RESULTS OF FEEDING SWINE ON SLOTTED FLOORS

by

CARL V. CHUMNEY

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Approved by

Paul N. Stevenson

Major Professor

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INTRODUCTION

The increased use of confinement facilities in swine handling has stimulated interest in floor and building design and materials as a means of improving sanitation and reducing manure-handling problems. (Confinement as used in this report will mean keeping hogs in an enclosed shed or barn and restricted from a pasture.) By using slots (slats) in the feeding floor less bedding is used and less floor space per animal is required. (As used in this report a slat is the individual beam or flooring member that comes in direct contact with the animal but does not produce a solid floor, whereas slots are small openings between the individual slats that allow the manure to pass through the floor.) Slats have been used in all stages of hog production, but primarily for finishing, when manure handling is the biggest problem.

The use of slotted floors for any livestock has been limited in the United States, but within recent years farmers have tried various types of slotted floors for many reasons. (Slotted floor is the term applied to an elevated floor with openings to allow the waste to pass through.) The use of slotted floors has presented some problems that have not been completely solved yet, but applied research will produce many of these answers in the near future.

The review of literature indicates that hogs prefer being clean to dirty if given a means of keeping comfortable

in clean conditions. With less floor space per hog the manure is trampled through the floor, thereby aiding in keeping the animal clean.

Several companies are offering slotted floors of metal, wood, concrete, and masonite, while other companies are offering complete building kits including the slotted floor.

Wood was the first material tried, but its service life is extremely short and it becomes slick when wet. Removal of manure from under slotted floors is a problem in some cases. To combat this problem wet pits under the floor, lagoons, and dry holding pits have all been tried, each method having a certain degree of satisfaction.

Slotted floors are an aid to good management, not a substitute. Confinement feeding will introduce problems such as tail biting and ear chewing that were not present before. Nor does a slotted floor eliminate diseases, alter the need for sound nutrition, replace good management, or produce meatier hogs.

A few of the many unanswered problems about slotted floors concern the best type of material to use for construction, correct spacing between slats, durability of each material, environment created, floor drafts, disease control, manure removal from under the slats, economics of the system, floor space per pig, growth rate, and feed conversion.

PURPOSE

It is the purpose of this investigation, first, to consolidate the results and findings of tests that have been conducted with hogs on slotted floors; second, to observe briefly hogs in a portable finishing unit with the pen having a slotted floor and the shed a solid floor; third, to compare several different coating materials on wood slats as to their ability to resist wear and reduce slippage.

REVIEW OF LITERATURE

Hammer (7)* states that slotted floors for livestock were first used in Iceland about 200 years ago. Since then they have increased in number in Europe; as early as 1952 European countries had conducted specific research to evaluate slotted-floors for livestock and poultry. Norwegian farmers have used slotted floors in loose housing for sheep and goats for the past 30 years.

Flattened expanded steel and heavy wire mesh have been used for many years in swine nutrition research units in the United States. These units were for individual pigs that allowed feces and urine to pass through the flooring. Jensen (13) listed three reasons for using this type of flooring:

(1) it reduced the possibility that the animal would consume any of the feces
(2) it permitted the excreta to be collected for analysis to determine actual retention of nutrients

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*Numbers in parentheses refer to the appended references.

(3) it gave the pig a cleaner environment.
However, continuous use of expanded metal or wire mesh resulted in soreness to the hogs' feet and legs. To overcome this difficulty the University of Illinois started the first extensive research of slotted floors in the winter of 1955. Since this time many universities and experiment stations have conducted more extensive tests of slotted floors.

