GLASS BEADS IN PAINT

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Several items of laboratory equipment were used to study glass beads in paint. Wear and abrasion of beads and paint were studied with a type of surface abrasion equipment developed by California. Texture of road surfaces was measured by the use of cores and linear traverse equipment. Binocular and petrographic microscopes were used to study paint and bead problems in the field and laboratory. Normal headlight angles were simulated with a vertical illuminator on a microscope. Internal fractures in beads are more detrimental to light retroreflection than are bubbles, impurities, or nonround beads. Kansas glass bead specifications have been changed and have resulted in a lower unit price.

•THE OBJECTIVE of this overall study was to determine economical paint and glass-bead application rates for reflectorized traffic control stripes in Kansas. Results of the 1967 and 1968 field studies have been reported (12, 13). One significant observation of the field studies was that paint loss in Kansas was primarily due to chipping, not wear. A binocular microscope was so useful in the field studies that binocular stereo-zoom and trinocular petrographic microscopes were used in the laboratory bead and paint study. The petrographic microscope had a vertical illuminator, mechanical stage, and universal stage attachments.

This report deals with the various ways that the microscopes and other laboratory equipment were used to study glass beads in paint (5). Features of the paint and bead combinations were observed that helped explain field performance. Many samples were prepared specifically for laboratory studies, but several samples of paint stripes were removed from road surfaces for a microscopic study of paint and beads.

USE OF MICROSCOPE IN STUDYING FIELD PROBLEMS

Dulling of Stripes

In our early studies, transverse stripes were utilized for comparison of different paints and different bead gradations. Some stripes placed on concrete pavement showed a slight dulling over the hot-poured joint filler after a few weeks. This was at first interpreted to be due to bleeding of the joint filler material through the paint stripes. The nighttime appearance of these areas, however, was not diminished and, in fact, seemed brighter than the rest of the same stripe. A microscope examination revealed that the joint sealer had expanded causing the paint over it to crack (Fig. 1). The cracks were small and could not be readily seen without magnification. The effect of a series of subparallel microscopic cracks, however, was a slight but noticeable daytime dulling of the stripe over the joint filler. The increase in nighttime visibility over the joint filler was due to the exposure of the full sides of beads that were adjacent to cracks. Enhanced reflection is usually short-lived because as the filler expands it exudes from the joint and breaks through the paint stripe (13).

In another instance, centerline stripes on bituminous pavement patches were observed to be dulling prematurely. Microscopic examination revealed that asphalt was bleeding through the paint or being tracked onto it. Samples of the paint stripes were removed for study. They were sawed vertically through the layers of paint, and the sawed surfaces were polished on a lap wheel.

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Microscopic study of the polished surface showed that the paint had many horizontal and vertical cracks that were filled with asphalt (Fig. 2). The asphalt was bleeding through cracks in the paint. The section of road in question, however, was scheduled for a new maintenance seal. After the seal was applied, no bleeding occurred, and the new stripes did not get prematurely dull.

Thick Buildup of Old Paint

During the microscope study of the asphalt-bleeding problem, we noted that several layers of paint were present. By observing a rough fractured surface through the paint, we found that the individual layers representing each striping operation during previous years could be studied. In this cross section of paint stripe, we could see the embedment of beads in each paint layer and determine which beads were effective reflectors and which ones were completely buried in the layer. The stripes were repainted before the buried beads could be exposed. Dust and grime were seen between some paint layers but did not seem to prevent bond.

This study confirmed Dale's contention (7, 8) that for a given wet paint film thickness there is only one size of bead that will give optimum optical performance. Seven separate layers of paint were present in one cross section of stripe. Each layer contained many beads that were buried and never exposed. This is not too surprising because Kansas was using an 18-mil wet paint film. Kansas glass-bead specifications allowed more than 60 percent of the beads to be 18 mils or smaller in diameter. When these beads were used in an 18-mil paint film, only the other 40 percent had any chance to retroreflect. Dale (8) calculated that in common usage the exposed beads capable of retroreflecting amount to only about 30 percent of the total beads used. Bead counts made from the cross sections of several old paint layers in Kansas showed this was closer to 25 percent, but we used 18 mils of paint whereas Dale calculated from 15 mils.

