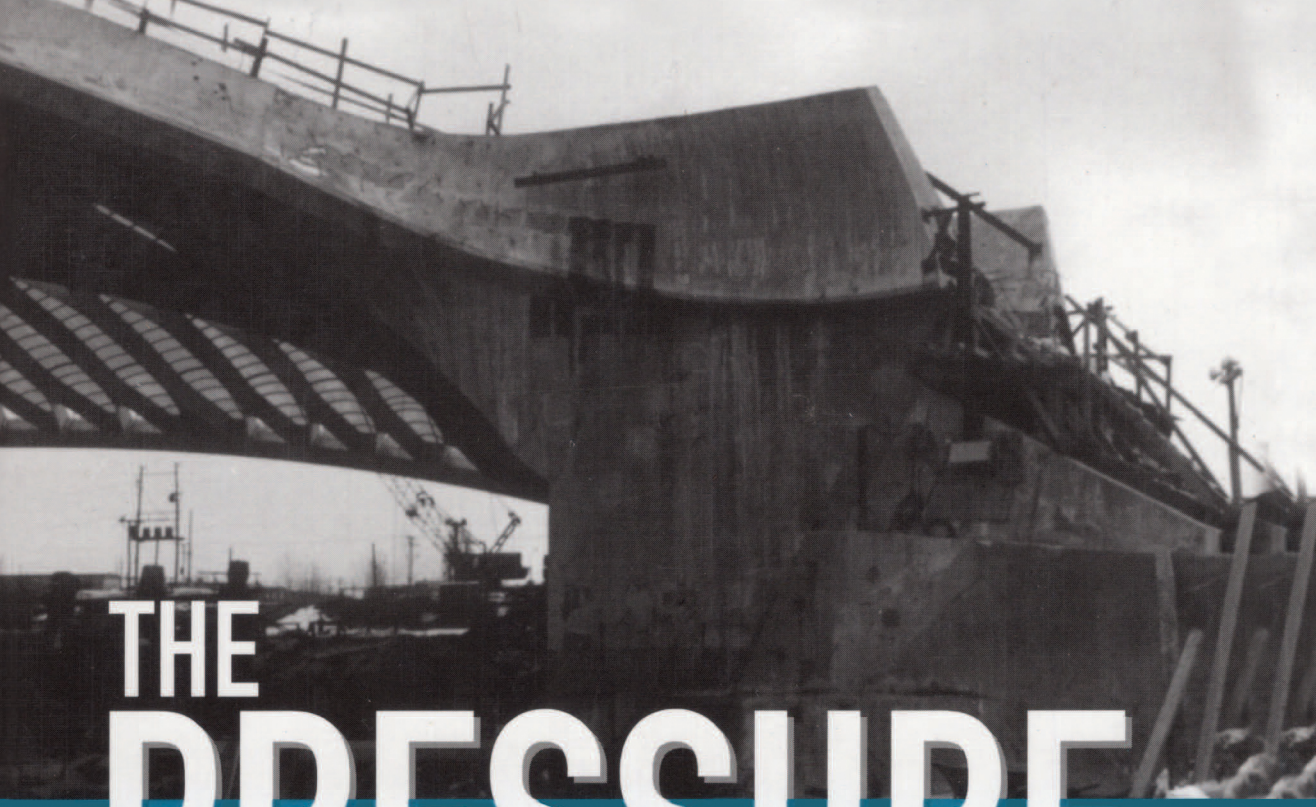

THE PRESSURE METER AND ITS NEW AVENUES

LE PRESSIOMÈTRE ET SES NOUVELLES ORIENTATIONS

GÉRARD BALLIVY, EDITOR

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Cover photograph: The structure of the velodrome in Montréal (Courtesy of G. Ballivy).

The texts of the various papers in this volume were set individually by typists under the supervision of each of the authors concerned./Les textes des divers articles dans ce volume ont été dactylographiés individuellement sous la supervision de chacun des auteurs concernés.