The main advantages of using slotted floors are that the cleaning time and labor are reduced. Harvey (8) pointed out one test in which cleaning concrete floors required 13 times longer per day than the same size slotted floor. Sanitation is improved because the hog's excreta drops or is trampled through slots, thus reducing direct contact with excreta which may contain disease organisms and parasites. This helps the pigs to stay cleaner and drier, which is especially important in farrowing units. Bedding is unnecessary, thus giving a saving in both cost and handling of materials. The capacity of a given pen can be increased since hogs must be crowded to keep the manure worked through slots. As little as four square feet per pig for weight up to 100 pounds and seven square feet up to 240 pounds has proved satisfactory. Harvey (8) showed that comparable weight gains can be obtained from pigs on slotted and solid floors when space allowances are identical. The slotted floor system offers flexibility and can be readily adapted to

EXPLANATION PLATE I

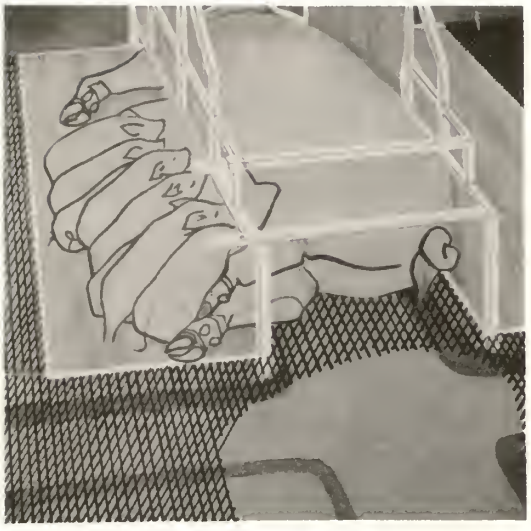
Slotted floors used in farrowing house

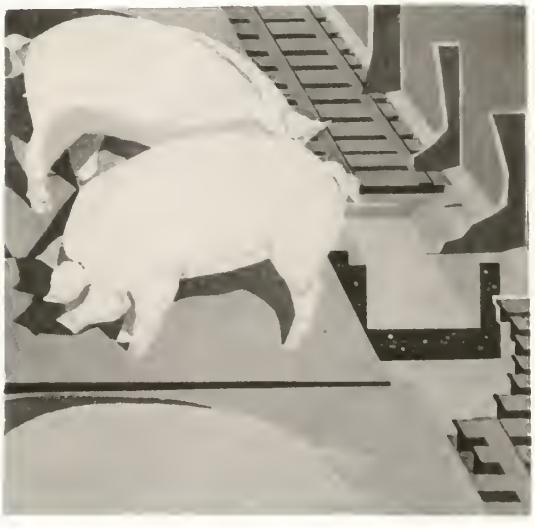
(Source: Successful Farming)

Partially slotted floor used in finishing

(Source: Successful Farming)

Plate I





either wet pits or lagoons, with the manure being disposed of or spread. The exact system is determined by the farmer's estimate of value of the manure and the problems created by using a lagoon.

From the foregoing discussion one could conclude that slotted floors have no disadvantages, but this would be misleading. One objection is the increased cost for the slotted floor, insulation, and extra mechanical ventilation control. Some flooring materials have a very limited lifetime, thus increasing the maintenance cost. Also, the slotted floor may produce more feet and leg injury as well as more tail biting and ear chewing than had existed under less crowded conditions. Feed loss may be greater because any feed dropped onto the floor passes through the slots beyond the reach of the animals and is wasted.

The materials most often used in construction of slotted floors are wood, masonite, metal, and concrete. Because of availability wood has been used longer, with elm, fir, hickory, and oak being used for slat construction. Elm is better than fir, but not as good as oak and not readily available in all locations. Fir slats have been made by cutting them from two inch lumber, but they usually last only one year because the wood is so soft. Oak is the best all-round type of wood for slats because it has better wear resistance and animals do not like to chew it as well as fir. In addition to these,

railroad ties are sometimes used with good results. However, untreated wood should be used to reduce the possibility of skin irritation.

The life of wood slats may be increased. Simonton (16) claims that covering the floor area with wire mesh reduces wear and keeps pigs from chewing the slats, without any damaging effects. Additionally the slats should be fastened together to prevent warping and movement while in use. To solve the problem of warping, some commercial firms use a 3/4 inch dowel 2 1/2 feet apart, allowing a reduction in the size of each slat. See Plate IV for one type wood slotted floor. A commercial slotted floor made of wood will cost between 50-75¢ per square feet.

