Asphalt Paving With Automatic Screed Control

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In Switzerland, deviation from the correct gradient is determined by a leveling instrument. Another device called a "Planum" records the profile of the road from one leveled point to another. Because a great deal of time is necessary to obtain an accurate surface profile by this means, movable testing instruments will be used and pavement quality will be classified by means of a smoothness index.

From 1963 through 1965 the author's firm carried out an extensive program of testing bituminous pavers with a floating screed unit, equipped with automatic screed control. Some of these tests are described and illustrated. For instance, on highway N 1, "Grauholz," an equalizing course and a wearing course were laid on a bituminous base course. Although the deviations from true profile in the base amounted to 2 in., no attempt was made to patch up the hollows first manually. The average deviation from true grade was (a) base course, 0.38 in.; (b) binder course, 0.13 in.; and (c) wearing course, 0.10 in. The tests prove that owing to the electronic screed control it is possible to lay surfaces of outstanding smoothness, even when there are large depressions and elevations in the base.

When a bituminous mat is laid with a finisher using an electronic controller special conditions must be fulfilled for obtaining a surface free from waves. These conditions are specified in the paper.

High primary compaction through the screed is of great importance in smoothing out an uneven base by machine without previous manual patching. As demonstrated by a test described in the paper, the degree of primary compaction by the screed unit determines the effectiveness of reducing the depth of potholes.

•SMOOTHNESS is one of the most important features of a pavement. A road with a smooth surface is safer and more comfortable for driving than a rough one. Research and experience have shown that the initial smoothness of a pavement has a direct influence on its durability.

Any unevenness in the structure of a road causes vehicles to bump. Unevenness in longitudinal direction causes vertical acceleration

$$a_v = s^2 \cdot dLS/d\ell$$

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where

a_v = vertical acceleration,
s = speed,
dLS = change of longitudinal slope, and
$d\ell$ = distance traversed.

The forces of negative acceleration reduce the adhesive weight and therefore reduce driving safety. There is a high correlation between acceleration and driving comfort. As the formula shows, the rate of change of slope with distance is of great importance, and short waves seriously impair comfort of the users, especially at high speeds.

Unevenness in the transverse direction causes additional horizontal acceleration

$$a_h = g \cdot dTS$$

where

a_h = horizontal acceleration,
g = gravity, and
dTS = change of transversal slope.

On curves, additional centrifugal force causes side-slip of vehicles. Changes of slope cause wheels to shimmy. Therefore it is important to maintain the designed slope.

RECORDING AND EVALUATING PAVEMENT ROUGHNESS

Swiss specifications for highway pavement surfaces can be summarized as follows:

1. The maximum variation from plan grade is ± 0.4 in.
2. When the pavement is tested with a 13-ft straightedge, the maximum permitted variance is ⅛ in.

Deviation from the correct gradient is determined by the Planum which consists of a 13-ft long plank with a recording wheel that records the profile of the road from one leveled point to another. The distance traversed is recorded on a drum in the scale 1:20, the ordinates in the scale 1:1. However, much time and care are required to obtain an accurate surface profile by this means. In addition, the correlation between road profile and actual driving comfort is lower than the correlation between acceleration profile and driving comfort. For these reasons, movable highway testing instruments will be used in Switzerland, and pavement quality will be classified by means of a roughness index. Tests have been made with the AASHO profilometer and with the BPR roughness indicator.

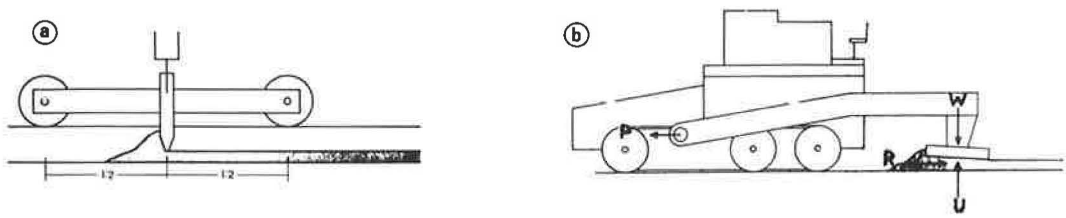
BITUMINOUS PAVERS

Fixed Screed Unit Paver

In European highway construction the same machines are often used for asphalt paving and for portland cement concrete paving. The equipment consists of two different units, the spreader and the finisher (Fig. 1a). The finisher consists mainly of a tractor, a small blade for striking off the material, and a screed for smoothing it. Blade and screed do not float on the mix; they are attached to the tractor. The finisher moves on rails or directly on a previously laid cement concrete curb (Fig. 2). The finisher is independent from the base, enabling it to lay a bituminous pavement which shows only slight deviations from true profile. However, every unevenness in the finisher's lane is directly transmitted to the surface in the scale 1:2, producing short, shallow waves which have perceptible effects on driving comfort (Fig. 3).

Paver With Floating Screed, Fitted With Electronic Screed Control

The main parts of the paver are a tractor unit and a screed unit. The screed unit is attached by long leveling arms, extending from the screed unit to a pivot point near the front of the tractor unit. Thus the screed floats on the mix as it is being spread.



$$U = \delta \cdot s^2 \cdot a \cdot \sin^2\alpha = W$$

Figure 1. (a) Paver with fixed screed; (b) paver with floating screed.

