CONSIDERATIONS IN FLOORING

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INTRODUCTION

Modern dairy cattle evolved over time from nomadic animals of the open range where they walked on resilient, yielding surfaces. When cows were initially confined by man, confinement occurred on dirt or generous amounts of soft bedding. McDaniel *et al.* (1982) reported that the primary complaint about feet and legs for these cattle was that their hooves did not wear properly. Recommendations for milking stall construction included putting carbundrum in the flooring so it would wear hooves and reduce the need for trimming (McDaniel *et al*., 1982).

The next development of dairy housing was to confine cows in stanchion barns during the winter in order to avoid the wet and dirty conditions associated with most outside dirt lots. In the summer, cows were almost always released to pasture and major foot and leg problems were seldom an issue (McDaniel *et al.,* 1982).

More recently, economic pressures have forced many dairy farmers to increase levels of confinement and animal intensification. The development of the freestall housing system was one answer that helped dairy producers cope with economic pressures in many ways. Bedding levels decreased as compared to that required for loose housing. Labor requirements decreased allowing for the care of more cows per worker.

Confinement in a freestall barn usually means housed cows stand or walk on scraped or washed concrete alleys for an entire lactation, or possibly all of their adult life. The freestall resting surface is sometimes also constructed from concrete and consequently cows may get little reprieve, especially if the stall is inadequately bedded or dimensions are incorrect resulting in poor stall use.

The trends in intensive animal confinement were accepted rapidly by producers and scientists at the expense of adequate data on the long-term effects on cows (Albright and Alliston, 1971). This 1971 statement is still substantiated today by the relatively little progress that has been made in cow comfort relative to flooring surfaces in this country. However, in Europe and other areas of the world, animal welfare is of primary concern and consequently foot and leg health has attracted significant attention. This has driven their scientists to look more closely at the impacts of hoof contact surfaces.

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The U.S. environmental policy is now concentrating on new regulations to protect the nation's water resources from both point source and non-point source agricultural pollution. These regulations will have a significant impact on the housing of dairy cattle. Producers probably will not be able to allow their cattle to freely use intensive exercise lots unless surface water runoff collection and treatment is provided. It is my opinion that many producers will opt to expand the level of housing to include their entire herd and forgo constructing and operating expensive practices to collection and treat rainwater runoff from exercise areas. This will be done despite the fact that providing a reprieve from concrete during the dry period for confined cows has been shown necessary to help maintain foot health (McDaniel *et al.,* 1982, and Hahn, *et al.,* 1986). Consequently, improvements in flooring surfaces must be identified to meet the needs of both the cow and dairy producer. Floors must provide confident footing for the cow and caretaker alike while resulting in minimal foot and leg problems for the cow. Floors also must be economically affordable and durable.

The objective of this paper is to discuss flooring systems relative to cow comfort and health and present recommendations when they are available for each specific area discussed. Specific areas include cast-in-place concrete floors, pre-cast concrete slatted floors, and alternative flooring surfaces. The allowable slope of flooring surfaces in various areas frequented by dairy cows will also be addressed.

COWS AND CONCRETE

Cows should be standing or walking about 10 hours per day if they follow the recommendations by Guard (2000) to be in stalls lying down for close to 14 hours per day. Excessive standing reduces blood flow in the hoof and is detrimental, excessive walking can lead to over-wearing of the soles, which become soft and easily bruised (Blowey, 1993). Cows are motivated to walk to consume food and water and seek companionship, shelter, resting space, and sexual partners. Cows are forced to walk by caretakers to and from milking, sorting, and treatment areas. Albright (1995) recommends that cows need to walk about 2 to 2-1/2 miles per day to keep them healthy and exercised.
Lameness is a huge problem with confined dairy cows and represents one of the major reasons cows are culled. Substantial economic loss by dairy farmers can occur when lameness is not controlled. Lameness has been shown to be followed by delayed estrus, poor breeding performance, shortened lactation, low yield of milk fat and a sudden drop in body weight (Dewes, 1978) all of which can cost the dairy producer money. Control of lameness is not always easy since it is a multifunctional condition that is influenced by variables including genetics, nutrition, and environmental factors.

