Reinstatement of utility cuts: an innovative solution to an old problem

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REINSTATEMENT OF UTILITY CUTS: AN INNOVATIVE SOLUTION TO AN OLD PROBLEM

by

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Abstract **Résumé**

Poor performance of reinstated cuts is one of the major utility issues. A multitude of studies has been carried out since 1950 to understand the effect of cuts on road life expectancy and serviceability and to develop guidelines for reinstatement and management. The majority of these studies were either limited to a certain region and did not address all the factors involved or were oriented to the interest of a particular party. This made the outcome of these studies and its application limited to a certain area and non-transferable to others. A proposal to concentrate on solving the problem in a consortium framework, for the benefit of all concerned parties and the public, is presented. Four interacting research components are proposed to solve the issues related to construction practices, which in turn will ease the solution of issues related to planning and management.

1. Introduction

Every day, many utility cuts are made and restored in every city in the world during the installation of new services or repair and upgrading of existing facilities. Utility cut reinstatement is one, if not the, major problem for urban roads. The cities and utility providers see the problem differently. The latter claim that all problems are not related to cut reinstatement but to the initial design of the road itself and they call for better road design. On the other hand, cities define reinstatement as returning the road to its existing state, before the cut, in terms of life expectancy and serviceability. There have been many cases that were taken to court. The outcome of this bitter situation is that cities and utility providers are pointing fingers at each other.

Many techniques exist today for rehabilitating distressed pavement structures in highways. However, these techniques are not readily transferable to urban road cut reinstatement because of the unique characteristics of urban roads. There are no specific guidelines for assessing the performance and cost impact of utility cuts on urban roads.

To date, there are a number of studies that have dealt with the issue of utility cut excavations and restorations. Municipalities initiated some of these studies while others were carried out under the direction of some of the utility companies. Due to the lack of a forum where all concerned parties

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can discuss common issues and share information about planning, construction and management, all studies reviewed were either oriented to the interest of a particular party or limited to a certain region. The American Public Works Association (APWA) announced the establishment of a Professional/Educational/Technical Committee that is expected to recommend a format for guidelines for utility issues.

This paper presents a literature review on the-state-of-the art of utility cut restoration and proposes a comprehensive research package that will bring together all concerned parties from across North America in the framework of a consortium. The project will be mainly concerned with construction practice, while considering planning and management issues, and will deliver guidelines that will help practitioners arrive at effective reinstatement techniques and ease communication between parties.

2. Literature Review (State of the Art)

2.1 Introduction

An early study that dealt with cut reinstatement was carried out in 1950 at the University of California, Berkley. Since then, many studies have been carried out around the world. Most of these were focused on evaluating the impact of utility cuts on streets. However, few tried to set some guidelines for their reinstatement. A summary of the most important investigations is presented. The studies are grouped under North American, European and others.

2.2 North American Studies

2.2.1 Burlington, Vermont (1984)

The city of Burlington, Vermont hired ERES Consultants Inc. to study the effect of utility cut patching on pavement performance and rehabilitation costs. The study made use of a visual survey and a non-destructive evaluation using the falling weight deflectometer. Three methods were used to calculate the Pavement Condition Index (PCI). The study achieved little success in presenting a quantitative measure of the goodness of fit of the derived curves and in discussing the adequacy of the limited data used to provide statistically significant conclusions (APWA, 1997).

2.2.2 Gas Research Institute (1984)

In 1984, the Southwest research division of the Gas Research Institute (GRI) investigated the problem of trench settlement and came up with a solution in the form of a newly developed soil stabilizer. This product, commercially available under the name MiSeal/Perma-Soil additive, uses the free moisture in the excavated material to form a hydrogel that quickly dries, strengthens and bonds to native materials. It was stated that the additive works well with virtually every type of soil and when mixed with the backfill soil, it will make it retain its strength properties and prevent excessive subsidence under the impact of vehicular traffic (GRI, 1984).

