# Slab Breaking and Seating on Wet Subgrades With Pneumatic Roller

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This paper reports on a long-range field study to determine the practicability of using a pneumatic tire 50-ton roller to break and seat old concrete pavements before overlaying with hot-mix asphaltic concrete. The method of study is a comparative analysis of the behavior, under traffic, of various roadway sections employing different breaking and seating techniques of the 50-ton pneumatic roller and an impact hammer on a construction project generally having a wet subgrade condition.

Observed results and field data are shown during the breaking and seating operation and after one and two years of traffic to support the conclusion that the 50-ton roller should be used in conjunction with an impact hammer, using three roller coverages for slab breaking and seating.

• FOR SEVERAL years the Louisiana Department of Highways Testing and Research Section has been interested in better construction methods using bituminous hot mix to overlay and renew old surfaces of which old concrete pavements are the major portion. After overlaying, a frequent problem is that slab movement and pumping have continued. Realizing the need for better concrete slab breaking and seating construction techniques, the Testing and Research Section has undertaken the task of determining the feasibility of using a high-intensity roller to prepare old concrete slabs for hot-mix overlaying. This study was undertaken on a construction project, using various treatments of a 50-ton roller in conjunction with the present impact hammer method of slab breaking and seating.

The project site being used for this study is 15¾ mi of old, badly pumping, 18-ft wide concrete pavement, comprising State Route 1 between Donaldsonville and Napoleonville, in the bayou country of south Louisiana (Fig. 1). The existing concrete slab is 6 in. thick at the center, thickened to 8 in. at the edges, and widened 3 ft on each side with concrete. It was overlaid in the winter months of 1959 with hot mix, after various slab breaking and seating techniques with the 50-ton roller and the presently used impact hammer. The hot-mix overlay was 3½ in. of binder and wearing course, with a quantity of binder course for leveling, equivalent to 1 in. of thickness (Fig. 2).

The average daily traffic on this project is approximately 3,000 vehicles per day; approximately 18 percent of this is trucks with 2 percent having axle loads in excess of 18,000 lb.

The subgrade soils immediately under the old slab are silty loams, silty clay loams, and silty clays containing more than 50 percent silt. These soils generally have moderate plasticity indexes, varying from 5 to 15, with optimum moistures ranging from 14 to 20 percent, and with group indexes of from 8 to 12. These soils would generally classify as ML and CL by the Unified Soil Classification System.

The concrete pavement was generally unreinforced (Fig. 3). Transverse, ½-in. round by 4-ft long, deformed bars, spaced 5 ft on centers, were employed along the longitudinal center joint. Transverse expansion joints consisted of a premolded joint filler and eight ¾-in. smooth, round dowel bars, 4-ft in length for load transfer. The

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general spacing of expansion joints was approximately 500 ft.

The impact hammer used for seating and breaking in this study was truck mounted, with a 4,000-lb dropping head. The 50-ton roller was a Bros model 450, with four 16.00-21 36-ply tires, mounted in line, and was towed by a Euclid prime mover. The roller was loaded to a gross load of 48 tons with sand and water. The tire pressure was 90 psi. The gross roller load and tire pressure were kept constant at all times in the study.

Economically, the use of the roller compared very favorably to the use of the hammer, per mile of roadway treated. The contract amount for concrete seating and breaking with the hammer was $15 per hr of actual operation. The amount for rolling with the 50-ton roller was $25 per hr. The impact hammer cost approximately $88.60 per mi treated. The roller cost approximately $90.80 per mi rolled.

For the purpose of this study, three roadway sections were chosen, with each section containing portions representative of the total project. The length of these sections varied from 3½ to 5 mi each. One test section was established as a control, with slab seating and breaking using the impact hammer. Another test section used the 50-ton roller for slab breaking and seating. The third test section used the roller and the impact hammer for slab breaking and seating. Within this third section, the general procedure was to locate the moving slabs with the roller, break with the drop hammer, and then seat the broken slabs with the roller.

