre-calculated capacity (see Option 3B). This approach is suited to proprietary outrigger mats and common mat arrangements, which can then be deployed quickly without requiring a specific temporary works assessment each time.

**46.** An outrigger should always be placed centrally on the outrigger mat unless an allowable eccentricity is specifically approved by a TWD or specifically noted within pre-calculated published capacity for that particular mat.

## Option 3A: Specific assessment of outrigger mat capacity

**47.** Where a specific outrigger mat assessment is undertaken, details of the proposed construction activity, location, ground conditions and preferred outrigger mat or mat arrangement will be known.

**48.** A specific outrigger mat assessment should be undertaken by a competent TWD, in accordance with the guidance set out in Part B. Even where the assessment is undertaken by the same TWD as the geotechnical assessment (Option 2A), the two will usually be completed as separate steps.

**49.** Alternatively, Step 2 (Option 2A) and Step 3 (Option 3A) can be undertaken as a single, integrated assessment provided that the guidance in Para. 53 et seq. is followed.

**50.** The completed outrigger mat verification should be recorded on a Temporary Works Design and Check Certificate [3.]. Where the outrigger mat verification is undertaken by the same TWD as the geotechnical assessment (Option 2A), the two can be recorded on a single certificate.

## Option 3B: Use of pre-calculated published capacities

**51.** Outrigger mats selected for use on the basis of pre-calculated published capacities should have been assessed in accordance with Part B of this guidance and should be accompanied by an 'Outrigger Mat Capacity Verification Certificate' (see Appendix A). Where such an assessment cannot be demonstrated or certificate provided, the outrigger mat capacity ought to be assessed in accordance with Option 3A.

**52.** The person selecting the outrigger mat (usually the AP or TWC) should ensure that:

- the outrigger mat has a rated capacity greater than or equal to the maximum outrigger load (determined in Step 1);
- the corresponding spread area of the outrigger mat is greater than or equal to the required bearing area (determined in Step 2).

Otherwise, an alternative outrigger mat should be selected, or the outrigger mat assessed in accordance with Option 3A.

## Combined geotechnical and mat analysis

**53.** Step 2 (Option 2A) and Step 3 (Option 3A) can be combined into a single, integrated analysis. This approach is only suitable for assessing a specific outrigger mat on specific ground. Such an approach can produce more efficient solutions and may be cost-effective for very large outrigger loads or complex situations.

**54.** Combined analysis of the outrigger mat and ground should only be undertaken by suitably competent TWDs with a sound understanding of soil-structure interaction, experienced in the use of the relevant techniques or tools required to undertake such an analysis.

**55.** Combined analysis should not be used for determining pre-calculated published outrigger mat capacities as per Step 3 (Option 3B). Such assessments should be undertaken in accordance with the guidance set out in Part B.

**56.** Whilst some of the guidance in Part B will remain relevant to combined analysis, it is intended for stand-alone outrigger mat assessments and may not all be relevant. TWDs should be suitably competent to use their own judgement when following the guidance in Part B for combined analysis.

## Part B: Assessment of outrigger mat capacity

### Overview

**57.** The following guidance has been developed to assist TWDs when undertaking assessment of outrigger mats or mat arrangements described in Part A (Step 3).

**58.** The guidance sets out over-arching principles to ensure that mat assessments are undertaken accurately and remain compatible with corresponding geotechnical assessments. It does not seek to limit competent designers from preferred methods of analysis, more than is considered necessary to avoid the most frequent and significant errors.

**59.** The guidance provides a common framework which interested parties (e.g. manufacturers or suppliers of proprietary mats, suppliers of construction plant or equipment, main contractors, etc.) may wish to reference or mandate compliance with, to demonstrate or maintain acceptable levels of engineering assurance.

**60.** In general, the following guidance does not relate to the combined analysis of mat and ground by as described in Para. 53 et seq. However, some of the principles remain relevant.

### Guidance Notes (GN) for Designers

### Definitions

**GN1.** For the purposes of these guidance notes, an "assessment" refers to the assessment of the capacity of an outrigger mat or mat arrangement. Distinction is drawn between a "specific assessment" (where a specific mat is assessed for its suitability for deployment in a specific location and for a specific purpose) and a "generic assessment" (where an outrigger mat or mat arrangement is being assessed for the purposes of providing pre-calculated published capacity data).

