The Investigation for, and Design of, Working Platforms

Brian Wilson, P.Eng.

Vice President, Keller Foundations Limited, Richmond, BC

ABSTRACT With the ongoing development of urban centres, construction is expanding into areas of marginal land, often requiring more sophisticated geotechnical solutions and consequently the use of large, and in many cases, specialized equipment to install deep foundations or even temporary construction elements. Such equipment often exerts very high contact pressures on the subgrade. Safe operation of the equipment consequently requires a stable working platform that must be engineered to account for the high contact pressures. Numerous cases are reported every year of equipment toppling or sinking through working platforms, some involving serious injury or even death. The responsibility for the assessment of the ground conditions and design of the structure of the working platform rests with the Geotechnical Engineer. In studying project sites, investigations are often focused on the key technical issue facing the foundation design of the structure itself which often implies detailed assessment of the engineering properties of the deep soils at the site. Assessment of the surficial soils, which directly impact the design of the working platform, are often a secondary thought. This paper is intended to show the importance of that component of the site investigation and to provide insight into the design of working platforms, as well as highlight the changes in regulatory requirements in other jurisdictions. The paper will also provide information on recently published technical resources to assist Engineers with such assessments.

Introduction

Every year incidences are reported around the world of rigs toppling over, or experiencing near misses, due to poor subgrade support. Examples are depicted in Figs 1, 3, 4, and 5. In addition to the obvious equipment damage, such incidents often result in injury and occasionally death of site personnel. In 2004 the United Kingdom (UK) piling industry took the initiative to improve site safety related to working platforms and launched its piling platform initiative. This dramatically changed site preparation practice within the UK industry, and led to a significant reduction in the number of piling rig instability incidents, and consequently a reduction in injuries to personnel. The UK has arguably led the charge on this important safety initiative, but the rest of the world is starting to take note and changes are slowly permeating the industry. Over the past few years the North American deep foundation fraternity, notably the Deep Foundation Institute (DFI) and the Association of Drilled Shaft Contractors (ADSC), has embraced the concept of working platform safety and has produced guidelines to mimic those of the UK and other jurisdictions. In Canada the subject has received some attention, the greatest being in Ontario, in large part due to the death of a worker in Toronto in 2015, but the uptake of appropriate working platform design and construction across the rest of the country has been limited.

As a result of the Toronto fatal accident, and the lobbying efforts of members of the deep foundation industry, regulations were put into place in Ontario to govern the requirements for adequate support of large construction equipment such as drill rigs - Ontario Regulation for Construction Projects (O. Reg 213/91) amendment (O. Reg 345/15). In parallel to this, the Ontario Association of Foundation Specialists issued guidelines for best practices to ensure that Owners, Consultants and Contractors are aware of the requirements and take the appropriate steps to ensure that they comply with the legal requirements of the July 1, 2016 amendment.

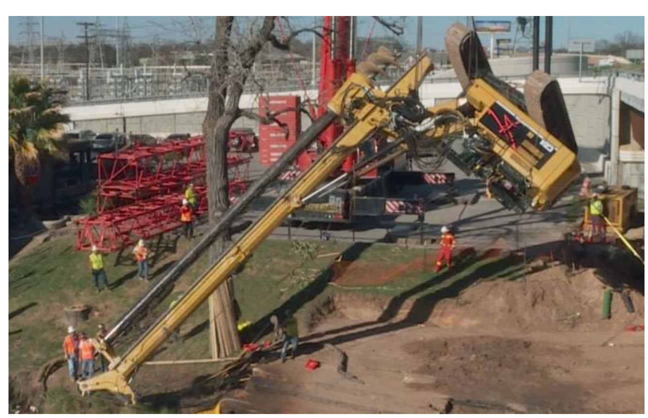
The Ontario Act states, in part, that:

Before a drilling operation described in section 156.3 begins, a Professional Engineer shall,

a) design a supporting surface for the drill rig in accordance with good engineering practice to adequately support the drill rig during all drilling and drill rig set-up activities;
b) designate and design a path of travel for the drill rig to use on the project to ensure the path of travel safely supports the drill rig; and
c) prepare a written report described in subsection (2).

The Act goes on to detail the requirements of the written report and the requirements for inspection during the construction period.