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Preface

In 1982, the first International Symposium on Pressuremeters took place in Paris, focussed on their marine applications. This theme was repeated in the second symposium presented at Texas A&M University, College Station, Texas in 1986. By 1990, in Oxford, the third symposium included the topics of pressuremeter technology analysis and interpretation of test data, as well as geotechnical applications.

Following on these first meetings, this fourth international symposium represents the knowledge gained from almost forty years of pressuremeter test applications. This progress is recounted by Professor Branko Ladanyi, speaker for the first Ménard Lecture, who will describe the wide applicability of this test method to natural materials. Other presentations in this symposium relate its use on manufactured material such as concrete and bituminous cement. Recently, new technologies have extended this test method for *in situ* radial loading, thus opening new avenues in applications.

The technical program of this fourth symposium includes 54 papers, from 17 different countries, as well as states-of-the-art for each of the five themes addressed by this meeting:

- Pressuremeter applications in granular and alluvial soils (9 papers);
- Pressuremeter applications in clays (14 papers);
- Pressuremeter applications in rock, concrete and permafrost (11 papers);
- Technical advances (9 papers);
- Geotechnical design (11 papers).

The fusion of the TC 16 and TC 27 committees of the International Society of Soil Mechanics and Foundation Engineering is a welcome move since pressuremeter testing is a true *in situ* test whose importance will extend to all geotechnical work. This includes its use in behaviour evaluation studies on infrastructures in actual service. The cover photograph of this volume shows the structure of the Vélodrome, part of the installations built for the 1976 Montréal Olympic Games. The site chosen required the excavation and removal of large amounts of silty sand and marine clays. These deposits were identified mainly using conventional pressuremeter tests. The Vélodrome foundations (the anchored arch and buttress type illustrated on the front page) were then constructed on a very fractured rock base which had been analyzed using a Goodman jack (a rigid pressuremeter).

In order to check the behaviour of the rock foundations and concrete buttresses some twenty years later, it was decided to carry out pressuremeter tests using new cylindrical probes under high pressure in 1993. This is just one example of how the range of pressuremeter testing applications is expanding every day.

In closing, we thank the contributors who have submitted the results of their work and who convened in Sherbrooke for wider discussions. To all, I extend a most cordial welcome.

Gérard Ballivy
Chairman
Fourth International Symposium on Pressuremeter

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Préface

Le premier colloque sur le pressiomètre et ses applications marines s'est tenu à Paris en 1982. Le deuxième colloque portait également sur ses applications marines et s'est déroulé à Texas en 1986. Pour le troisième colloque qui s'est tenu à Oxford en 1990, les thèmes principaux concernaient la technologie du pressiomètre, l'analyse et l'interprétation ainsi que les applications dans la conception géotechnique.

Dans cette suite, le quatrième colloque international sur le pressiomètre se veut donc le bilan de près de quarante ans d'applications de l'essai pressiométrique, témoin cette première lecture Ménard donnée par le professeur Branko Ladanyi. Cette lecture montre que cette technique d'essai peut être appliquée à des matériaux naturels très divers et plusieurs communications portent même sur des matériaux manufacturés tels les bétons de ciment et les bétons bitumineux. Il est intéressant de constater que les nouveaux développements technologiques apportés à cette technique d'essai de chargement radial *in situ* ouvrent de nouvelles avenues à son application.

Le programme technique de ce quatrième colloque comprend 54 articles provenant de 17 pays ainsi que des revues de la documentation concernant chacun des cinq thèmes retenus pour ce colloque:

- les applications de la pressiométrie dans les sols pulvérulents et alluviaux (9 articles);
- les applications de la pressiométrie dans les argiles (14 articles);
- les applications de la pressiométrie dans les roches, les bétons et les sols gelés (11 articles);
- l'avancement technologique (9 articles);
- la conception géotechnique (11 articles).