### Competency and checking

**GN2.** Assessments should be undertaken by a suitably competent designer, with relevant knowledge and experience in the analysis of structural behaviour and soil-structure interaction.

**GN3.** Specific assessments should be checked to an appropriate design check category (viz. 1, 2 or 3) in accordance with Clause 13.7 and Table 2 of BS 5975: 2019 [3.].

**GN4.** Generic assessments should be independently checked (i.e. Category 2 or 3) in accordance with Clause 13.7 and Table 2 of BS 5975: 2019 [3.], due to the multiplied potential for failure in the event of an assessment error.

- Where the assessment is undertaken on behalf of persons other than the manufacturer/supplier (e.g. main contractor, subcontractor, etc.), a Category 2 check is considered acceptable.
- Where the assessment is undertaken by or on behalf of the product manufacturer/supplier, a Category 3 check is recommended to ensure adequate organisational independence.

### Process

**GN5.** Specific assessments ordinarily consider Steps 2 and 3 in Part A separately and sequentially. Where combined analysis is to be undertaken, guidance set out in Para. 53 et seq. should be followed.

**GN6.** For generic assessments, it should be assumed that the location-specific management of outrigger loading will follow the guidance set out in Part A, with separate Steps 1, 2 and 3.

### Assessment

**GN7.** Generic assessments should not rely on integrated soil-structure modelling, due to the highly complex nature of the soil-structure interaction and the wide variability of potential ground conditions encountered on site. Doing so too frequently has the effect of placing reliance upon a presumed soil strength/stiffness to justify the capacity of the mat system, which can mask the true load-spreading capacity of the mat arrangement itself.

**GN8.** Generic assessments should follow a compatible lower bound approach which models the outrigger load as being distributed to a uniform pressure on an effective area of the underside of the mat arrangement (see Figure 2). This ensures that the assessment is capable of accounting for a full range of potential soil stiffness and maintains compatibility with the corresponding ground bearing verification described in Part A Step 2.

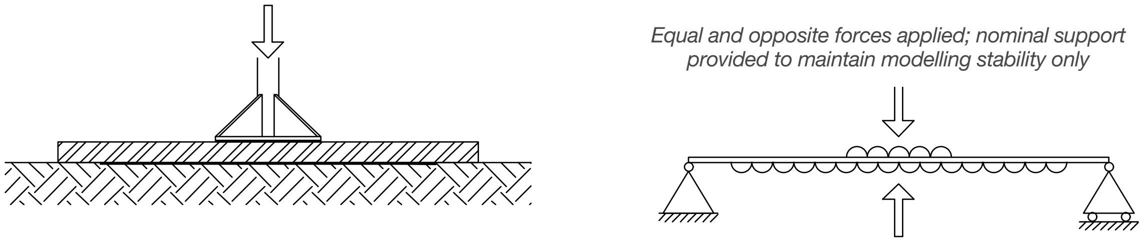



*Figure 2: Compatible lower bound approach to assessment of outrigger mat capacity*

*NOTE:*

- *As a minimum, generic assessments should assess the effective ground bearing area as full area of the underside of the mat.*
- *Generic assessments may also consider one or more reduced effective areas, provided the corresponding effective area and maximum outrigger load clearly stated within the published capacity data (e.g. a 2.0 x 2.0 m mat could have a published maximum outrigger load for a 2.0 x 2.0 m effective area, with higher published values for smaller effective areas of 1.8 x 1.8 m, 1.6 x 1.6 m, etc.).*

**GN9.** Specific assessments which consider Part A *Steps 2 and 3* separately and sequentially (see GN5) may also adopt the compatible lower bound approach (see GN8). Alternatively, they may incorporate a suitable presumed soil strength/stiffness (see GNs 16 and 17).