Tempered masonite 1/4 and 3/8 inches thick has also been tried as a slotted floor material, but in the review of literature no results of test on the suitability of masonite for slotted floor material were found. One company offers masonite slotted floors in 4 x 8 foot sections with the outer edge of the masonite being supported by 2 x 6 inch fir lumber. In between the fir supports a grate support of masonite three inches on center and three inches in depth is used. This type of floor should cost between 60-80¢ per square foot.

Steel has been widely used as a slat material with good results. Pipe, T-bars, expanded mesh, quarry screen, perforated plank, and channel iron have been used. Untreated

EXPLANATION PLATE II

Wire mesh being used to protect wood slats. (Source: Farm Journal)

Total slotted floor being used under feeder pigs. (Source: Successful Farming)

Plate II

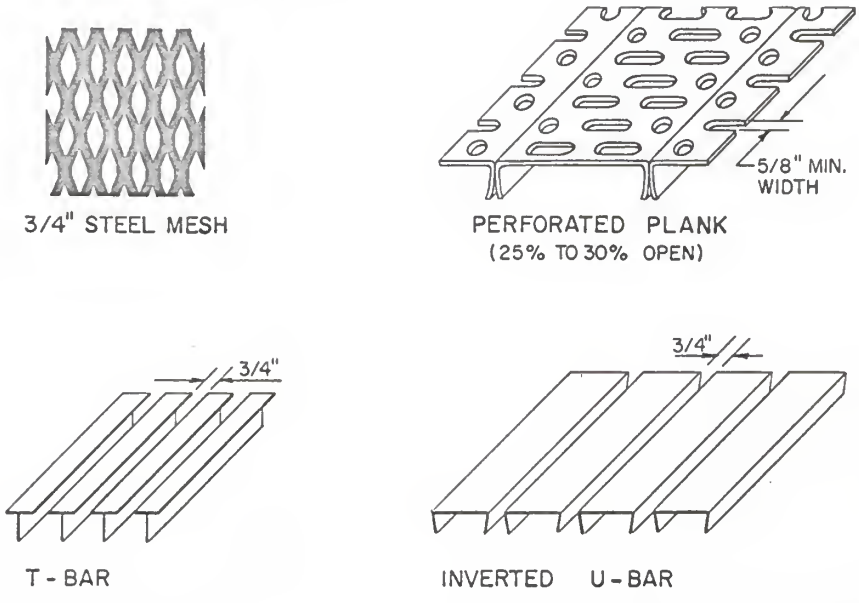


Figure 1. Commercially available steel slotted floors.