From four to eight test stations were established within each of the three sections. These test stations were used for collecting field data, representative of their respective section.

Figure 1. Typical slab pumping under truck traffic on old roadway before construction.

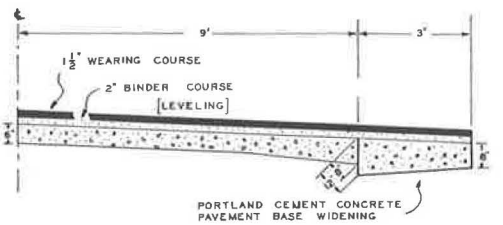


Figure 2. Typical section, as constructed.

Figure 3. Old roadway showing pumping under normal traffic; 3-ft base widening in place, before any breaking and seating operation.

## ACCUMULATION OF FIELD DATA

The basic consideration of this study is to detect continuing slab movement, its location, and its extent. To accomplish these aims, comparative data are being obtained on the various research treatments, taking surface roughness and deflection, and observing reflection cracking. With this in mind, the Benkelman beam, the road roughness recorder, and visual surveys, along with elevation checks for over-all subsidence are being used as prime study tools.

The Benkelman beam is a device that detects and measures movement of the roadway under a given load. In this study the axle load used was 18,000 lb (the Louisiana

single-axle legal load limit), and was applied with a Department maintenance dump truck loaded with sand. The pavement deflections were measured to 0.002 in. under this load. The Benkelman beam deflections reported in this study are relative, and not reported as an absolute measure of movement, as the beam itself was probably influenced by the movement of the 18,000-lb wheel load.

The L. D. H. road roughness recorder (an adaptation of the BPR single-wheel unit) measures an accumulation of vertical movement per the unit length of roadway under study. A change in this vertical movement, or roughness, would indicate moving slabs. Whereas the Benkelman beam directly measures the movement of the pavement at a point on the roadway, the roughness recorder is an accumulation of movements over a length of roadway. In effect, the two devices tend to complement each other, giving a relatively complete picture of movement over the entire roadway length under study.

In addition to the deflection readings and roughness data, moisture content data at 1- and 2-ft depths beneath the concrete pavement have been gathered, and water table variations have been measured in cased wells extending to an elevation at least 6 ft below the finished overlay grade. This is to determine the effects of moisture content variation on slab movement in conjunction with the various breaking and seating operations.

A culvert survey has been completed on the in-place cross-drains to determine the effects of the 50-ton roller.

## FIELD ROLLER RESULTS

In the first phases of the roller operation, the roller speed was varied from creep speed to 5 mph. It was found that a roller speed of 2 mph gave the best results. This speed was then maintained throughout the rest of the study for locating moving slabs, breaking, and seating. The roller can be an awkward piece of equipment, in that it is not very maneuverable on a restricted roadway. It cannot be turned around at will, and road intersections generally must be used for turning. In this study, this possibly caused overrolling just to move the roller where it was needed. It appears that the maximum effective length of roadway that could be rolled without excessive personnel fatigue was 2 continuous miles.

In spite of the heavy weight, there was no displacement or noticeable damage to the cross-drains, even though approximately one-half of the culverts had an overlying cover of from 10 to 18 in., including the old slab.

Rocking slabs can definitely be created or their rocking intensified, if the subgrade is wet and the slabs are overrolled with the 50-ton roller. Very little slab breaking was noted where the roller was used on a wet subgrade. From preliminary data it appears that the roller must be used with extreme caution wherever the in-place moisture contents exceed the optimum moisture by about 5 percent or more. Wherever the subgrade was rolled with a moisture content nearer optimum, the roller broke most of the rocking slabs transversely at or within the third points. Occasionally, slabs were broken longitudinally, again, at or within the third points. The slabs broke with a distinct popping and grinding sound; however, the breaks generally were not visible until the following pass. Where the old pavement had been badly broken under traffic, the roller did little to break the slabs further.

