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ust Control During Construction Operations

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Soil and weather conditions during construction of highways are often conducive to extensive dust formation. Dust may become a serious hazard to traffic and to residential areas if in the immediate vicinity of the job. It also presents a definite health hazard to working men.

The necessity of dust control has long been recognized. The most common medium for dust control has been, and in most instances continues to be, the use of water applied as often as necessary to "lay the dust."

To achieve a reduction in the cost of frequent water sprinkling, hygroscopic salts have been used in areas of relatively high humidity and diluted mixing-type asphaltic emulsion has been tried by a number of states. Recently a number of new products have made their appearance on the market.

On many of our California highway construction jobs the new project parallels the present travelway, or borders residential areas where the presence of dust in the air becomes a serious problem. In order to study the performance and possible economic advantages of various dust palliatives, a number of test sections were placed in the median strip on a recent highway project. The following products were used: water, diluted asphaltic mixing emulsion, a lignin product and a resinous petroleum product. Water proved to be the most expensive and for the most part the least effective method of combating the dust.

)URING CONSTRUCTION of our highways, the type of soil encountered combined h certain weather conditions are often times conducive to extensive dust formation ecially in the more arid regions. Dust becomes a serious hazard to traffic, is rimental to orchards, increases the cost of equipment maintenance and constitutes uisance to residential areas if in the immediate vicinity of the job site. Dust also sents a definite health hazard to working men.

Agencies engaged in heavy construction and some allied industries have long recoged the necessity of dust control. The most common medium for dust control has n, and in most instances continues to be, the use of water, applied as often as necary to "lay the dust."

In order to reduce the cost of frequent water sprinkling, certain hygroscopic salts 'e been used in areas of relatively high humidity and diluted mixing-type asphaltic ulsions have been tried by a number of states. Recently a number of new products 'e been developed and have been used on haul roads, certain open pit coal and ore ning operations, and in connection with the operation of air fields.

On a recent highway construction project the new construction paralleled the exist- roadway. The type of soil encountered in the new median strip and strong prevail- winds, created a serious dust hazard to the traveling public. To study the performe and possible economic advantages of various products, a number of test sections re placed in the median strip area.

DESCRIPTION OF THE TEST SITE

The project consisted of constructing 5.6 mi of new concrete pavement between 1.0 north of Greenfield and the Salinas River on US 101 in Highway District V. It was structed during 1957 under Contract 58-5TC4F. The route location is referred to V-Mon-2-D. The new alignment parallels the existing two-lane highway throughout

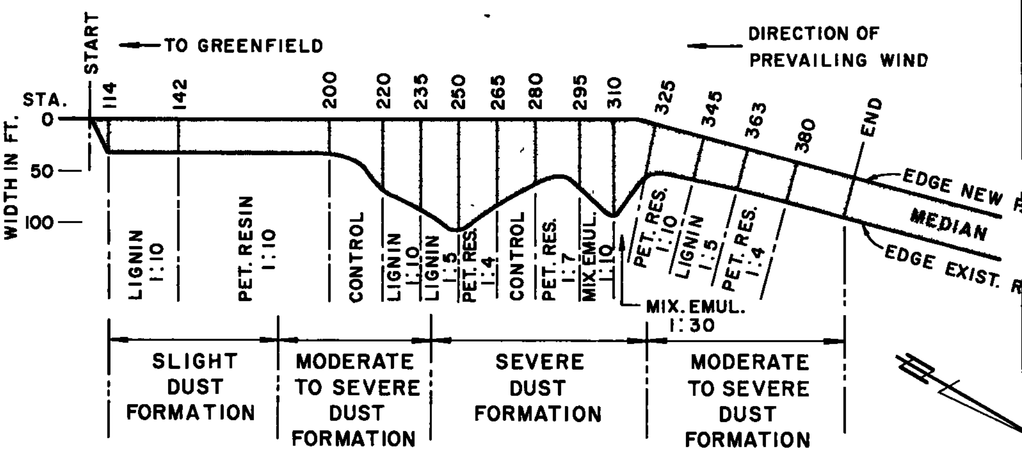


Figure 1. Dust control test sections—road V-Mon-2-D test sections laid on Aug. 12, and 14, 1957.

the entire 5.6 mi. The new roadbed is raised above the existing travelway and nece sitated extensive grading on the median strip. The new median varies from 35 to about 100 ft in width with 1:6 side slopes (Figs. 1 and 2).

Soil conditions on about 80 percent of the job made the area highly susceptible to vere dust formation, especially where the median was the widest. Unfortunately thi area has also a serious wind problem during the summer months. Winds of 25 to 3 mph occur almost daily in the Salinas Valley, and on the job site such winds began about 11 a.m. and subsided about 7 p.m. The wind direction was almost parallel to the major portion of the project. A serious dust hazard developed shortly after sta of construction requiring extensive and continuous dust abatement, which was done sprinkling with water up to the time of the laying of the test sections.

DESIGN

During discussions with the resident engineer the following information was obta relative to the dust problem on this contract. Dust formation was very severe betw stations 180± and 400±. From station 108 to 180±, the new construction is in an ar of rather granular rocky material, which only generated minor amounts of dust. It interesting to note that this area continues southward beyond Greenfield where a sim lar job was built without any serious dust hazard. It might be significant that the fa ing region also terminates in this area, indicating a marked change in soil characte tics. The field observations are further substantiated by the results of sieve analys and sand equivalent tests on representative samples from the median strip (Table 1

TABLE 1

GRADING AND SAND EQUIVALENT VALUES FOR SOILS FOUND IN THE MEDIAN ON CONTRACT 58-5TC4F, ROAD V-MON-2-D

			Grading—Percent Passing															S
Test No.	Sta. to Sta.	Dust Formation	2 in.	1½	1	¾	⅜	4	8	16	30	50	100	200	5μ	1μ	E
57-1870	110+00 to 180+00	Slight	100	97	92	87	79	74	69	60	47	24	12	7	4	3	[illegible]
57-1871	180+00 to 240+00	Moderate to severe	—	100	99	98	96	95	93	88	73	49	31	20	10	8	[illegible]
57-1872	240+00 to 310+00	Severe	—	—	—	—	—	100	99	99	96	91	80	63	25	16	[illegible]
57-1873	310+00 to 400±	Moderate to severe	—	—	—	—	100	99	98	97	93	78	62	57	27	17	[illegible]

The most severe dust formations occurred between stations 180± and 325±. It will noted from Figure 1 that the median strip is quite wide in this area and the prevail- winds, averaging 20-25 mph, blow almost parallel to the alignment. It appears t the slight difference in intensity of dust formation between stations 180 to 325 and to 400± is due to the change in alignment and the differences in median width. Af- consultation with the resident engineer, a series of test sections were laid out and necessary quantities of concentrates for the various types of proposed dust pallia- es were determined and ordered.

The final test section (Fig. 1) was based on the objective of comparing a number of wn commercially available products at dilutions recommended by the vendors. Mix- -type asphaltic emulsion, a petroleum resin product, and a lignin sulfonate were sen for the trial.

The properties of the standard mixing-type emulsions are well known and no further scription is required. The petroleum resin product is a concentrated emulsion com- sed of semi-liquid petroleum resins together with wetting agents and water. The concen- te may be further diluted with varying proportions of water. The wetting agents in-

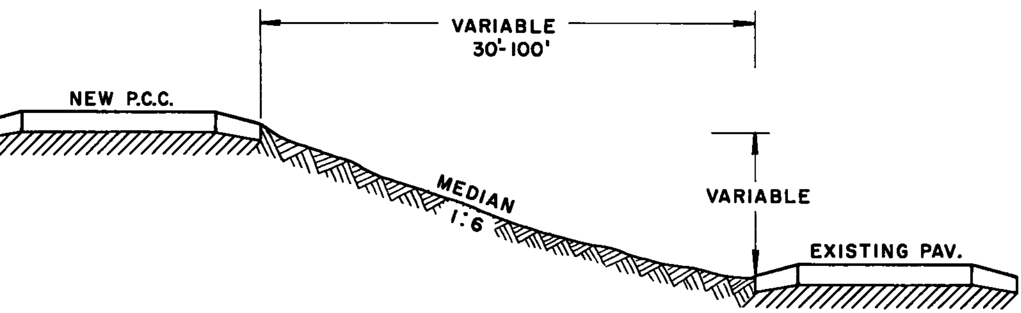


Figure 2. Cross-section—dust control test sections, road V-Mon-2-D.

ase the spreading power of the diluted emulsion and also increase the penetration the dust layer. The active cementing agent, for the dust forming particles, is the roleum resin fraction. Because this fraction is derived from petroleum, it is insol- e in water and is not leached out by rain. It is of a yellowish color and shortly after lication the treated surface appears almost the same color as the original ground. e lignin sulfonate is derived from waste products obtained in the manufacture of paper ducts. The material is a lignin derivative and contains chemical compounds derived m wood pulping. It may be purchased as a powder or a water solution containing 50 cent solids. The water solution was used on this job because of the economics of pping and handling on the job site. It is composed of surface active chemicals and, refore, acts as both a wetting and cementing agent. The cementing agent itself is uble in water and to some extent can be washed out by rain. The treated surface ap- rs quite dark, assuming a dark brown color when treated with the more concentrated utions.

An effort was made to place some of the various dilutions of each type of material in as of different dust intensity. Two controls were also established to determine the nparative water costs.

CONSTRUCTION

All of the test sections were placed on August 12, 13 and 14, 1957. The various parations were stored on the job site in trailers and spreading was performed with tandard asphalt distributor.

