Planning for Load Handling Activities

May 2024 Draft Revisions

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ASME Codes and Standards
FOREWORD

As load handling activities grow in complexity, there is an increased need to develop a set of recognized planning guidelines. While some guidance for planning of load handling activities, also referred to as lift planning, has been available in publications, literature from equipment manufacturers, and in-house procedures of various organizations and companies, there has not been any published comprehensive, broadly authoritative guidance available. The absence of uniform considerations or comprehensive practices has created an uneven range of planning activities.

In 2008, the B30 Standard Committee created a Task Group to consider the feasibility of developing a standard for lift planning. Based upon the report of the Task Group, the B30 Standard Committee favored the creation of a standard but recognized that such a standard would not fit the equipment-based orientation of B30. The American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) were petitioned to form a committee to develop a lift planning standard.

The formation of the ASME P30 Standards Committee, Planning for the Use of Cranes, Derricks, Hoists, Cableways, Aerial Devices, and Lifting Accessories, was approved by ASME on June 8, 2010, and a Project Initiation Notification System (PINS) was posted in ANSI Standards Action on July 2, 2010. The Committee held its inaugural meeting on September 20, 2010, with the intent to develop a standard that provides guidance on general planning considerations and practices for load handling operations occurring in all industries, so that users could apply the Standard as a template and adapt it to the needs of their specific industry or situation.


ASME P30.1-20XX was approved by the P30 Committee and by ASME, and was approved by ANSI and designated as an American National Standard on TBD.
MICACARD APPENDIX D
Planning for LHE Foundation and Support

D-1 INTRODUCTION

The purpose of this nonmandatory Appendix is to provide guidance in the following topics to those involved with planning LHA’s using an LHE:

(a) Assessing the forces and pressures that the LHE will impose during the various phases of the LHA.
(b) Establishing the capacity of the supporting surface at the site of the LHA.
(c) Outlining potential solutions to distribute loads imposed by the LHE into the supporting surface within the allowable limits.

There are instances where the LHE is installed with an engineered foundation or support (e.g., mass concrete, pile caps, structural frames, barges, crane rails). This appendix does not fully address these applications; guidance may be found in published sources.

D-2 ROLES AND RESPONSIBILITIES

Reference chapter 3 for roles and responsibilities.

D-3 GUIDANCE FOR LIFT PLANNERS

The lift plan should address support of the LHE throughout the LHA.

D-3.1 LHE INSTALLATION CONDITIONS

(a) When the installation is long-term or permanent, the support under the LHE may require verification of and conformance with the original design conditions.
(b) When the installation is short term, the lift plan should include an evaluation of the loads on the various support points and develop a system to distribute those loads to the supporting surface.
(c) When the LHE is supported by an independent structure, the lift plan should include an evaluation of the structure for loads imposed.

D-3.2 EQUIPMENT ASSESSMENT

When planning the LHE foundation and support, the lift plan should address at a minimum the following:

(a) Will there be simultaneous LHAs or other activities on the work site that affect one another?
(b) What loads are expected beneath the LHE during each planned LHA?
(c) Can loads be optimized through choice of the LHE, configuration and operating procedure?
(d) When not involved in an LHA, what loads are imposed by the LHE? The greatest loads may occur when the LHE is out of service, during assembly, or during disassembly.

(e) Where will the LHE be assembled and if additional LHE may be required for assembly?

(f) Will the LHE travel between LHAs?

(g) What is the condition and capacity of the travel path?

(h) How will the LHE be configured, positioned and what loads will be imposed by the LHE during travel?

(i) Will there be environmental conditions that will change loads?

**D-3.3 Initial Site Assessment**

A site assessment should be performed as part of the lift plan and should address the following:

(a) Identify conditions that may affect the capacity of the supporting surface. This includes any current or previous disturbance to the soil including backfill and compaction or soil stabilization. This may be recent site preparation work, but it also should include historic activities.

(b) Identify adjacent or parallel construction activities that could affect LHAs. Examples include work on nearby foundations, underground utilities, vibration, site drainage, and site dewatering.

(c) Identify open pits, voids, or underground structures such as basements, tunnels, drainage systems, or underground utilities that may affect LHAs. Manholes, drainage grates, utility boxes, or pipeline warning markers may provide an indication of what may lie beneath. The absence of surface indicators is not proof underground structures do not exist.

(d) Identify environmental conditions such as climate, season, and weather. Moisture content, frost depth, ice, and recent thaws may affect soil bearing capacity.

**D-3.4 Establishing Design Loads and Allowable Ground Bearing Pressure**

The loads imposed by the outrigger floats or crawler tracks of an LHE in use could be greater than the ground can safely withstand without some form of load distribution system. If a matting system is the appropriate solution, there are two primary factors to be considered:

a) The maximum loads the LHE will impose.

b) The support capacity of the supporting surface (native or improved).

Sections D4 through D8 provide guidance for determining these factors.

The process is outlined in Figure D-3.4-1.
Figure D-3.4-1 Process Map

1. Start
2. Basic lift plan
3. Establish maximum imposed crawler pressure / outrigger load
   - Yes: Estimator available?
     - Yes: Use manufacturer or other GBP estimator / software
     - No: Manufacturer data loading available?
       - Yes: Use manufacturer published data
       - No: Use accepted industry best practice for estimation
   - No: Seek expert advice
4. Establish ground bearing capacity
   - Permissible GBP specified?
     - Yes: Use controlling entity specified value
     - No: Reports available?
       - Yes: Use applicable geotech values
       - No: Standards available?
         - Yes: Use applicable standards e.g., AASHTO
         - No: Investigation feasible?
           - Yes: Commission engineering investigation
           - No: Observation & presumption feasible?
             - Yes: Use presumptive values
             - No: Maximum imposes pressure / load established
5. Input to Mat System Design
6. Maximum allowable GBP established
D-4 IDENTIFYING THE LOADS IMPOSED BY THE LHE

D-4.1 LHE Loading Scenarios

Figure D-4.1-1 is an example of how loads may be distributed on each outrigger. The outrigger loads change with slew and boom angles, and the lifted load. This is a typical case based on crane type and outrigger configuration. The maximum outrigger loads may occur at different slew angles than shown.

Figure D-4.1-1 Outrigger-Supported LHE Loading
Load On Hook | No Load
---|---

**Over Side**
- Front
- Highest Pressure On Side
- Outriggers Below Load
- Outriggers Below Counterweight

**Over Corner**
- Front
- Highest Pressure On Corner
- Outriggers Below Load
- Outrigger Below Counterweight

**Over Front**
- Front
- Highest Pressure On Front
- Outriggers Below Load
- Highest Pressure On Rear
- Outriggers Below Counterweight

= High Pressure  = Medium Pressure  = Low Pressure
Figure D-4.1-2 is an example of how loads are distributed by a crawler crane. The shape of the load distribution and bearing length along the tracks change with slew and boom angles, and the lifted load.

