FLOATING BEADS: BROAD OR NARROW GRADATION?

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Through the use of theory and in road service tests the 2 most common types of floating beads, narrow and broad gradation, were evaluated. These tests, which included several control lines using a broad-gradation non-floating bead, showed that the broad-gradation floating bead performed best under all conditions. The narrow-gradation floating beads gave good reflectivity under dry conditions but invariably demonstrated poor reflectivity under the slightest rainfall conditions. These effects are demonstrated through the use of wet and dry night photographs of dual centerline test sections.

•ONE of the major developments in the use of drop-on glass spheres in recent years has been the introduction of floating beads. Along with this development came a suggested change in the size range or gradation of drop-on beads.

Before the introduction of floating beads, virtually all specifications for drop-on beads required a broad-range gradation, which can be described as a 20-80 gradation. When floating beads were introduced, many of the specifications required a narrower size range, commonly termed a 40-80 gradation.

Since floating beads can be obtained in either size range, a question is raised as to which gradation should be specified. This paper attempts to outline the advantages and disadvantages of each gradation, both from a theoretical and practical point of view, with a view toward helping those concerned to make an intelligent choice between the 2 systems.

DESIGN THEORY OF THE 2 GRADATIONS

In order to discuss the 2 general size ranges it is helpful to know the physical characteristics of each gradation that determined their development.

The 20-80 gradation was originally a nonfloating drop-on bead. This gradation is correctly sized for optimum reflectivity and durability in a standard, 0.015 ±0.001-in. (0.38 ±0.025-mm) wet paint film thickness.

Traffic paints normally have a solids content between 50 and 60 percent. It is this property that determines the final dry film thickness. Thus, taking the range of wet film thicknesses given, 0.014 to 0.016 in. (0.36 to 0.41 mm), one obtains a dry paint film thickness range of 0.007 to 0.010 in. (0.18 to 0.25 mm).

Since it was known that the optimum embedment of a glass sphere is between 50 and 60 percent of its diameter, the optimum diameter of beads for the range of dry film thicknesses would be from 0.012 to 0.020 in. (0.30 to 0.51 mm). This range of bead diameters corresponds approximately to a U. S. sieve range between No. 35 and No. 50.

This range, however, is calculated on a rather close wet paint film tolerance. In reality, the wet paint film thickness will often vary considerably. Variations in machine speed, ambient temperature, paint viscosity, tank pressure, and amount of thinner used can cause rather large variations in film thickness. These variations can occur not only from day to day but also from mile to mile on any one day's application.

For these reasons it is desirable to have a broader range of bead sizes than the No. 35 to No. 50 mesh range calculated.

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Figures 1-11 demonstrate the effectiveness of the broad-range gradation over wide variations in application thicknesses. Figure 1 shows the various sizes of beads present in a broad-gradation specification. The full range of glass bead sizes at the bottom of the figure is represented by various hollow glass balls.

The diameters of these "beads" were carefully selected to correspond to the diameters represented by the U.S. sieve sizes between No. 20 and No. 120. The graph above the "beads" in Figure 1 is the weight distribution common to most 20-80 (broad range) gradation beads. From the graph one can see that a majority of the beads are between No. 35 and No. 50 mesh, with a smaller quantity above and below this range.

Figure 2 shows how a full range of standard bead sizes would appear when dropped into a wet film of paint 0.015 in. (0.38 mm) thick. Figure 3 is the same size range as it would appear when the 0.015-in. (0.38-mm) paint film dries to a film thickness of 0.008 in. (0.20 mm). From this, one can see that the beads between No. 35 and No. 50 mesh are embedded to approximately one-half their diameters. Also, those beads below No. 50 mesh that are not immediately effective will eventually become exposed as the film wears, giving long-term reflectivity.

From the size distribution shown previously, one can see that more than 80 percent of the beads in a 20-80 gradation are embedded to one-half their diameter or greater. Thus, in a 0.015-in. (0.38-mm) wet film of paint that dries to a thickness of 0.008 in. (0.20 mm), a 20-80 broad-range gradation is very efficient. A majority of the beads (No. 35 to No. 50 mesh) are embedded securely and effectively, and the beads smaller than No. 50 mesh are available for future use as the paint wears.

