CHAPTER SEVEN

OPTIMIZING WINTER CONSTRUCTION

Pieter Diedericks
Senior Project Director, Oil Sands Projects, Petro-Canada, Canada

Abstract

Large-scale construction projects usually span the winter months, with accompanying cold temperatures. Cold weather substantially lowers the efficiency of construction. Mitigation actions could lower the cost and schedule impact of cold weather. This paper discusses the effect of winter on construction personnel and operations. This research indicates a way of planning not only construction operations but also the overall project timeline to account for winter weather. The method offers ways of using cold weather to the project’s advantage by fully utilizing the heavy haul transportation window. A construction dome is introduced that offers substantial access flexibility while maintaining a shop-like environment on a construction site.

1 Introduction

Adverse weather can have a detrimental effect on construction costs and on the overall duration of a construction project. Planning does not always consider the full implications of adverse weather. There are several measures that can be taken to mitigate and to minimize the effects of adverse weather.

In general, construction contractors seem ill-prepared for timely response to adverse weather. The literature covers the effects of low and high temperatures to some extent but offers little guidance on mitigation actions and steps that can be
taken to avoid negative impacts on cost and schedule. Labour productivity deterioration as it relates to changes in temperature has also been studied to some extent.

This paper focuses substantially on the effects of adverse weather on construction in northern Alberta, Canada and specifically on projects related to the Canadian oil sands. All of the proposed expansion of fundamental principles may not be applicable to other areas where cold weather construction takes place.

2 Objectives

The first objective of this paper is to add to published fundamental principles for mitigating the negative effects of adverse weather as well as for planning work around winter to minimize the effects of winter while using winter for the benefit of project execution.

The second objective is to introduce the concept of a construction dome that offers flexibility in location and access while maintaining a shop-like environment on a construction site.

3 Effects of Cold Weather on Construction Productivity

Construction efficiency and productivity decreases during the colder months. The specific impact of cold temperatures was researched by Thomas et al. (2009), who concluded that “an average loss of labour efficiency from cold temperatures is around 50%”. They used temperatures below 20°F (-7°C) as the basis for a “cold temperature”. Some of the causal factors that may cause drops in productivity include the layers of clothing needed for warmth, the time duration that labourers can endure exposed to cold temperatures and wind chill, safety concerns with respect to slippery conditions, and visibility.

A normal set of clothing required for moderate cold weather construction work is shown in Figure 1. The effect of cold weather on the human body was addressed by Koehn et al. (1985). “At 10°F [-12°C] unscheduled warm-up and urination breaks were taken, and at 0°F [-18°C] workmanship deteriorated”. The time taken to undress and dress up again to address these bodily needs has a direct impact on cold weather construction productivity. The effect of wind chill was calculated by Gunars (1986). A wind speed of 20 mph [32 km/h] drops the air temperature from 0°F (-18°C) to a wind-chill equivalent temperature of around -30°F (-34°C). Heavier winter clothing will thus be necessary as the temperature gets colder or as the wind speed increases. The literature does not offer any guidance on the effect of wind chill; no conclusion can be made that both wind-chill and cold temperatures have the same effect, or reduce construction productivity to the same degree.
McFadden et al. (1991) describe the effects of working in the cold as “inherently more dangerous than similar work in a warm climate”. They suggest that “the reaction times of the individuals are slower when they are cold, and heavy clothing interferes with movement, vision and hearing”. Short days (fewer daylight hours), slippery footing, and objects, ditches and inclines hidden by snow create unsafe conditions typical to cold weather construction. Visibility through windows that are frosted over is poor to nonexistent, and it can cause delays due to the time taken to defrost windows before mobile equipment can be used.

5 Principles of Weather Mitigation

Thomas et al. (2009) published a table detailing their suggestions for the fundamental principles of weather mitigation. They claim that “if these principles are followed, contractors can avoid losing large sums of money”. They intentionally left the principles general for greater applicability to a wide range of projects and conditions.