Several pieces of traffic line, which we collected from the same geographic area, had 1 thin layer of paint. We carefully removed the layers of paint down to the thin layer. Most of the beads were buried in this layer to about 60 percent of their diameter and undoubtedly were retroreflective (5). The thinner layer of paint allowed more beads to be retroreflective. This observation reinforced our belief that we could use thinner paint stripes with fewer beads but still have a better reflecting line than by using 18 mils with 6 lb of beads. Field tests proved we were right (12, 13).

Lack of Reflectivity of New Stripes

We were asked why some newly painted stripes were not reflecting at night so well as usual. We microscopically examined the stripes and found an overspray of paint on many beads (Fig. 3). Too much spray pressure or painting into a heavy wind might cause overspray. The operator was using higher spray pressure than recommended by the manufacturer. When he reduced the pressure the problem was solved.

Loss of Beads Due to Mold Growth

A large number of beads were lost from one section of 18-month old paint stripes. Microscopic study revealed a mold growing in the empty bead sockets (Fig. 4). Several loose beads in the paint were pried out, and mold was present under the bead. We believe the mold growth caused loosening of the beads previously lost. This is not considered a problem because we observed the phenomenon only on one section of reasonably old paint. Most of our centerline stripes are repainted yearly, and we doubt that much mold would grow in the paint during this time. Mold was observed in the lower part of the thick buildup of old paint layers previously discussed. Mold may contribute to the adhesion loss of paint stripes inasmuch as growth was observed in a number of old paint layers from several locations. The newer, upper paint layers seldom exhibited mold growth.

USE OF MICROSCOPES IN LABORATORY STUDIES

During the field studies of paint and beads (12, 13), we made a number of different types of laboratory studies. They were conducted to give information that could not be derived from field studies alone. Wet paint films from less than 5 to about 30 mils were placed on 4- by 8-in. glass plates. We dropped glass beads of many different gradations and application rates into the wet paint. Narrow strips ¼ to 1 in. wide were cut transversely from the larger plates for microscopic study. Glass and metal plates were used to obtain paint and bead samples as they were placed on the road. These too were used in the microscopic studies. The larger plates were also used for nighttime viewing and were illuminated by a single headlight beam at normal road angles.

Simulation of Headlight Angles

Figure 5 shows the microscope equipped with a vertical illuminator. The glass slide with paint and beads is standing on edge in this picture such that a thin beam of light from the illuminator can impinge on the glass beads at the same small angles that headlight beams are effective in nighttime driving. According to Dale (7), the angle is small, being only 1 deg, 14 min at 100 ft and 0 deg, 21 min at 350 ft in front of the vehicle.

The researcher can focus on one single bead to determine its light-reflecting properties. By reducing the magnification slightly, he can view a few beads at one time; by lowering the magnification considerably, he can view many beads at one time and compare the light-reflecting properties and depths of embedment of the various beads with each other.

There are many possible pitfalls in interpreting the results. For instance, the 3 beads shown in Figure 6 appear to reflect light differently depending on the amount of bubbles present. The bead on the left apparently contains the most bubbles and reflects the least light. The center bead contains a few bubbles and reflects light intermediate to the amount reflected by the other 2 beads. This would seem to demonstrate that air bubbles in the beads diminish their light-reflecting properties. Our studies, however, have shown that the amount of the bead exposed usually has more effect on its retroreflection than bubble inclusions (this assumes that the back of the bead is covered with paint to more than 50 percent of its diameter). In Figure 6, the bead that reflects the most light has its entire side exposed to the light beam and this is why it reflects more light than the other 2 beads. The center bead has part of its bottom half exposed and, therefore, reflects more light than the left bead that has only its upper half exposed.

Figure 7 shows the effect of exposing more bead surface. The bead is about 85 percent buried in paint. About one-third of the buried portion is exposed on the left. On the right, most of the paint film has been removed from the front of the bead increasing its retroreflection by exposing more surface area. Some chipping of paint to expose the sides of beads can thus improve retroreflection.

