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Observations of Stabilized Turf Shoulders

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Memo to: D. V. Terrell  
Director of Research

As you know the treatment given shoulders of roads carrying high volumes of traffic has become of much concern to highway officials in the past few years. Expensive but thoroughly adequate shoulders can be made by methods that are well known, as evidenced by those that have been placed on turnpikes and similar facilities throughout the country. However, it is recognized that for the present at least, these are too costly in the construction of the average highway which must carry large volumes of traffic.

Over the years a few states have attempted so called stabilization of turf shoulders with the object of providing both reasonable load-supporting value and also the usual aesthetic value - as the traveling public judges it. Apparently there have been varying degrees of success, but in recent years the trend has been away from turf if stabilization of any sort is used. Undoubtedly the vast majority of shoulders on primary roads of this description built during the past few years were of turf, probably because there is no feasible alternative.

With a view toward reevaluating possibilities for the stabilized turf type construction, the Division of Design included crushed aggregate stabilization in the project for reconstruction of U. S. 31-W and U. S. 68 from the junction of the two routes to the north city limit of Bowling Green. The project was let in 1953, and the Research Division was asked to observe just the shoulder work, keep records on construction and performance, and report the progress from time to time.

Shoulder construction was carried out in the fall of 1954, at which time E. G. Williams made the observations and records requested. Intervening inspections and observations have carried our records past the first year in which the shoulders were in use. Data on both the construction and performance are included in the attached report which Mr. Williams has prepared.
It has been shown that a grass cover can be established and presumably maintained even when stabilization is carried full depth and there is no topsoil layer overlying the stone-soil mixture. However, the cover is better when there is a topsoil layer, and almost infinitely better when the shoulder is just plain soil and grass - or turf underlain by nothing but soil. Very satisfactory support for vehicles using the shoulder was accomplished either with hardstands made entirely of graded aggregate and located at regular intervals in sections of turf shoulder, or with the aggregate-soil combination throughout the full depth of stabilized shoulder. The stabilized material with topsoil and grass cover was damaged to some extent by rutting under the vehicle wheels, and of course the ordinary turf shoulders were severely damaged whenever they were subjected to traffic in wet weather.

The observations thus far indicate that a grass cover pleasing in appearance and sufficient to control erosion is hardly compatible with completely adequate support for vehicles using the shoulder. Possibly a reasonable compromise can be achieved with stabilization of this type, but also it may be that in the attempt both load support and grass cover will be sacrificed beyond a point that is satisfactory. We will continue our observations on this project to make certain the performance during the first year has not been misleading.

Respectfully submitted,

L. E. Gregg
Assistant Director of Research

Copies to: Members of Research Committee
J. S. Cobb (3)
The improvement of highway shoulders, from the standpoint of appearance and practical value, has been and is at present of considerable interest to all highway departments. A great deal of effort has been expended in the past to develop grass combinations which not only will prevent natural erosion of the surface materials but also impart a pleasing appearance to shoulders and slopes. Attempts to include factors of practical value, such as safe support of traffic loads, have greatly magnified the problem. Numerous types of paved shoulders have been introduced which are quite satisfactory with respect to load bearing but are expensive to construct and often do not equal in appearance the more attractive turf shoulders.

Stabilized turf shoulders have been adopted by several state and federal agencies in an attempt to combine aesthetic qualities with those of a practical nature. These shoulders are made principally of granular material but contain sufficient soil to support vegetation, and generally they are covered with a thin layer of topsoil to provide a seed bed. Limited data
available indicate that these efforts have been rather successful.

The first study of stabilized turf shoulders in Kentucky was initiated during the 1954 construction season when the Division of Design designated an experimental section to be used for this purpose. This site was located on a 6 mile reconstruction project on U. S. 31-W and U. S. 68 from Bowling Green, to the intersection of the two routes at a point approximately 7 miles northward, Project No. I 16 (2) and 113 (5), see Fig. 1. The Division of Research was requested to observe and report on construction procedures and the effectiveness of turf shoulders constructed in this area.

The roadway located in this section consists of two traffic lanes in each direction, separated by a depressed median strip 20 feet wide. The median strip was constructed in the conventional manner and only the outside shoulders were stabilized. Three different means of stabilization were used, including hardstands at selected intervals with conventional earth shoulders in between.

Materials

Aggregate used in the shoulder construction consisted of No. 4 and No. 610 crushed limestone which complied with requirements of the Kentucky Department of Highways 1945 Standard Specification for coarse aggregate.

