IMPROVING DAIRY BARN FLOORS

by

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INTRODUCTION

Today there are more than 140,000,000 people in the United States, practically all of whom depend to some extent upon the 25,165,000 dairy cows of the nation for food or means of livelihood or both. So dependent has civilization become upon the supply of milk from these cows until it has been said that if all necessities of life were to be suddenly discontinued, milk would be missed second only to water. It occupies a place of unchallenged supremacy in the diets of babies and children, and has come to be regarded as a necessity for optimum health for people of all ages. And because of its exceptionally high food value, it is used by people of all income levels.

Something of the importance of dairy cows to the economy of the nation may be realized when it is considered that multiplied thousands of American citizens are engaged in the production, processing and distribution of products from them. So vital is the welfare of dairy cows to the continued health and prosperity of the nation as a whole until every possible precaution should be taken for the safeguarding of their health.

The necessity for doing this becomes more apparent when it is realized that dairy cow numbers have recently declined while the nation's population has increased. This has so affected the ratio of people to cows until there are now six people for every dairy cow instead of the five previously existing. The change in ratio indicates that if needs for dairy products are to be supplied, either a greater number of dairy cows must be milked or the production per cow must be increased.

Authorities agree that higher production per cow could be obtained simply by preventing injuries to cows caused by slippery dairy barn floors. The assembling of large herds has gradually brought about the construction of barn floors that have caused cows to be subjected to treatment for which nature made no provision. Rather than walk on the soft carpet of grass which nature provided for the feet of cows, the dairy herds that supply the needs of the nation are now forced to walk on floors sufficiently hard to resist the day-by-day treading of large numbers of cows. But regardless of the hardness of the material used or the roughness of the surface finish applied, wear takes place and floors gradually but eventually become relatively smooth.

It is these smooth and treacherous slippery surfaces that present one of the gravest problems affecting the safety of present-day dairy herds. Every year losses sustained by the slipping and falling of cows on such floors reach staggering proportions. In addition to injuries that cause a sharp reduction in production, there are often veterinary fees to pay for treatment of injured animals, to say nothing of the time and trouble involved in nursing animals back to health. And valuable breeding animals have been so affected by injuries sustained in this way until their period of usefulness has been shortened considerably or even terminated.

Because of this recognized hazard, dairymen and breeders of purebred dairy cattle have attempted to adopt practices which would lessen the danger. One attempted treatment has been the spreading of a thin layer of abrasive material on the floor before cows are turned in to be milked, but this system has the disadvantage of stopping up drains and of requiring considerable time and effort.

It is true that slipping is not the problem in colder regions where cows are kept in the barn all the winter that it is in milder climates where they go in the barn twice daily to be milked. But with the trend toward more extensive use of milking parlors, the problem becomes more universal and more acute.

While slipperiness is not the only problem involving dairy barn floors, it is conceded to be the one of greatest importance. It is believed that thermal conductivity plays an important part in the prevalence of mastitis, but this is yet to be proved. The practice of placing bedding on floors used by cows is well established, and will likely continue to be followed regardless of the type of floor used. This serves as insulation and, in so doing, helps to solve the problem of thermal conductivity.

Durability is recognized as a desirable characteristic in a floor, but authorities believe that floor materials now in general use will last until dairy barns become obsolete. Sanitation requirements and moisture absorption factors appear to be well taken care of by materials already in use. These features are all recognized as important and desirable, but they appear to be much nearer a solution than does the one involving slipperiness.

In spite of the extreme need for solving the slipperiness problem, there has been relatively little research conducted on it. Commercial interests have naturally directed their efforts toward the manufacture of goods better adapted to the channels of commerce, thereby leaving floors of dairy barns to be constructed by unskilled labor on farms practically the same as they were a quarter of a century ago.

With the knowledge that dairy barn floor development has not kept pace with other dairy developments, and with the consciousness that slippery floors are a constant menace to the dairy herds of the nation, this study has been undertaken with the hope that findings might be of value in improving the floors of dairy barns.

REVIEW OF LITERATURE

According to Campbell (2), floors of dairy barns should be made of a material which can be easily kept clean, as sanitation is of paramount importance in the production of high quality milk. The material should also be resistant to wear, since one that wears out quickly will not prove satisfactory. It should not absorb moisture, as this would mean that filth would be absorbed and retained. He points out that a hard sanitary floor does much to lighten labor and, at the same time, it increases cleanliness.

A floor must have durability, states Fowler (5), if it is to withstand wear resulting from constant treading of animals on small areas with fore and hind feet. Should the floor not be durable, depressions will form and will hold water and urine. Such undesirables lead to damp stalls detrimental to the general health of the herd.

He further explains that a floor should have resilience, warmth, should be impermeable to liquids and should be continuous. He favors resilience to avoid swollen knees and hocks in cows from their standing for long periods on hard surfaces. It is his observation that Scotland has considerable trouble in this way with in-calf heifers that are in the barn for their first winter, but he points out that the condition is less marked in cows with their second and subsequent calves. He believes that resilience is of definitely more importance than is warmth.

It is the opinion of Bainer (1) that warmth of a floor is of much more importance than is any other quality. He states that the rate at which heat is carried away from the cow by the floor determines whether the floor is hot or cold. His explanation is that if a material with relatively high conductivity is used, heat will travel away from the surface very rapidly. On the other hand, if the relative conductivity of floor material is low, heat will travel away from the surface slowly. This would result in warmer floors.

This investigator found that the most important single factor affecting the warmth of floors was the rate at which they warmed up after the cows lay down on them. He cites as proof a case where two cows were placed in adjoining stalls, one surfaced with concrete and the other with creosoted pine blocks. Both cows were observed to lie down at 8 p.m. Two hours later the surface temperature of the pine blocks had increased from 50 degrees F. to 80 degrees, an increase of 30 degrees in the two hours. The surface of the concrete floor did not reach 75 degrees until 3 a.m. the following morning. The fact that seven hours were required to raise the temperature of the concrete floor to within five degrees of that reached by the pine block floor in two hours indicates that considerably more heat flowed from the body of the cow lying on the concrete floor.

The same research worker found that the pine block floor increased in temperature 15 degrees the first hour, as compared to seven degrees in the same period of time for the concrete. He also determined that it required three hours for cork brick to rise from 57 to 77 degrees, while eight hours were required for concrete to rise to the same level. His findings indicate that wood blocks and cork bricks were comparable in their ability to maintain a warm floor but that wood blocks would last approximately twice as long.

Slipperiness is a hazard, according to Justice (10), which should be carefully guarded against when constructing floors. This, he explains, may be taken care of by roughening the surfaces of floors.

Nelson (13) states that it is important to protect both men and cattle from injury while they are on floors in dairy barns. He concludes that it is a great achievement for a dairy farmer to develop a healthy, high-producing herd and to house it in a safe barn where high quality milk is produced on a sanitary, efficient basis.