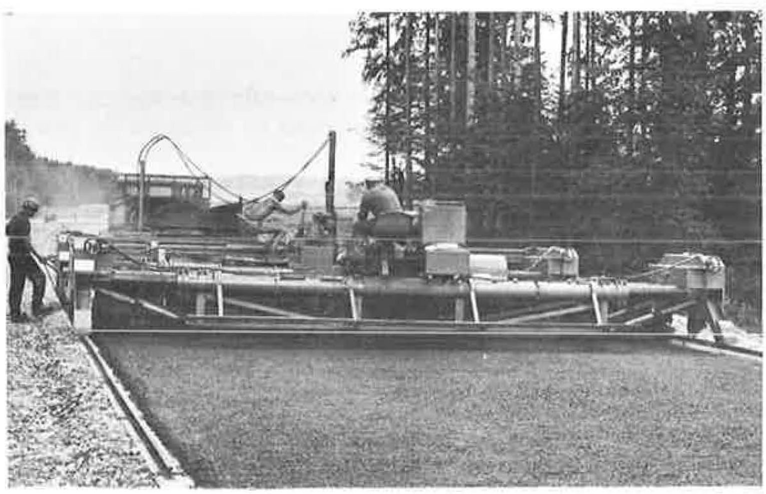


Figure 2. Paver with fixed screed, moving on rails.

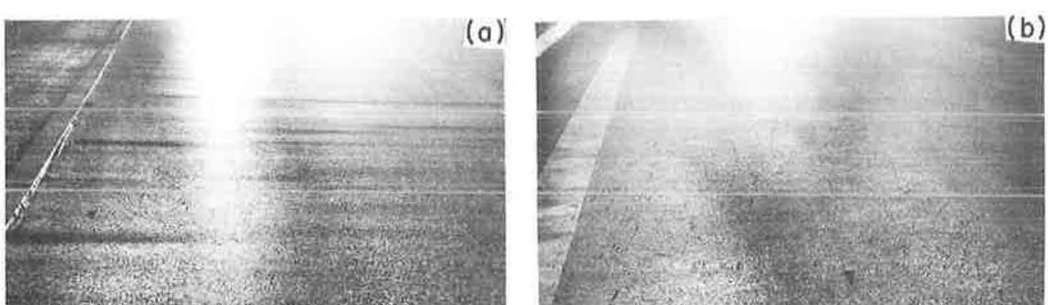


Figure 3. (a) Pavement laid with fixed screed paver; (b) pavement laid with floating screed paver.

Figure 1b shows the forces acting on the screed unit during the paving operations. As long as the paver is moving, pull, P, at the pivot point always exceeds horizontal resistance, R, in the screed plate. The screed constantly brings into balance or keeps in balance the vertical forces, vertical uplift, U, and weight, W, according to

$$U = s^2 \cdot \delta \cdot a \cdot \sin^2\alpha = W$$

$$\sin^2\alpha = W/a \cdot 1/s^2 \cdot f(t)$$

where

U = vertical uplift,
δ = density of mix,
s = paving speed,
α = angle of approach,
W = weight of screed unit,
a = area of screed, and
t = thickness.

At a given paving speed the paver has a tendency to lay a mat with a thickness that remains constant. A given tilt of the screed corresponds to each thickness. When the paver's track rollers pass over an elevation in the base, the screed plate is tilted upwards, and, as a result, the vertical uplift exceeds the weight and causes the screed plate to rise. While it rises U diminishes, until equality with W is restored and the vertical motion stops. Then the screed plate again moves in the horizontal direction only, in a path parallel to the direction of the pull. However, balance is not affected by the change of the angle of approach alone, but also by a change in the density of the mixture which occurs when the screed is pulled over an elevation or a depression in the base. When there is a hollow, the density diminishes and the screed lowers itself, but when there is an elevation the heightened density causes the screed to rise.

Irregularities in the base influence the smoothness of the surface by disturbing the balance of the forces acting on the screed. However, deviations are strongly reduced and do not appear immediately. A pavement which has been laid using a paver with a floating screed shows only a few slight waves, which have little influence on driving comfort (Fig. 2).

If the base on which the paver is moving does not correspond to the true profile, it is very difficult to lay a pavement conforming to standards. The operator has to change the tilt of the screed constantly in accordance with the thickness of the carpet. To do this at the right time and in the right proportion requires considerable skill.

Figure 4. Floating screed paver unit with electronic screed control.

The latest achievement in bituminous asphalt paving is a paver with floating screed, equipped with an electromatic screed controller system (Fig. 4) which makes it possible to lay pavements with exceptional smoothness and practically no deviation from true grade. In this system the necessary corrections of the screed approach angle are made with servomotors which react instantly to electric impulses from the control box (faster than is possible with manual screed control). Various tests made with the paver fitted with electronic grade and slope control are described in the following section.

EXPERIMENTS WITH ELECTRONIC SCREED CONTROL SYSTEM

Smoothing Out Irregularities in Subgrade

Heterogeneity of the soil is an important problem in Swiss highway construction. Often the subsoil has not quite consolidated at the time the pavement is laid, and settlement must be expected after traffic has begun. In such cases a 4-in. asphalt-concrete (AC) base is laid and exposed to traffic for two or three years and then the final pavement (1½-in. binder course and 1¼-in. surface course) is laid.