The natural soil consisted of a silty clay loam. The use of plastic, waxy soil was prohibited by specification and occasional nodules which contained such material were removed whenever detected.
Fig. 1 General Location of Experimental Shoulder Project
Topsoil fulfilled the requirements of Section 1-B (1) of Special Specification No. 52. Agricultural limestone and Commercial Fertilizer (10-6-4) met the requirements in Sections 2-B (1) and (2) of the same specification.

The grass seed mixture employed was non-standard and consisted of the following varieties combined in the stated proportions:

<table>
<thead>
<tr>
<th>Type</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky 31 Fescue</td>
<td>45</td>
</tr>
<tr>
<td>Chewing Fescue</td>
<td>25</td>
</tr>
<tr>
<td>Red Top</td>
<td>10</td>
</tr>
<tr>
<td>Domestic Rye Grass</td>
<td>10</td>
</tr>
<tr>
<td>White Clover</td>
<td>5</td>
</tr>
<tr>
<td>Balboa Rye</td>
<td>5</td>
</tr>
</tbody>
</table>

Rates of application of the several materials were designed as follows:

- No. 4 crushed limestone - 150 lb. per sq. yd.
- No. 610 crushed limestone - 100 lb. per sq. yd.
- Natural soil - 1 cu. ft. per sq. yd.
- Topsoil - 0.75 cu. ft. per sq. yd.
- Agricultural limestone - 50 lb. per 1000 sq. ft.
- Commercial fertilizer - 50 lb. per 1000 sq. ft.
- Grass seed mixture - 4 lb. per 1000 sq. ft.

At some locations these quantities were altered; however, the changes are noted at appropriate points in this report.

Approximately 70 per cent crushed limestone and 30 per cent natural soil were, in most cases, combined and the mixture designated Grading No. 1. One section of the project contained a mixture of approximately 60 per cent crushed limestone and 40 per cent topsoil, which was designated Grading No. 2. It should be understood that these gradations varied slightly throughout the project due to variations in mixing and in application of material (primarily soil).
Approximate gradations of the materials, separate and combined, are contained in Table 1. The recorded stone gradings were obtained by combining samples of No. 4 stone (60 per cent) and No. 610 stone (40 per cent). This blend, as noted in the tabulated rates of application, was used invariably in preparing the combined aggregate and soil. A negligible amount of soil was retained on the 3/8 in., No. 4, and No. 8 sieves, but for all practical purposes 100 per cent of the soil passed a No. 8 sieve. Further grading of this material was not attempted nor were other tests applied to it.

Table 1. Gradation of Separate and Combined Materials

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Stone No. 4</th>
<th>Stone No. 610</th>
<th>60% No. 4</th>
<th>40% No. 610</th>
<th>Soil Gradings</th>
<th>Aggregate - Soil Gradings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. 1</td>
<td>No. 2</td>
</tr>
<tr>
<td>1-1/2 in.</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1 in.</td>
<td>67</td>
<td>100</td>
<td>80</td>
<td></td>
<td>86</td>
<td>88</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>9</td>
<td>90</td>
<td>41</td>
<td></td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>1</td>
<td>64</td>
<td>26</td>
<td></td>
<td>48</td>
<td>56</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>1</td>
<td>49</td>
<td>20</td>
<td></td>
<td>44</td>
<td>52</td>
</tr>
<tr>
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<td>22</td>
<td>9</td>
<td></td>
<td>36</td>
<td>46</td>
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<tr>
<td>No. 8</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>100</td>
<td>32</td>
<td>42</td>
</tr>
</tbody>
</table>

Construction Procedure

Shoulder construction was delayed until all paving work and final dressing of ditches and backsloped had been completed.

Existing shoulders were scarified and graded down, for their entire
width, to a depth of approximately five inches below finished grade with slope maintained at one inch per foot. A diagrammatic representation of this section is shown in Fig. 2. Subgrade construction conformed to the requirements of Section 2.8.2 (b) of the Kentucky Department of Highways 1945 Standard Specification for non-rigid base and surface courses.

Essentially, subgrading consisted of cutting the shoulder to grade and rolling until firm with particular emphasis on the elimination of all low or soft spots which might entrap or retard the flow of water. A partially completed section of shoulder grade is shown in Fig. 3.

Three general methods of shoulder treatment were investigated to varying degrees. The principle method was stabilization with overlying topsoil and seeding as was originally set up for this project. Smaller sections were constructed to permit examination of seeded, full depth stabilization and conventional turf shoulders with graded aggregate hardstands interspersed at intervals.

