

McMahon & Mann
Consulting Engineers, P.C.

COST PROPOSAL

PHASE II: CONDITION ASSESSMENT AND EVALUATION OF ROCK REINFORCEMENT

ALONG I-93

BARRON MOUNTAIN ROCK CUT

WOODSTOCK, NEW HAMPSHIRE

Prepared for:

**The New Hampshire Department of Transportation
Bureau of Materials and Research
Concord, New Hampshire**

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Overview

The proposal for Phase II of this research includes invasive testing of selected rock bolts and tendons to verify results from Phase I, including NDT, condition assessment and service-life estimates. Invasive testing shall include lift-off tests; and physical, chemical and metallurgical testing on steel and grout samples retrieved from exhumed reinforcements. Replacement bolts must be installed prior to invasive testing of the reinforcements. We propose that two of the replacement bolts be instrumented with strain gages to facilitate future monitoring. The following recommendations include details of the test program, estimated costs and a proposed schedule.

MMCE proposes that a total of five rock bolts be selected for lift-off tests and subsequently exhumed. In addition, two tendon reinforcements should be exhumed. The test program will include some reinforcements with questionable condition, and some reinforcements considered to be in good condition, based on the results from NDT. Table 1 is a summary of the reinforcements we propose to include in the Phase II test program.

Table 1. Reinforcements Proposed for Phase II Testing

Bolt #	Station	Block Number	Length (ft)	Condition Assessment (NDT)	Comments
4	1775+15	23	30	Good	No apparent loss of prestress; relatively good quality grout; not likely corroded
5	1775+00	23	25	Questionable	Apparent loss of prestress; relatively poor quality grout near free end; possible loss of cross section or kink in bolt; very likely corroded
17	1775+45	11	25	Questionable	No apparent loss of prestress; relatively poor quality grout for full length; very likely corroded
11	1774+15	22	25	Questionable	Apparent loss of prestress; relatively poor quality grout along near the bonded zone; likely corroded
22	1776+75	6	25	Good	No apparent loss of prestress; relatively poor quality grout for full length; not likely corroded

Table 1. Reinforcements Proposed for Phase II Testing (continued)

Tendon #	Station	Approx. EL. (ft)	Length (ft)	Condition Assessment (NDT)	Comments
1-2	1774+50	735	60	Good	Relatively poor grout quality; not likely corroded
2-2	1775+00	735	60	Questionable	Relatively good grout condition; likely corroded

Description of Testing and Sampling

Lift-Off Tests

Lift-off tests will be performed on selected rock bolts as described in PTI (1996). Lift-off tests are conducted to confirm the magnitude of the load carried by the rock bolt. Load will be applied to the end of the rock bolt with a center hole hydraulic jack. The lift-off load is determined by applying load to the end of the rock bolts to lift the anchor nut off the bearing plate (without turning the nut). Subsequent to determining the liftoff load, the rock bolts will be overcored.

Overcoring

Five rock bolts and two tendons will be selected for exhumation by overcoring. Overcoring may be accomplished using a hydraulic drill unit traveling along a steel bar anchored to the rock face at an adjustable angle. Water shall be used to lubricate the bit and core barrels and to flush away the rock powder. The drilling process should be started after anchoring the drillmount into the rockface and aligning the drill and first core barrel with the bolt. Alignment of the drill and core barrel with respect to the bolt is critical if samples are to be retrieved from the full length of the reinforcement. The diameter of the overcore shall be larger than the diameter of the original drill hole such that the reinforcement and grout surrounding the reinforcement are retrieved. The drill hole diameter for the rock tendons is 3 inches, and for the rock bolts the drill hole diameter is approximately 1.625 inches (letter from NHDOT to Inland Ryerson dated December 11, 1973). A five inch core barrel should be sufficient for both cases, but the outer core of rock will need to be separated from the grout after removal from the drill hole.

There is some experience in the mining industry exhuming rock reinforcements. However, MMCE and could not identify any local contractors with prior experience. One contractor, with experience installing and testing rock reinforcements, was willing to make an attempt, but only on the basis of time and materials (i.e., the contractor does not guarantee success). MMCE expects that exhuming reinforcements will be a difficult task and **the chances for successfully exhuming reinforcements are uncertain.**

Reinforcements that are exhumed will be measured, sketched, photographed and carefully stored on-site prior to being cut into manageable lengths. The outer

part of the core will be split, the separated parts of the core will be photographed, and the steel reinforcements will be examined for signs of corrosion, loss of cross section or kinks/bends. Grout will also be examined to locate areas where cracking has occurred. Samples of cement and resin grout will be separated from the bars and sent to the laboratory for testing. When applicable, grout samples will be selected from areas where corrosion of the reinforcements has been observed.

