

FINAL REPORT

INVESTIGATION OF IMPROVED COMPACTION BY RUBBER-TIRE ROLLERS

by

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Senior Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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INTRODUCTION

In the late 1950s and early 1960s, the most discussed compaction equipment was the rubber-tire roller. Many papers were presented at TRP and AAPT meetings extolling the virtues of these rollers (1-7). However, with the importing of vibratory rollers from Europe in the late 60s and their domestic development in the early 70s, attention was diverted to the improved compaction by vibratory rollers and away from the use of rubber-tire rollers. However, the addition of the vibratory roller to the compaction train should not have influenced interest in the rubber-tire roller since it applies a different compactive effort to bituminous concrete mixes. The vibratory roller applies a vibratory force and the rubber-tire roller a kneading action.

Some state highway agencies (e.g., Georgia and Texas) still require rubber-tire rollers, and others (such as South Carolina) are starting to require their use again.

It has been claimed that the rubber-tire roller improves compaction because its kneading action seals the surface better than steel-wheel rollers, it doesn't have the tendency to bridge low areas as does the steel-wheel roller, and it provides compaction that is similar to vehicular traffic thus ameliorating the tendency of mixes to rut.

Longitudinal joint performance appears to be a substantial problem in Virginia as well as elsewhere (8). One possible improvement in joint construction is the use of the rubber-tire roller because of the kneading action that it provides as well as its being able to overcome the bridging problem of steel-wheel rollers.

For these reasons, the Flexible Pavement Task Force requested that the Council look into potential benefits of using a rubber-tire roller as an addition to the compaction train.

PURPOSE

The purpose of this study was to determine whether or not significant benefits can be derived from the addition of a rubber-tire roller to the compaction train. Potential benefits were considered in terms of more uniform density at the joint and across the pavement, improved air voids, permeabilities, and laboratory strengths. Also considered were possible negative effects such as the requirement for additional equipment and asphalt pickup on tires. The study consisted of a review of the literature and field testing on five projects.

LITERATURE REVIEW

A very informative discussion of rubber-tire rollers is contained in a chapter by the knowledgeable author Myron Geller (1). He states that "Pneumatic tire rolling has had strong advocates but there have been a number of reports that did not carry the same strength in their conclusions." He goes on to say that "It appears that pneumatic rollers and static steel wheel rollers do exert the same range of pressures. Therefore, the differences in the respective performances have to do with shape of the contact area, the size of the contact area for a given pressure, and the difference in the macro surface texture developed by steel versus rubber."

A very real concern is to prevent asphalt from adhering to the tires. Geller states "This tendency is minimal when the tire temperature approaches the temperature of the mat, but it is sometimes difficult to maintain the tires at proper temperature during job circumstances. As a solution, diesel fuel is an effective release agent, but is objectionable because of the inherent risk to the fresh pavement if it is not used carefully."

As for advantages and unsubstantiated claims, these comments are pertinent.

1. "Pneumatic tire rollers do have the advantage of being able to eliminate hair cracks and shallow surface heat checks. When such conditions exist, pneumatic tire rollers are ideally used as a finishing roller working to the rear of the breakdown roller, and in such cases they usually operate on a temperature zone that does not involve pickup of material."
2. "For harsh mixtures, the pneumatic tire roller has not demonstrated any particular advantage over static steel wheel rollers. Claims for improved mix impermeability for pneumatic tire rollers are not well supported by evidence of comparative

permeability tests between static steel and pneumatic rollers This is probably correct as long as the densities are comparable, and there are no surface cracks or heat checks left by the steel wheel. There is a visual difference in the surface texture of the mat when rolled by a pneumatic tire compared to a steel wheel that gradually disappears in time as traffic works the surface."

3. "Pneumatic tires have a greater tendency to deform an unsupported edge"
4. "Claims for the benefits derived from the kneading effect of a pneumatic tire roller are also not especially well substantiated in test report literature. Unless there is a substantial penetration of the tire into the mix, the kneading or manipulative effect of a pneumatic tire roller is limited to the upper layer of the lift."