Apparently six or more coverages of the 50-ton roller tend to create rocking slabs on this particular type of subgrade, regardless of moisture content. Generally, slab breaking was accomplished in the first two coverages of the roller, with the majority of the breaking occurring on the first coverage. Moving slabs are easily detected with one pass of the roller. The use of a diamond saw to score the rocking slabs before rolling did not appear to facilitate the breaking of the slabs. In addition, the sawing of the slabs was slow, and impractical for relatively long sections of roadway.

The 3-ft base widening definitely interferes with the lateral movement of any underlying wet soil slurry. The roller forces this material through the joints or breaks in the slab and along the edge of the slab when the existing shoulder or the 3-ft base widening was in place. The majority of this project was studied with the base widening in place (Figs. 4, 5, and 6).

Figure 4. Wet material displaced by rolling at typical pumping slabs.

Figure 5. Wet material removed by roller from subgrade under slabs broken by traffic; removed mud in trench.

Figure 6. Wet subgrade material forced through shoulder by roller.

The 50-ton roller is a relatively fast and thorough piece of equipment for breaking and seating. The roller generally covers the entire lane width being treated. This, in effect, gives more complete slab breaking and seating than that of the impact hammer, which is generally a spot means of breaking and seating. It appears that the presently used impact hammer method of slab breaking breaks and partially seats the old slabs, but traps a major portion of the underlying soil slurry. The roller appears to remove a greater proportion of this soft material, inferring better seating.

Subgrade soil conditions should be considered in determining the gross roller weight and the tire pressures to be used. The roller should be weighted to an amount that would give the desired results without damaging the subgrade. The least number of coverages that will give the desired results should be used. The possibility of overrolling and the location of the turnarounds should be considered in developing rolling sections. Additional passes just to move the roller to various locations should be avoided.

The use of the roller by itself does not inhibit reflection cracking. However, the use of the hammer together with the roller at its optimum number of coverages does drastically reduce reflection cracking. No pumping joints have been noticed in any of the three test sections.

For improved results, using the roller for breaking and seating, field observations indicate that a narrow trench should be opened adjacent to the slab, extending below the

bottom of the slab. After rolling with the 50-ton roller, a leveling course of hot mix should then be laid on the old slab. The trench cut to facilitate the removal of soft material should then be closed. The base widening could then be placed to the grade of the leveling course previously applied. The binder and wearing courses could then be laid over the leveling course and base widening.

## GENERAL RESULTS

The entire length of this project has been closely studied for signs of slab pumping. After two years of service, there are no physical evidences of any pumping in any test section, whether rolled, hammered, or treated with a combination of rolling and hammering.

Maximum and minimum deflections, as measured by Benkelman beams, before slab seating and at one year and two years after overlaying, are given in Table 1. The deflection study, on this research project indicates that a relative slab movement of 0.040 in. or less is necessary for a continued pavement life without excessive maintenance and without a loss of riding qualities.

Sections 1, 2, and 3 had good areas before overlaying, as indicated by the minimum deflection values, and bad areas having more than 0.040 in. of movement, as indicated by the maximum deflection values. At one year after overlaying, the deflections are very consistent, being within a range of 0.005 to 0.014 in., and the highest deflection within any section, is equal to, or less than, the lowest deflection before breaking and seating operations. The greatest deflection changes from before seating to one year after overlaying are in sections 2 and 3, particularly the reduction of the maximum deflection values of section 3.

The average maximum deflection of section 3 for two years after overlaying has not increased from that of one year after overlaying. Whereas, there is some increase in these deflections for sections 1 and 2.

