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SUMMARY

This paper describes studies and efforts to overcome a 3500-person highway hand-labor shortage which came as a result of progressive and radical changes in the North Carolina penal system prisoner rehabilitation program. Basic needs for maintenance were unchanged.

The acute hand-labor shortage resulted in an investigation of improved methods of production by machinery and increase in production per employee to overcome the shortage. A further shortage in trained equipment operators was overcome by a personnel training program which is described.

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* As of January 31, 1967

NORTH CAROLINA STATE HIGHWAY COMMISSION

Maintenance Department

MECHANIZATION FOR MAINTENANCE OPERATIONS

Someone has said that industry thrives or dies as a result of the fierce competition which is a part of the American way of life; perhaps this is best illustrated in the story of the chewing gum business. Throughout the history of this business the costs of materials and labor have maintained pace with other industry, and it may be assumed that today's price for a package of gum should range between forty and fifty cents. Yet, the price for the past fifty years has remained at five cents. The reason: The manufacturers have found a better way to do the job. And so it is with all industry if they are to survive.

Highway maintenance is a big business, and although not dependent upon competition for actual survival, it can become the albatross around the neck of the taxpayer unless we assume the attitude of industry in finding better, more and efficient methods. All too often we are content to follow the procedures of our predecessors; tradition is our worst enemy.

This paper does not present any spectacular changes in maintenance needs. It does illustrate studies and efforts to overcome conditions which came as a result of progressive and radical changes in the administration of the Penal System in North Carolina toward rehabilitation of inmates which brought about drastic reductions in the number of prison inmates for use in highway work. The basic needs for maintenance are unchanged. Pavement patching, drainage, vegetation control and other maintenance functions remain the same, but some of the methods have been changed and improved. Most of the improvements to be discussed are simple, but now that progress can be evaluated, the possibilities are almost unlimited. For perspective, the following background material is offered:

North Carolina maintains more than 72,800 miles of roads, of which some 44,000 miles are paved.

	Primary	Secondary	Total
Paved	12,963	31,428	44,391
Unpaved	77	28,354	28,431
Total ----------	13,040	59,782	72,822

This includes nearly 750 miles of four-lane divided highways and 3,297 miles of system streets in cities and towns.

Comparison of paid field labor forces, including Landscape, Signs, Road Oil and Force Account Construction, in June 1961 with June 1966, reveals the following:

	June 1961	June 1966
Permanent employees	4,567	5,009
Temporary employees	1,255	2,667
Prison inmates	5,997	2,702
Total ----------	11,819	10,388
Average miles per employee, including foreman ----------	6.13	6.98
Total reduction in field forces ----------		1,431

On July 1, 1966, the prison labor quota was revised to 2,500 inmates, making a total reduction of approximately 3,500 since June 1961. We have eliminated all prison labor in 41 of the 100 counties and employed 950 unskilled laborers to replace them, and have moved the 2,500 to counties where unskilled labor is not available, mostly in the Piedmont section of the State. Thus, the unskilled work force, prisoners and unskilled laborers, now total 3,450 as compared with 5,997 in June 1961. Fortunately, the decline of available prison inmates was gradual, averaging about 700 per year, which allowed time for study and evaluation of machinery for this work.

Analysis of the work performed by prison labor revealed that slightly less than 90% were engaged in three work areas, viz.; asphalt patching, drainage (which includes pipe laying, ditch cleaning, etc.) and vegetation

control (which includes cutting brush on right of way). Others were assigned work with garages, sign crews, bridge crews, etc. Approximately 250 honor grade inmates were assigned to operate mowers in company with permanent employees in teams of two; others operated patch rollers with patch crews, and other small machinery. With the establishment of the new 2,500 quota, all prison labor has been eliminated from machinery operation, from bridge crews, sign crews and garages.

With the impending prison labor shortage in 1961, after a study of possible means of mechanization, several machines were purchased in modest quantity, and we shall deal with them under the work area in which they were used experimentally.

