Evaluation and Improvement of Inductive Loop Traffic Detectors

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ABSTRACT

It was determined in 1980 that approximately a quarter of New York State's 15,000 inductive loop detectors, used to control traffic signals, were out of order at any given time and were maintenance-free for an average of only 2 years. A study was made to find the major causes of loop failures and how to reduce them. Installation methods in New York and elsewhere were investigated, and hundreds of failed loops were studied to find failure types and causes. Data suggested that failure was mainly caused by improper installation, inadequate loop sealants, or wire failure. Encased wire (regular signal wire protected by continuous smooth-bore polyethylene tubing), which provided greater freedom of movement in areas of pavement distress, was being evaluated in other states. Also, instead of diagonal cuts at the corners of the loop, it was decided to cut the corners at 90-degree angles and then chisel or core them, thus saving sawing time and equipment wear and also having negligible impact on the loop wire itself. Another cause of failure is damaged or broken wire because of its floating to the surface of the sealed slot, which can be avoided with a simple hold-down device. Other recommendations included saws with greater horsepower, and complete pressurized washing and drying of the saw slot to enhance sealant bond. Laboratory tests were developed to evaluate sealants before purchase to assure that those used would provide strength, longevity, water resistance, good bond to the pavement, flexibility, wire encapsulation, and ease of installation. New York's new methods and materials appear to be the best currently available, and a program has been established for continued evaluation of these detector systems. A special training video tape is now available that covers these new materials and procedures.

Traffic loops are an integral part of today's highway system; they are used to control traffic flow at intersections by providing information to microprocessors that control signal patterns. Current estimates place the number of loop detectors maintained by the New York State Department of Transportation (NYSDOT) at about 15,000--a number that is increasing as improved traffic control is sought. The current trend in New York is to couple a loop detector with a computer to improve traffic control. The computer-enhanced system, although more costly, has the added ability of adjusting signal timing to meet traffic demands during different time periods throughout an entire area, rather than just one intersection for a fixed time period. With increased sophistication, these systems are becoming ever more dependent on continued successful operation of in-pavement loop detectors.

The inductive loop detector (ILD) consists of a specified number of turns of wire buried in the pavement and connected to a detector unit or amplifier. Current is passed through the wire loops to create a magnetic field; as vehicles break the field the overall inductance of the loop circuit changes. The detector senses this change and sends a message to the controller circuit, which adjusts the light signal according to its programming. Unfortunately, reliability of these loops has not been good, resulting in expensive replacement and, perhaps more important, in serious delays and inconvenience to motorists. In the past most inductive loops were maintenance free for about 2 years. By then systems began to suffer about 25 percent failures, thus requiring loop repair. The investigation reported here was initiated to study inductive loops and find ways to increase their reliability and lengthen service life.

Various means were employed to determine how to increase loop life: field evaluation of current failures, questioning of maintenance crews, a literature review, and questionnaires to other states. Results from these inquiries could be classified into two areas: materials and installation techniques. Each required extensive changes to correct their deficiencies.

INSTALLATION TECHNIQUES AND IMPROVEMENTS

Reliability Problems with Installation

Before discussing physical changes in installation methods, it should be pointed out that one problem area--lack of consistency in loop installation from region to region--was solved. Signal-loop materials and installation techniques are controlled by state standards and specifications. New York installs traffic loops either by contract or by department maintenance forces, and although all persons should follow the specifications, installers frequently varied slightly in methods and materials. As a result of this study, stricter policy was established to ensure that different areas used the same techniques and materials. This policy was explained as an attempt to establish known controls against which to compare experimental techniques rather than as an attempt to limit their efforts to find better procedures.

The investigation revealed several areas within the installation process that needed revision to improve loop reliability and several other areas in which speed, safety, and efficiency could be improved. The areas involving reliability were corner cutting, wire floating, splicing at the pavement edge, and cleaning of the sawed slot. Areas involving efficiency and safety were type of saw blade to be used, saw power [9.2 versus 18.09 horsepower (hp)], dry versus wet cutting, and use of small air tools.