In 1961-1962 highway N 1 "Grauholz" was laid with a bituminous base course by means of a conventional paver. Under traffic several hollows appeared which were to be corrected when the final pavement was laid during 1964-1965. Although the deviations from true profile in the base amounted to + 0.8 and - 2.7 in., no attempt was made to patch the hollows manually with a smoothing course mixture.

The following process was chosen:

1. A wire was stretched parallel to the determined grade on the left side for a reference line (Fig. 5).
2. The sensor glides along this reference line; any deviation from the correct height releases electronic impulses controlling the left side servomotor, which corrects the tilt of the screed.
3. The position for the correct slope can be set on the control panel (Fig. 6). A pendulum device senses every deviation and reports it to the control box. From there the right side servomotor, which raises or lowers the outer screed, is actuated.

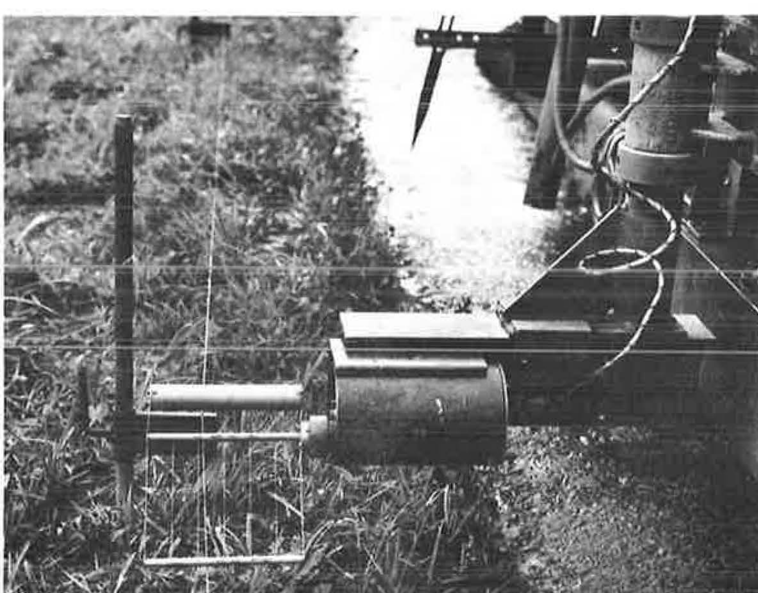


Figure 5. Grade sensor following stretched wire reference line.

Figure 6. Automatic screed control paver, showing control panel.

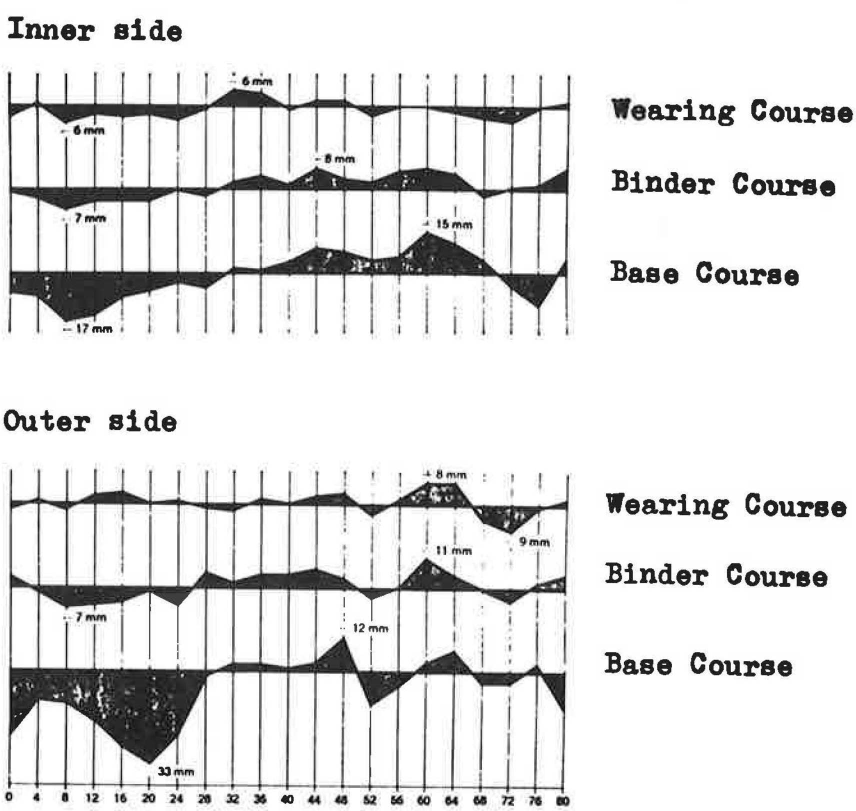


Figure 7. Deviation from true profile.

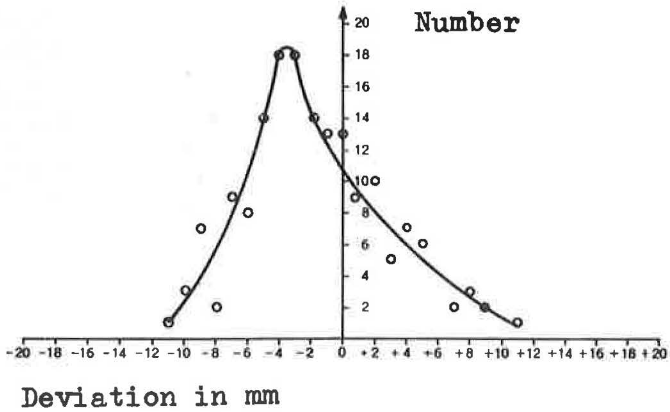


Figure 8. Frequency of deviations from true profile (168 leveled points).

