Limits and difficulties in applying the Quebec safety code for the construction industry – The case of excavations.

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Limits and Difficulties in Applying the Quebec Safety Code for the construction industry - The Case of excavations

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by

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Abstract

In Quebec, construction work safety is governed by the Quebec Safety Code for the construction industry. This Code provides a basic set of rules for preventing work accidents. It is an effective and necessary tool, but like any tool, it also has some limits. On the one hand, confusion may occur between risk prevention and compliance with regulations, and on the other, some articles of the Code are more difficult to apply. For example, for excavation, article 3.15.3 gives the criteria for determining whether shoring is required or not. A first criterion is whether there is a worker at the bottom of the excavation; in the event of a landslide, the workers at the top of the slope may be injured. A second criterion is the presence of sound rock; the definition of sound rock (whether it can be excavated by explosive or not) is an excavation contractor's definition and not a geomechanical definition applicable to the problem of slope stability. A third criterion mentions a so-called safe slope of 45^{o} without mentioning the type of soil and the presence of a water table. These contradictions create a lot of confusion and may lead to accidents. The Code should be more specific about the required slopes in relation to the types of soil and the conditions of the water table. The Safety Codes from Canadian and American regulatory organizations all take into account the nature of the soils in the maximum slopes, while, in its current version, the Quebec Code does not mention this important information. A proposal for soil classification, taking into account the presence of soft sensitive clay in Quebec, is presented.

Keywords: Safety code, trenches, excavation, shoring, slope, soil classification, accidents.

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1. Introduction

Trench work exposes workers to many risks. Collapse is the most serious and common risk during this work; unfortunately it is often underestimated, when only a fraction of a m^3 of earth is sufficient, by its weight, to fatally injure a worker. Very often, workers consider deep trenches as the most hazardous. Figure 1 (Rice, 1992) shows that several fatalities occurred in trenches 3 metres deep or less. The workers also consider recently-excavated trenches as safe trenches, while figure 2 (Rice, 1992) shows that accidents occur more frequently in trenches excavated within the last two hours.

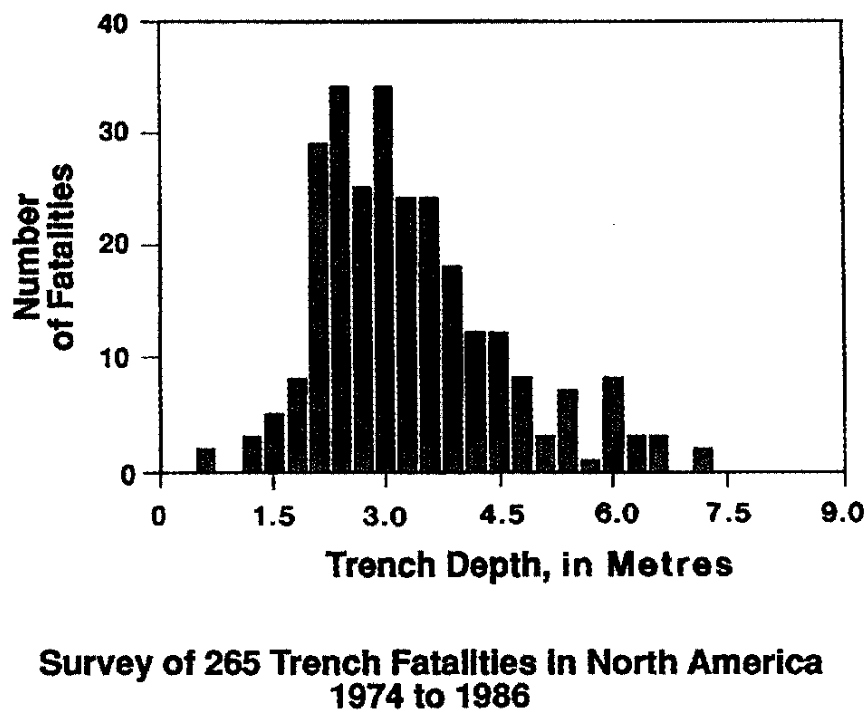

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Figure 1 - Trench accident fatalities related to trench depth (Rice, 1992)

Occupational accident statistics confirm that many serious or fatal accidents occur in excavation and trench work. In Quebec, workers buried at the bottom of trenches when walls collapse result in a minimum of 1.2 deaths per year, or approximately 1% of the deaths resulting from occupational accidents (Bouchard). An analysis of fatal accidents, carried out by OSHA from 1985 to 1989 in the United States (Culver, 1990), shows that there were 3,496 construction deaths, 239 of which occurred during work in trenches and in trench work. Governmental authorities recognize the dangerousness of excavation and trench work, since in each country's regulations, there is a series of measures to be followed to protect workers in excavation and trench work.