2.2.3 Southern California Gas, Dames and Moore (1984)

The objective of the study was to evaluate the field compaction, soil types and compaction characteristics of bell holes reinstated in the Los Angeles area. The analysis concluded that only 20% of the bell holes inspected met the set 90% maximum dry density criterion and there is evidence that inadequate compactive effort was used. Furthermore, many of the silt and clay soils were too wet to be properly compacted and needed to be dried or stabilized.

2.2.4 Metro Toronto, Ontario (1985-1987)

Based on the recommendation of previous studies, Metro Toronto launched two studies to investigate the possibility of using unshrinkable materials and a single stage restoration method. The outcome of these studies is the adoption of these materials as a backfill by Metro Toronto. However, the use of a single stage restoration procedure did not present any economic advantages and its quality varied excessively with variability of workmanship. The adequacy of these materials with respect to frost action and freeze/thaw behavior is yet to be evaluated.

2.2.5 Southern California (SoCal) Gas, Evans and Coulter (1988)

This study was an extension of Dames and Moore work. It had an objective to develop practical and simple field tools to assess the adequacy of backfill compaction. The outcome of the study is a new field procedure. The use of a dynamic cone penetrometer and moisture meter was adopted to measure relative in-place dry density and moisture content, respectively. The SoCal Gas Company, in response to pressure from the city, initiated the study and $900,000, per year, savings were to be gained by adopting this new procedure.

2.2.6 Southern California Gas, Are Inc./Institute of Gas Technology (1989-1995)

Are Inc. and the Institute of Gas Technology conducted an extensive investigation to evaluate repair patches for asphalt paved streets. The study included three main components: a) a literature review, interviews and questionnaire surveys (1989), b) a theoretical analysis to assess critical elements of the repair (1990), and c) field experiments to confirm finding of the theoretical component (1995). The first component identified the density of the backfill, the soil type and the cut configuration as the major factors affecting the behavior of reinstated cuts. The second phase of the study investigated cuts using a finite element program assuming linear elastic materials and static conditions and employed an idealized circular cut shape in the analysis. The last component included two studies at two different streets in California and concluded that there is no significant benefits gained by using T-section instead of the standard configuration.

2.2.7 San Francisco, California (1992)

The department of public works at the county of San Francisco commissioned the Engineering Design Center at San Francisco University to study the impact of utility cuts on the service life of the city streets, 98% of which were asphalt paved. Using a pavement condition score, the study showed that increased levels of utility cuts accelerated the pavement aging process. The analysis concluded that a reduction in the service life of pavements of 30% and 50% is expected in streets with 3 to 9 cuts and streets with more than 9 cuts, respectively.

2.2.8 Cincinnati, Ohio (1991-1994)

The Cincinnati Infrastructure Institute of the Department of Civil and Environmental Engineering at the University of Cincinnati, on behalf of the City of Cincinnati and the American Public Work Association, conducted a study to investigate the impact of utility cuts on the performance of street pavements. A utility cut management system (UCMS) was developed based on an objective measurement of deflections and a subjective visual distress evaluation. The intended use of the UCMS is for identifying conditions of utility cuts in a city and assigning priorities for their maintenance and for monitoring newly repaired cuts. The study was limited to the city of Cincinnati.

2.2.9 Kansas City, Missouri (1995)

The study assessed the effect of utility cuts and patch construction on the structural capacity of the surrounding pavements. The results indicated that the area around the edges of the patch is about 50-65% weaker than the center of the patch (APWA, 1997).

2.2.10 Los Angeles, California (1996)

This is an in-house investigation conducted with the assistance of the principal investigator of the Burlington, Vermont study. The city of Los Angeles used the pavement condition index (PCI) to compare the surface condition of the patched and unpatched sections of roads. The investigation followed the same approach and line of analysis adopted in the Burlington study and revealed similar conclusions: patched sections have a life expectancy lower than unpatched ones.

2.2.11 Interlocking Concrete Pavement Institute (1996-1997)

The Interlocking Concrete Pavement Institute presented an innovative procedure for utility cut reinstatement, which involves the use of interlocking concrete pavers. Pavers are made of high strength concrete. The local gas company in the city of London, Ontario started experimenting with this method in 1994 and used the pavers as temporary repair during winter with the intent of being removed and replaced by hot mix asphalt in the spring. However, the reported good performance of pavers motivated the city to leave them indefinitely.

