Construction and Benefits of Rubber-Modified Asphalt Pavements

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Abstract:

A paving system was developed in Sweden in the 1960's in which relatively large rubber particles are incorporated into asphalt concrete pavements. The original purpose was to increase skid resistance and durability. This system, distributed under the trade names "Skega Asphalt" or "Rubit" in Scandinavia and "PlusRide" in the U.S.A., was also found to provide a new form of wintertime ice control because of the increased flexibility and the action of protruding rubber particles. The Alaska Department of Transportation and Public Facilities installed five experimental pavement sections using the PlusRide system between 1979 and 1981. Major modifications to normal asphalt pavement aggregate gradations, asphalt contents, and mix design procedures are considered essential to achieve durable non-ravelling rubber-asphalt pavements. The attainment of low voids in the pavement is the primary design and construction objective, and mix design and construction activities are discussed in this report. Observations of the skid reduction benefits under icy road conditions made with a British Pendulum Tester and a vehicle equipped with a Tapley Brake Meter are also reported. The exact extent of benefits in reducing vehicle stopping distances could not be determined from the limited field testing done in Alaska, but tests indicated that significant reductions in icy road stopping distances commonly resulted from the use of the PlusRide paving system. Laboratory tests of PlusRide paving mixes also indicate a potential for greatly increased pavement fatigue life as a result of the elasticity of this material.

Introduction:

In the late 1960s, experimentation was done in Sweden on the effects of mixing rubber particles in asphaltic pavements. A system incorporating 3 to 4 percent by weight of relatively large (1/16" to 1/4") rubber particles into an asphalt pavement was developed to increase skid resistance and durability, and found to provide a new form of wintertime ice control as well as a reduced noise level. The ice control mechanism apparently results from the flexing of the protruding rubber particles and the greater flexibility of the mix under traffic action, which cause a breakdown of surface ice deposits.

Roadway surface ice deposits become a major problem in urbanized areas with high traffic volumes and stop and go traffic movements. Costs of maintaining ice-free pavements through de-icing chemicals or improving traction through sand applications are very high, and would justify considerably increased expenditures on pavement construction if ice-free pavements could be obtained.

An unrelated problem, but one of considerable magnitude, has been the disposal of hundreds of millions of used tires which are discarded each year. The possibility of beneficially using this form of refuse to the benefit of the public must be seriously considered.

Encouraged by the successes of rubber-asphalt paving mixes in Scandinavia, the Alaska Department of Transportation and Public Facilities has installed five experimental pavement sections in Fairbanks and Anchorage between 1979 and 1981 utilizing different pavement mixtures. Periodic measurements of surface friction have been made during icy winter conditions in 1980 and 1981 to analyze the benefits of the rubber in increasing traction and reducing stopping distances. Laboratory tests for resilient modulus and durability have also been performed on samples of these mixes, and indicate that major increases in fatigue life and crack reflection control are anticipated due to the increased flexibility.

Background:

Asphalt and Rubber Mixtures:

The original development work in the area of coarse rubber-asphalt paving mixtures was performed by the Swedish companies Skega AB and AB Vaegfoerbaettringar (ABV). The material application was patented under the trade name "Rubit." In America, the trademark "Plusride" asphalt is now used to designate this material.

It should be noted that considerable experimental work and field trials have been performed in the United States, and particularly in Arizona, California, and Colorado, on rubberized asphalt seal coats. These installations have utilized finely ground (-#16 to +#25) crumb rubber, reacted with asphalt at elevated temperatures to form a thick elastomeric material which is then diluted with 5 percent kerosene to aid in application. It was learned from studies by the Arizona Department of Transportation that these small rubber particles swell to 2 to 3 times their original size when reacted with asphalt at temperatures of 350°F to 400°F for periods of 30 minutes or more. As such, these installations differ substantially from the materials discussed herein. Little or no use of the concept of incorporating larger rubber particles in pavement surfacing layers is indicated in North America. The potential savings in ice control costs may justify the increased cost of rubberized surfacings. Use of such surfacings on bridge decks and on insulated roadway sections should offset the icing occurrences commonly noted on bridges and sometimes found over insulated sections of roadway.

Ice Control Considerations:

The use of sands for ice control provides only temporary skid resistance, and sand must be reapplied often. Stopping distances on sanded ice are also much greater than on dry pavement. In addition, sand must be removed from gutters and inlets in urban areas following spring thawing to avoid blockage of drainage systems.

Some recent analyses of the costs and benefits of using salt to remove roadway ice have indicated that the ultimate costs to the road-user may be as much as 15 times as high as the sum of the benefits. The major cost item in these studies, premature vehicle destruction through corrosion, greatly outweighed the benefits of reduced maintenance and accident costs. Salts also present the possibility of contamination of ground and surface waters from roadway runoff. A benefit of salt usage which is difficult to quantify, however, is the savings in travel time which results when roadways are free of ice.

Paving Mix Consideration:

Aggregate and Rubber Proportions:

From experience in Sweden, three different aggregate (sand and gravel) gradations are currently recommended to serve different traffic levels, as shown by Table 1.

The rubber particles used in these mixes are produced in roughly cubical form from grinding of waste tires, which have first had the steel wires in the tire bead area removed. The rubber may include some tire cord and steel fibers from the tire belts, and is required to meet the gradation specifications in Table 2. Product experience by the parent ABV company has indicated that some durability benefits result from the use of a modified rubber gradation, replacing 20 percent of the originally used coarse rubber with a finely ground (#10-40) rubber size. This change corresponds with use of a similar rubber grading in the construction of the rubberized asphalt seal coats previously mentioned, and was the basis of Alaska's modified rubber gradings used in 1981.

To those knowledgeable in the area of design of asphalt paving mixtures, a review of these specifications will reveal some critical differences between modified and normal pavements. The most important difference is indicated by the shape of the aggregate gradation curve (Figure 1). To provide space for the rubber particles, it is necessary to create a "gap" in the gradation curve for the aggregates, primarily in the 1/8" to 1/4" size range. In effect, the rubber particles replace the rock particles which normally occupy this size range. Unless this gradation curve gap is present, the rubber particles will resist compaction of the mix during the rolling operation, and the resultant pavement will have excessively high voids and no durability.

Asphalt Content Determination:

The asphalt contents recommended in Table 1 will generally be found to be 1 to 2 percent higher than in conventional mixes. This higher asphalt level is an important factor in the durability of rubber-asphalt pavements. Laboratory mixes should be prepared at

TABLE 1

Recommended Specifications for Rubber-Asphalt (PlusRide) Paving Mixtures for Different Levels of Traffic

Mix Designation	PlusRide 8	PlusRide 12	PlusRide 16
Average Daily Traffic	< 2500	2500-10,000	> 10,000
Thickness (in.) min.	0.75	1.5	1.75
Aggregate % Passing			
Sieve Sizes:			
3/4"	--	--	100
5/8"	--	100	--
1/2"	--	--	65-80
3/8"	100	60-80	50-60
1/4"	60-80	30-42	30-42
#10	23-38	19-32	19-32
#30	15-27	13-25	12-23
#200	7-11	8-12	6-10
Preliminary Mix Design:			
Rubber, % of Total Mix			
by weight	3.0	3.0	3.0
by volume (approx.)	6.7	6.7	6.7
Asphalt, % of Total Mix			
by weight	7.5	7.5	7.5
by volume (approx.)	20.2	20.2	20.2
Maximum Voids (%)	2	3	4

TABLE 2

Particle Size Specifications Used for Rubber

Sieve Size	Alaska 1979-80	Alaska 1981	ABV Co. Combined Coarse & Fine	PlusRide 1981
1/4"	--	--	100	--
#4	100	100	76-92	100
#10	15-35	15-36	28-36	28-40
#20	--	10-25	10-24	--
#40	0-6	--	--	0-6
#200	0-2	--	--	--

several different asphalt contents. Compaction and testing are performed using the Marshall procedure in which samples are placed in greased open ended steel ring molds and compacted with 50 blows of a drop hammer on each end. Samples are then weighed both in air and immersed in water, and the percentage of voids is determined by calculation. As the asphalt content is increased, the voids will decrease as shown by Figure 2. It has been found critical to achieve low voids and thereby prevent the intrusion of water. The minimum asphalt content permitted should be that at which 3 percent voids is achieved. Some minor changes in aggregate gradation may be necessary if this low voids level cannot be attained with reasonable asphalt contents. Marshall stability criteria cannot normally be met with Plusride paving mixes. Stabilities as low as 350 pounds were recorded for the paving mixes used in the 1979 Fairbanks installations, yet these pavements have resisted bleeding in the 2 years since constuction, in spite of air temperatures as high as 90°F.