ASPHALT PATCHING

Unfortunately, no one has yet invented an asphalt patching machine. However, a study of the procedures and problems revealed two operations which could be expedited and the quality of the work improved:

1. Edge failures (or raveling edges):

   These occur predominately on the Secondary System, particularly where the pavement width is less than 20 feet. Patching edges is tedious and time-consuming. One of the District Engineers developed a simple slide gadget which more than quadrupled production and improved the quality of work. These slides are simple, easy and inexpensive to build, and may be built to any desired width. Originally, they were used for repair work only, but now where repairs are caught up, they are used to strengthen flexible pavement edges to prevent raveling or failures. In many areas, usage of this gadget is prerequisite to resurfacing or resealing flexible pavements. Incidentally, it works exceptionally well on paved shoulders which have settled. These edgers, although relatively simple and inexpensive, are capable of placing approximately one mile of material per hour (on one side) if sufficient haul trucks are available. Strike-off blades are adjustable for desired thickness at outer edge. Periodic inspections over a period of four years indicate an edge failure rate of less than five per cent (5%) after this treatment.

Shows condition of raveled edges.

Tack coat with hand spray.

Oiling slide surfaces.

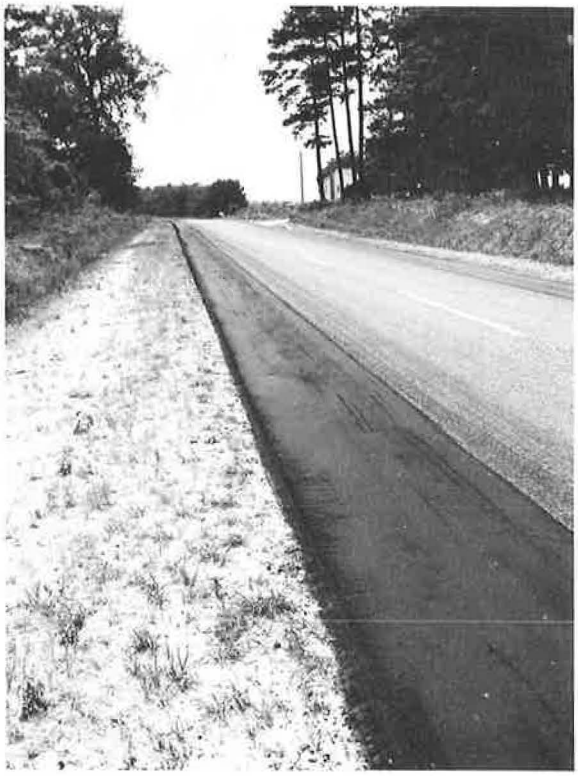
Tow chain attaches to front bumper hook. Edger is 42" wide.

Truck body raised to permit rake-out with hand rake.

Hand rake deposits material in front of slide. Raker keeps it evenly distributed in front of strike-off. Hand hooks steer front and rear of slide.

Roller stays immediately behind placing of material.

Inner edge should be rolled first.



Finished edge is ready for traffic.

Five-foot edger with four strike-off blades. Note first blade has saw-tooth edge.

Side view showing skids and hopper.

Truck dumps directly into hopper.

Crew consists of:
Flagman, 2 squeegees,
1 raker, 1 sweeper,
and 1 utility man.

Inside edges are
rolled first.

Note comparison
between two sections.

Required Personnel and Equipment

Personnel	Equipment
1 Foreman	1 Edger-Slide
3 Laborers	1 Asphalt Kettle
1 Roller Operator	1 Portable Roller
Truck Drivers as required	Trucks as required

2. Progressive failures:

(Usually at the quarter-point and usually due to weak base or drainage failure)

This problem is one of which patch crews find it necessary to return repeatedly as the pavement failures continue longitudinally beyond the first patch. Often these failures can only be corrected by digging out unsatisfactory base materials. However, regardless of the method employed, it is difficult to obtain a smooth riding surface over long patches. We have found that in most cases, where the base materials are known to be satisfactory, both a smooth riding surface and a stable patch can be accomplished faster and cheaper by placing a hot-mix overlay across the entire width of the paved surface. These range in length from fifty (50) feet to three hundred (300) feet, depending upon the condition of the surface. This is accomplished through the use of a small rubber-tired asphalt finishing machine which is rotated among the counties. Planning and scheduling are essential in order to achieve the maximum coverage. Two of these machines have been operated for almost three years and the results have been excellent.