Figure 7 shows the effects of roller coverages on the subgrade moisture contents at 1- and 2-ft depths below the concrete pavement expressed as a percentage of the moisture content immediately after rolling, as compared to that just prior to rolling. Two roller coverages appear to draw moisture from the 2-ft depth into the 1-ft depth in an amount that would offset the moisture removed from the 1-ft depth. Three roller coverages appear to be more effective in subgrade drying, removing relatively more water from either the 1- or 2-ft depths than that pumped up into these layers. Four roller coverages apparently pump water into the 1-ft depth faster than it is removed. Also, four coverages probably begin to draw water from the deeper subgrade into the upper 2 ft of the subgrade. Six roller coverages were observed during breaking and seating operations, and field observations indicated that slab pumping was intensified under this number of coverages. Although the 50-ton roller undoubtedly created a

TABLE 1

AVERAGE MAXIMUM AND MINIMUM DEFLECTIONS

| Section | Method | Avg. Deflections (in.) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Before Seating | | 1 Yr After Overlay | | 2 Yr After Overlay | |
| | | Max. | Min. | Max. | Min. | Max. | Min. |
| 1 | Hammer only | 0.085 | 0.016 | 0.010 | 0.005 | 0.013 | 0.008 |
| 2 | Roller only | 0.122 | 0.018 | 0.014 | 0.008 | 0.019 | 0.008 |
| 3 | Hammer and roller | 0.154 | 0.012 | 0.013 | 0.006 | 0.013 | 0.009 |

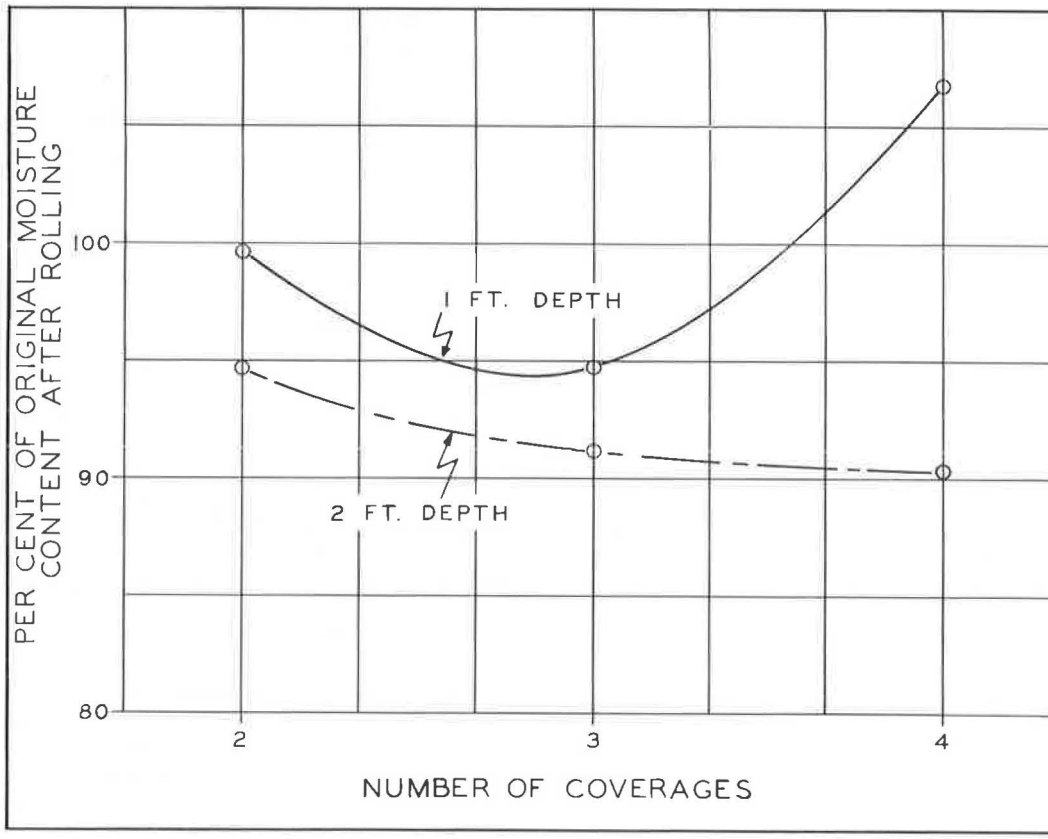


Figure 7. Effects of roller coverages on subgrade moisture contents during rolling.

migrating moisture condition, three coverages appear to be optimum for maximum water removal.