The materials were pumped into the distributor from the storage trailer and water was ded to produce the desired dilution. In the case of the lignin and asphalt emulsion, concentrate was first pumped into the distributor and the water added. With the res- us petroleum product, the concentrate was added after the water in order to reduce foaming. In all cases, no extra agitation was necessary for blending. The water wa under high pressure and dropped from an 8-in. standpipe through the manhole on top of the distributor into the tank. This caused a pronounced surging action which aide in mixing. It should be noted that both the lignin and resinous petroleum product hav additives incorporated in the concentrate for promoting a very rapid mixing in high dilutions.

One of the difficult field decisions in the use of any material is to determine the best spread rate for the particular soil being treated. On this job, the median area between stations 180± and 400± had been extensively watered over a period of about one month. The movement of the water trucks had compacted the material in the top ¼ to ½ in., and coupled with the fact that the major portion of the median was on a fa slope, indications were that a runoff might be expected during spreading operations.

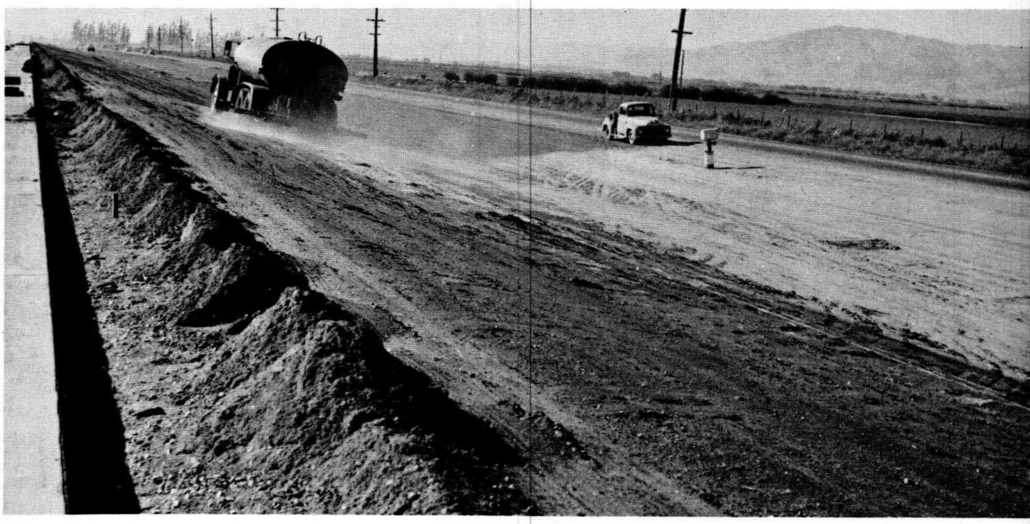


Figure 3. Typical appearance of various dilutions of dust controlling agents immedi ately after first spread of 0.25 gal per sq yd on median slope. None or only ver slight runoff was noted on the first pass.

Preliminary trials, with a hand watering can, indicated that definite penetration coul be obtained, with a minimum of runoff, when a maximum of 0.25 gallon per sq yd wa spread in a single application. Recommendations from the producers literature indi cated that 0.5 gallon per sq yd should be satisfactory in preventing dust formation or an area not subjected to traffic movements. Therefore, it was decided to spread a to tal of 0.5 gallon per sq yd with two passes of 0.25 gallon per sq yd. This procedure was followed throughout all of the test sections. Some difficulties were encountered establishing the spread rate and a number of trials were necessary, inasmuch as the available charts for spreading the more viscous asphalts proved useless with these d lutions. However, final calculations indicate that an average of 0.56 gallon per sq y was spread in the lignin and resin test sections and 0.54 gallon per sq yd in the asph emulsion sections. The final spread rates show that calibration trials are necessary when using normal oil or asphalt spreading equipment. These trials only required a short delay on the morning of the first day.

The normal procedure was to make the first pass forward, back up along the test section, and then immediately spread the second pass over the same strip. On the first pass there was very little runoff on the slopes, and penetration was about ⅛ to in. with the second pass showing a slight runoff (Fig. 3). On one of the sections attempt was made to increase the total spread by a third and fourth pass over the er portion of the slope of the median. There was considerable runoff and it was dent that 0.5 gallon per sq yd was the maximum amount that would properly pene- te and stay on the slope. It is interesting to note, that good penetration with no run- was achieved with the same spreading procedure in the area between station 114 180± where a rather rocky, granular material was encountered. There were no iculties in spreading operations with the various dilutions of the three products ap- ed in the test sections.

EVALUATION STUDIES

Approximately 24 hours after completion of spreading, the test sections were eval- ed on the basis of surface appearance and dust formation (Fig. 6).

The lignin-treated sections of 1:5 and 1:10 dilutions, were a darkish brown shortly er spreading. They tended to form a definite crust on the surface which began to ck and curl slightly in some areas, about 24 hours after spreading (Fig. 4). The etration appeared to vary from 1/16 to 3/16 in. After 48 hours the crust tended to crack small blocks roughly 3- by 3-in., with a tendency of the edges of the blocks to l upwards. These blocks did not, however, separate from the underlying material no dust or distress was noted in the sections with winds averaging 20 to 25 mph.

The petroleum resin sections gave a yellowish brown appearance after completion spreading. Penetration was the same as in the lignin sections; but no cracking or ling was noted, even in the 1:4 dilution, indicating a uniform cohesiveness of the ated soil.

he asphaltic mixing emulsion, 1:10 dilution turned very black, shortly after spread- . The asphalt appeared to have formed a mat at the surface although it was quite ntly bound to the underlying material, indicating at least a partial penetration of the ulsion prior to separation of the asphalt. At the end of 24 hours the section was in ellent condition. There was no cracking or curling of the thin asphaltic membrane ering the surface. The original plan also called for a 1:20 dilution of emulsion, the quantity available did not provide a sufficient volume and the final dilution was

ure 4. Lignin sulfonate 1:5 test section showing cracking and beginning of curling of edges of small blocks 24 hours after application.

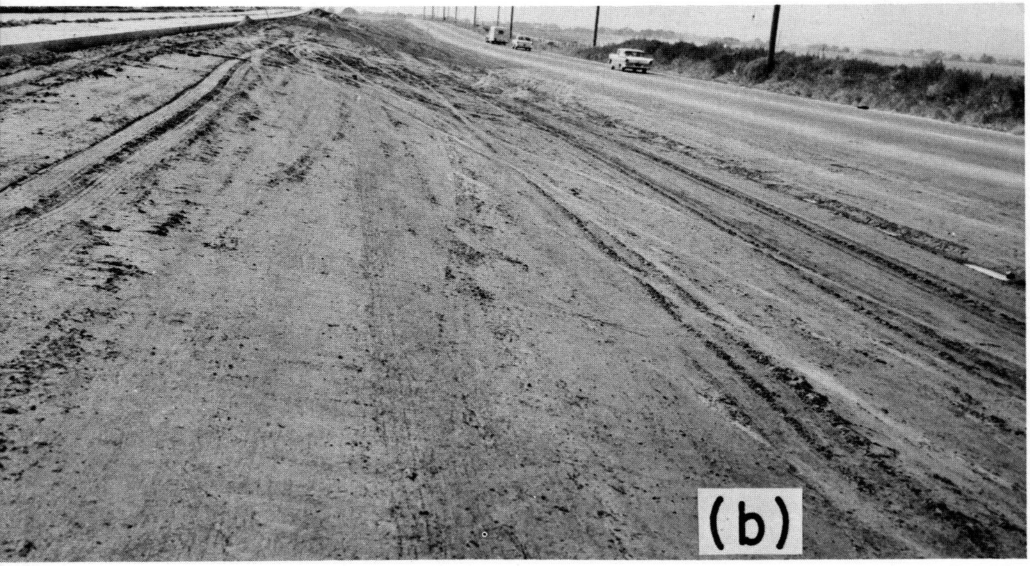
1:30. It was surprising to note that this high dilution provided a darkish brown surfa with quite good penetration. One could definitely tell that a treatment had been performed. After 24 hours the section looked good with no cracking or curling.

As mentioned previously, the median strip on Monday morning, August 12, was i a tightly compacted condition. Water had been placed on the median during the nigh and it was decided to stop all sprinkling in order to secure maximum penetration of products under test. Because of problems involving transfer of the concentrates to storage trailers and checking of spread rates, only one section, the lignin 1:5, was completed by noon. About 11 a.m. the wind began to blow and by 1 p.m. the wind v locity was averaging around 20 mph, with gusts up to 25 mph. By 1:30 p.m. visibil on the adjacent travelway had been reduced by dust from the median so that lights w required. The photographs shown in Figure 5 indicate the extent of dust formation.

Figure 5. Typical dust formation on untreated sections 5 hours after cessation of w tering operations. Wind speed 20-25 mph. Note reduced visibility on existing trave way on left side of photograph. Median had previously been heavily watered for mo than a month and tightly compacted by movement of water trucks.

