PILING SPECIFICATIONS AND DISPUTE AVOIDANCE

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Abstract

Surprises costing money and time occur frequently during the construction of foundation projects, and in particular in the case of piling projects. The contract specifications often fail to spell out the responsibilities for such events and the result is disputed claims and litigation. Much of this can be avoided by careful wording of the specifications, expressing all quality requirements in quantifiable terms and by anticipating difficulties, setting out beforehand who is responsible. New Public Works Canada master specifications are presented and specific aspects are discussed, such as how to specify a pile driving hammer, quality of equipment, tolerance limits for bending and location, and terms to avoid. Example case histories of contract disputes are presented.

When the unexpected occurs at a site and costs escalate and delays develop, the Contractor feels justified to submit a claim that the Owner sees little reason to accept. When the parties refer to the technical specifications for the rules of the contract, they often turn out to be fueling the dispute instead of mitigating it, because the specifications are vague, unclear, unbalanced, and do not anticipate that deviations from the expected can occur, but instead contain weasel clauses that help nobody in resolving the conflict.

Surprises occur frequently during the construction of foundation projects, and in particular in the case of piling projects. The surprises take many forms, but one aspect is shared between them: they invariably result in difficulties at the site and, more often than not, in disputes between the parties involved.

For example, the soil conditions sometimes turn out to differ substantially from what the contract documents indicate. On other occasions, the piles do not go down as easily as anticipated by the Owners' design engineers and/or by the Contractor's estimator. Or, they may go down more easily and become much longer than anticipated. Or, a proof test shows that the pile capacity is inadequate. Or, the piles do not meet a distinct "refusal" and, consequently, the stringent termination criterion in the specifications results in a very prolonged driving costing time and wear on the Contractor's equipment.

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Quite often, the Contractor's equipment fails to do the job. Perhaps, the equipment required by specifications is "misdirected". Perhaps, the Contractor is inexperienced and can not perform well, or the equipment is poorly maintained and difficult to use. Whether or not the Contractor honestly believes that the subsequent delays, the inadequate capacity, the breakage, etc. are his fault, he will submit a claim for compensation. Often, when the claim is disputed by the Owner, the Contractor nevertheless is awarded compensation by the court, because the contract specifications do normally not clearly contain any clear requirement for quality of equipment.

Or, the Contractor's leads are not straight and the helmet occasionally jams in the leads, but are the leads out of the ordinary—after all, they are the same as used on the previous job—and, besides, can they really be called bent, or crooked?

Or, on looking down a pipe pile, the bottom of the pipe can not be seen. Well, is then the pile bent and is it bent in excess?

Or, when the use of a water jet is required to aid the pile penetration, the pile does not advance or advances too quickly and drifts to the side or a crater opens up in the soil next to the side of the pile. The pump pressure and volume are usually detailed in the specifications, but the size and length of the hose and the size of the nozzle are rarely indicated. Yet these details are vital to the performance of the jetting system.

Frequently, sentences are used such as "in the Engineers' opinion", but with no specific reference to what the opinion would be based on. Such general "come-into-my-parlor" clauses do not hold much water in court, but they are the root of much controversy.

Be careful of the meaning of the terms used. For example, 'allowable load capacity' is a totally confusing set of words. I once worked on a case where the Engineer used these words to indicate the required working load of the piles. Unfortunately, the Contractor interpreted the words to refer to the capacity to which he had to drive the piles.

Furthermore, the word "set" is not a synonym for "blow-count" (the blows per certain length of penetration). Set is the penetration for one blow or, possibly for a series of blows. In one case, the specifications stated that the Contractor was to drive the piles (concrete piles of limited strength concrete) "to a very small set and he was cautioned not to overdrive the piles". Of course, the Contractor took care not to damage the piles by driving them too hard, which is what "overdriving" means. In fact, the driving turned out to be very easy and several of the piles drove much deeper than the plans and drawings indicated. Unfortunately, in writing the sentence I just quoted, the spec-writer meant to warn the Contractor that the blow-count was expected to be very small and that the piles, therefore, could easily drive too deep. Talk about diametrically opposed interpretations. And predictable surprises. However, the Engineer insisted that his intended interpretation was the right one and a costly claim and litigation ensued.