Figure 8 shows the effects of moisture content variation and roller operations on deflection. The moisture content scale is a comparison of the moisture content after rolling to that determined immediately before rolling. The percent deflections are comparisons of the deflections one year after overlaying to those determined before breaking and seating. The operation of the roller in conjunction with the impact hammer gives a relatively consistent change in deflection regardless of any changes in moisture content. This is shown by the horizontal plots of two roller coverages with hammering, and three roller coverages with hammering. Where the roller only was used, changes in moisture content have a definite effect on changes in deflection. However, the most significant indication of this is the effect of three roller coverages and the impact hammer on deflection, regardless of moisture content variation, reducing one-year deflections to less than 10 percent of that before breaking and seating.

A comparison of data on this problem indicates that the use of the impact hammer in conjunction with the roller increases their effectiveness much more than that of either when used for breaking and seating alone.

Figure 9 shows the effects of the number of roller coverages on the deflection at one and two years, expressed as a percentage of the deflection before breaking and seating operations. Of interest is a comparison of the changes in deflection between the use of the roller alone and the use of the roller in conjunction with the hammer. The number of coverages of the roller alone apparently would not require as close a field control as that of the roller and hammer; however, the reduction in deflection would not be of the

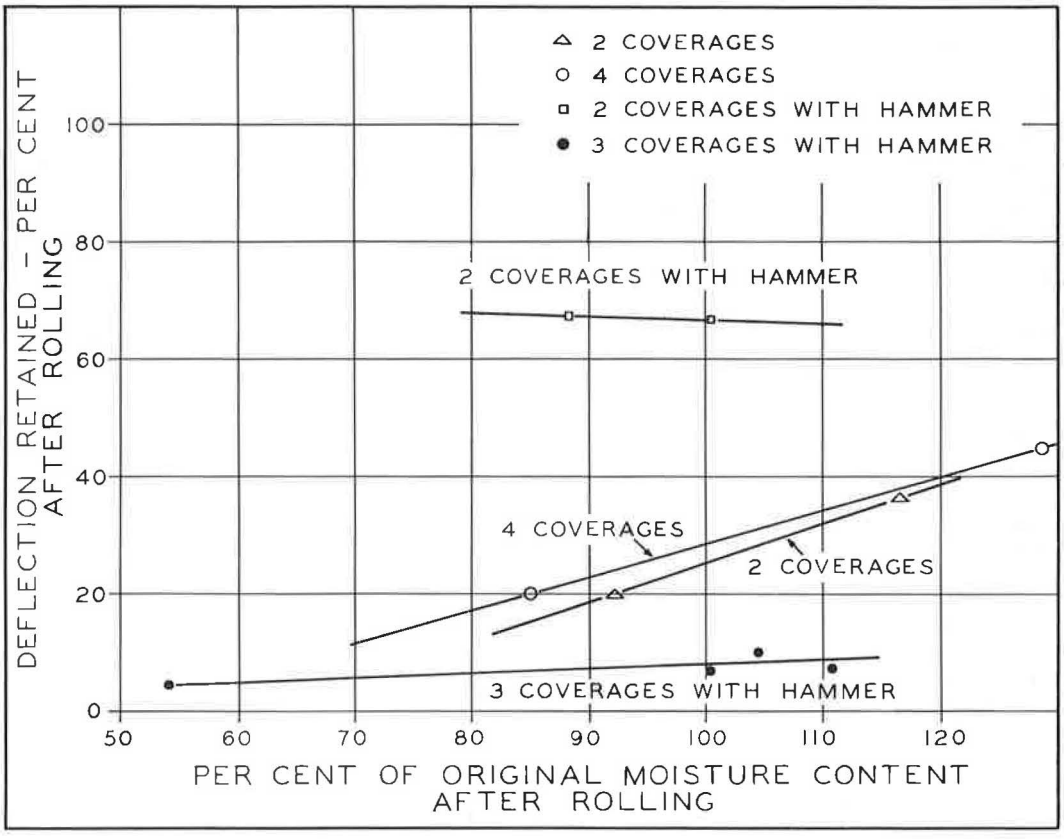


Figure 8. Effects of various roller treatments and moisture content changes during rolling on deflections after 1 yr of traffic vs that immediately before rolling operations.