**Figure D-4.1-2  Crawler Crane Loading**

<table>
<thead>
<tr>
<th></th>
<th>Load On Hook</th>
<th>No Load</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Over Side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Highest Uniform Pressure On Side Track Below Load</td>
<td>Higher Uniform Pressure On Side Track Below Counterweight</td>
<td></td>
</tr>
<tr>
<td><strong>Over Corner</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Non-Uniform Pressure Increasing Towards Corner Of Track Below Load</td>
<td>Non-Uniform Pressure Increasing Towards Corner Of Track Below Counterweight</td>
<td></td>
</tr>
<tr>
<td><strong>Over Front</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>Front</td>
<td>Front</td>
</tr>
<tr>
<td>Non-Uniform Pressure Increasing Equally Towards Front Of Tracks Below Load</td>
<td>Non-Uniform Pressure Increasing Equally Towards Rear Of Tracks Below Counterweight</td>
<td></td>
</tr>
</tbody>
</table>

[Image of load distribution diagram]

\[
\text{= Pressure}
\]
D-4.2 Manufacturer's Information

Many manufacturers provide ground bearing pressure calculators: the outrigger loads, or track pressures are calculated based on the configuration and parameters for the LHA entered by the Lift Planner. The calculator will usually give results over-the-front, over-the-side and critical slew angle.

A Lift Planner could conservatively design for the maximum load the crane could impose during use, a value that might be found in the crane manual.

D-4.3 Lift Planning Software

There are lift planning software packages available to determine outrigger loads or track pressures.

D-4.4 LHE Fleet Company Software

Some crane operating companies have proprietary software.

D-4.5 Engineering Principles (Manual Calculation)

Imposed loads can be calculated manually if the dimensions, weights, and centers of gravity of the major components of the LHE are known.

D-4.6 Methods to Reduce LHE Imposed Loads

There are multiple ways to reduce the imposed loads by the LHE:

(a) LHE selection or configuration
(b) Reduce the lifting radius
(c) Reduce the size or weight of the loads to be lifted
(d) Minimizing operations in unfavorable directions

D-4.7 Other Considerations

The maximum loads imposed by the LHE might not occur when lifting.

Other considerations may include:

(a) During assembly, disassembly, and reconfiguration
(b) Raising and lowering the boom
(c) Stacking counterweights
(d) Minimum radius, no load on hook, or retracted boom
(e) When traveling
(f) Reduced counterweight configuration
The Lift Planner should determine if there are other factors that may have an influence on the loads imposed such as wind, levelness, uniformity of ground, and environmental conditions.

D-5 ASSESSMENT OF THE GROUND CONDITIONS

D-5.1 Introduction
For safe operation of an LHE, the supporting surface should withstand the imposed loads such that the LHE remains level within the manufacturer’s tolerance. There is enormous variety in the locations in which lifting activities take place and the nature of the operations to be conducted; from green field to brown field, swamp to rock, improved/unimproved, existing facilities, new construction. It is necessary to assess the ground conditions to determine general suitability and load-bearing capability. This in turn will guide whether improvements are necessary, and the extent of load distribution required.

D-5.2 Data Collection – Available Documented Information
Information relating to the supporting surface may be obtained or compiled from a variety of sources such as:
- The facility owner
- The controlling entity
- Project geotechnical sources / client e.g., an allowable ground bearing pressure (GBP) for the whole site or a defined area (from a competent source)
- Pre-existing geotechnical engineering report for the site and/or LHE location (check its continued validity)
- Government Geological Survey records
- Governing authority of the site, city or state sources
- Records of demolition contractor’s on-site reinstatement on Brownfield sites
- Records of fill placement and compaction
- A detailed site inspection/subsurface investigation
- Local knowledge - local building codes
- Applicable standards such as AASHTO (American Association of State Highway and Transportation Officials) or similar.

If an LHE is to be set up on a bridge, building, structure or similar, the suitability should be assessed by an engineer, preferably the engineer of record.

Additionally, it is necessary to evaluate the location for underground or adjacent items that could affect the support of the LHE or could be adversely impacted such as:
- Structures (i.e., adjacent/underground)
- Embankments and/or retaining walls.
- Buried / surface utilities and or services, manhole covers, curb drains etc.
(d) Excavations  
(e) Voids  
(f) Tanks

The controlling entity may have available information, such as:

(a) Design drawings  
(b) As-built drawings  
(c) Surveys  
(d) Photographs

**D-5.3 Data Collection – Physical Observation**

Without available site-specific information, it is difficult to determine an allowable ground bearing pressure for the LHE. At a minimum, the top layer(surface) of the site can provide some clues as to the immediate soil type just below the LHE, for example:

(a) Soft, compressible, or loose soils observed at the ground surface.  
(b) Rock (or rock outcrops) observed at the ground surface.  
(c) Variability of support surfaces such as:  
   1. Hard next to soft  
   2. Multiple colorations of soils  
   3. Concrete pad next to fill  
   4. Stiffness of support under the same track on a crawler  
   5. Surface discontinuity  
(d) Condition of subgrade disturbance from construction activities or inclement weather  
   1. Presence of washed-in material.  
   2. Subgrade is visually disturbed from excavation with toothed-bucket.  
   3. Subgrade is visually firm and stable.  
(e) Temperature of soils  
   1. Freeze thaw cycle of soils.  
   2. Frozen soil  
(f) Condition of surfaces such as pavement or concrete (i.e., undulating pavement can indicate the presence of soft, compressible soils)  
(g) Topographical properties:  
   1. Gradient and Flatness.  
   2. Minor / Major obstacles i.e., rock protrusions.  
(h) Water:  
   1. Groundwater, underground springs, streams, ditches, wet areas, land drain indicators.  
   2. Potential for liquefaction of the soil  
   3. Rainfall - recent history or likely effect of fresh rainfall.  
   4. Proximity to bodies of water.  
(i) Underground structures:  
   1. Backfilled areas cracking/differential settlement at junction with undisturbed ground  
D-5.4 Presumptive Bearing Capacities Based on Observation

A detailed investigation or testing is often neither practical nor justified for routine lifting operations. In such cases the observations from D-5.3 can be used to establish a presumptive bearing capacity. Presumptive bearing capacities are the allowable bearing capacity based only on visual classification of surface soil.

The approach should be to observe the location and its designed use and, if satisfactory by inspection, select a conservatively low presumptive bearing capacity from a source such as Table D-5.4-1. When matched to a conservatively high estimate of the loads the LHE could impose, load distribution mats (or equivalent) of adequate effective area can be specified. If in doubt, err on the side of caution, use a low bearing capacity, and distribute the load over a larger area.

The use of presumptive bearing capacities is based upon an assumption that ground conditions, such as compaction, soil type and consistency are uniform throughout its depth and layers. The purpose of this table is to provide very generalized allowable bearing capacity values. Table D-5.4-1 can be used before a soil analysis has been conducted and used as a reference value when developing the initial plan.

Table D-5.4-1 can be used to determine a presumptive ground bearing capacity. The table is a general value for allowable GBP. Allowable GBP should be based on a qualified person’s evaluation of the subsurface conditions.

Table D-5.4-1 U.S. Department of the Navy (1982) NAVFAC DM-7.02
Investigation and Testing

If an allowable ground bearing pressure cannot be provided or determined by the methods in D-5.2 through D-5.4, the preferred method to establish a value is through investigation and
testing to determine the ground conditions. This option requires competent geotechnical expertise.