**Stabilization With Topsoil Cover**

After grading has been completed, the proper quantities of stone were placed with a towed spreader box of the Buckeye type (Fig. 4). No. 4 stone was spread first and this was followed by an application of No. 610 stone. Very uniform distribution of the two was maintained with the equipment and procedure used, and there was no manipulation or rolling at this stage.

Next, natural soil was distributed by end dumping from trucks into small piles at various points on the previously applied stone. The desired
Fig. 2 - Section of shoulder showing quantity and distribution of materials.

Fig. 3 - Partially completed shoulder grade. After final dressing this section was ready to receive stone.
Fig. 4 - Spreading No. 610 stone with a Buckeye type spreader box.

Fig. 5 - Natural soil redistributed on the shoulder from windrow along the pavement edge.
quantity of soil for a given area was distributed in this manner, after which, spreading with a motor grader was used to complete the coverage.

Two methods were utilized in this phase of construction. In the first method soil was flat-bladed only, but this procedure failed in two respects: desired uniformity of distribution was not accomplished, and clods tended to roll into the ditches resulting in loss of soil and a need for extra work cleaning out ditches.

The second method was more satisfactory and is recommended for future situations of this type. Once again blading was employed; however, in this case soil was bladed into a windrow at the pavement edge. When soil rolled along the blade, clods were effectively dispersed. Blading of the soil back onto the shoulder resulted in a desirable uniform distribution. Fig. 5 depicts results of spreading by this method immediately after the windrow was cut back onto the shoulder. The method described necessitates careful blade work to avoid scarring of the pavement surface. In addition, the pavement must be swept immediately to remove soil or stone.

After this procedure had been completed, agricultural limestone was added at the prescribed rate. The entire soil-limestone mixture was thoroughly blended by a Pulvimixer, generally two passes being required to produce the desired blending. When the natural soil had been well distributed no difficulty in blending was observed, but where distribution was poor a desirable mixture could not be achieved. A comparison of Figs. 6 and 7 illustrates the effects of poor distribution which resulted in a serious lack of soil in some locations and excessive quantities.
Fig. 6 - Near view of completed soil-aggregate mixture on a section of shoulder where the quantity of natural soil was insufficient.

Fig. 7 - Near view of a location where the amount of natural soil was excessive.

Fig. 8 - Typical appearance of mixed and compacted shoulder material where distribution of the natural soil was uniform.
in others. In the former, it was obvious that a substantial growth of vegetation could not be expected, while the latter condition was certain to result in inadequate stability. A desired condition, which was representative of the majority of the project, can be seen in Fig. 8.

Following the intermixing of the materials, completion of the shoulder to final section was carried out with a motor grader. In order to obtain the required section and produce the final grade, it was necessary to first blade the material into a windrow at the pavement edge, (see Fig. 9) then blade it back uniformly across the shoulder. Sweeping of the pavement was required after this procedure. A slope of 3/4 inch per foot was maintained and checked with a template to insure conformance to these grade requirements. A very satisfactory degree of uniformity, as illustrated in Fig. 10, was maintained throughout the project.

After the blended mixture had been spread, it was found that a small excess of material was present at almost all points. This condition resulted in spillage of the mixture onto the previously dressed, seeded and straw-mulched ditch slopes. These slopes were dragged lightly with a farrow in order to provide a uniform shoulder line, however, in most cases, the shoulder width was increased slightly.

Compaction of the blended mixture was accomplished with a 10-ton, three-wheel roller (Fig. 11). Following this phase of construction, the shoulders were once again checked by template and, if necessary, reshaped by a grader and recompacted. The latter operation was rarely required.
Fig. 9 - Intermixed soil-aggregate material was worked to a windrow at the pavement edge prior to final distribution to the required section.

Fig. 10 - Typical section of the shoulder after stone and natural soil had been laid out. Note spillage of mixture onto the ditch slopes.
The equipment used for compaction performed satisfactorily except in a few instances where a high degree of subgrade saturation existed. In these cases, side-slip of the roller and resultant shoving of the shoulder edge toward the ditch necessitated reshaping and subsequent rolling. Probably a conventional pneumatic roller could have accomplished this work more effectively since it has a lesser tendency to side-slip. The pneumatic roller would be especially useful in construction under normal rainfall conditions as opposed to the very dry weather prevailing in 1954 at the time the Warren County project was carried out.