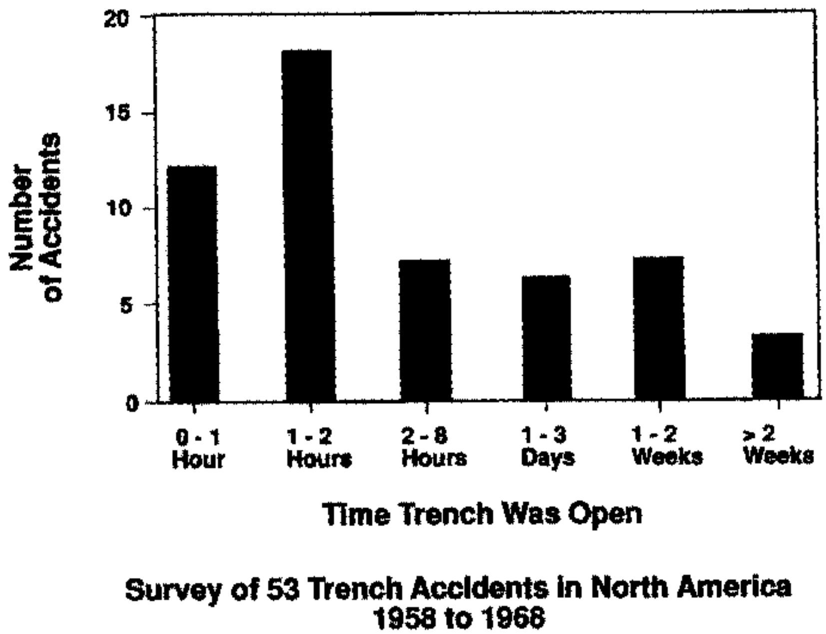

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Figure 2 - Accidents related to length of time trench was open (Rice, 1992)

2. Objective

The objective of each regulation is to focus on a set of criteria that ensure occupational safety. The question then raised is the following: What criteria must be included in a regulation so that it is a good regulation? This is a difficult question to answer because the perception of the risks inherent in a task varies from person to person and from country to country. The Quebec Safety Code for the construction industry can be used to illustrate a good regulation. First, the Code includes a definition of the terms used and the general and specific provisions defining the legal framework for applying the regulation. The Quebec Code covers all construction work. It contains the most important construction-related aspects and is performance oriented. In addition, the equivalency principle in the Code offers users flexibility by allowing them to use methods based on trade practices that comply with the spirit of the Code. A standing review committee ensures that the Code is continually updated. These mechanisms are where the strength of the Quebec Safety Code for the construction industry lies.

However, a good regulation for excavation and trench work must be more specific; it must first clearly identify the risks inherent in the nature of the work and the condition of the soils in which the work will be done. Risk identification will lead to a description of the soils and hydraulic conditions, and consequently a soil classification. This classification will then result in a prevention and protection strategy against the risks inherent in the nature of the work.

3. Review of the regulations and guides

In Quebec, trench work is mainly governed by article 3.15.3 of the Quebec Safety Code for the construction industry. For trenches used for burying water and sewer mains, the Quebec government has also published the "Devis normalisé sur les clauses techniques générales" relating to this work carried out by the Bureau de normalisation du Québec (BNQ). These two documents are complementary. The safety rules can be obtained from the Code, while the geometry of the trenches depending on the outlay of the pipes are obtained from the "devis normalisé". Note that the Quebec Safety Code for the construction industry contains no soil classification, nor a description of the hydraulic conditions, but instead a set of general criteria. The other provinces of Canada each have their respective regulations. Several guides also exist, such as the *Guide pratique de travaux de fouilles en tranchées* of the *Organisme Professionnel de Prévention du Bâtiment et des Travaux Publics (OPPBTP, 1989)*, and *Trenching Practice* of the *Construction Industry Research and Information Association (CIRIA, 1983)*. These guides give instructions based on a pertinent regulation for worker protection on construction sites.

In the United States, besides complying with safety regulations of each state, excavation and trench work can be performed according to the provisions of *Part 1926 Subpart P - Authority* of *OSHA :*

1926.550 - Scope, Application, and definitions applicable to this subpart;
1926.651 - Specific Excavation Requirements;
1926.652 - Requirements for protection systems; and the following appendices:

App A - Soil Classification;
App B - Sloping and Benching;
App C - Timber Shoring for Trenches;
App D - Aluminium Hydraulic Shoring for Trenches;
App E - Alternatives to Timber Shoring;
App F - Selection of Protective Systems.

The description of the soils and the hydraulic conditions leads to a soil classification and the adoption of safe slopes based on this classification. The soil classification also allows a worker protection strategy to be established. If the soil does not allow a safe slope to be produced, shoring will be used for the trench. For unfavorable hydraulic conditions, a network of well points can be used to lower the water table to a level that does not jeopardize the safety of the walls.

4. Detailed analysis of the Quebec Safety Code for the construction industry

4.1. Loose deposits in Quebec

Loose deposits in Quebec are linked to the Wisconsin Glaciation and the events that followed glacial retreat (figure 3). During this retreat, the glacial front moved back and forth, and salt water invaded the interior of the continent and large lakes were formed (figure 4). As a result, there are 3 main classes of loose deposits:

1) In elevated locations, namely Laurentia and the Appalachians, rock outcrops predominate and are intersected by moraine, sand and gravel deposits.

2) The lowlands to the south of James Bay are covered with water-laid clays from Ojibway Lake, and in the northern part, with marine clays from the Tyrrell Sea.

3) The lowlands of the St. Lawrence basin and the Saguenay are mainly covered with deposits of marine clay intersected here and there by fluvioglacial sand and gravel deposits (e.g., Champlain Sea, Laflamme Sea).

These last deposits cover the urbanized part of Quebec, and are therefore located where most of the excavation takes place (figure 4). The geotechnical properties of these soils are presented in table I. Marine clays are sensitive clays which occasionally produce quick clay flows of several square kilometers.