The extent of the investigation will depend on the requirements of the supporting materials and loaded areas that can include some or all of the following in-situ and laboratory tests:
(a) Identification and limits of soil and rock type(s) and groundwater elevation
(b) Soil characterization, soil strength tests, soil compressibility tests, and any other evaluation of the soil’s engineering properties
(c) On-site tests to confirm the adequacy of the ground investigation during installation of the support measures and/or the LHE.

Field tests may include:
(a) Evaluation of subgrade through excavation of test pits
(b) Collection of soil samples by boring
(c) Collection of rock samples by coring
(d) Measurement of groundwater monitoring wells
(e) In-situ shear strength testing
(f) Plate bearing test.

Laboratory tests may include:
(a) Soil Characterization
(b) Maximum Dry Density
(c) Compressibility/Consolidation
(d) Shear Strength Testing
(e) Rock Quality and Fracture Orientation
(f) Rock strength

Although proof rolling is also often suggested as a method to verify the allowable bearing capacity of an area, this method has limitations:
a) Proof rolling typically finds defects or helps stabilize the very top layer of soil. It can also identify large deficiencies. Some of these issues can also be visualized, such as rutting from truck traffic.
b) It is important to put the weights and the bearing areas of the LHE versus the proof rolling equipment into perspective. LHE typically impose significant pressure on deeper strata. Proof rolling is not capable of mobilizing deeper strata engaged by heavy LHE loading; this is the same reason why backfill is compacted in layers.

For these reasons, proof rolling is not a reliable method to confirm the allowable ground bearing pressure.
**D-6 USE OF GEOTECHNICAL REPORT TO DETERMINE ALLOWABLE GROUND BEARING PRESSURE**

**D-6.1 Introduction**

The best and most reliable means of assessing the **allowable ground bearing pressure (GBP)** for an LHE is to utilize a geotechnical report prepared for the site by a qualified person. New construction sites will often have such a report that should be available upon request. However, other sites may require site investigations including borings or test pits to determine an allowable GBP. Alternately, historical data for nearby areas may be available. In that case, consideration should be given to historical activity in the area and its effect to the subgrade.

A comprehensive geotechnical report will provide specific information on subsurface soil, rock, and groundwater conditions. Interpretation of the site investigation information, by a qualified person, results in design and construction recommendations for a project site.

**D-6.2 Boring Logs**

A boring log is a geotechnical exploration record of subsurface conditions. This log presents a variety of data utilized in analyzing and assessing ground conditions. Figures D-6.2-1, D-6.2-2 and D-6.2-3 are examples of information presented in a boring log report.

Geotechnical test methods used to characterize in-situ subsurface conditions include the Standard Penetration Test (SPT), the Cone Penetration Test (CPT), and the Dynamic Cone Penetration test (DCPT). These tests provide soil resistance data essential for determining the allowable GBP.

SPT utilizes auger drilling to open a small diameter excavation to a given depth, where a split spoon sample tube is then placed in contact with the bottom of the borehole. A trihammer then drives the sample tube into the ground with the number of blows required to drive the sampler a predetermined distance being recorded. Based on the number of hammer blows required to advance the tube, i.e., the blow count or N value, for that soil layer is entered on the boring log. Utilizing the N value, the allowable GBP can then be calculated.

CPT, rather than using a hammering technique, collects data continuously as a cone tipped rod of specified dimension is advanced at a uniform rate into the ground. As the cone is advanced deeper into the soil, the system measures the tip resistance or stress, which is then used to calculate the allowable GBP.

DCPT incorporates features of both SPT and CPT. Like SPT, DCPT is performed by dropping a standardized weight hammer from a specified height and measuring the penetration depth per blow. The shape of DCPT probe is a cone, similar to that of the CPT penetrometer. DCPT data is then correlated with California Bearing Ratio (CBR) values to calculate the allowable GBP.

SPT, CPT, and DCPT geotechnical methods provide empirical data useful in calculating the allowable GBP. These methods collect data at individual, discrete locations with conditions
interpolated between test points across a site. These methods do not identify other underground conditions at the specific LHE location, such as voids, groundwater, or underground utilities, that could have significant effect on LHE support. Noninvasive, geophysical test methods, such as ground penetrating radar (GPR) or electromagnetic induction surveys, may also be employed to provide a more complete characterization of underground conditions.

Figure D-6.2-1 Boring Log
Figure D-6.2-2 Boring Log Legend
### Legend for Boring Logs

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Water Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>While Drilling</td>
</tr>
<tr>
<td>ST</td>
<td>End of Boring</td>
</tr>
<tr>
<td>A</td>
<td>24 Hours</td>
</tr>
<tr>
<td>MC</td>
<td></td>
</tr>
</tbody>
</table>

### Field and Laboratory Test Data

- **N** = Standard Penetration Resistance in Blows per Foot
- **WC** = In-Situ Water Content
- **Qu** = Unconfined Compressive Strength in Tons per Square Foot
  - * = Pocket Penetrometer Measurement, Maximum Reading = 4.5 tsf
- **γ<sub>DRY</sub>** = Dry Unit Weight in Pounds per Cubic Foot

### Soil Description

<table>
<thead>
<tr>
<th>Material</th>
<th>Particle Size Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>Over 12 inches</td>
</tr>
<tr>
<td>Cobble</td>
<td>12 inches to 3 inches</td>
</tr>
<tr>
<td>Coarse Gravel</td>
<td>3 inches to 2½ inch</td>
</tr>
<tr>
<td>Small Gravel</td>
<td>¾ inch to No. 4 Sieve</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>No. 4 Sieve to No. 10 Sieve</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>No. 10 Sieve to No. 40 Sieve</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>No. 40 Sieve to No. 200 Sieve</td>
</tr>
<tr>
<td>Silt and Clay</td>
<td>Passing No. 200 Sieve</td>
</tr>
</tbody>
</table>

#### Cohesive Soils

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Qu (tsf)</th>
<th>Relative Density</th>
<th>N (bpf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>Less than 0.3</td>
<td>Very Loose</td>
<td>0 - 4</td>
</tr>
<tr>
<td>Soft</td>
<td>0.3 to 0.6</td>
<td>Loose</td>
<td>4 - 10</td>
</tr>
<tr>
<td>Stiff</td>
<td>0.6 to 1.0</td>
<td>Firm</td>
<td>10 - 30</td>
</tr>
<tr>
<td>Tough</td>
<td>1.0 to 2.0</td>
<td>Dense</td>
<td>20 - 50</td>
</tr>
<tr>
<td>Very Tough</td>
<td>2.0 to 4.0</td>
<td>Very Dense</td>
<td>50 and over</td>
</tr>
<tr>
<td>Hard</td>
<td>4.0 and over</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Cohesionless Soils

<table>
<thead>
<tr>
<th>Modifying Term</th>
<th>Percent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trace</td>
<td>1 - 10</td>
</tr>
<tr>
<td>Little</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Some</td>
<td>20 - 35</td>
</tr>
</tbody>
</table>
D-6.3 Boring Log Interpretation

Boring logs can provide required properties of the subgrade present immediately beneath the placement area of an LHE. Three key areas are most needed for subgrade analysis, all of which should be found on a boring log:

(a) Soil type: cohesive (silt and clay) and non-cohesive (sand and gravel)
(b) Groundwater table
(c) Soil consistency
   (1) Silt/Clay - soft to hard
   (2) Sand/Gravel – loose to dense

With this knowledge, a qualified person has the information needed to evaluate the existing conditions and determine the ultimate bearing capacity of the soil.
D-6.4 Allowable Ground Bearing Pressure

Once the ultimate bearing capacity \( q_{\text{ult}} \) has been determined, the allowable GBP \( q_a \) is found by reducing the ultimate by a factor of safety (FOS):

\[
q_a = \frac{q_{\text{ult}}}{\text{FOS}}
\]

Permanent structure foundations are typically designed with an FOS of 3. Because of the temporary nature of LHE installations, sufficiently defined LHE loading and higher tolerance for settlement compared to a permanent structure, a FOS of 2 often is acceptable.