All of the test sections were completed by noon on Wednesday, August 14. At 11 a.m. the wind again started and reached Monday's velocity by 1:00 p.m. No water been applied to any of the test sections, except the controls, after spreading was co pleted and although high winds persisted throughout Wednesday afternoon and evenin there were no signs of dust. Photographs shown in Figure 7 show the absence of du over the treated sections. It may be concluded that dust formation had been comple eliminated by all of the various dilutions of the preparations placed in the test secti

Generally, to justify the use of dust controlling agents, it is necessary to prove t they are more economical than the normal method of sprinkling with water. To pre an economic analysis for this job, two control sections were established for the pur of determining watering costs during the evaluation period. The resident engineer maintained cost records on watering of the control sections during a 23-day period, lowing completion of the treated sections. During this interval 138,000 gallons of w were applied to Control No. 1, station 265-380; and 104,000 gallons to Control No. station 200-220. At a price of $1.75 per 1,000 gallons of water, including supplyin hauling and spreading, an average figure of $0.0009 per sq yd per day for cost of wate the control sections, during the 23-day evaluation period is obtained. This cost figure



gure 6. Appearance of test sections, 24 hours after application: (a) asphalt mixing
ilsion—1:10 section in foreground, petroleum resin 1:7 section in background; (b) untreated section in foreground, lignin sulfonate 1:10 section in background.

nsiderably lower than the watering costs of the entire median during a 10-day period st prior to spreading the test sections. The cost of watering the entire median of out 161,000 sq yd (total treated sections plus two controls) as furnished by the resint engineer amounted to \$450 per day, or

$$\frac{450.00}{161,000} = \$0.0028 \text{ per sq yd per day.}$$

is apparent that the controls were not watered as much as equivalent areas prior to eatment. This was due to the fact that the dust generated from the comparatively nall areas of the two controls, was less hazardous to traffic than the dust generated om the original total median area. It therefore appears reasonable to assume that the figure obtained from the cost of sprinkling the entire median during the 10-day p od just prior to treatment should be used for economic comparisons.

The total costs per sq yd for the various dilutions used are given in Table 2. Th direct comparison with the cost of watering is also given on the basis of the number days that each test section must provide against dust formation before the costs of t agents used equals that of applying water. It will be noted that this "break even" pe od varies from 4 to 14 days.

An evaluation study was made on September 18 and 19, 1957, or 35 days after pla ment. At this time, all of the test sections that had not been disturbed by construct activity, were in good condition and were fully effective in preventing dust formation without additional watering. A very small amount of water was being used on areas jacent to shoulder construction where blading operations had torn up the surface and along the shoulder edge of the existing travelway. No water had been applied to any disturbed areas of the treated sections since the original spreading operations. On basis of the 35-day evaluation period, the saving by treatment amounted to $391.49 day for each day beyond the "break even" point for any specific dilution. The $391. figure was obtained by multiplying the total treated area, 139,819 sq yd, by the aver water cost per sq yd per day for the 10-day period prior to treatment. In other wor if the most expensive treatments, lignin 1:5 or resin 1:4, had been placed over all o the test sections, then at the end of 14 days of no watering, such treatment would ha paid for itself. The continued protection up to the evaluation period of 35 days had saved $8,221 ($391.49 x 21 days).

Figuring one of the less expensive treatments with an average "break even" point 8 days, the actual saving amounted to $349.49 x 27 days or $9,436.

The surface appearance of the test sections was such that it could reasonably be a sumed they would give additional protection from dust formation for at least another

TABLE 2

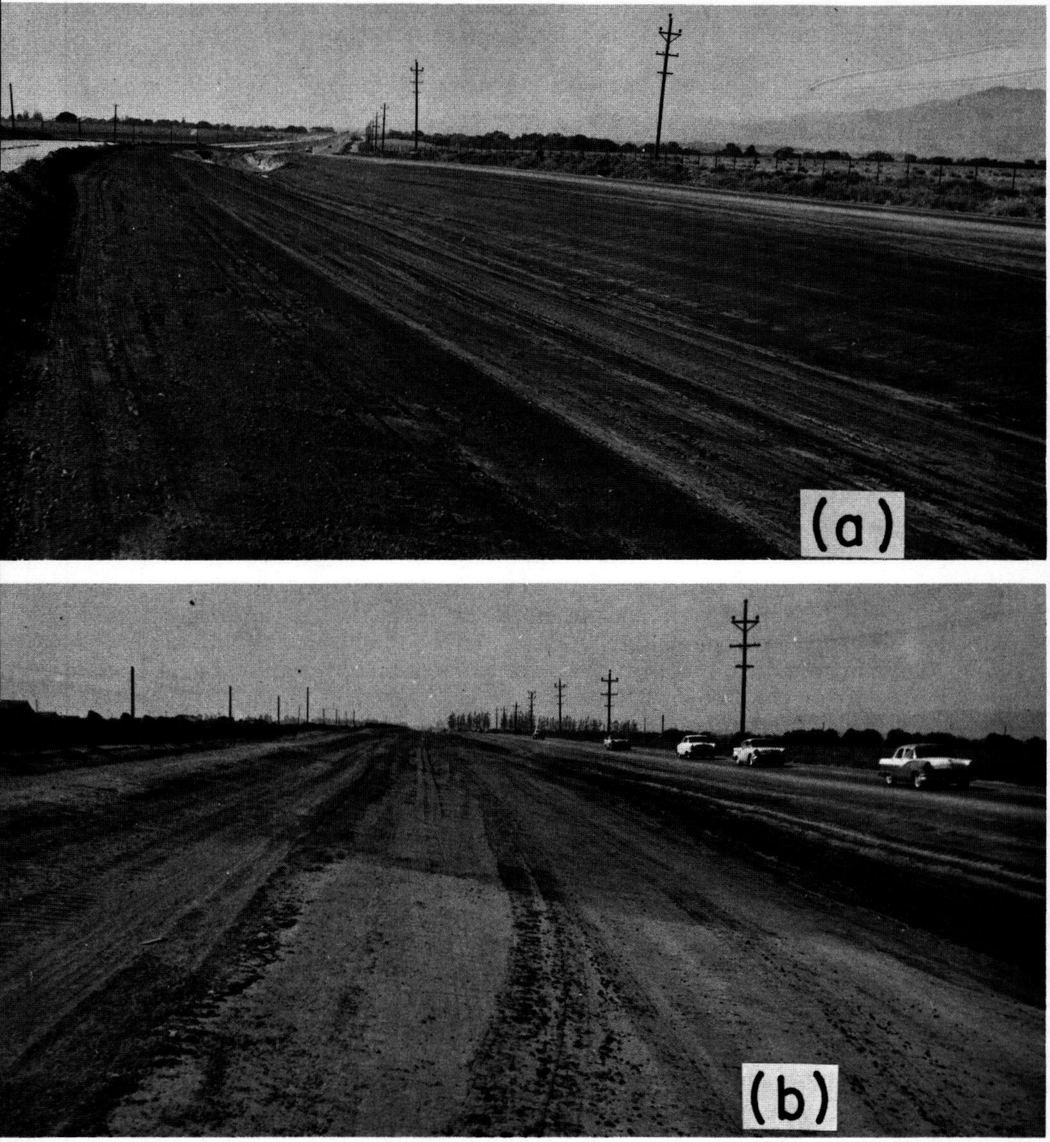
COST ANALYSIS FOR DUST CONTROLLING AGENTS USED ON CONTRACT 58-5TC4F, ROAD V-MON-2-D

Dust Binder Type	Dilution	Total Spread Area (sq yd)	Spread Rate (gal per sq yd)	Cost of Material Conc.	Cost of Water	Cost of Spreading	Cost of Total	Cost of Dust Controlling Agent (per sq yd)	Cost of Water Per Sq Yd per day Prior to Treatment	Break Ev Point fo Dust Contro in Day
Petroleum resin compound	1:4	22,677	0.56	$749.30	$17.78	$ 90.71	$857.79	$0.038	$0.0028	14
	1:7	9,750	0.56	201.19	8.37	39.00	248.56	0.026	0.0028	9
	1:10	32,000	0.56	480.56	28.51	128.00	637.07	0.020	0.0028	7
Lignin sulfonate	1:5	25,117	0.56	850.87	20.51	100.47	971.85	0.039	0.0028	14
	1:10	22,500	0.56	415.64	20.06	90.00	525.70	0.023	0.0028	8
Asphaltic mixing emulsion	1:10	12,750	0.54	188.43	10.96	51.00	250.39	0.020	0.0028	7
	1:30	14,966	0.54	78.56	13.69	59.86	152.11	0.010	0.0028	4

days or even longer if not disturbed by construction equipment. On this basis, the a tual saving to the state could have amounted to $349.49 x (50-14) days or $12,582 f the most expensive treatment and $349.49 x (50-8) days or $14,679 for the less exp sive treatment.

The survey made after 35 days indicated that all of the various sections were per forming in a satisfactory manner, with the same general wind conditions encountere prior to treatment (Fig. 8). The general appearance of the test sections at that tim may be summarized as follows:

1. Lignin sulfonate 1:5 and 1:10 dilutions still appeared quite dark, with quite ext sive cracking and curling in the 1:5 section. This cracking and curling had not caus separation of the crust from the underlying layer and no evidence of dust formation v present.
2. All of the various petroleum resin dilutions showed a remarkable change in co



'igure 7. Lack of dust formation over treated sections: (a) asphalt mixing emulsion :30—shows an area where the most severe dust formation was encountered on the job; (b) sphalt mixing emulsion, 1:10 background, petroleum resin 1:7 foreground. These photographs were taken approximately 48 hours after treatment with a wind velocity of 20-25 mph. Compare with photograph shown in Figure 5.

'rom the freshly sprayed surface. The sections gave no appareance of having been sprayed and showed no signs of cracking or curling as noted in the lignin section. On close inspection one could detect yellowish-like streaks where runoff had occurred during the second pass. Although these sections had assumed the color of the native soil he treatment provided full protection against dust formation at wind velocities exceeding 25 mph.

3. There was no major change in the appearance of the emulsion sections. There was no evidence of drying out or cracking and curling.

The condition of the various sections definitely indicated that protection in undisturbed areas would continue for a much longer period of time.