Most specifications only identify a required pile driving hammer by the manufacturer's rated energy. However, the rated energy says very little of what performance to expect from the hammer. The performance of hammers varies widely and depend on pile size, choice of helmet and cushions, soil behavior, etc. Whether or not a hammer is "performing to specs" is one of the most common causes of discord at a site. It is also one of the easiest to correct, as will be outlined below.

A Contractor undertakes to complete a design according to drawings and documents. Amongst these are the Technical Specifications, which purport to describe the requirements for the project in regard to codes, stresses, loads, and materials. Usually, however, only little is stated about the construction. Yet, in the case of a piling project, the conditions during the construction are very different to those during the service of the foundation, and the latter conditions depend very much on the former. When the project is similar to previous projects and the Contractor is experienced and knowledgeable, the technical specifications can be short and essentially only spell out what the end product should be. Such specifications are Performance Specifications. However, these are very difficult to write and can easily become very unbalanced, detailing some aspects and only cursorily mentioning others of equal importance. The text must spell out what is optional to the Contractor and what the Contractor must comply with. Even if the intent is that the specifications be Performance Specifications, and even if they so state, most specifications are actually written as Compliance Specifications (sometimes called Detailed Specifications). Government specifications are almost always Compliance Specifications.

When surprises arise and the Contractor as a consequence is slowed down, has to make changes to procedures and equipment, and generally is losing time and money, then, disputes as to the interpretation of the specifications easily develop. Therefore, the writer of Specifications must strive to avoid loose statements when referring to quality and endeavor to quantify every aspect of importance. Do not just say that a pile must be straight, but define the limit for when it becomes bent! Do not just say that the pile shall have a certain capacity, but indicate how the capacity will be defined! Do not forget to give the maximum allowable driving stresses and how they will be measured, if measured! In short, take care not to include undefined or unquantified requirements. One of the most non-constructive situation is when the Engineer says that a pile is damaged, or bent, or too short, etc. and the Contractor says "no it ain't". The Engineer answers "it is, too!", and before long whatever communication that existed is gone, the lawyers arrive, and everybody is a looser (well, perhaps not the lawyers).

Public Works Canada (PWC), recently commissioned the author to prepare new master construction specifications for piling in collaboration with the PWC. It is the intent that upon formal approval, the specifications will become new National Master Construction Specifications.

The prime objective in the new specifications has been to obtain specifications which will reduce the incidence of disputed claims in the construction process, such as those broached above. Therefore, in writing the specifications, much effort has been placed on quantifying the requirements. It is expected that the specifications will significantly reduce the incidence of <u>disputed</u> claims in the piling construction work.

Notice, a undisputed claim is not necessarily a negative aspect of a project. When the Contractor knows that should a difficulty arise that lies outside what one normally would expect, incurred costs will be compensated, then, his price will reflect the removal of the contingency charge otherwise necessary. If, on the other hand, he must consider that, should the difficulty appear, his claim for compensation may be rejected, he will include a contingency for this eventuality. Then, should the difficulties occur, the Contractor often tries to claim for the incurred costs anyway, and he might win the claim, collecting twice, as it were. Or because of his including the contingency, his bid was high and he lost the contract to the less experienced competitor, who indeed, claimed compensation for the difficulty along with a few more of his own doing. The continual loser is the Owner and the Society.

The new Master Specifications follow the standard format of the present Canadian National Master Specifications. That is, they include a general section, a section on the static loading test, and separate sections for specific pile types, such as pipe piles, socketed piles, wood piles, H-piles, precast concrete piles, and expanded-base piles. Of course, the system of measurements is SI.

Spec Notes are frequently interspersed in the text to provide explanation and advice to the designer adapting the master specifications to a project. The Spec Notes and any irrelevant clauses are to be deleted by the Spec-writer before the particular project specifications are completed.

For example, instead of specifying a pile driving hammer by its rated energy, the new specifications specify a hammer by the energy transferred to the pile and the impact force delivered to the pile, which are well defined quantities. In the design phase, energy and force values are to be obtained by means of a wave equation analysis. The wave equation analysis will "marry" the hammer to the pile and soil and to the particular drivability conditions and desired capacity. Naturally, the Owner has the obligation to provide correct values and the Contractor has the right to expect that the values specified are correct. If the values are incorrect, and the Contractor suffers as a consequence, the Owner must compensate the Contractor.