One of the main causes of loop failure was wire breakage. In terms of installation problems, this could be related to several areas: sharp corners in the slots wearing through the loop wire, the loop floating to the top of the slot and being exposed to traffic wear, splicing of the loop wire and detector leads at the pavement edge, and failure of the loop sealant to bond to a dirty or wet slot.

Before this study, the loop corners were cut on diagonals (Figure 1). This did reduce some of the corner-cutting problem, but created another problem in that pie-shaped segments of pavement could break out, thus exposing whole corners of the loop to traffic and weather. The solution chosen was to saw the loop in four straight cuts, chisel out the corners, and round them off as smoothly as possible.

Once a slot is cut, it must be cleaned before installing the wire. If not properly done, many fine particles remain in the slot, thereby decreasing the chance of a good bond between the sealer and the sidewalls. A poor bond eventually causes the sealer

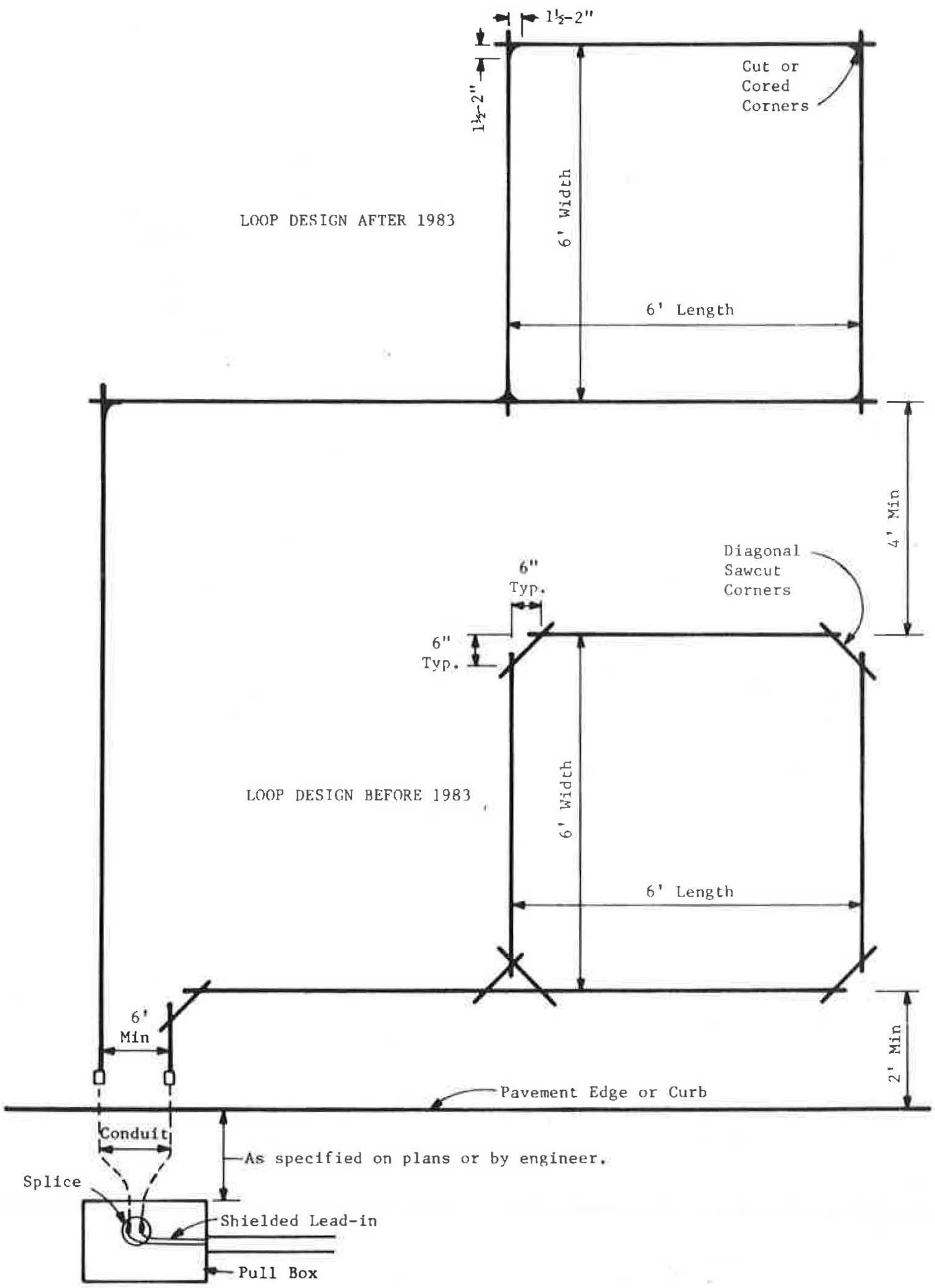

FIGURE 1 Sawed slot patterns before and after 1983.

and wire to pop out of the loop, which results in early exposure to traffic and weather. The former method, using only the air supply from a large compressor, was inefficient. A pressurized water system was desired, but the increased cost of having a water-pumping truck was not justifiable. Instead, a special nozzle was devised to combine a standing gravity-fed water supply and the already available air compressor. Using the Venturi principle, a nozzle was fabricated to supply pressurized water. The air supply from the compressor passes through a restricted chamber to propel the water from the standing water supply. This system resulted in a much cleaner slot. The same nozzle is used to dry out the slot by simply shutting off the water supply. If the compressor were to have hot-air capability, the work would proceed even faster. It should be noted that once this nozzle was shown around the state, many department maintenance forces found uses for it in other areas.

At this point in the installation process the wire is placed in the loop starting and ending at the pavement edge. Wire continuity is checked now, and if there is no problem the loop wire is spliced to the detector leads. As in any electrical installation, the splice is one of the most critical components of the electrical circuit. Past experience indicated that the method of splicing varied from region to region, and no one method was more reliable than any other method. Evaluation of all current techniques plus some questioning of the research electronics staff resulted in the following splicing specification.