Crew consists of:
Machine operator,
2 squeegees,
1 raker, and
1 roller operator.

Note pavement failure in foreground.

Length and thickness of overlay depends upon conditions at each location.

Short overlays are more common.

In summary, it appears that no additional manpower is required because planned and scheduled operation has reduced the need for conventional patch crews in both divisions where these machines have been used. The quality of work is superior to hand patching methods.

MECHANIZED PIPE LAYING PROCEDURES IN MAINTENANCE OPERATIONS

A study of drainage pipe replacement, or new pipe installation revealed that under the old procedures the following personnel and equipment were needed:

Personnel	Equipment
1 Foreman	1 Truck
1 Truck Driver	1 Truck Crane
1 Truck Crane Operator	1 Trailer
10 Prison Inmates	1 Air Compressor
	2 Pneumatic Tamps
	Small tools as required

The average installation time under favorable conditions was approximately four hours. In most cases it limited the crew to one installation per day because the trench could not be left open over-night. Two lines per day were the absolute maximum. Experiments, time and motion studies indicated that a three-man crew, using a backhoe, could excavate, lay the pipe, grout, tamp and dress the roadway in one hour and forty-five minutes; therefore, increasing production to four lines per day if necessary. This procedure was adopted by using the following:

Personnel	Equipment
1 Machine Operator II	1 Truck
2 Laborers	1 Backhoe (with attachments)
	1 Air Compressor
	2 Pneumatic Tamps
	Small tools as required

The backhoe is equipped with Insta-hitch attachments, including a loader bucket (Photo 1) and a crane boom (Photo 5). These attachments may be switched in two minutes, making the machine more versatile.

The production potential was quadrupled and costs were reduced by approximately fifty per cent (50%). The procedure is illustrated in the following photographs:

1. Beginning of operation. Backhoe is beginning excavation. One laborer is mixing grout and the other is cleaning tail ditches.

2. As the backhoe progresses with excavation the two laborers begin leveling and fine grading.

3. Excavation and fine grading carried out simultaneously.

4. At the conclusion of the excavation one laborer finishes the fine grading and the other prepares chain and pipe hook at pipe stockpile.

5. The first joint is picked up preparatory to laying.

6. The first joint is placed in the ditch.

7. Grout is applied to the bell. As each joint is placed the bell is grouted.

8. Progressive laying and grouting.

9. The final joint is placed.

10. Grouting is begun on the outside of the joints. Note that one man has placed grout at each joint ahead of the grouting operation.

11. Grouting is completed and the line is ready for covering.

12. The two laborers begin backfilling and working the soil under the bottom of the pipe.

13. Pneumatic tamping.

14. Pneumatic tamping.

15. Pneumatic tamping is completed. Loader bucket has been attached and backfilling begins.

16. The tractor is used as a pneumatic roller.

17. Waste material is spread and road is re-opened to traffic.

MAINTENANCE OF SIDE DITCHES, TAIL DITCHES AND LATERAL DITCHES

A review of methods and procedures for the maintenance of drainage showed that approximately four thousand prison inmates were involved in cleaning ditches during a large portion of the year. This was usually by ten-man squads, and generally related to tail ditches, lateral ditches, and cleaning out at the ends of the drainage pipe. Most of the side ditches, except in the coastal plain regions, were maintained by motor graders.

Experimental use of special buckets on backhoes proved that hand labor could be eliminated on more than half of this type of work and that one Machine Operator II, working alone, could produce approximately the same amount as three 10-man squads, or thirty (30) laborers, three (3) foremen and three (3) trucks. This is illustrated in the following photographs:

Drainage has ceased to function.(Secondary unpaved roads.)