Il faut saluer aussi la fusion des comités TC 16 et TC 27 de la Société internationale de mécanique des sols et des travaux de fondation, car l'essai pressiométrique est réellement un essai en place dont l'importance va grandissante dans toute étude géotechnique et même dans les études d'évaluation de comportement d'ouvrages en service. La photographie de la couverture de ce volume illustre une telle évolution: il s'agit de la structure du vélodrome faisant partie des installations olympiques érigées pour les jeux olympiques de Montréal de 1976. Le site des jeux a nécessité l'excavation d'importants dépôts de mort-terrain caractérisés notamment à l'aide d'essais pressiométriques conventionnels; les fondations du vélodrome (arche et butée ancrée illustrées sur la photographie) établies sur un socle rocheux très disloqué furent analysées à l'aide du vérin Goodman. Quelques vingt ans plus tard, en 1993, afin de valider le comportement des fondations rocheuses et des butées de béton, il fut décidé de procéder à des essais pressiométriques avec des sondes cylindriques à haute pression. Ainsi les champs d'application des techniques d'essais pressiométriques s'élargissent de jour en jour...

Finalement, nous tenons à remercier l'ensemble des auteurs qui ont bien voulu soumettre les résultats de leurs travaux et venir en discuter à Sherbrooke.

À tous, la plus cordiale bienvenue.

Gérard Ballivy
Président
4e Colloque international sur le pressiomètre

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The Organizing Committee of the Fourth International Symposium on Pressuremeters express their gratitude to the members of the Technical Committee, who have worked hard to set up this event. Equally, our thanks go to the following organizations for their financial assistance:

- The Canadian Geotechnical Society;
- Le Centre de recherche interuniversitaire sur le béton (CRIB, Université de Sherbrooke et Université Laval);
- The Faculty of Applied Sciences, Université de Sherbrooke.

The active contribution of the members of the Rock Mechanics and Applied Geology Laboratory of the Université de Sherbrooke to the physical organization of the symposium and preparation of the proceedings is gratefully acknowledged.

Finally, we use this occasion to make special mention of the enthusiastic collaboration of our colleague, Professor Jean-Paul Morin, specialist in deep foundations at the Université de Sherbrooke who had generously agreed to participate in the organization of the symposium, but who, sadly, passed away in October of 1993.

Les membres du comité d'organisation du 4e Colloque international sur le pressiomètre tiennent d'abord à exprimer toute leur gratitude aux membres du comité technique qui ont bien voulu participer de près ou de loin à la mise sur pied de ce projet. Nous tenons également à remercier les organismes suivants pour leur aide financière:

- La Société canadienne de géotechnique;
- Le Centre de recherche interuniversitaire sur le béton (CRIB, Université de Sherbrooke et Université Laval);
- La Faculté des sciences appliquées de l'Université de Sherbrooke.

L'organisation matérielle de ce colloque et l'édition des communications a exigé une importante participation des membres du Laboratoire de mécanique des roches et de géologie appliquée de l'Université de Sherbrooke auxquels nous adressons nos plus vifs remerciements.

Enfin, nous profitons de cette occasion pour souligner la collaboration enthousiaste de notre collègue Jean-Paul Morin, professeur spécialisé en fondations profondes à l'Université de Sherbrooke qui avait généreusement accepté de participer à l'organisation de ce colloque, mais qui fut emporté par la maladie en octobre 1993.

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Ménard lecture

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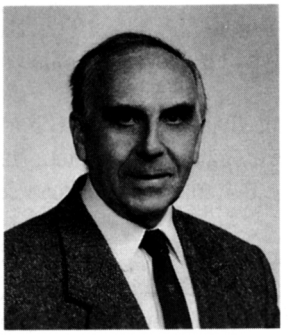
Biography/Biographie



Professor B. Ladanyi

Branko Ladanyi is Professor Emeritus at the Department of Civil Engineering of École polytechnique de Montréal. He received a Civil Engineering degree from the University of Zagreb, Croatia, and a Ph. D. Degree in Geotechnical Engineering from the University of Louvain, Belgium. He came to Canada in 1962 to take a teaching post in Geotechnical Engineering at the Laval University in Québec. In 1967, he moved to Montréal to join first Mining, and then, in 1977, Civil Engineering Department of École polytechnique de Montréal, where he was involved in teaching and research in Geotechnical Engineering and Rock Mechanics. Since 1972, he has also been director of Northern Engineering Centre of École polytechnique, which he helped to establish in 1970.