The gas bubble on the surface of the bead shown in Figure 7 appears to be a small dark spot but does not prevent reflection. Gas bubbles reduce retroreflection roughly by the amount of the surface area they comprise. This is an estimate based on a study of thousands of beads with various sizes and numbers of gas bubbles and not an accurately measured quantity of light reflection. In fact, the terms reflection and retroreflection as applied to glass beads may be misnomers. A bead more or less lights up like a diffusion light globe. There is no distinct beam of light reflecting back from a bead.

Our microscope studies show that internal fractures affect retroreflection considerably (Fig. 8). The beads shown in the paint panel on the left have been heated and then dropped into iced water to create internal fractures (the same procedure used in making "fried marble" jewelry). The beads on the right have not been internally fractured. The nonfractured beads reflect light, but the fractured beads do not.

Shadow Effect of Large Beads

The microscope was used to study the effect that shadows cast by large beads have on the reflection from smaller beads (7, 8). In our study, the paint and bead slide was

Figure 1. Subparallel microscopic cracks in paint caused by expansion of joint filler.

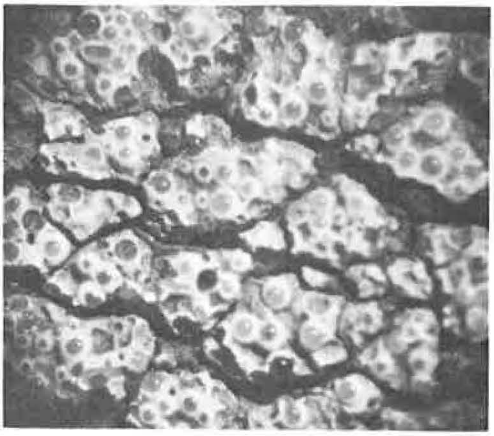

Figure 2. Vertical cross section through several layers of glass-beaded paint stripe with asphalt-filled vertical cracks and subhorizontal planes.

Figure 3. Beads coated with paint because of too much spray pressure on paint gun.

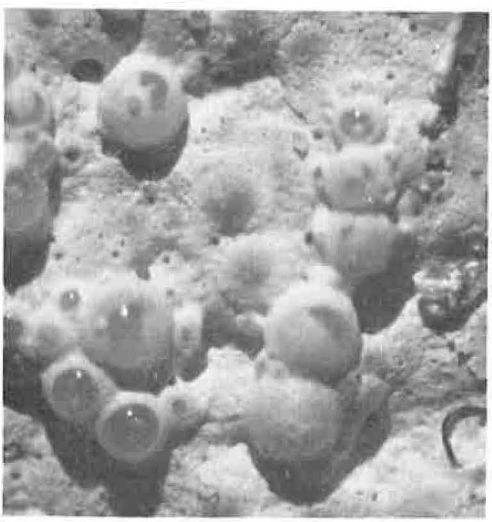

Figure 4. Mold growth in empty bead socket.

Figure 5. Microscope with vertical illuminator.

Figure 6. Three beads that retroreflect different amounts of light.

laid flat on the stage of the microscope. The light was beamed in from the side at the approximate headlight angle. The researcher viewed the beads from above to see their back or shadow side. Many small beads fall in the shadows of larger beads and, thus, do not retroreflect (Fig. 9). The fact that beads cast shadows, however, indicates that they are retroreflecting. If light passed through a bead with no retroreflection, there would be little or no shadow. A bright spot at the back (left) of several beads shown in Figure 9 indicates that some light gets through.

The shadow effect is reduced when beads of only one size are used in a paint film that covers about 60 percent of the bead diameter. Using fewer beads reduces shadow problems too. Floating beads also reduce the shadow effect because of a more uniform size and because nearly half of each bead is exposed. The Colorado highway department (3, 4) reported benefits and savings when it used floating beads. Our studies indicate that the floating principle is important if a thick paint film is used. If, however, the wet thickness of the paint film is engineered to the diameter of a single-sized bead, then the results are much the same. The wet paint film thickness should cover 55 to 60 percent of the diameter of the beads used (6, 7, 8).