The relationship between environmental factors and lameness have been investigated by many individuals. Specific to flooring surfaces, Bee *et al*. (1986) reported that poor concrete surfaces and low freestall utilization caused a high incidence of sole ulcer and white line disease in herds fed low levels of concentrates. Dumelow and Albutt (1988) stated that leg joints, ligaments and tendons are the main tissues damaged when a cow slips and falls onto or against hard surfaces as a result of slippery floors. Hahn *et al*. (1986) found that hooves of cows confined on new abrasive concrete wore 35 percent more than control cows housed on dirt. Hahn *et al.* (1978) also found that hooves of all cows confined on a new concrete surface that had no special surface preparation wore more than they grew for the first two months after exposure.

Concrete floors that are roughened to preclude slippage can wear hooves excessively and smooth floors do not offer sufficient traction. There is a fine line between a concrete floor surface that is too rough and causes injury due to abrasion and one that is too smooth and causes injury because of inadequate footing. Experience has shown that the finish on a floor is often the biggest mistake made during barn construction. Rough finished floors will speed foot wear by up to 20 percent, with cows being culled in three weeks of new barn occupancy due to lameness (Bray, 1998).

CAST-IN-PLACE CONCRETE FLOORS

By far, the most prevalent flooring surface in new and older barns alike is cast-in-place concrete. Concrete is attractive to many dairy producers because it is durable, economical, relatively easy to place, conforms to irregular areas well, and can be finished in various ways to provide some level of traction to dairy cows. Traction by the cow is traditionally provided by creating parallel grooves or groove patterns in the concrete surface. In special instances, anti-slip aggregates applied to the concrete surface and epoxy floor coatings can also be utilized.

In many cases the method employed to provide cow traction by the producer or the concrete finishing contractor is based on their individual experiences and preferences or the tools currently in-hand to accomplish the task. Rather, the design of the floor finish should be based on enhancing the traction offered to the cow by maximizing characteristics of the cow's sole that are partially responsible for her overall stability.
In determining how to best provide traction for cows, the recommended dimensions, orientation, and configuration of grooves and patterns should be known. Then this information can be used to determine how to best apply grooves or patterns to a concrete surface.

Groove Dimensions, Orientation, and Configuration

There seems to be a lack of consensus between references reviewed regarding the most appropriate dimensions, orientation and configuration of grooves or patterns installed in concrete to create a slip resistant floor. It appears that two schools of thought exist relative to grooving concrete.

The first theory is to provide grooves with spaced such that they provide an edge to catch a cow's hoof soon after slippage initiates. For example, Albright (1995)

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reports that grooves can be spaced from 4 to 8 inches apart. MWPS-7 (1997) recommends that 1/2 to 1 inch wide parallel grooves with a depth of 1/2 inch should be spaced 4 inches on center with alignment diagonal to the direction of animal traffic flow. If a diamond pattern is desired, MWPS-7 (1997) indicates it can be constructed using the same groove dimensions with the spacing adjusted to 6 inches on center. Bray (1998) reports that grooves should be 1/2 inch wide and 3/8 inch deep, spaced 3-3/4 inches on center; grooves should be first cut parallel to the longitudinal direction of the alley and then cross grooved.

With grooves spaced at these distances, slippage may occur before the hoof contacts a groove.

The other theory is to space grooves closer together so that at least one of the four primary hoof contact surfaces lands in a groove when a foot is put down to preclude initial slip. This theory is based on research conducted by Dumelow (1993). Dumelow looked at the slippage of a simulated hoof on various grooved concrete surfaces topped with dairy manure. Dumelow concluded the following for creating a floor that provides confident footing.

1. Space parallel grooves 1.5 inches apart.

2. Grooves lateral to the cow's backbone produce less slip than longitudinal grooves.

3. Maximum traction is provided by creating a regular pattern of hexagons with sides of 1.8 inches in length.

4. Groove width should not exceed 0.40 inches.

In practice, creating a hexagonal pattern in concrete is difficult to properly accomplish. Orientating grooves perpendicular to the length of an alley will maximize their effectiveness for cows but may compromise manure removal. In order to mesh the theoretical research results with practicality, Graves *et al.* (1997) recommends installing 3/8 to 1/2 inch wide by 3/8 to 1/2 inch deep grooves parallel to the direction of scraper travel. Grooves should be spaced 2 to 3 inches on center. This reference also states that a diamond floor pattern can be developed by installing two sets of parallel grooves in different directions spaced 4 to 6 inches apart.