According to Graf and Johnson (9), sawdust-cement concrete has been investigated for use as barn floors. They state that the use of sawdust, or ground wood, as an aggregate dates back into ancient times. Prior to the days of Egypt, the Arabs used ground wood in making pottery by working in natural clay as a binder.

Some claim, according to these investigators, that sawdust properties make possible lower thermal conductivity, greater resistance to settling, vibration and impact and more resistance to changes in the weather. It is apparent, however, these workers continue, that bark in the sawdust weakens the mix. Upon investigation they found that a mix containing 25 percent cement would set and have measurable strength in ninety days, provided it contained no bark, while the same proportion which contained some bark would have little or no strength.

They point out that while sawdust-cement material is a better thermal insulator than concrete, it does not have as much compressive strength. They further found that in order to obtain sufficient strength in a sawdust-cement mixture, it is necessary to have such a high proportion of cement until the cost, in spite of cheapness of sawdust, will be greater than that of ordinary concrete.

Sawdust-cement concrete is said by Skelton (15) to have compressive strength of 300 to 400 pounds per square inch. He explains that it has a coefficient of thermal conductivity of 0.60 to 0.70, while that for wood is 1.00 and that for concrete 8.00. The sawdust-cement concrete, he claims, is also water repellent and is relatively resistant to abrasion.

His observation is that it not only will not support combustion but that it will withstand temperatures up to 250 degrees F. without detrimental effect. He recommends using white pine, spruce or hemlock sawdust from the main saw, this to be not less than one year old. His experience is that hardwood sawdust has grains too small and too uniform in size for best results. For surface wear he recommends a mix at the rate of 5 bags of cement, 14 cubic feet sawdust and 9 cubic feet of sand. He suggests using no more water than is required to bring the mix to a good consistency.

According to Teutsch (17), sawdust-cement floors have much to recommend them. He cites the case of an Oregon dairyman who has used a floor of this composition for more than 20 years and has found it to give complete satisfaction in every respect. The floor proved to be durable, was warmer than concrete, was easier on the feet of cows in the herd and it still permitted the sanitation practices used on a regular concrete floor.

The mix, he points out, was composed of 1 sack cement, 1-1/2 cubic feet of clean sawdust free from bark, 1/4 cubic foot of clean sand and sufficient water for easy placing, the amount of water to depend upon moisture content of the sawdust. He claims that in 28 days the mix developed compressive strength of 1,500 to 1,700 pounds per square inch.

In order to determine the opinion of users and interested persons of sawdust-cement concrete, Hoard's Dairyman (3) wrote some 125 letters to those who had previously requested information concerning its use. The reason given by 100 non-users for their failure to adopt its use was that they were doubtful of its value. Of the 25 users who replied, all except one were satisfied, but they were not too enthusiastic. Some reported wear due to softness. Others reported that the set was rather slow but that it was firm when properly cured. Still others thought that such floors seemed warmer and more resilient than other floors.

Several individuals used a mix composed of one part cement, two parts sawdust and two parts of sand. It was the practice of some to screen the sawdust through a 1/4 inch mesh screen prior to mixing. A topping two to three inches thick was usually placed over a regular concrete base.

It is reported by Hoard's Dairyman (4) that a farmer in Illinois used creosoted wood blocks for a floor with complete satisfaction. These blocks did not absorb moisture, swell or bulge. It was further pointed out that there was no objectionable odor from the creosote. The user is reported to have stated that he believed the blocks sufficiently durable to last as long as his barn.

The same report indicates that a Wisconsin dairyman had no trouble with odor from the blocks, and only one case of heaving, that being where water from a leaky tank ran under the block floor. It is believed by some (4) that where objectionable odors arise from the creosoted blocks, the wrong kind of oil was used in their treatment.

Manufacturers recommend, according to Hoard's Dairymen (4) that the most desirable way to put down a floor of wood blocks is to place a smooth concrete foundation and then put the blocks on top of it, while Frudden (7) feels that most satisfactory results will come from placing blocks on top of sand cushion and concrete. He suggests putting fibre ends in vertical position, as this position should cause blocks to last for a long period of years. He further suggests that wood block floors are absolutely sanitary if properly treated with a good antiseptic preservative. Joints between blocks, he continues, should be filled with any of the good, sanitary joint fillers. Under these conditions, he concludes, it is possible to have a dairy barn floor that is economical, sanitary, permanent, simple and attractive.

It is the opinion of Goodman (8) that concrete floors, properly made of desirable materials, will last for a number of years. He states that the most common criticism of them is that they become damp and cold, but he points out that such conditions are often caused by improper drainage and insulation. It is his belief that only cement in the powder form, or that which can be pulverized easily with the hand, should be used. His reason for this is that cement that has been stored in a damp place will become lumpy and will not make strong concrete. It is important to use, the authority emphasizes, only water that is clean and just enough of that to enable the mix to work well, as excess water weakens the concrete. He recommends one part cement, two parts sand and four parts gravel for floor use.

According to Smith (16), concrete dairy barn floors are sanitary, moderate in cost and permanent. He states that they eliminate repair cost often necessary with other types of floors. It is his opinion that satisfactory service from floors depends upon care with which the floor is planned and built and the subsequent attention given to cows standing on it. He suggests a broom finish, and feels that all floors need litter on them regardless of their composition.

MATERIALS AND METHODS

In making a study of the slipperiness problem of dairy barn floors, friction tests were conducted by using test specimens made of materials and combinations of materials thought to have a place in the experiment. Specimens made were twelve inches long, eight inches wide and two inches thick (Fig. 1). For obtaining reliable data, three uniform specimens of each material to be tested were made.

As soon as specimens were removed from forms, they were assigned numbers and, for positive and permanent identification, the number assigned for each specimen was painted on it in two different places. The three specimens of a given mix were numbered in consecutive order.

While most materials were sufficiently hardened to be removed from forms at the end of a 24-hour period, it was necessary to leave those containing substantial proportions of sawdust for as long as 48 hours to prevent crumbling. With the exception of pine block, plywood and griptred, all specimens were cured upon being removed from forms by submerging in water for a period of seven days.