Cechetini in a AAPT paper (2) that reports on compactive tests between compaction trains using vibratory rollers and those using pneumatic rollers found water permeability results to be lower with the former than with static and pneumatic rollers. This report also found that vibratory compaction tends to cause asphalt and fines to migrate to the surface to a greater extent than do compaction trains incorporating pneumatic-tire rollers.

Two other reports from California, although written earlier than Cechetini's, indicate that pneumatic compaction is important in reducing permeability and air voids. Zube (3) states "Field tests indicate that adequate compaction, together with some form of pneumatic rolling, are very important factors in reducing pavement permeability." Schmidt, et al. (4) found that intermediate pneumatic compaction at high pavement temperatures resulted in complete compaction than was obtained with steel-wheel rolling alone. Pneumatic compaction with a light-weight pneumatic compactor was of no value when made at 135°F, a temperature low enough to prevent sticking between the tires and pavement. It was concluded that high density, low permeability, low air voids, and highly durable pavements can be obtained with the use of a pneumatic roller for intermediate compaction of a mix at high temperatures (> 195°F). It was also reported that the relative compaction was the same at tire pressures of 40 and 90 psi with the same number of passes and at similarly high temperatures.

Serafin and Kole (6) found that a tighter-looking surface texture results from pneumatic-tire rolling.

FIELD TESTING

Five projects were selected for testing with the rubber-tire roller. The first four used a CP-15 Dynapac roller on loan from Capital Equipment Company. The roller with ballast tanks, containing water only, weighed approximately 18,000 lbs providing a wheel load of 2,000 lbs and a ground contact pressure of about 50 psi. The roller on the fifth project was one furnished by the Abingdon Residency. Tire pressures on this roller were about 45 psi.

The five projects and mix types tested were Route 340, Augusta County, S-10; Route 622, Amherst County, S-10; Route 81, Pulaski County, S-5; Route 250, Albemarle County, S-10; and Route 81, Washington County, S-5.

Test Sequence

A 500- to 1,000-ft section using the contractor's normal equipment and normal rolling pattern was designated as the conventional section. Conventional rolling included vibratory, static tandem or three-wheel breakdown rolling and tandem finish rolling. After rolling, ten nuclear readings were taken transversely across the pavement at four locations beginning adjacent to the longitudinal joint. Six 4-in cores were taken from the same section with two taken adjacent to the longitudinal joint and four spaced at random transverse locations.

Another 500- to 1,000-ft section with the rubber-tire roller used as an intermediate roller making three passes was designated the test section. The normal roller pattern used on the conventional section was not changed. The same nuclear and coring sequence was followed for the test sections.

Rubber-Tire Roller Operation

Rubber-tire rollers used as intermediate rollers may or may not use water on the tires. The reason for using water is to prevent the mix from sticking to the tires. The disadvantage of using water is that the tires often do not become hot enough, as Geller states, to approach the temperature of the mat, and depending on the temperature of the mat, may still pickup mix on the tires. Whether to use water on the tires is often a decision made in the field depending on the mat temperature at the time of rolling with the rubber-tire roller. No water was used on the tires on the first project and no problems occurred. However, both the conventional and test sections on this project were conducted during a rain storm and the pavement temperatures dropped quickly. The second project was paved on a very hot day and the pavement temperatures

remained above 200°F for a considerable time. Water was not used on the rubber tires on this project, and the tires did pickup to a disturbing degree. Evidently the tires never reached a sufficient temperature to prevent this. This was the only project on which pickup was a serious problem.

RESULTS

Table 1 shows averages and standard deviations for nuclear densities, air voids, permeability, resilient modulus and indirect tensile strength. These properties will be discussed one by one.