Beads in Black Paint

It has been stated that the bottom of a bead should not touch the pavement because the bead will reflect the pavement color, which, if it is black, will reduce the bead's visibility at night. We have not found this to be so. A bead is round and will rest on the pavement surface with only a small contact area at the very bottom of the bead. Pocock and Rhodes (15) show diagrams of the path of light entering a bead embedded in traffic paint. The rays of light focus on the back of the bead below the top paint line. The light rays do not refract to focus on the bottom of the bead. Dale (7, 8) photographed the back side of beads covered to various depths with paint. Dale's photographs showed the focal spot of light rays at the back of the beads, which indicated that the focusing diagrams of Pocock and Rhodes were likely correct.

In one of our studies we put beads into black paint. The beads appeared black when viewed directly from above (Fig. 10, left). When the panel was viewed at ordinary headlight angles, however, the beads reflected white (Fig. 10, right). Inasmuch as we did not foresee much benefit for Kansas, we did not pursue the research. If beads are found to reflect well in black paint, then states that use black lines between their white lines might wish to pursue the research and consider putting the beads in the black paint so that the white paint would remain cleaner and brighter in the daytime. Dale (7) stated that marking materials with dropped-on beads exhibit a far greater tendency to pick up road film than do unbeaded materials. These markings with heavy road film can be 100 percent intact and reflect at night yet fail in terms of delineation of the roadway in daytime. The road film would not show on black paint, and the unbeaded white lines would remain brighter for daytime use. We do not know why the beads reflected in black paint but wonder whether internal bubbles might act as small beads and actually enhance reflection in some cases. More research is needed on the reflectivity of beads in black paint to determine why they reflect for us but not for others.

OTHER STUDIES

Road Grime and Abrasion

Some paint stripes on new and old pavement sections in a city lost effectiveness rapidly during daylight but were satisfactory during nighttime. The city was subject to rather high traffic dust, and the roads were swept daily. We repainted the pavements and studied the new stripes. Less than 4 hours after placement, the stripes were noticeably duller. In one week the stripes had low daytime effectiveness but still reflected well at night. Using the microscope, we found traffic dust and grime covering the stripes even though they were swept a few minutes earlier. Figure 11 shows a 1-week old stripe. The brighter white spots are areas where the stripe was brushed with soap and water and then rinsed. A means of washing these stripes would improve their daylight effectiveness but perhaps only temporarily. The traffic grime and dust problem is usually worse in cities than in rural areas where faster traffic blows the dust away

Paint and bead wear is increased if in areas similar to those just mentioned the traffic dust is coarse and harder than the beads. McCaskill and Crumpton (12, 13) reported paint and bead wear where sand- or gravel-surfaced roads intersected pavements with paint stripes. We studied this phenomenon in our laboratory by using a modified California surface abrasion device. Our asphalt research section uses it for evaluating slurry seal materials, but it has been used to study accelerated pavement wear (11) and paint stripes as well. Four-inch diameter concrete cylinders or Marshall asphalt plugs were painted and beaded on top for laboratory study. Field samples of 4-in. diameter pavement cores through a paint stripe can be used to study the pavement materials as well as the surface texture and beaded-paint layer. Figure 12 shows a beaded-paint film that has been subjected to 5 min in the abrasion machine. In addition to the rubber balls (17) used to evaluate asphalt slurry materials, a small amount of fine sand was added to simulate abrasive traffic material. Most of the beads abraded as badly as the paint. These surface-abraded beads are of little value as reflectors. The condition of the paint and beads shown in Figure 12 is almost identical to that of actual in-service paint stripes that are subject to abrasion.

Surface Profile Studies

Dale (7) discussed the importance of the pavement surface profile in bead retroreflection during rain. McCaskill and Crumpton (12, 13) reported that beaded-paint stripes on coarse seals were duller during dry weather but brighter at night during rain than comparable stripes on smooth seals. Our microscope studies showed that the beads did blank out when completely covered by water. To study the texture thoroughly, we made surface profiles across our paint stripes by using the device described by Dale (7), which we borrowed from him. It was satisfactory for field use and for many laboratory applications. In the overall surface texture studies, however, we were also interested in texture of trial asphalt slurry mixes in the laboratory. These materials were too soft for the mechanical surface profile recorder at the curing stage during which we wished to study them.