Table I
Typical values - Shear strength parameters
Loose deposits in Quebec

	Total Specific weight γ (kN/m^3)	Total stress C_u (kPa)	Effective Stresses C' (kPa)	φ'(^{o})
I Compact moraine deposits	20-23	100-200	0-15	36-44
II Overconsolidated clays Cemented sands	17-21	50-100 NA	0-10	32-36
III Medium clays Fine sands	17-19	25-50 NA	0	25-35
IV Sensitive loose Clays	15-17	10-25	0-10	20-30

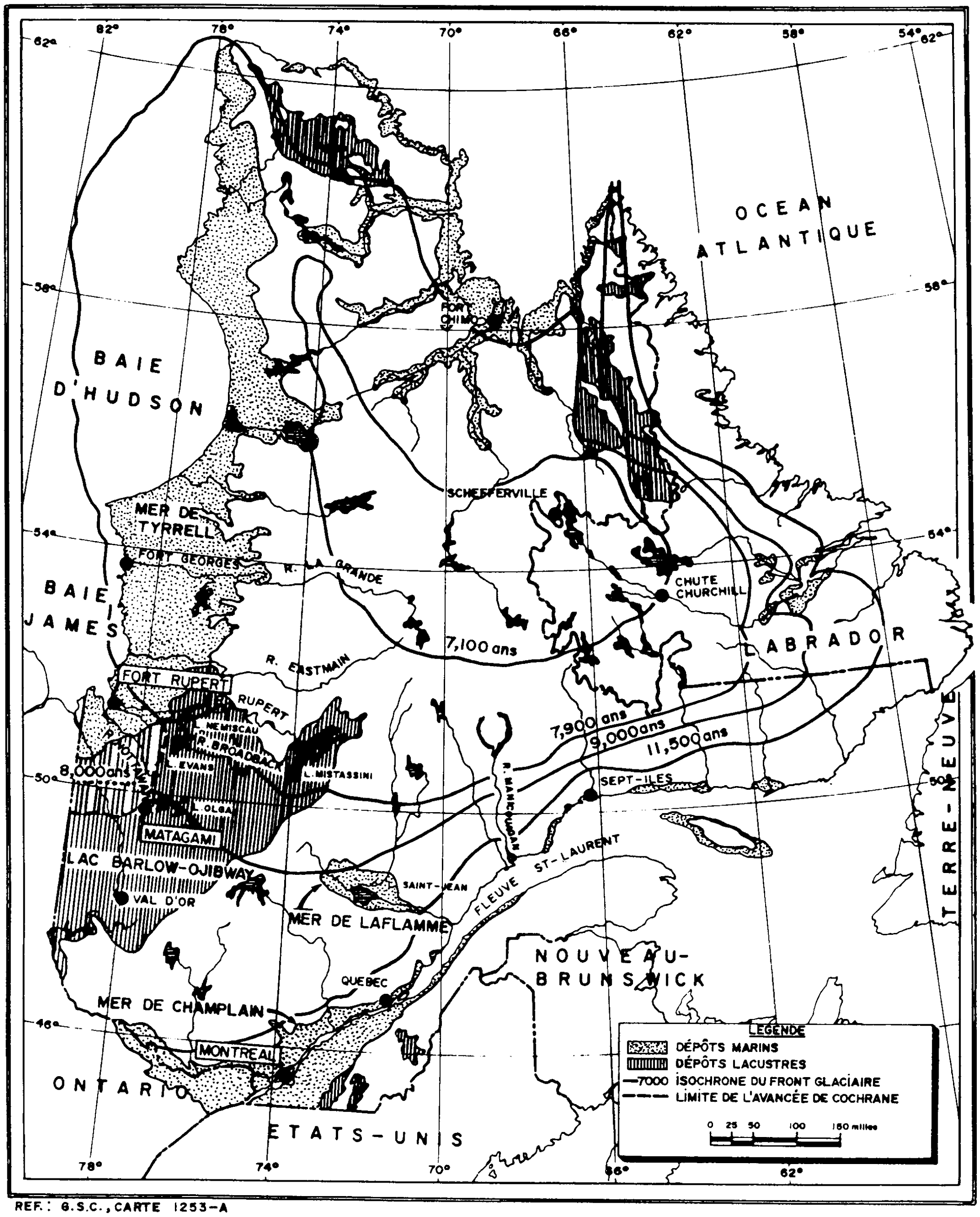

Figure 3 -Loose deposits in Quebec linked to Wisconsin Glaciation (Ballivy et al, 1975)