The principles cover specific sections, including: general management, excavation and site work, labour, and materials. The general section covers works schedules, annual cycles, schedule acceleration, reservation of work that can be done on inclement workdays and enclosing of buildings for weather protection. Excavation and site work addresses daily sealing of exposed areas, effective site drainage, the
possibility of early installation of permanent draining facilities, providing adequate working surface, ploughing wet ground to accelerate drying, all-weather roads and using the snow as insulation until the work area is needed. The principles suggested for labour include shifting work-hours and considering break trailers. The materials section covers protection and using pallets for material storage.

These principles can be used by owners as well as contractors for alternative planning of construction around the adverse winter effects, as well as planning differently for all the activities leading up to construction.

6 Effective Winter Construction

The annual cycle principle is defined by Thomas et al. as follows: “Use annual cycles to schedule around trades most affected by weather”. The erection of all equipment can be done cost effectively in cold weather. Road preparation from the lay down yard and for tailing cranes can be easier in winter frost conditions than in muddy soft soil conditions. Fewer crane mats are usually required, and the lifts are generally as safe as in warm weather. Module erection is also an activity that can be done cost effectively in cold weather conditions. Large and heavy modules can be transported effectively on site on frosted roads and can be lifted into place. This activity can open up substantial work fronts for cost effective construction when better weather conditions arrive. Piling work can also be undertaken sometimes more cost effectively in winter frost conditions than in hot weather conditions as less surface preparation is needed when the ground is frozen. The frost in the ground does not affect the cost of drilling piles substantially.

Ideally, winter and cold weather conditions can be used to the benefit of the project and for construction despite their negative effects. Winter temperatures can be used to maximize the weight of heavy load transportation, and they improve the effectiveness of the erection of heavy equipment as well as large heavy modules.

The Government of Alberta maintains a program controlling heavy hauls on the road system based on seasonal changes. They publicize a “spring season” on their website (http://www.infratrans.gov.ab.ca) when road bans are in place. During winter, it is permissible to transport heavier loads than in summer, allowing for the transportation of larger and heavier equipment. Better economy of scale on the size of facilities can be achieved by utilizing frosty winter road conditions. Vessels can be dressed completely in a shop fabrication environment, which normally has better productivity than a field erection. Modules can also be larger and heavier when they are transported in winter than what would be allowable in summer conditions. This again utilizes the more efficient method of module yard construction. Overall costs can thus be reduced by optimizing the transportation advantages that winter provides. However, this can only be realized by carefully planning the work around the heavy haul transportation window.
7 Execution Planning Around Winter

The general principles above address planning on a general basis, but do not address the effect that timely engineering and procurement can have on construction in adverse site conditions, including low temperatures.

A high level execution schedule is shown in Figure 2. It shows the planning relationships that can be developed around the heavy haul transportation window. The heavy haul transportation window could be used as the pivot point for execution planning. Missing the transportation window may have a substantial effect on the overall schedule. The fundamental principles of winter mitigation could be expanded to include the effect that planning of detailed engineering and procurement can have on winter construction, construction execution planning around the heavy haul transportation window, and the effect of holidays on workforce planning around winter construction.

Firstly the fundamental principles of winter mitigation could be expanded to include the effect of detailed engineering and procurement planning on winter construction. An optimal relationship between detailed engineering and construction was described by Bent et al. (1996), who claim that engineering should be 80% complete when piping fabrication and full mechanical construction work starts. This means that engineering should be around 80% at the starting point of pipe fabrication for module construction if the project is utilizing an off-site module fabrication strategy, as is the case in most of the recent Alberta mega projects. The modules should be fabricated in time so that they can be delivered to the site during the heavy haul transportation window. Procurement of long lead heavy weight equipment and packages should be done in time to ensure that the delivery will also match the heavy haul transportation window. Erection of the major equipment, packages and modules can then be done during the cold period. The above will set the date for the start of detailed engineering. A thorough basic
engineering package and a detailed execution plan is a prerequisite for effective
detailed engineering and procurement. The setting of the start of the detailed
engineering sets the date for the start of the basic engineering package
development, which subsequently sets the start date for design basis memorandum.