<u>Grooves In Green Concrete</u>
Bullfloating is a standard task that is performed when constructing concrete slabs-on-grade after screeding takes place. The primary purpose of bullfloating concrete is to eliminate high and low spots (bird baths) and to embed large aggregate particles below the finished surface.

Commercially available bronze grooving attachments can be attached to standard bullfloats and be used to install concrete grooves. By using many of these grooving attachments at once on a bullfloat, parallel grooving can be accomplished. Thumbscrews on each attachment allow for lateral adjustment relative to the bullfloat allowing the bull float operator to change the distance between grooves as needed. Grooves can also be installed with a home-made beveled groover fabricated from plywood and wood strips (see MWPS-7, 1997 for details).

Proper moisture content of concrete grooved by using a bullfloat groover makes for easier grooving by the bullfloat operator and results in a quality finished product. Bullfloating grooves should be formed after the concrete has been placed and screeded but before any excess bleed water accumulates on the surface (when normal bullfloating should occur). When the concrete is too wet, the bullfloat is hard to operate due to increased resistance and the grooves tend to fill in soon after created. When the concrete is too dry, the grooving attachments will not fully penetrate the concrete surface resulting in less than desirable groove depths and possibly some exposed aggregates along the edge of the grooves.

Practical experience is needed in order to become proficient at creating a quality grooved floor with the bullfloat grooving method. After experience is obtained, a worker can groove a floor rather rapidly compared to installing grooves with the stamp method (discussed below). Another plus for floating grooves versus stamping is due to the inherent nature of the bullfloat tool; the concrete material displaced by each attached groover is smoothed by the bullfloat passing over the surface of the concrete. This produces grooves without sharp or rough edges and exposed aggregates.

Cut Grooves

New concrete floors can also be grooved after initial curing takes place. Older concrete floors can be re-grooved as needed to enhance traction. A saw similar to that used to cut expansion joints in concrete roadways can be adapted with a series of diamond dato blades to cut grooves in cured concrete.

The primary advantages of cutting grooves in hardened concrete is the elimination of the need for contractor experience with grooving wet concrete and the requirement for time-sensitive completion. Concrete slabs-on-grade for use as barn alleys can be placed, screeded, floated, and trowled to provide satisfactory results by readily available concrete finishing crews. However, adding in the requirement to install a specific groove pattern in the slab that is free of rough edges is a job that is only successfully accomplished by an experienced crew. Even experienced crews can fall behind in their work because of erratic delivery of ready-mix concrete to the job site resulting in a poor grooving job.

Stamped Patterns

Diamond and hexagonal patterns can be created in green concrete by using a metal stamp. Usually, the metal stamp is fabricated from round stock material that is cut and meticulously welded together. The stamp has a metal handle assembly attached allowing it to be pushed into and removed from the concrete surface while workers are in a standing position. The stamp must be moved several times to fully pattern a barn alley. A stamp is the best way to create the hexagonal pattern recommended by Dumelow.

Personal experience has shown that stamping concrete is more difficult to accomplish properly than grooving and stamping is very sensitive to concrete moisture conditions. Concrete that is too wet will tend to stick to the stamp causing undesirable rough edges and a sloppy finish. Concrete that is too dry will bulge up in the inner space between each round stock member used to form the pattern. This bulging of concrete results in the floor having several convex areas that may not uniformly support the cows' hooves. Also, when the concrete bulges it usually cracks on the surface. The quantity of cracks and their size depend on the moisture content of the concrete at the time the stamp is applied, the design of the stamp, and how far it was pushed into the concrete. Surface cracks like this are not good as they provide an opening for moisture to penetrate, potentially causing premature deterioration due to freeze thaw action.

Concrete that has a rough, abrasive final finish after stamping can be remediated by dragging concrete blocks behind a tractor or skid-steer loader for several passes. This process should be done before the problem areas are populated with cows. Walking on the concrete floor comfortably with your bare feet is a good way to determine the floor will be acceptable for cows.

Anti-Slip Aggregates

Milking center cow decks, areas in and around remotely located restraint facilities, and cattle loading chutes are all locations where cows and people interact. This interaction may be accepted, or at least tolerated by a cow depending on several factors including her past experiences in the given area. In certain circumstances, human contact or perceived human contact by the cow will cause flight. Flight may result in a cow attempting to flee from the objectionable area. The lack of confident footing while attempting to flee may cause hoof slip and trigger additional fear. For this reason, extra attention needs to be dedicated to providing adequate flooring in these areas.