Steel reinforcements will be cut and samples will be selected for metallurgical analysis, and physical testing including laboratory tension tests. Bar diameters will be measured at a number of locations to document loss of cross section, and, if pitting is present, pit geometry and location will be documented.

Laboratory analysis

Grout samples will be subjected to chemical and physical testing. Absorption of the grout will be evaluated as described in AASHTO Test Method T85 "Specific Gravity and Absorption of Coarse Aggregate." These tests will be performed on samples of polymer resin and Portland cement grout. Test results will be useful to examine the porosity of the grout, and assess the potential for diffusion of chloride or sulfate ions through the grouted annulus surrounding the reinforcements and the effectiveness of the grout to coat the reinforcements.

Samples of resin grout will be tested for hardness as described by ASTM D2583 to examine the consistency of the mixture, and areas where grout properties may have degraded.

Portland cement grout samples will be tested for chloride ion content as described by AASHTO Test Method T260 "Sampling and Testing for Total Chloride Ion Content and Concrete Raw Materials." Chloride concentration will be evaluated relative to position within the grouted annulus surrounding the tendon. This data will be useful to study chloride diffusion and the corresponding potential for depassivation of steel surrounded by Portland cement grout.

Samples of metal reinforcements will be subject to tension tests as described by ASTM A370. This will involve application of a measured load sufficient to cause rupture. Percent elongation (strain) will also be measured and the corresponding stress-strain curve will be presented. Results will be compared to ASTM specifications for A722, Grade 150, prestressing steel.

If excessive corrosion, pitting type corrosion, or evidence of stress corrosion cracking or hydrogen embrittlement is observed, then metallurgical tests will be performed on samples of metal reinforcements. Metallurgical test will include spectrographic analysis to assess the metal composition, and metallographic examination to observe the microstructure of the thread bar material.

Additional NDT

The NDT tests performed during Phase I will be repeated on elements selected for invasive testing. These tests are necessary to verify the baseline measurements prior to invasive testing. At the Request of NHDOT a company from the United Kingdom (UK), AMEC Group Ltd., will also perform their patented GRANIT integrity test to the same rock bolt reinforcements that were tested during Phase I. The GRANIT test is a type of impact test useful for assessing rock bolt prestress, and the condition of grout near the proximal end of the reinforcement. The GRANIT integrity test will provide a useful comparison with results from the NDT performed by MMCE.

MMCE also proposes that additional NDT be performed on reinforcements located above Elevation 820, North of Station 1777+00 that could not be accessed during Phase I. The services of a specialty contractor, equipped to access areas in difficult terrain, will be required to perform this testing. This may be the same specialty contractor retained to perform invasive testing, and install replacement reinforcements. MMCE proposes to test approximately 10 rock bolts and five tendons within this area. Additional ground water and weathered rock samples will also be obtained if feasible.

Monitor Replacement Reinforcements

At the request of NHDOT, MMCE proposes to attach strain gages along the replacement tendons that will be installed near Stations 1774+50 and 1775+00 at approximate Elevation 735 ft (see Table 1). Instrumented tendons will serve as transducers to monitor rock mass performance, and strain accumulation may indicate loss of service from nearby reinforcements. Strain gage readings collected over time may be a possible trigger for initiating detailed condition assessment of reinforcements as service-life is approached.

Five vibrating wire strain gages will be installed along each of the reinforcements for a total of 10 gages. Strain gages will be installed at distances of 5, 15, 25, 35, and 45 feet from the proximal end of each 60 feet long tendon. MMCE will install and wire the gages onsite, after tendons are delivered. The ends of the strain gages will be protected with a waterproofing compound applied over the mounting area and the gage will be protected with a metal cover. Centralizers shall be used along the tendon length to avoid contact between the strain gages and the wall of the drill hole during installation. Electrical cables shall pass through the centralizers towards the rock face where they will be collected at a junction box. The elevations of the access boxes will be such that readings will be possible by personnel while standing at ground level. MMCE will coordinate activities with the contractor to minimize the possibility of damage to the strain gages during installation of the tendon. MMCE estimates that the useful life of strain gages installed at this site will be approximately 10 years.