**GN10.** Where assessments follow the compatible lower bound approach and are undertaken using structural analysis software, the reaction from the ground should be modelled as a uniform pressure on the effective area of the underside of the mat arrangement, and not as a passive ground support condition (e.g. a linear or non-linear modulus of subgrade reaction or spring stiffness). It is typically necessary to introduce a nominal support condition to maintain modelling stability (see Figure 2). If the nominal support condition is applied correctly (i.e. ensuring it does not introduce unintended rotational or horizontal fixity), the subsequent application of the outrigger load as a concentrated load on the top of the mat arrangement and the corresponding uniform ground bearing pressure as an equal and opposite positive reaction on the underside of the mat arrangement should result in the nominal support condition resolving to zero (or as close to zero as to be deemed negligible).

**GN11.** Assessments may assume that the outrigger load is applied centrally on the mat arrangement, without a specific allowance for eccentricity (and corresponding reduction in capacity). Alternatively, assessments may make some allowance for eccentricity (e.g. the 'middle third' or a given % of the mat width, or an absolute value). In all cases, the assumed maximum eccentricity must be clearly communicated to the end user (e.g. the AP or TWC) within the design deliverables (for specific assessments) or alongside the published capacity data (for generic assessments). Where the actual eccentricity on site is greater than the stated maximum eccentricity (e.g. due to adjacent obstructions, etc.), a further specific assessment will be required.

*NOTE:*

- *'Handleable' mats (i.e. those of sufficiently small size and weight) can be positioned centrally beneath the crane outrigger with relative ease, allowing for last-minute adjustment.*
- *Mats which require mechanical lifting into place due to their size and/or weight should have their position set out in advance to ensure that they are loaded centrally, where required.*

**GN12.** Assessments can consider the outrigger load to be applied as a point load (generally more conservative) or as a concentrated uniform pressure under the area of the outrigger foot. Where the assessment considers a concentrated uniform pressure rather than a point load, the assumed outrigger foot area should be clearly communicated to the end user (e.g. the AP or TWC) within the design deliverables (for specific assessments) or alongside the published capacity data (for generic assessments). Where the actual outrigger size on site is smaller than stated outrigger size:

- An ancillary spreader mat can be used to spread the load from the actual outrigger foot to the assumed outrigger foot area, provided that this ancillary mat has been assessed (via a generic or specific assessment) as adequate to achieve the required load spread; or
- A further specific assessment can be carried out, to demonstrate that the main outrigger mat arrangement still has sufficient capacity when the more concentrated load is applied.

**GN13.** For steel, timber and aluminium mats, assessment is typically undertaken with reference to the appropriate Eurocodes [10.] [11.] [12.] (or equivalent British Standards). Particular care should be taken with the assessment of plastic outrigger mats (e.g. nylon compounds, polyethylene, etc.) for which there is no recognised equivalent structural design code.

**GN14.** Homogeneous mat components (e.g. plastic) can be assessed as two-way spanning [23.]. Non-homogeneous mat components (e.g. timber sleepers, extruded aluminium planks, fabricated steel beam mats) are typically assessed as one-way spanning in the 'strong' direction, although suitable allowance can be made for load spread in the 'weak' direction, as appropriate and as demonstrated within the assessment.

**GN15.** In both specific and generic assessments, consideration should be given to the potential for relative stiffness/deflection of different components within the mat system (e.g. plastic mat over timber sleepers or aluminium planks) and between the mat system and the underlying ground. Where required, a suitable compressible layer (e.g. builder's sand, expanded polystyrene/ polyethylene, etc.) may be specified for placement between layers to accommodate potential or calculated differential deflection (see Figure 3). In particular:

- Where outrigger mats are placed on flexible surfaces (e.g. asphalt), the relative deflection of the mat can cause permanent deformation of the surface at high pressures. Bituminous surfaces are particularly prone in warmer weather. Where it is necessary to mitigate this risk, a suitable compressible layer may be specified to be placed between the underside of the mat and the flexible surface.