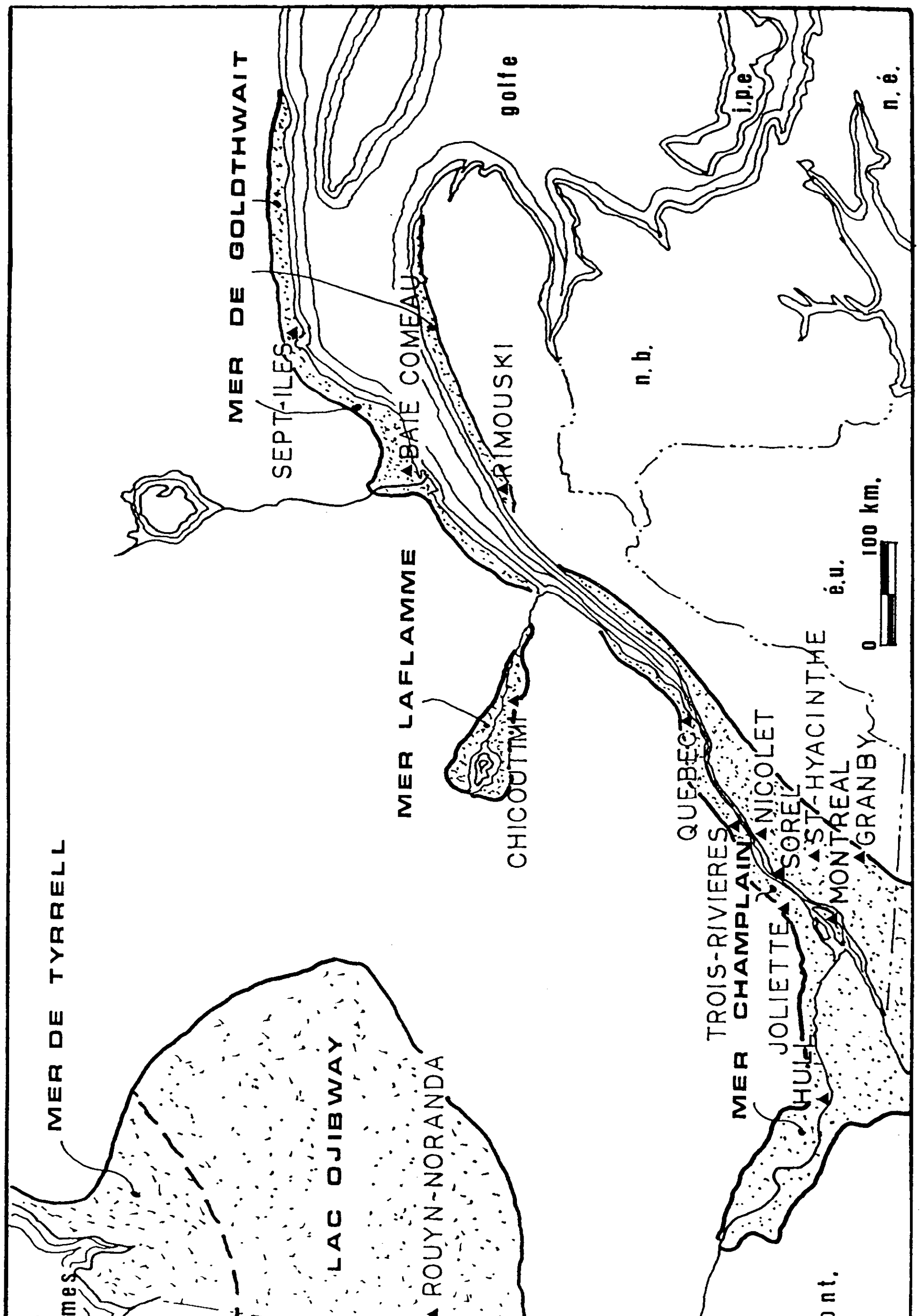

Figure 4 - Creation of major lakes (Lafleur et al., 1987)

4.2. Article 3.15.3 of the Quebec Safety Code

For excavations, article 3.15.3 presents the criteria for determining whether shoring is required or not. The first criterion is the presence of a worker at the bottom of the trench. If no worker has to descend to the bottom of the trench, shoring is not required even if workers are working at the top of the slope. While complying with the spirit of the Code, in the event the wall of the excavation collapses, the workers at the top of the slope can be carried to the bottom of the excavation and be seriously or fatally injured, particularly if the excavation is done in sensitive clay.

4.2.1. Sound rock

The second criterion is the presence of sound rock. The Quebec Safety Code for the construction industry defines sound rock as being "*rock that cannot be excavated otherwise than by blasting*". This definition is an excavation contractor's definition and not a geomechanical definition appropriate to the problem of slope stability. In chapter 2 of section IV, Excavations: Hazard Recognition in Trenching and Shoring, OSHA defines *stable rock* as follows:

Stable rock *is natural solid mineral matter that can be excavated with vertical sides and remained intact while exposed. It is usually identified by a rock name such as granite or sandstone. Determining whether a deposit is of this type may be difficult unless it is known whether cracks exist and whether or not the cracks run into or away from the excavation.*

This definition goes one step further because it makes use of geomechanical concepts such as weather resistance and the presence of discontinuities with unfavorable orientations.

The definition of stable rock by Hoek and Bray (Hoek and Bray, 1981) is broad, imprecise and complex. They define the rock instead in geological terms such as rock material, rock mass, waste rock, with or without discontinuities, major discontinuities and continuities respectively. These factors are very important because they affect the rock's behavior. One must admit that the definition of sound rock, even by experts, is broad, imprecise and very complex. These definitions are suitable for the rock mechanics engineer, but they do not necessarily provide a clearer definition of sound rock that can be used by excavation contractors.