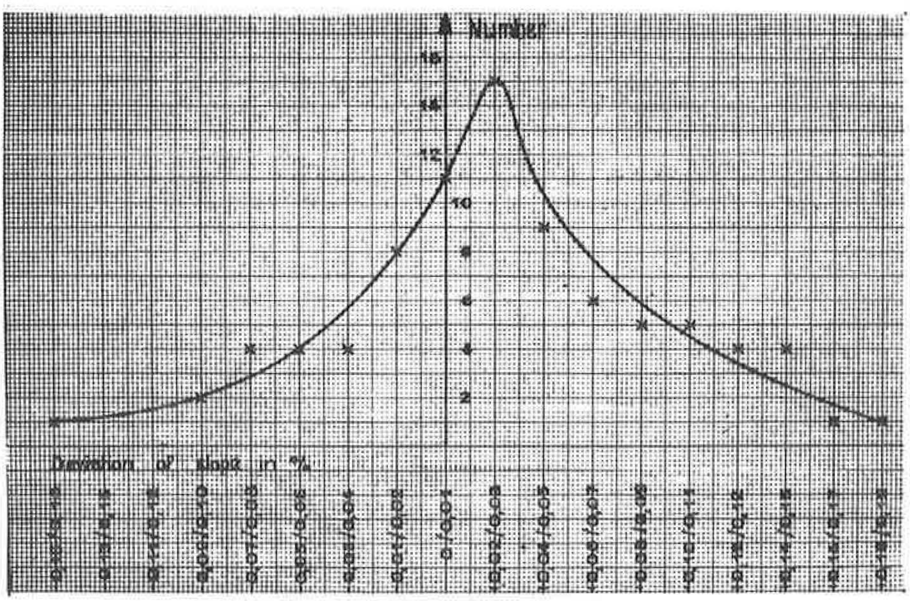


Figure 9. Frequency of slope deviations.

In two test sections of 330 ft each, the heights of the base, the binder and the wearing course were leveled and compared with heights on the plan. The results attained on section Nordrampe are shown in Figure 7.

For comparison purposes, we have calculated the profile variance, PV, which is defined as the average squared deviation from true grade.

Section	Base Course, $\sqrt{PV}$ (in.)	Binder Course, $\sqrt{PV}$ (in.)	Wearing Course, $\sqrt{PV}$ (in.)
Nordrampe			
Inner side	0.34	0.14	0.09
Outer side	0.38	0.13	0.10
Eyfeld			
Inner side	0.25	0.15	0.11
Outer side	0.41	0.14	0.10