One operator and machine covers drainage needs through entire route systematically.

Cleaning partially-filled driveway pipe. (Note special bucket attachment made from discarded moldboard.)

Special bucket increases production.

Spoil-dirt previously picked up by force-feed loader is now loaded directly into trucks.

Special template on bucket expedites laying of half-pipe.

Sloper attachment on motor grader has increased quality and production in maintenance of side ditches.

MOWING AND VEGETATION CONTROL

This study was divided into two parts: (1) The problems of mowing equipment and procedures; and (2) the problems of brush control with hand labor and the possible development of machinery for this work.

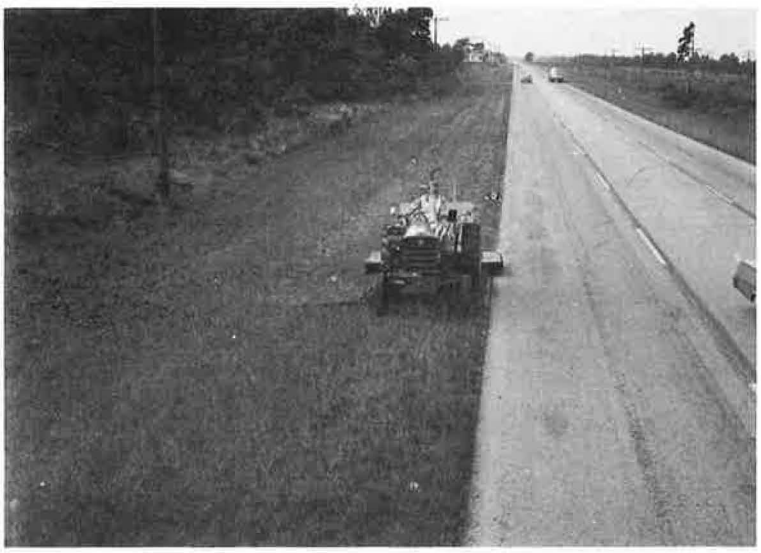
Mowing Equipment consisted of the conventional farm tractor with a six-foot sickle cutter bar. Time and motion studies indicated that under the most favorable conditions, continuous mowing (not including travel time, service time and down time) maximum production for three hours averaged 2.9 acres per hour. To make the shoulder cut, the machine and operator were exposed to traffic unless it was operated against traffic.

Single sickle mower exposed to traffic.

Single sickle mower operating against traffic.

The Interstate System and other four-lane divided highways greatly increased the acreage and mowing responsibility and pointed out the need for considerable increase in machines and operators.

Nine experimental machines were developed by attaching a 90-inch rotary mower to the rear of the tractor on a 3-point hitch. This would appear to be simple today, but at the time of the experiment there were problems in matching the equipment. Once the experimental machines were proved, specifications were written which simplified the matching problems. The experimental machines could cut a 13-foot swath and time and motion studies, as outlined above, indicated production at 6.25 acres per hour. This machine is operated completely off the pavement, thus eliminating most of the traffic hazards.



Dual Mower -------- 13-Ft. Swath

Rear view --- 13-ft. mower. Reflectorized amber lights and reflectorized sign.

Operation on secondary paved road.

Rear view - Secondary paved road.

As additional segments of the Interstate System were completed, experiments were started with a triple mower, using two 6-ft. sickle cutter bars and a 90-inch rotary with a cutting swath of slightly over 19 feet. Twelve of these machines were put into service and time and motion studies indicated a production of 11.0 acres per hour under the most favorable conditions and not including travel and service time or down time.

Median mowing trips were reduced 50% for 40-ft. width.

Interchange mowing shows increase of 50% in production as compared with dual machine and 200% over single sickle machine.

Shoulder mowing 19-ft. swath. Sickles may be raised for narrower shoulders.