Fig1: Example of toppled rig

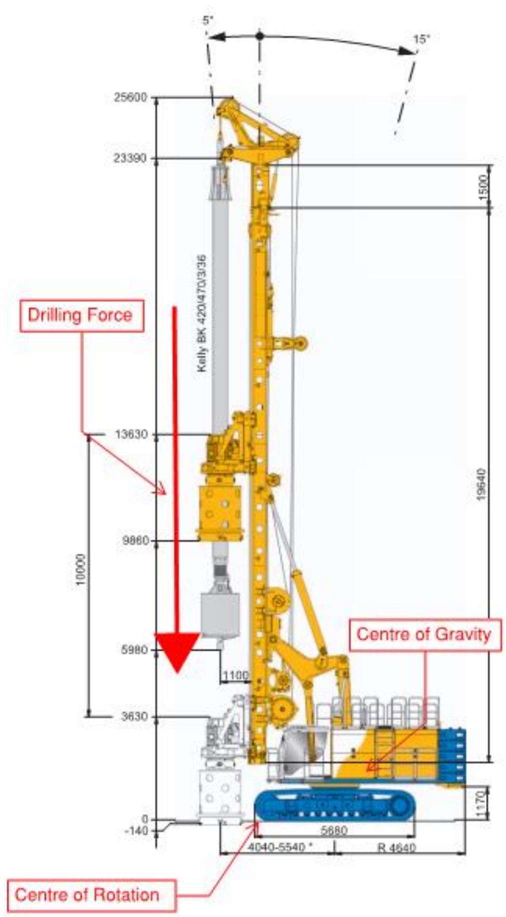


To the author's knowledge, no comparable regulations or guidelines exist anywhere else in Canada, or even the general awareness of the need for such guidelines, and the responsibilities that might rest with the Geotechnical Engineer of Record.

Determining Loads and Resultant Track Ground Bearing Pressures

As indicated above, UK practice in this field is the most mature. The Building Research Establishment (BRE) have developed a number of technical guidelines, and the Federation of Piling Specialists (FPS) have developed tools for industry use, including a design spreadsheet, that permits suitably experienced Engineers to assess foundation support requirements for drill rigs in a variety of configurations. Of key importance in the assessment of the needs of the working platform is an understanding of the actual loads that large drilling equipment exert on the ground that has to support them. In UK practice, both the equipment manufacturers and the engineering contractors appear readily able to supply design engineers with the loading parameters that they require to complete the design. This does not appear to be the norm in British Columbia. An example of a typical load capacity chart obtained from a manufacturer is included as Appendix A.

Fig 2: Drill Rig Schematic



The non-operational static situation is the simplest case for most rigs and appears to often be the only information that is relayed in local practice, but in most cases the peak applied loads during operation of the equipment far exceed the non-operational loads. It is important therefore that the industry as a whole, contribute to ensuring a proper understanding of the loading conditions that must be considered for the rigs in question and the subsequent design of the working platforms.

In the absence of information from manufacturers, guidance on how to estimate track bearing pressures can be found in BS EN 16228-1:2104. The approach uses static equilibrium equations to determine the resultant force for a particular configuration and operational setup. This requires knowledge of the mass and position of the various rig components that will be used in a specific application, as well as any applied winch or crowd forces, and their location relative to the centre of the tracks. The magnitude and position of the resulting reaction forces under each track are then determined, and utilizing Table F1 of BS EN 16228-1:2014, the applied bearing pressure distribution under the rig tracks is assessed. The calculations must be repeated for all combinations of slew angles and operating situations to find the most adverse situation and hence parameters for design. The FPS spreadsheet, which is available via its website (https://www.fps.org.uk/guidance/working-platform-guidance/1065/), facilitates the calculation of these track bearing pressures and aids in the assessment of bearing pressures for rigs with outriggers or foot pads where the system is statically indeterminate. A more detailed discussion of the procedures to be used are provided in the paper by Egan (2018).

Fig 3: Toppled rig

Assessing Geotechnical Conditions

Determining the loads is of course only one part of the equation. Understanding the geotechnical conditions at the subject site and how these might be impacted by the various site preparation and actual construction activities is an even more critical aspect of the assessment. In British Columbia, assessment of these conditions is generally the responsibility of the Geotechnical Engineer of Record, and in particular those Engineers who sign and seal the Letters of Assurance related to temporary works at the site.