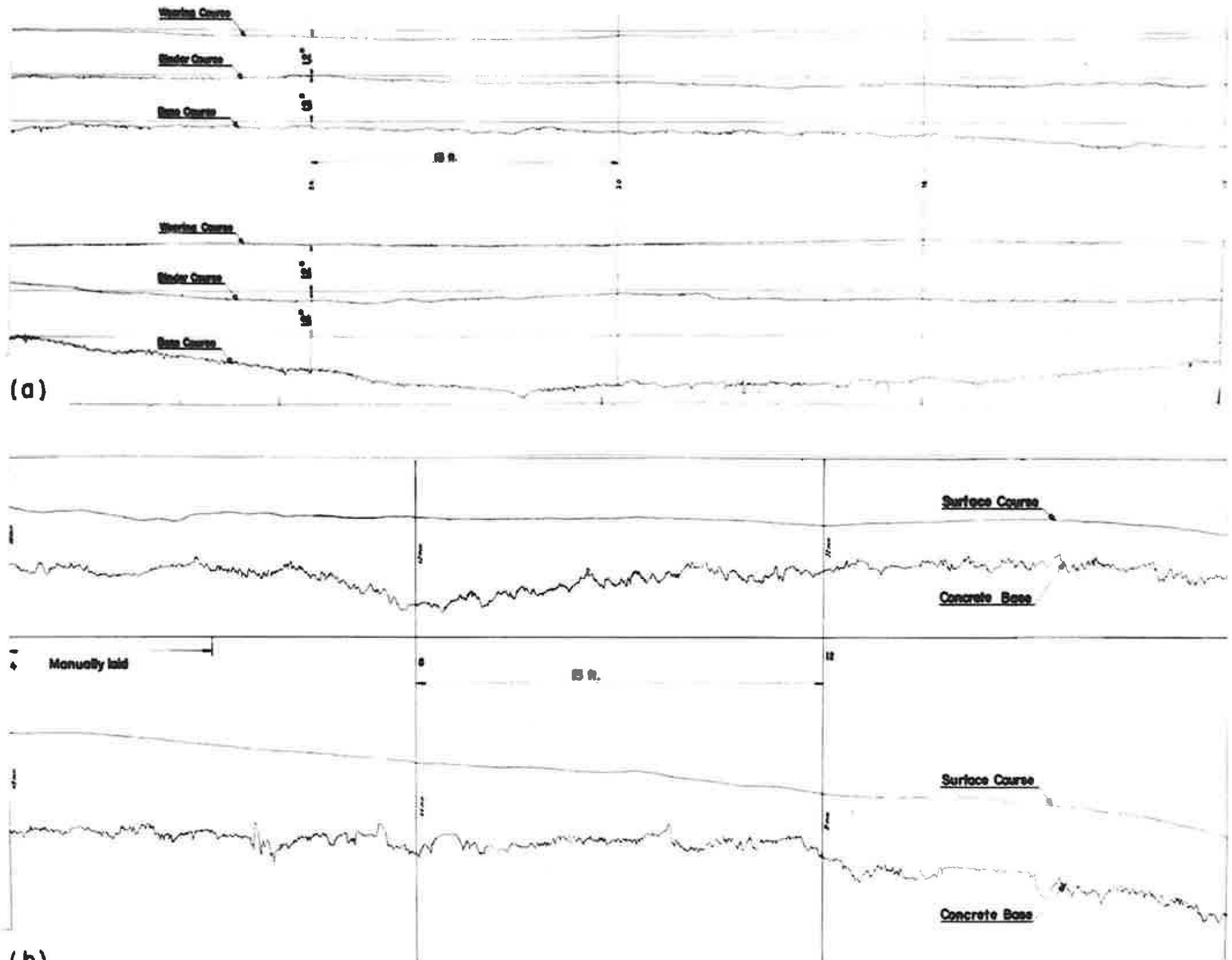


Figure 10. Evenness diagram made with Planum instrument: (a) typical pattern of highway N 1, Grauholz; (b) resurfacing on cement concrete of a bridgway.

The base course was laid with a conventional paver; for the binder and wearing courses a paver with electronic screed control was used.

Figure 8 shows the deviations of binder and surface from true profile at 168 leveled points; 166 points are within the allowed tolerance of ± 0.40 in., and only 2 exceeded this tolerance. Figure 9 shows the frequency of deviation from correct slope in 84 controlled cross-sections. Figure 10a shows the evenness diagram for a 330-ft section made with the Planum instrument.

These tests demonstrate that with electronic screed control it is possible to lay surfaces of exceptional evenness despite large depressions and elevations in the base. The deviations from true profile are well within the tolerances allowed both along the reference line and on the opposite side which is corrected with the pendulum.

The electronic screed control system permits establishment of a reference line on both sides of a lane, and makes it possible to transmit the heights by using two sensors. However, experience has shown that only one reference line on one side is necessary, because the pendulum does the transmitting to the other side.

When there is a change of slope in a transition to a curve, the slope must be indicated at the edge, and the operator has to make constant adjustments through the control panel. With this method exact results can be obtained even when the transitions are very short and extreme (Fig. 11).

Paving With the Traveling String-Line Procedure

The work is not always done with a stretched wire as reference line. Sometimes the height can be transmitted from the base or from the asphalt or concrete curbs (Fig. 12). To straighten out irregularities in the reference line, a 20-ft long ski is towed along. The electronic grade-control sensor receives the height values from the ski.

In one operation, a bordering strip of prefabricated concrete elements was at our disposal. On the evenness diagram the joints and every other unevenness were clearly visible. By means of the 20-ft ski, these irregularities could be completely wiped out. The smoothness of the pavement, after it had been laid, was even better than that of the reference line. All further layers were then built on this base.

In another operation (Fig. 10b), a bituminous resurfacing approximately 1¼ in. thick was laid on the very uneven cement concrete of a bridgeway. According to conventional methods the deep hollows in the cement concrete should first have been manually filled with bituminous mixture. But in this case the patching was omitted and the paving was done with the paver having a 20-ft long ski towed over the concrete. The evenness diagram shows that all the hollows under 20 ft long have vanished (Fig. 10b). The surface conforms to the specifications.

Smoothness of Wearing Course

It has been suggested that the adjustments in height achieved by use of the electronic controller might impair the smoothness of the mat. Some authorities think that only the lower courses, i.e., the bituminous base course and the equalizing course should be laid with electronic control, and the natural leveling quality of the finisher should be used for laying the wearing course. This procedure may be correct for roads on which several courses are laid consecutively. But in cases where mats must be laid in two separate phases, or for single-layer corrections of the profile, it is important to be able to make height corrections. In such cases the controller is necessary, even in laying the wearing course.

When a bituminous mat is laid with a finisher whose electronic controller is switched on, certain conditions must be fulfilled to obtain a surface that is absolutely free of waves. These conditions are partly related to the construction of the paver itself and partly related to the method of its operation.

1. The balance of forces in the paver unit is such that changes in the angle of approach or in the density of the mix can disturb the balance when the laying is performed at constant speed. Accordingly, one unevenness in the base can cause two in the covering mat: (a) when the tractor unit passes across the unevenness and (b) when the paver unit is directly over the unevenness (Fig. 13).