Realizing that floors usually have a tendency to become more slippery as surfaces are worn to a smooth finish, it was desired to produce a worn condition on test specimens in order that slipperiness on smooth surfaces might be compared with that on sur-

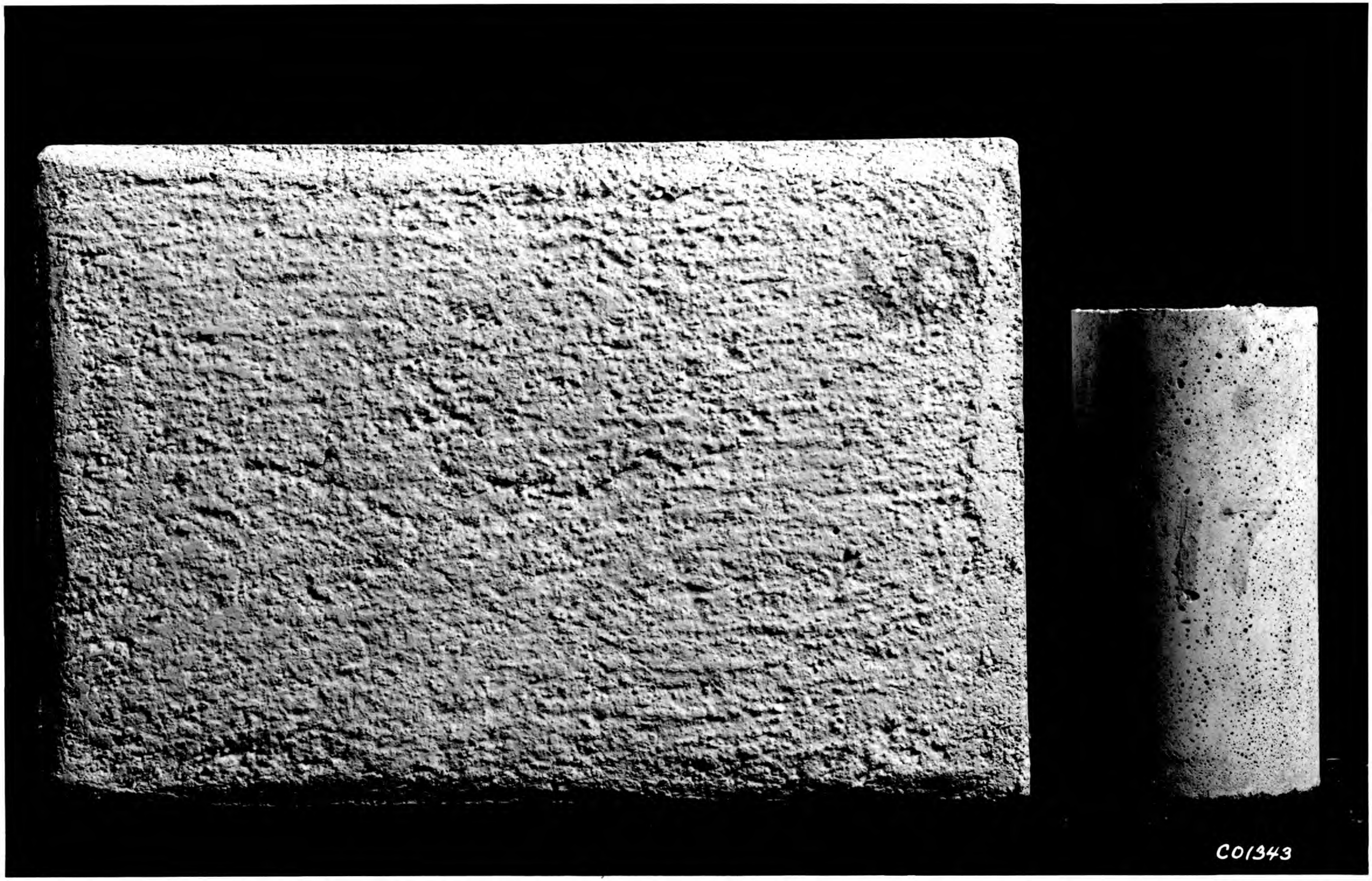

Fig. 1. Large specimen (left) is sample of specimens used in conducting slipperiness tests.

faces finished with wood float and broom. For producing the desired wear on one end of specimens so as to conduct the test, a machine (Fig. 2) was designed and constructed for wearing twelve specimens simultaneously. Slots were provided on the machine for holding specimens during the wearing process. Rectangular concrete blocks six inches long, four inches wide and two inches thick and standardized to a weight of five and one-half pounds each were passed back and forth across the test specimens by means of a motor-driven shaft to which they were attached. The wearing surface of the blocks contained carborundum dust to a depth of one-half inch to make the surface more abrasive and longer lasting.

Since no weight was used other than that of the abrasive blocks, braces attaching blocks to shaft were adjusted loosely enough to permit each block to be lowered by its own weight as wear resulted, thereby causing desired constant weight and wear as the degree of wear became progressively greater on test specimens.

A machine for conducting slipperiness tests was designed and built (Fig. 3), the desire being to, as nearly as possible, duplicate actual barn conditions under which slipping would be expected to occur. To more nearly approach such conditions, a cow's foot which had been preserved was mounted on the machine as the object to come in contact with specimens as they were tested. As this foot was at rest on specimen to be tested, varying specified amounts of normal force, or vertical pressure, were applied to it, amounts applied registering on spring balance which was

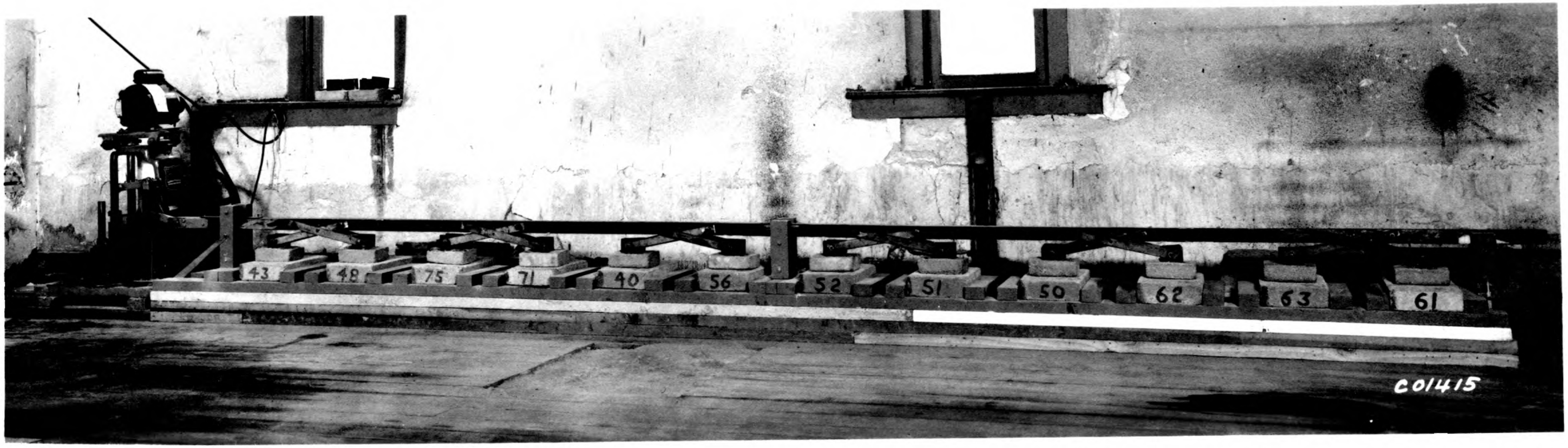

Fig. 2. Machine for producing wear on specimens tested. Numbered specimens are shown in slots provided for them.