Consulting Geotechnical Engineers often find themselves under client pressure to work with limited budgets to investigate sites and develop recommendations for building or site development. As a consequence, investigation efforts are generally aimed at the foundation bearing strata, and there is often minimal data available to assess the bearing capacity of soils at elevations where working platforms are required. This is both problematic for the Engineer when it comes time to design the working platform, but also for the contractors who are bidding the work and who are having to assess potential site preparation requirements in their tenders.

Since the installation of deep foundation elements typically requires the deployment of large heavy equipment, understanding the engineering properties of the soils in the 1 to 2 m below the proposed working grade of a site, as well as the prevailing groundwater elevations anticipated during the construction period, are critical to a realistic and safe design for a working platform. Safe performance of the working platforms also relies heavily on regular inspection, and where appropriate, re-assessment of the platform throughout the construction period, and in particular after periods of heavy rain.

For sites in a geologic environment where it is known that deep foundation elements such as piles are a likely solution there is a tendency to focus investigative efforts and associated testing on the soils at depth. However, by virtue of the anticipated solution, there is an implication that the near surface soils may be weak. It is consequently very important to collect the data on the equipment load bearing soil horizons to inform the decisions that will need to be made with respect to working platform design. Similarly, where deep basement excavations are proposed, the focus of the investigation is often on the foundation soils into which anchors will be drilled. In many instances minimal attention is paid to the surficial soils or the soils at progressive excavation depths that have to support heavy equipment such as the large excavators completing the dig, or the drill rigs installing the tie-back anchors.

The main driver for the appropriate design and construction of working platforms is obviously safety, however, from an owner's perspective there is also an economic aspect that must be accounted for. Specialty contractors such as those in the deep foundation industry typically require that the owner, through his general contractor, provide safe working platforms for the equipment necessary to execute the work. If the need for, and extent of such platforms is not highlighted in the geotechnical investigation report, and subsequently reviewed in the field, this aspect of the work can be overlooked, or at least underestimated, and not accounted for in either the General Contractor or Owner's budget. This then places an economic burden on the project which can result in attempts to save cost at the expense of safety.

Fig 4: Platform failure results in mast hitting adjacent rig

Fig 5: Lack of adequate platform results in damage to adjacent property

At the time of the geotechnical site investigation, the Geotechnical Engineer is often unaware of the size and type of equipment that will be necessary to construct the works, or even the type of foundation or ground improvement that will be required, and consequently is unable to make specific recommendations that can be incorporated into budget estimates for the work. However, by the time the report is produced the Geotechnical Engineer should have a reasonable idea of the types of equipment that will be deployed to a site and consequently the typical loads that will be applied. With this information the Engineer can provide an indication of the allowable bearing pressures for tracked equipment that will be generally representative of the existing surficial soils in either their native or improved (e.g. compacted) state, and where appropriate provide recommendations for removal of unsuitable soils that would be a hazard to heavy equipment. The Engineer can also, knowing what the typical applied pressures from large equipment are, provide recommendations on typical import fill thickness and compaction requirements to achieve adequate support of such loads. The inclusion of such information in site investigation reports will allow contractors to more readily assess the potential implications for working at the site and provide for a levelling of the "playing field" in the selection of contractors.

Track widths for large tracked equipment are typically in the range of 0.5 to 1.0 m hence the upper 2.0 m of the profile, whether that be native soils or imported fill, is the zone that will be most impacted by the applied stresses and is consequently fundamental to the design of the working platform. Collecting sufficient data to be able to assess the engineering properties of the near surface soils as well as the likely groundwater conditions during construction is a fundamental step in the safe execution of the project. Whether the data is collected during the first phase of the investigation, or as a subsequent phase that potentially includes more specific testing such as plate load tests for very heavy loads, guidance must be available to the contractors to permit safe deployment and operation of large equipment.

Design of Working Platform

As indicated above, establishing the near surface soil and groundwater conditions across the entire work area is a clear prerequisite for the design process. Understanding any spatial variation in soil properties, as well as having adequate topographical information and knowledge of the final elevation of the proposed working surface(s), particularly as they relate to weak subgrade layers, plays a big part in this process.

Where the natural subgrade, even if improved by compaction or cement stabilization, is incapable of providing sufficient bearing resistance for the anticipated loads, it will be necessary to supplement with placement of a compacted granular layer and/or the provision of load spreading rig mats or plates. In some instances a geosynthetic reinforcement layer may also be considered. Where a thin granular layer is placed over top of the natural subgrade, the bearing resistance offered by the working platform is the sum of the shear required to punch through a vertical plane in the granular platform and the bearing capacity of the subgrade, hence appropriate selection and specification of the compaction of the granular platform material will be an important aspect of performance and to some degree cost.