PLANT GROWTH

The treatment of median strips and other areas where future plant or grass growth is planned has raised the question as to whether dust controlling agents will tend to retard or destroy such growth. In the case of the three agents discussed here, there are reasons for believing that such growth might be accelerated. The lignin compound is water soluble and is relatively easily decomposed by soil bacteria, thereby enriching the soil. In fact, the only evidence of growth on the median strip was in the lignin sections where small amounts of alfalfa had started to grow, 35 days after application. Previous studies by the Air Force with the resin compound on a 20-acre semi-desert location clearly showed an improvement in growth of vegetation when compared with an adjacent untreated control area. All of these agents, including the highly diluted asphaltic mixing emulsion tend to prevent the upper layer of soil from drying out, and because of their dark color, they tend to increase the soil temperature near the surface, thus providing more favorable growing conditions.

OTHER APPLICATIONS

One of the important factors in the decision to use a special product to alleviate dust is the amount and price of water considered necessary for dust abatement on any specific project. If the water requirement is quite low, then the "break even" period may be extended beyond the period requiring dust control and any material may prove too expensive compared to water costs, although some monetary value should be assigned to the complete absence of dust at all times.

Consideration must also be given to other conditions on the job site. It should be stressed that, in using any kind of dust control, one must realize the marked differences between conditions encountered in undisturbed areas such as are cited in this report and those found on a haul road or detour under traffic. A single treatment, that may adequately protect an undisturbed area, may provide only a temporary protection for a heavily traveled haul road or detour. In most cases, where serious dust formation is encountered, the soil is extremely fine and if dust is present at the time of treatment, the actual penetration may be quite low even in high dilutions. The movement of vehicles, especially heavily loaded construction equipment, will disturb and break up the surface layer and immediately generate dust. It is, therefore, logical to expect that more frequent treatments will be necessary in such cases, and that the various agents will perform differently. While crust formation has been found to be of no disadvantage in controlling wind erosion, the absence of a brittle surface crust may be advantageous in traveled areas.

Some preliminary studies have been performed on the use of dust binder agents on haul roads and detours. An economic analysis is complicated by the amount and type of traffic and the necessity for retreatment as the original treated surface is abraded or raveled away.

On one contract traffic was routed through the job over 7.8 mi of untreated rock base. Prior to the start of paving operations a severe dust problem had developed and considerable water was required. Although such watering reduced the hazard to traffic, there were times when there was sufficient dust in the air to be annoying. Therefore, mixing-type emulsion was tried, by treating six sections varying from 1,000 to 10,000 ft in length. A 1:10 mixture was used and applied from the water truck at about the same speed as with normal watering operations. On three of the sections two spreads were made and on the other three only one spread. The penetration on all sections was quite good and the results were effective at the start and one of the two water trucks previously used was eliminated.

Three weeks later the entire area required blading because of raveling, and watering was again required on all of the treated sections. However, it was noted that the water requirements on these reworked treated areas were considerably less than before the application of the diluted emulsion.

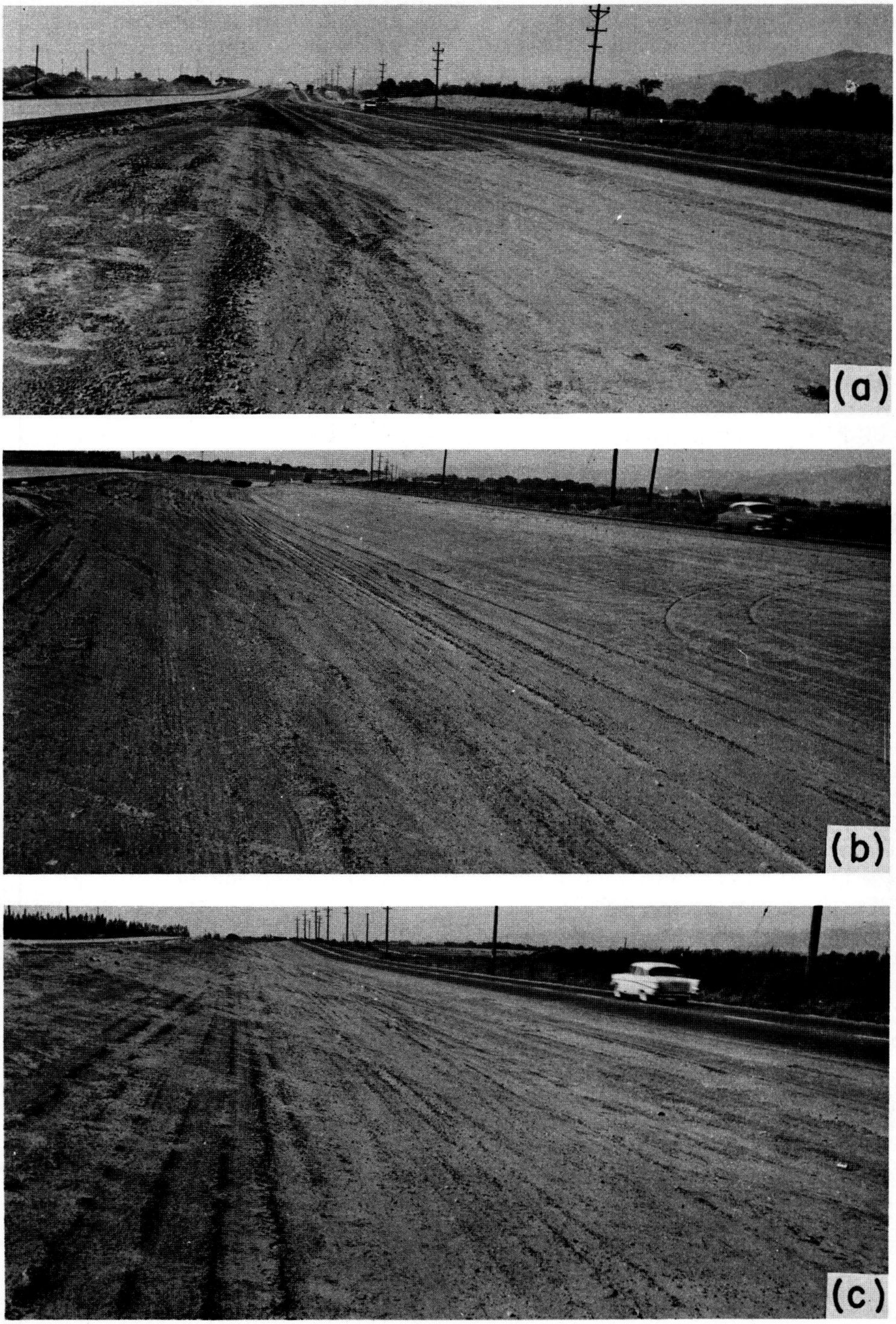


Figure 8. Typical appearance of various areas of the treated median 35 days after completion of treatment: (a) petroleum resin 1:10 foreground, lignin sulfonate 1:5 background; (b) asphalt mixing emulsion, 1:10 foreground, 1:30 background; (c) petroleum resin 1:7 foreground, asphalt mixing emulsion 1:10 background. Wind velocity at time that photographs were taken was 20-25 mph. No water had been applied to these sections following treatment. Note complete freedom from dust.

The following conclusions were drawn by the resident engineer on the basis of his observations: "A conservative estimate in the amount of water saved by using the diluted emulsion also showed a savings in money since water on this contract was pricec at $1.50 per M-gallons. In addition other benefits were realized, such as more effec tive control of dust at all times, day and night, and less annoyance to traffic."

On another contract, approximately 6,000 ft of processed selected material had bee laid. This section was being used by the contractor for heavy hauling operations and was adjacent to homes and several orchards where choice fruit was grown. Although the surface was extensively watered, many complaints were received because of dust raised by the passage of trucks. The 6,000-ft stretch was divided into three 2,000-ft sections. One of the sections was established as a control and watered at the same rate as previously used. On one section an initial treatment of 0.7 gallons per sq yd of a resinous petroleum product in 1:7 dilution was applied and after penetration follow by 0.3 gallons per sq yd of the same dilution. On the other treated section a mixing-type asphaltic emulsion was used at the same application rates, but with a 1:10 dilutio The heavy volume of traffic required periodic retreatment. In the case of the resin se tion these treatments involved an application of 0.2 gallons per sq yd of either a 1:10 c 1:20 dilution and the asphalt emulsion was applied at the same rate, but at a 1:10 dilution.

The study was continued for a period of 83 days, during which there was no rain, a traffic included not only heavy-duty trucks, but also DW20 scrapers. During this inte val the petroleum resin section was treated seven times and the emulsion section thre times. However, the comparison is complicated by the fact that in four of the seven treatments the resin binder was applied at 1:20 dilution, whereas a 1:10 dilution was f the asphalt emulsion.

During the 83-day test period the total costs for each section were: water control = $496, resin = $588, and emulsion = $279. The emulsion treatment showed a definite saving based on the relatively high cost of water at $1.50 per M-gallons.

The resident engineer, who observed the areas during the test period, states, "Bot materials were more effective than water in controlling dust. In both treated sections the development of dust was very slow, allowing the scheduling of a supplemental appli cation well in advance of critical dustiness."

The additional advantages of more positive control of dust and the fact that watering alone may not adequately control dust formation indicates that in some cases a dust controlling agent should be used even though the total cost is higher.

Experience to date indicates that the decision to use special products on haul roads must be made on the basis of each individual job and economical considerations may not be the most important factor.