Figures 4 and 5 show how a 20-80 gradation gives good initial reflectivity when the paint is applied at a somewhat thick wet film thickness of 0.020 in. (0.51 mm). Figure 4 is the wet film at 0.020 in. (0.51 mm), and Figure 5 is the same film when dried to a film thickness of 0.010 in. (0.25 mm). From these one can see that there are still a sufficient number of beads exposed, even in a dry film thickness of 0.010 in. (0.25 mm), to give good initial brightness. Also, the beads below No. 35 mesh, which are completely covered, are available for long-term reflectivity as the paint film wears.

If one were to view the same Figure 5 and consider it to be a film of wet paint 0.010 in. (0.25 mm) thick, one can visualize how 20-80 gradation beads would appear when dropped on a 0.010-in. (0.25-mm) wet film of paint. This wet film will dry to approximately 0.005 in. (0.13 mm), and the resulting effect can be seen in Figure 6. In this case, one can see that the large beads will be more readily removed, but there are still a significant number of beads embedded securely for optimum initial and long-term reflectivity.

Thus, a broad-range gradation bead with a majority of beads sized for a wet film thickness of 0.015 in. (0.38 mm) will give optimum reflectivity and durability, even under wide variations in the final dry film thickness.

Floating beads, when properly manufactured, will embed themselves approximately 50 percent in a wet paint film and remain embedded at this level as the paint film dries and shrinks. In this way the brightness of the line is somewhat, although not completely, independent of film thickness. If one were to place a broad-range gradation floating bead on a 0.015-in. (0.38 mm) wet film of paint, all the beads would be supported at approximately one-half their diameters, as shown in Figure 7. However, as the paint film shrinks to a final dry film thickness of 0.008 in. (0.20 mm), the beads larger than 0.016 in. (0.41 mm) in diameter would "bottom out". This is shown in Figure 8, where the beads over 0.016 in. (0.41 mm) in diameter (approximately No. 40 mesh) are no longer embedded at one-half their diameters. The same "bottoming" effect, but to a lesser degree, is observable in a representation of 20-80 mesh floating beads in 0.020-in. (0.51-mm) wet and 0.010-in. (0.25 mm) dry paint film (Figures 9 and 10). All those beads larger than 0.020 in. (0.51 mm) in diameter (approximately No. 35 mesh) bottom out in a dry film 0.010 in. (0.25 mm) thick. In a 10-mil wet paint film (Figure 10), all the beads are not embedded to one-half their diameter initially, and as the paint film shrinks those beads more than 0.010 in. (0.25 mm) in diameter (approximately No. 60 mesh) will bottom out, as shown in Figure 11.

Thus, at a theoretical dry paint film of 0.008 in. (0.20 mm), it would seem that those beads above 0.016 in. (0.41 mm) in diameter (approximately No. 40 mesh) are unnec-

Figure 1. Size distribution for 20-80 gradation beads.

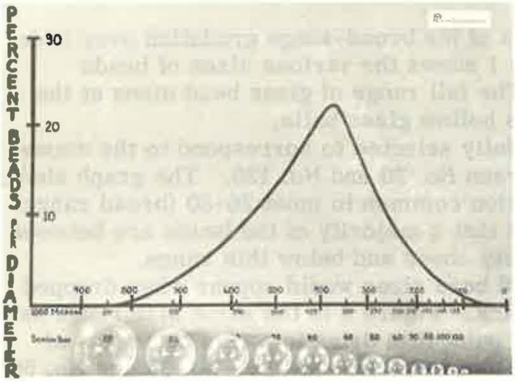

Figure 2. Embedment of 20-80 gradation beads in a wet paint film 0.015 in. thick.

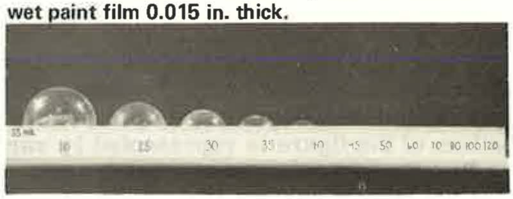

Figure 3. Embedment of 20-80 gradation beads in a dry paint film 0.008 in. thick.

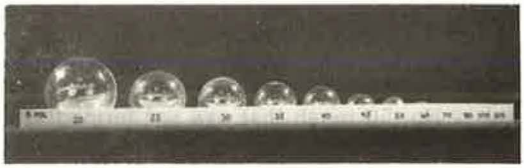

Figure 4. Embedment of 20-80 gradation beads in a wet paint film 0.020 in. thick.

Figure 5. Embedment of 20-80 gradation beads in a wet or dry paint film 0.010 in. thick.