For certain operations the use of rig mats may not be practical, however in others, such as the support of equipment within on-going deep excavations, it may be the only viable option. For this type of situation the appropriate design and operation of groundwater control measures often delivers the greatest benefit to working platform stability. Design of the platform needs to account for the proposed operation and the potential impact that the proposed construction process itself can have on stability. If the plan is to drill holes or excavate slots through the platform this needs to be considered in the design, particularly in situations where there is a reliance on geosynthetics. There are unfortunately a number of documented incidents where drilled holes have led to a failure of the working platform resulting in toppling of the rig and death of the operator.

Following completion of the design and construction of the working platform it is incumbent on the designer to ensure that the as-built platform meets the requirements and caters for variations in soil properties and groundwater conditions. Isolated spots of weak subgrade, including poorly backfilled excavations, or test-pits, pose a significant risk to large heavy plant. In addition to the theoretical design of the allowable bearing pressure based on the engineering properties of the soils, the use of thorough proof rolling of the final subgrade elevation is important to verify platform competency.

Fig 6: Example of well-prepared working platform that incorporates the use of steel plates to spread the load

Fig 7: Example of a poorly prepared platform with poor drainage

While proof rolling serves as an indicator it is certainly not a complete safeguard. The pressures exerted by the tires of a truck may be high, but the depth of influence of the load from the wheel of a fully loaded dump truck may not match that of the tracks of the proposed drill rig or crane, but at least it provides some indication. Proof rolling should be completed under the watchful eye of a competent person and any soft spots identified and repaired.

While much of the focus on working platforms is on the surface of the site, excavations for deep basements, such as those in areas like Richmond, Port Moody or along the waterfront, often require the use of large equipment to install combined shoring and groundwater cutoff walls. There is consequently a need to both assess the near surface soils for the large drill rigs and cranes, and assess the requirements for the excavators and tie-back rig(s) working at a variety of elevations throughout the profile. Such rigs, while typically lighter than most large drilling rigs, can still exert quite high loads, and often through much narrower tracks. Within an on-going deep excavation it is not practical to build a working platform, but from a safety point of view it is essential that the stability of the rig and hence the safety of the personnel working on or around that rig are protected. The specified use of rig mats and the adequate control of groundwater elevations within the excavation can overcome this, however it is rare to see these specified, and in many situations the control of groundwater appears to be viewed more as a convenience than a requirement to promote a safe working environment. In many situations, the control of the groundwater elevation within a basement excavation is one of the most critical aspects for working platform safety, and one which is frequently ignored.

Driving Industry Change

The drive to change how the industry views working platform safety is currently being led by the specialty contractors of the deep foundations industry. The introduction of legislation in jurisdictions like Ontario is helping to develop wider acceptance of the need for such good practice, however there still appears to be some reluctance to embrace the practice, particularly in areas outside of Ontario.

Following the introduction of regulations in the UK, two common complaints were that granular working platforms suddenly became thicker and more expensive, and that additional time was required to design, construct and test platforms, which ate into already tight schedules. On the positive side the incidences of toppling drill and piling rigs was reduced, there were fewer injuries to site personnel, less damage to equipment and property, and the industry developed a better understanding of the causes of failures.

Consulting Geotechnical Engineers have a responsibility to inform the owners and contractors engaged on the sites that they investigate of the potential for unsafe conditions. Inclusion of a specific section on Working Platforms in the site investigation report would, at the very least, raise awareness of all parties as to the need for any special measures. The design of the working platform is arguably as fundamental an issue to the overall site development as the design of the foundations, and there are potential cost implications which owners should be aware of. By taking an active leading position on the subject consulting Geotechnical Engineers will play a key role in designing, inspecting, certifying and controlling the cost of platforms. Communication between contractors, equipment manufacturers and consultants will aid in the adoption of realistic design loads and hence rational design that will address the safety issues and control costs.

References

Building Research Establishment (BRE), 2004. BR470 Working Platforms for Tracked Plant. Bucknalls Lane, Watford.

BS EN 16228-1:2014. Drilling and Foundation Equipment – Safety. Pt.1 Common Requirements. BSI, London.