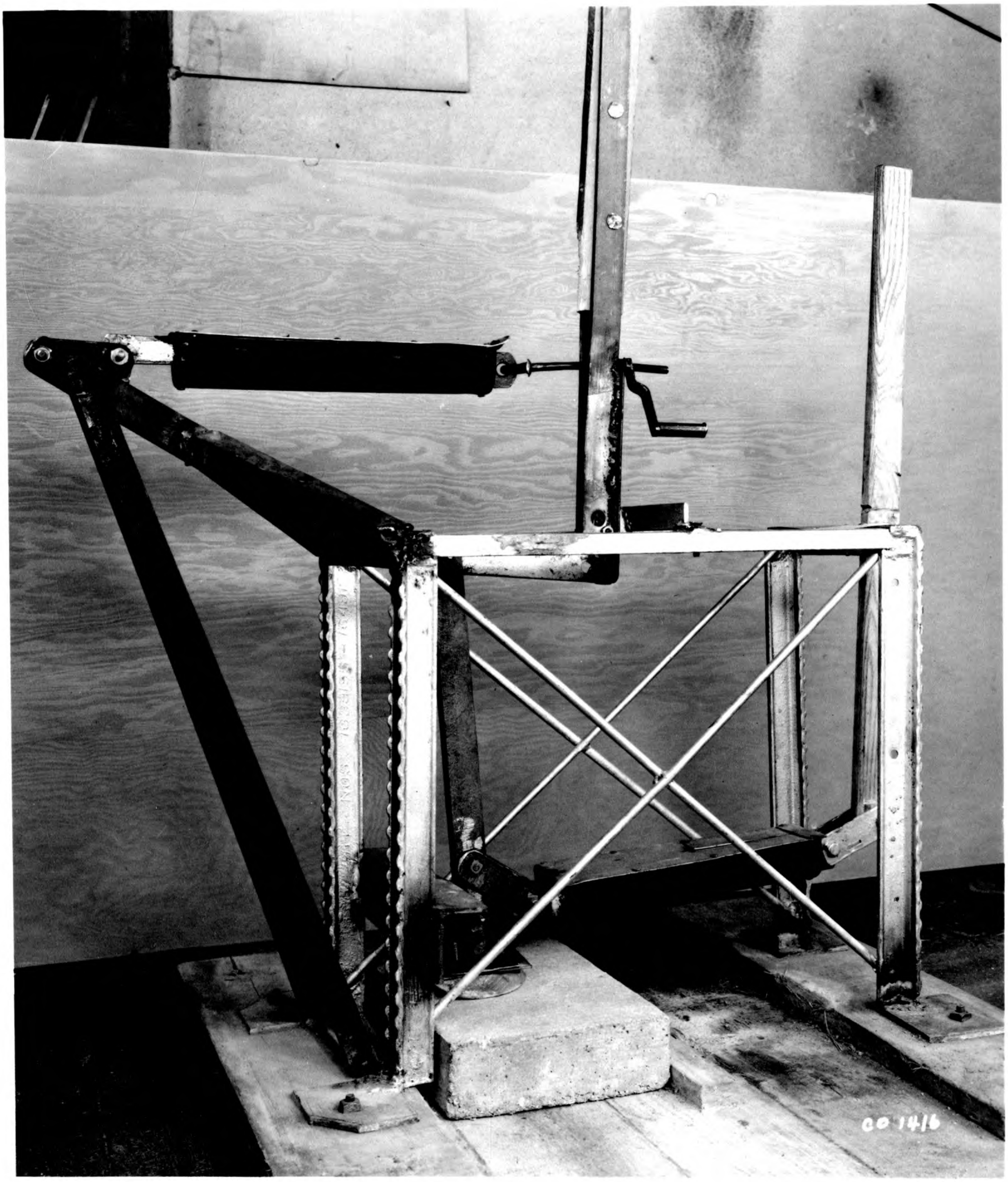

Fig. 3. Machine designed and built for conducting slipperiness tests. Cow's foot is shown resting upon surface of one of specimens tested.

part of the machine. The standard normal force used to press cow's foot against specimens tested was 20, 40, 60 and 80 pounds.

When the desired pressure was registered for the test, a lever connected with the cow's foot and with another spring balance was pushed until slipping of the foot occurred. Readings were taken from the point on the balance where slipping took place in order to determine the sliding or horizontal force required to make the foot slip. If the first three readings were identical for a given applied normal force, no further readings were taken. If the readings were not the same, but were well grouped, five to seven readings would be made. In the event wider variations occurred, as many as 10 or 12 readings would be taken in order to obtain more accurate results. An average of the several readings was taken as the recorded data.

Since the slipperiness machine was constructed for ease of extensive operation, the vertical pressure, or normal force, as registered on balance used was not the actual amount applied. This necessitated the application of a correction factor. Final results reflect its application.

Inasmuch as wet floors influence the degree of slipping, and since they are found on many dairy farms, all specimens were tested both wet and dry. The three areas of specimens tested were the top unworn surface, top worn surface and the bottom surface, as the bottom was believed smooth enough to resemble the condition found in many floors. Exceptions existed for specimens only topped with the material tested, as there would have been no point in testing their bottom surfaces. Pine block, plywood and griptred specimens were not tested under worn condition or on bottom surface. The composition of griptred was such that wear would not have affected the degree of slipperiness; therefore, this phase of the test was omitted.

In preparing griptred specimens, material was applied to the clean, smooth bottom surface of ordinary concrete specimens with a notched trowel, the notches being 3/32 of an inch in depth. When the first layer had dried, another was applied with a smoothing trowel and permitted to dry without curing under water.

Materials used for topping surfaces were applied one-half inch thick on top of ordinary concrete base, both base and topping being made as near the same time as possible. At least the topping was applied soon after the base was placed in form so as to be sure of adhesion of the two materials.

Upon completion of all slipperiness tests, data obtained were used to determine the coefficient of friction for the materials used. The following formula was used in finding the coefficient of friction:

$$\frac{S}{N} \text{ or } \frac{\text{Sliding force}}{\text{Normal force}}$$

The coefficients of friction for materials under each of the four pressures were averaged and the result was taken as the coefficient of friction for the specimen involved. By averaging the three coefficients of friction for each of the three specimens of a material, the coefficient of friction was obtained for that material when tested wet and again when tested in the dry form.