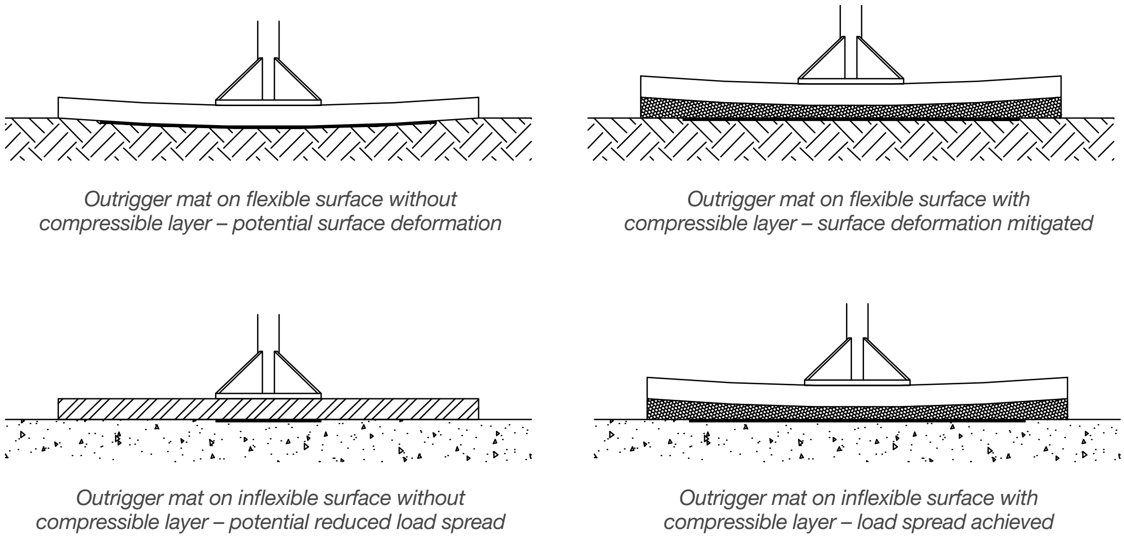



*Figure 3: Use of compressible layer to mitigate risk of permanent deformation of flexible surfaces or inadequate load spread on inflexible surfaces*

*Figure 4: Deflection limits as a proportion of cantilever length or mat width*

- Where outrigger mats are placed on inflexible surfaces (e.g. concrete paving slabs) a suitable compressible layer may be specified to be placed between the underside of the mat and the inflexible surface to permit the mat to adopt the deflected shape compatible with the required load spread.

**GN16**. Where a compressible layer is used, it must be of a material with adequate bearing capacity to withstand the applied pressure (structural grade expanded polystyrene and polyethylene are typically rated to withstand a given pressure at a given % compressive strain) and of adequate thickness to accommodate the sum of the net compression and the relative deflection.

### Material properties

**GN17.** Assessments should consider appropriate material properties. For the mat arrangement, appropriate material properties will typically include density, yield stress (flexural and shear), elastic stiffness and Poisson's ratio from recognised published sources such as material data sheets. Timber mats should be assumed as Service Class 3 and appropriately conservative stress grade, with consideration to difficulty of identification and potential for deterioration (particularly due to water absorption) over time [9.].

**GN18.** Where a specific assessment considers both the ground and the outrigger mat in a single assessment (see GN5), the assessment should also consider appropriate material properties for the underlying ground. These should typically include density, drained and/or undrained strength, ultimate bearing stress, (linear or non-linear) elastic stiffness or modulus of subgrade reaction and Poisson's ratio.

**GN19.** Particular care should be taken in the use of linear-elastic stiffness assumptions except at low strains since many plastic compounds (in particular) do not exhibit linear-elastic behaviour as they approach or exceed their yield or ultimate stress.

### Capacity

**GN20.** For generic assessments, the stated capacity of the outrigger mat should be defined as the maximum load which can be applied (on a stated outrigger area, spreading to a stated effective ground bearing area) without exceeding acceptable strength and stiffness limits, as set out in GNs 21 and 22.

**GN21.** Strength capacity should ensure that the mat arrangement has adequate bending, shear and crushing strength under the applied maximum load case.

**GN22.** Stiffness capacity should ensure that the maximum calculated relative deflection within the mat (i.e. the vertical distance between the outer edge/corner and the middle of the mat) does not exceed acceptable limits. Several definitions of acceptable limits exist, including:

- 0.75 % of the cantilever length [13.], e.g. an acceptable deflection limit of 2.6 mm for a 300 mm wide outrigger on a 1 m wide outrigger mat.
- 10 mm per metre width of mat, e.g. an acceptable deflection limit of 10 mm for a 300 mm wide outrigger on a 1 m wide outrigger mat.