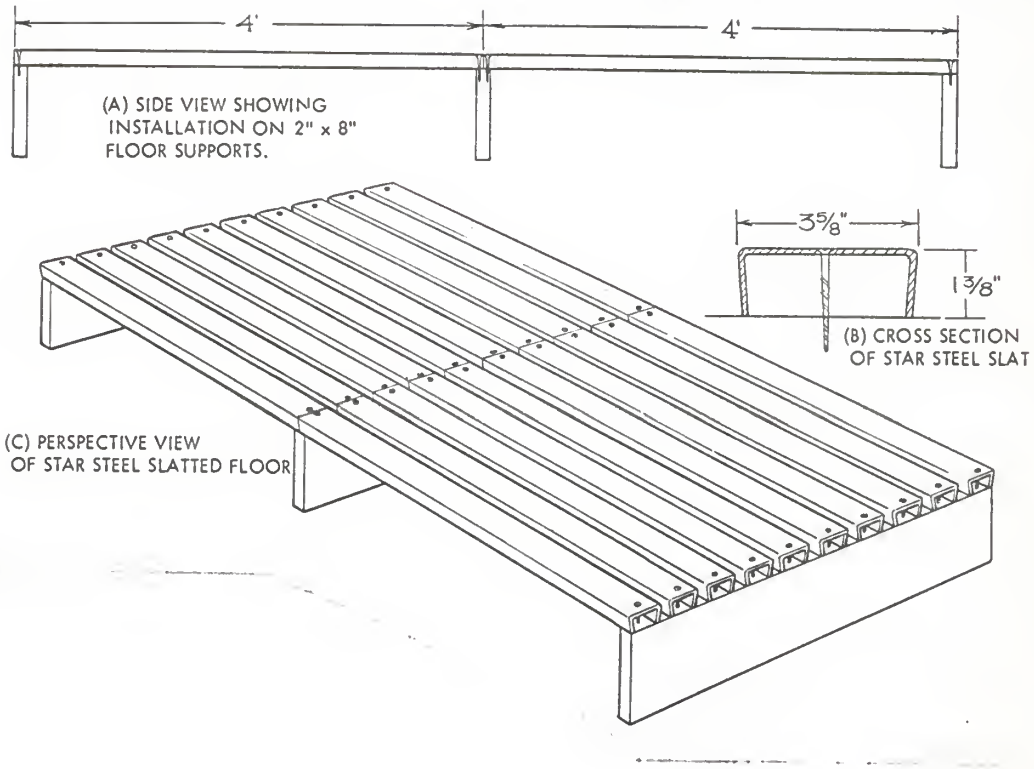


Figure 2. Details of another metal slotted floor.

steel rusts and corrodes to such an extent that it may need replacing in a few years, thus greatly increasing the cost of using steel. Galvanization, glass coating and other treatments have been tried to extend the life span. At least three companies are now offering slotted floors made of corrosion-resistant steel, but actual field tests are unavailable to determine the expected life. One building company (14) is offering a slotted floor of a resistant-type steel containing copper, chrominum and nickel. It claims to be much stronger and have more spring than mild steel. These steel slats are covered with red oxide and finished with a coat of clear polyurethane to obtain the necessary corrosion resistance. The cost of metal flooring varies between $ .80 and $1.50 per square foot.

Burgener (4) reported that the Voss School of Agriculture in Norway started testing slotted floors of concrete soon after 1953. Concrete offers the advantage of being longer lasting than wood and steel. It compares very favorably with wood in price and animal performance, and is cheaper than steel. Concrete should be of high density and have a compressive strength of at least 3750 pounds per square inch, according to Wendling (23). Rough edges on concrete can injure the pigs' feet and legs; however, the surface should not be so smooth that it is slick when wet. Burgener also reported that European concrete slats have a slight crown (.08") to prevent water from standing, which may produce a slick floor

or an ice sheet in cold weather. As would be expected, concrete has greater weight per square foot than wood and steel, which have about the same weight per square foot. A commercial slotted floor made of concrete should cost between 50-90¢ per square foot.

In order to properly design a slotted floor, the size and weight of animal and equipment should be taken into account. Hazen and Mangold (9) gave the average width of a 200 pound hog as 13.4 inches. If we assume that the weight is equally distributed on all four feet, then for an eight foot slat the uniform load would be equal to 87.5 pounds per foot for a 200 pound hog. Using these assumptions, Roth (19), and Wendling (23), and Fletcher (5) recommended various size slats for different spans for wood and concrete. Roth also indicated that the top and bottom width of a tapered wood slat may be reduced by 1/2 inch for 4 and 6 foot lengths and 5/8 inch for 8 and 10 foot lengths, if the slats are connected together by dowels. The exact size of individual wood slats for various spans will be given in the appendix.

One of the problems previously mentioned is how hogs perform on slotted floors. To this question Hoefer and Harmon (11) replied that hogs gained almost as fast in the summer of 1959 on slotted floors as those on concrete, with less feed per pound gain for the same space allowance. For the summer 1961, they reported faster gains for 15 square feet per pig than those with only 7.5 or 5.35 square feet.