Data concerning proportions of various mixes are shown in

Fig. 4. The different materials used in the experiment, together with their sources, are as follows:

1. Portland cement. Building and Repair Department, Kansas State College, Manhattan, Kansas.

2. Zonolite. Lambert Lumber Company, Manhattan, Kansas.

3. Air-entraining cement. Ash Grove Lime and Portland Cement Company, Kansas City, Missouri.

4. Emery aggregate (Type "C" and Number 20). The Creamery Package Manufacturing Company, Kansas City, Missouri.

5. Griptred. The Goodyear Tire and Rubber Company, Incorporated, Akron, Ohio.

6. Ferem. A. C. Horn Company, Incorporated, Long Island City, New York.

7. Duromit. American Fluresit Company, Incorporated, Cincinnati, Ohio.

8. Aluminum oxide sidewalk grain (Size 8/16). The Carborundum Company, Niagara Falls, New York.

9. Kreolite pine blocks. The Jennison-Wright Corporation, Granite City, Illinois.

10. Plywood. Douglas Fir Plywood Association, Tacoma, Washington.

11. Yellow pine sawdust. Troy Wade, Collins, Mississippi.

12. Resaw sawdust. Agricultural engineering shop, Kansas State College, Manhattan, Kansas.

13. Haydite. Carter-Waters Company, Kansas City, Missouri.

14. Alundum. The Norton Company, Worcester, Massachusetts.

15. Calcium chloride. Chemistry department, Kansas State College, Manhattan, Kansas.

Mix	Material tested	Proportions of Mix (By volume)	Finish
A	Mikolite	Mikolite - 20 quarts Water - 9 quarts	Wood float
B	Ordinary concrete	Sand - 18 quarts Portland cement - 5 quarts Water - 3-1/2 quarts	Same
C	Zonolite	Sand - 8 quarts Zonolite - 12 quarts Portland cement - 4 quarts Water - 4-1/2 quarts	Same
D	Air-entraining cement	Sand - 24 quarts Air-entraining cement - 8 quarts Water - 4 quarts	Same
E	Resaw sawdust (pine)	Sawdust (dry) - 20 quarts Portland cement - 6-2/3 quarts Water - 14 quarts	Same
F	Yellow pine sawdust	Sawdust (dry) - 12 quarts Sand - 8 quarts Portland cement - 4 quarts Water - 3-1/3 quarts	Same
G	Yellow pine sawdust	Sawdust (dry) - 22 quarts Portland cement - 7-1/3 quarts Water - 6-1/2 quarts	Same
H	Yellow pine sawdust	Sawdust (dry) - 10 quarts Sand - 4 quarts Portland cement - 12 quarts Water - 6 quarts	Same
I	Portland cement	Sand - 20 quarts Portland cement - 4 quarts Water - 1-1/8 quarts. (Sand was wet)	Same
J	Haydite	Haydite - 21 quarts Portland cement - 6 quarts Water - 4-3/4 quarts	Same
K	Yellow pine sawdust	Sawdust (soaked) - 12 quarts Sand - 8 quarts Portland cement - 4 quarts Water - 2-1/2 quarts	Same
L	Horn ferem	Ferem - 6 quarts Portland cement - 4 quarts Water - 2 quarts	Same
M	Aluminum oxide sidewalk grain	Sidewalk grain (size 8/16) 1-1/2 qts. Concrete (soft) - 3 quarts	Same
N	Emery aggregate	Emery aggregate - 4 quarts Emery 20 - 1/5 quart Portland cement - 2-1/2 quarts Water - 1 quart	Wood float, then apply emery 20 and trowel
O	Duromit	Duromit - 4 quarts Portland cement - 4 quarts Water - 3 quarts	Wood float
P	Alundum	Alundum - 4 quarts Portland cement - 2-1/2 quarts Water - 1 quart	Same
Q	Calcium chloride	Sand - 18 quarts Portland cement - 6 quarts Calcium chloride (granular) - 0.3 lb. Water - 3-1/2 quarts	Broom
R	Griptred	Commercial heavy liquid preparation that comes ready to apply. With notched trowel applied one coat to clean surface of concrete. After this dried, second coat was applied with smoothing trowel.	Smooth trowel
S	Plywood	Ready for use	Natural
T	Pine blocks	Ready for use	Creosote

Fig. 4. Identification of mixes used in experiment, materials included, proportions of materials used and finishes applied to surface of specimens.

PRESENTATION OF EXPERIMENTAL DATA

Experimental data obtained by testing the twenty different groups of dairy barn floor specimens for slipperiness indicate that some materials are decidedly superior to others in their ability to resist slipperiness.

In order to more adequately portray findings, results were tabulated and are graphically presented in Plate I, Figs. 5, 6, 7 and 8 and Plate II, Figs. 9, 10, 11 and 12. In addition to showing detailed results in these graphs, a dry test average is shown in Plate I, Fig. 8, while the wet test average is presented in Plate II, Fig. 12. Since it is obvious that both wet and dry conditions would not exist on a given floor area at the same time, no attempt was made to combine data for wet and dry tests.

Results of Tests Conducted on Dry Specimens

As is shown in Plate I, Fig. 8, the material found to have the highest average coefficient of friction when tested under dry conditions was griptred. The high coefficient of 1.05 for this material indicates that slipping was difficult to produce.

Ranking next in order of friction coefficients was 8/16 aluminum oxide sidewalk grain with a coefficient of .98 when dry. This material was used as a topping on concrete base and, as is shown in Plate I, Figs. 5 and 7, rated well both before and after wear.

The third place material was a sawdust preparation (Mix G) with the coefficient of friction being .81. It might be mentioned that coefficients of friction were more uniform for the three dry tests conducted on this material than for any other material included in the experiment, these being 0.82, 0.79 and 0.82. It should be pointed out, however, that specimens of this material wore rapidly when placed upon the wear machine and that wear produced was of an irregular nature. It is thought that perhaps the irregular worn surface accounted in part for the favorable performance of the material under worn conditions. In addition to rapid wear, it appeared that the high proportion of sawdust in the mix caused insufficient binding on the part of the cement to permit the specimens to be classed as high quality.

Duromit aggregate and emery aggregate each had a friction coefficient of 0.80 for fourth place in the dry test. These materials were used to top concrete bases, and appeared to stand up exceptionally well when subjected to wear, as approximately 170 hours were required for the wear machine to produce sufficient wear for conducting the test.

It was determined that coefficients of friction for other materials gradually declined until pine blocks and plywood were reached, and then a sudden decline was noted. Friction coefficients for these two materials were 0.29 and 0.25, the former for pine blocks and the latter for plywood. It should be pointed out, however, that plywood manufacturers do not recommend their product for this particular use.

Results of Tests Conducted on Dry Worn Specimens

Since floors retain their original finish for only a comparatively short part of their period of usefulness, and since it is generally conceded that the trouble from slipperiness is greater after they have been worn to a smooth surface, results of tests under dry worn conditions are considered of importance.