2.2.12 Humphrey and Parker (1998)

Three-dimensional finite element analysis was used to study the magnitude and extent of distress associated with cuts in urban roads. It was concluded that when an utility cut is made, a stretching zone is created behind the unsupported face of the utility cut, extending up to 3.5 feet into the pavement structure. The fill/subgrade layer seems to be the subject of the worst distress. Based on the results of the analysis it was recommended that the utility cut be restored up to the top of base elevation and to induce a cut-back equal to the distance of distress. The whole-uncovered area is then compacted and resurfaced.

2.3 European Studies

2.3.1 Laboratoires Central de Ponts et Chaussees (LCPC)/Service d'Etude Technique des Ponts et Autoroutes (SETPA), France (1981-1994)

In 1981, LCPC and SETPA of France published a technical note about trench reinstatements. The study was well planned and implemented. All concerned parties had a training program to make sure they all followed the same format in carrying out the investigation. Furthermore, the reinstatement sites were monitored for 13 years and the practitioners consider it a success. This motivated the publication of a guide for trench reinstatements in 1994. The success is attributed to the collaboration of all concerned parties all over France. The LCPC and SETPA consider compaction control as the major component in trench reinstatement. The following are the major features in the French guide:

- A density objective is set for every layer
- Typical cases of trench locations are identified
- Tables of materials to be used for each density specified are presented
- Tables of recommended and possible repair for each road structure as a function of traffic level are shown
- Characteristics of compacting equipment are given
- Tables of compaction to achieve specified density for different materials are listed: lift thickness and number of passes are defined as a function of material to be compacted, as well as proposed construction equipment to be used
- Quality assurance steps are defined and quality control tests are listed.

2.3.2 British Gas, United Kingdom

The Engineering Research Station of British Gas examined trench excavation and reinstatement practices and concluded that using the excavated materials as backfill poses several difficulties related to the compatibility of these materials. The study presented foamed concrete mix as a backfill alternative with performance characteristics equal to that of conventional granular fills. Furthermore, the study suggested visual inspection to identify unsuitable materials for backfill and a micro-processor-controlled version of the Clegg impact soil tester to monitor compaction.

2.4 Other Studies

2.4.1 Central Road Research Institute, India (1984)

In 1984, the Central Road Research Institute conducted an investigation and concluded that the general experience with prevailing practices for the reinstatement of cuts is not satisfactory and that the affected portions are usually poor in riding quality and require repeated attention. The Institute developed a method for cut reinstatement in urban roads. The method recommendations are:

- All excavated granular materials should be screened in two sizes 60-40 and 40-20 mm
- The granular layers should be constructed so that the 60-40 mm portion is used in the lower layer of the backfill and the 40-20 mm material in the upper layer.
- Two layers, of 75 mm thickness each, of built-up spray-grout are laid over the granular material
- The top 20mm should be covered with a bituminous premix carpet and a bituminous seal coat should be applied to prevent water penetration.

2.4.2 Ministry of Work and Development, New Zealand (1987)

The road research unit conducted an investigation of trench excavation and reinstatement in New Zealand. It was concluded that there is a lack of firm guidelines. Compaction was promoted as the primary element to achieve better trench reinstatement.

3. Unresolved Issues

For the past fifty years, different parties have been looking into the utility cut problem but many issues remain unresolved. Previous studies fall short in addressing all aspects related to coordination, planning, construction and management of utility cuts.

3.1 Management

Many management schemes were identified while reviewing these studies. Construction control, specifying the use of alternative innovative backfill materials, performance-oriented and fee structured or bond managed schemes are all listed as potential techniques for managing utility cut reinstatement. However, the performance-based scheme received little attention since it requires sound analytical tools, laboratory and field techniques to provide realistic performance predictions to support management in making the correct choices. Current analytical models do not posses such capabilities and the performance-based scheme has not materialized.