Table 1
Test Results

Project	Nuclear Den. pcf		Air Voids %		Permeability ml/min		M _R psi		Indirect Ten. psi	
	Conv.	Test	Conv.	Test	Conv.	Test	Conv.	Test	Conv.	Test
Rte. 340 \bar{X}	135.0	133.3	11.6	10.3	83	19	40000	41000	68.8	73.2
σ	3.44	2.08	3.12	1.49	109.6	13.1	7705	5955	19.88	9.87
Rte. 622 \bar{X}	140.8	141.7	9.8	9.0	9	4	49000	61000	85.1	88.0
σ	2.81	2.56	1.98	1.18	7.5	4.4	15240	9350	9.33	9.53
Rte. 81S \bar{X}	135.6	137.3	10.5	11.2	7	2	42000	44000	91.3	94.6
σ	3.08	3.05	1.75	2.53	4.2	1.3	10335	9950	13.78	14.43
Rte. 250 \bar{X}	144.1	146.2	9.8	9.7	38	46	41000	51000	69.3	74.6
σ	2.50	2.43	1.74	1.40	37.1	38.3	8610	11650	18.40	9.20
Rte. 81B \bar{X}	134.9	135.4	11.4	11.9	24	55	46000	44000	66.4	52.9
σ	3.39	3.16	2.57	1.76	19.7	31.2	10820	6975	11.62	11.10

Nuclear Densities

On four of the five projects, the average nuclear density for the rubber-tire test section is slightly higher than for the adjacent conventional section, but the difference is so slight as to be inconsequential. The standard deviations of the nuclear density is lower for the test section, indicating a more uniform density across the pavement, which can be interpreted to mean that the rubber-tire roller applies a more uniform compaction and tends to overcome some of the bridging effects of the steel-wheel rollers. The first nuclear density in each testing sequence is adjacent to the longitudinal joint and averaging these first readings on each section provides an indication of the average joint density. The average joint density was higher on every rubber-tire section than on the comparative conventional section and the overall average difference was 2.6 pcf. This indicates that some

improvement in joint density does occur with the use of the rubber-tire roller. As anticipated, the average joint density was lower than the average density across the pavement.

Air Voids

The average air void results pretty much reflect the results of the average nuclear density with the rubber-tire test sections generally being slightly better than the conventional. But the differences based on six cores and the standard deviations measured are not significant. The results of the standard deviations of air voids on the test sections again show a slight improvement over those of the conventional sections. For the joint air voids, with only two cores taken adjacent to the joint on each section, it requires a large average difference and small standard deviation to be able to discern a difference between sections. The rubber-tire roller appeared to reduce the air voids on only Routes 340 and 622 compared to the results using the conventional rollers.

Permeability

As mentioned earlier, the use of rubber-tire rollers has been reported to reduce the permeability of pavements compared to those rolled with steel-wheel rollers. This study used two permeability tests, a falling head and a constant head, to determine whether any differences occurred. The first measured the amount of water flow over a period of time with a falling head. The measurement was in milliliters per minute and the test is shown in Figure 1. In most cores the