MMCE will collect four sets of initial readings corresponding to: (1) before the gages are attached to the tendon, (2) subsequent to attachment but before installation of the tendons into the drill hole, (3) after the tendons have been inserted into the drill hole, and (4) after the drill hole is grouted.

Proposed Tasks

MMCE will participate in Phase II activities with cooperation from the NHDOT. NHDOT will be responsible for site access and traffic control. This will include use of Jersey Barriers, posting of appropriate traffic control devices, and use of a 40 ft. manlift and truck crane, similar to the equipment used during Phase I.

MMCE will coordinate activities, perform NDT, observe invasive tests and the condition of reinforcements extracted from the site, install and take initial readings from strain gages on two replacement reinforcements, send selected samples to the laboratory for physical, chemical and metallurgical analysis, compare observed results with those from NDT, and render an opinion on the overall condition of reinforcements at the Barron Mountain site based on the results of NDT and invasive testing.

The following tasks are including within the scope of the Phase II condition assessment:

1. Prepare subcontracts and solicit required laboratory services. A specialty subcontractor will be necessary for performing lift-off tests, exhuming reinforcements, installing replacement reinforcements and providing access to reinforcements at the north end of the site for nondestructive testing. Laboratory services are required for analysis of electrochemical properties of weathered rock and groundwater (geotechnical testing lab); chemical and physical analysis of grout (materials testing lab); metallurgical analysis (metallurgy lab), and tension testing of metal specimens (structural testing lab).
2. Install vibrating wire type strain gages on two replacement reinforcements. This task will include procuring materials, supplies and equipment for installing strain gages, attaching strain gages to reinforcements, coordinating installation of instrumented reinforcements with the specialty subcontractor, taking initial readings of the strain gages, data processing, and reporting details of the installation and initial readings.
3. Invite AMEC Group Ltd. to perform their patented GRANIT integrity test on 20 selected rock bolts. Costs for this task include reimbursement of expenses including one person from AMEC to travel to the site and perform testing with the GRANIT system.
4. Perform fieldwork with subcontractor and observe performance of

- GRANIT integrity test. Perform NDT, observe lift off testing and exhumed reinforcements.
5. Prepare and send samples to laboratories for physical, chemical and metallurgical analysis.
 6. Analyze data collected from Phase II and compare to results from Phase I
 7. Prepare final report based on the results of Tasks 1-6. The report will include a summary and interpretation of results from Phase II, and recommendations for future monitoring and/or replacement and retrofit of existing reinforcements.

Schedule

MMCE expects to complete Phase II within a six-month time frame. The proposed schedule, shown in Table 2, assumes a project start date of June 15, 2004.

An onsite meeting with MMCE, NHDOT and the specialty contractor will be required as part of Task 1. The purpose of the meeting will be to clarify details of the scope, and discuss scheduling and coordination of activities for Phase II.

MMCE estimates that three weeks will be required for the fieldwork (Task 4), however, a two and a half month time frame is proposed to accommodate the schedules of MMCE, the specialty subcontractor and NHDOT.

Table 2. Proposed Project Schedule for Phase II

Task	Description	Begin	End
1	Prepare subcontracts and solicit required laboratory services.	6/15/04	7/01/04
2	Install vibrating wire strain gages	6/15/04	9/15/04
3	Invite AMEC Group Ltd. and GRANIT Testing	6/15/04	9/15/04
4	Perform fieldwork	7/01/04	9/15/04
5	Prepare and send samples to laboratory	7/01/04	9/15/04
6	Data analysis and interpretation	9/15/04	10/15/04
7	Final Report	10/15/04	12/15/04

Basis and Estimate of FEES

MMCE estimates the cost for Phase II to be approximately \$166,724.00 and this includes approximately three weeks of fieldwork, the cost of a specialty contractor to test and exhume existing reinforcements and install replacements, costs for attaching strain gages to two of the replacement reinforcements, and expenses for AMEC Group Ltd. to perform their patented GRANIT integrity test. MMCE has assumed that the NHDOT will provide traffic control and access to the site.

Itemized Budget

MMCE's estimated costs for the proposed research are presented in Table 3. The estimated Level of Effort by Task is presented in Table 4 and an Itemized Summary Budget by Task is presented in Table 5.