In trench excavation work, the discontinuities present in the rock mass control its behavior; this is what rock mechanics engineers call surface behavior with low ground pressures as compared to the behavior at great depth in an underground mine for example. Thus the rock mass can be compared to a pile of boulders with total interlocking. As a result, the definition of "sound" rock will depend on the orientation of the excavation in relation to the discontinuities. For example, the rock mass in figure 5, with folds oriented as illustrated, can be considered as "sound" rock if the structure is built as illustrated. However, the rock mass in figure 6, with folds having the same

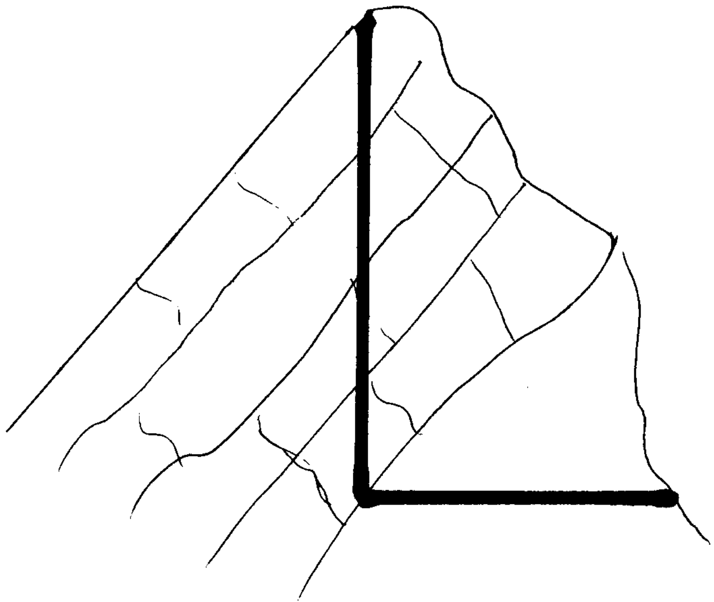

Figure 5 -Rock mass with discontinuities considered as "sound" rock with the structure oriented along the thick line

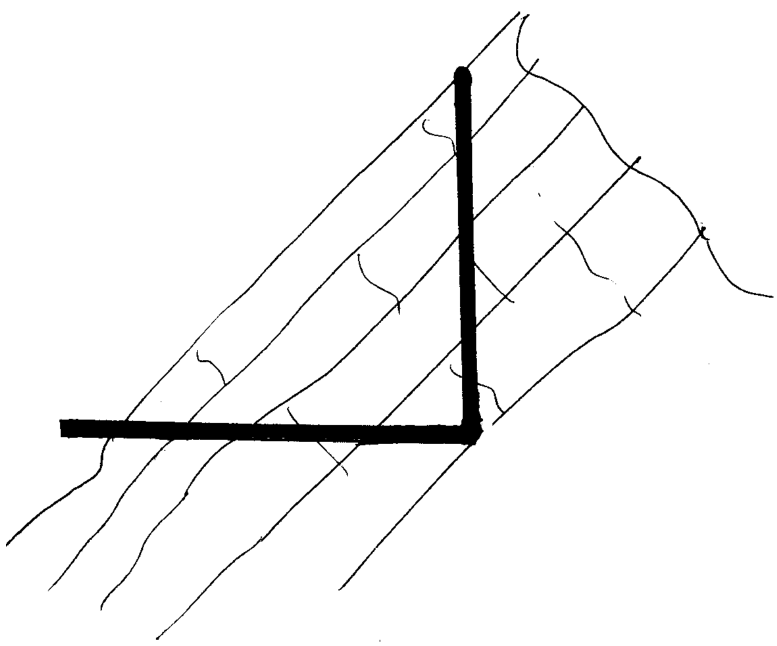

Figure 6 -Rock mass with discontinuities which cannot be considered as "sound" rock with the structure oriented along the thick line

orientation as in figure 5, is clearly not "sound" rock for the structure because the folds represent sliding surfaces that lead towards the excavation. In addition to the orientation of the discontinuities, the average spacing between them compared to the dimensions of the excavation must be considered and may result in stable conditions (figure 7).

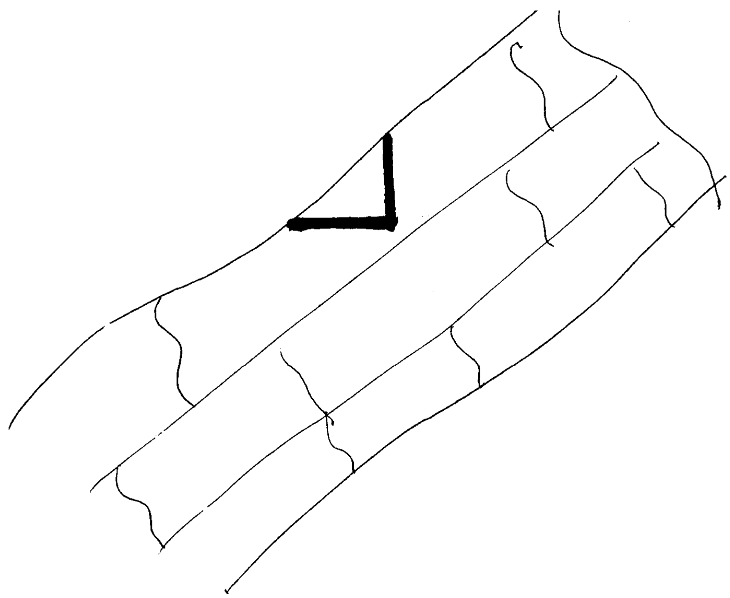

Figure 7 -Rock mass with discontinuities considered as "sound" rock due to the scale of the structure built along the thick line

Figure 8 illustrates a trench excavated in rock (shale) that closed following the failure of one of its walls, resulting in the death of a worker working in the trench. The slope of the walls is approximately 1H:5V. With the orientation of the discontinuities, the left wall (SE - southeast) is stable; however, in the right wall (NW (NO for nord-ouest in figure 8) - Northwest), the rock slabs inclined towards the trench are free to move downwards under the effect of gravity. Only friction on the surface of the dominant plane retains the mass. Since this surface was already smooth, it could not retain a material already loosened by the excavation activities.