Figure 6. Embedment of 20-80 gradation beads in a dry paint film 0.005 in. thick.

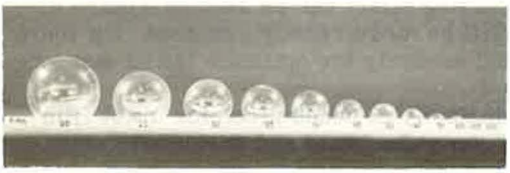

Figure 7. Embedment of 20-80 floating beads in a wet paint film 0.015 in. thick.

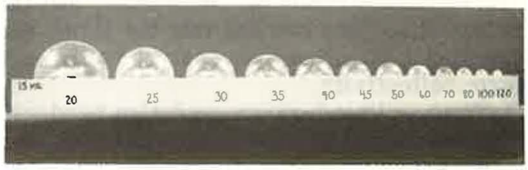

Figure 8. Embedment of 20-80 floating beads in a dry paint film 0.008 in. thick.

Figure 9. Embedment of 20-80 floating beads in a wet paint film 0.020 in. thick.

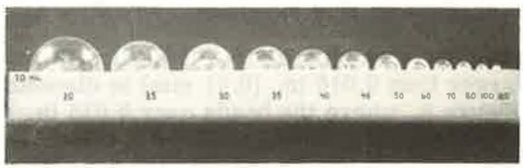

Figure 10. Embedment of 20-80 floating beads in a wet or dry paint film 0.010 in. thick.

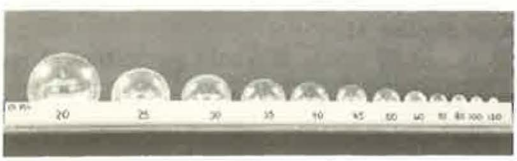

Figure 11. Embedment of 20-80 floating beads in a dry paint film 0.005 in thick.

essary in a floating system. However, because of other considerations not evident in a theoretical discussion, the beads larger than No. 40 mesh are necessary for full effectiveness under all conditions of use. One of these conditions is wet-weather visibility. From road service tests conducted on both the 20-80 and 40-80 gradation floating beads, the distinct advantage of a broad size distribution is evident.

ROAD SERVICE TESTS

Since 1971 Potters Industries, Inc., has been conducting dual centerline road service tests on various paint and bead systems. The test program was described in a paper by Ritter (1).

Most of the test sections compare a test line having various combinations and quantities of paint and beads with a standard line consisting of a 0.015-in. (0.38-mm) film of yellow alkyd traffic paint with 6 lb/gal (0.72 kg/liter) of 20-80 gradation beads dropped on. These 2 lines form a dual yellow centerline test section that is typically ½ to 1 mile (0.8 to 1.6 km) long. The sections are evaluated monthly by impartial observers from automobiles at night and rated on a scale of 10 (brightest) to 0 (least bright). In addition to the evaluations, night still photographs and motion pictures are taken for documentation purposes.

From the photographic documentation it is possible to illustrate the consistently poor wet-weather performance of the 40-80 floating beads and in the same way observe the relatively good performance of the 20-80 floating beads.

Figure 12 was taken on a dry night 6 days after the test lines were applied. The left line is a standard line as described previously and the right line consists of the same thickness of paint with 4 lb/gal (0.48 kg/liter) of the 40-80 gradation floating beads dropped on. From this one can see that the line with the floating beads is somewhat brighter initially. Figure 13 was taken 20 days later under moderate rainfall conditions. Here, the substantially poorer wet-weather performance of the narrow gradation is evident. The standard line, although somewhat less bright under dry conditions, is more visible under wet-weather conditions.

Approximately 6 months later the same section shows the right line to be still somewhat brighter in dry weather (Figure 14). However, again 20 days later, under moderate rainfall conditions, the 40-80 gradation line (right) demonstrates very poor performance (Figure 15).

To further study this effect, another test section of 40-80 floating beads was placed later that year. Section 22A was identical to section 8-1 (standard line versus 4 lb/gal of 40-80 floating beads. Much the same effect was observed in this section. The 40-80 floating beads, right line in Figures 16 and 17, again displayed noticeably poor wet night visibility.