Welchert and Armstrong (1992) present one possible solution for providing enhanced traction in potentially high anxiety areas. They describe how to top newly placed, uncured concrete with a dry shake mix composed of 3 parts anti-slip aggregates (aluminum oxide or corundum) and one part Portland cement by weight. Welchert and Armstrong (1992) give a complete description of how to accomplish this process. A brief synopsis of the procedure is as follows. After the shake mix is prepared, it is hand applied at a rate of 60 to 100 pounds per 100 square feet of floor space after the concrete has been placed, screeded and floated, and surface water has disappeared. Subsequent to application, the mix is power floated lightly to partially imbed the anti-slip aggregates and then steel trowelled until the aggregate surface is uniform and lightly textured.

When applied as prescribed, Welchert and Armstrong (1992) report that the resulting floor surface will be non-slip and highly wear resistant. Floor life is estimated to be 20 years as opposed to seven years for regular floors.

One experience with the application of a dry shake mix by the author resulted in two cow decks in a new milking center with an unacceptable level of traction. The reason for the poor outcome can be attributed to the lack of experience by the finishing crew relative to the dry shake mix application process. This is a sensitive process and only crews experienced with applying a dry shake mix for the intended final application should be used. Otherwise an extremely hard floor surface will most likely result that offers no enhancement of traction over a hard trowled concrete floor.

It should be emphasized that a dry shake mix should not be used in freestall alleys or other areas frequented by cows several hours per day. Experience has shown that excessive wear of cows' hooves will result causing the need to prematurely cull many animals from the herd soon after barn population (Martin, 1999).

<u>Epoxy Floor Coatings</u>

A carefully selected epoxy flooring system, which is appropriate for the application, can be employed to improve cow traction. Epoxy flooring is most applicable as a surface rejuvenation agent to relatively small areas that can be made free of cow traffic for a few consecutive days. Ample time is needed to properly prepare the existing floor (which is crucial to final product durability), apply the product, and allow for proper curing. Additionally, the cost normally associated with an appropriate high quality epoxy flooring material is usually high and precludes its use on a wide scale basis.

Cow decks in milking centers that operate less than 12 hours per day are the primary candidates for installing an epoxy flooring system. The epoxy coating works well for this application since it can be cleanly installed around the structural support post for each milking stall. To facilitate installation cows can be milked on one side of the parlor while work is undertaken on the other side. After the first side is completed, milking sides can be switched and the other side can be addressed.

The U.S. Navel Academy dairy, located outside of Annapolis, Maryland, used an epoxy flooring system in their milking parlor about 20 years ago to remediate poor floor conditions. In fall 1995 it was noted that the floor appeared to be holding up well. The herdsperson reported that the cows experienced no significant slippage problems since the epoxy floor was installed at that time.

When considering the use of an epoxy flooring system, a producer must do their homework to ensure that the product they are considering will meet their needs. It is recommended that a manufacturer's product specialist be consulted to discuss the application before a final product is chosen.

PRE-CAST CONCRETE SLATTED FLOORS

Pre-cast concrete slatted floors (slats) where primarily developed to reduce the amount of daily labor required to clean barn alleys and as a means to transfer liquid manure directly to a storage or gravity collection gutter located immediately below. Slats can be used in many areas including: alleys between rows of stalls, adjacent to feeding surfaces, transfer lanes, and in milking center holding areas. Some producers locate slats at the ends of poured-in-place concrete alleys with the intention of using them as scraped manure drop sites. However, slats are not recommended for this application. The relatively large volume of manure deposited in an alley will not efficiently drop through the few narrow slots located at the alley's end.

Slats are available in two basic configurations - "conventional slats" & "waffle slats". McFarland (1994) reports that conventional slats have a 1-3/4 to 2 inch slotted opening that spans the width of an alley, and between each slot is a 6 to 8 inch wide tread. The MidWest Plan Service Livestock Waste Facilities Handbook (1993) states that the distance between slats for dairy cows should be 1-1/2 to 1-3/4 inches. Albright (1995) and Kirchner and Boxberger (1987) recommend that a slot width does not exceed 1-1/4 inches with a maximum tread width of 3-1/4 inches as these dimensions avoid excessive pressure on the cow's sole and help to prevent feces build-up on the slats.