magnitude as when using the roller and hammer together. Although the number of coverages of the roller, when used with the hammer, appears to be critical, this treatment reduced the deflection, when three coverages were used, more than any other treatment or combination of treatments used in this study. In addition, there is no change in roadway conditions from the one and two years' results where the roller and hammer were used together.

Figure 10 shows the effects roller coverages have on the reflection cracking at one year and at two years after overlaying, as compared to the joints and cracks observed before breaking, seating, and overlaying. Three coverages of the roller with impact hammering eliminated reflection cracking at the applicable test stations. Where the roller only was used, reflection cracking was increased when four roller coverages were applied, indicating overrolling. There is a large amount of change in reflection cracking between the one-year and two-year results where the roller only was used. There is no change in reflection cracking where the hammer and roller were jointly used.

## CONCLUSIONS

This study, after two years of service, points out the superiority of a breaking and seating procedure for old pavements on wet subgrades, consisting of a combination of three roller coverages and impact hammering, as shown in Figure 11. The recommended field procedure would be to locate moving slabs with one coverage of the 50-

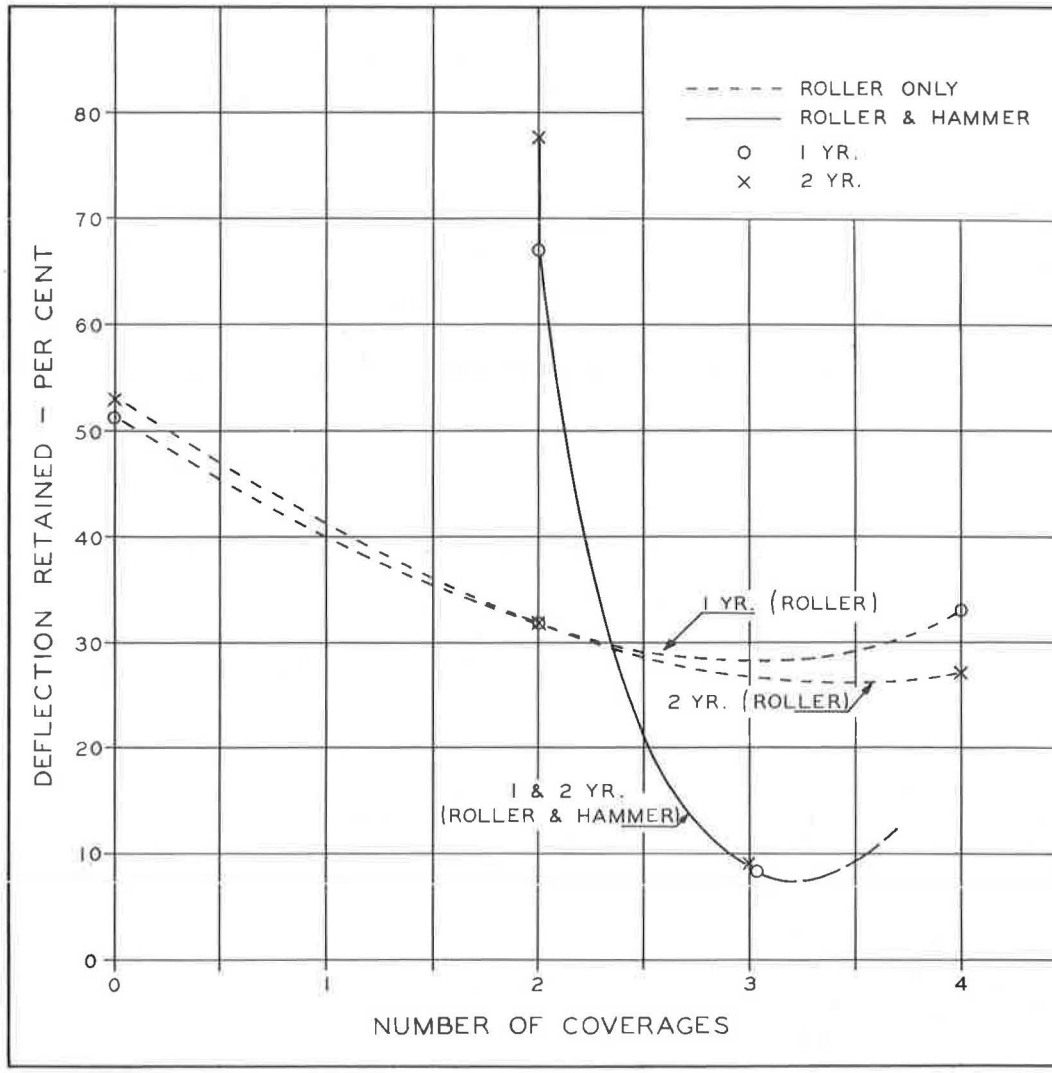


Figure 9. Effects of various roller treatments on Benkelman beam deflections after 1 and 2 yr of traffic vs deflections immediately before breaking and seating operations.