3.2 Construction

Due to the fact that there is no forum where municipalities and utility providers can discuss issues of common interest, all parties turned to the political process to secure their interests. As a consequence, few studies were initiated to deal with construction issues. Some limited studies defined guidelines for reinstatement but failed to effectively address all the factors involved. The following is a list of factors left out or not fully investigated:

- Cuts: the influence of the cut geometry (square, rectangle and circle), the cut orientation (longitudinal vs. transversal) and the cut position in the road (in the wheel path, near the curb) has been almost ignored. However, some investigators tried to address the cut configuration influence by comparing the performance of standard and T sections.
- Cutting and excavation tools and methods: the effect of different cutting and excavation tools and methods on the existing structures and on the reinstated cuts remains almost undefined.
- Materials: all studies (including the ones presenting innovative materials) failed to evaluate the influence of seasonal variations such as temperature and moisture. Furthermore, they did not present an extensive evaluation of natural soil materials for use as backfill or of most materials used to reinstate utility cuts in terms of characteristic response of the pavement.
- Construction procedures: no formal evaluation and/or comparison of different construction techniques have been done. Consequently, the following questions, among others, remained unanswered: Is the specified degree of compaction suited to satisfy performance requirements? Is the number of passes compatible with the material, equipment and lift thickness used. Are the existing procedures good enough to satisfy performance requirements? If the answer is yes, why are the reinstated cuts not performing adequately? In

the case where the procedures are not adequate, what are they lacking? Can they be improved or should other alternatives for reinstatement be sought?
- Equipment: the sensitivity of reinstatement techniques to the equipment used, and its characteristics have not been investigated. The best equipment to be used for a specific situation (cut specifics, material specifics...etc) has yet to be defined.
- Quality control: no evaluation of the effectiveness of existing quality control measures in satisfying performance requirements have been achieved. Do we need more appropriate quality control measures?

A few studies have analyzed the problem analytically employing the finite element technique. These provided a better understanding of the problem and constitute a base for further analysis. The analytical approach can be a very powerful tool for analyzing all the factors involved especially when combined with laboratory and field tests for benchmarking and validation. The analytical method is fast and inexpensive compared to full-scale field-testing.

4. The Need for a Comprehensive Research Program

4.1 Introduction

Almost half a decade after utility cut restoration studies started, the issue is still standing as one of the sources of contention between municipalities and utility providers. Municipalities claim that the utility work is inadequate and costs them a lot of money to revisit those sites. Utilities argue that municipal requirements are excessive and usually ineffective. In fact, after all the investigation and analysis conducted, the concerned parties have no clear answer as to what is causing poor performance and what constitutes a good restoration technique. The majority of the existing solutions were developed for a specific region under certain climate and environmental conditions. Other solutions are considered by many as oriented to the interest of a particular party. A large number of small municipalities, who do not have funds to initiate their own studies, face problems when adopting solutions developed in other localities.

The National Research Council Canada's Institute for Research in Construction (IRC) and the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) have taken the initiative to gather together concerned parties for a tight collaboration, a sound diagnosis of the problem and a practical solution that takes into account all the factors involved and addresses the concerns of all parties.

4.2 Objective

IRC and CRREL have joined forces to build a collaborative research and development project that will produce practical, cost-effective solutions to extend the expected service life of urban roads that experience extensive road cuts.

This initiative is the first comprehensive project of its type to bring together organizations from across North America with participants from each of the stakeholder groups (e.g., municipalities, utility providers, material suppliers and equipment manufacturers) which are intimately involved in the reinstatement of urban road cuts.

The consortium project, through an integrated research approach that includes laboratory testing, analytical modeling, field investigation and accelerated loading tests, will produce deliverables that will help practitioners arrive at effective reinstatement practices to mitigate today's perceived problems.

4.3 Deliverables

Deliverables of the project include:

- Guidelines for best reinstatement practices that include technical specifications and quality control measures suitable for real-life construction activities;
- A structural design procedure for the utility cut/pavement system that considers the available technical expertise of municipal and consulting engineers and that permits the incorporation of data related to prevailing traffic and environmental conditions; and
- An easy-to-use, performance prediction, software tool to support decision-makers in conducting life cycle cost analysis based on evaluation of alternative reinstatement options.