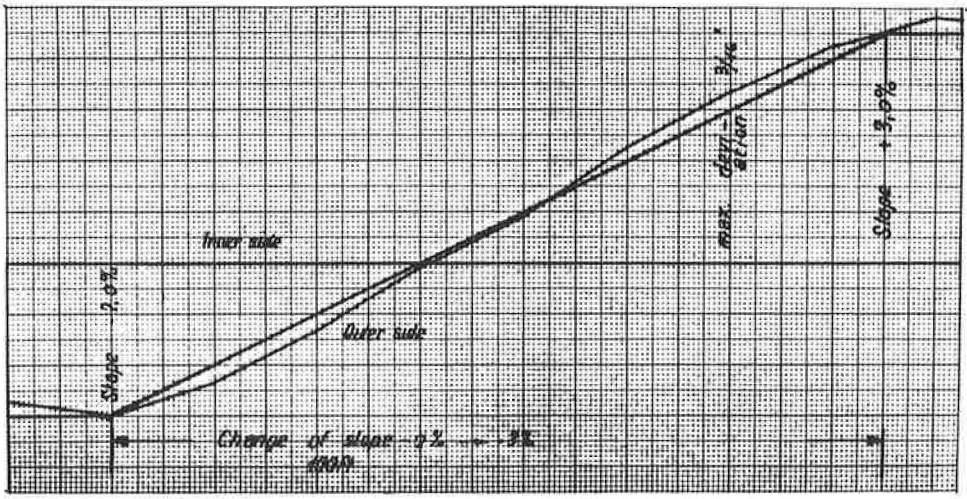


Figure 11. Deviation from true profile in a curve (change of slope - 2% to +3%).

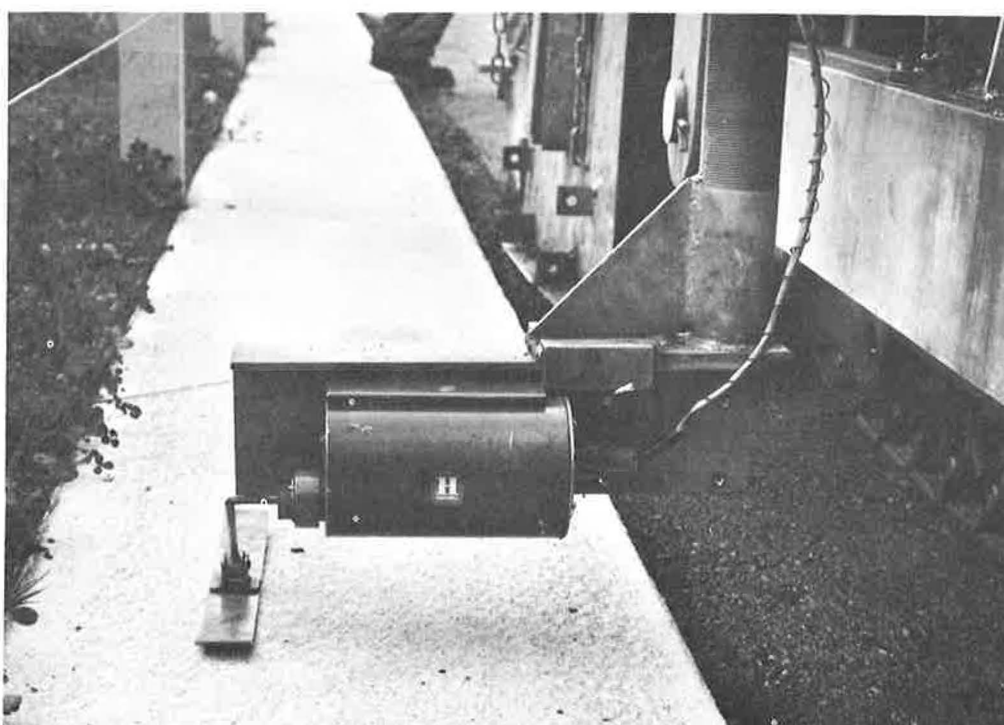


Figure 12. Follower shoe, concrete curb as reference line.

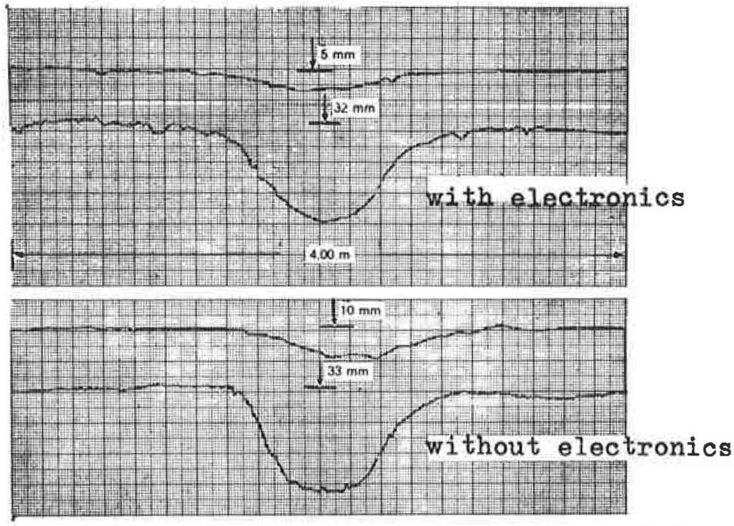


Figure 13. Evenness diagram of wearing course laid over pothole.

These deviations are corrected by the operation of the controller; they are registered by a sensor and transmitted to servomotors through electronic impulses. The motors change the angle of approach accordingly. In this operation the point at which the sensor is fastened to the leveling arm is crucial. When fastened to the forward pivot point, the sensor can transmit only the deviations of the tractor unit, and it is not influenced by a subsequent sinking of the paver unit caused by decreased density of the mix. However, if the sensor is fastened to the screed, it cannot register a movement of the forward pivot point. In this case the angle of approach is only altered when the screed moves upwards or downwards, which is comparatively late.