More often than not, the analysis will show that theoretical analysis alone is not able to sufficiently accurately determine the hammer requirements. This is then not an argument against specifying the values. It is an argument proving the inadequacy of simply picking a rated energy, which puts the risk onto the Contractor. It is also an argument for the Owner's obligation to find out ahead of time, or at the outset of a project, what the correct values are. For example, by means of taking dynamic measurements with the Pile Driving Analyzer (PDA). PDA measurements are since many years routinely used to finalize a pile design in connection with test driving or during the Contractor's installation of index piles.

Then, if, during the course of the piling work, reasons arise to question the hammer performance, PDA measurements can be taken and the hammer can be accepted or rejected as based on the measurement results. Opinion may differ with regard to the adequacy of the specified values, but such differences are technical in nature and easily resolved without involving the lawyers.

The dynamic measurements may interfere with the Contractor's work, therefore, the general specification section contains a clause that outlines how the measurements are performed and what the responsibilities are for the parties involved.

Dynamic measurements are also commonly carried out to determine pile capacity and integrity. Notice, the PDA measurements are only a set of measurements. They need analysis to be useful. Also, they are only one set of measurements, simple conventional records taking, that is, observing the pile installation and writing down the observations in a log, will go along way toward finding out what really is happening on a project. The new PWC specifications include a list of what records to take that may look long, but the logging effort costs little and the records may save a good deal of cost in the end, perhaps even making more elaborate measurements redundant.

Further, bending and doglegging of a pile have been defined by a specific bending radius, and straightness and out-of-location have been given specific tolerances. For example, the specifications require that piles must not be bent more than to a radius of 200 m (600 ft) after driving (bending limits are also given for conditions before driving). For pipe piles, this is readily determined by means of an inspection probe, also detailed in the specifications, designed to jam in the pipe at this radius. A pipe pile for which the bottom can not be seen, but into which the probe reaches the bottom, is then by definition straight and acceptable.

The new specifications have increased the requirements on how to perform a static loading test. Details are given on the arrangement of the test, choice of gages, and the method of testing (the quick method is the preferred method). The use of a load cell for determining the applied test load is mandatory.

Requirements particular to each pile type are given in separate sections. For example, requirements are given for long precast prestressed concrete piles pertaining to splices, placing center tubes in the piles, and for measuring and documenting strand slippage on release of strands into the pile.

In the following, a selection of direct quotes are given from the general section of the new specifications, Section 02351. The full text is available in a Continuing Education Guidelines booklet published by the Deep Foundation Institute.

Notice, the numbers given in brackets are suggested values, but may be changed by the spec-writer to fit the project. Sometimes, the brackets only enclose the term "VALUE", or similar, to remind the spec-writer to insert an appropriate value.

3.1 Equipment

.1 Equipment information

.1.1 Prior to commencement of pile installation operation, submit to [Engineer] for [approval] [review], details of equipment for installation of piles.

SPEC NOTE: The information requested in 3.1.1.2 is necessary as input to a detailed wave equation analysis of the pile driving.

.1.2 For impact hammers, give manufacturer's name, type, rated energy per blow at normal working rate, mass of striking parts of hammer, mass of driving cap, and type and elastic parameters of hammer cushion.

.2 Impact Hammer

SPEC NOTE: Do not exclude a hammer type unless for very specific reason.

.2.1 For final driving of [TYPE] piles, provide a hammer capable of delivering to the pile a non-erratic impact stress not smaller than [VALUE] Pascal and transferring a non-erratic energy not smaller than [VALUE] Joules per blow to the pile head at normal working rate.

SPEC NOTE: Bounce-chamber gages in double-acting diesel hammers are frequently inaccurate.

.2.2 For air/steam hammer and double-acting diesel hammer, provide a calibrated pressure gage and position the pressure gage on the hammer side of all valves, with no more than 30 m of hose away from the hammer intake, and so it can be easily observed by [Engineer]. Provide a calibration certificate of the pressure gage that is current within 6 months.

SPEC NOTE: For driving of concrete piles, where tensile stresses are of concern in easy driving, include 3.1.2.3. For both ordinary precast concrete piles and prestressed precast concrete piles, the limiting driving tension is governed by the yield strength of the reinforcement with no allowance for tensile strength of the concrete. Therefore, the maximum tensile resistance in a driven concrete pile is equal to the axial tension capacity of the reinforcing bars or of the prestressing strands. When applying a factor of safety of about 1.4, the maximum allowable tensile stress is 70 % of the steel yield. Coincidentally, this percentage is about equal to the net prestress in a prestressed pile.