Results of tests conducted on dry worn specimens (Plate I, Fig. 7) reveal that a sawdust preparation (Fig. 4, Mix G) had a higher coefficient of friction than did the other materials tested. Another sawdust mix of different proportion (Fig. 4, Mix H) was found to rank second. It was of considerably higher quality than Mix G because of the higher proportion of cement used. This would make it more expensive than the first ranking specimens, but it is possible that the extra expense would be justified by the added quality of the product.

Next in order was duromit aggregate, one of the topping materials used in the experiment. This material appeared to be exceedingly resistant to wear.

Ranking fourth in the dry worn test was zonolite, a material light in weight and easy to wear when placed upon the wear machine. This material also appeared spongy when mixed for placing in forms.

The fifth place material was aluminum oxide sidewalk grain, a topping material that appeared to be very resistant to wear.

Ranges in coefficients of friction for this phase of the test ranged from a high of 0.82 to a low of 0.51, a significant feature being that high and low coefficients were obtained from different mixes (Fig. 7) of the same material, the difference being caused by varied proportions. Since sawdust varied this much in the tests, it was apparently one of the materials that should be carefully studied before being put into actual use.

Results of Tests Conducted on Wet Specimens

Before being subjected to tests in this phase of the experiment, all specimens were soaked in water to be sure that they were thoroughly wet. Any specimens showing a tendency to become dry prior to completion of tests were again moistened for the purpose of making uniform tests.

Contrary to what might have been expected, some materials had higher coefficients of friction when tested wet (Plate II, Figs. 9, 10 and 11) than when tested under dry conditions.

As was the case in dry test, the griptred material showed the highest average coefficient of friction with 1.00. It also appeared to be very resistant to moisture absorption, as it would not retain water upon the surface when tilted at an angle.

Aluminum oxide sidewalk grain was second with a coefficient of 0.89. Horn ferem and emery aggregate tied for third place at 0.88, both of these being materials used for topping.

Three materials tied for fourth place with coefficients of 0.87, these being haydite, alundum and the concrete with calcium chloride hardener. In fifth place, with a coefficient of friction of 0.86, was the weak mix of concrete, being composed of five parts of sand to one of cement.

Variations for coefficients ranged from the griptred high of 1.00 to the low for pine blocks of 0.53.

Tests Conducted on Wet Worn Specimens

Inasmuch as practically all dairy barn floors are eventually used in a worn condition, and many of them are used by animals while at least some part of their area is wet, testing worn specimens while in a wet condition was considered of importance.

In this phase of the experiment, one of the sawdust preparations had the highest coefficient of friction (Plate II, Fig. 11) with 0.89. It should be mentioned that this material did not appear to be very resistant to wear, as it readily showed signs of wear when placed on the wear machine prior to test.

Second in the test was Horn ferem, one of the topping materials, with a coefficient of friction of 0.83. This material was exceedingly resistant to wear when subjected to the wear machine action.

Tied for third place were emery aggregate and alundum, both topping materials with coefficients of 0.81. They were both exceedingly resistant to wear.

Haydite was fourth with a coefficient of 0.79. This material is reputed to be light in weight but strong.

Duromit aggregate and the concrete with calcium chloride hardener were in fifth place with coefficients of friction of 0.78.

Extremes ranged from a high of 0.89 to a low of 0.51, both of which were different mixes and proportions of sawdust.

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the degree of slipperiness of various materials regarded as desirable for use as dairy barn floors.

In conducting the investigation, small floor specimens were made, sizes being 12 inches long, eight inches wide and two inches thick. In order to obtain more desirable finishes, a wood float was used as the finishing tool for all specimens except those of pine blocks, plywood, griptred, emery aggregate and calcium chloride in concrete. Pine blocks and plywood were used as manufactured, griptred and emery aggregate were given a trowel finish and calcium chloride specimens were given a broom finish.

Machines were designed and constructed for producing wear on specimens to be tested in the worn condition and for testing for slipperiness. The wear machine accommodated twelve specimens at one time, these being worn by means of small concrete blocks with carborundum dust wearing surfaces.

The machine for conducting slipperiness tests was capable of applying and registering normal and sliding force by means of levers and balances. In order to make tests nearer identical to actual conditions, the foot of a cow was obtained and used on the slipperiness machine. This foot was mounted on the machine and was used to contact the specimens tested.

In conducting slipperiness tests, normal force was applied to the foot as it rested on the specimen being tested, and as pressure was applied to a lever horizontally, the amount of sliding force required to produce slipping was recorded.

All specimens were tested both wet and dry, these conditions existing on dairy farms of the country. In addition, most specimens were tested as worn specimens, since practically all dairy barn floors are used throughout most of their period of usefulness in such condition.

By the use of data obtained from these tests, the coefficient of friction was determined for each of the twenty different mixes or materials included in the experiment. The formula used to determine the coefficient of friction was as follows:

$$\frac{S}{N} \text{ or } \frac{\text{Sliding force}}{\text{Normal force}}$$

The coefficient of friction was obtained for materials for top unworn surfaces, bottom surfaces and for top worn surfaces, both wet and dry. Since wet and dry conditions would not occur simultaneously, results were not combined for them. Composite coefficients of friction were obtained for the three tests under both wet and dry conditions.

Results of the investigation revealed that griptred had the highest coefficient of friction of any of the materials used, this material leading in both dry and wet tests with friction coefficients of 1.05 and 1.00, respectively.

This material was not subjected to wear, as it was given a smooth trowel finish, and was, therefore, considered to be fully as smooth as it would become under conditions of wear. Although its ability to withstand wear is unknown, it should be mentioned that repeat applications could be made if necessary with little difficulty, as material dries readily when applied. It appears to be resistant to moisture absorption.

There was a conflict in results for a second place material, as is reasonable to expect. Aluminum oxide sidewalk grain ranked second in average friction coefficient for both wet and dry tests, but fourth for wet test under worn condition and fifth for dry test under worn condition. Horn ferem ranked second for wet test under worn condition, and was one of four materials in sixth place for dry test when worn. One of the pine sawdust mixes was second when tested dry after having been worn. These results indicate that conditions under which a floor will be used should probably be of considerable importance in selecting material for maximum efficiency.

Since injuries sustained from slipping occur most frequently when cows are moving across treacherous surfaces, it appears that results of this study might well be considered in planning floors, alleys or walkways where cows do most of their walking. Plans for future use might include to advantage safer walking surfaces for cows even though the stanchion platform might be of an entirely different composition.

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APPENDIX

EXPLANATION OF PLATE I

Fig. 5. Coefficient of friction for top unworn surface of dry specimens.

A. Heavy bars indicate dry specimen ratings, while light bars show wet rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig. 6. Coefficient of friction for bottom of dry specimens.

A. Heavy bars indicate dry specimen ratings, while light bars show wet rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig. 7. Coefficient of friction for top worn surface of dry specimens.

A. Heavy bars indicate dry specimen ratings, while light bars show wet rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig. 8. Average coefficient of friction for all dry specimens.