Fertilizer, in the specified quantity, was spread uniformly with a drill over the compacted stone and natural soil mixture. In most instances this mixture had a sufficiently open texture to encourage penetration, and dispersion of the fertilizer by harrowing was considered unnecessary.

The application of topsoil presented the most difficult problem of the entire project. It was desired to place this material with a minimum of manipulation and several types of spreader boxes were tried without success. A side delivery paver was also investigated by proved unsuccessful for this application. It is possible that a small scraper, reportedly used elsewhere in the past on similar projects, would have served the purpose but equipment of this description was not available. The method finally employed was quite successful and can be recommended for future work of this type.

Briefly, the procedure was similar to that used for distribution.
Fig. 11 - Three-wheel roller employed for compaction of the soil-stone mixture.

Fig. 12 - Near view of the uncompacted mixture obtained when the full quantity of soil was applied at one time and pulverized.
of natural soil. Material was dumped in small piles, windrowed on the pavement edge and then spread. Use of this method differed slightly from its previous application to natural soil in that more manipulation was needed to break up clods and uniformly distribute the material on the shoulder. In some instances, topsoil was carried beyond the point of shoulder to the cover stone on the slope. When necessary, a straight tooth harrow was used to straighten the shoulder line, however, this operation was best accomplished prior to topsoil placement. After the topsoil was spread, seeding and straw mulching proceeded in the conventional manner.

**Full-Depth Stabilization**

The second method of building the top course was applied to a section of the east shoulder (outer shoulder-north bound lane) extending approximately 2000 feet southward from the railroad overpass. In this section, the total quantities of materials were not varied but natural soil was eliminated and replaced by an equal amount of topsoil. The full quantity of soil (1.75 cu. ft. per. sq. yd.) was applied uniformly over the stone, agricultural limestone was spread, and the combination of materials was mixed for the entire depth. The mixture was then laid out, fertilized, and rolled as previously described. A typical appearance of this mixture before final rolling is shown in Fig. 12. After rolling had taken place, the appearance was quite similar to that shown in Fig. 6. In order to provide a seed bed, a straight tooth harrow was used to loosen the top 1 1/2 inches of shoulder prepared in this way. Then, seeding and mulching proceeded in the usual manner.
The section described above was constructed for two reasons. First, considerable difficulty had been encountered previously in efforts to achieve uniform topsoil distribution, whereas pulvimixer operations had been rather simple. Thus, the second method offered a means of insuring uniform construction by application of the full quantity of soil and blending the materials by pulvimixing. Secondly, it was believed that the additional quantity of topsoil used would enable the mixture to support vegetation better without causing a great loss in load-supporting strength of the shoulder. In addition, the mixture would result in a more granular shoulder having more resistance to surface disfiguration by traffic and provide relatively high skid resistance. Although the mixture would be less stable than the one originally designed, it would probably be strong enough to resist occasional loads.

Turf Shoulder - Hardstand Combination

A third method of construction, entirely different from the previous methods, was employed in another section of the project. This procedure began on the west shoulder (outer shoulder - south bound lane) at the northern end of the project and extended southward for approximately 7000 feet. Essentially, the section consisted of normal turf shoulders with interspersed hardstands of dense aggregate 300 feet long and spaced approximately 1000 feet apart (Fig. 13). The method combines desirable appearance with a highly stable hardstand for emergency use. The portion of the shoulder not devoted to hardstands was similar to the shoulder normally built on high-type construction in the past, but the inclusion of some limestone made a difference sufficient to mention.
Fig. 13 - General view of section containing hardstands separated by normal turf shoulders.

Fig. 14 - Near view of compacted aggregate in a hardstand area prior to sealing with asphalt and No. 8 stone chips.
Construction of this section was accomplished by agreement with the contractor rather than by change order. Therefore, some modifications were made in order to maintain the original material quantities designated in the contract. Turf sections were underlain by approximately two inches of compacted No. 610 stone. Only topsoil was used, and it was spread two to three inches deep. Agricultural limestone, fertilizer and seed were not changed in quantity and were applied in the usual manner.

Hardstands were constructed of an aggregate composed of a combination of No. 610 stone (65 per cent) and agricultural limestone (35 per cent) by weight. The stone was blade-mixed (with approximately 7 per cent water added for workability) and laid out and compacted by a three-wheel roller. After curing, the hardstands were primed with asphalt and covered with stone (No. 8). General appearance of the compacted aggregate prior to sealing is given in Fig. 14.