.2.3 The hammer shall be adjustable to delivering a reduced impact so that during easy driving of the pile, when tensile stresses are of concern, the largest reflected tensile stress is at all times smaller than [VALUE] Pascal.

.2.5 Approval of the hammer equipment [will] [may] be subject to [Engineer's] assessment of the results of the dynamic monitoring of the pile driving using the Pile Driving Analyzer, as described in Clause [3.13].

.2.6 Remedial action due to failure of the Contractor's hammer equipment to satisfy the requirements in Clause [3.1.2] will be at the Contractor's own expense. Such remedial action may consist of, but need not be limited to, adjustment or replacement of hammer cushion, or of pile cushion, or to adjustment or replacement of hammer.

.4 Leads

.4.1 Provide leads that will enable the hammer to deliver impacts concentrically and in alignment with the pile longitudinal axis without inducing bending moments in pile.

.4.2 Provide fixed leads held in position at or near the top and at or near the bottom except where swinging leads are authorized by [Engineer].

.4.3 Provide leads that are parallel and not bent beyond a 15 mm deviation from a straight line over any 5.00 m length (0.3 %).

.4.4 Provide leads of sufficient length to accommodate the combined length of pile and hammer.

.4.5 Performance of the leads will be subject to assessment of [Engineer]. Any remedial action required will be at the Contractor's own expense.

.5 Follower

.5.1 Do not use follower without [Engineer's] permission.

.5.2 When permitted, provide a uniform follower with constant dynamic impedance (EA/c) equal to that of pile and of shape and length enabling driving of pile in specified location to required depth and resistance. Provide follower with socket or hood carefully fitted to the pile head to minimize loss of energy and prevent damage to pile.

.5.3 Where follower is to be used, drive applicable test piles using similar follower.

.5.4 Proper design and performance of follower will be subject to the assessment of [Engineer] which may include dynamic monitoring using the Pile Driving Analyzer as described in Clause [3.13] and any remedial action will be at the Contractor's own expense.

SPEC NOTE: Include 3.1.6 for long, closed-toe, pipe piles and for concrete piles equipped with center tubes. The probes should be designed to react for 200-metre and 100-metre bending radii as described by the Canadian Foundation Engineering Manual (1985), Chapter 24, Section 24.3.3.

.6 Inspection probes

.6.1 Provide two inspection probes for use for pile inspection. The probes shall be made from heavy steel pipe and have dimensions length [ ] metre ("Probe Radius 200 m") and [ ] metre ("Probe Radius 100 m") and outside diameter [ ] mm ("Probe Radius 200 m") and [ ] mm ("Probe Radius 100 m").

.6.2 After initial driving of pile, lower the probe marked "Probe Radius 200 m" into [pile] [center tube] to the toe of the pile. If the probe fails to reach the toe, record depth of stop, and proceed to lower the probe marked "Probe Radius 100 m".

.6.3 Pile in which the "Probe Radius 200 m" fails to reach the pile toe may be rejected subject to the assessment of [Engineer].

3.3 Field Measurements

SPEC NOTE: Careful records are very important for assessing the unexpected occurrence of any event at a piling project. Delete or modify to suit project.

.1 Maintain accurate and daily records of driving for each pile, including:

.1.1 Type, make, and rated energy of hammer.

.1.2 Other installation equipment including details on use of pile cushion, follower, and water jet.

.1.3 Pile size and length, location of pile in pile group, and location or designation of pile group.

.1.4 Time for start and finish of driving pile and sequence of pile driving for piles in group.

.1.5 Penetration for own weight and own weight and weight of hammer, number of blows per 300 mm of penetration from start of driving, and penetration for [four] consecutive series of [ ] blows when approaching termination of driving of pile.

.1.6 Observed stroke and blow rate (blows/minute) of hammer.

.1.7 Toe elevation on termination of driving pile and final toe and cut-off elevations on completion of pile group.

.1.8 On termination of the driving of open-toe pipe piles, record depth from ground surface outside pile to soil surface inside pipe.

.1.9 Records of restriking.

.1.10 Result of inspection of pile by means of inspection probe, as described in [3.1.6].

.1.11 Other pertinent information, such as interruption of continuous driving, observed pile damage, etc.

.1.12 Records of elevation of adjacent piles before and after driving of pile.

.1.13 Record all information on forms provided by [Engineer]

.2 Provide [Engineer] with three copies of the records.