SUMMARY

Findings indicate that if machines are assigned according to the needs of the area, the following comparisons may be drawn:

> The triple mower will produce in 6 days the equivalent of 17 days production by the single sickle mower.
>
> The dual mower will produce in 9 days the equivalent of 17 days production by the single sickle mower.

Since manpower is perhaps the greatest single cost factor in mowing operations, the dual machine has been adopted as standard for primary and secondary roads and approximately five hundred (500) are in operation. The triple machine is standard for Interstate and four-lane divided highways and thirty-two (32) are in operation. Although 5,419 miles of paved roads have been added to the System since 1960 no additional mowers have been required. More importantly, had we continued the use of the single sickle mower, approximately 135 additional machines and operators would have been necessary for today's operations.

The Problem of Brush Control With Hand Labor And The Possible Development of Machinery For This Work. Traditionally, the State has cut vegetation on rights-of-way with hand labor, utilizing the vast majority of the 6,000 prison inmates during the fall months. Surveys indicated that since priority was on the primary system, brush control was kept current with the fall clean-up, generally keeping sight distance, appearance, etc., in fairly good condition; but on the secondary system brush and woody growth were cut on an average of once each five years. Consequently, small trees had attained a size which made vegetation control with hand labor more difficult each year. Since the right-of-way on the secondary system is generally limited to sixty-foot (60') width, policy called for brush cutting on the entire width with exceptions for landscaping and beautification wherever possible.

The problem was related to the decrease in hand labor which undoubtedly would increase the time required to cut over each cycle, and the solution could be found only in some type of machinery for this work. One of the Division Engineers conceived the idea of an attachment for motor graders which impressed the Equipment Engineer and in cooperation with a local manufacturer one machine was produced and operated experimentally for fifteen (15) months. The attachment was mounted on a retired (10-yr. old) motor grader and production over the trial period indicated the production was equivalent to thirty (30) hand laborers or prison inmates. Within two years thirty-nine (39) of the machines were purchased and have been operating in areas of dense growth.

Attachment is hydraulically operated from pump on motor grader. Boom folds for travel clearance.

Hard to reach vegetation may be cut with machine on firm ground. Cutter head will mulch small trees up to 3 inches in diameter without damage to the machine.

Shows boom extended to bottom of canal bank. Extended reach is 20 ft.

Machine mulches vegetation, eliminating blockage of drainage.

In areas of medium growth, a machine was developed with a five-foot (5') sickle bar capable of cutting back slopes and banks which were previously out of reach of conventional mowers. The extended reach is sixteen feet (16') and in most cases it will meet the needs of the secondary system with the tractor operating on the shoulder. Four of these machines were purchased and operated over a full year. Finding them satisfactory, a total of one hundred and twenty (120) have been purchased.

Machine has an extended reach of 16 feet and will cut up to 1½-inch diameter without damage.

Extension boom raised to cut top of back slope.

Front view.
Operator keeps tractor on solid shoulder.
Cab enables operation during rain showers.

Astron rotary, generally used on primary system. Slope cover is serecia lespedezia which grows to a height of 18"-24" and should be cut only in fall each three to four years.

Thus, with increased production ability in the machines discussed above, we began a program which was designed to eventually cut all right-of-way each year. This effort is intended to prevent excessive size in the growth, not necessarily for beautification. Forty-one of the one hundred counties have reported that they have cut over the entire mileage within the past twelve months and the balance report they expect to meet the goal this year. Time and motion studies and field reports indicate a production of five to six miles production per day, and that cutting is less difficult after the first clearance.

Thirty (30) counties have utilized section motor graders during dry seasons, when they are not effective for unpaved road machinery, to level back slopes so that conventional mowers can operate on the flat surfaces. Preliminary reports indicate that this procedure will expedite production where the terrain is favorable.

SUMMARY

Preliminary estimates indicate a need for one extension type mower for each five hundred miles of roadway which will require a total of approximately one hundred and fifty (150) machines which we already have.