*NOTE: It is recommended that under no circumstances should the calculated deflection in the outrigger mat exceed 25 mm, noting that this does not include additional net settlement which may occur in the underlying ground. Where this limit is not being achieved, designers should consider increasing the elastic section modulus of the mat under consideration (typically by increasing the thickness).*

### Residual risks and certification

**GN23.** The risk associated with any limitations or assumptions considered in the assessment or the verification of permissible ground bearing pressure should be mitigated as far as is reasonably practicable in accordance with the general principles of prevention (hierarchy of controls). Any residual risks should be clearly stated within the design output (for specific assessments) or alongside the published capacity data (for generic assessments).

**GN24.** Assessments should be recorded on a Temporary Works Design & Check Certificate, setting out:

- the outrigger mat(s) or mat arrangement(s) covered by the certificate (defined by key dimensions, e.g. length, width, thickness, weight);
- key parameters used in the assessment (e.g. flexural strength, flexural stiffness, elastic modulus, Poisson's ratio, etc.);
- any limitations or restrictions assumed or identified in the assessment;
- maximum allowable loads for specific combinations of outrigger foot size and bearing area, with corresponding calculated deflection values.

**GN25.** A recommended Certificate template for generic assessments has been developed to capture this information and is included as Appendix A to this document. It is proposed that this certificate accompanies all outrigger mats given a published capacity.

### Assessment by testing

**GN26.** Assessment by testing is generally not recommended.

- For specific assessments, a representative load test would be required (i.e. an equivalent load on the proposed mat in the proposed location), which is rarely practicable.
- For generic assessments, any testing arrangement must accurately model the applied load and corresponding reaction (see GN8), to ensure that the test arrangement does not inadvertently place reliance upon a presumed soil strength/ stiffness to justify the capacity of the mat system (see GN7).

## References

The following existing sources of information are listed for reference. The list is not exhaustive, and publications listed are subject to periodic updates.


[1] **Temporary Works Forum (TWf) Safety Bulletin – Plastic Outrigger Mats/Systems (Ref: TW21.144)**

https://www.twforum.org.uk/viewdocument/twf-safety-bulletin-plastic-outrig

Issued 20th December 2021 following concerns raised by several members regarding the stated capacity of some plastic outrigger mats/systems, resulting in the publication of this guidance document (TWf2022:02).

[2] **BS 7121, Code of Practice for Safe Use of Cranes (BSI)**

Part 1 of this series sets out the role of the Appointed Person (Lifting).

[3] **BS 5975: 2019, Code of practice for temporary works procedures and the permissible stress design of falsework**

The BSI Code of Practice for the procedural control of temporary works, including the selection of an appropriate 'design check category'. Table 1 describes implementation risk classes ('very low', 'low', 'medium' or 'high') corresponding to descriptions within this guidance.

*NOTE: Whilst Table 18 is frequently used as a point of reference for permissible ground bearing pressures, the footnotes state that the data in the table is for buried foundations, and other sources of information should be used for surface foundations.*

[4] **Crane stability on site (Second Edition, C703) – Construction Industry Research and Information Association (2003)**

Comprehensive guidance on managing crane stability on site. Section 2.5.2 contains charts for outrigger foundation areas on granular and cohesive soils.

[5] **Good practice guide – Ground Conditions for Construction, Plant Strategic Forum for Construction – Plant Safety Group**

https://www.cpa.uk.net/downloads/110/SFPSG-Guidance-on-Ground-Conditions-Published-Document-with-logos.pdf

Contains a lot of useful guidance regarding ground conditions and required bearing areas.

*NOTE: It focusses on the suitability of the ground and does not specifically address the issue of outrigger mat capacity. In particular, the information presented in Table E1 provides areas in accordance with Step 2 Option 2B (described in Part A of this document) but does not consider the strength/stiffness of the outrigger mat itself (as per Step 3 described in Part A of this document).*

[6] **IPAF – Spreader Pad Calculator**

https://www.ipaf.org/en/spreader-pad-calculator

Recommends required outrigger mat size (minimum effective bearing area) for a given load and permissible ground bearing pressure (as per Steps 1 and 2 described in Part A of this document).