A newer slatted floor configuration, called waffle slats, is popular in Pennsylvania and other areas of the country. This design uses a series of openings approximately 1-3/4 inches by 8 inches spaced about 3 inches lengthwise and 5 to 6 inches apart (McFarland, 1994). McFarland reports that cows seem to walk very comfortably on this flooring surface and manure passes through quite easily.

Little research appears to exist relative to the impact of "slats" on foot health. Albright (1995) suggests that slats for dairy cattle have been de-emphasized over the years due to foot problems, poorer estrous detection and lack of cow comfort. Hill *et al.* (1973) states that there is an absence of assertive behavior, possibly because animals have much less confidence on slatted floors than on other types of flooring surfaces. Kirchner and Boxberger (1987) report that cattle cannot walk on slatted floors and avoid the slots while moving. Injury of the sole of the claw often happens when they slip into the slot (Kirchner and Boxberger, 1987, and Albright, 1995). All of these references refer to cows on conventional slats. No literature was found that discussed comfort and health issues relative to waffle slats. Anecdotal evidence suggests that waffle slats may work well based on the continuously increasing use of them by dairy producers. Maton (1987) and Thyssen (1987) indicate that a lower incidence of lameness due to interdigital dermatitis occurred on slatted floors versus solid floors.

The best advice that can be given to a producer who is considering slatted floors is for them to visit several existing slatted floor barns and discuss with each owner their thoughts and experiences. Information obtained from the discussion combined with a first-hand look at the floor and the cows will help the producer make an informed decision. Strongly consider waffle slats if choosing a slatted floor.

ALTERNATIVE FLOORING SURFACES

Like people, foot and leg stress increases for cows when they stand on a concrete surface for extended periods of time. Many producers who have confinement facilities recognize this fact and usually try to give cows a reprieve from concrete by moving them to managed grassed areas or to earthen lots during the dry period. This practice has been shown to be beneficial to foot and leg health by studies cited earlier.

As previously discussed, the level of dairy animal confinement will most likely continue to increase with time due to economic and environmental factors. Some form of an alternative flooring surface may be a large component of the overall solution that is needed to provide a satisfactory level of foot and leg health and improve cow welfare for lifelong confined cattle.

The consequences of standing on concrete are considered to be very important in the development of hoof lesions (Bergsten, 1988). Guard (2000) reports that claws of dairy cattle are commonly shaped in less than desirable forms and misshapen claws will experience extreme localized pressures created by unforgiving surfaces. High pressures are reported to contribute greatly to damage of underlying hoof structures. Durable flooring surfaces that are forgiving and conform to the cow's hoof and are economical to install should be considered. Guard (2000) suggests barn floors should be surfaced with something other than concrete and that combined with routine trimming may prevent many cases of severe lameness.

Perhaps the initial reason many producers employed alternative flooring surfaces was to increase cow comfort at the feed bunk and hope that dry matter intake would correspondingly increase. The thinking was that perhaps cows would stand longer at the feed bunk and thus would be tempted to take that extra mouthful of food. Research would be useful to determine the potential economic gain by this practice.

Flooring alternatives to a traditional concrete surface include but are not limited to reclaimed rubber belting, rolled rubber flooring, rubber mats, and constructed-in-place rubber flooring. All options require a concrete or another non-forgiving base material to provide support and a means to anchor the product. These alternative flooring products are easiest installed during new construction but may also be retrofitted into existing facilities with various degrees of preparation effort required.

An alternative flooring surface installed in the scrape alley adjacent to the feeding bunk is best installed flush with adjacent concrete surfaces by recessing the floor where the product is destined to be placed. Otherwise adjustments will need to be made to the scraper blades to accommodate an uneven alley.

Required Characteristics of Alternative Flooring Materials

Materials selected for installation to enhance cow comfort and welfare must also be capable of withstanding the many barn environmental factors that are present. Flooring materials are subjected to repetitive compressive loads from cows' hooves and manure removal and bedding delivery equipment. Turning cows and equipment create torsional loads. Shear loads are developed when cows and equipment move across the floor. Temperature variations can cause thermal expansion and contraction. Automatic alley scrapers and skid-steer loader blades cause abrasion forces when they pass over a floor. Skid-steer loaders used when bedding stalls probably exert the most force on a floor surface due to the short, quick turns performed by the operator.