A. Heavy bars indicate dry specimen ratings, while light bars show wet rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

PLATE I

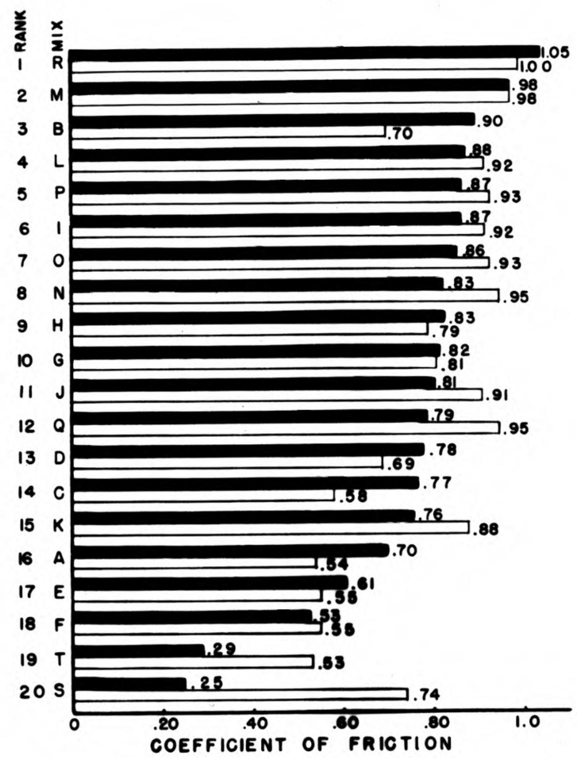


Fig. 5.

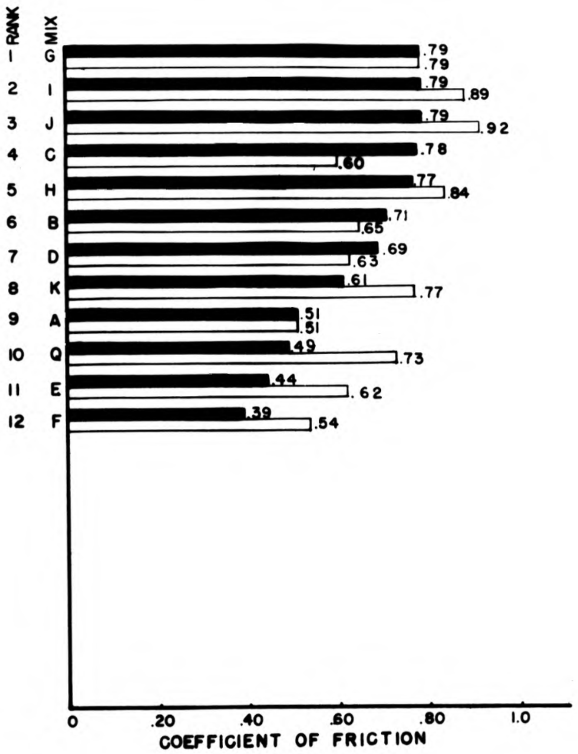
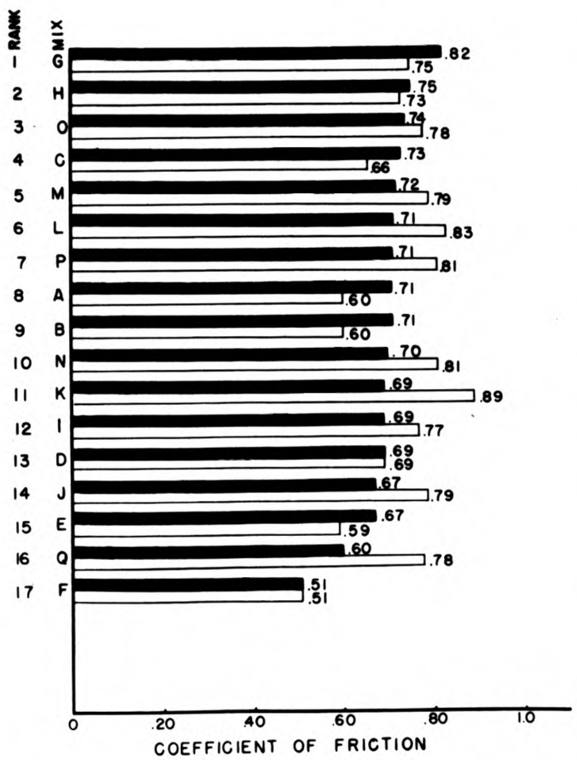


Fig. 6.



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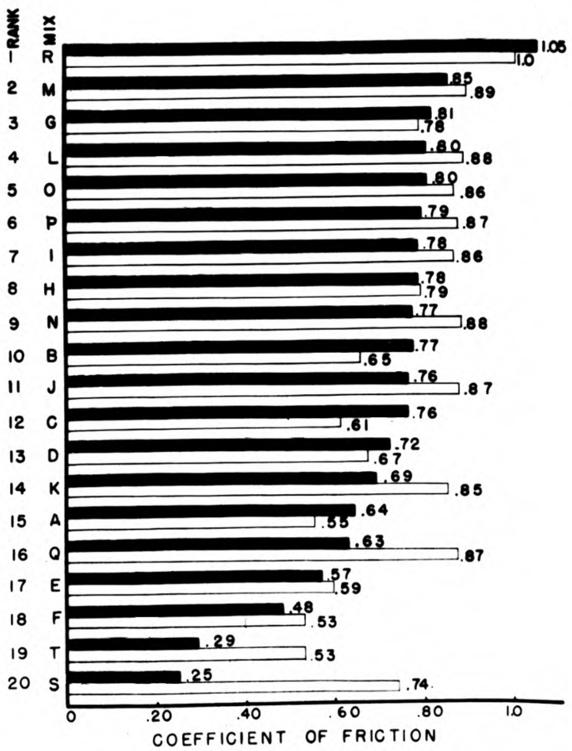

Fig. 8.

EXPLANATION OF PLATE II

Fig. 9. Coefficient of friction for top unworn surface of wet specimens.

A. Heavy bars indicate wet specimen ratings, while light bars show dry rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig.10. Coefficient of friction for bottom of wet specimens.

A. Heavy bars indicate wet specimen ratings, while light bars show dry rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig.11. Coefficient of friction for top worn surface of wet specimens.

A. Heavy bars indicate wet specimen ratings, while light bars show dry rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

Fig.12. Average coefficient of friction for all wet specimens.