Secondly, the list of fundamental principles of winter mitigation could be further
expanded to include construction execution planning around the heavy haul
transportation window. A sensible plan for mega projects (larger than $1 billion)
can be as follows. Piling can be completed in the first winter. Site preparation, deep
undergrounds, shallow undergrounds and foundations could be installed in
summer and fall. When the cold temperatures set in during the second winter, the
heavy hauling and heavy lifts can be done, modules can be set and limited
structural steel can be erected. When spring and higher temperatures arrive, the
work fronts will be available for piping and electrical construction. The loss of
efficiency of construction during winter can be up to 50%. Progress planning
should take this into account. Six percent progress per month can be achieved in the
warmer months in Northern Alberta on mega projects; the planned progress in the
colder months should be less per month because it should only include work that
can be done cost effectively in winter conditions.

Thirdly, the list of fundamental principles of winter mitigation could also be
expanded to include the effect of holidays on workforce planning around winter
construction. The holidays in December and early January will result in less
progress and progress during the two remaining weeks in December and one in
January can be close to zero. Late spring, summer and early fall months are the
seasons when maximum construction progress can be achieved in Northern
Alberta. The days are warm but not near the 110°F mark (43°C), where high
temperature progressive loss sets in. However, the brief summer season is also the
prime holiday season as it coincides with the summer school break. Construction
labour have usually worked a full year and want to claim their holiday breaks.
Construction planning should take high turnover into account and be ready for this
during the peak construction period. It is difficult if not impossible to keep the high
progress up during the summer break when there are labour shortages. One way to
overcome these labour constraints is to bring in temporary travelers and foreign
workers during the breaks to keep the overall bulk construction work and the work
on the critical path going. Construction work will be pushed into less productive
low temperature work season if the project planners do not plan to ensure that they
will have a full work force during the peak progress periods. However, these
activities will put constraints on the site indoctrination and safety training activities
and facilities.

Owners should take all these constraints into account when they do their overall
investment planning. Winter and cold weather occurrences do not change, and
holiday seasons occur every year during the same periods. Two principles can be
added to the table. The first one is to plan the complete project such a way that it
will minimize the effect that winter and cold temperatures may have on the project.
The second principle is to plan around known holiday periods.
8 Enclosures to increase winter productivity

The fundamental principle of enclosing of buildings for weather protection can be expanded to include the provision of site enclosures that can protect the work fronts from adverse conditions. This can be achieved by planning for and installing hoarding and construction domes on specific areas on a construction site.

One way of increasing construction productivity is to hoard in areas where construction can be executed with less exposure to the cold weather elements. The hoarded areas can be heated and construction can be executed with higher productivity than if it was executed open to the adverse conditions. Typical hoarding efforts are presented in Figures 3 and 4, which show winter construction at the Petro-Canada Edmonton refinery in Edmonton, Alberta, Canada. Hoarding can be done using a sprung structure and/or attaching the hoarding to erected structural steel to enclose large areas. Scaffolding can also be used to support localized hoarding and as additional support for the larger hoarding areas. Hoarding provides maximum benefits when installed over the highest density work area. More labour hours worked inside the hoarded area will offset the cost of hoarding as well as heating.

Hoarding provides protection against snow and wind. Snow needs to be removed after a heavy snow fall if an area is not hoarded in. The interior also protects the workers from wind chill and blowing snows.
Figure 4. Typical hoarding in winter

Figure 5. Inside a typical hoarding structure
It is clear from Figure 5 (winter construction at the Petro-Canada Edmonton refinery in Edmonton, Alberta, Canada) that work can be done effectively inside the hoarded areas. Pumps, small vessels, and heat exchangers can be set up, and piping can be installed around this equipment without being affected by cold temperatures, snow, and wind chill. The insulation properties of the sheet material utilized for the hoarding is not good, however, and it can be difficult to ensure the elimination of the wind chill effect when the tarpaulins used for hoarding are damaged or torn or when an area cannot be completely enclosed. The nature of the hoarding also requires substantial heating to ensure an acceptable working environment.