Reclaimed Rubber Belting

Many producers are installing rubber belting in a 6 to 8-foot wide portion of the scrape alley adjacent to the feed bunk. Much of this rubber belting has been reclaimed from the mining industry where it was once used as aggregate conveyor belt. Because of the varying nature of the belts relative to their original application, the reclaimed rubber belt available to the dairy producer has different levels of hardness. Jackson (1999) reports the A-shore scale durometer reading is typically between 70 and 85 for most reclaimed belting that is being used for floor surfaces. The thickness of the carbon steel reinforced belt varies between 3/4 and 1-1/4 inches depending on the original manufacturer of the material. The heavy-duty nature of the belting seems to allow it to hold up very well in a barn environment when properly installed. I have heard of no reports of cows, skid-steer loaders, or automatic alley scrapers damaging reclaimed belting.

The belting can be custom cut in various widths and lengths to meet particular needs and is delivered to the project site in large rolls. Belting is unrolled in the barn and fastened down with corrosion resistant fasteners. Fasteners should be sufficiently imbedded in the concrete to resist the forces transferred to the belt and slightly counter-sunk into the belting so puncture of a cow's sole is precluded.
Additional traction may be obtained by grooving the belt material, and this can be performed by at least one of the companies in the business of supplying reclaimed belting. Personal experience has shown that non-grooved belting topped with urine and manure can be slick.

The market price for grooved rubber belting is approximately $2.50 per square foot installed (freight cost are extra).

Rolled Rubber Flooring

Rolled rubber flooring is similar to the rubber belting discussed above but it is not a surplus product. At least one manufacturer is producing this material for the dairy industry at this time. Their product is manufactured from 40 percent post-consumer, 60 percent post-industrial recycled material that is fiber reinforced with nylon/polyester chords. The fiber reinforcement makes this product easier to cut in the field than the metal cable reinforced belting. Another advantage of this product is that its thickness and hardness is more consistent from roll to roll which is not necessarily the case with using reclaimed belting. The durometer reading for one product is reported by the manufacturer to be 80±5 on the A-shore scale. This indicates that this material is about the same relative hardness as the reclaimed belting offering about the same level of resiliency per unit thickness. Standard roll dimensions are 1/2 inch thick, 4 feet wide and 150 feet in length.

A ball park price for the rolled rubber flooring material is about the same as for reclaimed rubber belting - between $2.25 and $2.50 per sq. ft. installed.

Recommended installation is to use corrosion resistant nails placed 12 to 16 inches on center along the rubber floor perimeter. An angled seam at each joint location is suggested to better resist alley scrapers and skid-steer buckets.

Rubber Mats

Rubber mats are available for use in barn alleys and transfer lanes. Jackson (1990) reports rubber composition is similar to that of the rolled rubber flooring. Mats sizes are typically available in either rectangular or square configurations with dimensions ranging from 4 to 6 feet. Some mats are puzzle cut on the ends with a water jet cutting tool at the factory. Both the square cut end and the puzzle cut needs to be secured to a base material to ensure each remains in place.

Constructed In-Place Rubber Floor

Another consideration for providing a resilient surface for cows is a constructed in-place rubber floor. This type of flooring material is comparable to that used in athletic running tracts found at some high schools, colleges and universities. Investigation of such surfaces indicates that a high level of resiliency exists. Contacts made to a few major material suppliers and installation contractors revealed neither have provided or installed their materials for a dairy housing application, but they believe that their floors should be able to endure the environmental factors found in a barn. Contacts were quick to mention that they routinely installed their products in horse stalls and in riding arenas and that product service has met customer expectations. Much of the following information was obtained by discussing the application of the contact’s product with specific application to the dairy industry.

In general, constructing a constructed in-place rubber floor is analogous to constructing a concrete slab-on-grade. Ground post-consumer rubber (aggregates) and a urethane resin (Portland cement and water) are proportioned and mixed together in a stationary batch mixer. The resulting product is placed between forms, screeded to the desired depth, trowled, and finally cured before putting it into service. The material placement process can be performed manually for smaller jobs or with special paving equipment that lays the material in 11-foot wide strips for larger projects. Like concrete, this process has optimum temperature and humidity ranges that must be present in order to obtain a quality final product.