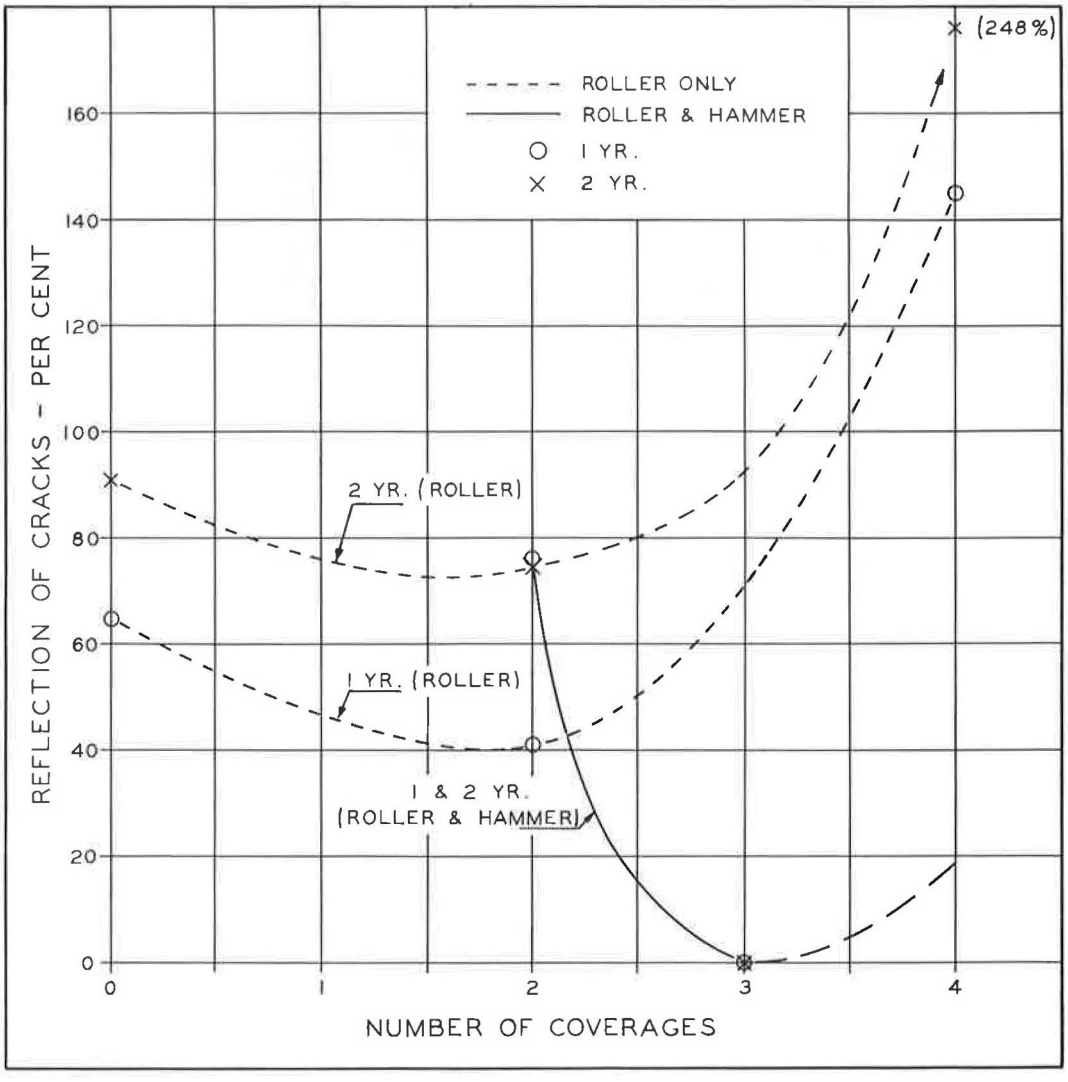


Figure 10. Effects of various roller treatments on reflection cracking after 1 and 2 yr of traffic vs joints and transverse cracks before any treatment.

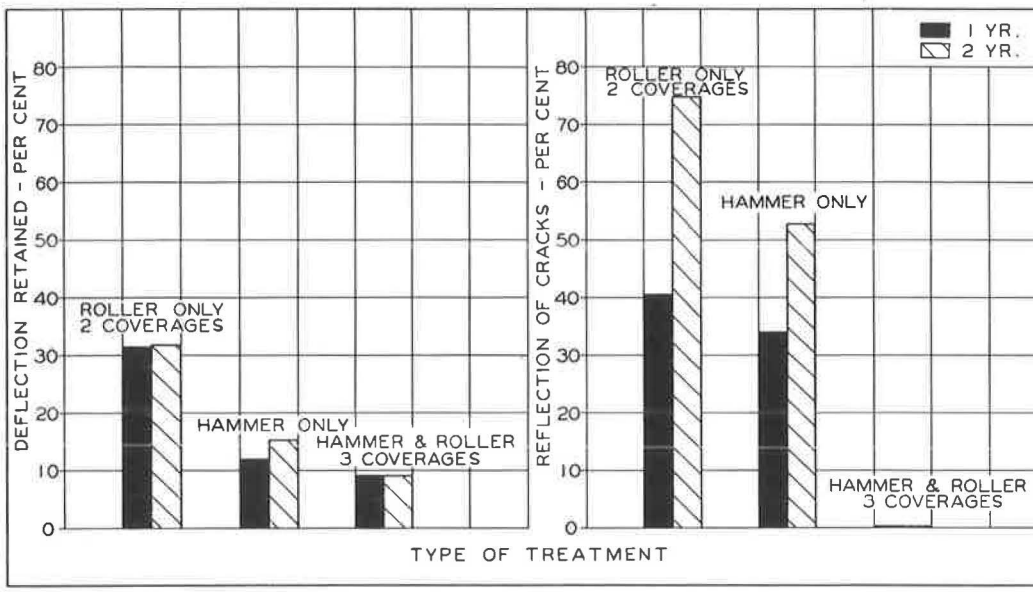


Figure 11. Changes in reflection cracking and deflections for 1 and 2 yr of traffic vs original conditions, for various optimum treatments.

ton roller; to break these slabs with the impact hammer; to apply a seating coverage with the 50-ton roller, also locating additional or continual rocking slabs with this coverage; to accomplish what additional breaking may be required with the impact hammer; and to follow this with the final seating coverage of the 50-ton roller.