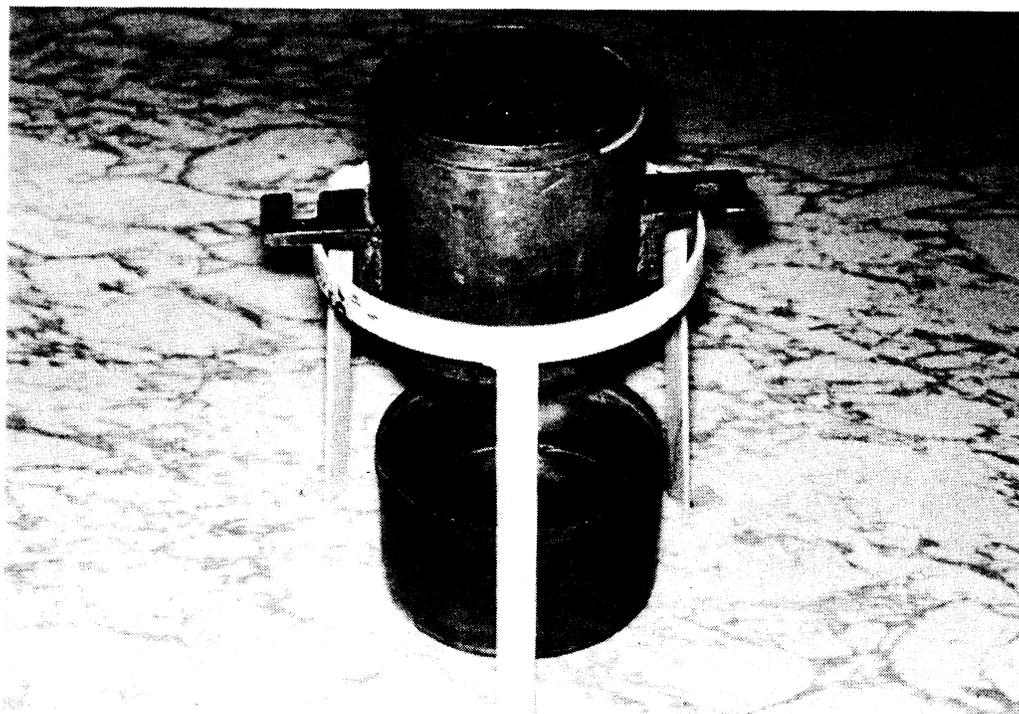


Figure 1. Apparatus for the falling head permeability test.

water flowed through the samples, which were sealed in 4-in molds, very quickly. The permeability data for this test is shown in Table 1.

Figure 2 shows the correlation between air voids and the falling head permeability. The correlation coefficient, r , of 0.553 confirms Zube's (3) data that a correlation, although not strong, does exist between air voids and permeability. The permeability values from this study also are in the general range that Zube found. The constant head permeabilities were much less variable than the falling head but they also indicated very high permeabilities in the range of 2×10^{-3} to 4×10^{-4} cm/s. Values this high are described in Davies' and Walker's paper on permeability (9) as indicative of good drainage material, which is not the normal purpose of an asphalt surface course. The correlation between air voids and constant head permeability (Figure 3) was better than the falling head permeability test as evidenced by the correlation coefficient of .857.

Resilient Modulus

One indicator of strength is the resilient modulus, M_R , test. The variability of this test, particularly when run on cores, can be high, and this is the case in the results in Table 1. (The tests were performed on the Retsina Device at 72°F.) The standard deviations under the M_R results are sufficiently high to make seemingly large differences between averages not significant between the rubber-tire and conventional sections.