The differences in mix properties which can occur within the aggregate size specification limits used for Fairbanks' rubber-modified pavements in 1981 were studied by performing four mix designs using a single aggregate source, AC-2.5 asphalt, and a rubber content of 3 percent. Gradings used in this study are shown by Figure 3, and represent the coarse and fine gradation limits (Mixes A and B), the middle of the specification band (Mix C), and the "straightest line" grading possible with this specification band (Mix D). Results of this testing at asphalt contents from 6 percent to 9 percent by weight of the dry aggregate are shown by Figures 4 to 6, and demonstrate the low stability and high flow test results typically obtained on these "Plus-Ride" mixes, as well as the sensitivity of the voids levels and other mix properties to aggregate gradation changes. It should be noted that these specification limits, shown by Figure 3, are wider than those recommended for the similar "Plus-Ride 12" mix in Table 1, and this specification band was used by the Alaska Department of Transportation to provide more contractor flexibility in choice of a final mix gradation. It is obvious from this study that a good laboratory mix design is

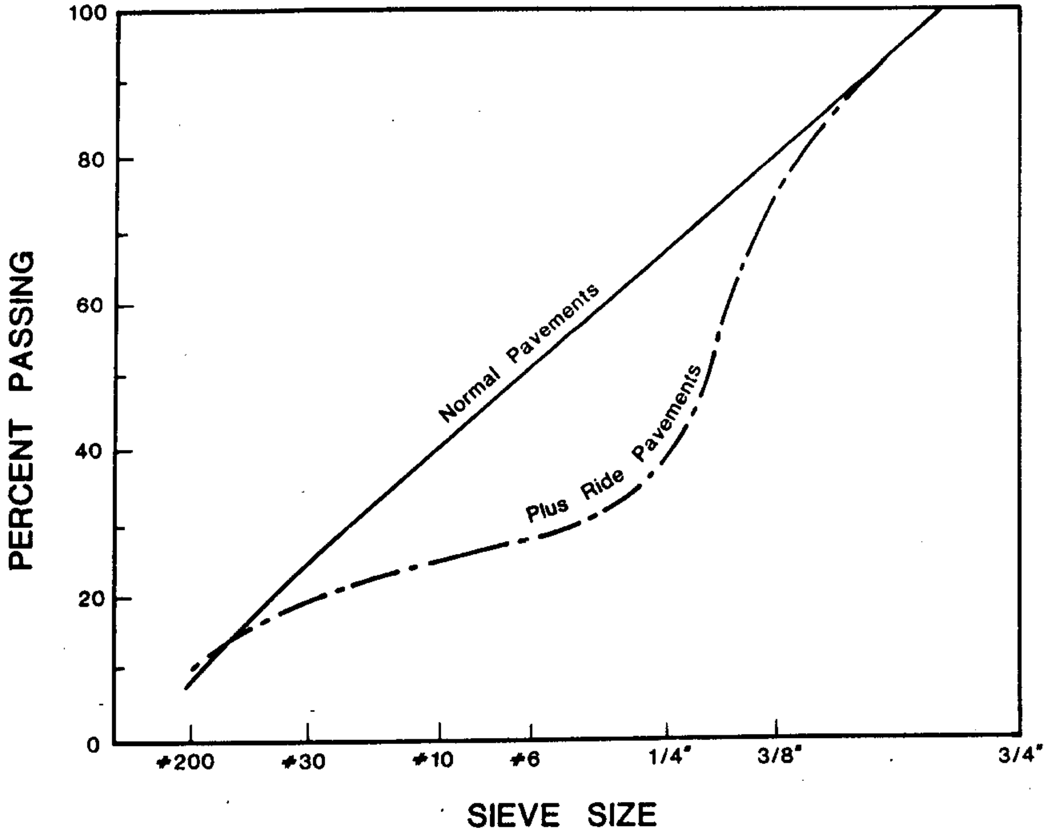

Figure 1: Comparative Aggregate Gradation Curves for Normal and "Plus-Ride" Asphalt-Rubber Pavements

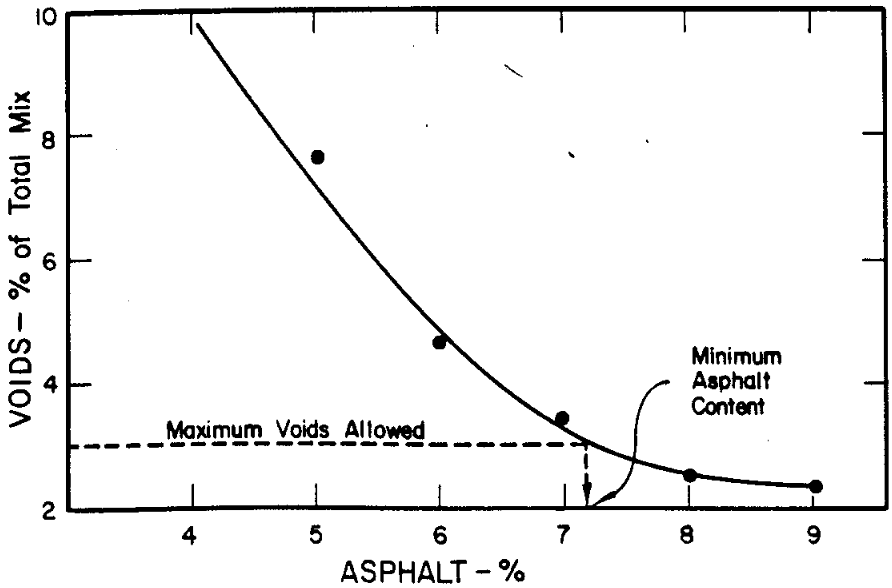

Figure 2: Asphalt Content Determination on the Basis of Voids in Mix

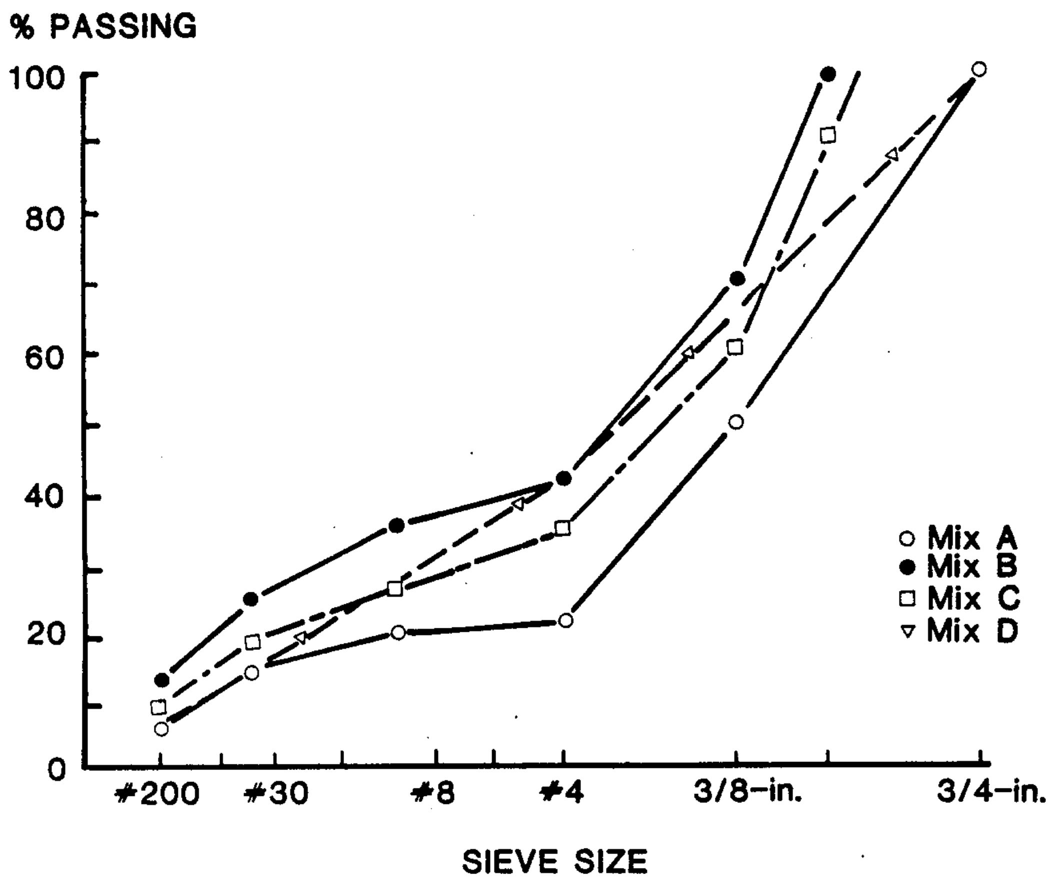

Figure 3: Aggregate Gradations Used to Test for Variations in Mix Properties due to Gradation Variations within a Specification Band