CONCLUSIONS

The studies outlined in this report clearly indicate the economic advantage of treati dust areas whether undisturbed by equipment or traffic or consisting of haul roads witl some type of agents other than water. In the first cited example, Contract 58-5TC4F the saving to the state by using the preparations is estimated to be about $10,000. Th various agents tested can be easily diluted with water and spread with normal construc tion equipment. The additional advantage of more positive dust control indicates that i some cases a dust controlling preparation should be used, even though the total cost is somewhat higher than watering.

ACKNOWLEDGMENTS

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,ongitudinal and Transverse Control for 3ituminous Pavers

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Projects amounting to approximately 67 miles of asphaltic concrete on new base, 92 miles of asphaltic concrete overlay on old surface, and 277 miles of bituminous mat overlay on old surface, were placed under contract in Kansas during 1958.

The materials for these projects were mixed in hot-mix plants and placed on the road through bituminous pavers. Because of the limit to which bituminous pavers can level or smooth a road surface, the problem of placing the mixture to a smooth grade line with a true crown confronts both the engineer and the contractor on each project, particularly on overlays. With modern high-speed traffic a smooth grade line and true crown are musts in pavement construction.

This paper describes the development of two attachments that have been placed on the leading makes of bituminous pavers and have been successful in aiding the operators to cause the paver screeds to follow a smooth theoretical grade line with a definite uniform crown.

This method of paving requires several normal operations, such as ascertaining a new grade line from the original profile and the use of pneumatic-tired rollers for compaction. This method of paving requires less over-all work on the part of the contractor, because the skin patching in all cases can be reduced, and in some cases eliminated.

THE longitudinal and transverse control hereafter described is the outgrowth of an ktensive study of the bituminous paver motivated by irregularities in asphaltic surfaces, esults of the "lay it and see how it rides" method of laying hot-mix. The purpose of is paper is to show how the usefulness of the floating screed can be extended to far beond that which has been expected in the past.

Not many years back automobiles were traveling at speeds of 50 and 60 mph and at ose speeds a long gentle sag in the road surface was not noticeable. Now with speeds creased to 70 and 80 mph and with automobiles improved tremendously in operating d riding characteristics, this same long gentle sag becomes an abrupt bump.

Each year many miles of roads in Kansas become rough and distorted from their orinal condition yet their structural adequacy is still basically sound. This condition unubtedly also exists in other states.

Each year Kansas has been faced with the problem of making these roads smooth gain. In all cases short of reconstruction, some form of bituminous material is used, d until only recently, except for overlays on concrete, the bituminous material has een a road-mix, blade-laid type of construction.

The results of this method of construction are satisfactory, however, in avoiding the kpense of constructing costly detours, the work was done under traffic causing inconenience and danger to the traveling public. Three years ago this type of construction as changed to make use of plant-mix machine-laid methods. The traffic problem was olved and most opinions are that the quality of the mixture had been improved, however e riding surface, to say the least, was left with something to be desired.

Blade-laid method of construction can produce a good riding surface because of the ontinuous shifting of the mixture with the motor-grader to areas of the roadway where epressions exist in the subgrade. The shifting is both lateral and longitudinal. The ocations and limits of irregularities are of little concern to anyone except the blade operator. In a sense the leveling is accomplished automatically and the placement thicknesses are evidenced only by depth cores.

With machine-laid methods of construction the leveling is accomplished by skin patching, and to restore a satisfactory surface by this method is difficult or almost i possible because of the absence of ample material to shift, coupled with the lack of space in which to operate a motor-grader efficiently.

The problem at hand becomes very plain in that the bituminous paver needs help in placing asphalt to a true crown along a smooth grade line meaning that longitudinal ar transverse control of the paver becomes increasingly important.

The present-day paver is advertised to possess an inherent automatic leveling prir ciple which is true only in short areas, lengths of less than the machine's wheel base pull arm length. The leveling claim is accepted by contractors and engineers alike a when irregularities show up on the final surface their presence is accredited to have come from the subbase. The result of this complacency is that advancements and im provements made on the bituminous pavers have all been in the direction of speed, pc and output leaving the leveling capabilities both longitudinally and transversely exactl at the stage they were when the floating screed was first invented. In all fairness it should be stated that advancements have been made in consolidation or compaction of mixture prior to strikeoff which have improved the surface texture and final compacti of the asphalt surface.

Under present operational methods there is no positive control in either the longitu dinal or transverse direction. The paver is simply set on the surface and sent down road with the hope that the results will be good, after which the engineer gives it the driving test to judge its riding qualities. At times the desire to obtain a smooth ridin surface is even overshadowed by efforts to hold the amount of material used to a mini mum.

All bituminous pavers can be equipped with a crown or slope indicator that is attac to the screed at the rear of the machine. The obvious fact that very few of the machi are equipped with these devices should be reason enough that an indicator at that stag

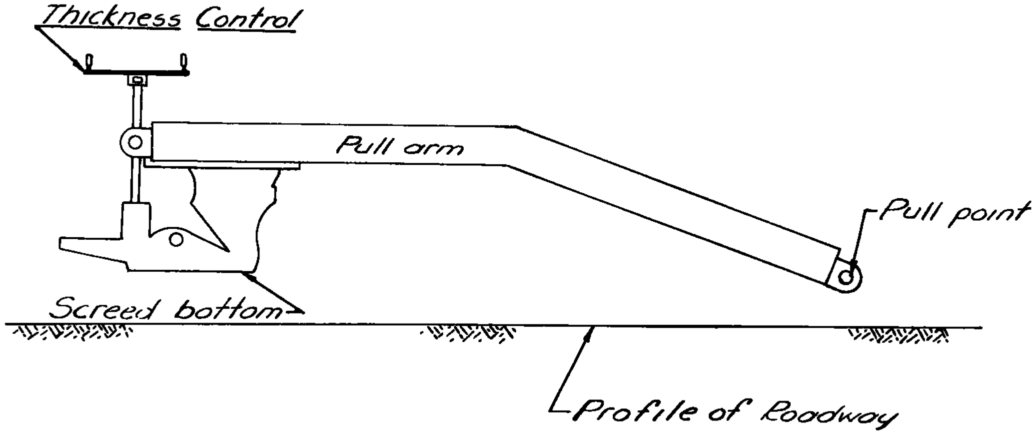

Figure 1.

of the placing of the mixture is inadequate. Further reasoning will prove that such an indicator only shows the slope of the crown of that part of the surface course which ha already been placed. Corrections made from this method of measuring are like walki in the dark; they are made in ignorance of the condition of the crown of the subbase a-head. At this time this is the only crown control available.

Pavers can also be equipped with an auxiliary screed or roller extending backward from the floating screed to extend the length of the screeding action of the machine.

'his is another negative approach in that the asphalt mix is placed to conform to a sur-
ace in the rear of the machine; a surface that has already been placed. The auxiliary creed or roller to be effective in these circumstances must force the floating screed hereby taking away its freedom and floating action.

The solutions to these two problems are similar in character to those mentioned ex-
ept that the point of attention must be moved forward to the center of control which is he area around the pull points. The pull point, of course, being the point at which the creed is suspended and by which the screed is towed.

This shift of attention can be immediately and easily accomplished on pavers where hickness adjustments are made in the front by raising and lowering the pull points.

On pavers with the thickness control on the rear of the floating screed the solution s not quite so simple, but nonetheless possible. The parts involved in the description

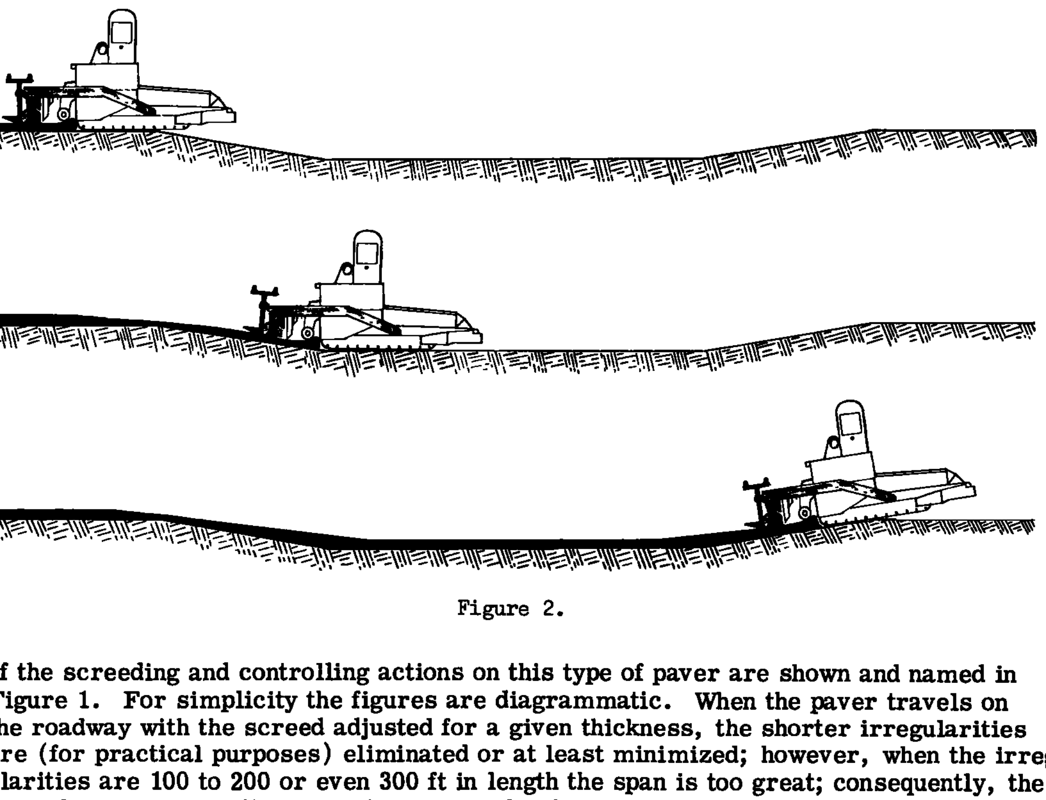

Figure 2.

f the screeding and controlling actions on this type of paver are shown and named in 'igure 1. For simplicity the figures are diagrammatic. When the paver travels on he roadway with the screed adjusted for a given thickness, the shorter irregularities re (for practical purposes) eliminated or at least minimized; however, when the irreg-
larities are 100 to 200 or even 300 ft in length the span is too great; consequently, the creeding action is effective only at the ends of the irregularity. In Figure 2 the screed ravels through a long sag with its thickness control at a given thickness setting. The ef-
ect of the screed is that in Figure 3 the length between crests of the irregularity is in-
reased and the length of the bottom is decreased while the depth of the irregularity is nchanged.