4.4 Technical Approach

A comprehensive research program has been developed to address the concerns of all stakeholders, namely municipalities, utility providers, material suppliers and equipment manufacturers, involved in the reinstatement of road cuts. The approach consists of two information-gathering tasks and four major interconnected research components. The information-gathering phase includes a state-of-the-art literature review and a survey questionnaire. The questionnaire, which will be prepared after identifying from the literature search factors considered important to the performance of restored utility cuts, will be distributed to project participants. It will seek to obtain information regarding local reinstatement practices covering both construction techniques and management schemes used. The survey will also inquire about observed and recorded performance histories of techniques and materials that were successful and those that were considered unsuccessful.

The four research components of the proposed project are designed to respond to the specific elements of the problem, including the pavement structure, the material used as backfill and the construction-related variables, all of which influence the performance of the restored utility cuts.

4.4.1 Structural Analysis

Analytical modeling will be used with several tasks to overcome any limitations associated with conducting an experiment on a specific site and, later, to produce a general solution based on that experiment. The absence of effective analytical modeling in previous studies rendered most of them less effective in recommending a widely accepted solution to reinstating utility cuts.

Structural analysis will be carried out using an IRC proprietary, state-of-the-art, analytical model that uses a micro-mechanical damage-based approach. The model naturally blends the theories of plasticity, fracture and viscosity to determine the overall inelastic responses of the system under loading conditions (e.g., traffic, temperature and moisture). The model also includes an improved format for material characterization pertaining to both asphalt concrete and materials used as backfill. The model accounts for the strong heterogeneity of asphalt concrete by considering the distinct properties of the mix composition. Results from digital image analysis will be used as input to the model to quantify aggregate shape and size, particle distribution and orientation in a compacted asphalt concrete layer. The characteristic response of unbound aggregate materials and other engineered backfill materials will be modeled using the resilient modulus parameter. Analysis of damage predictions provided by the analytical model will allow for identifying the primary variables associated with the structure, backfill material and construction, which have an impact on the performance of reinstated utility cuts. These variables may include cut geometry, cut location and orientation, layer thickness, type of backfill and seasonal variations in material properties. Results obtained from this exercise will be used in a subsequent parametric study designed for quantifying the effect of each of the significant variables identified. The output from the structural analysis will be used in designing field and accelerated loading experiments and in developing a structural design procedure as one of the deliverables of the project.

4.4.2 Material Characterization

The laboratory investigation will focus on characterization of materials used to reinstate utility cuts, which may include the following:

- A number of subgrade soil types will be evaluated to determine any special measures needed to avoid unfavorable performance associated with this layer of the pavement;
- Flowable fill materials used underneath utility pipes to provide adequate support by filling the space beneath the pipe;
- Backfill materials used above the utility pipe and up to the level of the granular road layers (these materials may include excavated natural soils removed during the cutting stage, borrowed soil, recycled materials or other engineered backfills such as controlled low strength materials [CLSM] and fly ash-stabilized materials);
- Unbound granular materials used as bases and sub-bases within the road structure; and
- Bituminous materials used as road surfaces, which may include hot-mix asphalt (HMA) or cold mixes of different compositions.

Material characterization will include a number of physical tests commonly used for quality control (QC), such as those used to determine density gradation, voids content, etc. Mechanical tests will also be conducted to determine the characteristic response of individual materials used in the different layers under simulated traffic and thermal loading conditions. Sample preparation and conditioning that proceed testing involve the achievement of specific physical properties, moisture saturation levels and temperature conditions. The study will rely on the determination of the resilient properties of all unbound aggregate materials and, therefore, consider the impact of changes in the material condition associated with seasonal variations. The proposed test uses dynamic repetitive loading to simulate traffic action. Data acquired from this test reflect both elastic and permanent deformation responses, which will later provide the analytical model with inputs needed for structural analysis and damage prediction. These results will also be used in pilot field experiments and in the design of various reinstatement options for evaluation in the accelerated loading facility located at CRREL. Furthermore, the results of the laboratory investigation will be used to evaluate the effectiveness of existing quality control measures in satisfying performance requirements. In case of their failure to do so, modification to new testing techniques will be proposed to replace currently used tests. Every effort will be made to avoid complicated test procedures that may prove impractical in the field.