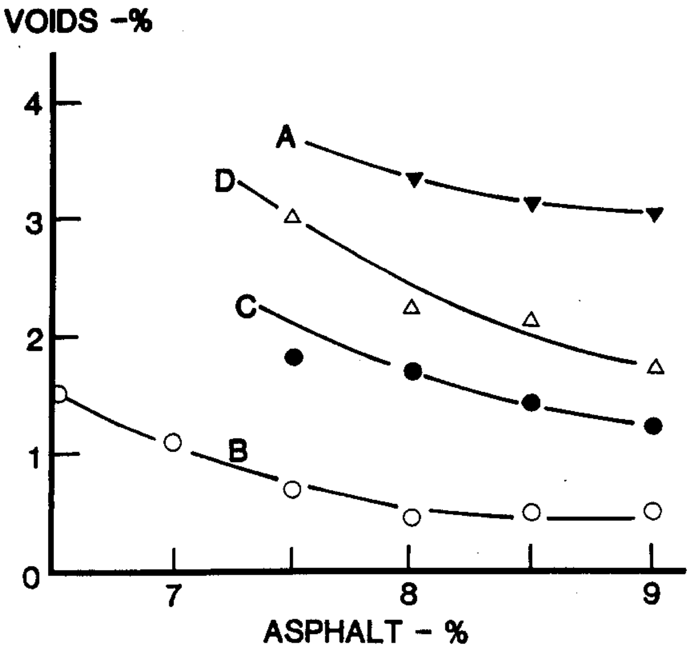

Figure 4: Differences in Voids Contents for Different Aggregate Gradations within a single Specification Band

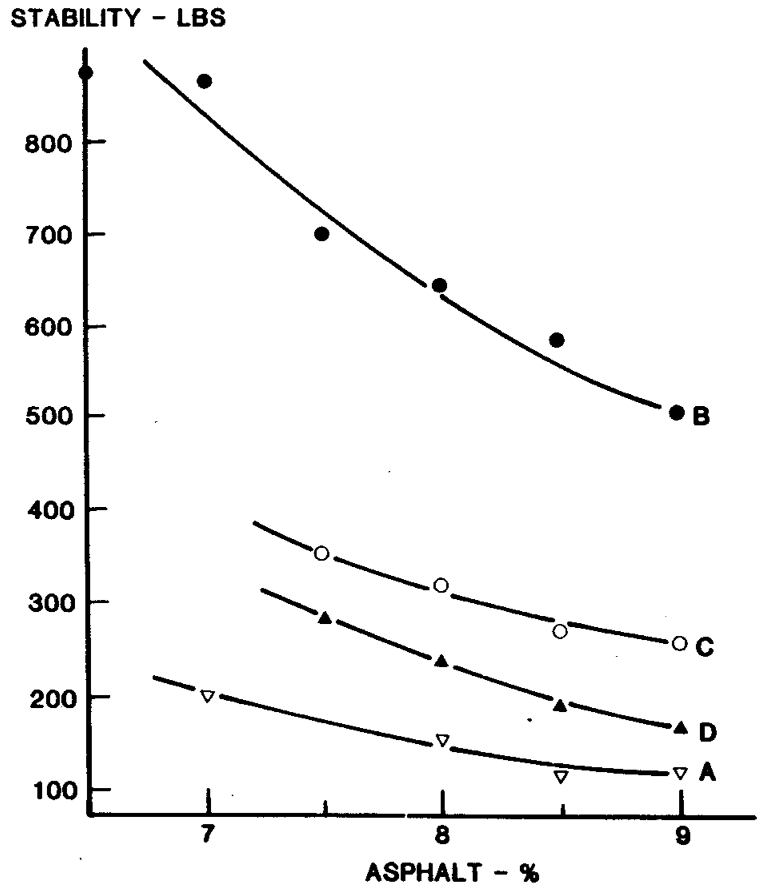

Figure 5:

Differences in Marshall Stability for Different Aggregate Gradations within a Single Specification Band

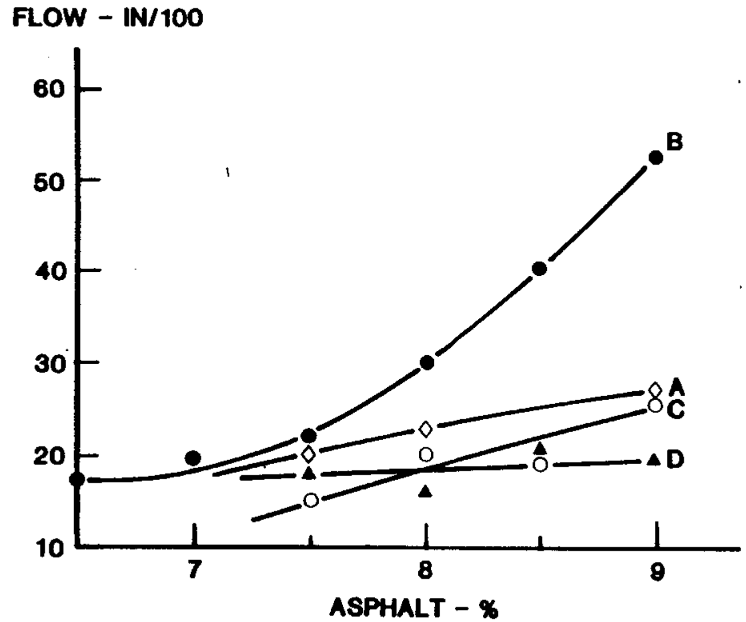

Figure 6:

Differences in Marshall Flow for Different Aggregate Gradations within a Single Specification Band critical to obtaining a proper mix with low voids and adequate stability. The "minimum required" value for stability of these mixes has not yet been determined.

Special Construction Considerations:

Mixing:

In the preparation of rubber-asphalt paving mixes, use of a "batch" mixing plant is preferred because the required quantities of rubber, asphalt, and aggregates can be exactly measured and added separately to the "pugmill" or mixing chamber. In this plant type preweighed sack rubber can be used to advantage, with quantity control by bag count. However, both continuous mix and drum-dryer mix asphalt paving plants have been used without difficulty. In these plants in which the mixing operation goes on continuously rather than in batches, the rubber must be continuously added from a separate bin with a belt feed to maintain uniformity. Very close control of the rubber content is critical to assure proper field performance. Mixing temperatures and asphalt grades used are similar to those for normal paving mixes, with some indications that mixes may benefit from mixing at temperatures as high as +350°F.

Placement and Compaction:

Placement of the hot paving mix should be performed by paving machines equipped with full width vibratory screeds. Rolling should commence as soon as possible after placement, without the mix sticking to the roller, and should continue until the mix temperature cools below 140°F. Rubber mixes are very resilient and rebound noticeably behind the roller. Rollers may be either steel-wheel static or vibratory types. Rubber-tire rollers were not to be used, according to original recommendations. However, recent experiences with rubber-asphalt pavements placed in Vancouver, B.C. and Anchorage, Alaska in 1981 indicate that significant surface tightening might be achieved by use of a rubber-tire roller after the mix has cooled below 140°F.

Compaction to the highest possible density with minimal voids is essential to good pavement performance. When core samples are taken from the finished pavement and tested, the average voids content should be less than 5 percent. Rubber-asphalt paving mixes will appear excessively high in asphalt content to personnel familiar with normal mixes, but the presence of the rubber has been reported to prevent the possibility of the "bleeding" of excess asphalt from the mix, as the rubber and asphalt combine to form a more elastic binder.

Costs:

Factors which increase the cost of a rubber-asphalt paving mixture over a normal mix include the purchase, shipping, and handling of the rubber, the plant modifications needed for rubber addition, and possibly some additional rolling costs. At the present time, the closest rubber production to Alaska is in the Seattle area, and the shipping costs are a major factor in the delivered Fairbanks rubber price of approximately 30¢/lb. The addition of 3 percent rubber in the Fairbanks area including royalty fees paid to the patent holder, All Seasons Surfacings Corp., will increase the in-place pavement cost by roughly 50 percent, for a total cost increase of $15,000 to $30,000 per mile depending on width and thickness.