A more detailed look at the screeding action in Figure 4 reveals that the pull point ravels a line parallel to the profile of the road, and because the pull point is in front of he screed the screed bottom is tilted to conform to the irregularity before the screed ottom arrives at the irregularity thereby minimizing the roughness. Therefore it may e said that the pull point travels along a line parallel to the profile of the road and the creed bottom follows along a smoother profile spreading and compacting a mixture to flattened or evened profile.

In Figure 5, suppose that an imaginary line is projected forward from the screed ottom to about the pull point to a new point called the projected point that lies in the ame plane as the screed bottom. In Figure 6 the screed again travels the same sag

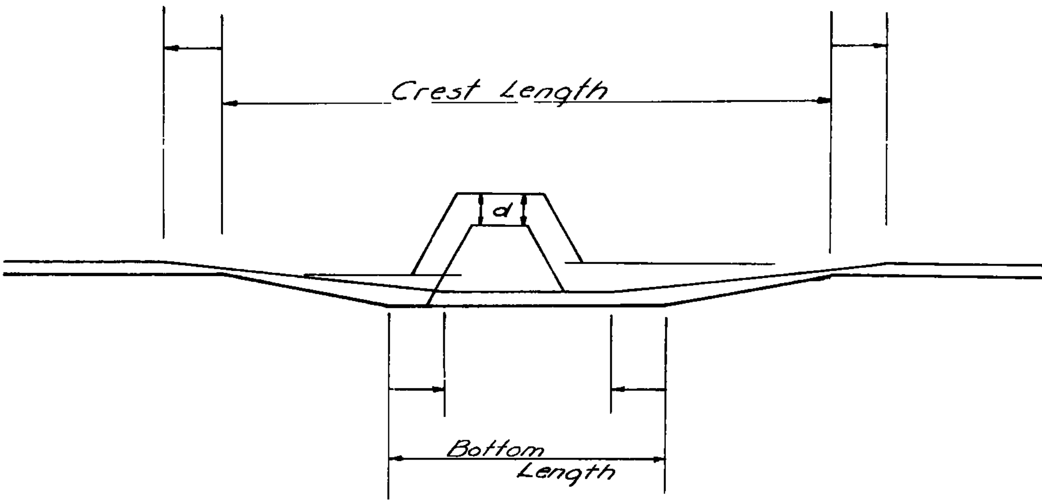

Figure 3.

with a given thickness setting thereby showing the course of travel of the projected point and that the screed bottom follows the projected point in the same manner in whi it follows the pull point.

In Figure 7 the screed bottom follows the projected point and the projected point is controllable by turning the thickness control on the screed. The screed again travels the sag in Figure 8; however, on this trip the projected point is caused to travel a line smooth in profile instead of allowed to follow the natural line parallel to the roadway profile and the screed bottom follows.

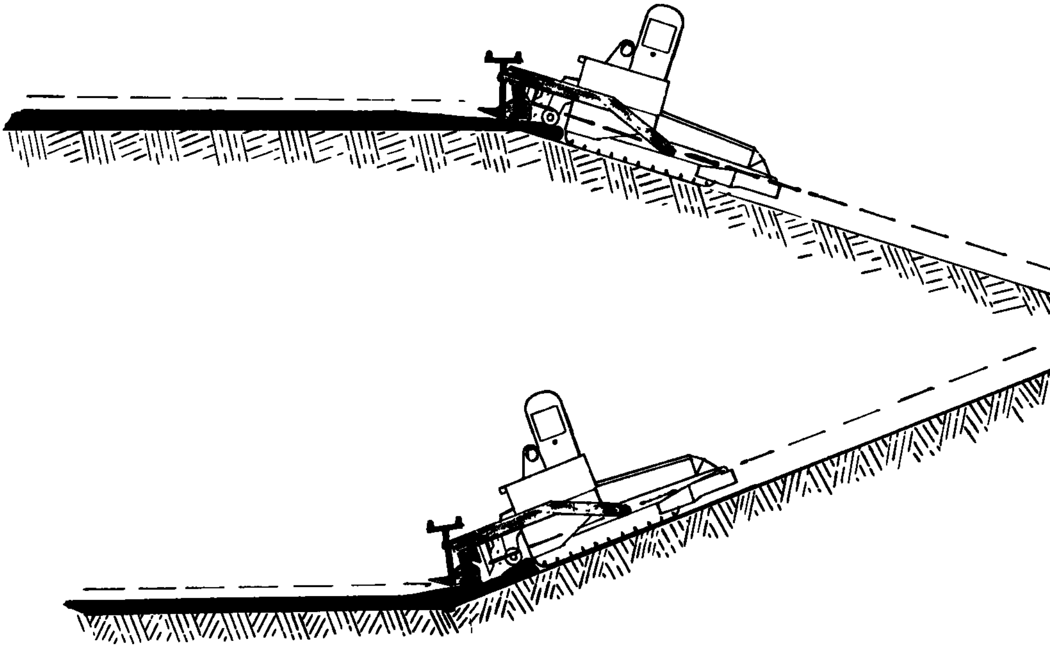

Figure 4.

To now, the projected point has been imaginary for explanation purposes. A projection at this location on the machine is impossible; however, in Figure 9 an offset linkage arrangement can be easily placed over the pull arm and pull point. The projected point

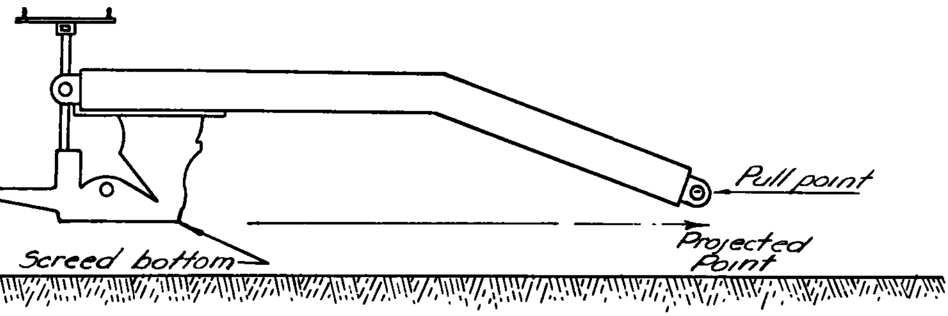

Figure 5.

is now real and no longer imaginary and can be maneuvered into ascending or descending positions by turning the thickness control. In Figure 10 the screed once more travels the sag with adjustments being made on the thickness controls so that the real projected point travels the theoretical grade line. The screed bottom (as described earlier) also follows the theoretical grade line thereby eliminating the sag.

With the longitudinal control achieved, the transverse problem in Figure 11 is approached by attaching the same linkage on the opposite side of the paver and placing a carpenter's level or slope indicator between the forward ends of the two projection arms. The allowance for crown may be provided for on the cross member between the forward ends of the projected arms or adjusting the turnbuckle placed in the linkage at the rear.

In summary, the projected point in one side of the paver is maneuvered with the thickness control to conform to an erected string line as the paver moves forward and the projected point on the opposite side is maneuvered with its respective thickness con-

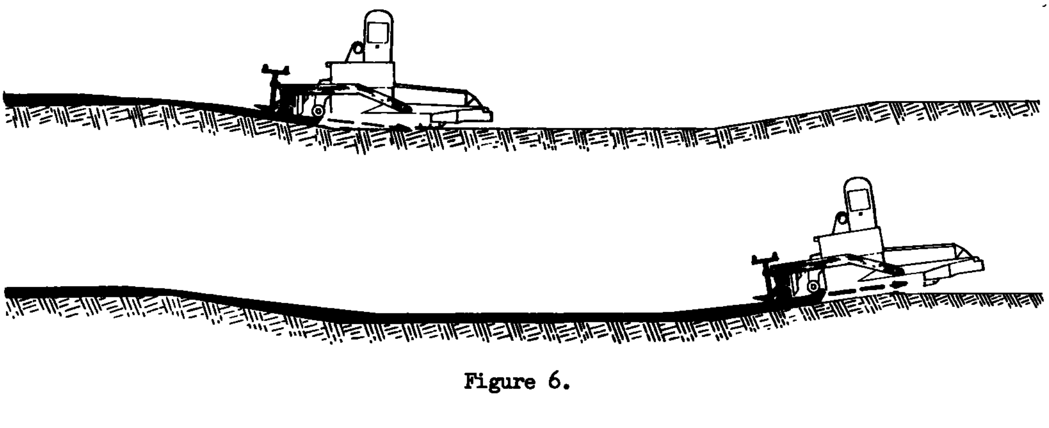

Figure 6.

trol along a similar line conforming to the indication dictated by the level between the two projected points. The screed then, because of design principle, must follow with a constant crown to a smooth grade line.

