OPENING REMARKS

Good morning, good afternoon and good evening. It is at once a great honor and distinction, as well as a real pleasure for me to welcome all of you here at this Second Shotcrete Conference. We are happy that so many of you have been able to make this week available to share with others the exchange of ideas and experience in the informal setting of an Engineering Foundation Conference. Among the 100 participants registered so far, there are no less than 34 from overseas, including three from as far away as South Africa and one from Japan. We of the Organizing Committee are particularly pleased to have found such an enthusiastic response among our European colleagues.

On behalf of the Engineering Foundation, Dr. Cole its Executive Director and on behalf of the Organizing Committee, it is a pleasure to acknowledge at this time the co-sponsorship of the following organizations: The Department of Transportation, the American Concrete Institute, the Society of Mining Engineers of AIME, and the Canadian Geotechnical Society.

It is a great personal pleasure for me to recognize at this time the members of the Organizing Committee:

Bob Bates, Supervisory Mining Engineer at the Spokane Mining Research Center of the USBM in Spokane, Washington.

Jan Blanck, Shotcrete expert and troubleshooter with Di-Mambro Majestic. He lives in Lanham, Maryland.

Robin Mason, also a consultant on shotcrete and senior engineer with the A. A. Mathews Company from their project office in Montreal, Canada.

Harvey Parker, Parsons, Brinkerhoff, Quade and Douglas in New York, where he is Head, Geotechnical Department. Previously he was with the University of Illinois.

Tom Reading, Materials Engineer from the Missouri River Division of the Corps of Engineers in Omaha, Nebraska.

In addition, the committee has had the active participation of two associate members: Hans Egger of Meynadier in Zurich, Switzerland and my colleague, stand in, helper and coordinator, Ed Cikanek of Harza.

I wish to acknowledge the continuous, unflagging support of Dr. Cole's staff of the Engineering Foundation in New York.

Three years and three months ago, we met in South Berwick, Maine to discuss shotcrete as a means for stabilizing underground openings. Recently, I glanced through the 16-page report I prepared for my own company. I was impressed with the broad and wide ranging discussions of successful (and some not so successful) endeavors and also of the many problems that still remained. I hope to see some of these questions answered here, at least I trust that new light will be thrown on all of them, including such interesting controversies as wet vs. dry process, the effect of accelerators on durability, the bond at the shotcrete/rock interface, better control of rebound, quality control of shotcrete in place, improvements in delivery to the nozzle and last, but not least, improvement of specifications and contractual conditions.

I trust the exchange of experience with our many friends from abroad will be useful and beneficial for all, will contribute in particular to a more wide ranging application of shotcrete on the North American continent, and further clarify the ongoing discussions of the proper place for shotcrete applications. I hope this conference will contribute to the better use of shotcrete, to a better understanding among the sceptics and to the advancement of both the science and the lart of its application.

J. A. Veltrop
Conference Chairman

KEYNOTE ADDRESS

by

E. E. Mason*

I was invited to speak here today as we were early users of coarse aggregate shotcrete on this continent. It might be of interest to tell you how we became involved.

I first heard of its use in tunneling from Helmut Kobler, a project superintendent of one of the mixed ground projects on the Montreal Subway in 1964. He had been in charge of construction of twin vehicular tunnels in Venezuela, one driven with conventional steel supports and the other with shotcrete. The latter was under the direction of Rabcewicz.

Kobler's lucid descriptions of the relative difficulties in both headings, supported by a collection of large photographs was impressive. It seemed evident a new and improved method had been developed of tunneling support in poor ground.

We had used gunite as a sealant against ravelling in the arch of an unsupported section of a tunnel in downtown Vancouver in 1957. While the application proved effective, it did not suggest itself as a substitute for the steel supported sections underway.

---

* President, Dolmage, Mason & Stewart Ltd.
Vancouver, Canada

The 1965 Rabcewicz article in "Water Power" was the first documented account that came to us, of the use of coarse aggregate shotcrete for support in poor to very poor ground.

In particular, it offered a practical alternative to spiling or fore-poling, an unnecessarily slow and painful exercise usually in rock. An early personal experience had been the mining of 18 acres of a bed of gold-bearing gravels at 120 ft. depth. In corollary, the relative unskillfulness and slow tempo of work in unstable and caved rock obviously compounded the difficulties with increased loadings.

The use of shotcrete offered an immediacy of application and an increase in standing time, at least. The differentiation made between incipient and detrimental loosening also rang the bell of past experience. Descriptions of work done were impressive, having regard to the difficulties that could be expected with conventional support.

We proceeded to gather what we could in German and Italian literature for translation, with particular interest in guidelines used and product application and standards; of which probably the most useful were, in addition to Rabcewicz, the papers of Drogsler, Linder and Rotter. Among papers printed in English, Claes Alberts' represented proven practice that had become routine in the extent of its successful application.

In 1966, we were retained by Canadian National Railways for the construction of a tunnel under a dormitory area of Vancouver, B.C., through semi-indurated tertiary sediments and glacial tills. Ample surface exposures and drill cores indicated the necessity of support and lining throughout. We decided on shotcrete support as a viable option.

A visit by John Stewart and myself to the Craigmont Mine in B.C., where wet-mix shotcrete was under test, confirmed our decision. A highlight in the mine's experience was a 50 foot drift, just completed in finely shattered graphitic schist. It had been considered too dangerous to muck out without spiling. Shotcrete had been tried, applied above the muck pile, and stood as a monument of a simpler technique in caving ground.