Field Trials-Fairbanks Area-1979:

Site Selections:

Two sites were selected in the Fairbanks area for the first trial installations of Plusride rubber modified pavement mixtures. The first site is on a frontage road curve at the northeast side of the junction between University Avenue and Airport Road, referred to as the "Carnation" site after the adjacent Carnation Dairy warehouse. The second site covers the northern half of a roadway insulation test site which was constructed in early August of 1968, on the Fairhill Subdivision access road 1/2 mile north of the junction of the Steese Highway and Farmers Loop Road. The Carnation site was selected because of the proximity to the Research Laboratory and the frequent occurrence of skidding accidents due to the very sharp curvature of the roadway. This site was designed for a pavement thickness of $1\frac{1}{2}$ inches to be applied over the existing pavement width of 33 feet. The existing pavement was constructed in 1967 and was in good condition. The total section length was 212 feet. Fairhill was selected because the presence of the insulation layer resulted in significant differential surface icing during the 1978-79 winter, where the roadway was ice covered above the insulation but not over adjacent non-insulated areas. At Fairhill, the rubberized pavement section was designed to cover the northern half of the insulated roadway segment. In this area the original pavement was placed in 1978 and was 24 feet in width. The total length was set at 125 feet, including two 25-foot end tapers leading into the $1\frac{1}{2}$-inch center section.

Pavement Construction:

The first Fairbanks area rubber-asphalt paving mix was prepared on September 4, 1979 by Associated Asphalt Company from Chena River gravels. The rubber was supplied by the All Seasons Surfacing Corp. Because the asphalt plant to be used was of the continuous mix single-entry "drum-dryer" type, it was necessary to utilize the existing stockpile aggregate gradations. As a consequence, the final gradation was slightly lower (4 to 5 percent) than desirable (6 to 11 percent) in the dust or "fines" size range. The rubber was fed from one of the plant's four aggregate feed bins (Figure 7) after first calibrating the belt speed to provide a 3 percent rubber content. No problems were encountered in the mixing operation except for minor clumping of the rubber on the feed belt (Figure 8), but the mixing operation appeared to thoroughly distribute the rubber particles through the mix.

At the Carnation site, the mix was placed at an initial temperature of 240°F with a tracked paver in a thickness averaging nearly 2 inches. Compaction commenced immediately behind the paver except for an initial delay from concerns over roller pickup of the mix. Compaction continued until the pavement had cooled below 120°F, with minor rebound still apparent at that temperature. At this site, the final voids contents ranged from 2.3 to 7 percent and averaged 4.6 percent, slightly higher than the desired average of 3.5 percent.

At the Fairhill site, the mix was truck end dumped after first applying an RC-800 asphalt tack coat. Placement was performed with a road grader rather than a paver to evaluate the ease of placing this mix with minimal equipment. Unfortunately, the mix proved too sticky for good laydown by this method. The resultant manipulations and delays in final leveling of the mix caused the mix to cool too much for good compaction. Field voids at this site therefore averaged 9 percent; much too high for good durability.

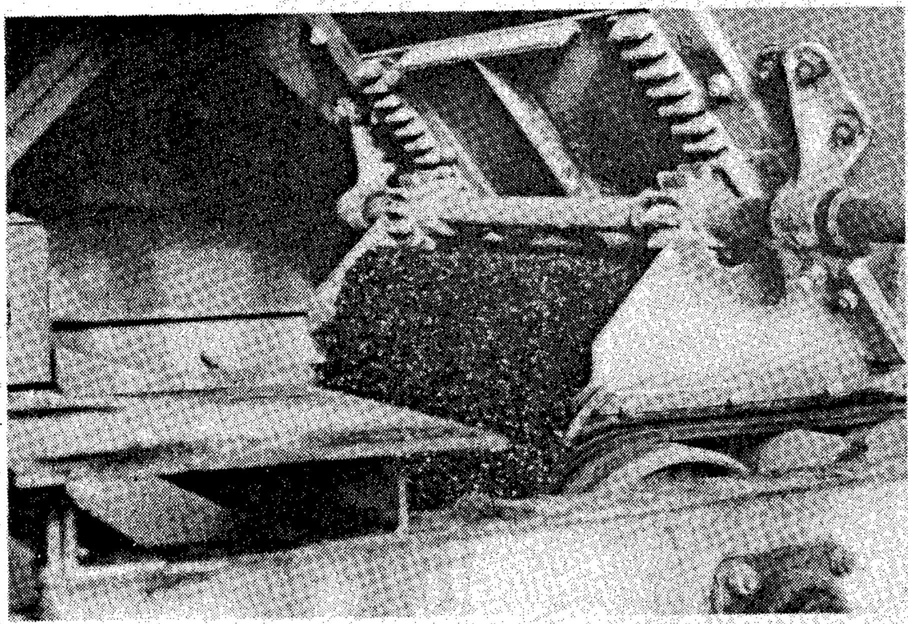

Figure 7: Rubber Feeding From Aggregate Bin

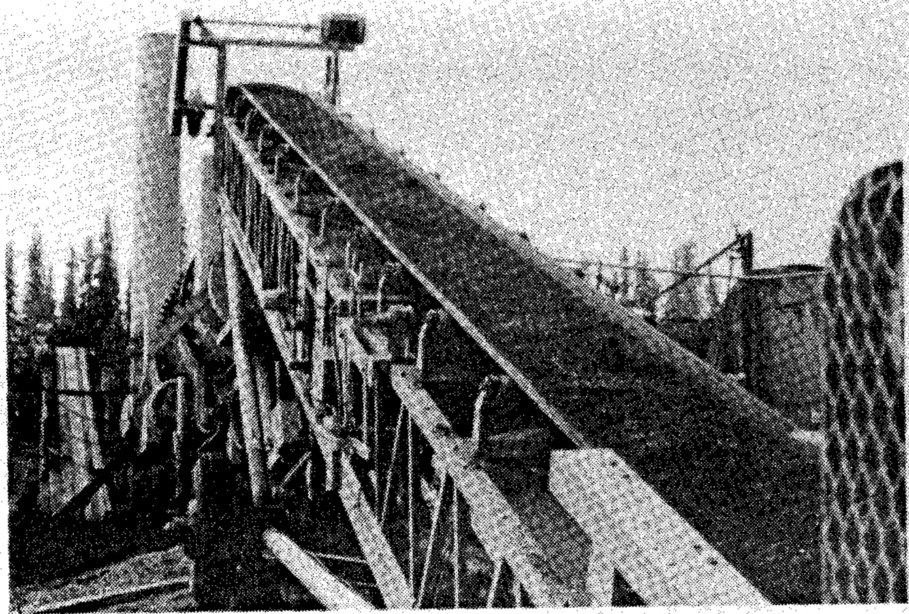

Figure 8: Feeder Belt to Drum-Dryer Showing Rubber on Top of Aggregate

Field Trials-Anchorage Area-1980:

Three trial sections of rubber-asphalt pavement were included in the contract for the 1980 Old Seward Highway repaving project (State Project No. X-14490). To investigate the effects of a range of rubber contents on performance, provisions were made to place $1\frac{1}{4}$-inch thick pavement overlays having rubber contents of 3, $3\frac{1}{2}$, and 4 percent. All of these rubber-asphalt sections were placed on the Old Seward Highway after first placing a leveling layer of normal asphalt pavement on top of the existing old rutted and alligator cracked pavement.

Traffic volumes on this road are much higher than on the Fairbanks sections, averaging 9500 vehicles per day. Preliminary mix designs were prepared for each rubber content, and indicated that the original project gradation needed modification to reduce total voids to acceptable levels while retaining some stability. Based on this testing, an increase in the dust content of the mixes to 8 percent was recommended, which reduced the recommended asphalt content to 6.6 percent for all rubber contents.

The rubber-asphalt paving mixes were prepared on June 14, 1980 in a Standard Steel batch plant, with the rubber added by manually breaking the 52 pound bags into a hopper at ground level, and feeding it into the mixing chamber by conveyor (Figure 9).

All three different paving mixes were placed with a tracked Barber-Green paving machine, and compacted with a minimum of two passes of a vibratory roller, followed by two passes of a 12-ton steel-wheel roller. Temperatures of the 3 and $3\frac{1}{2}$ percent mixes varied from 240°F to 280°F at the time of laydown. However, due to equipment and traffic problems, placement of the 4 percent rubber mix was delayed for several hours, and the mix had cooled excessively prior to placement.