D-7 METHODS TO IMPROVE SOIL PROPERTIES
D-7.1 Introduction

There are many methods and techniques for subgrade improvement and stabilization, though most are not practical for lift planning in general. Regardless of the method used, the work should be performed under the guidance of a qualified person.

When results from a subsurface exploration indicate less than adequate bearing capacity, and LHE foundation options have been maximized, soil improvement options should be considered. There are extreme cases where pile foundations or large-scale site improvements are required. These occurrences and several other techniques are beyond the scope of this appendix. However, there are effective methods that can increase bearing capacity and stability of subgrades for LHA needs.

Most soil issues, when supporting LHEs, occur with high void ratios, low strength materials and unsatisfactory water content, where the subgrade is composed of loose sands and silts, wet clays, organic soils, or a combination of these materials. The basic soil modification techniques in Sections D-7.2 through D-7.4 are suitable options.

D-7.2 Structural Fill

Structural fill is the simplest of the two methods and requires minor site preparation work. The foundation of the LHE is placed on a layer of structural fill that has been placed on top of the existing subgrade. The structural fill should be placed in lifts, compacted, and leveled throughout. The structural fill minimally should cover the full extent of the LHE footprint.

The bearing capacity of the existing subgrade does not increase. Instead, the LHE foundation bearing area increases by a factor of the structural fill depth. This increase in area produces a decrease in bearing pressure from the LHE. Figure D-7.2-1 illustrates the influence line of the LHE foundation through the structural fill layer. The figure presents a typical distribution; however, the ratio may vary based on fill type and installation. The area beneath the fill can then be calculated. The structural fill weight should be added to the reduced LHE bearing pressure and still be within the allowable bearing capacity of the subgrade.

This technique does have limitations:
(a) Excessive fill depths.
(b) Insufficient area to increase the length and width.
(c) Mobilization of the LHE onto an elevated surface.
(d) If the subgrade is compressible, levelness of the LHE may be affected.

Figure D-7.2-1 Load Distribution Through a Layer of Fill
D-7.3 Remove (Undercut) and Replace

As the name implies, this method removes the unsuitable materials to expose a desirable subgrade and replaces it with a layer of structural fill placed in lifts and compacted. Depending on the depth of the undercut, support of excavation design may be required. As an alternative to the structural replacement fill, the excavated material may be treated with chemical admixtures such as lime, fly ash, or cement; however, this process may not be permissible for temporary works. Adding a layer of geotextile at the bottom of excavations prior to replacement of structural fill can increase soils capacity and bridge over localized soft spots. The structural fill can also be used to increase the loaded area as in Section D-7.2.

One disadvantage to this method may be the need for dewatering if the water table influences the excavation.

D-7.4 Other Specialized Techniques

(a) In-situ stabilization provides subgrade improvement by applying a stabilizing agent without removing subgrade materials. This technology offers the benefit of improving subgrade for deep foundations, shallow foundations, and contaminated sites.

This technique involves injection of a cementitious material or lime in dry or wet forms into the subgrade.

(b) Deep mixing involves the stabilization of the subgrade at depth in which a wet or dry binder is injected into the ground and blended with the in-situ soft subgrade with a mechanical mixing tool.

(c) Wet mixing involves a binder turned into slurry form, which is then injected into the subgrade through the nozzles located at the end of the auger or mixing tool.

(d) Dry mixing involves the use of dry binders injected and mixed with the subgrade.

(e) Jet grouting involves the injection of a stabilizing fluid into the subgrade under high pressure and velocity.

D-7.5 Considerations

The following factors negatively affect subgrade stabilization:

(a) The presence of organic matter which retards the hydration process and affects the hardening of the stabilized subgrade.

(b) The presence of environmental contaminants.

(c) Insufficient moisture content.

(d) Temperature affects the reaction process. In colder temperatures, the reaction process may be slowed to the point of being ineffective, resulting in a lower strength of the stabilized mass.
(e) The stabilized subgrade cannot withstand freeze-thaw cycles; therefore, it may be necessary to protect the stabilized subgrade against frost damage.

D-8 METHODS TO DISTRIBUTE IMPOSED LOADS

D-8.1 Manner of Transmission of Imposed Loads into the Ground

To effectively establish the methods available to distribute loads imposed by the LHE during a LHA or when traversing the jobsite, it is necessary first to understand how those loads are transmitted to the supporting surface under the LHE.

There are two important principles to understand. The first is the manner in which loads are distributed to the surface of the ground via the supporting structure of the LHE, i.e., wheels, tracks or outrigger floats. The second is the way ground pressures are distributed through the subgrade.

The supporting material beneath the LHE should:

a) Provide an effective bearing area great enough to result in a bearing pressure less than the allowable ground bearing pressure
b) Be rigid enough to prevent excessive deflection
c) Be strong enough to withstand the forces imposed
d) Account for any asymmetrical load distribution

D-8.2 Matting Systems

The most common methods used to distribute LHE loads into the supporting surface include outrigger pads and crane mats typically constructed of timber, steel or synthetics, possibly a combination of the three.

Ground mats generally are not appropriate for distribution of substantial loads to the subsurface. A qualified person should evaluate the use of ground mats when supporting LHE.

When choosing supporting materials, consider the following:

(a) Strength, stiffness, and material properties
(b) Application requirements such as bridging.
(c) Close dimensional tolerances
(d) Consistency of material properties
(e) Resistance to degradation
(f) Combining different materials to achieve desired results.

D-8.3 Strength v Stiffness

Strength and stiffness are determined by the material and dimensions. Strength and stiffness are not directly proportional to thickness. For solid rectangular sections, doubling the thickness increases the strength four times and the stiffness eight times.
Two identical pads or mats stacked do not have the same strength or stiffness as a single pad or mat of the same total thickness. The two pads function independently of each other as they deflect.

It is important to understand that a pad may have adequate strength but may lack the stiffness to distribute the load over the required effective bearing area. If the pad is less rigid than the supporting surface, the bearing pressure will be concentrated on a smaller area.

A rigid surface, such as rock or concrete, may not allow the mat or pad to deflect to distribute the load to the edges of the mat or pad. Instead, the load will pass directly through the supporting material without significant distribution. Deflection could be a limiting condition for supporting materials with a long cantilever or with low stiffness.