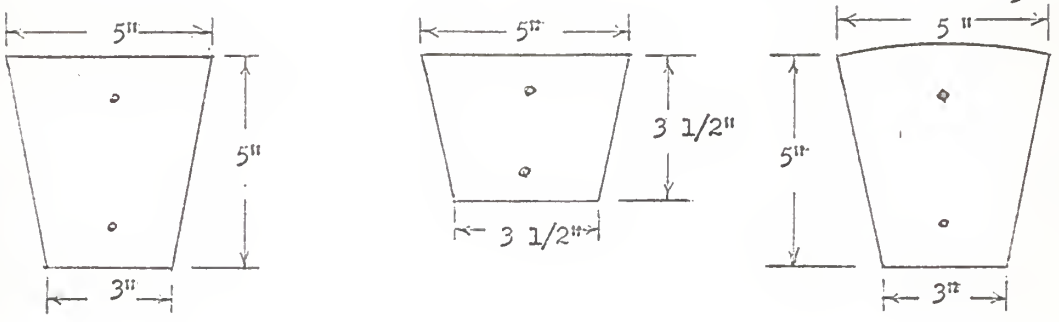


Figure 3. Typical concrete slat cross section

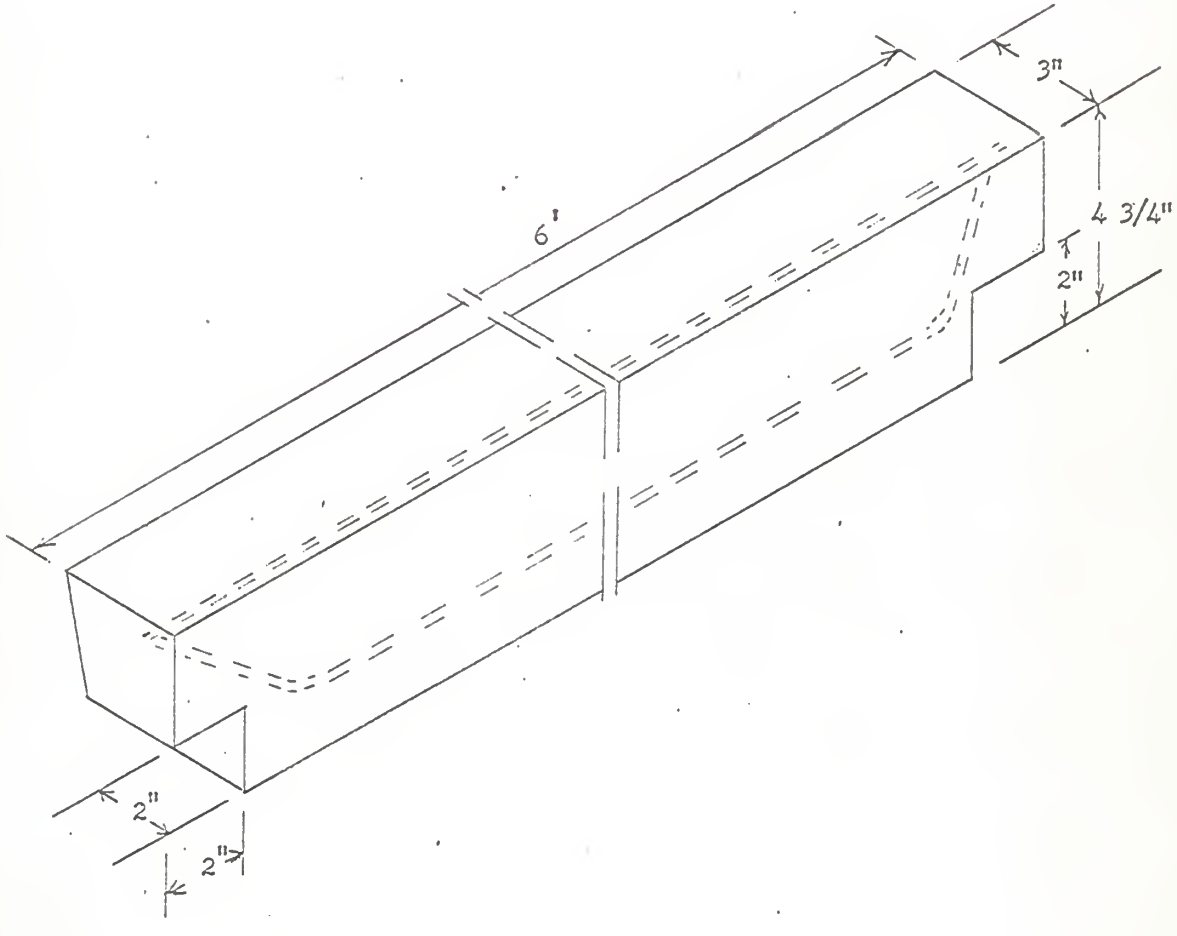
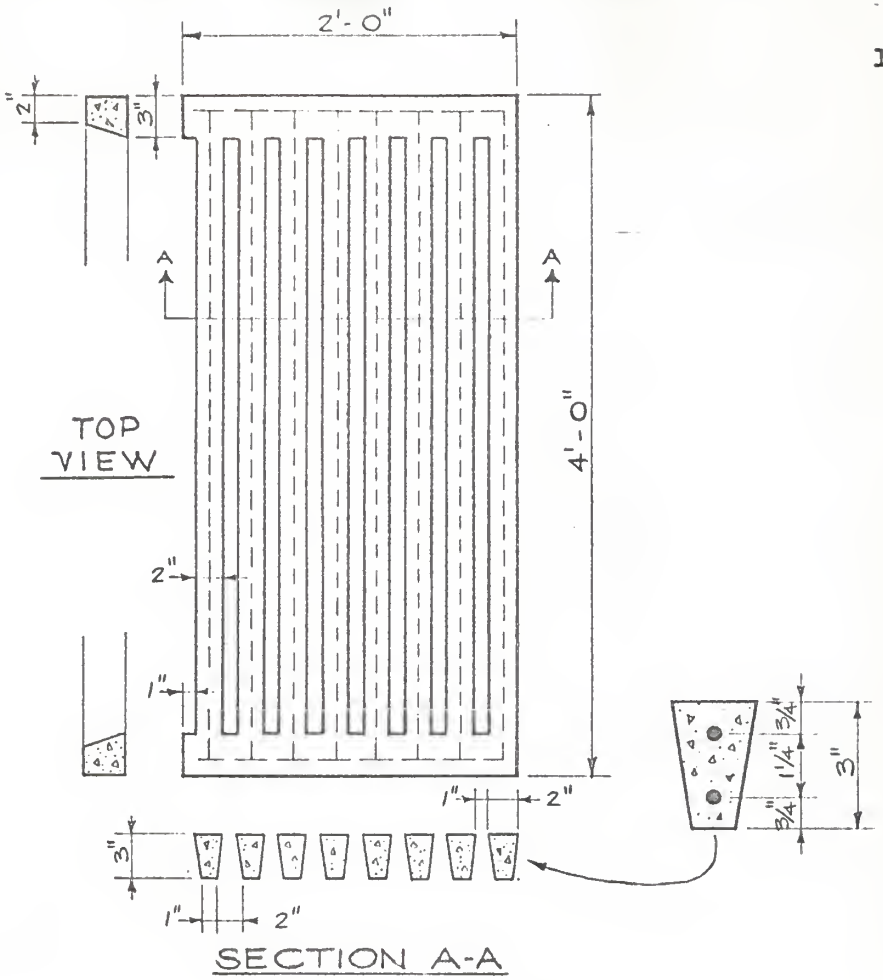