Pavement cores taken shortly after placement showed the 4 percent rubber section to have field voids of around 12 percent compared to a

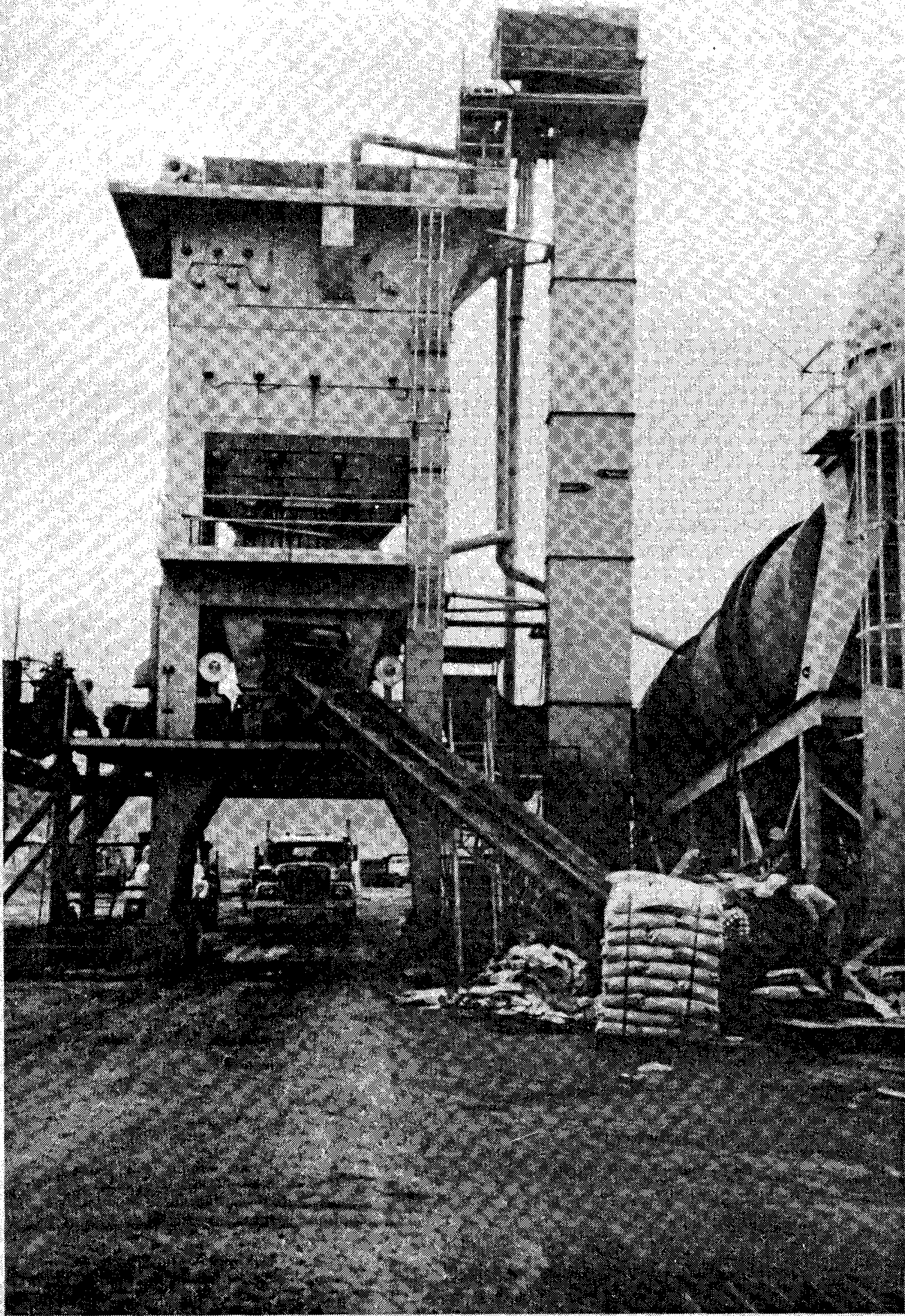

Figure 9: Conveyor Loading Rubber into Pugmill

desirable average of 3.5 percent, and ravelling and potholing began to occur several days after placement. On the 3 percent and 3.5 percent rubber mixes, field voids averaged 7.5 percent, still much too high for good long-term durability. Analysis of the construction operations indicated the high voids to be the result of aggregates being out of specification on some sieves and lower than desirable in fines, in combination with a specified asphalt content which was too low. Specifications used for the various Plusride paving mixes placed in 1979 through 1981 are summarized in Table 3.

TABLE 3

Aggregate and Mix Specifications
Used for Field Control of Alaska's Rubber-Modified Asphalt Pavements

Project:	Carnation 1979	Seward Hwy. 1980	Peger 1981	Huffman 1981
Sieve Size:				
3/4"	100	100	100	--
1/2"	--	78-94	--	--
3/8"	60-77	43-57	53-67	100
#4	45-59	29-43	28-42	47-60
#10	29-41	22-34	20-32	30-42
#40	12-20	15-23	14-22	15-24
#200	4-10	5-11	5-11	5-11
Asphalt (% Dry Aggregate)	7-8	6.1-7.1	8.0-9.0	9.0-10.0
Rubber (%)	3-3.5	3.0-3.5 & 4.0	3.0	3.0
Asphalt Type	AC-5	AC-5	AC-2.5	AC-5
Thickness (ave.)	2.25"	1.5"	1.7"	.75"
Base	2" AC	3" AC	Gravel	1½" AC
Length of Paving	212'	6,792'	649'	5,330'

Note: These are developmental specifications previously used and do not constitute current recommendations.

Field Trials-1981:

Fairbanks-Peger Road:

A total of 280 tons of rubber-modified paving mix were placed in late July at the intersection of Peger and VanHorn roads, including 304 feet on VanHorn and 345 feet on Peger Road. This intersection was chosen because it required a 90° turn on a major truck route.

The mix was produced by Paving Products Co. of Fairbanks with a Barber-Greene Batchomatic Plant in 3000 pound batches. Mixing started at 8 percent asphalt, mixed at 310°F. After noting no laydown problems, the asphalt content was increased to 8.2 percent at 330°F, and finally to 8.5 percent at 345°F. At the final asphalt content some asphalt bleeding was noted in the trucks and the pavement was moderately tender, but still placed satisfactorily.

Rolling commenced at a temperature of about 295°F, with ten to fifteen passes of a 10-ton steel-wheel roller, continuing until the temperature was below 140°F. Due to tenderness, traffic was kept off until evening cooling had lowered the pavement temperature to 60°F. No subsequent problems were noted, although air temperatures did not exceed 75°F after the date of placement. Subsequent pavement coring indicated voids to range from 1.3 to 7.1 percent, and averaging 4.2 percent.

Anchorage-Upper Huffman Road:

The 1981 Anchorage site, Upper Huffman Road, was chosen because the very steep grades on this road, as high as 14 percent, created a severe trafficability problem during icy winter conditions. A total of 1.01 miles of road was first reconstructed, then paved with a 1½-inch asphalt concrete "binder course," and finally capped with a 3/4-inch thick rubber-modified asphalt pavement. The rubber mix was produced with approximately 9.5 percent asphalt in a commercial batch plant at approximately 360°F. Due to the thin lift thickness, cooling was accelerated and field voids were indicated to be approximately 10 percent. However, due to the thin lift thickness and the resultant flexibility of the cores, the laboratory voids determinations may not be extremely accurate. The pavement durability to date has been excellent.

Performance Observations:

Fairbanks (1979-80):

Visual surface ice observations were made during the winter of 1979-80 in an attempt to determine the percentage of time in which the rubber would be of benefit to motorists. Some benefits of the rubber were noted during October when freeze-up was occurring. From November through early February, however, most of the roadways in the Fairbanks area received a cover of ice and packed snow caused by abnormal freezing rains in November. This ice cover at first exceeded 1/2 inch in thickness, and the rubber-asphalt pavement showed no benefit. By mid-February, tire studs and sand abrasion had removed the ice cover, and benefits of the rubber were again noted. A British Portable Friction Tester was obtained on loan and was used for occasional verifications of observed friction levels. This apparatus uses a weighted pendulum with a 3-inch wide rubber foot which sweeps across a 5-inch length of the pavement surface. The test result is a number (BPN) which reflects the height of the pendulum upswing after the foot sweeps the pavement surface, with testing under method ASTM-E303. It became apparent from the field testing that the rubber sections did not have to be totally snow or ice free to show increased friction levels. Results of some typical field tests are shown by Table 4, with friction levels calculated as percentages of dry pavement friction at 68°F.

By February 19, the ice cover was gone from the rubber section, but remained on the normal pavement nearby until the end of February of 1980, when all pavements in the Fairbanks area remained generally ice-free, and little further data could be obtained.

Because of the very low densities achieved at the Fairhill site, some pavement ravelling occurred. Snow also packed into the surface voids and created an abnormally high surface bond. The Carnation test site also proved less than ideal for measurement of differences in surface friction. Because the site is on a very sharp slow speed curve, traffic tends to converge into one lane to hug the inside of the curve.