Placing the supporting materials partially on ground and partially on concrete foundations will result in concentration of loads into the stiffer elements.

**D-8.4 Eccentric Loading**

The load from the LHE should be centrally located on the mats or pads. If this placement is not possible, accommodation for eccentric loading should be made. See Figure D-8.4-1. This may include:

a) Disregarding the pad area outside of the area of symmetry.

b) Evaluating the GBP for the peak value as an unequal distribution.

c) Seeking the advice of a qualified person.

For any pad loaded eccentrically, ensure the pad is constructed in a manner to support the load at the loaded location.

**Figure D-8.4-1 Area Disregarded Due to Eccentric Loading**
D-9 INSPECTION CRITERIA

D-9.1 Introduction

The following provides guidance to evaluate crane mat or outrigger pad condition. Crane mats and outrigger pads are tools and should be inspected before each use. Mats and pads should be clean to allow proper inspection of all surfaces. Inspections should be performed, and any deficiency identified should be examined and a determination made by a qualified person as to whether it constitutes a hazard, and if so, what additional steps need to be taken to address the hazard.

D-9.2 Timber

D-9.2.1 Visual Techniques

Visual inspection is the first step in assessment. This step identifies issues such as

(a) Missing or damaged components.
(b) Environmental damage including weather exposure or fungus.
(c) Splitting and cracking may reduce the mat strength and create pathways for agents of decay to get deep into the mat interior.
(d) Insect damage: Frass or mud tubes indicate the presence of burrowing insects which may be destroying the mat from the inside out.

D-9.2.2 Probing Techniques

Probing techniques utilize a sharp or pointed tool to identify surface rot and assess the condition of the mat surface. Soft surfaces or the lack of resistance to probe insertion are indicators of decay. The use of a probe for mat assessment is a simple technique but requires the inspector to have knowledge of wood behavior in both sound and decayed conditions.

D-9.2.3 Sounding Techniques

A sounding test is performed by striking the timber with a blunt object such as a hammer. The inspector determines the likely presence of rot by both the feel of the hammer at impact and the resulting sound of the impact. A sharp, ringing sound is indicative of sound wood. A hollow sound or a damped “thud” are indicative of internal decay. Sounding will often reveal advanced decay or hollowed centers but is unlikely to reveal incipient or moderate decay. To be effective a relatively heavy (3-4 pound) hammer should be used for larger cross-section materials. The interpretation and effectiveness of sounding is dependent upon the experience of the inspector.

D-9.2.4 Drilling Techniques

Sudden decreases in resistance during drilling or coring are indicative of voids or areas of rot. Once the defect size is estimated, then a decision can be made regarding treatment, reinforcement, or replacement.

D-9.2.5 Loss of Strength Over Time

The service life of a timber mat is dependent on numerous factors. It is incumbent upon the user to verify that the condition of the mat is and remains suitable for its intended use. It
should be noted that a small reduction in timber cross-section, such as that caused by decay, weathering, or mechanical damage due to aggressive use or improper storage, causes large reductions in strength and stiffness.

D-9.3 Steel

Steel mats and pads are not subject to the same environmental degradation as a timber mat. It is still important that their suitability be verified by the user.

The following points should be used for inspection.

(a) Confirm individual elements meet specified steel grade, shape, and dimensions.
(b) Check for deformation that affects load bearing.
(c) Check all sides of elements for defects such as cracks, pits, impact damage, corrosion, and flakes.
(d) Check all connections (e.g., bolted, and welded)

D-9.4 Synthetic

Synthetic mats and pads vary greatly in their design and manufacture. Follow the criteria and guidelines of the manufacturer or qualified person for inspections. At a minimum the following items should be inspected:

(a) Modifications outside of the guidance of the manufacturer or qualified person.
(b) Racking, misalignment, delamination, or deformation.
(c) Evidence of bending such as strain hardening or whitening.
(d) Surface degradation such as cracking, spalling, blistering, or significant discoloration.
(e) Loose, missing, deformed, or corroded components and hardware.

D-10 METHODS TO CALCULATE THE EFFECTIVE BEARING AREA

D-10.1 Crane Mat Analysis

Rigorous analysis of the pressure distribution beneath a crane mat and exact calculation of the stresses induced in the mat is neither justified nor practical in most cases. Such an analysis would require data such as the soil elastic properties or the modulus of subgrade reaction that are not readily available.

The Effective Bearing Area Calculation method is a simplified, practical, but conservative approach that requires only the mat properties, the maximum imposed load from the LHE and the allowable ground bearing pressure. This method determines an effective length ($L_{eff}$) for the mat over which the pressure can be considered uniform. The effective length is calculated through consideration of the soil bearing capacity and the mat bending strength and stiffness. Knowledge of the soil’s elastic properties is not required.

The analysis quantifies the maximum load that can be imposed on the mat without exceeding:

(a) the allowable bending stress.
(b) the allowable shear stress.
(c) an established deflection limit.
Finding the three limiting conditions and simplifying the analysis, the pressure distribution under the mat is considered uniform and equal to the allowable ground bearing pressure. This allows the maximum load carried by the mat to be simply expressed as a function of the allowable ground bearing pressure (a constant) and an effective length over which the allowable ground bearing pressure is applied (a variable). That in turn allows the bending stress, shear stress and deflection all to be expressed in three equations where $L_{\text{eff}}$ is the only variable, allowing a solution for $L_{\text{eff}}$ for each of the three criteria. The lowest value of $L_{\text{eff}}$ governs. The allowable load to the mat may be calculated. Knowing the allowable load that is to be designed for, the percentage utilization may be calculated and should not exceed 100%.

**D-10.2 Wood Crane Mat Construction**

Crane mats should be constructed using full dimension and continuous length timbers of good quality. The timbers are typically one or more of the species listed in Table D-10.2-1.

<table>
<thead>
<tr>
<th>Species Combination</th>
<th>Species Excluded for Crane Mats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech-Birch-Hickory</td>
<td>none excluded</td>
</tr>
<tr>
<td>Mixed Maple</td>
<td>Silver Maple</td>
</tr>
<tr>
<td>Northern Red Oak</td>
<td>none excluded</td>
</tr>
<tr>
<td>Red Oak</td>
<td>none excluded</td>
</tr>
<tr>
<td>White Oak</td>
<td>Bur Oak</td>
</tr>
<tr>
<td>Douglas Fir - Larch</td>
<td>none excluded</td>
</tr>
<tr>
<td>Eastern Hemlock</td>
<td>none excluded</td>
</tr>
</tbody>
</table>

Table D-10.2-2 provides commonly used design values for mats constructed from timbers of the species listed in Table D-10.2-1. These values are suitable for the evaluation of mats with the mat section properties calculated using the nominal dimensions of the timbers.

<table>
<thead>
<tr>
<th>Design Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Bending Stress $F_b$</td>
<td>1,400 psi</td>
</tr>
<tr>
<td>Allowable Shear Stress $F_v$</td>
<td>200 psi</td>
</tr>
<tr>
<td>Allowable Compression Stress Perpendicular to the Grain - Hardwoods $F_{\perp}$</td>
<td>750 psi</td>
</tr>
<tr>
<td>Allowable Compression Stress Perpendicular to the Grain - Softwoods $F_{\perp}$</td>
<td>575 psi</td>
</tr>
<tr>
<td>Modulus of Elasticity $E$</td>
<td>1,200,000 psi</td>
</tr>
</tbody>
</table>

The appropriate design values for timber mats should be determined by the mat producer or a qualified person. Differences from these provisions may include using timbers of different species, or different qualities.