To overcome the problem, we utilized the motorized lathe and stereomicroscope portion of our linear traverse equipment. One focusing knob of the microscope was removed, and the shaft of a small rheostat used as a potentiometer was attached to the microscope focusing shaft. The rheostat body was affixed to the microscope so that the shaft was all that could move. During use a small constant voltage was fed into the rheostat, the output of which feeds through a preamplifier to a strip-chart recorder. The sample was placed on the lathe bed, and the equipment was referenced vertically and horizontally. The sample was then moved under the microscope just as in linear traverse work, and the operator kept the microscope in constant focus on the surface of the sample. As he focused up and down to compensate for differences in elevation of the surface, the voltage output from the rheostat was changed. This change was amplified and recorded. The end result was a tracing at several times vertical exaggeration of the surface texture.

This test is quite reproducible by different operators and was highly reproducible by one operator rerunning the same traverse. Figure 13 shows a trace of a paint surface on a 4-in. diameter core taken through a paint stripe on an in-service pavement. The trace is quite similar to those presented by Dale (7). The linear traverse method of surface profile, however, is not readily adaptable to field use. Cores of road surface must be obtained and brought to the laboratory for study. We have studied pavement surface texture in relation to skid properties with the equipment (11).

Raised Reflectors

Kansas has tried several types of raised reflectors for nighttime visibility during rain. The raised markers were plowed from the pavement during snowstorms. Chaiken (2) reported that some states prevented damage to raised markers by using rubber snowplow blades. Kansas tried rubber blades, but they were not suited to our average snowplowing conditions. The state has gone to carbide-tipped snowplow blades because they were the most suitable and economical of those tried.

Figure 7. Bead 0.012 in. wide buried in paint (left) and then exposed (right).

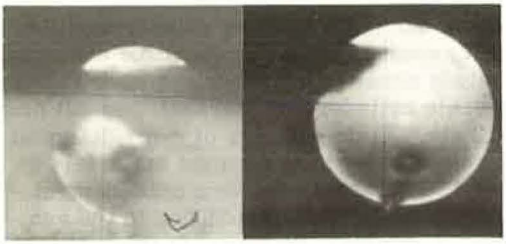

Figure 8. Beads with (left) and without (right) internal fractures.

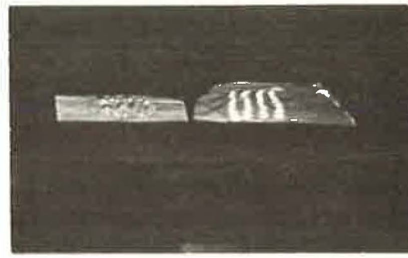

Figure 9. Effect of shadows cast by large beads.

Figure 10. Beads in black paint where light strikes directly from above (left) and at average headlight angle (right).

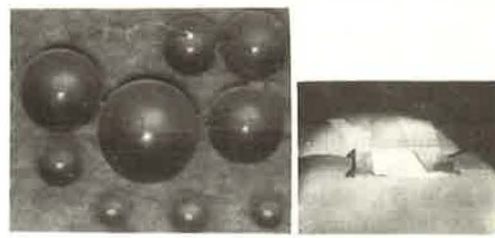

Figure 11. Week old paint stripe dulled in daylight by traffic dust and grime.

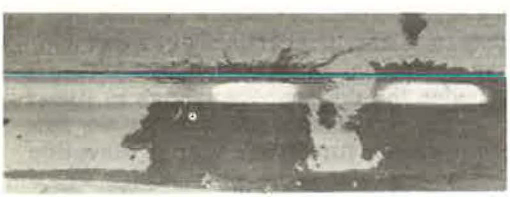

Figure 12. Beaded-paint stripe abraded for 5 min.