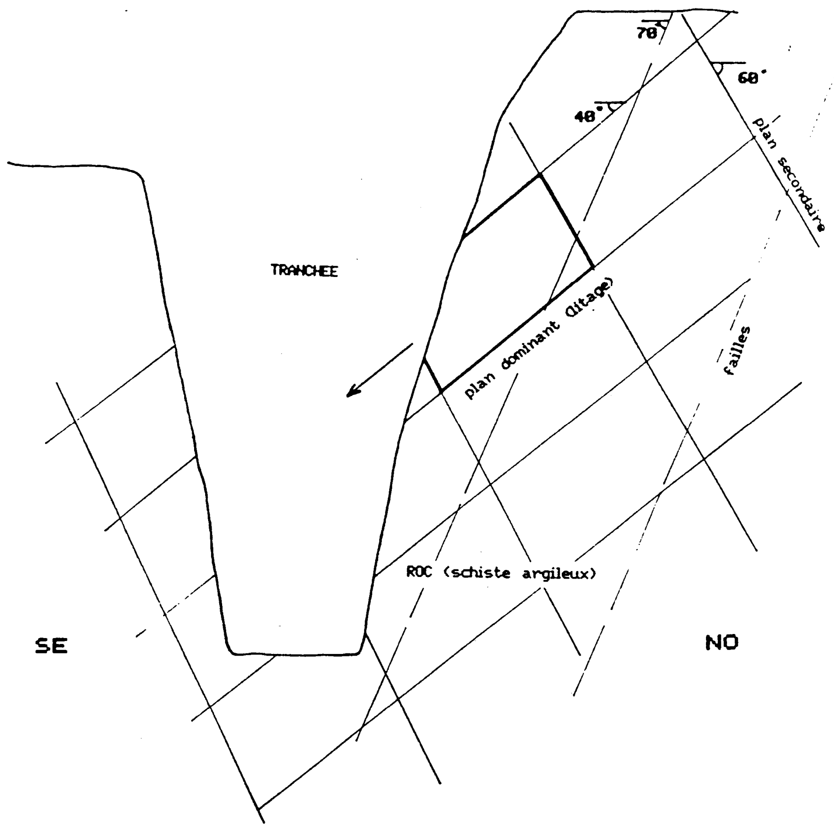

Figure 8 - Trench excavated in rock (shale) where a death occurred (Chagnon)

4.2.2. Safe slopes and type of soil

The third criterion mentions a so-called safe slope of 45° without mentioning the type of soil and the presence of a water table. All soil mechanic engineers state: *the maximum allowable slope of a wall depends mainly on the type of soil present and the water table conditions*. Depending on the type of soils present and the water table conditions, the walls of all trenches will collapse if they are not shored. This can take 10 minutes, an hour, a month; it is only a question of time.

A study of the strength of excavation walls in relation to their slopes was carried out by Lafleur et al. (1988) in a soft clay deposit ($c'_m = 8$ KPa and $\varphi'_m = 23^o$), typical of the Champlain Sea at Mont-Saint-Hilaire, Quebec. This is one of the rare studies of realistic scale that was carried out in soft clay to investigate the stability of the slopes of an excavation. The project consisted of excavating to a depth of 8 meters and of giving the walls angles of 45°, 34°, 27°, and 18° in soft clay as illustrated in figure 9. The 45 degrees slope was the first to give; a major collapse occurred in this slope. In the 34° slope, two major breaks appeared a few days after excavation. Minor movements were observed in the 27° wall. The 18° slope held, even several years after excavation. This study clearly shows that the Quebec Safety Code for the construction industry is not stringent enough, particularly when it does not take into account the nature of the soil.

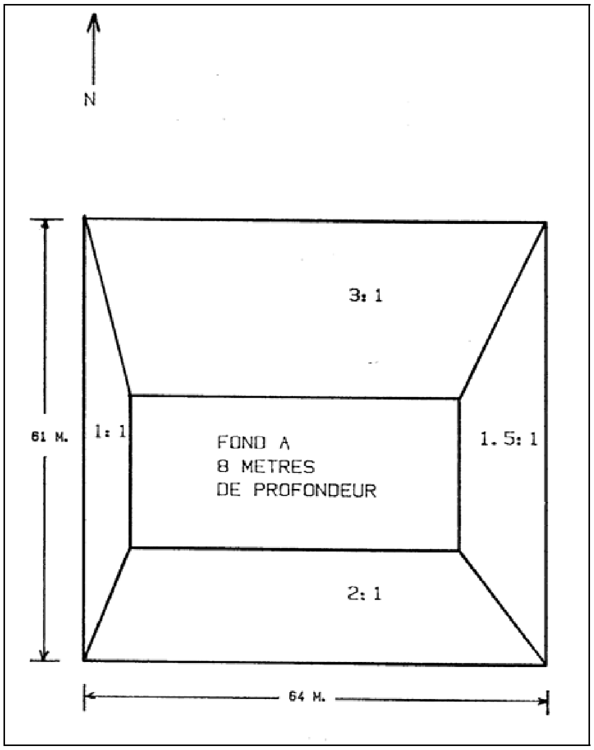

Figure 9 - 8-metre deep excavation with walls of 45°, 34°, 27°, and 18°

All in all, it seems that a 45° slope in soft clay would comply with the Quebec Safety Code for the construction industry, while the study by Lafleur et al. clearly shows that a 45° slope in soft clay is unsafe. Slopes of 45° would be effective in moraine. For sand and gravel soils, 45° slopes could be excavated from the bottom. For clay soils, the slopes would have to be inclined 18° from the bottom. Clay soils are present in most urbanized zones in Québec.