TABLE 4

British Portable Friction Tester Measurements on Carnation Field Site Under Icy Conditions - 1980

Date	Air Temperature	Pavement Type	BPN	% of Dry Pavement @ 68°F
2/15/80	+14°F	Rubber	46	65
2/15/80	+14°F	Normal	35	49
2/19/80	+5°F	Rubber	94	99
2/19/80	+5°F	Normal	49	52

TABLE 5

1981 Comparative Tests of PlusRide and Normal AC Pavements Under Icy Road Conditions

Date	Pavement Temp. (°F)	Site	Stop Distance (ft.) PlusRide	Stop Distance (ft.) Normal	% Reduction with Rubber
1/22/81	-13	Carnation	91	114	20
1/22/81	-13	Fairhill	64	129	50
1/30/81	+27	Fairhill	75	113	34
2/02/81	+27	Carnation	98	101	3
2/05/81	+27	Carnation	53	91	42
2/06/81	+21	Carnation	52	64	19
				Average	28%

Speeds are also so low that snow is not blown from the pavement by traffic-generated air movements.

In spite of these factors which make comparisons with normal roadways difficult, public reaction to the rubber sections was favorable. In summary, the 1979-80 winter performance at the Carnation site was as follows:

1. No skidding incidents where vehicles left the roadway were noticed on this corner since the end of the first snowfall. Skidding off of the roadway was commonly noted at this point in prior years.
2. Improved traction was often noticeable over the rubber area during the early portion of the winter.
3. During much of the winter, thick ice deposits resulting from November rains totally covered the roadway and no benefit of the rubber could again be noted until mid-February. This weather condition was abnormal, and the ice was controlled by frequent sanding.
4. Driver comments of area residents indicated that the improved traction was detected by people not aware of the rubber-asphalt test.

Anchorage (1980-81):

The durability of the high-voids rubber-asphalt pavement placed on the Old Seward Highway in June of 1980 was very low, particularly for those sections having rubber contents above 3 percent. Ravelling commenced soon after placement, and it was necessary to patch and eventually repave over the 4 percent rubber area. The center two-thirds of the roadway width over the 3.5 percent rubber area also required repaving during September of 1980. Observations for surface ice differences were made occasionally during the 1980-81 winter on the 3 percent and outer wheelpath areas of the 3.5 percent rubber areas. However, this winter was exceptionally warm and surface ice was rarely noted on any area pavements.

Fairbanks (1980-81):

A Mu-Meter trailer for measuring surface friction was obtained and used for early winter testing to determine the differences in friction between pavements with and without rubber particles at the Carnation and Fairhill sites. However, it rapidly became apparent that this device was unsuitable for measuring friction on icy roads, sanded roads, or Plusride sections. Test runs on sanded roads demonstrated that the Mu-Meter, apparently because of its design, could not distinguish friction differences even between glare ice and sanded ice. To provide better data, a "Tapley" decelerometer was installed in a sedan and used in studies of sands on ice and also for measurements of friction levels for PlusRide pavements. This device has the advantage of directly measuring the maximum vehicle braking G-forces and gives estimated stopping distances from a speed of 25 mph. It has proven to be much superior to the Mu-Meter and British Pendulum for measuring the merits of different roadway treatments under icy conditions. The same vehicle was used for all 1981 tests, eliminating correlation problems between vehicles.

Testing procedures for stopping distance comparisons between PlusRide rubber-asphalt and normal asphalt concrete pavements involved making a series of stops on each surface type. On an icy road surface not in a normal stopping zone, repeated test stops were found to polish the surface and increase subsequent stopping distances, as shown by Figure 10. On the date of this test series a thin ice cover was present on all sections, but the protruding rubber particles of the PlusRide pavement still resulted in a 50 percent reduction in stopping distances compared to adjacent normal pavements.

Average stopping distances for the Fairhill and Carnation sites at pavement temperatures of $-12^{\circ}F$ and $+28^{\circ}F$ are compared in Figure 11, with tests at the two different temperatures occurring 8 days apart, using the same vehicle and tire type. The vehicle tires were then changed from bias ply to radial tires on February 5. Later tests made with the radial tires did not correlate well with earlier results. The

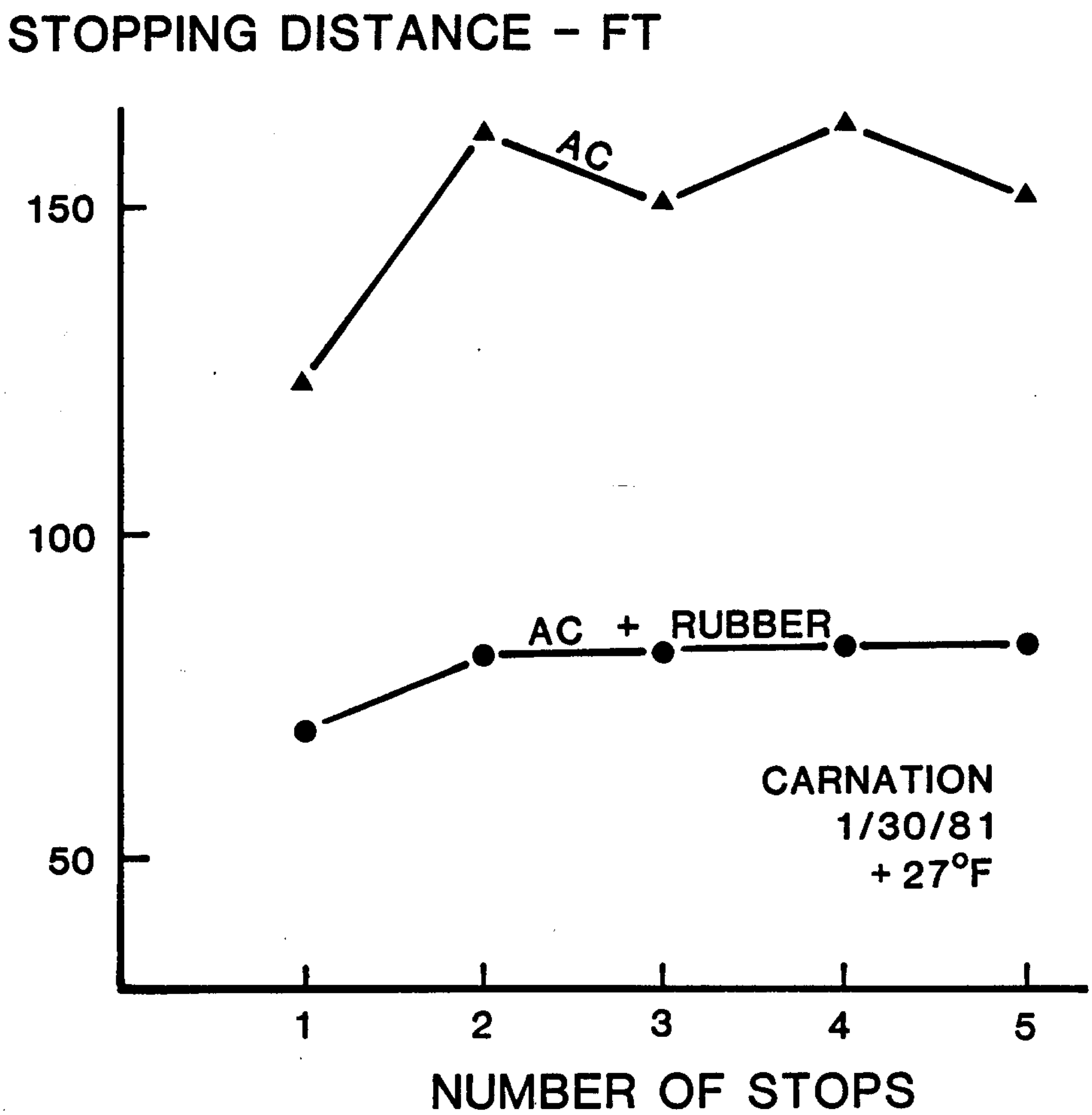

Figure 10: Tapley Meter Test Comparisons of Stopping Distances for Rubber-Asphalt versus Regular Asphalt Pavement, by Repeated Stops in Same Wheel Path