**D-10.3 Assumptions and Limitations for the Effective Bearing Area Method**

The Effective Bearing Area Calculation Method is applicable to a single layer of supporting materials with the following assumptions and limitations.

(a) The crane mat or outrigger pad should be in good serviceable condition. See Sec D-9 for inspection criteria.
(b) For crane mats the effective bearing method assumes a load bears across the entire width of the mat. This can be accomplished with a transition layer capable of distributing the load from the float to all timbers in the assembly. See Figure D-10.3-1
(c) The load should be centrally located on the crane mat or outrigger pad. See Sec D-8.4
(d) The crane mats or outrigger pads are to be located on a level surface within the LHE manufacturer’s specification and with uniform contact on the supporting surface.
(e) If the crane mat or outrigger pad is located close to subsurface structures, engage a qualified person to assess the impact on the structures.
(f) If the crane mat or outrigger pad is located close to excavations, slopes, embankments, retaining walls or bulkheads, engage a qualified person to assess the impact on the allowable GBP.
(g) The supporting surface should provide uniform support to the crane mat or outrigger pad.

Figure D-10.3-1 Transition Layer
D-10.4 Sample Spreadsheet for Wood Mats

To simplify the calculation, a spreadsheet can be developed to automate the process. Figure D-10.4-1 is an example of such a spreadsheet. The commonly used bending and shear stresses for wood crane mats as described in Section D-10.2 are used in this example.

Required inputs:

(a) The properties of the wood mats being used. The values shown are specific to this example. The user should determine the appropriate values.
(b) The size of the mats, length, width, thickness
(c) The bearing width of the float or track.
(d) The load to be applied to the mat. In the case of an outrigger-based crane this is the maximum outrigger force; in the case of a crawler-based crane this is the maximum track pressure multiplied by the bearing width and the mat width.
(e) The allowable GBP

Figure D-10.4-1 Example wood mat load distribution spreadsheet.
In this spreadsheet example, the boxed cells are user inputs, all other cells are calculated or fixed data.

**D-10.5 Wood Mat Thickness Selection Tool**

This tool is applicable to single layer hardwood mats of nominal thickness 6 in. to 12 in. loaded centrally.
In many cases it is more useful to the Lift Planner to know what minimum mat thickness is required to gain the required effective length than it is to calculate what effective length a particular mat thickness will yield.

To achieve this, the Effective Bearing Area Calculation Method can be rearranged, and graphs produced of maximum cantilevered length of mat versus GBP for standard mat thicknesses. This allows a simple mat thickness selector tool to be produced.

The assumptions and limitations on the use of the tool are the same as those for the Effective Bearing Area Calculation Method. Note that mat self-weight is not considered in this tool as it generally provides only a small contribution to the imposed ground loading and can be accounted for by not designing to the allowable. Note that the mat self-weight is considered in the design example of Figure D-10.4-1. Mat deflection is not considered as it is rarely a limiting factor in the range of pressures and mat thicknesses graphed. If in doubt, verify the selection by running the Effective Bearing Area Calculation Method. The mat properties used in the preparation of Figure D-10.6-1 are those listed in D-10.2. It is the responsibility of the user of this graph to verify these properties are appropriate.

D-10.6  Using the Wood Mat Thickness Estimator.

For analysis, the mat is considered as a beam, supported beneath by a uniformly distributed load. The crawler track or outrigger is considered to impose load over a certain bearing width ($L_b$) and across the entire mat width. To distribute the imposed load at the allowable GBP requires the mat to be effective over a minimum length without being overstressed in either bending or (horizontal) shear.

The tool provides curves plotting cantilevered length versus allowable GBP for mats of various standard thicknesses ($d$) and materials. The first step is to calculate the cantilevered length ($L_c$) required to achieve the minimum effective length ($L_{eff}$) as shown in Figure D-10.6-1.

Figure D-10.6-1 Effective Bearing Length
D-10.6.1 Procedure for Track Loading

(a) Determine the maximum track bearing pressure – see Note (1)
(b) Identify the bearing width of the track – see Note (2)
(c) Determine the allowable GBP.
(d) Calculate the required distribution ratio to spread the track pressure down to the allowable GBP.
(e) Multiply the bearing width of the track by the distribution ratio to determine the minimum required effective length of the mat.
(f) Calculate the required effective cantilevered length: \( L_c = (L_{\text{eff}} - L_b) / 2 \)
(g) Using Figure D-10.6.1-1, determine the minimum mat thickness that yields a cantilever length equal to or greater than \( L_c \). See note (3)

Notes:

(1) Some LHE manufacturers provide “hard” and “soft” pressure estimations. The “hard” values are the pressures imposed when the track bears on a non-compliant surface; it presumes loads are transmitted only through the flat part of the track width that is in contact with the supporting surface. The “soft” estimation is based on the track bearing on compliant ground, the assumption being that the entire width and length of the track is transmitting...
load. When using these curves, it is recommended to select the hard surface track bearing pressures. Refer to the LHE manufacturer or qualified person for application of these estimations.

(2) The bearing width \( (L_b) \) is the flat width of the track that is in contact with the mat.
(3) Figure D-10.6.1-1 was developed using wood design values in section D-10.2.

Figure D-10.6.1-1 Wood Mats
Example

Peak track bearing pressure = 13.3ksf (13,300 psf)

Bearing width ($L_b$) = 36in. = 3ft
Allowable GBP = 4 ksf (4,000 psf)
Distribution ratio = 13.3 ksf/4 ksf = 3.325
Minimum required effective length $L_{eff} = 3 \text{ ft} \times 3.325 = 9.975 \text{ ft}$

Required cantilever length,

$$L_c = \left(\frac{L_{eff} - L_b}{2}\right)$$

$L_c = (9.975 \text{ ft} - 3 \text{ ft})/2 = 3.49 \text{ ft}$

Referring to Figure D-10.6.1-2 and following the 4 ksf line up, a 10 in. mat has an effective cantilever length of approximately 3.4 ft; this is less than the 3.49 ft required. A 12 in. mat has an effective cantilever length of 4.1 ft, which is more than adequate.

Figure D-10.6.1-2 Wood Mats Track Example
D-10.6.2 Procedure for Outrigger Loading

(a) Determine the maximum outrigger load.