Table 3 – Phase II Itemized Summary Budget for MMCE

(a)	Direct Salaries:	
	K.L. Fishman	\$ 8137.50
	Senior Engineer	\$ 3180.00
	Project Engineer	\$ 3708.00
	Senior Technician	\$ 720.00
	Administrator	\$ 650.00
	CAD Operator	\$ 180.00
	(a1) Subtotal	\$ 16,575.50
	Overhead (124% × a1)	\$ 20,553.62
(b)	Borrowed Personnel:	\$ 0.00
(c)	Consultants:	
	AMEC Group Ltd. ¹	\$ 4695.00 ¹
(d)	Subcontracts:	
	Rock Reinforcement Contractor	\$ 78,638.38
(e)	Equipment Cost	\$ 4650.00
(f)	Materials and Services:	
	Metallurgy Lab	\$ 2000.00
	Structural Testing Lab	\$ 3000.00
	Materials Testing Lab	\$ 3500.00
	Geotechnical Testing Lab	\$ 2000.00
	Strain Gages and Cables	\$ 1350.00
	Copying	\$ 150.00
(g)	Commun. and Shipping:	\$ 1650.00
(h)	Travel:	\$ 6215.00
	Subtotal (b)+(c)+(d) + (e) + (f) + (g) + (h)	\$ 107,848.38
	Total	\$ 144,977.50
(i)	Fixed Fee (Total × 15.0%)	\$ 21,746.63
	Grand Total	\$ 166,724.13

¹ AMEC expenses are detailed in Table 5, Task 3.

Assumptions Used to Develop Scope and Cost Estimate

1. Travel expenses for Task 1 includes round trip mileage between Buffalo, NY and the job site, two travel days and three days per diem.
2. Costs for Task 2 are as follows:

Item	Cost	Unit	Qty	Total
VK4150 Strain Gage	\$120.00	ea.	10	\$1200.00
Cable	\$0.50	feet	300	\$150.00
Spot Welder	\$160.00	week	2	\$320.00
Read-out (MMCE)	\$165.00	week	2	\$330.00

3. Expenses for AMEC Group Ltd. described in Task 3 include round trip travel, between Manchester, UK and the job site, 8 days per diem (hotel, meals, rental car, gas) communications and shipping, and costs for manufacturing special adapters to fit the ends of the reinforcements. Approximately 20 reinforcements will be tested using the GRANIT system. NHDOT will provide access to reinforcements and traffic control in support of GRANIT testing. These activities may be conducted concurrently with Task 4. AMEC will be responsible for performing the GRANIT test, interpretation of the results, and presentation of results suitable for incorporation into the final report for the project.
4. MMCE will perform NDT as part of Task 4. NDT, performed in Phase I, will be repeated on five rock bolts and 2 tendon reinforcements identified for invasive testing as shown in Table 1. In addition, NDT will be performed on 10 more rock bolts and 5 more tendon reinforcements if access is provided to reinforcements located above Elevation 820 ft, North of Station 1777+00.
5. MMCE travel expenses for Task 4 includes round trip mileage between Buffalo, NY and the job site, two travel days and per diem for the duration of the fieldwork. MMCE assumes that the fieldwork will be completed in 15 days and will require two persons for nine of the days, and three persons for another six days.
6. A summary of the contractor's proposal and cost details relative to Task 4 are attached to this proposal. Contractor costs included in Task 4 include a three- man crew plus equipment for 15 days of fieldwork, and the cost of materials for replacement bolts. Costs of buying special drilling equipment for exhuming reinforcements are included in the contractor's mobilization cost. The contractor's costs include a 10% mark-up to the costs of materials and assume that the cost of materials for this project is \$2249.00. Actual prices may vary due to the fluctuation of the steel industry. The contractor's proposal includes scaling which has to be done for the safety of the workforce. MMCE assumes that NHDOT is responsible for removing debris generated from scaling by the contractor.
7. The contractor makes no guarantee as to the number of reinforcements that may be exhumed. MMCE expects that exhuming reinforcements will be a difficult task and could not identify any local contractors with prior

experience. **Therefore, the chances for successfully exhuming reinforcements are uncertain.**

8. The budget for Task 4 assumes that NHDOT will provide traffic control at the site and access to the reinforcements located below El. 820 ft. Site access will include use of a crane and basket and a forty foot man-lift to access bolts and tendons along the rock face.
9. MMCE anticipates that the rock bolt contractor selected for Task 4, will provide access to reinforcements located above El. 820 ft., north of Station 1777+00. Special rock climbing equipment and techniques may be required to access these reinforcements.
10. MMCE estimates that the following numbers of samples will be included in the laboratory test program as part of Task 5:

Description	No. of Samples
Tension tests of steel reinforcements	40
Metallurgical examination of steel reinforcement	10
Absorption and specific gravity test on grout samples	40
Chloride ion content on samples of Portland cement grout	30
Hardness test for resin grout samples	30
Samples of weathered rock tested for pH, sulfates, chlorides and resistivity	4
Groundwater samples tested for pH, sulfates, and chlorides	2

References

1. American Association of State Highway and Transportation Officials (AASHTO), 2002, Standard Specifications for Transportation Materials, and Methods of Sampling and Testing, 21st Ed., AASHTO, Washington, D.C.
2. American Society for Testing and Materials (ASTM), 2001, Annual Books of ASTM Standards, Volume 04.02, Concrete and Aggregates, ASTM, West Conshohocken, PA.
3. Post-Tensioning Institute (PTI), 1996, Recommendations for Prestressed Rock and Soil Anchors, Phoenix, AZ.

Table 4. Barron Mountain Project: Phase II Level of Effort by Tasks (Person-Hours and Costs)

		Time																	
		(%)																	
		Over																	
Principal		Contract	Task	Cost	Task	Cost	Task	Cost	Task	Cost	Task	Cost	Task	Cost	Task	Cost	Total	Hourly	Total
Staff Members	Role in Study	Period	1	(\$)	2	(\$)	3	(\$)	4	(\$)	5	(\$)	6	(\$)	7	(\$)	Hours	Rate (\$)	Cost (\$)
MMCE																			
K.L. Fishman	Principal Investigator	29.7	40	1050.00	10	262.50	10	262.50	150	3937.50	20	525.00	20.00	525.00	60.00	1575.00	310	26.25	8137.50
Staff	Senior Engineer	14.4		0.00		0.00		0.00	150	3180.00		0.00		0.00		0.00	150	21.20	3180.00
Staff	Engineer	17.2	30	618.00	10	206.00		0.00	60	1236.00	40	824.00	40.00	824.00		0.00	180	20.60	3708.00
Staff	Senior Technician	7.7		0.00		0.00		0.00		0.00	60	540.00	20.00	180.00		0.00	80	9.00	720.00
Staff	Administrator	4.8	20	260.00		0.00	10	130.00		0.00		0.00		0.00	20.00	260.00	50	13.00	650.00
Staff	CAD Operator	1.9		0.00		0.00		0.00		0.00	0	0.00		0.00	20.00	180.00	20	9.00	180.00
Σ Direct labor				1928.00	468.50	392.50	8353.50	1889.00	1529.00	2015.00	16575.50								
Overhead				2390.72	580.94	486.70	10358.34	2342.36	1895.96	2498.60	20553.62								
Total Hours			90	20	20	360	120	80	100	790									
Total Labor				4318.72	1049.44	879.20	18711.84	4231.36	3424.96	4513.60	37129.12								
Expenses				765.00	2200.00	4695.00	85838.38	14000.00	0.00	350.00	107848.38								
Fee (15%)				762.56	487.42	836.13	15682.53	2734.70	513.74	729.54	21746.63								
Totals				5846.28	3736.86	6410.33	120232.75	20966.06	3938.70	5593.14	166724.13								

Note: Hourly rates projected, based on anticipated salary adjustments.

Table 5. PHASE II: ITEMIZED SUMMARY BUDGET BY TASK

Task	COSTS						Total
	Wages	Overhead	Capital Equipment	Materials & Services	Commun. & Shipping	Travel	
Task 1	1,928.00	2,390.72	0.00	0.00	50.00	715.00	5,083.72
Task 2	468.50	580.94	650.00	1,350.00	200.00	0.00	3,249.44
Task 3 ¹	392.50	486.70	0.00	880	900.00	2,915.00	5,574.20
Task 4 ²	8,353.50	10,358.34	1,500.00	78,638.38	200.00	5,500.00	104,550.22
Task 5	1,889.00	2,342.36	2,500.00	10,500.00	1,000.00	0.00	18,231.36
Task 6	1,529.00	1,895.96	0.00	0.00	0.00	0.00	3,424.96
Task 7	2,015.00	2,498.60	0.00	150.00	200.00	0.00	4,863.60
Total	16,575.50	20,553.62	4,650.00	91,518.38	2,550.00	9,130.00	144,977.50

¹ Task 3 costs for materials & services, commun. & shipping, and travel are eestimated expenses for AMEC Group

² Task 4 costs for materials and services are the estimated cost of the specialty contractor and includes materials and supplies for exhuming reinforcements, lif-off tests, replacement reinforcements, and access for NDT.