A. Heavy bars indicate wet specimen ratings, while light bars show dry rating for same specimens.

B. Mixes of specimens shown in "Mix" column identified in Fig. 4.

C. Column headed "Rank" used to designate order of desirability from slipperiness standpoint.

PLATE II

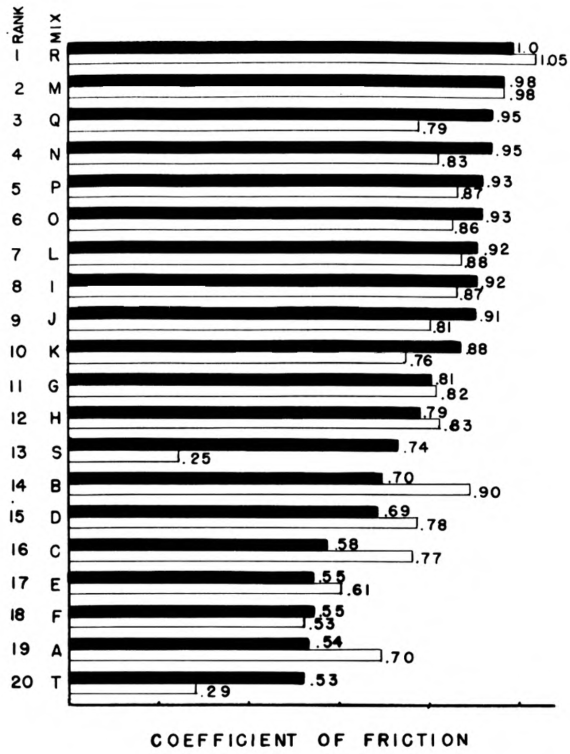

Fig. 9.

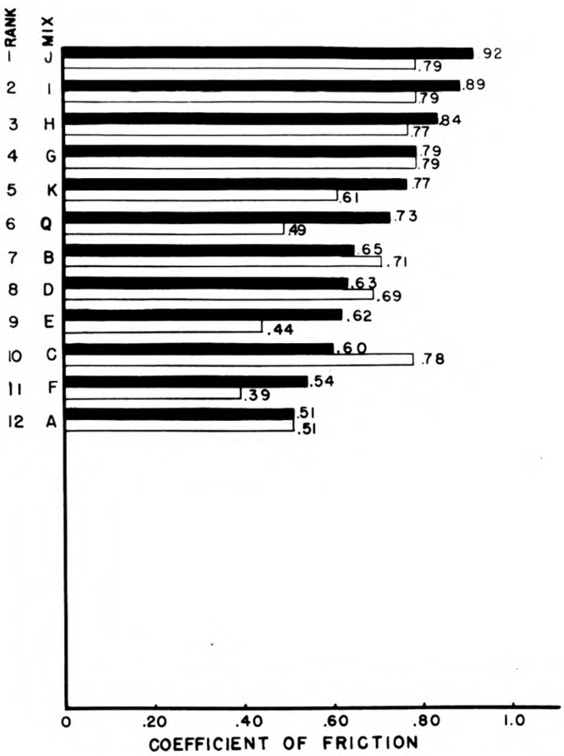

Fig. 10.

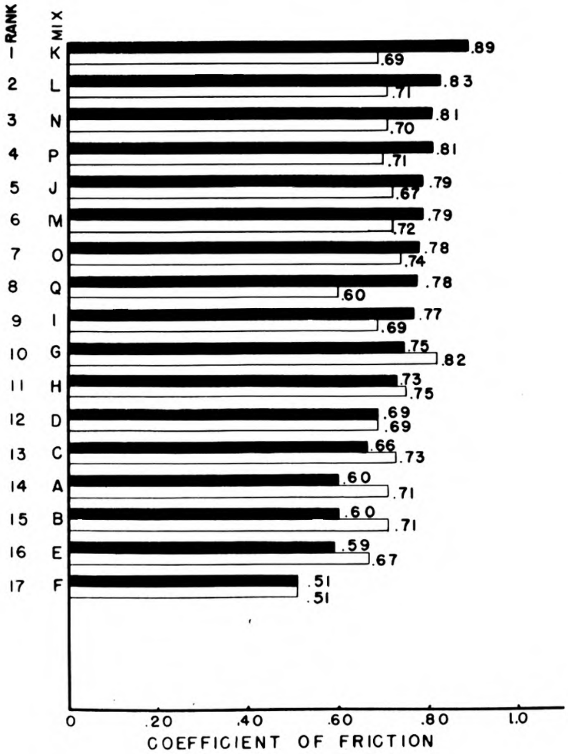

Fig. 11.

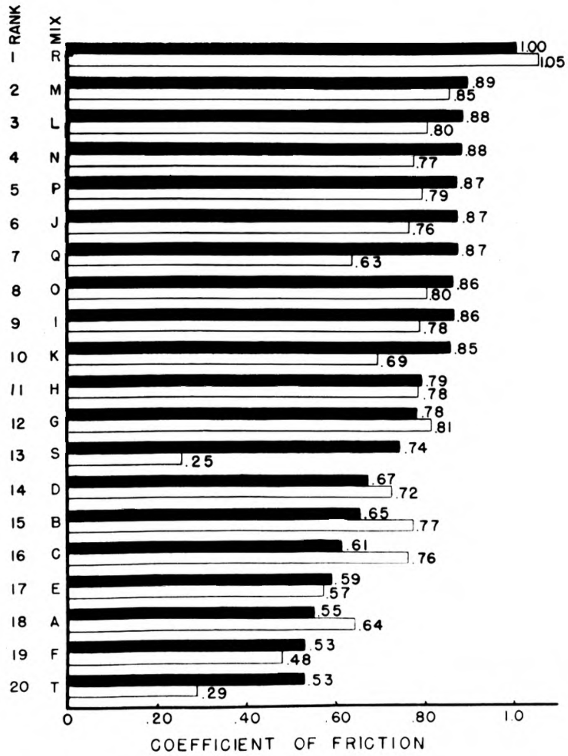

Fig. 12.

EXPLANATION

It was originally planned to make a more comprehensive study of the dairy barn floor problem than that embraced by this report, but the time allotted for the completion of an undertaking for which there was little or no previous research was insufficient for a satisfactory completion of outlined procedure. The original plan included the testing of floor material specimens for thermal conductivity, moisture absorption, freezing and thawing, wear, compression and slipperiness.

For the moisture absorption tests it was planned to record the weights of oven-dry 3 x 6 inch cylinders (Fig. 1), soak them in water and remove and weigh for the amount of moisture absorbed for the material.

In testing for thermal conductivity, the plan was to mold specimens of material to be used that would be 18 x 18 x 1-1/2 inches and test by use of a guarded hot plate.

The compression tests were to have been conducted by using the same samples made for the moisture absorption test after the moisture absorption tests had been completed. Amount of pressure required to cause the breaking of samples was to have been used in calculating results.

For freezing and thawing tests, it was planned to intermittently freeze and thaw specimens and, by observation, determine the ability of the several materials to withstand the extremes of temperature.

Wear tests were planned, specimens intended for use being those used in the slipperiness tests. The machine used for the smoothing of specimens for slipperiness investigations could have been used to produce the required degree of wear, although it is possible that some device for producing wear at a faster rate might be used to advantage.