A further problem with hoarding is that it inhibits larger equipment installation and placement of larger spools. MegaWorks Structures Inc. developed a construction dome structure that overcomes most of the restrictions of fixed hoarding structures on a construction site. A number of construction dome sizes were completely designed and a smaller pilot dome was tested on the Petro-Canada site at MacKay River in northern Alberta, Canada. The results of the testing of the pilot dome confirmed all the design parameters.

The dome consists out of a series of cylindrical tubes that forms the sides and roof of the dome as can be seen in Figure 6. Each tube is inflated and self-sustainable. Separate tubes are also installed on the ends of the dome to provide a complete enclosure. Sheet material is installed on the outside as well as on the inside over the tubes for the side as well as for the end tubes to ensure that the dome is watertight. The larger entrances to the dome are at the sides and at both ends. The largest dome that was designed was 200 m long, 100 m wide and 45 m high. These dimensions allow the dome to cover a substantial part of a process plant under construction. A suspension structure is installed over the dome, and each one of the tubes is tied to the suspension structure. Each tube is also anchored to prevent shifting during high winds. A further way to mitigate high winds is to increase the pressure in the tubes during high wind conditions. Then pilot construction dome was exposed to cold temperatures and high winds, and it successfully passed all the tests. If one of the tubes is damaged, it can be repaired with a patch similar to fixing a leak on the inner tube of a car tire by deflating the tube, gluing an inside and outside patch over the damage area, waiting for the glue to dry, and re-inflating the tube. The process can be completed in a limited number of hours.
When it is necessary to install a major piece of equipment or a major module that is too large for the end doors, a number of tubes can be deflated (see Figure 7, showing the actual pilot construction dome on the Petro-Canada site). The inside and outside coversheets can be removed. Then, with the use of the suspension structure, the tubes can be moved aside. The major lift can then be done without any obstructions. When the lift is complete, the tubes can be inflated. They will
expand and fill up the empty space. The inside and outside sheets can then be installed and the dome is again water- and wind-tight.

Figure 8. Partial side opening

A partial side opening can also be made for access for a smaller load (See Figure 8, showing the same pilot construction dome on the Petro-Canada site). This can easily be accomplished by deflating the required number of tubes and partially opening the inside and outside cover sheets. After the load is moved inside, the tubes can be re-inflated and the sheets re-installed to return the dome to a water- and wind-tight state.

Sufficient lighting to enable productive construction is installed inside the dome. Air is circulated inside the dome and monitored at a number of locations. If the air quality deteriorates at any spot, the air-conditioning unit replaces the air to maintain a healthy environment inside the dome.

The inside of the dome can be heated so that the temperatures will always be higher than 10°C. The dome will keep out both the snow and rain, and the wind chill factor is eliminated. It will also protect the work inside against winds that prevents crane lifts. A shop like site environment can thus be created with the installation of the dome.

Cost benefit analyses were done to determine the viability of construction domes. The viability is directly dependent on the number of construction labour hours spent under the dome. The dome protects the workers and the site against wind, rain, snow, and cold temperatures. Productivity improvement can thus be experienced throughout the year in northern Alberta. Winter has snow and cold temperatures. Fall and spring have snow, rain, wind, and some cold spells. It can
also be used for a super module yard on site and then moved to cover a construction area. Summer has rain and wind. The dome can be dismantled and re-erected in less than two weeks. Studies indicate that a dome can pay for itself on one construction project for dense construction areas, and if it does not pay for itself during the first project, it will do so during the second usage of the dome.

9 Conclusions

Weather plays a large role in construction execution. Cold weather conditions lower construction efficiency up to 50% and can have a severe impact on construction workers. Working in the cold is substantially more dangerous and extra precautions need to be taken to prevent incidents and to protect workers’ health and safety. Previous publications identified a list of fundamental principles of weather mitigation. This paper suggests an expansion of the fundamental principles to offer further fundamentals for utilizing the winter conditions for overall project success by planning construction around winter, fully utilizing labour, preparing for availability, and installing enclosed structures on construction work sites.

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11 References