These two controls require the screed operators to disregard recommendations made by the manufacturer. Their instructions have been "Don't over control" and "Don't adjust for more than ⅛ inch in one machine length of travel." However, for these controls to be effective, the operator on the side of the paver next to the string

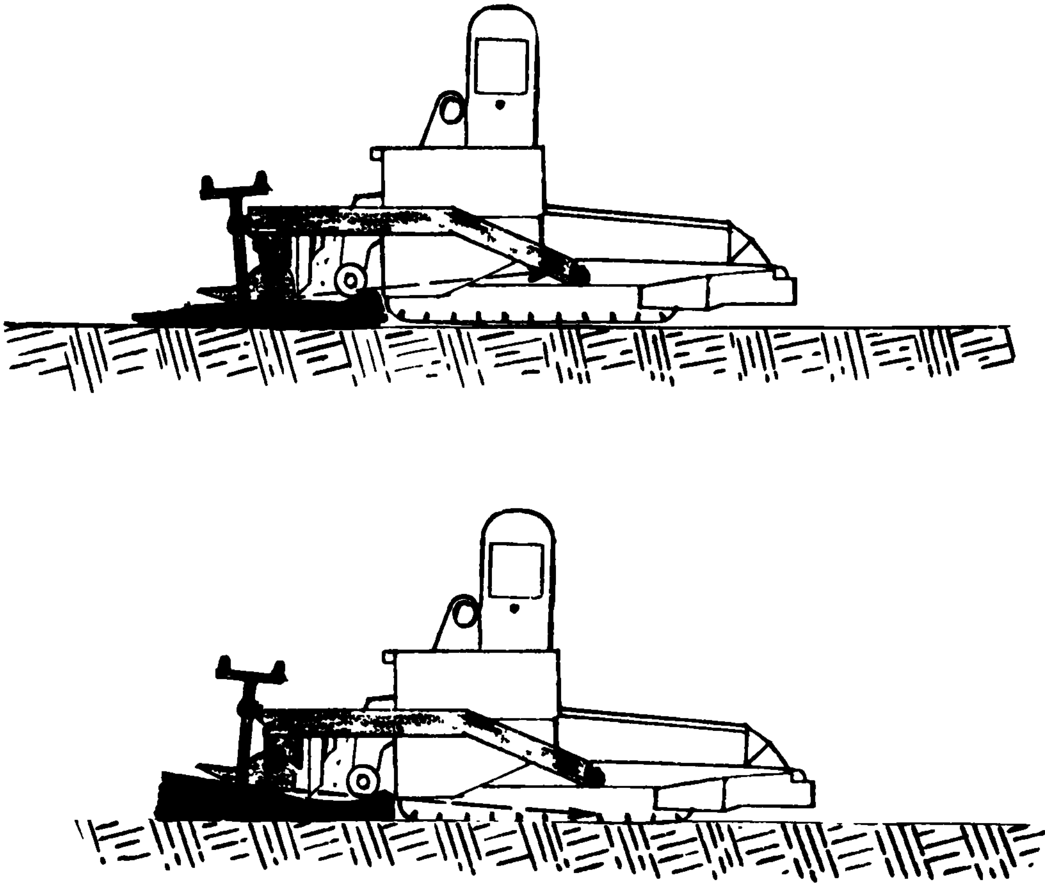

Figure 7.

line must cause the marker below the projected point to conform to the string line, regardless of the direction or speed necessary to turn the thickness control. Similarly, the level between the front ends of the projected points must be held in a level position regardless of the direction of adjustment or the speed in which it is made.

The string line referred to is erected near the center line of the road 6 or 8 in. outside of the area on which the mat is spread. The string line is erected to a grade line determined from profile elevations taken at 25-ft intervals along the center line of the road. In Figure 12 the grade line may be determined by plotting the profile to a distorted scale; horizontal—1 in. = 25 ft, and vertical—1 in. = ½ ft. This combination of scales magnifies the irregularities to the proportions that a mechanical adjustment can be made visually and the thickness values which would be the necessary thickness at the respective points are easily measured on the profile and entered in the field book.

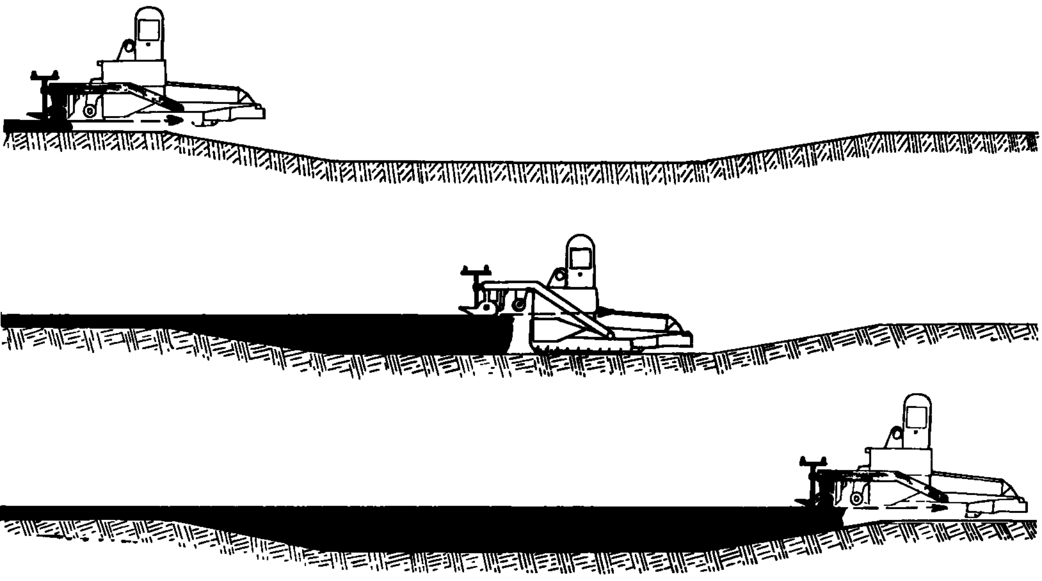

Figure 8.

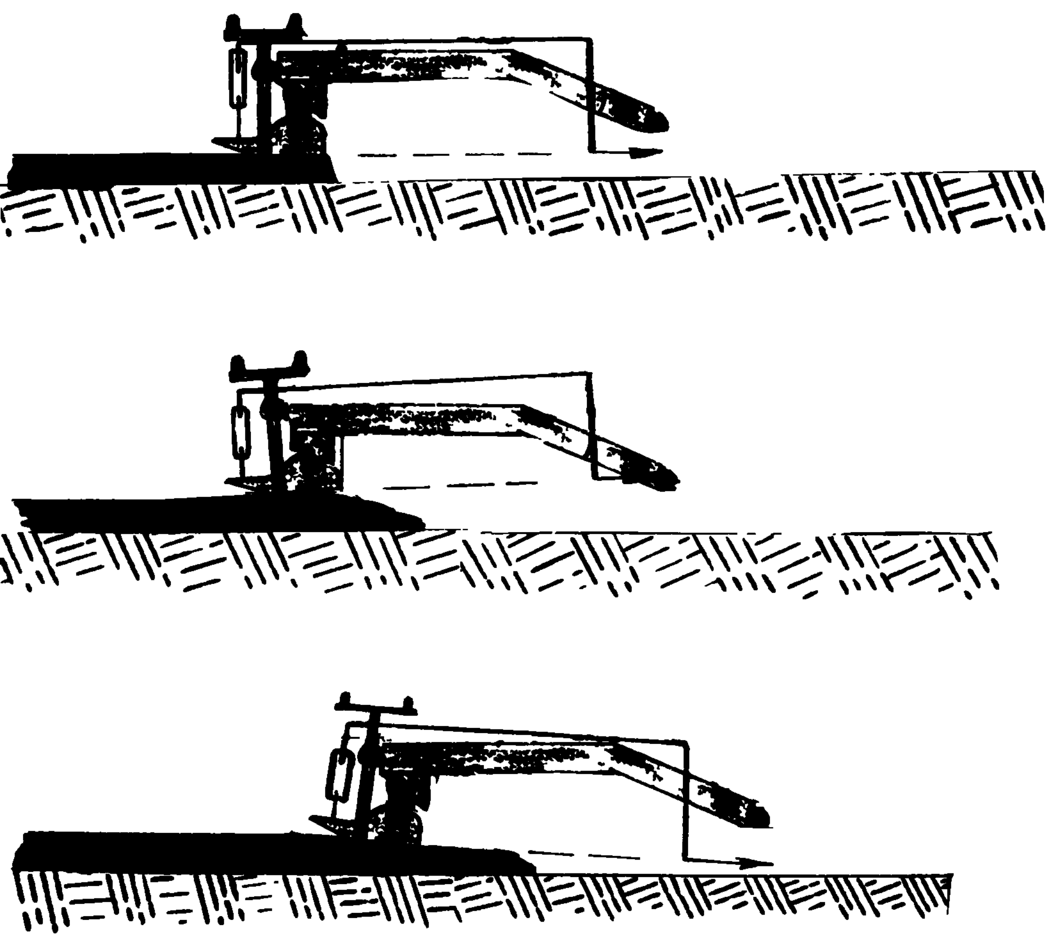

Figure 9.