Application thickness can vary between 1/2 to 1-1/2 inches. With a concrete base, one installer indicated an application of 1/2 inch is sufficient for horse stalls. If compacted stone is used as a base material a 1-1/2 thick rubber floor is needed. When the product is applied properly to a clean, moisture free base and has cured contacts indicate that it should stick to the base indefinitely. A urethane sealer can be used to seal the top of the floor after it has cured offering enhanced wear resistance and prevent moisture penetration.

Currently, cost is the prevailing reason why dairy producers interested in this type of product have avoided using it. One estimated price received to install a 1/2 thick floor in all alleys of a new 200-foot long 6-row freestall barn was $2.75 per square foot. A 1-1/2 inch thick application was $5.40 per square foot. A closer look at the cost of the raw products indicate that the material needed to construct a 1/2 inch thick floor should be able to be purchased for around $1.00 per sq. ft. (Jackson, 1999). The high price quote received appears to be reflective of the price acceptable to the equine industry.

While this type of rubber flooring system has not been proven in the dairy industry, it appears to be the type of flooring system that may better meet the needs of the cows.

Alternative Flooring Questions

All new products available to the dairy producer generate several questions regarding their merit and value as an addition to the farm business. Alternative flooring surfaces are no exception. The author is not aware of any data addressing the effects alternative flooring has on lameness or increasing dry matter intake that can be used to assist with making a purchase decision. However, numerous anecdotal reports by dairy producers indicate that their cows prefer standing and walking on resilient surfaces when given a choice. Guard (2000) believes that rubber flooring surfaces "are a step" in the right direction. Unanswered questions include the following.

- What surface(s) available best meets the requirements?
- Does using alternative flooring surfaces solely at the feed bunk offer sufficient escape from concrete?
- How thick should the alternative flooring surface be?
- What kind of return on investment does an alternative flooring surface provide?

FLOOR SLOPE

The need to slope any floor used by dairy cows is usually driven by the need to provide adequate drainage of surface water runoff control or to facilitate the connection of two different cow use areas with unequal elevations. Sloping of barn alleys provides drainage of urine, rainwater, and excesses sprinkling water, if such a heat stress relief system is in place. Alleys are also sloped to facilitate planned or future flushing operations and to possibly conform to existing topography. Sloping of barn alleys is not possible if gravity flow waterers are used. All waterers need to be at the same elevation for the water delivery system to function properly.

Barns connected to a milking center may have sloped walkways depending on the existing elevations and the configuration and layout of each building. As the magnitude of any sloped floor increases, the level of cow slip hazard correspondingly increases. Table I provides the range and optimum level of slope for different cow frequented areas on a dairy farm. Most of the values found in the table were initially presented by Welchert and Armstrong (1992) with a few of them updated by the author.

Cow Area	Range	Optimum
Parlor Cow Decks & Exit Area	1 to 3 percent	1.5 percent
Parlor Holding Area	1.5 to 6 percent	2 to 3 percent
Feedline & Freestall Alleys	1 to 4 percent	1.5 to 3 percent
Flushed Alleys	1 to 4 percent	3 percent

Table 1. Floor Slope Specifications for Various Cow Areas Frequented on a Dairy Farm.

The maximum slope in any cow transfer lane or walkway should not exceed 5 percent. If specific circumstances require that walkways must be greater that 5 percent to create a connection between two areas, install 6 to 8 inch steps placed at least 3 feet apart. The treads may be sloped no more than 1.5 percent to help achieve the required elevation change.

SUMMARY

Modern dairy confinement facilities are housing cows for much if not all of their entire lives. Concrete is the prevalent flooring surface in dairy barns and shelters at this time. Concrete must be properly grooved or patterned to provide confident footing for cows. Ragged groove edges and rough finished surfaces are abrasive to cows hooves and must be avoided. Even a properly finished and grooved concrete surface causes excessive stress on cows' feet and legs due to its unforgiving nature. Alternative flooring surface options like rubber belting, rubber mats, and constructed in-place rubber floors are more resilient than concrete and seem to offer a degree a relief to the cows. Research is needed to determine the optimum alternative flooring surfaces for cows and how much of it needs to be installed in a barn.

Whatever flooring surfaces is chosen by the dairy producer for a new facility, the desired end product must be clearly understood by the contractor to help ensure an acceptable product is provided. Contractual documents should clearly specify type of flooring to be provided by the contractor along with minimum levels of acceptance. Floors that do not conform to the specifications should not be accepted by the dairy producer.

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