Egan, D 2018. Working Platforms for Tracked Plant – Experience from 13 Years of Best Practice. DFI-EFFC International Conference on Deep Foundations and Ground Improvement, Rome

Federation of Piling Specialists (FPS). Working platform Guidance. Accessed May 2019.
https://www.fps.org.uk/guidance/working-platform-guidance/

Marshall, R. and Holman, T.P. 2017. Working Platforms for Large Rotary Foundation Drilling Rigs – Engineering for Safety. DFI Superpile, San Diego, CA

Meyer, M.E. and Taube, M.G. 2017. Working Platforms – A DFI Multi-Committee Topic: Concepts, Comments on Worldwide and US Approach, Examples and Consideration Going Forward. DFI Superpile, San Diego, CA

Appendix A – Typical Load Capacity Chart from Manufacturer

Operating conditions for drilling rigs acc. to EN791 (Kelly drilling):

Notice: the machine may only be operated under the following conditions:

Machine type: LB28
ID no.: 10529535
Drg. no.: 509 001 2028 02 001

- Carrier machine with 5.2t + 10.2t rear counterweight and HD undercarriage extended
- Ground firm and level
- Drilling axis 1100mm in front of front edge of leader
- Radius measured from excavator swing ring center to drilling axis (on the ground)
- Max. swing speed with load: 1rpm

This stability calculation applies to:
- Vertical operation only!
- Concrete supply pipe and leader access ladder not attached
- 1.120m leader extension not installed
- Platform not attached to rotary drive
- 2. auxiliary winch on Kelly leader top not installed
Kelly bar MD28/3/36 max. 6.8t is completely compressed in its highest position
- Top Kelly guide not installed
- Kelly transmission BA280 with attached damping and cardan without pressure pipe
- Weight of drilling tool max. 1.5t
- The stated loads for the different winches are only permitted individually and may not be combined!
- Load on auxiliary winch only with completely empty drilling tool!

Vertical leader:	Rotary gearbox lifted max. 2m			Rotary gearbox lifted max. 10m			Rotary gearbox lifted all the way		
Support arm angle:	86.0°	75.1°	62.6°	86.0°	75.1°	62.6°	86.0°	75.1°	62.6°
Radius:	Min: 4.2m	Center: 4.8m	Max.: 5.4m	Min: 4.2m	Center: 4.8m	Max.: 5.4m	Min: 4.2m	Center: 4.8m	Max.: 5.4m
Auxiliary winch [t]:	10.0	7.5	2.0	10.0	6.5	1.0	10.0	5.0	-
Kelly winch [t]:	25.0	19.0	11.0	25.0	17.5	9.5	25.0	15.5	-
Feed winch [t]:	31.5	19.0	10.0	24.0	15.0	8.0	19.0	12.0	-
Max. ground pressure [kg/cm2] under the chain with 900mm base plates for:	Load (front):			Load (lateral):			Load (diagonal):		
Support arm angle:	86.0°	75.1°	62.6°	86.0°	75.1°	62.6°	86.0°	75.1°	62.6°
Radius:	Min: 4.2m	Center: 4.8m	Max.: 5.4m	Min: 4.2m	Center: 4.8m	Max.: 5.4m	Min: 4.2m	Center: 4.8m	Max.: 5.4m
Max. permitted load on auxiliary winch:	2.51	2.82	2.88	1.78	1.88	1.84	2.86	3.27	3.34
Max. permitted load on Kelly winch:	3.04	3.16	2.97	2.03	2.01	1.87	3.52	3.67	3.44
Max. permitted load on feed winch:	3.75	3.30	3.00	2.30	2.06	1.88	4.33	3.82	3.48
Max. ground pressure [kg/cm2] beneath support pad (diameter: 500mm) when pulling:									43.50

Machine travel is only allowed under the following conditions:
- Max. load on rotary drive 14.5t with rotary drive lifted to a max. of 10m. Ground pressure 2.86kg/cm^2
- Drilling tool emptied
- Rotary drive and tool are in lowest possible position
- No load on auxiliary hoist
- Support arm cylinder fully extended
- Ground firm and level
- Vertical leader
- Max. travel speed with load: 0.5 km/h, travel only permitted on firm ground or excavator support mats
- Travel only permitted when uppercarriage is parallel to undercarriage!
- No dynamic effects whatsoever permitted, travel with extreme caution and think one step ahead!