An uncoated, metal, solderless crimp connector or solder or both are used to make the initial connection. After joining the wires, liquid waterproofing is applied. Next, heat-shrink tape or rubber tape is applied over the splice, making sure the outside tubing is securely joined to the encased wire. The advantage of using heat-shrink tape is that there is less seam area for possible debonding. After applying the heat-shrink or rubber tape, another coat of waterproofing material is recommended. Next, layers of polyvinyl chloride (PVC) tape are added in combination with waterproofing material. A final layer of PVC tape is applied, followed by a waterproof coat. A third layer of heat-shrink or rubber tape is added, followed by another waterproof coating. The signal wire should be reinsulated with the proper combination of materials to equal 1.5 times the original wire insulation thickness.

At this point the encased wire must be secured in the slot. It must be prevented from floating to the top of the sealant during curing or during hot summer days when the sealant softens. A hold-down was required, but the type of material to be used had never been specified. The study indicated that most hold-downs failed to perform properly; that is, some absorbed water, melted at higher sealant curing temperatures, lacked holding ability, lacked recovery from deformation, or were difficult to install. One material found to perform well was an open-celled backer rod. It is readily available, inexpensive, and easy to use; compresses well; does not wick water; and some brands resist intermittent temperatures in excess of 400° F. One-inch strips were installed every 2 ft, taking care to include strips on either side of the corners or wherever the wire changed direction.

The sealant, when properly mixed and prepared, is poured into the slot. In the past it was found that not enough emphasis was placed on leveling the sealer. If the sealer is higher than the pavement surface, it is exposed to both tire and snowplow wear. A snowplow or even a car conceivably could hit the protruding sealant and jerk it and the wire from the slot. To handle this, department forces developed a special tool: a V-shaped rubber-bladed squeegee on a 4-ft wooden handle, made from old broom handles and old rubber mudflaps. This tool proved adequate and convenient for pulling sealant into the slot, leveling it, and also reducing waste. At this point the sealant surface, once cured, may be dusted with cement dust or dry silica sand to eliminate any slight surface tackiness, and traffic is allowed to resume as quickly as possible. Road dust, gravel, or stone dust should not be used because incompressibles may be introduced into the loop, thus causing problems later.