3.4 Pile Installation

.1 Use driving helmet to protect pile head.

.2 Do not use any loose inserts in the helmet. The Engineer is sole judge of the acceptability of the helmet.

.6 Advance pile to [toe elevation as indicated on drawing] [penetration resistance specified in Clause [3.9]].

.10 Restrike piles which have settled or heaved during driving of adjacent piles. No additional compensation will be made for pile restruck due to such settlement or heave.

.11 Restrike piles as directed by [Engineer].

SPEC NOTE: Include Clause 3.4.14 for closed-toe pipe piles and precast concrete piles equipped with center tubes.

.14 After driving, pile must be accessible for inspection of integrity and bending through the full length of pile. Presence of any foreign material and water is a cause for rejection of the pile at the discretion of [Engineer].

3.6 Obstruction

.1 Where obstruction is encountered that results in sudden, unexpected change in penetration resistance and deviation from specified tolerances, the Contractor may be required to perform one or all of the following:

.1.1 Removal of obstruction.

.1.2 Extraction, repositioning, and redriving.

.1.3 Addition of extra piles.

.2 If in the opinion of [Engineer] work done as per Clause [3.6.1] could not have been reasonably anticipated by the Contractor, additional compensation for work done will be considered for payment.

3.9 Penetration Resistance

.1 Installation of each pile will be subject to [approval] [review] of [Engineer], who will be sole judge of accept-ability of pile with respect to penetration resistance at end-of-initial-driving as well as at restriking, depth of penetration, or other criteria. [Engineer] to [approve] [review] final penetration resistance of all piles prior to removal of pile driving equipment from site.

.2 [Engineer's] assessment of penetration resistance [will] [may] necessitate dynamic monitoring using the Pile Driving Analyzer, as described in Clause [3.13].

SPEC NOTE: Select and modify 3.9.3 through 3.9.8 to suit project. Notice, Clause .3 is intended to minimize the risk for excessive and prolonged driving, while still ensuring the pile capacity; all three alternative termination criteria are meant to be included.

.3 Drive each pile to a final penetration resistance during initial driving of at least [120] blows for [three] contiguous penetrations of 300 mm, or to a penetration resistance of at least [200] blows for a penetration smaller than 300 mm, or to a penetration smaller than 25 mm for [two] contiguous series of [50] blows, whichever occurs first.

.4 Drive each pile to a final resistance measured in penetration for [three] consecutive series of [20] blows. The required penetration will be established by [Engineer] from results of [dynamic monitoring] [and] [static loading test] as described in Clause [3.13] and Section [02356], respectively.

.5 Prior to taking final penetration resistance, drive piles without interruption for a sufficient interval to break or prevent development of soil set-up.

.6 Drive each pile to a minimum penetration of [VALUE] metre. In measuring such minimum penetration, do not include penetration caused by the weight of pile and hammer alone.

.7 Drive each pile to a minimum [toe penetration of [VALUE] metre] [toe elevation of [+ ELEV]] [as indicated].

.8 When required by [Engineer], restrike piles to [the same criterion as applied in initial driving—Clause [3.9.3]] [to a penetration of [VALUE] mm for [three] consecutive series of [20] blows]. No additional compensation will be made for restriking.

3.10 Tolerances

.1 Pile heads, at cut-off elevation, to be within [75] mm of locations indicated, [as measured immediately after termination of initial driving, and [150] mm as measured after all piles have been driven]. [To achieve pile installation within tolerances specified, the Contractor may have to resort to using temporary bracing and templates, as specified in Clause [3.5].

.2 Pile, at cut-off elevation, to be no more than [2] % of length out of alignment.

<u>SPEC NOTE</u>: Clause 3.10.3 applies to pipe piles and concrete piles equipped with a center tube.

.3 Piles must not be bent beyond a bending radius of 200 m, as determined by means of the inspection probe in Clause [3.1.5], which is to be provided and used by the Contractor, or determined, additionally, by means of inclinometer measurements performed by [Engineer].

<u>SPEC NOTE</u>: Include 3.10.4 for soldier piles on specific occasions.

.4 Pile rotation to be limited to [VALUE] degrees.

.5 Maintain piling within tolerances specified throughout execution of work.

<u>SPEC NOTE</u>: Clause 3.10.6 addresses location of an individual pile immediately after its placement. Mislocation of groups of piles and individual piles due to drifting after placement should be addressed separately, as it often is due to causes beyond the Contractor's control.