Dr Ladanyi is author of about 170 papers dealing with various geotechnical subjects and a contributor to several geotechnical books, published since 1978. He is also co-author of the book: 'An introduction to frozen ground engineering' (O. B. Andersland & B. Ladanyi, Chapman & Hall, 1994).

Professor Ladanyi has accumulated many distinctions since 1974, the year in which he received the Scientific Award of Québec. He is successively recipient of the Canadian Geotechnical Award (1981), the Belgium Geotechnical Award (1987), the E. F. Rice Commemorative Award of the University of Alaska (1991) and the Roger J. E. Brown Award of the Canadian Geotechnical Society (1993). He has also been named Fellow of both Scientific Academy of Royal Canadian Society and Canadian Academy of Engineering.

His main engineering and research interests involve laboratory and in situ determination of physical and mechanical properties of earth materials, including frozen soils, ice and rock masses, in particular as related to the design of foundations and underground openings in soils, rocks and permafrost. He has had a continuous interest in the pressuremeter since the 1960s, not only as a

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theoretical problem, which he considered in his Ph.D. thesis of 1959, but also as a practical field device, which he has since that time tried to use, not only in sands and clays, but also in rocks, frozen soils and ice. Since the beginning of the 1960s, he maintained friendly relations with Louis Ménard, with whom he often exchanged opinions on the theory and practice of the pressuremeter.

Branko Ladanyi est Professeur Émérite au Département de génie civil de l'École polytechnique de Montréal. Il a reçu un diplôme d'ingénieur civil de l'Université de Zagreb en Croatie, et un doctorat en sciences appliquées (géotechnique) de l'Université de Louvain en Belgique. En 1962, il est venu au Canada pour devenir professeur de géotechnique au Département de génie civil de l'Université Laval à Québec. En 1967, il a accepté le poste de professeur à l'École polytechnique de Montréal, où il a joint d'abord le Département de génie minier, et ensuite, en 1977, le Département de génie civil. En plus de l'enseignement, il a été impliqué dans la recherche en géotechnique, et surtout dans les domaines de la mécanique des roches et la géotechnique des régions froides. Depuis 1972, Dr Ladanyi dirige également le Centre d'ingénierie nordique de l'École polytechnique, qu'il a aidé à établir en 1970.

Dr Ladanyi est l'auteur d'environ 170 publications scientifiques, traitant divers sujets géotechniques. Depuis 1978, il a contribué à plusieurs livres géotechniques, et il est également coauteur du livre: 'An introduction to frozen ground engineering' (O.B.Andersland & B.Ladanyi, Chapman & Hall, 1994).

Le professeur Ladanyi accumule des distinctions depuis 1974, année où il reçoit le Prix scientifique du Québec. Il est successivement récipiendaire du Prix géotechnique canadien (1981), du Prix géotechnique belge (1987), du Prix commémoratif E.F.Rice de l'Université de l'Alaska (1991) et du Prix Roger J.E.Brown de la Société de géotechnique (1993). Il a également été nommé Fellow de l'Académie des sciences de la Société Royale du Canada et de l'Académie canadienne du génie.

Ses principaux domaines de recherche sont la détermination en laboratoire et sur place des propriétés géotechniques des matériaux terrestres, ci-inclus les sols gelés et la glace, surtout en relation avec la conception des fondations et des souterrains dans les sols, les roches et le pergélisol. Depuis les années 1960, il s'est intéressé au pressiomètre d'une façon continue, tant comme problème théorique, qu'il a traité dans sa thèse de doctorat en 1959, qu'un instrument pratique, qu'il a essayé d'utiliser non seulement dans les sables et les argiles, mais aussi dans les roches, les sols gelés et la glace. Depuis le début des années 1960, il a maintenu des relations amicales avec Louis Ménard, avec lequel il a souvent échangé des opinions sur la théorie et la pratique du pressiomètre.

A brief history of pressuremeter

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