Performance

Three inspections of the project have been made; in December, 1954, April, 1955 and October, 1955. These were supplemented by brief observations at intervening times to insure that no significant changes occurred between inspections. From the time of the first inspection it was apparent that vehicles had been on the shoulders at many locations, so in effect the shoulders were being "tested" for stability as well as appearance.

Stability

Sections where stabilized material was overlain by a one-inch
seed bed of topsoil showed rather prominent tracking at the first inspection, made when the project was approximately two months old (Fig. 15). Ruts extended only through the topsoil layer with no apparent displacement of stabilized material. In April and in October, 1955, this same condition was apparent (Fig. 16 and 17). Depth of penetration of traffic had not increased; however, disfiguration was more prominent due to the absence of vegetation in the tire tracks. Also, it was evident that surface water had been trapped in some of these depressions.

Where stone and topsoil were pulvimixed for the full depth (2000-foot section south of railroad bridge), tracking was also observed during the first inspection (Fig. 18). On close inspection it became apparent that disfiguration was limited almost entirely to the straw mulch with negligible deformation of the shoulder. Inspections in April and October, 1955 indicated this condition was continuing, Fig. 19, while not typical of the section since the shoulder at this point had been subjected to far more than average use, convincingly illustrates the stability of this type of treatment.

The third type of shoulder construction - turf shoulders with 300-foot dense aggregate hardstands spaced approximately 1000 feet apart - had a very satisfactory appearance on the first inspection (See Fig. 13). Rarely had traffic been on the turf sections of this shoulder. However, where it had, rutting was deep and apparently dangerous. At that time hardstands were in excellent condition. On the second inspection little more evidence was available to indicate usage of the turf portion of the
Fig. 15 - Near view of vehicle tracks on a shoulder stabilized in the normal way and having 1-in. of topsoil.

Fig. 16 - Tracking in the section illustrated in Fig. 15, at the time of the second inspection six months after completion of the project. Tracking extended no deeper than topsoil layer, so principal damage pertained to appearance and not stability.

Fig. 17 - Section shown in Figs. 15 and 16 at the time of the October, 1955 inspection (age one year). Damage was still limited to tracking of the topsoil layer. Trapping of surface water was indicated in both these tracks, as well as those observed in the preceding April.
Fig. 18 - Tracking in section pulvimixed for full depth, December 1954. Close inspection revealed that most of the disfiguration was limited to the straw mulch with little displacement of the shoulder.

Fig. 19 - At the time of the October, 1955 inspection very slight tracking was observed in the shoulder pulvimixed full depth. Area in this view is not typical but was selected to show the negligible effect of concentrated traffic on the shoulder adjacent to a side road.
One hardstand was showing a slight tendency to shove laterally toward the ditch and the seal treatment was cracked very slightly. When the project was inspected in October, 1955, the turf shoulders indicated additional rutting at the points where traffic had used the shoulder and these were definite water traps (Fig. 20). The condition was not general but was readily apparent. All hardstands, except one, were in excellent condition with the seal intact (Fig. 21 and 22). Heavy use of hardstands was indicated by considerable collections of trash adjacent to these areas in contrast with the lack of debris elsewhere along the shoulder. Failure of the one hardstand noted on the April inspection had become much more pronounced in October, and the surface was in need of repair. With this exception shoulders stabilized in this way have performed satisfactorily.

Grass Cover

When the first inspection was made in December, 1954, seed germination and growth of grass cover on stabilized shoulders appeared to be developing at a rate equal to that observed in the median strip - which had a normal turf treatment. This observation applied to the entire project except a few isolated locations having large quantities of stone not covered with topsoil. However, due to the extended period of drought, germination could not be considered normal on any portion of the project.

In April, 1955, germination and seedling growth was normal and essentially equal in all sections of the project. The exceptions to this were a few spotty locations where poor distribution of natural soil had
Fig. 20 - Normal turf shoulders between hardstands showed relatively severe rutting at the points where they had been subjected to traffic. At the time of the third inspection (October, 1955), several of the ruts had become definite water traps.
Fig. 21 - General view showing excellent condition of hardstand in October, 1955 (age one year)

Fig. 22 - Near view of hardstand surface. Seal coat was intact and in excellent condition as shown. Only one hardstand showed damage.
resulted in very open stone shoulders (See Fig. 6). The overlying topsoil had settled into the large voids leaving a very granular surface unsuitable for supporting grass.

Differences in growth of vegetation were apparent when the October inspection was made. As expected, there was appreciably greater growth on the normal turf shoulders and median than on the stabilized shoulders. Here the grass was rather dense except in localized areas disturbed by traffic. Fig. 23 illustrates the appearance typical of unstabilized shoulders.