4.4.3 Field Experiments

This phase of the investigation is dedicated to studying construction-related variables and evaluating the potential for using NDT techniques for designing utility cut reinstatements and predicting their performance. Information obtained from the two information gathering tasks and the analytical modeling will be used to design the field experiments. Test sections (road cuts) will be built in different cities, within defined categories related to the environment, traffic, foundation materials and construction practices. The fact that road damage associated with poorly performing reinstated utility cuts occurs within the first year of service, will enable the research team to transfer learned experience to the accelerated loading experiment. The field experiments are also critical for identifying construction-related variables that are neglected in current practices. The test sections will be instrumented to collect data needed for analysis and to provide information related to the effectiveness of quality control measures adopted in various regions.

In the past, NDT techniques did not provide conclusive information for effective determination of the impact of utility cuts on the performance of roads. However, coupled with the proposed system of pavement analysis based on implementing a micro-mechanical damaged-based model, NDT will be more effective in providing the data needed for the evaluation process. IRC's model is capable of analyzing the structure while considering pavement in-service condition, which includes such discontinuities in the road as joints and cracks. This built-in capability will eliminate the shortcomings associated with the use of the current systems developed for analyzing the results of NDT tests, which completely ignore the impact of in-service condition on the response. Performance data collected throughout the project life will be used to improve the ability of NDT techniques to support the task of managing utility cuts through the evaluation of the structural integrity of the pavement with and without the cut. The project will also study the potential of using NDT data in supporting the design of utility cuts in the future.

4.4.4 Accelerated Loading Tests

Experimental sections with different road structures, cut geometry (width/depth/shape), backfill materials and construction specifications will be built and evaluated in the accelerated loading facility located at CRREL. The design of full-scale test sections will be based on preliminary findings obtained from the literature, initial results of the structural analysis and other information from a selected number of field experiments conducted across North America. The test sections at CRREL will be constructed under controlled conditions to examine a number of variables known to influence the performance of reinstated utility cuts. The variables investigated will include a spectrum of structural, geometric, material and construction parameters.

Following the completion of construction of the road sections, an initial conditioning of these sections, using the accelerated loading equipment, will be performed to simulate the period that precedes cutting of the road. Cuts will then be made across the built sections. After laying the utility pipes within these excavations, cuts will be restored using the selected materials and reinstatement techniques. Accelerated loading will then be resumed to the prescribed number of cycles, and a number of distress types will be monitored and recorded for analysis. Moisture and temperature conditions within the experimental sections will be controlled at pre-set values selected to represent those prevailing in different climatic regions of North America. Recorded accumulated damage will be used to quantify the performance of the techniques tested. The techniques evaluated will include some representing currently used practices as well as others developed during this project.

Performance determined in the accelerated loading facility will be compared with that predicted by the analytical model to validate the model. The validated model will then be used to expand the analysis beyond the ranges of the variables studied during accelerated loading tests. A flowchart of the proposed approach is shown in Figure 1.