*NOTE: It does not consider the required strength/stiffness of the outrigger mat itself (as described by Step 3 described in Part A of this document).*

[7] **Working Platforms - Design of granular working platforms for construction plant: A guide to good practice, Temporary Works Forum (TWf2019.02, April 2019)**

https://www.twforum.org.uk/viewdocument/working-platforms-design-of-granu

Guidance on the design of granular working platforms, which can be installed to enhance the bearing capacity (and reduce the required bearing area) of existing ground.

[8] **Working platforms for tracked plant (BRE470, 2004)**

Guidance on the design and construction of granular working platforms for tracked plant specifically, although relevant to granular working platforms more generally.

[9] **Mobile crane support handbook – Second Edition – David Duerr**

Contains a number of recommendations for the assessment of outrigger mats. It notes particular caution regarding the transverse load spreading capability of tie rods used in timber mat arrangements.

[10] **BS EN 1993 (& National Annex), Design of steel structures (BSI)**

Code of Practice for the design of steel structures, which can be used for the capacity assessment of steel outrigger mats.

[11] **BS EN 1995 (& National Annex), Design of timber structures (BSI)**

BSI code of practice for the design of timber structures, which can be used for the capacity assessment of timber outrigger mats. For timber outrigger mats, which are frequently stored outside for long periods of time, the use of Service Class 3 is recommended.

**[12] BS EN 1999 (& National Annex), Design of aluminium structures (BSI)**

BSI code of practice for the design of aluminium structures, which can be used for the capacity assessment of aluminium outrigger mats.

**[13] Effective bearing length of crane mats – David Duerr – Crane & Rigging Conference, Houston, Texas (2010)**

https://www.academia.edu/8227807/Effective_Bearing_Length_of_Crane_Mats_

Describes the principal approaches to considering the capacity of both the outrigger mat and the underlying ground, the first of which is recommended in this document (as described in Part A, Overview).

**[14] Responsibilities during contract lifting (TIN 103), Construction Plant-Hire Association Crane Interest Group (2022)**

https://www.cpa.uk.net/downloads/421/CPA%20CIG%20TIN%20103%20(21)%20Issue%20B%20220601.pdf

A technical note outlining responsibilities during a contract lift.

**[15] Guide to the management of site lifting operations, Publication No. 47/09 (BCSA)**

https://www.steelconstruction.info/images/8/8a/BCSA_47-09.pdf

Guidance on how to lift and position steel/steelwork after fabrication and onsite.

**[16] BS EN 1991 (& National Annex), Actions on structures (BSI)**

Code of Practice for assessment of actions on structures.

**[17] Stabiliser forces, GN013 (ALLMI)**

https://www.allmi.com/guidance-documents/guidance-notes/gn013-stabiliser-forces-detail

Guidance on the derivation and assessment of lorry loader stabiliser forces.

*NOTE: This focusses on the capacity of the lorry loader itself, and the maximum outrigger load generated at full capacity, rather than specific consideration of the capacity of the outrigger mat or underlying ground. Use of maximum outrigger loads as per the ALLMI Ready Reckoner typically over-estimates actual outrigger loads, requiring larger / stronger / stiffer mats.*

**[18] CPCS Appointed Persons: Lifting Operations A61**

A 5-day course suitable for supervisors and managers with responsibility for lifting operations. Gives an understanding of the AP's responsibilities and how to fulfil them. On passing the technical test, candidates gain the CPCS trained operator card (red card).

**[19] BS EN 1997 (& National Annex), Geotechnical design (BSI)**

BSI code of practice for the geotechnical assessment of shallow foundations, which can be used for the capacity assessment of the ground beneath an outrigger mat or mat arrangement.

**[20] BS 8004:1986, Code of practice for foundations**

Withdrawn (and superseded by BS 8004:2015 which aligns with the Eurocodes) but contains guidance on global factor of safety method which is still widely used by TWDs in practice.

**[21] Requirements for mobile cranes alongside railways controlled by Network Rail, Good practice guide (CPA 1801, December 2018)**

https://www.cpa.uk.net/downloads/80/CPA-CIG-Mobile-Cranes-Alongside-Railways-181201.pdf

Provides guidance on the use of mobile cranes alongside the railway. Applies to temporarily installed equipment such as wheeled and crawler cranes as well as lorry loaders, mini/compact cranes, truck-mounted self-erecting tower cranes, telehandlers and excavators used for lifting suspended loads.

