



COMMONWEALTH OF KENTUCKY

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MEMORANDUM TO: W. B. Drake
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SUBJECT: Evaluation of Vibratory Roller; Ashland-Cannonsburg Road, US 60

Submitted herewith is a brief report on the evaluation of the RayGo 404 vibratory roller on the Ashland-Cannonsburg experimental paving project.

The report more or less superimposes some practical and theoretical considerations upon practical field observations. Much depends on how the roller is operated. I am inclined to favor nuclear-type density measurements as the principal field and construction control of compaction -- at least to establish rolling patterns, make check tests, and to establish temperature limitations. Although the foregoing statement constitutes a recommendation; the basis for it extends beyond the Ashland-Cannonsburg Road project.

We have reported roller evaluations on three previous occasions:

1. "Evaluation of Vibratory Roller for Use in Compacting Bituminous Concrete Mixes," US 60, Olive Hill, FFG (13)8; R. C. Deen, February 1961.
2. "Study of Light Compaction Equipment for Maintenance Patching," R. L. Florence, September 1961.
3. "Test Rolling with the Buffalo-Springfield, PSR 14 Roller Equipped with Solid Rubber Tires," Research Division Memorandum Report (uncirculated, File H-2-9) R. L. Florence, October 29, 1963, (Mountain Parkway Extension; used Nuclear-Chicago asphalt density probe).

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Attachment

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**COMPARATIVE EVALUATION
OF
RAYGO 404 VIBRATORY ROLLER**

KYP-72-41, HPR-1(7), Part III

by

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**COMPARATIVE EVALUATION
OF
RAYGO 404 VIBRATORY ROLLER**

Roller evaluations are rather phenomenological -- that is, one must rely somewhat on observations. Density measurements following each excursion of the compactor may not relate directly to the work done in compressing the layer. When no increase in density is realized, no work is accomplished. Work is defined here in the classical sense. Energy expended without producing an increase in density is wasted. Thereafter, the only way additional classical work can be done on the layer is to reduce density.

The number of excursions necessary to achieve an acceptable or comparable density generally reflects efficiency of the compactor. Much may depend on weight, speed, size of wheels, and modes of operation. When viscous traction (time-dependent resistance to densification) is involved, the dwell time (or dwell time x number of excursions) becomes very significant. Dwell time is proportional to speed; but, in a vibrating mode, bearing stress of the roller wheel varies.

During the first excursion of a roller wheel on a loose layer, a large area of the cylinder (wheel) is presumed to be in contact (in bearing); and so, the average bearing stress is low. During successive excursions, assuming that each induces an increase in density, the contact area diminishes; and the roller wheel exerts its maximum bearing stress. Here, again, excessive rolling becomes wasted energy. The equivalent, mean, normal bearing stresses can be calculated from the deflection of the pavement -- i.e. indentation of wheel. For example, letting

- R = radius of roller wheel,
- d = distance from wheel axis to chord of wheel arc in contact with pavement surface,
- l = length of chord of wheel arc in contact with pavement surface,
- L = width of roller wheel, and
- P = static weight of roller wheel and surload,

the equivalent normal area is given by

$$l \times L = 2L \sqrt{R^2 - d^2}$$

and the equivalent mean normal stress is

$$P/lL = P/2L \sqrt{R^2 - d^2}.$$

Conceivably, some kind of instrumentation could be

contrived to indicate the chord length or indentation of the roller wheel and display a message to the roller operator that a minimum contact area has been achieved.

Of course, the evaluation of the subject roller did not include measurements of deflections and imprint areas; neither was speed controlled. It was intended only to measure densities (nuclear) following each excursion of the RayGo roller and to do as much with whatever roller had been approved for the project. The comparison was a cursory one indeed. Rolling temperatures were not controlled nor measured; neither were the rollers used concurrently (not same day). Nevertheless, the data indicate that comparable densities were achieved. There were no attempts to make any comparisons between the RayGo machine operating altogether in the nonvibrating mode and the reference roller; and so the data do not show any benefits directly attributable to vibration.