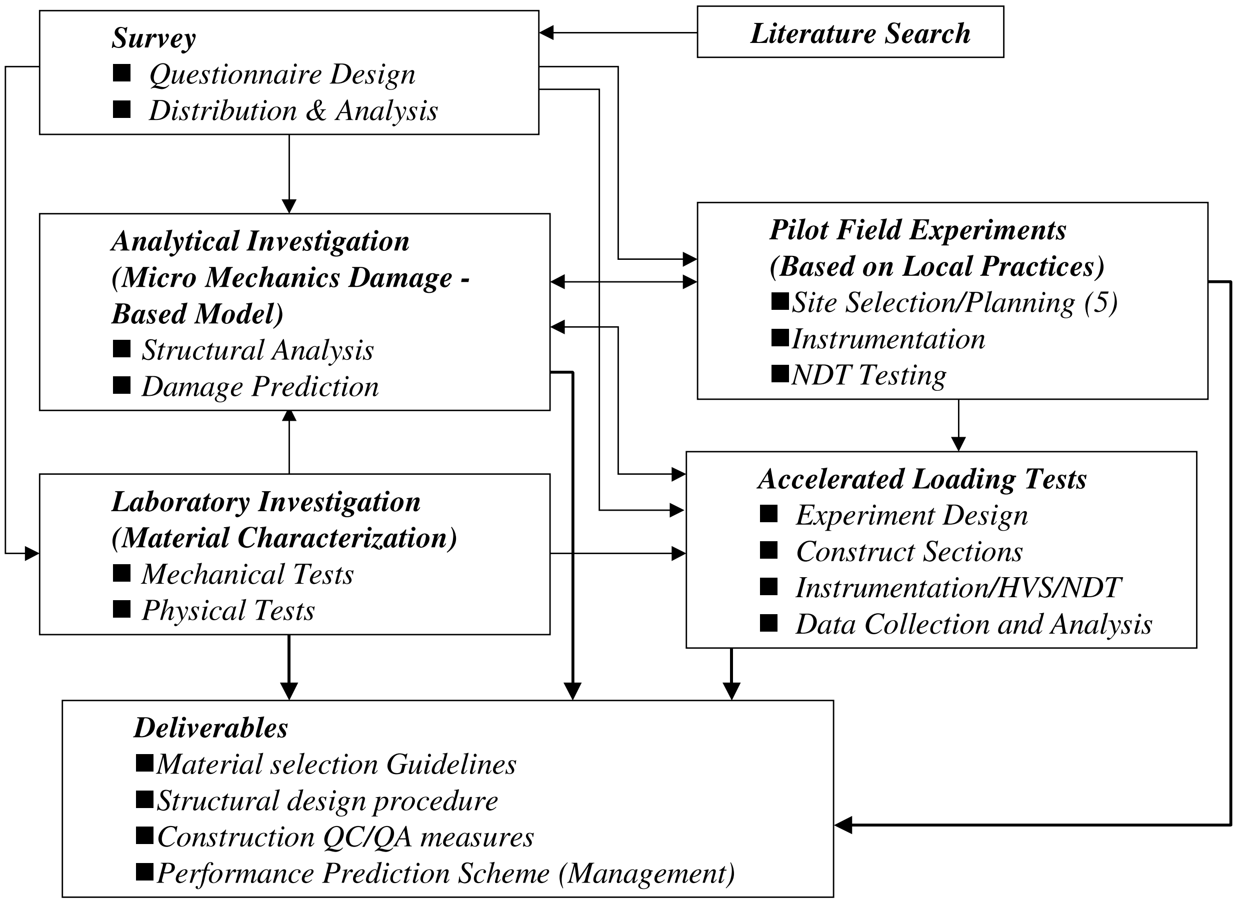

Figure 1: Research Approach

5. Summary and Conclusions

The cuts, that utility providers make, have been a recurring issue for a long time. The municipalities claim that cuts have a big impact on the life and serviceability of roads. The utility providers claim that their reinstatement work performs well if technical specifications are adhered to. Since there is no forum in which common problems can be discussed and solved, each party turned to political channels to insure its interest which in turn motivated many studies sponsored by the two parties. Due to the lack of communication, coordination and agreement between all concerned parties, all studies reviewed are being categorized as party benefit oriented and/or only suitable for certain localities. The need for complete and comprehensive research by a third party that is sponsored and adopted by all parties is justified in order to produce a practical, cost-effective, transferable solution to the problem. The IRC and CRREL have joined together to propose an extensive research program composed of four interacting phases (analytical modeling, laboratory investigation, pilot field and accelerated loading tests preceded by two information gathering tasks. A

Consortium is being formed of cities, utility providers and material and equipment suppliers to fund the research program.

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