**[22] Piling, drilling, crane, MEWP and SMPT operations adjacent to the Railway, NR/L3/CIV/0063 (Network Rail)**

This standard addresses risk and sets the minimum standards and processes to be applied whenever piling, drilling, MEWP, SPMT or crane operations are to be carried out on or adjacent to Network Rail Managed Infrastructure where, in the event of mishandling or failure, any part of the equipment in use of its load may fall within 4m of the boundary.

**[23] Roark's Formulas for Stress & Strain – Young & Budnas**

https://www.academia.edu/27031636/Roarks_Formulas_for_Stress_and_Strain

Contains several formulas which can be superimposed to achieve a range of loading and reaction conditions (with a net-zero nominal support reaction), enabling stresses and deflections to be determined. Particularly useful for assessing plastic outrigger mats, which do not benefit from a corresponding Eurocode.

## Bibliography

The following existing sources of information are listed for reference. The list is not exhaustive, and publications listed are subject to periodic updates.

[24] **Temporary Works; principles of design and construction, Second edition, ICE Publishing (2019)**

A book about designing and building temporary works.

[25] **Safe use of MEWPs – Guidance on the assessment of ground conditions, (IPAF)**

https://www.ipaf.org/en-gb/resource-library/guidance-assessment-ground-conditions

Guidance on how to assess ground conditions for outriggers. It has some useful diagrams.

[26] **Code of practice for planning and executing lifting operations, COP0011 (RSSB)**

https://www.rssb.co.uk/en/standards-catalogue/CatalogueItem/COP0011-Iss-5

A code of practice for lifting operations in the rail environment.

[27] **Code of practice for use and loading of MEWPs, COP0024 (RSSB)**

https://www.rssb.co.uk/standards-catalogue/catalogueitem/cop0024%20iss%206

Details the use of MEWPs, particularly with processes for loads that should safely be permitted in the work platform of a MEWP.

[28] **Crane Stability and Ground Pressure, CICA & CANZ Guidance Note, CICA-GN-0013-A, 2017 (The Crane Industry Council of Australia)**

https://www.cranes.org.nz/uploads/2/0/5/7/20572552/crane_stability_and_ground_pressure.pdf

A guidance note from Australia on how to assess outrigger loads, picking mats and assess the bearing capacity of the different soil types.

[29] **Mobile crane, Code of Practice, Workplace Health and Safety Queensland, Australia (2006)**

https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0019/17128/mobile-crane-cop-2006.pdf

A code of practice to give practical advice about how to manage risks associated with mobile cranes, vehicle-loading cranes and other mobile plant used as a mobile crane to raise or lower a freely suspended load.

[30] **Mobile cranes overturning on construction sites – A guide to loss prevention, HSB Engineering Insurance (Munich Re)**

https://www.munichre.com/hsbeil/en/insights/guides-to-loss-prevention1/construction-guides-to-loss-prevention/1307-mobile-cranes-overturning-on-construction-sites-rgn.html

Aims to provide supporting information to assist in preventing the overturning of mobile cranes. There are different types of mobile crane. The specific operating instructions for a particular manufacturer and model of crane should be referred to. This guide does not attempt to cover the design of cranes, nor does it cover all aspects of lifting operations.

[31] **Mobile crane planning, Safety bulletin – Hardstanding assessment/outrigger loadings, 2009 (HSE, BCSA and Precast Flooring Federation)**

http://www.safetymark.net/pdf/Joint%20PFF%20BCSA%20Crane%20Planning%20Safety%20Bulletin%203rd%20Aug%202009.pdf

A good practice guidance note to assist companies in the planning and assessment of hardstand requirements for mobile crane use.

[32] **Calculation of track bearing pressures for platform design, 2005 (Federation of Piling Specialists)**

https://www.fps.org.uk/content/uploads/2017/01/bearing-pressure-calculation-Rev-3.pdf

Sets out the basic procedure for calculating the track bearing pressures for a crane or piling rig for use in the working platform design process set out in the BRE Report BR470.