.6 If in the opinion of [Engineer] piles are placed beyond tolerances specified, the Contractor may be required to remove such piles and install new piles to the specified tolerances at his own expense.

3.13 Pile Driving <u>Analyzer</u>

<u>SPEC NOTE</u>: It is not possible to say beforehand that no problems or disputes will occur a specific site, and for that reason, it is not possible to say that monitoring is not going to be helpful or required at piling project. Therefore, dynamic monitoring should considered for all piling projects and all piling should include specifications on dynamic monitoring with option not to use it or to use it only to a limited extent.

<u>SPEC NOTE</u>: The Contractors costs for dynamic monitoring at initial driving differ from costs during restriking, which may require special movement of the equipment. Therefore, it is necessary to indicate whether or not the monitoring will occur during initial driving or at restriking.

.1 Dynamic monitoring of the Pile Driving using the Pile Driving Analyzer will be used on [[ten] piles during initial driving and on [ten] piles during restriking] [15 % of all piles] as selected and directed by [Engineer].

.2 The dynamic monitoring will be used to determine the performance of the hammer, the driving stresses in the pile, the mobilized capacity of the piles, and the required final penetration resistance in initial driving and in restriking.

.3 The Contractor shall co-operate to ensure that the schedule for these specific piles is adhered to by providing all related access and assistance to enable the testing company to perform the monitoring.

.4 The dynamic monitoring consists of attaching strain transducers and accelerometers to the pile, usually close to the pile head, and connecting these to a monitoring station on the ground by means of a cable. Care must be taken to ensure that no damage is done to the transducers, cables, or equipment.

.5 The preparation of the pile head will be done by the testing company, usually while the pile is on the ground. The preparation consists of drilling and tapping holes in the pile. The transducers are attached after the pile is secured in the leads. The Contractor shall assist the testing company in providing a man to climb the leads carrying the transducers and cable and attaching the transducers by bolting them to the holes. The testing company will instruct the Contractor in the details of this work. Attaching the transducers to the prepared pile head requires installation of a total of seven threaded bolts into the prepared holes. Before commencement of pile driving, the testing company will check that all connections are functioning. Occasionally, the driving may have to be temporarily interrupted for the transducers to be adjusted or replaced, or the monitoring results assessed. Such interruptions do not constitute a new monitoring event.

.6 No additional compensation will be made for dynamic monitoring specified in Clause [3.13.1].

SPEC NOTE: It is frequently necessary to perform dynamic monitoring beyond the amount anticipated in the design. Payment must therefore separate between compensation for monitoring according to Clause [3.13.1] and compensation for additionally requested monitoring. Such monitoring may be carried out during initial driving and/or during restriking.

.7 Monitoring beyond the amount specified in Clause [3.13.1] will be measured for additional compensation.

The need for some of the clauses are illustrated by several examples taken from some project disputes that went to litigation. A summary of four of these cases is presented in the following.

1. Overdriving of a group of steel piles. Several steel piles were to be driven into a dense sand to a predetermined embedment depth of 85 feet. Already at a depth of about 30 ft, penetration resistance values began to exceed 200 blows/foot. The 'Engineer' insisted that the Contractor drive the piles to the specified depth despite that blow-counts reached and exceeded 1,000 blows/foot! A "post mortem" review of the records makes it quite clear that although the heads of the about 90 feet long piles were beaten into the vicinity of the ground surface, the pile toes probably never went past a depth of 60 feet. The Contractor had planned for a two-week project in early Fall. In reality, it took almost three months. As the project was located north of the 60th parallel, one can perhaps realize that the subsequent claim for $6,000,000 was justified. Incidentally, the Contractor could not get out of his obligation to drive the piles. His bond saw to that. However, he won the full amount of his claim from the Owner. The Owner later sued the Engineer for negligence and won.