(b) Identify bearing width ($L_b$) of the outrigger float applied to the mat.
(c) Determine the allowable GBP.
(d) Divide the outrigger load by the allowable GBP to determine the required effective mat area. This is valid on the basis that measures are taken to ensure that the entire width of the mat is uniformly loaded.
(e) Divide the area by the mat width to determine the minimum required effective length of the mat.
(f) Calculate the required effective cantilevered length: \( L_c = \frac{(L_{\text{eff}} - L_b)}{2} \)
(g) Using Figure D-10.6.1-1, determine the minimum mat thickness that yields a cantilever length equal to or greater than \( L_c \)

**Example**

Max outrigger load = 100 kips (100,000 lb)
Allowable GBP = 4 ksf (4,000 lb)
Minimum required effective area = 100 kips/4 ksf = 25 ft\(^2\)
Mat width = 4 ft
Minimum required effective length (L) = 25 ft\(^2\)/4 ft = 6.25 ft
Bearing width (L\(_b\)) = 24 in. = 2 ft
Required cantilever length,

\[
L_c = \left( \frac{L_{\text{eff}} - L_b}{2} \right)
\]

\( L_c = (6.25 \text{ ft} - 2 \text{ ft})/2 = 2.125 \text{ ft} \)

Referring to Figure D-10.6.2-1 and following the 4 ksf line up, a 6 in. mat has an effective cantilever length of approximately 2 ft; this is less than the 2.125 ft required. An 8 in. mat has an effective cantilever length of 2.7 ft, which is more than adequate.
Common species timber mats

\[ F_b = 1,400 \text{ psi}; \ F_v = 200 \text{ psi} \]

- 6in. thick mat
- 8in. thick mat
- 10in. thick mat
- 12in. thick mat

**Figure D-10.6.2-1 Wood Mats Float Example**
D-10.7 Steel Mat Analysis

The Effective Bearing Area Calculation Method can also be applied to steel mats. Mat properties are dependent on the construction of the mat. Note the limiting shear stress is vertical rather than horizontal.

To simplify the calculation, a spreadsheet can be developed to automate the process. Figure D-10.7-1 is an example of such a spreadsheet.

The assumptions and limitations in Section D-10.3 also apply to steel mats with the addition of the items listed below.

(a) Standard structural allowable stresses for the appropriate steel grade are generally used (typically Grade 36 or Grade 50). If in doubt as to the grade, use Grade 36 values.
(b) The following example is for mats typically fabricated with I-shape beams running longitudinally and welded together. Cover plates are sometimes provided.
(c) There are other modes of failures for steel mats such as local beam failure and member connections that are not considered in the following example.
(d) For mats constructed in other manners, consult the manufacturer or a qualified person.

Required inputs:

(a) Grade of steel
(b) Construction: number of members, presence of cover plates, etc.
(c) Size: length, width, depth
(d) Properties: elastic section modulus $S_x$, moment of inertia $I_x$, shear area $A_v$, and weight
(e) Applied load. In the case of floats, this is the maximum outrigger force; in the case of tracks, this will be the track pressure multiplied by the track bearing width multiplied by the mat width.
(f) Bearing width of the float, track, or transition layer
(g) Allowable ground bearing pressure
In this spreadsheet example, the boxed cells are user inputs, all other cells are calculated or fixed data.
D-10.8  Steel Mat Property Estimator

This tool will assist the Lift Planner to make an initial selection of a steel mat that has the minimum required section modulus to distribute the imposed load at the required distributed pressure without exceeding the allowable bending stress.

The tool is applicable to single layer steel mats loaded centrally over the entire width by an outrigger float, crawler track, or transition mats.

The assumptions and limitations on the use of the tool are the same as those for the Effective Bearing Area Calculation Method. Note that mat self-weight is not considered in this tool as it generally provides only a small contribution to the imposed ground loading and can be accounted for by not designing to the allowable. Note that the self-weight is considered in the design example of Figure D-10.7-1. Mat deflection is not considered as it is rarely a limiting factor in the range of pressures and mat thicknesses graphed. If in doubt, verify the selection by running the Effective Bearing Area Calculation Method. The mat properties used in the preparation of the graphs in Figure D-10.9-2 and Figure D-10.9-3 are listed thereon. It is the responsibility of the user of these graphs to verify these properties are appropriate.

D-10.9  Using the Steel Mat Property Estimator

For analysis, the mat is considered as a beam, supported beneath by a uniformly distributed load. The crawler track or outrigger is considered to impose load over a certain bearing width $L_b$ and across the entire mat width see Figure D-10.6-1. To distribute the imposed load at the allowable GBP requires the mat to be effective over a minimum length without being overstressed in either bending or shear.

The first step is to calculate the cantilevered length of the mat needed beyond the bearing width to achieve the required minimum effective length.

Figure D-10.9-1 and Figure D-10.9-2 illustrate several curves of section modulus showing what cantilevered length can be obtained at a range of allowable ground bearing pressures. Knowing the allowable GBP and required minimum effective cantilevered length, the user can determine the minimum section modulus to be used. Note that the weight of the mat and local web and flange checks are not considered in this simplified analysis.
Figure D-10.9-1 Grade 36 Steel Mat

4' wide Grade 36 steel mat

$S_x$ (in$^3$) curves for required $L_c$ and permissible GBP

Required Cantilever Length $L_c$ (ft)

Allowable Ground Bearing Pressure (ksf)
Figure D-10.9-2 Grade 50 Steel Mat
D-10.9.1 Procedure for Track Loading

(a) Determine the maximum track bearing pressure – see Note (1)
(b) Identify the bearing width \( L_b \) of the track – see Note (2)
(c) Determine the allowable GBP.
(d) Calculate the required distribution ratio to spread the track pressure down to the allowable GBP.
(e) Multiply the bearing width of the track by the distribution ratio to determine the minimum required effective length \( L_{eff} \) of the mat.
(f) Calculate the required effective cantilevered length: \( L_c = \frac{(L_{eff} - L_b)}{2} \)
(g) Using Figure D-10.9-1 or Figure D-10.9-2 determine the minimum section modulus that yields a cantilever length equal to or greater than \( L_c \).
(h) The sum of the section modulus for the beams used in the mat should exceed the value determined in (g).

Notes:

(1) Some LHE manufacturers provide “hard” and “soft” pressure estimations. The “hard” values are the pressures imposed when the track bears on a non-compliant surface; it presumes loads are transmitted only through the flat part of the track width that is in contact with the supporting surface. The “soft” estimation is based on the track bearing on compliant ground, the assumption being that the entire width and length of the track is transmitting load. When using these curves, it is recommended to select the hard surface track bearing pressures. Refer to the LHE manufacturer or qualified person for application of these estimations.
(2) The bearing width \( (L_b) \) is the flat width of the track that is in contact with the mat.

Example

Maximum track bearing pressure = 202.5psi = 29.16 ksf (29,160 psf)
Bearing width \( L_b \) = 36 in. = 3ft
Allowable GBP = 5 ksf (5,000 psf)
Distribution ratio = 29.16 ksf/5 ksf = 5.83
Minimum required effective length \( L_{eff} = 3\text{ft} \times 5.83 = 17.5\text{ft} \)
Required cantilever length,
\[
L_c = \frac{(L_{eff} - L_b)}{2} = \frac{(17.5\text{ft} - 3\text{ft})}{2} = 7.25\text{ft}
\]
The mat is 4ft wide and Fy=36 ksi material.