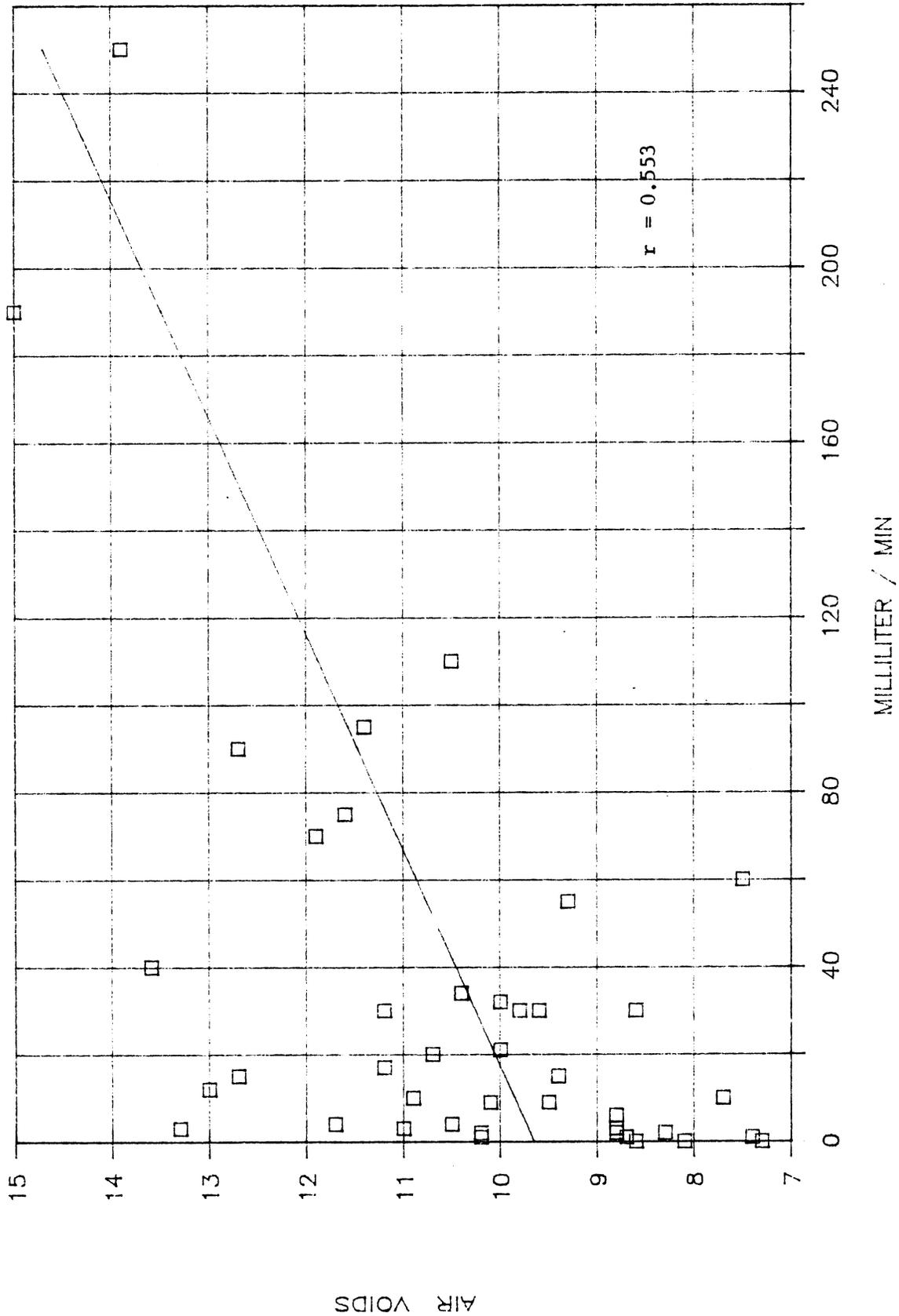
Indirect Tensile Strength

No significant differences were found in averages of the Indirect Tensile Strengths between rubber-tire and conventional roller sections. If any significant difference is surmised, such as from the results on Rte. 81 S., this difference is masked by the variability found in the results.

Mix Type

The S-5 mix, which may be considered to be a denser mix than the S-10, proved to be as permeable as the S-10. No differences are apparent by mix type when compared to roller type.