Project F1 (11), SP 10-165, Boyd County, Ashland-Cannonsburg Road (US 60) was chosen to evaluate the RayGo "Rustler" 404 Vibratory Roller. Change Order No. 11, issued August 19, 1971, permitted experimental use of this roller to compact composite lifts in the 14-inch full depth asphaltic concrete pavement in the eastbound lanes from Station 373+50 to Station 399+50. For comparison, a ten-ton, tandem roller was used in the westbound lanes from Station 373+50 to Station 399+50. In the eastbound lanes, the base courses were compacted using only the RayGo roller. The first four passes were made with the vibrator on and the last two passes with the vibrator off. On the surface course only, compaction was accomplished by one pass with the vibrator on and two passes with the vibrator off. Nuclear density tests were made after each pass of the RayGo roller. The surface course was also finished with two or three passes of an eight-ton, tandem roller. In the westbound lanes (control section), all courses were compacted using six passes of a ten-ton, two wheeled tandem roller, two or three passes of a pneumatic-tired roller, and two or three passes of an eight-ton, tandem roller. Nuclear density measurements were made after each of the six passes of the ten-ton roller.

Density growth curves are shown in the eleven graphs which follow. The curves there envelop discrete events. The "Final" densities on the base courses were taken a few hours before the succeeding lifts were laid; the "Final" test may have been made three to five days after construction and therefore reflect densities after finish rolling and incidental traffic. For the surface course, the "Final" test was made as much as a week after the course was laid and compacted. Mean unit weights of the asphaltic concrete for the entire project

are summarized in the following table for comparison.

ASPHALTIC CONCRETE UNIT WEIGHTS			
LIFT	MEAN ASPHALT CONTENT (percent)	MEAN UNIT WEIGHT (lbs/cu ft)	MEAN DEGREE OF COMPACTION (percent)
SURFACE	5.8	135	97
5th BASE COURSE	4.6	129	93
4th BASE COURSE	4.9	128	92
3rd BASE COURSE	4.7	130	94
2nd BASE COURSE	5.1	130	93
1st BASE COURSE	5.9	129	92
SHOULDER, 2nd COURSE	4.4	127	91
SHOULDER, 1st COURSE	5.3	124	89

The following are noteworthy from on-site observations:

1. One pass of the vibratory roller on the surface course with the vibrator on produced surface rippling which was not entirely removed after two non-vibrating passes. A two-wheel, eight-ton, tandem roller had to be used afterwards to produce a smooth surface.
2. In the curb and gutter section, compaction at the edge of the concrete curb by the vibratory roller was not properly achieved because the operator had difficulty seeing the edge of the roller.
3. On highly superelevated curves, the vibratory roller had a tendency to shove the asphaltic concrete toward the lower side.
4. On steeper grades, the vibratory roller caused rippling and shoving downgrade. The non-vibrating passes of the vibratory roller did not cause such rippling or shoving.
5. Spacing between ripples seemed to be dependent on the forward speed of the vibratory roller. The ripples were about six inches peak to peak at high speeds. When speeds were reduced to normal operating speed, the peak-to-peak spacing was reduced to approximately three inches.
6. It was noted that, on the surface lift, a single vibratory roller could not make the normal rolling pattern and keep pace with the paver.

The RayGo 404 is claimed to exert a maximum dynamic force of 27,000 pounds in the vibrating mode. In the interval between maxima, the force would be less than the static weight; and so, compaction may be somewhat "saw-toothed" or sinusoidal. The observed reality of this appeared in compacting the surface course. When the vibrating roller was operated at

relatively slow speeds, ripples about three inches apart appeared in the surface (and could only be erased by using an eight-ton, tandem roller); at faster speeds, the ripples were about six inches apart. The rated frequency of this machine is 1100 to 1500 vpm (both amplitude and frequency could be varied). Using 1500 vpm in the equation $1/f \times V = \lambda$ (V = velocity, λ = wave length, represented by peak-to-peak distance between ripples), yields a roller speed of 4.3 mph for the three-inch ripples and 8.5 mph for the six-inch ripples. The probability of controlling the spacing of peak, dynamic impulses during successive excursions (to obtain smoothness) seems very remote. The only possibility would be to operate the roller at creep speed -- so that the interval between roller impulses would be very short. A 0.5-inch interval would equate to a speed of 0.7 mph. This hypothetical operating mode would be about equivalent to operating a 27,000-pound roller wheel at an equivalent dwell time (slightly greater speed). The foregoing considerations are in agreement with the manufacturer's literature (RGS-189 11-71-2M).

Intuitively, it is feared that operating the roller in the vibratory mode in certain stages of construction could be very damaging to the surface and sublayers. As the pavement structure becomes more rigid, crushing or fracturing of aggregate could occur. If the frequency of vibration approaches the resonant frequency of the surface and (or) sublayers, the roller could shake the structure apart. Vibrations sensed (felt) some distance away from the roller may represent wasted if not damaging energy.