In the next year's test program 2 sections were striped to compare the performance of a line having 4 lb/gal (0.48 kg/liter) of 40-80 floating beads and a line having 6 lb/gal (0.72 kg/liter) of 20-80 floating beads to a standard line. Both sections were placed in May 1972. The first section consisted of a standard line on the left next to the line with 40-80 floating beads at 4 lb/gal (0.48 kg/liter) on the right. Figure 18 shows the improved brightness of a floating-bead line over a standard line under dry road conditions. Figure 19, taken 2 days later on a rainy night, shows the same reversal of performance observed in the 1971 test sections.

The next section contained a standard line on the left versus the 6-lb/gal (0.72-kg/liter), 20-80 floating-bead line on the right. Figure 20, taken on a dry night, again shows the improved brightness of a floating-bead line over a standard line. Figure 21, taken under moderate rainfall conditions, shows the 20-80 floating-bead line to be noticeably brighter than the standard line. Because the dry photographs of both of these sections (Figures 18 and 20) were taken on the same night and the wet photographs (Figures 19 and 21) were both taken 2 days later, an effective comparison is possible. The 20-80 floating-bead line was noticeably brighter than the standard line under both wet and dry road conditions, while the 40-80 floating-bead line gave poor performance under wet conditions.

Figure 12. Test section 8-1, dry, April 23, 1971.

Figure 13. Test section 8-1, wet, May 13, 1971.

Figure 14. Test section 8-1, dry, October 4, 1971.

Figure 15. Test section 8-1, wet, October 24, 1971.

Figure 16. Test section 22A, dry, October 4, 1971.

Figure 17. Test section 22A, wet, October 24, 1971.

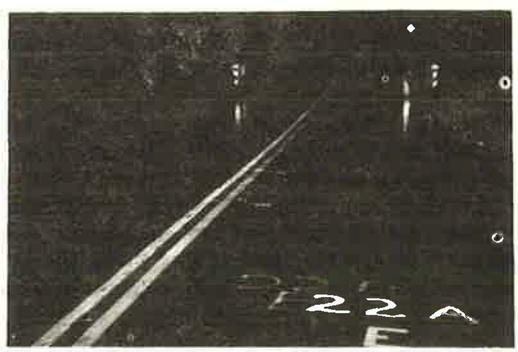

Figure 18. Test section 11, dry, November 6, 1972.

Figure 19. Test section 11, wet, November 8, 1972.

Figure 20. Test section 13, dry, November 6, 1972.

Figure 21. Test section 13, wet, November 8, 1972.

Figure 22. Test section 38, dry, April 27, 1974.

Figure 23. Test section 38, wet, April 30, 1974.

To obtain a closer comparison of the performance of the two types of gradations of floating beads under both wet and dry conditions, section 38 was applied in April 1974. In Figure 22, taken April 27, 1974, under dry conditions, the left line contains 6 lb/gal (0.72 kg/liter) of 20-80 floating beads while the right line contains 4 lb/gal (0.48 kg/liter) of 40-80 floating beads. The film thickness is the same for both lines. From this dry-night photograph one can see that the brightness of both lines is approximately equal. However, Figure 23, taken just 3 days later, directly demonstrates the dramatic difference between the 2 systems in wet-night performance. The 20-80 line (left) is noticeably brighter and more visible than the 40-80 line.

CONCLUSIONS

In the section on design theory it was demonstrated how a broad-gradation nonfloating bead is correctly sized for optimum embedment in a dry paint film that can vary in thickness over a relatively wide range.

Under the same general conditions, it was also shown how a broad-gradation floating type of bead is effective. From the illustrations of the floating beads in a 0.015-in. (0.38-mm) wet, 0.008-in. (0.20-mm) dry paint film, one of the reasons for specifying a narrow gradation with floating beads was shown.

In road service tests of the various types of floating-bead lines currently applied it was shown that

1. A 40-80 gradation floating-bead line was brighter than a standard nonfloating-bead line only under dry conditions.
2. The same 40-80 gradation floating-bead line under wet road conditions invariably showed substantially poorer performance.
3. A 20-80 gradation floating-bead line was also brighter than a 20-80 gradation nonfloating-bead line under dry conditions.
4. The 20-80 gradation floating-bead line was far more visible under wet road conditions than the 40-80 gradation floating-bead line.

Thus, from a standpoint of effectiveness under all conditions of use, the broad-range gradation floating beads would seem to be the choice if floating beads were to be specified. This choice would give optimum performance under dry conditions and improved, not decreased, visibility under wet conditions.

REFERENCE

1. James R. Ritter. A Unique Approach to Evaluating Road Stripe Material on Two-Lane Rural Roads. Highway Research Record 447, 1973, pp. 1-7.