When the dense growth is under control, it may be possible to substitute the smaller and less expensive tractor-mounted extension mowers for the motor grader attachments. The present annual cut-over represents approximately two hundred per cent (200%) increase in production and positive control of growth size. Thus, in two years we may reasonably expect virtual elimination of hand labor in the control of vegetation.

PERSONNEL TRAINING

As this and other equipment was developed operator training became a matter of prime importance, since all of the equipment was new and there was little background experience among the personnel.

Discussions with field supervisory personnel developed the consensus that concentrated training was necessary but that it should be kept simple, uncomplicated and on the job if possible. Since the normal assignment of mileage for Area Foreman was approximately five hundred (500) miles, it appeared that training could be effectively directed at this level with District Engineers and Maintenance Supervisors observing the program and evaluating progress. Each of the one hundred and fifty (150) Area Foreman began by selecting at least one man from the lower ranks for operator training (on the job) and has followed his progress until he was fully qualified, or until it

was found that he could not qualify. Failures were surprisingly low. A series of 16mm color film were made which illustrated proper methods of operation, time and motion studies, etc., and were shown to personnel during six-hour instruction periods. During the filming errors and mistakes were included and were pointed out during the instruction. The "talk back" discussions have been valuable, both to the instructor and the trainees.

This program has now been expanded to train operators for ascending grades with the ultimate goal of developing at least two fully trained operators for each machine in the authorized equipment table. Reports indicate that the program is 75% complete, and that two main benefits were derived:

1. During snow or emergency periods equipment is kept in continuous operation; and

2. When a vacancy occurs because of resignation, retirement, death, etc., a trained operator is immediately available for replacement.

Record keeping and paper work are kept at a minimum by a simple form, kept in the Maintenance Supervisor's office, which indicates the trainees' progress. The Central Administration may call for photo-copies of these forms periodically as a means for keeping up with the program.

CONCLUSION

1. Loss of prison labor virtually forced the Commission toward investigation of improved methods of production by machinery.

2. Simple mechanization or improvement of existing machinery in work areas of asphalt patching, drainage and pipe laying, mowing, and vegetation control has brought about a considerable increase in production per employee performing these functions, which has overcome the hand-labor shortage and increased the overall production potential.

3. The simple training program has challenged the Area Foremen and has been proved to be successful and stimulating.

INSTRUCTIONS FOR AREA FOREMEN

OPERATOR TRAINING

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1. The ultimate goal in the operator training program is to qualify as many of our employees as possible to fill future vacancies for equipment operators.

2. Each Area Foreman should select from among the ranks of truck drivers and temporary employees at least one man whom he feels is capable of advancing. The man should be of good character, willing to work, and able to learn. He should be told that he is being given the opportunity to learn and qualify for a better job, but that he will not be promoted until a vacancy occurs, and then only if he is the best qualified of the trainees.

3. Trainees should be given as much "on the job" training as possible without disrupting the scheduled work. As they learn they should fill in for operators who are out because of vacation, sick leave, compensatory time, etc. However, trainees should not be worked out of classification more than thirty per cent (30%) of the time.

4. As the trainee qualifies and you are satisfied with his ability to produce, enter the date beside the appropriate machine listed on the attached sheet. Photo copies of trainee records will be called for periodically as a means of reviewing progress.

Division_____; District_____; County_____

Trainee's Name_____; Classification_____

Item	Date Training Began	Date Training Completed
Backhoe		
Drill, Air Track		
Drill, Wagon		
Dumptor		
Grader, Motor		
Loader		
Lowboy, Tractor-Trailer		
Mixer, Self-Propelled		
Mower, Regular		
Mower, Contour		
Mower, Motor Grader		
Plant, Asphalt		
Plant, Crusher		
Plant, Pipe		
Pump, Sand		
Roller, Patch		
Roller, Pneumatic, Self-Propelled		
Shovel, Dragline		
Sweeper, Self-Propelled		
Tractor, Dozer		
Tractor, Pan		
Tractor, Wheel		
Tractor-Trailer, 8-yard		
Truck, 2-ton		
Truck, Lube		

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