Speeding Up Installation

From the field study and discussions with maintenance personnel, it was decided that the speed of installation could be increased, thereby reducing costs. The major area in which operations could be accelerated was cutting of the slot. Maintenance forces believed that the 9.2 hp of the saw then supplied was too low for the heavy-duty cutting required. This could be justified because of the change in the wire diameter called for in the new specifications (i.e., larger-diameter wire required a larger-width slot). Advice on horsepower was obtained from several sources, including regional maintenance crews, contractors, rental agencies, saw manufacturers, and other states. Almost all agreed that saws were underpowered even when cutting 1/4-in.-wide slots, and to try to cut 3/8-in. slots with the same saw would result in much slower work and more saw breakdowns. Most agreed that the minimum power of the saw should be 18 hp. The regions are now receiving 18-hp saws as replacements for 9.2-hp saws.

Along with the increase in the power of the saw, changes were also made in the type of blade used. Regions varied as to whether abrasive or diamond blades should be used. Also, by varying the blade type a change is made from using a wet-cutting method (diamond) to using a dry-cutting method (abrasives). Dry cutting creates large dust clouds that are irritating and dangerous to the work crews, passing motorists, and nearby neighbors. Wet cutting with a diamond blade produces fewer hazardous side effects. The only advantage of the abrasive blade over the diamond blade is initial cost, but when life expectancies of the two kinds of blades are compared the diamond blade wins by a margin large enough to overcome the cost difference. The life expectancy of diamond blades is equal to 35 abrasive blades, and the diamond blade could reduce cutting time by two-thirds.

It was also necessary to select the proper type of diamond blade. Diamond blades are rated to cut specific types of pavement. In New York it is estimated that 75 percent of all state-maintained signal loops are located in some type of asphalt road surface. A diamond blade rated to cut asphalt was selected for test installation and later recommended for statewide use.

Along with the change in the saw and blade, other tool improvements were recommended. Because all maintenance crews have a compressor as part of their assigned equipment when doing loop installations, why not supply them with air-powered hand tools? Chipping the loop corners, finding and removing old feeder tubes, and general slot cleanup could be greatly speeded up by their use. In fact, chipping out by hand with a cold chisel is now the way to install feeder tubes and the extra-wide slot where the loop wire crosses from one slab to another.

LOOP MATERIAL CHANGES

Wire Specification Changes

Field observations, a literature search, and letter surveys all indicated that wire breakage was a major factor in loop failures. New York's current wire standard called for a seven-strand copper UL Type XHHW, No. 14 AWG single-conductor cable, insulated with a polyethylene cover that had an outside diameter of about 0.14 in. Installers believed that this wire was not as durable as others. This wire was totally restrained, and when a pavement moved the wire could be stressed or broken or both. In fact, one department agency is using a solid-core heavy-jacketed wire that does a good job. With this in mind, a search was made to find the best wire for the job.

The search found that only Illinois had studied the problem extensively. They found that encasing the wire in a flexible vinyl tube along with other changes resulted in a large reduction in failures. Based on Illinois' experience and New York's research, a No. 14 AWG, Type THWN or THHN stranded copper wire encased in a vinyl tube was chosen for evaluation (Figure 2). Before field testing, the wire was checked in the laboratory for resistance to temperatures experienced during installation. Once it passed this test, it was taken into the field for final evaluation where it has proved effective.

FIGURE 2 Standard 14-gauge stranded wire (top), with polyethylene sheath (bottom).

Sealer Changes

Sealants were known to be a problem from the beginning of this study. New York had no sealant testing procedure, and an informal approved list was based mostly on the manufacturer's sales literature rather than any testing or field results. Field surveys revealed many problems with most sealants in use.

The first types of sealers tested were cold-applied, asphalt-based emulsions. This type of sealant was too thin, ran out on slight grades, and soaked into the subgrade surface. It was also susceptible to washout if there was unforeseen wet weather before it cured.

Caulking tubes of sealant were evaluated and found to be difficult to work with. They were prone to poor encapsulation and had long curing times, considerable shrinkage, and poor bonding. In fact, one important consideration applicable to any sealer is how curing occurs. If it cures by evaporation or loss of volume it is probably not usable because the resulting shrinkage encourages bond failure and eventual loop failure.