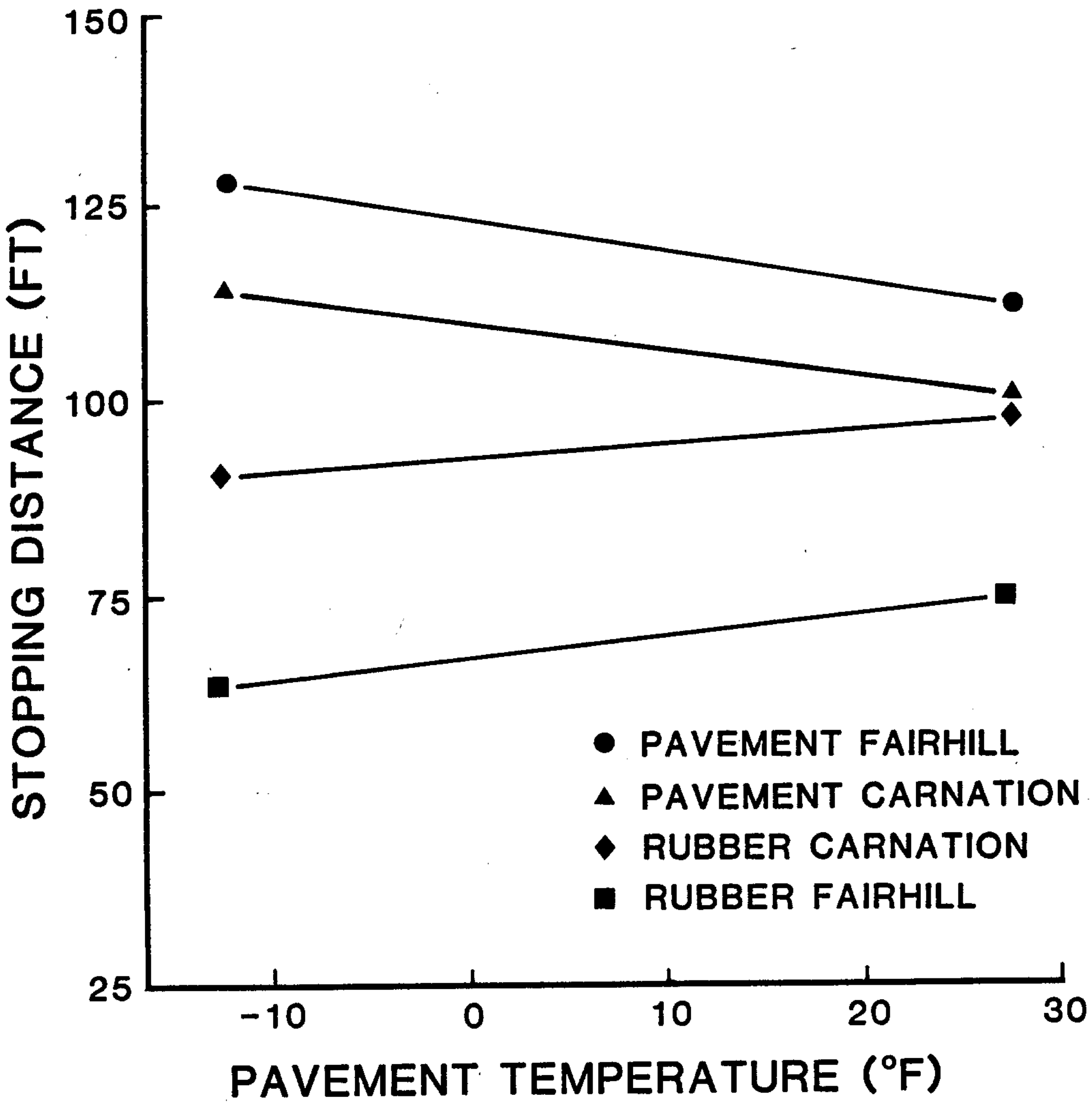

Figure 11 STOPPING DISTANCE (FT) VS. TEMPERATURE (°F)

radials resulted in roughly a 20 to 30 percent decrease in average stopping distances and appeared to show slightly greater decreases on the rubber sections as compared to normal pavements.

Results of all stopping distance tests made on the Fairbanks area PlusRide sections during 1981 are shown by Table 5. All test results represent the average of six stops. For this test series, performed under icy road conditions with some roadway sand present, an average reduction of 28 percent in stopping distance was apparently achieved from the use of rubber in the paving mix. No salting for ice control had been done on these pavements. By comparison, tests of bare pavements at these air temperatures indicated minimum stopping distances of 25 to 30 feet. The use of coarse sands for ice control in similar areas would normally result in reduced stopping distances for only a short period of time, as the sand blows off under traffic action. Results of Tapley meter stopping tests for sands on road ice adjacent to the Carnation test site (Figure 12) show that stopping distances were not significantly reduced from a normal icy road value of 140 feet by sanding, except for the first two to four stops.

From these comparative tests, it can be seen that stopping distance reductions achieved with the PlusRide pavements were lasting and quite significant in magnitude, while roadway sanding was of only temporary and minor benefit. A few tests of sand applications over PlusRide pavements indicated that significantly greater reductions in stoppings distances were obtained from the use of sand than on normal pavements. The use of rubber in the pavements tested did not provide the same degree of reduction in stopping distances which would have been achieved by salting, but did significantly increase the safety aspect at the locations where it was applied.

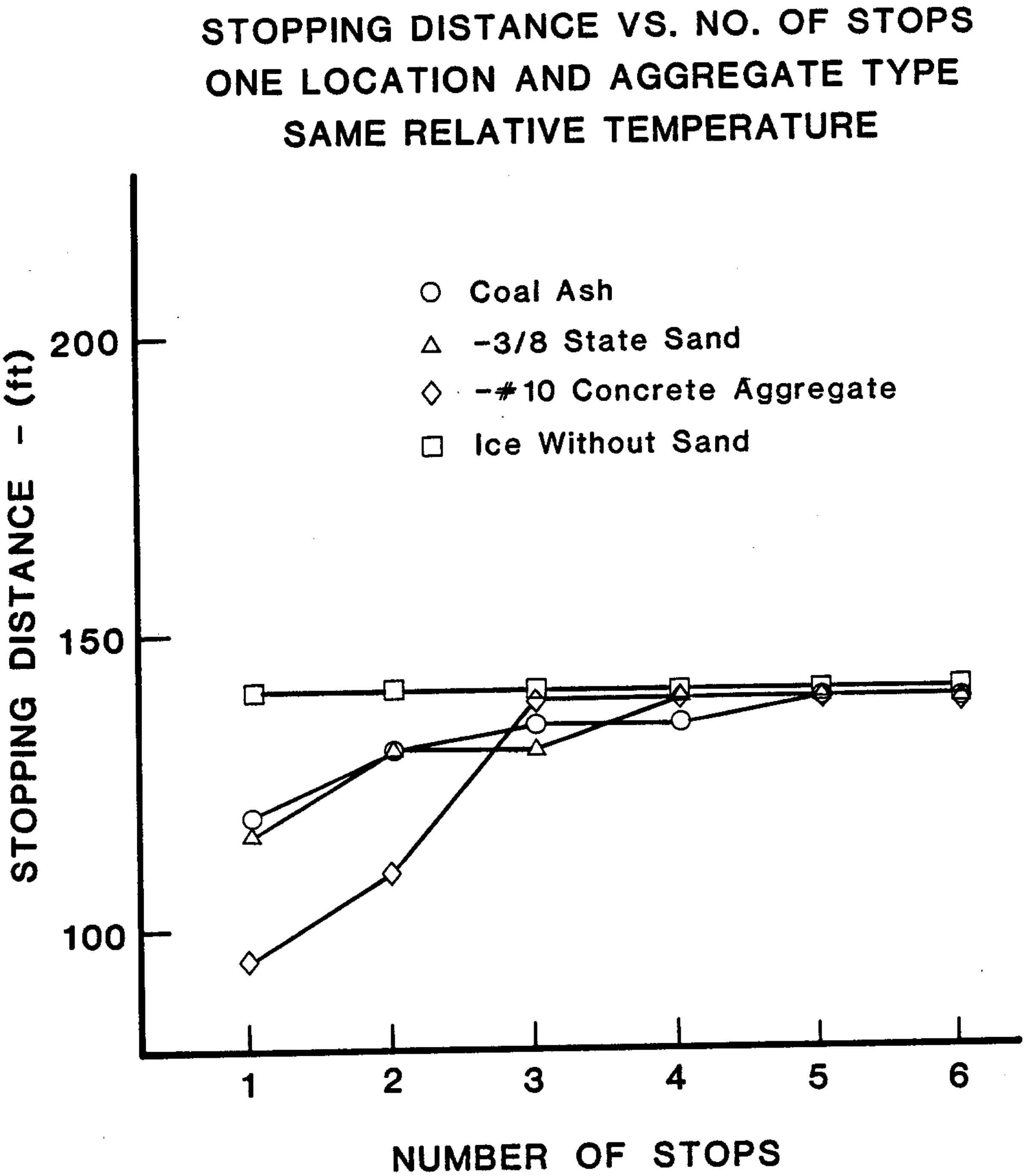

Figure 12: Effects of different sands on stopping distance for repeated stops on smooth road ice, tests at 0.1 #1 sand per square foot at $-6^{o}F$.