5. Content of a good occupational health and safety regulation for excavations and trenches

5.1. A good occupational health and safety regulation

In general, a good occupational health and safety regulation focuses first on identifying the risks inherent in the work to be carried out. Once the risks have been identified, the possible solution scenarios for eliminating risks of danger at source must be considered first. If this is impossible, the risks must be controlled and the means for protecting the workers against these risks must be considered. The Act respecting occupational health and safety of Quebec, the guides of the OPPBTP, and the occupational health and safety directives published by the European Community take this approach.

5.2. Excavation and trench work

5.2.1. Risk identification

Risk identification for excavation and trench work necessarily involves a description of the soils and hydraulic conditions (presence of a water table) in which the work will be done, since the soils are the causal agents of injuries. The description of the surrounding soils inevitably leads to a soil classification; this in turn allows a prevention strategy to be established which focuses first on the elimination of hazards at source. If elimination at source is impossible, the workers in the trenches and excavations must be protected.

Soil classification is the basis for the following regulations:

- Part 1926 Subpart P - Excavations from OSHA;
- New regulations on trenches and excavations of Ontario;
- Certain guides such as those of OPPBTP and CIRIA.

This classification unfortunately does not appear in the Quebec Safety Code for the construction industry.

5.2.2. Elimination of risks at source

For certain duct installation or repair work, the *Trenchless* method eliminates the risks at source since excavation is unnecessary for this work. This method does not apply to all work, but it should be considered when developing the specifications. For some countries such as Canada, the use of thermal insulating backfill avoids the break or failure of mains during very cold weather. This type of fill is currently being used by some cities in Canada.

The use of safe slopes based on the nature of the soil also eliminates the risk of collapse at source. This is the oldest technique used to ensure that the excavation is safe; it is not necessarily the most economical since it requires a large area and the removal of a large volume of cut. The slopes would be suitable for a rural environment, but not for an urban environment, where the volume of cut must be minimized in order to avoid general obstruction.

5.2.3. Shoring

If elimination at source is a problem, the workers must be protected as a last resort by shoring the walls. The use of shoring depends on the type of soils present and the surrounding conditions, which brings us back to the starting point, namely soil classification.

6. Analysis of several regulations

Part 1926 Subpart P - Excavations from OSHA in the United States, the Regulation for Construction Projects of Ontario, Canada, and certain guides for excavation work such as from the OPPBTP and CIRIA, all involve the nature of the soils in the maximum slopes, while the Quebec Safety Code for the construction industry disregards this important information. An analysis of a few regulations will allow more precise, clear and easily implemented rules to be formulated. As a reminder, the Quebec Safety Code for the construction industry has already been analyzed in section 4.

The OSHA, Part 1926 Subpart P - Authority bases its regulation on the classification of the soil where the excavation occurs. This is based on the following documents: "1926.550 - Scope, Application, and definitions applicable to this subpart, 1926.651 - Specific Excavation Requirements, 1926.652 - Requirements for protection systems", and the following appendices: "App A - Soil Classification, App B - Sloping and Benching, App C - Timber Shoring for Trenches, App D - Aluminium Hydraulic Shoring for Trenches, App E - Alternatives to Timber Shoring, and App F - Selection of Protective Systems".

American regulations go into greater detail by separating the means of protection against collapse from the excavation. It recommends maximum slopes based on the type of soils, and provides the pertinent details for the design of protection systems. The appendices provide information on the types of shoring to be used. Appendix F gives an algorithm allowing the person doing the work to establish the type of protection appropriate for his work.

The Regulation for Construction Projects of Ontario (Ontario Ministry of Labour, 1981) includes a definition of the terms used and the general and specific provisions for the legal framework for the regulation. Part III (sections 222 to 242) gives the requirements for excavation and trench work. These requirements are also based on the classification of the soil where the excavation is done.

The practical guide "Travaux de fouilles en tranchées" of the OPPBTP and "Trenching Practice" from CIRIA supply methods based on current regulations in their respective countries. The OPPBTP guide is based on the risks present in the soils where the excavation work is being carried out, construction-site organization, bank sloping (maximum slopes) and shoring. Laws, regulations, recommendations and health and safety guidelines are found in the appendix to the guide.

The "Trenching Practice" guide from CIRIA focuses on the risks involved in excavation work, the depth of the trenches, earth movement, soil identification, the hydraulic conditions in the soils, and the different shoring methods available. The regulation, the notes on the wood, extracts from "Construction Regulations 1961", and a checklist for the supervisor are found in this guide's appendices. Table II briefly summarizes the different aspects of each document.