Growth on stabilized shoulders covered by topsoil ranked next. Portions of this type shoulder which were constructed early in the project often showed rather spotty growth due to non-uniform distribution (Fig. 24). However, portions constructed after this difficulty was overcome had good growth but still a growth appreciably less than that of normal turf sections. Typical condition of the majority of shoulder area involved is illustrated in Figs. 25 and 26.

Poorest growth was very apparent on the section where topsoil and stone was pulvimixed for the full treated depth. Here grass was neither as dense nor as well developed (Fig. 27) as in other sections. Distribution was fairly uniform even though sparse, but the overall appearance was reasonably pleasing.

It was interesting to note in all sections that while only Fescue and White Clover had survived the summer, numerous seedlings appearing to be Rye Grass were developing.
Fig. 23 - Near view of turf on an unstabilized shoulder one year after construction is typical of the growth observed in all unstabilized sections.

Fig. 24 - Spotty growth prevailing in stabilized sections where distribution of either natural soil or topsoil was not uniform. Locations of this type were limited and represented a small portion of the shoulder stabilized in this way.
Fig. 25 - General view of stabilized section having one inch of topsoil cover. This condition was typical on shoulders stabilized in this way (October, 1955).

Fig. 26 - Near view of the section shown in Fig. 25. Note uniformity of growth and rather wide spacing of clumps. Compared with the growth on unstabilized sections (Fig. 23), grass stand was sparse.
Fig. 27 - Near view of shoulder stabilized for full depth (October, 1955). Grass was neither as dense nor as well developed as in other sections.
Slipperiness

Only the section pulvimixed to full depth, and of course the hardstands, appeared to offer good skid resistance. In the section covered by topsoil tire tracking indicated some skidding. It is logical to assume that the topsoil when wet acts as a lubricating layer over a firm base and thus produces a very slick surface. Normal turf shoulders, of course, offered little resistance to skidding.
Summary of Observations

While it is too early to reach final conclusions concerning this type of construction, there are several pertinent points concerning the project and methods of building the shoulders which may be summarized as follows:

1. The construction of stabilized turf shoulders presents no problem that can not be solved with materials and equipment normally used in highway construction.

2. The actual quantities of material used on this project as evidenced by increased shoulder width were slightly in excess of requirements. As general requirements they were satisfactory, however, in the future they should be adjusted to the particular conditions of the project. This will prevent the placing of more material than is required or can be paid for under the specification.

3. Distribution of natural soil must be essentially uniform prior to mixing in order to prevent non-uniformity of the finished product. This can best be accomplished by blading soil into a windrow on the pavement edge and uniformly spreading it across the shoulder.

4. Topsoil should be distributed in a manner similar to that used for natural soil, but more care is necessary to insure very uniform distribution. When topsoil is spread, enough should be premitted to spill over the point of shoulder to adequately cover all exposed stone.

5. Light dragging with a straight tooth harrow (teeth sloping away from the direction of motion) will adequately dress the shoulder line and provide a straight and uniform appearance. This operation can be performed best prior to the addition of topsoil.

6. Seeding and mulching of ditch slopes should proceed only after completion of the shoulder. In short, all seeding and mulching should be done in one operation.
7. With regard to differences in growth of vegetation, normal turf shoulders (unstabilized) had the highest rate of germination and fastest growth. Stabilized sections covered with topsoil were reasonably satisfactory in this respect, and shoulders stabilized for full depth were relatively poor. On the latter, grass cover was sparse and poorly developed even a year after construction.

8. Traffic use of stabilized shoulders has resulted in very little damage. Rutting has penetrated only the layer of topsoil on sections stabilized in that manner. Normal turf sections rutted deeply, and penetration of traffic was negligible where full depth stabilization was used. Thus, the full depth stabilized shoulder rated best in this respect, followed by stabilized shoulders covered with topsoil. Turf shoulders rated a poor third in ability to support traffic.

9. Only areas having considerable surface stone offer satisfactory skid resistance for vehicles turning onto the shoulder. Shoulders stabilized for full depth met this condition but other sections (excluding hardstands) appeared dangerously slick when wet.

10. The section consisting of intermittent hardstands separated by normal turf shoulders has considerable merit. It presents no construction difficulties and provides a clear differentiation between turf and stable shoulders. It lacks a continuously safe emergency pull-out area but does offer a high type hardstand at frequent intervals.


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