Fatigue Life Aspects:

A series of laboratory fatigue tests have been performed on PlusRide paving mixes at Oregon State University to analyze the resistance of these mixes to failure in tension under the diametral split tension test mode. In this work, samples were loaded to failure at selected tensile strain levels. Results as shown by Figure 13 indicate that the fatigue life of PlusRide pavements may be more than 10 times greater than normal mixes. This testing program provides hope that the PlusRide paving system might prove of benefit in roadways over weak foundations where fatigue cracking is the dominant failure mode.

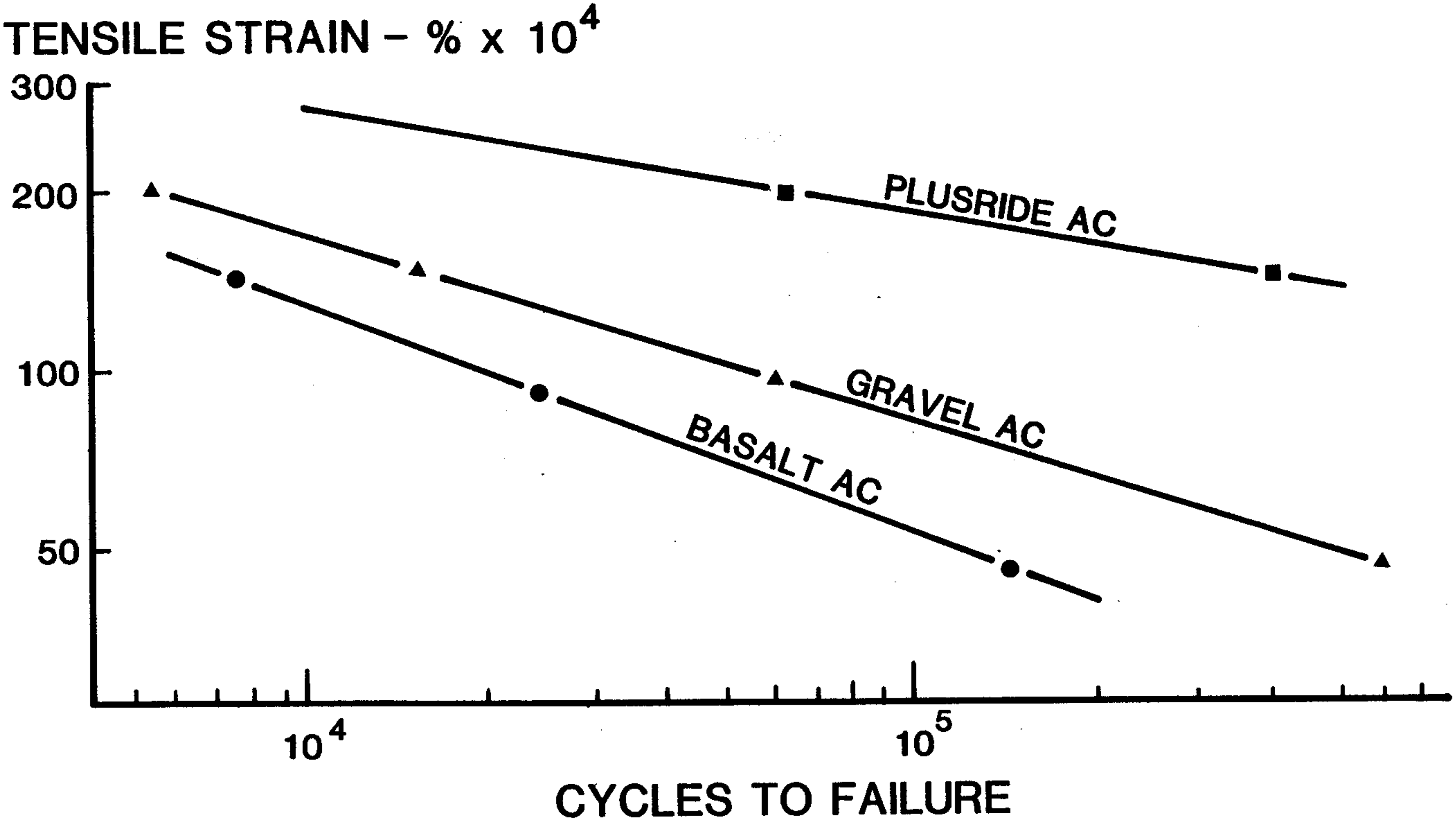

Figure 13: Comparison of Fatigue Lives for Asphalt Mix Sample without and with Rubber Particles "PLUSRIDE" System

Summary:

Between 1979 and 1981, seven experimental rubber-modified pavement sections, totalling 2.5 miles in length, were constructed by the Alaska Department of Transportation. In these projects 3 to 4 percent of coarse rubber particles were incorporated into hot mixed asphalt pavements, using a system developed in Sweden under the trade name "Rubit," and now patented in the U.S.A. under the name "PlusRide." The paving mixes have been successfully prepared in both batch and drum-dryer type plants, and placed with conventional pavers and rollers. Mix design experience by the Marshall method has demonstrated that the rubber greatly changes the mix properties, and from 1 to 2 percent more asphalt is normally required for the attainment of a 3 percent or lower voids content, the primary factor used in selection of a suitable mix design. The attainment of a field voids level of less than 8 percent, through high asphalt contents and compactive effort, has been shown by field experience to be critical to pavement resistance to ravelling. Field voids of less than 5 percent are highly desirable. In spite of the high asphalt contents and soft asphalt grades used in these mixes, no asphalt bleeding has occurred.

Benefits of rubber-modified paving mixes include the ability to shed an ice cover much more quickly than conventional pavements, the development of a more flexible and fatigue-resistant pavement, a significant reduction in tire noise, and the beneficial use of what is normally a troublesome waste product, used tires. The magnitudes of these benefits have not yet been quantified due to the developmental stage of rubber-modified asphalt pavements. Further field and laboratory studies are needed to optimize these benefits and determine the most satisfactory material specifications.

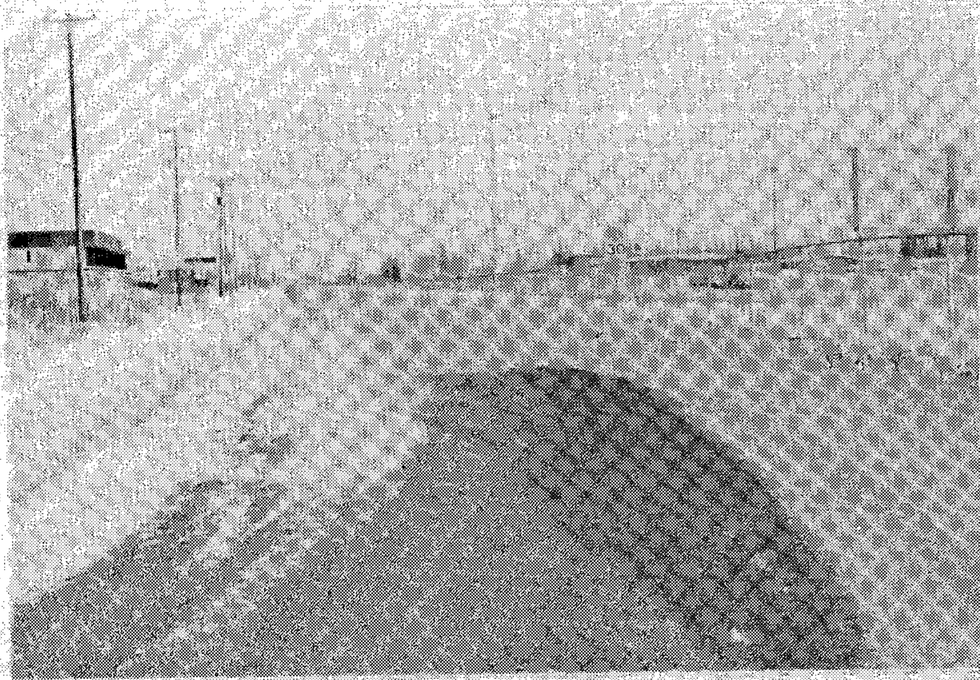

Figure 14: Demonstration of Ice-Free Benefit of Rubber-Modified Asphalt Pavement in Foreground versus Ice-Covered Normal Pavement in Background. February 1980.

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