Table II
Examples of regulations - Analysis of several regulations

Regulations/ Guides	Soil Classification	Safe slopes		Shoring required if safe slopes are not used
		H:V	Degrees	
Ontario	Rock			no
	Types I & II	1H:1V 1.2 m from bottom	45^{o}	yes
	Type III	1H:1V	45^{o}	yes
	Type IV	3H:1V	18.5^{o}	yes
OSHA	Stable rock		90^{o}	no
	Type A	¾H:1V	54^{o}	yes
	Type B	1H:1V	45^{o}	yes
	Type C	1½H:1V	34^{o}	yes
Quebec	None		45^{o}	art. 3.15.3
OPPBTP Guide	Rocky terrain		Mechanical study of the soils, but _ 60^{o}	see guide
	Loose terrain without cohesion		"	"
	Loose terrain with cohesion		"	"
CIRIA Guide	Granular		$35/45^{o}$	see guide
	Cohesive		$20/45^{o}$	"
	Mixed soils		depends on soil	"
	Fill		depends on fill	"
	Rock (see guide for definition)		vary with orientation of planes	no

7. Proposal

For excavation and trenching work, article 3.15.3 of the Quebec Safety Code for the construction industry and standard NQ 1809-300 leave the excavation contractor with general concepts and may introduce some confusion which may result in accidents. The detailed analysis of article 3.15.3 of the Quebec Safety Code for the construction industry in section 4 reveals these contradictions. If no worker has to descend to the bottom of the trench, there is no need for shoring even if workers are working on the top of the slope. The definition of sound rock, even by experts in the field, is broad and complex and provides no further clarifications. The use of a 45^{o} slope in any kind of soil, particularly soft clay, is unsafe. Since the slopes to be given to the walls and the type of shoring chosen depend mainly on the characteristics of the soil where the excavation is being done, inspiration could come from the soil classification proposed by Lafleur (1989). Table III illustrates this soil classification. Figure 10 illustrates the maximum slopes permitted with this classification.

8. Conclusion

In Quebec, trench work is mainly governed by article 3.15.3 of the Quebec Safety Code for the construction industry. This article presents a set of basic rules for the prevention of work-related accidents. Article 3.15.3, even correctly applied, may generate contradictions that lead to confusion. As with any good occupational health and safety regulations for excavation and trench work, the Quebec Safety Code for the construction industry should be more specific. It must include a definition of the terms used, a set of general criteria, risk identification, a description of the soils and hydraulic conditions, and a soil classification. These aspects will allow a prevention strategy to be established, and risks to be eliminated at source. The use of the trenchless method, and the maximum slopes permitted in relation to the type of soils, may eliminate the risks at source. If elimination at source is impossible, shoring is necessary.

TABLE III
Soil classification proposed by Jean Lafleur

- I - ■Hard, solid, resistant ■Can be excavated only with mechanical equipment ■Low water content	*example:* *compact moraine*
- II - ■Cracks and crumbles ■Average resistance ■Difficult to excavate with manual tools ■Shows a firm appearance after excavation	*example:* *stiff clay*
- III - ■Of granular appearance ■Soft or slightly compacted consistency ■Easily excavated with manual tools ■If dry, it piles in the form of a cone ■If moist, it flows or slides	*example :* *sand, gravel*
- IV - ■Muddy appearance ■Crumbles easily or flows if not immediately supported ■Exerts significant pressure on the shoring of the support system ■High water content	*example:* *soft clay*

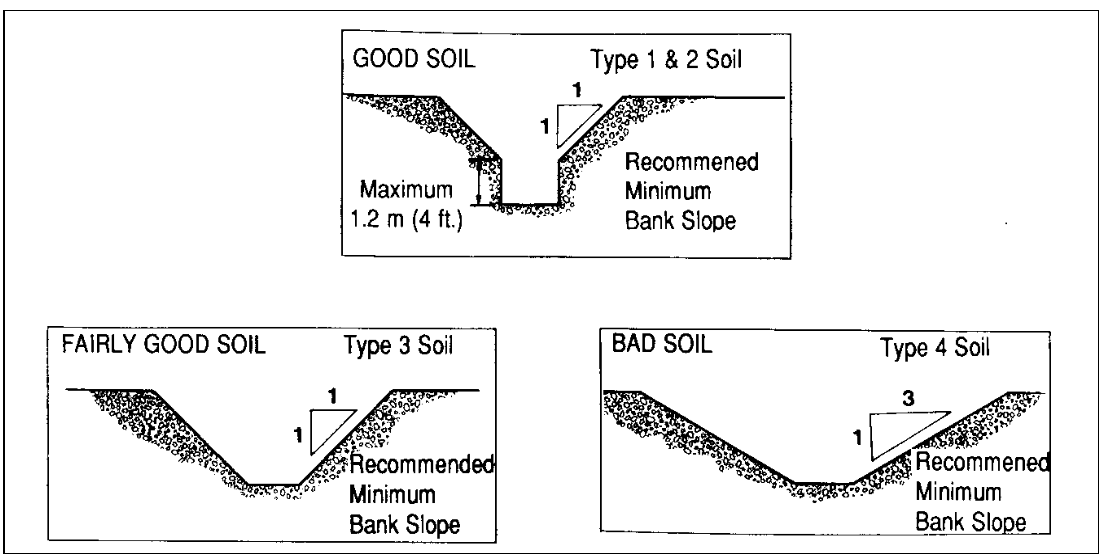

Figure 10 - Slopes recommended by Lafleur (1989)

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