[33] **CFA Piling: Preventing ground & rig instability through over-flighting, 2014 (Federation of Piling Specialists)**

https://www.fps.org.uk/content/uploads/2017/01/CFA-Piling-Preventing-ground-rig-instability-through-over-flighting-FINAL.pdf

Outlines the key factors that may lead to settlement or instability of the piling rig when carrying out Continuous Flight Auger (CFA) piling as a result of over-flighting and to present best practice to mitigate these risks. This document is not intended to replace the requirements to use competent supervision and operatives when carrying out CFA piling.

## Appendix A: Outrigger mat capacity verification certificate

### Outrigger Mat Capacity Verification Certificate

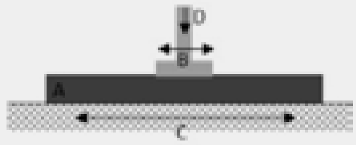
| | |
|---|---|
| **Manufacturer / Supplier:** | |
| **Outrigger mat(s) or mat arrangement(s) covered by this certificate:** | |

**GUIDANCE FOR END USER**

The outrigger mat(s)/mat arrangement(s) listed above can be used in accordance with **Part A** of Temporary Works Forum guide, **TWf2022:02**. It is the responsibility of the Appointed Person or Temporary Works Coordinator to ensure that the selected outrigger mat/mat arrangement has sufficient capacity to spread the outrigger load determined in Step 1 to the ground bearing area determined in *Step 2*.

**MAXIMUM SAFE WORKING LOAD(S)**

- *Multiple line entries can be included, listing the maximum outrigger load [D] for different mats or mat arrangements [A] and/or different combinations of parameters [B], [C].*
- *Parameter [C] does not necessarily need to be the full area of the mat, but at least one line entry should indicate the maximum safe working load when the outrigger mat or mat arrangement is spreading load to its full area.*




| A. Outrigger mat or mat arrangement description | B. Minimum size of outrigger foot (diameter or diagonal dimension) | C. Area of mat in use | | | D. Maximum outrigger load allowed for this configuration *(State in tonnes or kN, N.B. 1tonne = 10kN)* | E. Calculated deflection corresponding to this configuration |
|---|---|---|---|---|---|---|
| | | Rectangle/ Square | | (or) Circular | | |
| | | Length | Width | Diameter | | |
| *e.g. 600mm diameter, 50mm thick HDPE mat* | *e.g. 230mm* | | | *e.g. 600mm* | *e.g. 6.0 tonnes* | *e.g. 6mm* |

**KEY PARAMETERS**

*NOTE: Include all relevant parameters used in the assessment (including relevant units); extra rows may be added for additional parameters not already listed.*

| | | | |
|---|---|---|---|
| Flexural strength, $\sigma$ | | Elastic modulus, Z | |
| Flexural stiffness, K | | Poisson's ratio, v | |
| | | | |
| | | | |

**LIMITATIONS / RESTRICTIONS**

*NOTE: List any limitations or restrictions assumed in the assessment*

**STATEMENT OF CERTIFICATION**

- *We certify that reasonable professional skill and care has been used in the assessment of the outrigger mat(s) or mat arrangement(s) listed above.*
- *Assessment has been carried out in accordance with Temporary Works Forum guide, TWf2022.02, to ensure that the maximum safe working load(s) stated below is/are compatible with industry-recognised methods used to determine plant outrigger loading and allowable ground bearing pressure under vertical static loading.*
- *Key parameters used in the assessment are listed below.*
- *All relevant limitations / restrictions on use are described below.*
- *The maximum safe working load(s) of the mat(s) / mat arrangement(s) are listed above.*

| **SIGNATURES** | BS 5975 Design Check Category: 2 / 3* (** delete as appropriate; Refer to Temporary Works Forum Guide,* ***TWf2022.02****, for guidance.)* | | | |
|---|---|---|---|---|
| | **Name and Qualifications:** | **Organisation and address:** | **Signature:** | **Date:** |
| Designer | | | | |
| Checker | | | | |

**Notes:**

Temporary Works forum

**Chair: Rob Millard, CEng, MICE, MIDE**
**Secretary: David Thomas, CEng, FICE, CFIOSH, MInstRE**

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