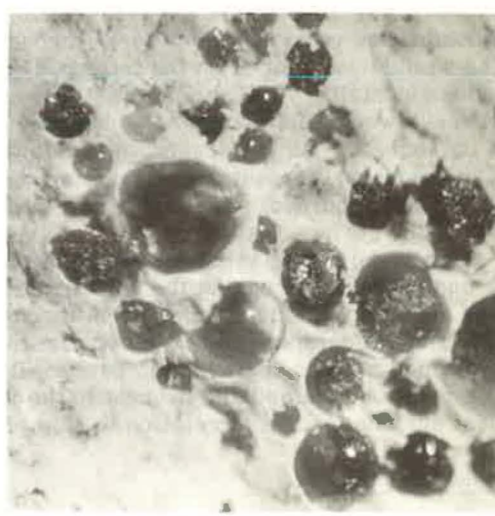

Figure 13. Trace of painted surface of asphalt road ("valley" at arrow is slightly less than $^{1}/_{16}$ in. deep).

We have observed that grass growing in a crack between the pavement and a paved shoulder reflected light during a slow rain. Small rounded water droplets on the grass blades were responsible for the retroreflection. The water drops performed like glass beads. This observation leads us to wonder whether a system similar to synthetic turf material coated with paint and beads might work as raised reflectors that could "bend over" when necessary and withstand hard-surfaced, snowplow blade action. Posey (16) described a system of snow removal in which the blade rides above the pavement surface and the snow is lifted to the blade by air pressure. This system, if it is perfected, would be a boon to raised reflector use and snowplow blade life.

Intermittent Beading

Several years ago we placed three 18-in. long "pips" of beads on each 17.5-ft long paint stripe following the pattern suggested by Anderson (1). This worked satisfactorily, and the 3 beaded pips all blended together on the third stripe in front of a moving vehicle to appear as one fully beaded stripe. The intermittent pattern could be seen in the first and second stripe in front of the vehicle, but it was not distractive. A driver seldom looks at the first 2 stripes ahead; his attention has to be focused farther down the road. This research was not pursued, and our studies centered on using fewer beads and a thinner paint stripe. Partial beading has great potential, especially for edge lines, and merits more study.

Wicking of Paint on Beads

Many microscope pictures indicated that the paint wicked up the sides of the beads. Other samples from the same source of beads and paint, however, did not show the wicking effect. To study this discrepancy, we put beads in wet paint films of various thicknesses and watched the paint surface on the sides of the beads as the paint dried. No wicking was seen with our standard beads and paint.

The wicking appearance occurred only when the paint was thin and the beads large enough to drop to the bottom of the wet paint film and rest there with the bead protruding out of the paint film. The apparent wicking effect was due to the loss of volatiles and concurrent shrinkage of the paint film. The original top level of the paint film remained around each bead but as the paint dried the area between beads shrank and gave as the end result the false impression that the paint had wicked up the side of the beads. When thick films of paint were used and the bottom of the beads did not drop to the glass plate, there was no sign of wicking. In this case, as the paint shrank because of evaporation of solvent, the entire original surface, beads and all, settled to a lower elevation. Some paint and bead combinations did wick, and with a microscope the paint film could be seen moving up the side of the beads. This was very evident on some of the black paint we tried.

General Observations

During the microscope studies of glass beads in paint, a number of general observations were made that have not been covered elsewhere in this report. They will be listed here without much discussion although some have been discussed by other researchers.

Transmitted light was better for studying the internal conditions of glass beads (fractures, bubbles, and impurities) than reflected light. Switching from transmitted to reflected light for individual beads helps in studying how the internal conditions affect retroreflection. Beads with only a few bubbles and impurities were about as reflective as beads with no flaws, and in some cases small internal bubbles may have enhanced reflection. Slightly out-of-round beads reflected about as well as round beads. Very oblong beads gave some reflection but not so much as round beads unless the beam of light was parallel to the long axis. There are fragments and stringers of glass in many bead samples, and such particles do not reflect. Two or more beads fused together or beads with large protruding surface knobs generally reflect little light, but sometimes they reflect well. Most beads "blank out" when covered with a thin film of water, but a very few from each sample were reflective under water.

Studded tires, if they pass over a paint stripe, fracture some of the beads and render them useless. Studded-tire wear is being seen in Kansas, but the problem is less than in some states; however, the situation may get worse. Some Kansas drivers use their studded tires all year even though such use during the summer is unlawful.