Referring to Figure D-10.9.1-1 and following the 5 ksf GBP line and across at \( L_c = 7.25 \text{ ft} \), the intersection is below the \( S_x = 300 \text{ in}^3 \) curve and above the \( S_x =250 \text{ in}^3 \) curve. i.e., a mat with an \( S_x \) of 300in\(^3\) or better would likely work.
Figure D-10.9.1-1 Grade 36 Steel Mat Example

4' wide Grade 36 steel mat
$S_x$ (in$^3$) curves for required $L_c$ and permissible GBP

Required Cantilever Length $L_c$ (ft)

Allowable Ground Bearing Pressure (ksf)
Using Table D-10.9.1-1, the W12 x 40 mats (Sₓ = 309in³) or better should be selected.

Table D-10.9.1-1  Sample Steel Mat Properties

<table>
<thead>
<tr>
<th></th>
<th>No. of Beams</th>
<th>Beam Width (in)</th>
<th>Mat Width (in)</th>
<th>Beam Sₓ (in³)</th>
<th>Mat Sₓ (in³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W8x31</td>
<td>6</td>
<td>8.0</td>
<td>48.0</td>
<td>27.5</td>
<td>165</td>
</tr>
<tr>
<td>W10x39</td>
<td>6</td>
<td>8.0</td>
<td>47.9</td>
<td>42.1</td>
<td>253</td>
</tr>
<tr>
<td>W12x40</td>
<td>6</td>
<td>8.0</td>
<td>48.1</td>
<td>51.5</td>
<td>309</td>
</tr>
<tr>
<td>W12x65</td>
<td>4</td>
<td>12.0</td>
<td>48.0</td>
<td>87.9</td>
<td>352</td>
</tr>
<tr>
<td>W14x48</td>
<td>6</td>
<td>8.0</td>
<td>48.2</td>
<td>70.2</td>
<td>421</td>
</tr>
</tbody>
</table>

D-10.9.2  Procedure for Outrigger Loading
(a) Determine the maximum outrigger load.
(b) Identify bearing width (L_b) of the outrigger float applied to the mat.
(c) Determine the allowable GBP.
(d) Divide the outrigger load by the allowable GBP to determine the required effective mat area. This is valid on the basis that measures are taken to ensure that the entire width of the mat is uniformly loaded.
(e) Divide the area by the mat width to determine the minimum required effective length of the mat.
(f) Calculate the required effective cantilevered length: \( L_c = \frac{(L_{eff} - L_b)}{2} \)
(g) Using Figure D-10.9-1 and Figure D-10.9-2, determine the minimum mat thickness that yields a cantilever length equal to or greater than \( L_c \)

Example
Maximum outrigger load = 350kips
Allowable GBP = 5ksf (5,000 psf)
Minimum required effective area = 350kips/5ksf = 70ft².
Mat width = 4ft.
Minimum required effective length \( L_{eff} = 70ft² / 4ft. = 17.5ft. \)
Bearing outrigger width \( L_b = 36in = 3ft \)
Required cantilever length,
\[
L_c = \left( \frac{L_{eff} - L_b}{2} \right) = \frac{(17.5ft.-3ft.)/2} = 7.25ft.
\]
The mat is 4ft wide and Fy=36 ksi material.

Referring to Figure D-10.9-1 shows that a mat with an $S_x$ of 300in$^3$ or better is required. This example would be satisfied with a W12x40 mat as shown in Table D-10.9.1-1.

D-10.10 Steel Plates
This section provides guidance on the selection and use of steel plates as load distribution methods to support LHEs and transfer the imposed loads to the supporting surface. Steel plates are commonly used under outriggers. Crawler-based equipment use of steel plate is possible; however, it may require additional layers of timber or steel matting.

D-10.10.1 Considerations
Some of the properties of steel plates to be considered include the following:

(a) Standard structural allowable stresses for the appropriate steel grade are generally used (typically Grade 36 or Grade 50).
(b) The load should be applied in the center of the square/round plate to be most effective; otherwise, effective length and bearing area will be reduced.
(c) Steel plates can have lesser stiffness than the supporting surface which makes them ineffective at spreading load and generating the needed bearing area. Sand, soil, timber, or insulation board placed between the plate and the supporting surface can allow the plate to function as designed.
(d) Shear is rarely a governing factor in the design of steel plates for LHE outrigger use, rather bending stress and deflection will determine the thickness requirements.
(e) Applicable structural steel design specifications can provide guidance on steel plate bending and deflection limitations.
(f) When selecting a steel plate, deflection should be considered. The plate stiffness will affect its ability to disperse the load from the LHE.
(g) The steel plates should be in good serviceable condition.
(h) The weight of the steel plate should be considered when evaluating the GBP.

D-10.10.2 User Responsibilities
The user is responsible for:

(a) The selection of the appropriate crane mats or outrigger pads.
(b) When in use, the effective area of the plate should make contact with the supporting surface without voids. Avoid placement on uneven surfaces.
(c) Steel plates should be inspected and maintained. They should be free of debris, and properly stored when not in use.

D-10.11 Synthetic Crane Mats and Outrigger Pads
This section provides guidance on the selection and use of synthetic products as load distribution methods to support LHEs and transfer the imposed loads to the supporting surface. Synthetic materials have advantages and limitations that should be taken into consideration before use. Always consult with the manufacturer to understand the performance characteristics of these products and how they apply to the intended application. The decision
to use synthetic crane mats or outrigger pads as a load distribution method should be based on
the considerations in Section D-10.11.1.

Refer to Sections D-5, D-6, D-7, D-8, and D-10 for guidance on determining the required area to
reduce equipment loads below the allowable GBP.

**D-10.11.1 Considerations**

Synthetic and composite materials often have high strength, but low stiffness compared to
steel or wood. However, these pads and mats can be engineered and manufactured to increase
stiffness to provide enhanced load distribution properties. Due to the different types of
materials and designs, manufacturers and users should collaborate to determine the
appropriate product.

Some of the properties to be considered include the following:

(a) Synthetic and composite materials may be thinner and lighter due to their high strength
properties, making them easier to handle.

(b) These products may not be as stiff as wood or steel. Therefore, uniform load
distribution or the effective bearing area should not be assumed.

(c) Consult the manufacturer for material properties and performance information.
Manufacturers use different materials, manufacturing, and construction methods.
Users should confirm the product selected aligns with the needs and objectives.

Synthetic and composite materials are engineered with varying properties and can include the
following:

(a) Plastics - homogeneous (uniform material composition) and isotropic (uniform
properties in all directions).

(b) Homogenous composites - Manufactured to be homogeneous and isotropic.

(c) Non-Homogenous composites - Manufactured to be non-homogeneous either through
strand orientations or distinct layers. These can be isotropic, or orthotropic (different
properties in different directions).

**D-10.11.2 Manufacturer Responsibilities**

The manufacturer is responsible for the design and manufacture of products that meet the
published performance criteria. They should provide adequate information to the user to allow
selection of the appropriate crane mats or outrigger pads. That information may include
strength and stiffness data.

**D-10.11.3 User Responsibilities**

The user is responsible for the selection of the appropriate crane mats or outrigger pads. If the
user needs additional information, the user should provide any necessary application details to
the manufacturer. These details may include LHE outrigger loads and dimensions and allowable
GBP. The user is responsible for using the selected crane mats or outrigger pads in accordance
with the manufacturer’s guidelines.