Our experience with different types of finishers has shown that some do not achieve as good results as others, and that machines with a sensor fastened to the paver unit react very quickly to the slightest vertical movement of the screed and therefore have a tendency to oversteer. Although this oscillation in the range of the zero position produces good conformity to the reference line, it is undesirable because it also produces shallow but short and regular waves which seriously impair the driving comfort. A sensor positioned near the pivot point is more advantageous, because its detection of the vertical movements of the screed is considerably diminished, and it only reacts to more important deviations. The mat is admittedly less true to the reference line, but at worst it will only have a long wave type of unevenness, over which it is possible to drive smoothly.

Obviously what is true for the position of the sensor applies to the position of the pendulum as well, because it controls the heights on the opposite side of the sensor. The pendulum should also be as far removed from the finisher screed as possible and be able to detect deviations as early as possible, so that corrections can be carried out gradually.

2. The finisher with a floating screed reacts sharply to differences in the mix laid before it. Therefore, the mix should be homogenous and of uniform temperature. Under no circumstances should it be unloaded directly from the truck to the base. It must be brought to the screed in such a way as to keep the height of the roll in front of the screed as constant as possible. The best results are achieved when the mistakes of the operator can be eliminated by a material depth control which automatically switches feed conveyors and spreading screws on and off.

3. The acting forces in the paver unit are dependent on the working speed, which should be as nearly constant as possible and adjusted to the amount of mix delivered per hour. Even when feeding, the finisher should not stop.

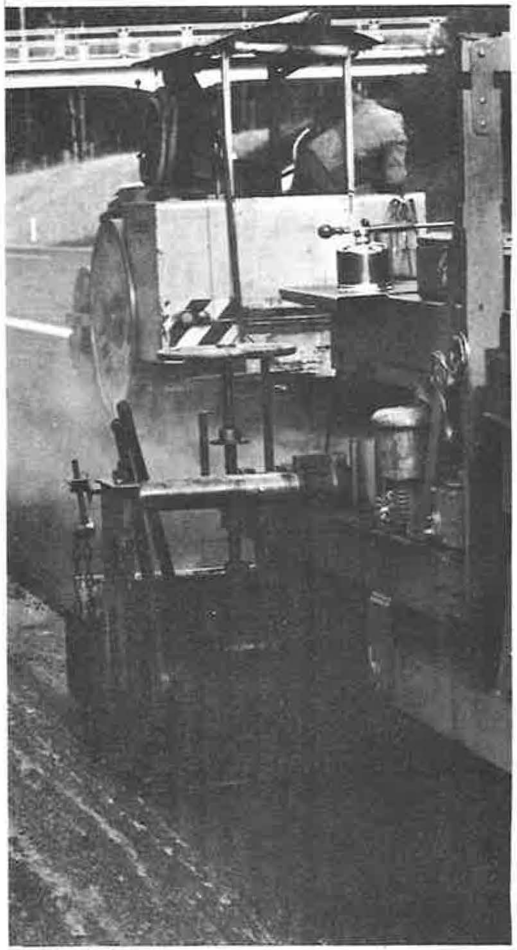


Figure 14. Compacting by vibrating screed and by steel-wheel roller.

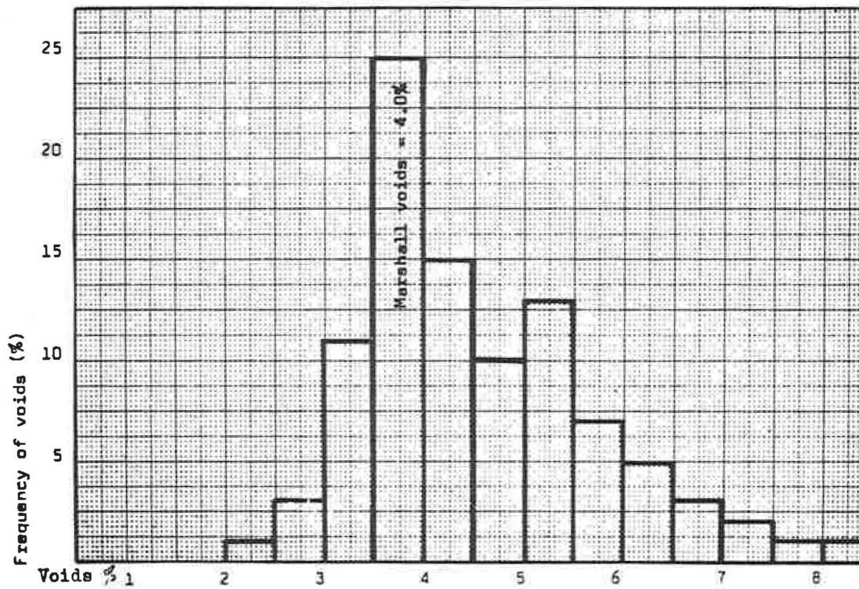


Figure 15. Void frequency of 100 samples cut from base course.

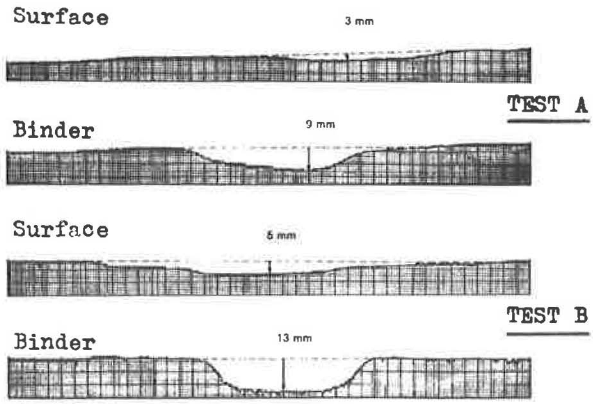


Figure 16. Evenness diagram of binder and surface course over pothole: test A, high vibrating intensity of paver screed; test B, low vibrating intensity of paver screed.