An ordinary mirror can be used above the ocular of the microscope to project the image of the beads onto a movie screen for group viewing in a darkened room. A section of sieve screen cut from any desired size of screen stock along with Scotch tape as backing makes a handy bead holding and sizing device for microscope study. The tape adheres to the screen and sticks to the beads that are small enough to drop into the square holes of the sieve. Different sieve stock can be used for different-sized beads.

REMOVAL OF OLD PAINT BEFORE REPAINTING

One way that glass beads become ineffective is loss through chipping of a beaded-paint stripe. Chipping is the primary loss mechanism in Kansas (13). A suggestion for reducing the paint-chipping problem was to find a cheap, fast method of removing old loose paint before the pavement is repainted (13). We investigated various methods of paint removal under the following restrictions:

1. They had to be rapid and fit into the regular painting operation (more than 100 miles of painting in 1 day in some instances); and
2. The stripes removed had to be repainted the same day (safety standards in Kansas do not provide for allowing sections of centerline to go unpainted very long).

Heater units were too slow and unsuited to Kansas painting operations. Sandblasting was too slow and a hazard to traffic. Chemical removers were too slow, hazardous to workers, and harmful to the finish of cars. High-pressure water jets were too slow, hazardous to traffic, and required too much drying time before repainting could be done. Mechanical burring and brushing methods were too slow. All of these methods were too expensive.

The only technique we tried that was even partially successful under the restrictions listed was a jet of air directed at a low angle onto the paint stripe right ahead of the striper. This removed the loosest and thus most detrimental flakes of old paint. The air can be supplied by the striper if its compressor is sufficient to place the paint and beads and still have capacity to send a stream of air onto the old stripe. Most Kansas stripers cannot supply the extra air.

Inasmuch as Kansas now uses a thinner stripe and repaints less frequently, the paint buildup is less of a problem. If the chipping problem persists, however, a separate truck-mounted, high-capacity, high-pressure air supply unit to work ahead of the paint striper would be worthy of consideration. Posey (16) described a similar system for snow removal, and it might be engineered to remove loose paint.

Allowing more time to elapse before repainting and letting the loose paint be removed by traffic, wind, or rain were considered. Painting individual centerline stripes in the skip area between the old stripes was also considered. Another suggestion was to paint the minimum stripe width allowed and to repaint the new line alongside the old with about an inch of sidelap between them. These considerations were generally rejected, however, because of the probability of a less attractive finished stripe.

IMPLEMENTATION OF RESULTS

We have reported the previous implementation of results (13). We also recommended that the paint thickness be reduced to 10 mils with 4 lb of beads per gallon. This was based on field results and on laboratory studies described here. Kansas has implemented that recommendation.

As a result of our laboratory microscope studies of various bead gradations in paint films of different thicknesses, we agreed to a change in Kansas bead gradations to bring the bead sizes into a more compatible relation with our lesser paint film thickness. The numbers of large and small beads were both reduced.

Before the gradation changes were written into specifications, microscope slides and metal plates with 4-in. wide panels of the new gradation of beads in a 10-mil paint film

were prepared. We examined the slides by using the vertical illuminator and simulated headlight angles as shown in Figure 5. The larger plates of paint and beads were examined at distances as great as 200 ft in our laboratory after dark; a single headlight beam was used. Both the microscope and headlight studies indicated that the new bead gradation would provide good retroreflection in 10 mils of paint.

Inasmuch as we were making a gradation change that might be difficult or expensive to produce, our Materials Department contacted all the major glass-bead manufacturers to discuss the proposed changes. All agreed that the new gradation would present no problems to them. Since a change in specifications was being made, it was decided to look at other parts of Kansas glass-bead specifications also to see whether other changes might be worthwhile. The company representatives were each asked for their recommendations on other requirements that should be considered for change. In addition to the gradation changes, 14 other items were considered and more changes made. The number of imperfect beads allowed was changed; packaging and marking requirements were changed. Lot sizes for testing purposes were changed and resulted in less sampling and testing. The new specifications, No. TS 46.19, were issued on May 9, 1969, in time to make bead purchases for fiscal 1970.