Silicon-based material that uses a primer was also tested and rejected. The sealer was too thick and did not appear to encapsulate the wire. It was also found that the primer, a toluene-based material, acted as a cutback on the asphalt and actually weakened the bond area. Field surveys verified that it debonded early.

One of the more popular sealers was hot asphalt. Most states and maintenance crews were found to use this material because of low cost, ready availability, and extensive experience in using it in the past. The hot-asphalt sealer is not recommended for several reasons. First, it is often heated to temperatures exceeding the insulating properties of the wire. Second, it requires frequent resealing from season to season. Third, and most important of all, it is dangerous to work with because it presents not only health hazards because of exposure to fumes but also because of the possibility of fire and explosion while the material is being heated. The dangers involved in its use are enough to disqualify it from consideration as a sealer.

As a result of this study, a laboratory sealant evaluation and testing program was established to set specifications for screening loop sealers before actual highway use. To aid in setting up a specification, the following qualities for a good sealant are desirable:

1. Adequate pot life,
2. Minimal curing time,
3. Sufficient viscosity to encapsulate the wire and not flow out on a slight grade,
4. Sufficient flexibility to accept some pavement movement without cracking the sealant or debonding the wire,
5. Good bond to both concrete and asphalt,
6. Ease of preparation and use,
7. Ease of cleanup,
8. Longevity with a minimum of maintenance,
9. Lack of shrinkage, and
10. Safe use.

The desirable properties were combined with engineering estimates and laboratory results for successful sealants to establish laboratory specifications. Any sealer could be submitted for testing and, if acceptable, would be evaluated in the field for a 6-month test period. This was necessary because laboratory tests could not adequately judge how the sealer would perform in the field. It is hoped that current specifications can be further refined as more information is gathered from laboratory and field evaluations. As a result, New York now has uniform procedures for judging sealers and establishing an approved list.

CONCLUSIONS

As a result of this study, statewide installation methods and specifications have been established.

For three construction seasons, these changes were used in approximately 30 installations, most of which were failed sites. After 3 years, all sites are still operational except for a few damaged by highway reconstruction.

Except for the introduction of encased wire and cold-applied sealants, change in materials is less important than emphasis on correct, uniform methods of signal-wire installation. A survey of the department's regional offices indicated that installation techniques varied among locations because of different interpretations of specifications and availability of materials. Major specification changes were

1. Use of No. 14 AWG stranded, single-conductor wire encased in a continuous vinyl or polyethylene plastic tube;
2. Use of improved roadway loop-embedding sealer; and
3. Use of chipped-out or cored corners instead of diagonal sawcuts at the corners of the loop slot cutouts.

Use of state-specified encased signal wire makes it necessary to saw a 3/8-in.-wide slot. The corner diagonal saw cuts have been replaced with chipped or cored corners. Hot bituminous-based sealants have been replaced by an approved list of cold-applied sealers. However, these changes are less critical to loop longevity and operation than the proper loop installation method, which should be standardized throughout the state.

In an attempt to standardize installation methods, a loop-wire informational seminar was conducted. Representatives from various regional construction and maintenance crews attended a 1-day presentation and a 1-day demonstration of field techniques. A special report was prepared for this seminar (1). This special report and the final report (2) are available from NYSDOT for those seeking more details. A video tape (3) that shows correct installation techniques has been prepared by NYSDOT for FHWA and is now available as a training film.

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Evaluation of Reflectorized Sign Sheeting for Nonilluminated Freeway Overhead Guide Signs

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ABSTRACT

A comparative evaluation of various combinations of reflective sheeting (Level 1 = high-intensity, super-engineering grade; and Level 2 = engineering grade) on nonilluminated freeway overhead guide signs was made under road test conditions. A panel of nontechnical observers was used in a subjective evaluation of the signs. Luminance measurements were made by using a telephotometer at the front passenger's eye position using low-beam headlights together with traffic stream headlight illumination. Cost analyses were also performed. The study concluded that, pending the results of further tests on high-intensity versus super-engineering grade for sign message and border, the recommended course of action for freeway overhead guide signs was to implement high-intensity foreground (legend and border) on engineering-grade background.