The grade line can also be calculated longhand or with the electronic computer. Whether the calculations are made longhand or on the electronic computer there are several possible methods, the most satisfactory is possibly by projection. Using this approach the adjusted elevation of the second 25-ft point is determined by a ratio between the elevations of the first and fifth, the first is assumed to be correct. The adjusted elevation of the third point is determined by the ratio between the adjusted eleva-

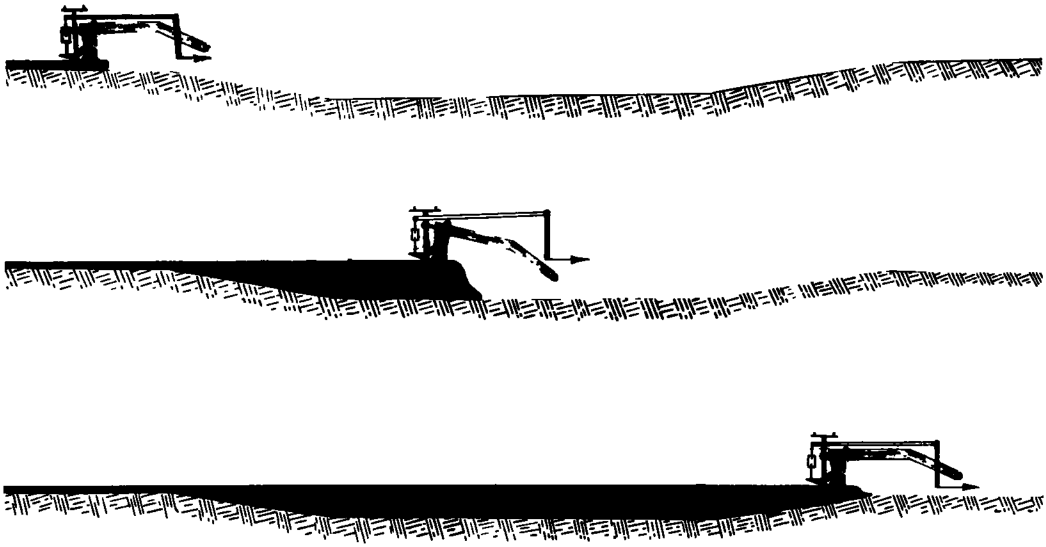

Figure 10.

tion of the second point and the actual elevation at the sixth. Once more the adjusted elevation at point number 4 is determined by the ratio between the adjusted elevation at number three and the actual elevation at number seven. This calculation along the entire profile will result in a smooth grade line. In either case the respective placement thickness values are entered in to a field book for reference at the paving site.

Interference of the string line with the batch truck operation is avoided by driving to grade large nails at the 25-ft points and attaching the string only a short distance in front of the paver thereby allowing the batch trucks to pass between nails not too far distant in front of the paver.

The placing of the mixture on the second half of the road is done in the same manner as the first except that the center line side on the second laydown is guided along the surface of the first half laydown instead of the string line.

There are many applications of the longitudinal and transverse controls to asphaltic concrete paving. Quite often the profile at the center line is smooth while the edges have become distorted, in which case the profiling is not necessary and the use of only the transverse or crown control will produce a satisfactory surface. The two controls are applicable to paving on horizontal curves by resetting the transverse control. Through transitions the resetting can be prorated or a string line can be erected for both sides of the paver. The surface of a laydown next to curb and gutter can be match with the lip of the gutter in the same manner that the surface is laid to a string line.

To say that these controls have produced gratifying results is putting it mildly. The results are visible to the eye and the ride test is unnecessary. Sagging and bulging center line and scalloped edges have been replaced with long graceful lines.

This does not mean that it all comes easily and automatically because about the time every thing is going along fine an operator pulls a boner and a ripple is formed. This has been one objection to this approach and certainly is a valid criticism; where human

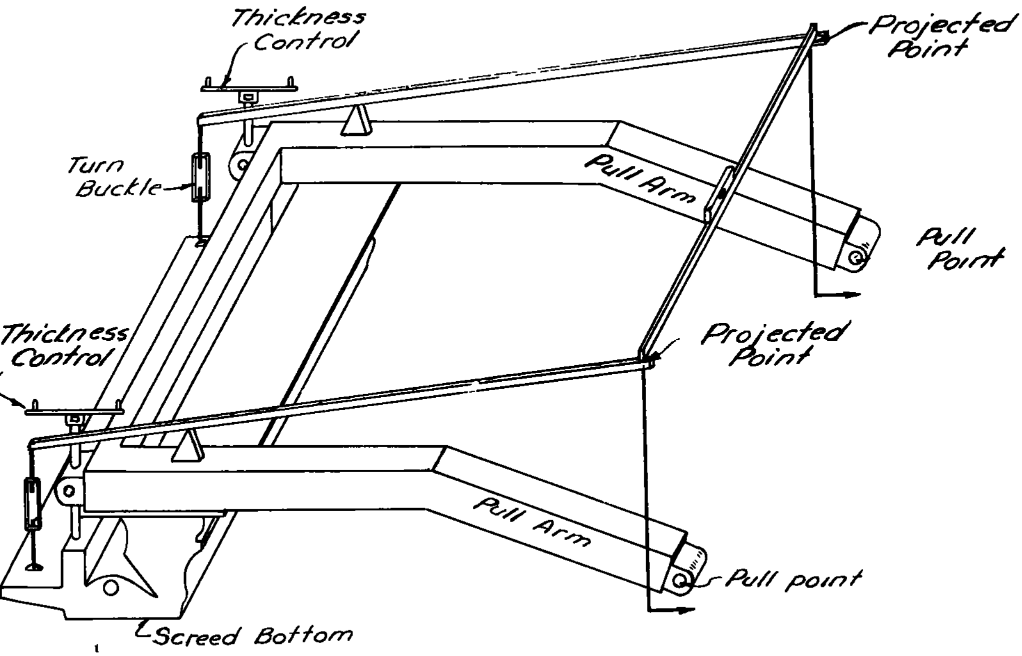

Figure 11.

ement is involved mistakes are made. However, this is no different from other construction work in that these mistakes can be held to a minimum or even eliminated with cooperation between contractor and engineer.

It is the author's opinion that bituminous surfacing of higher surface quality can be produced with a little more effort on the part of the engineer and less work effort and more skillful operational effort on the part of the contractor.

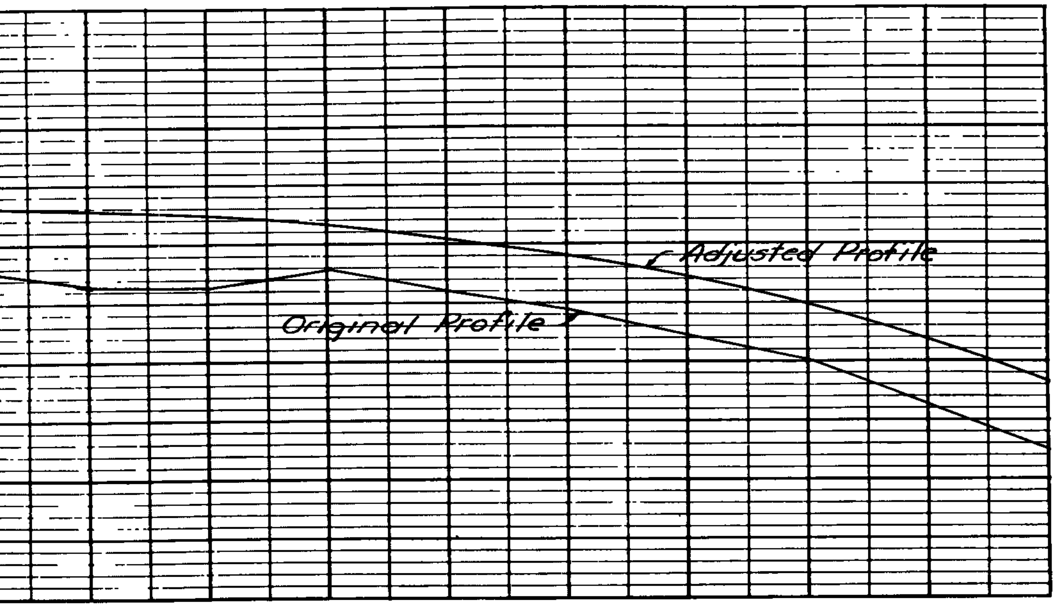

Figure 12. Scale: horizontal—1 in. = 25 ft; and vertical—1 in. = 0.5 ft.

It is also this author's opinion that the amount of material needed can be held to a minimum because there is no guessing and the risk of building high places higher wit blade work is eliminated.

Aside from the necessary effort on the part of the operator there are three "musts in this method to control: (1) the devices attached to the machine must be made stur and neat to details that will make them functionable and not vulnerable to vibration, (the devices must be constructed to include all paver linkage so that the devices will i dicate only the path of the screed bottom, and (3) the operators must make the adjus ments in such directions and at such speeds that the indicators are held at zero positi This approach does not mean that the manufacturer's recommendation of "don't over trol" is wrong, it simply means that adjustments made toward the true surface canno possibly be called over controlling.

There are reports that designs are now on the drawing boards for pavers with auto matic crown control and some form of longitudinal control. After reading the variou magazine articles on the use of electronics in longitudinal control, the question of co and versatility comes to mind. At the present the concern is with pavers now in oper tion and that will remain in operation until fully depreciated.

Two interesting notes might be mentioned. First, bases for asphalt are construct essentially in the same manner and with the same equipment as bases for concrete pa ment. Yet, no matter how accurately the base for concrete is placed the forms are s to tacked hub lines and on the same base asphalt construction has no positive control its operation. Second, in operating a bituminous paver an attempt is made to guide t screed in two directions—vertically and horizontally. For riding qualities the vertic direction is the most important. Yet, the control or indicator for the horizontal dire tion is located on the front of the machine while all of the devices and indicators concerning the vertical controls have been placed on the rear of the machine.

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