We were warned that the proposed changes might raise the price, but instead a big reduction occurred. Even the price of the highest bidder was below the price we had been paying for beads. With the additional miles of edge lines being painted, a reduction in the cost of beads was indeed welcome.

In the earlier report, we stated that not all of the savings would show up in the records as less money spent on paint and beads (13). The savings in materials costs were used in large part to pay for many miles of additional edge-line striping. According to the data supplied to Permoda, Moore, and Chaiken (14), only 21 percent of the Kansas white paint striping in 1965 was edge lines. Now edge lines account for about 60 percent of the white paint striping. This additional edge-line striping is being paid for by the overall savings in material costs.

There has also been less spent for materials even though the unit cost of paint is up. Calculations from data presented by Permoda, Moore, and Chaiken (14) show that Kansas spent $668,582 on paint and beads placed on roads in 1965. Maintenance department records show that the materials used for striping in fiscal year 1969 cost $665,122 or $13,460 less than in 1965. Records for fiscal 1970 show $506,862 spent for the paint and beads used that year, $161,720 less than in 1965. The purchase requests for paint and beads for fiscal year 1971 amounted to $519,553, which is $149,029 less than 1965 usage. This brings the total 3-year savings to $324,209. In a period of spiralling inflation, such savings are rare and can be used to offset increasing prices in other operations.

Savings in materials costs are not the only benefit gained from the study. A new pride in the striping work has been established as a result of the attention given to it. The interest of the paint-striping crews has improved, and a competitive spirit has developed among them. New striping records have been set and broken several times (9) since the record was established of 92 miles of painting in one day (13). The latest Kansas record is 118.1 miles—41.3 miles of center stripes and 76.8 miles of edge lines (10). Other side benefits from the lesser paint and bead requirements is that overall there is less testing, less storage space, and less handling problems than would be involved with greater paint thickness and bead application rates. Lesser amounts of materials used also mean less pollution. There is less solvent to escape into the atmosphere and less solid materials to flake and wear away to add to the world's waste products.

SUMMARY AND CONCLUSIONS

This report explains the practical use of several items of laboratory equipment to study the performance of glass beads in paint. Many aspects of the paint and bead problem were studied with the use of binocular and petrographic microscopes. Wear and abrasion of paint and beads were studied with the use of the California-developed surface abrasion equipment. Cores and linear traverse equipment were used to measure

the texture of road surfaces. The following observations and results are based on field and laboratory studies:

1. Microscopes are very useful in studying paint and bead problems both in the field and in the laboratory. A vertical illuminator can be used on a microscope to simulate normal headlight angles to study the performance of various bead sizes and gradations in paint films of differing thicknesses. Much of the engineering of glass-bead size and gradation to fit the wet film thickness of paint being used or anticipated for use can be done in the laboratory with the use of the microscope techniques described. Our glass-bead specifications were changed with such studies as a guide. This has resulted in a lower unit price for beads. Microscope studies indicate that internal fractures are more detrimental to light retroreflection than are bubbles, impurities, or nonround beads.
2. Glass beads in some black paints do reflect light.
3. New stripes that are dull in daytime may only be covered by traffic grime and dust. The dust problem is greater in cities than in rural areas because of the slower city traffic.
4. Kansas now uses 10 mils (wet) paint with 4 lb of drop-on beads per gallon of paint.
5. Painting is now faster than before, and one crew has placed more than 118 miles of beaded paint stripes in an 8-hour day.
6. This project, which cost less than $20,000 in research funds, has saved about $324,209 in paint and bead costs for fiscal years 1969, 1970, and 1971 compared with 1965. In addition, the cost of the materials for many additional miles of edge-line painting has been paid for by the implemented changes.
7. Savings in storage space, testing, and handling of paint and beads have also occurred.
8. A stream of air blown over an old stripe just ahead of the paint striper removes the loosest and most detrimental flakes of old paint and, therefore, is somewhat effective in increasing paint and bead life. Other attempts to rapidly remove the old paint prior to repainting have been largely negative.

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