2. Complete breakdown of communications between Contractor and Engineer. A Contractor got permission to use a heavy diesel hammer at an energy setting lower than the maximum which, according to the hammer manufacturer's notes would be equal to the rated energy given in the specifications for the project. At the outset of the piling, it became obvious that the piles drove very slowly at that setting, requiring more than 1,000 blows before the specified termination criterion (minimum depth and penetration resistance) was reached. Static testing showed that the capacity was insufficient. The specifications included provision for jetting and the Engineer required this for all piles. Yet, it was clear that the pile could be driven down to the depths and capacities quickly and without jetting if the hammer was set to work at the maximum energy setting. Of course, this meant that the hammer energy was to be set at a values higher than that given in the specifications. The Engineers were willing to accept this change. However, the Contractor required extra payment for the deviation from the contract to do this, which the Engineer did not want to grant. One thing led to another. The Contractor continued to drive at reduced hammer setting and diligently worked to adhere to the smallest detail of the specification wordings. The Engineer refused to budge and required jetting and recorded everything the Contractor did to ensure that, as the Contractor now wanted to follow the specs to the letter, he was not to deviate from any of the details.

Incidentally, the specifications called for outside jetting (rather than interior jetting) in silty soil, which resulted in drifting, bending, and breaking of piles. The final suit involved claims for compensation of more than $10,000,000.

3. Specification for a near-shore piling project required piles to be driven flush with the sea bottom by means of a follower and stated that the follower should have 'sufficient impedance', but did not explained what this was and nobody checked the impedance of the follower. The Contractor drove the piles with a follower consisting of a steel pipe filled with wood chips. As the driving proceeded, the follower deteriorated and it became harder and harder to drive the piles. This was thought to be caused by densification of the sand at the site and the Contractor stated that the soil report failed to show that densifiable soils existed at the site and claimed compensation for changed soil conditions. The contract required that dynamic measurements be performed at the project, and they were. However, the results of the PDA measurements were not looked at by anyone! Eventually they were, of course, and it became obvious to all that the root of the problem was with the inadequate follower. Well, better late than never, but the delay certainly cost the parties a bundle of money.

4. Long prestressed piles were required to support a new dock for a port extension. The soil profile consisted of an about 35 m to 40 m very soft soil deposit with some dense sand layers of varying thickness and depth, followed by very dense gravel and sand with boulders. The depth to the bearing soil layer required piles of such length that they became heavier than the available equipment could handle. The piles problem was solved by building the piles as composite piles, the upper about 30 m long solid concrete section and a lower about 15 m long H-pile section. The penetration into the dense soil was expected to vary because of the presence of the boulders. During driving through the soft soils, care was taken not to drive too hard as this would have induced damaging tension in the pile. However, when the pile toe reached the dense soil and the penetration resistance increased, the hammer was set to hit harder to build up capacity and to advance the H-pile end into the bearing layer.. Several piles broke already at moderate blow-count and others a few feet further into the very dense bearing layer during hard termination driving.. Expressed reasons for the breakage ranged from poor quality of the piles through sudden barge movements and inadequate equipment and/or use of wrong pile cushions. Not until the case was before the courts was it established that the H-pile extension was so light that the impact wave on reaching the end of the concrete section, which was in the very soft soil, a large portion of the wave was reflected as a tension wave. When the pile toe was in the dense soil and the remainder of the wave reached the pile toe, a strong compression wave was reflected. The low blow-count and good toe response made the hammer ram rise high and provide a strong impact to the pile. The tension from the end of the concrete section being proportional to the impact force, therefore, reached damaging levels. A study compiling driving logs showed that the breakage correlated well with the presence of soft soil at the bottom end of the concrete section. Dynamic measurements had been conducted for determining capacity early in the project. The 'post mortem' study of the records established that when the bottom end of the concrete section was in soft soil, tension reflections occur red that exceeded safe levels.

It is not possible to give too many details on projects that went to dispute, because space limitation precludes giving an adequately impartial background to the cases. An account giving some of the details could easily appear slanted toward one or the other of the various players, who may then be justified in feeling slighted. Therefore, only the above cursorily information is presented in these notes. The oral presentation will be illustrated and include more details.

Lucid, comprehensive, and equitable specifications are necessary for successful projects. However, even when the specs are good, if the communication lines break down, the project may still end up keeping our fellow professionals in the legal field living well. However, it is my experience that rarely are the initial 'surprises' and difficulties such that the parties really need to go the full way of the courts. Instead of posturing and jockeying for legal position, if the parties show a bit of good intent and willingness to understand each other and make some effort toward finding out what really is happening and why so, litigation can often be avoided. When people keep talking to each other, an understanding can usually develop that the specs are unclear or special technical difficulties have indeed arisen, and that some common sense 'horse trading' may settle the money issues. Going to the lawyers should be the last resort.