Figure 17. Two pavers equipped with electronic screed control, working in echelon, on Swiss highway N 1 Berne-Zurich.

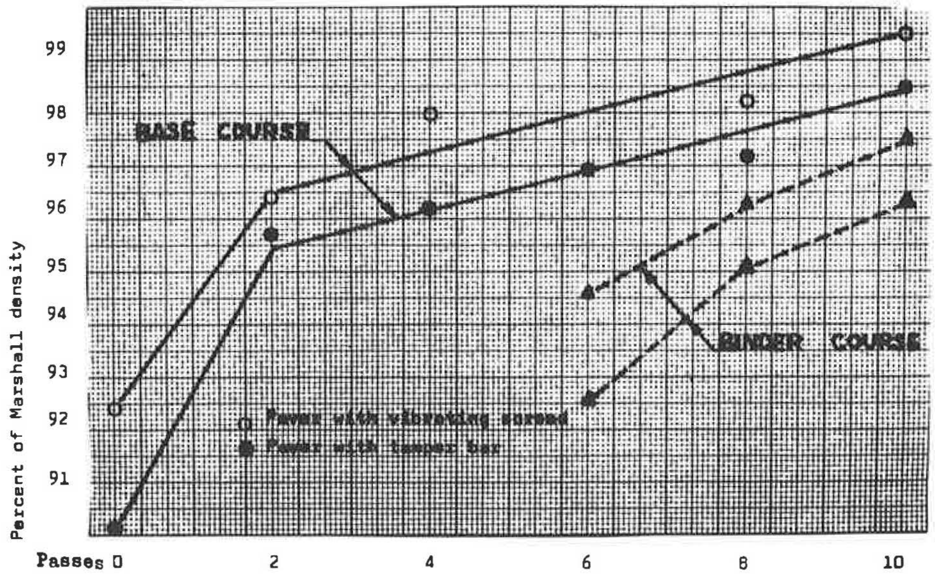


Figure 18. Density of mix, behind paver and after rolling.

4. Even high quality electronic controllers can suffer from disturbances, for instance, through changes of temperature. It is therefore essential that the height and transverse slope of the mat which has been laid be continuously checked behind the machine. The controller should be operated by the most reliable man of the crew. When a deviation is detected, work must be stopped and readjustments made.

5. Every paving operation must be prepared with great care. The leveling apparatus is useless, when the reference line is not true to profile.

CORRELATION OF SMOOTHNESS AND COMPACTING

The compacting process of bituminous mixtures goes through three stages: the paver's screed, the rollers, and traffic. Only a very slight degree of further consolidation by traffic is permissible, because otherwise settlement and rutting will be caused by wheel pressures. The finisher should achieve the highest possible compaction for the following reasons:

1. The precompacted mixture is more resistant to the horizontal forces when it is rolled. No rolling waves can form.

2. Breakdown rolling can take place directly behind the finisher, at a time when the mixture is still hot and can be well compacted (Fig. 14).

3. The screed permits absolutely homogenous compaction on the entire width of the spread. But with rolling, it cannot be determined whether all the areas on the surface have received the same amount of compaction by the roller.

Swiss specifications demand 6 rollers for compacting 1,000 tons of base mix per day. Results (Fig. 15) show that with high primary compaction by the screed compaction can be obtained using only three rollers.

High primary compacting through the screed is of even greater importance when smoothing out the uneven base by machine without prior manual patching. Each hollow in the subgrade causes a smaller hollow in the compacted mat. The higher the degree of primary compaction by the screed unit, the better is the reduction of the depth of hollows. This is conclusively proved by the following tests (Fig. 16):

Test A

Two layers of bituminous mat cover a pothole in a base of 2.4 in. Compacting was done with a vibrating paver screed (high-vibrating intensity), followed by ten passes with a steel-wheel roller.

Hollow in first (equalizing) course: 0.36 in. = 15 percent of original hollow.
Hollow in second (wearing) course: 0.12 in. = 5 percent.

Test B

Spreading and compacting are performed as previously described, but with low vibrating intensity of screed.

Hollow in first course: 0.52 in. = 22 percent of original hollow.
Hollow in second course: 0.20 in. = 9 percent of original hollow.

There are two different ways of obtaining a high compaction by screed. Some pavers use a tamper bar at a rate of 1,200 to 1,500 impacts a minute; others use a vibrating screed unit with a frequency of 3,600 vibrations per minute. For comparison purposes, two pavers were operated in echelon to lay a bituminous base course of 2½ in. (Fig. 17). One was fitted with a tamper bar, the other with a vibrating screed. To compare the effectiveness of each compaction, the density of the mat was first measured immediately behind the paver and then after the 21-ton pneumatic tire roller had passed a few times (Fig. 18).

The results prove that compaction with a vibrating screed produces higher densities. The density is higher before rolling, i.e., immediately behind the finisher, and remains higher until after the last rolling. Results of a second test with a binder course were similar. Both tests demonstrate that high primary compaction is equivalent to high final compaction.