Failing acceptance of bids, we participated in negotiating a contract with the low bidder, Northern Construction and J. W. Stewart Ltd., Noel Lambert, President. We remained responsible for construction and performance. Fred Langfeldt was project manager. The method, naturally, was received with scepticism.

Next, we both visited Switzerland, Austria and Italy, with the Aliva people, and in company of representatives of the contractors. Much of what we saw of interest chiefly in the mechanics of shotcrete application. An exception was a freeway tunnel in Italy advanced with shotcrete in soft, wet, clayey rock, the perimeter being advanced with shotcrete first to receive steel ribs. The remainder of the cross-section formed a diminishing wedge-like shotcreted belly reaching some sets distant behind the face. There was some discussion as to the need of the steel.

Entry in the C.N.R. tunnel commenced August 1, 1966 with standard steel support in soft, water-logged, crushed and coaly shale. Converted quickly to top heading, fore-poling was commenced. The surface drainage with the slow advance made quite a mess, slime pouring through the hay-packed lagging. It provided the opportunity to start shot-creting.

As normally, short sections of wall plates were advan-ced and a ring cut to accommodate the steel arch. The ring was excavated in short sections, each section being shot-creted before continuing with the next, the face also being held with shotcrete. As the ground improved the steel sets were extended to 4 foot centres. With the introduction of a stronger shale in the roof, two sets at 6 foot centres completed the steel rib and shotcrete supported section of the tunnel in rock. Certainly the crushed shale ground had improved with water control, but the shotcrete could be credited with limiting loosening at and beyond the face.

Subsequent advance of this heading was largely routine, such difficulties as occurred as could be expected of a newly introduced technique. The project was fortunate to have its own mixing plant, with a quick drop to the tunnel, and grading was to Drogsler standards, and ready reference was had to Kobler's article in ACI Publication SP-14. Walter Lang of Aliva, Switzerland, initiated the shotcreting.

Control of shotcrete application and auxiliary reinforcement, and of blasting practice, was monitored on site throughout the working hours. Numerous photoelastic and three pressure cell stations were set up to monitor arch pressures. Perfo-bolted sections totalled 1,660 feet, emplaced radially in three, four and six-bolt patterns. Of this, 1,450 feet was required in the final 1,700 feet of brittle shales approaching break-through to the South Heading, which was driven with standard steel support in till. Total length supported with shotcrete was 10,742 feet. The section in till was 1,244 feet.

We early reached the conclusion the till section could very well have been done with shotcrete and bolting. Thus, in the construction of a 16-foot diameter ventilation shaft, it was sunk with shotcrete and fully grouted bolt support 70 feet through till, thence expanded in rock to form the Fan House at tunnel elevation. Shotcrete thicknesses were six inches on the arch and four inches on the walls, and without wire mesh reinforcement. Accelerators were used on the arch, and on the walls only when wet.

Following detailed inspection and mapping at the completion of the work, it was decided the shotcrete lining provided an adequate final support. The rock shotcrete bond was examined by drilling at questionable locations, as we believed bond strength was of primary importance in gaining the composite structural rock mass-shotcrete effect. Instrumentation loadings had levelled off some time past.

A tendency towards minor cracking was found migrating from rock protruberances with a shotcrete thickness of one inch or less. A section of the arch where calcium chloride had been substituted when a satisfactory accelerator was unavailable had developed tension cracks soon after application. No further movement was found a year or more later.

At last inspection, April 1976, by John Stewart and C.N.R. engineers, no changes could be detected. Minor variations were found in the Gloetzl cells. Readings, however, showed pressure levels similar or lower than 1968.

We have worked since in a wide range of ground conditions, (though by no means the extremes documented in NATM literature) including participation in several instances of restoring caved ground in tunnels. On the whole such work as we took was confined to that we could direct and monitor performance. Major projects of lengthy duration were the 28 miles of Emisor Central outfall in Mexico City, and the central third of the 50 mile Orange and Fish rivers diversion tunnel in South Africa.

Shotcrete, properly mixed and applied, with or without fully grouted rock bolting, has been capable of coping with any ground in our experience, including the restoration of caved ground, soft ground tunnelling, rock stabilization of canyon walls along existing railways and highways, and a number of shoring jobs in rock and soils.

We have preferred the fully grouted untensioned bolt, initially the perfo-bolt (which suffers from carelessness in drill hole tolerances); alternatively, a simpler rebar thrust into a fully grouted hole, essentially the Swedish SN bolt. Up-holes require a viscous grout, for which the Moyno pump is an effective placer. Bolting of this type was standard at one of our largest metal mines, used in spans up to 60 feet. We found this practice also existed in the South African gold mines.

Thus, in the Mexico project, our first work was in a transition from a 26 foot Boston horseshoe to two 20 foots at 150 foot depth. Maximum span reached was 56 feet, height 30 feet, the ground consisting of flatly-dipping, saturated sandy and silty tuffs of 28-70 psi compressive strength (2.0 - 5.0 TSF soil criteria). A top heading was advanced full face, once standing-time had been established, the core being lightly blasted, the perimeter hand trimmed, and the bench following in seven-eight days. An 18-24 inch bed of unconsolidated sand passed through the working, delivering surges of water to total deliveries of 350-400 gpm. Damage was caused by voiding at one springline, and massive voiding occurred approaching invert level. The invert reached a semi-liquid state complete with water boils.