RUBBER-TIRE ROLLER STUDY



RUBBER-TIRE ROLLER STUDY

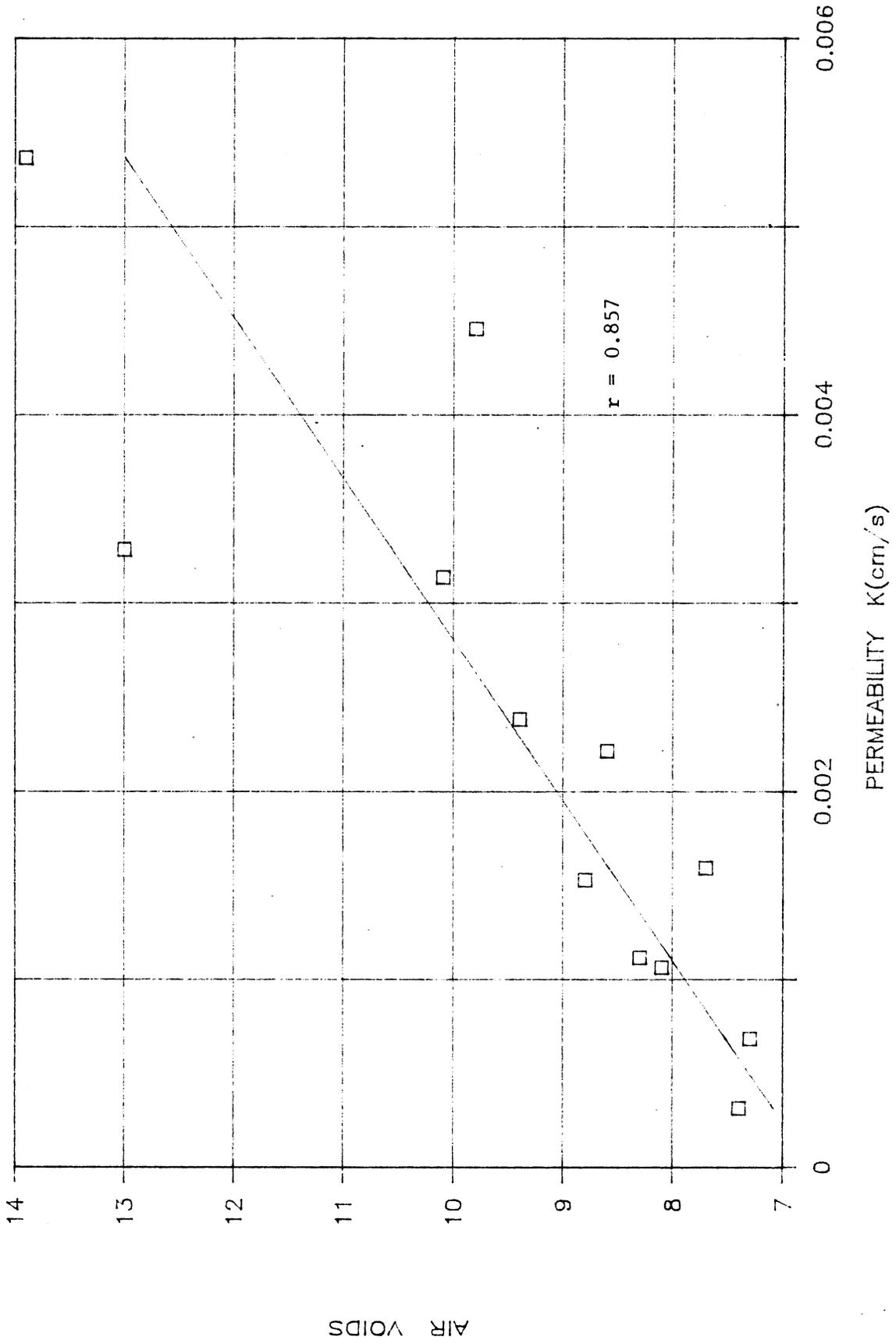


Figure 3. Correlation between air voids and constant head permeability.

CONCLUSIONS

Adding a rubber-tire roller to a compaction train is not a difficult procedure, but would likely increase compaction cost from the standpoint of depreciating the equipment and requiring an additional roller operator. To optimize the use of a rubber-tire roller, the temperature of the mat is very important, thus some experience in determining when to roll is needed. These conclusions, while not a part of the testing program, became apparent during the field study.

Conclusions from the testing are as follows:

1. The use of the rubber-tire roller neither significantly increased the average nuclear density nor decreased the average air voids.
2. Its use decreased the standard deviations of the nuclear density and air void results indicating somewhat more uniform density than with the conventional rollers. This result indicates that the rubber-tire roller overcomes bridging that cannot be overcome by steel-wheel rollers.
3. Its use improved the nuclear density results obtained at the longitudinal joint and may have had a positive effect on air voids measured on cores taken adjacent to the joint on two projects.
4. Its use had no significant effect on the permeability of the pavement.
5. Its use had no significant effect on the results of either the Resilient Modulus or Indirect Tensile Strength tests.

ACKNOWLEDGEMENTS

The cooperation of both Dynapac and Capital Equipment Companies is greatly appreciated for the use of the CP-15 roller. Using one roller on four projects required quite a bit of transportation coordination by the District Equipment Engineers. Every time they were asked, they responded quickly and efficiently, simplifying the logistics greatly. Lastly, the District Materials Engineers were helpful, as usual, in locating projects and providing support for obtaining the cores. Without the help of many individuals, this project would have been much more difficult to conduct.

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