Figure 4. Concrete slat used in the portable unit



SECTION A-A

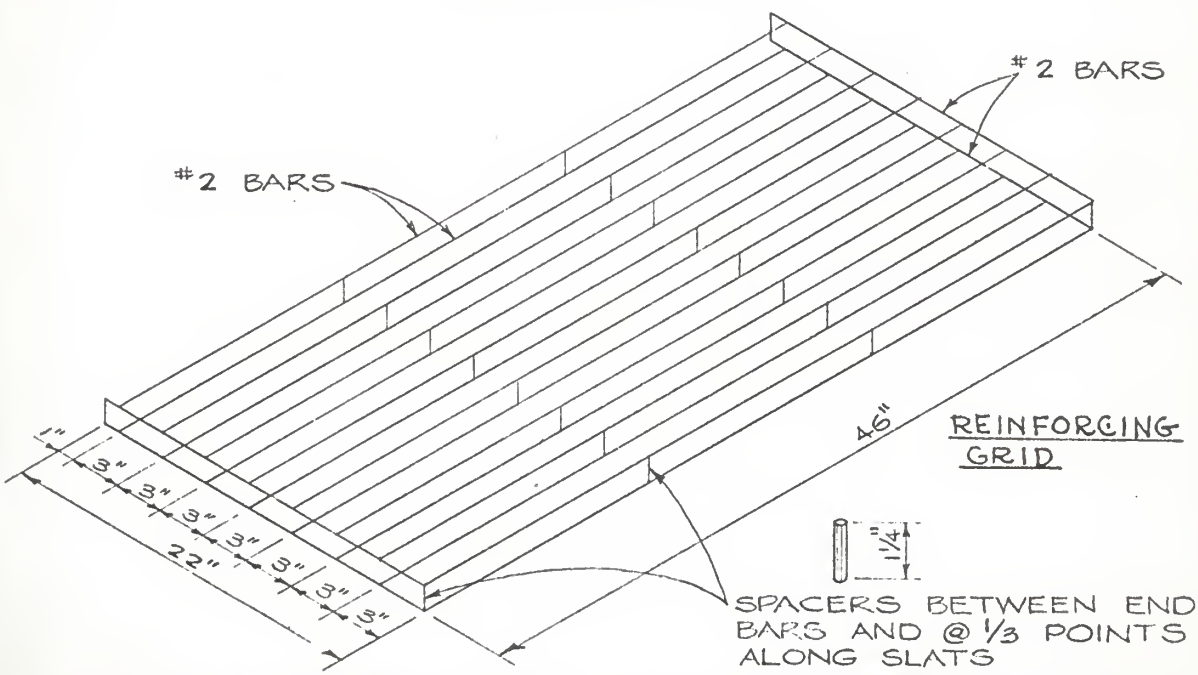


Figure 5. Precast Concrete Floor Grate (source: University of Illinois)

However, the feed required per pound of gain was less for those with reduced area per pig.

Jensen (12) reported favorably on slotted floors when he concluded that hogs gain as fast on concrete slotted floors as on solid concrete floors, and are cleaner. Burgener (4) reported that hogs gained only 1.18 pounds per day on wire mesh as compared to 1.49 and 1.40 pounds per day on concrete slotted floors and wood slotted floors respectively. This reduced gain may have been caused by the reluctancy of the animal to move on the wire mesh, as the animals showed definite evidence of foot and leg discomfort. This discomfort was not noticed on the wood or concrete slotted floor.

Zeller (24) expressed the opinion that steel is the best kind of material, provided it is corrosion resistant. He said that concrete makes the animals' feet sore a little sooner than wood or steel. Roth and Whiteker (14) pointed out the fact that in 14 trials in Illinois using 728 pigs, the pigs on steel slotted floors gained faster than pigs on solid concrete floor. However, in most other experiments pigs on slotted floors have not shown a consistent advantage in the rate of gain or feed conversion.

Heitman et al (10) pointed out that increasing the space for feeder to finishing size hogs from 5 to 20 square feet caused an increase in weight gain and feed utilization of about 10% on solid floors. They also showed that a hog with 10 square feet of space spends less time eating and standing

and more time sleeping or resting than does a hog with only 5 square feet of space. Jorgenson (21) said from actual feeding experience that hogs do better in smaller groups, 20-30 pigs per pen, than do 100 per pen.

Geurin (6) concluded that pigs on concrete slotted floor gain slower in the cold of the winter and heat of the summer than those on solid concrete. He also observed that the hogs on slotted floors were visibly affected by the heat more than those lying on concrete floors right beside the slotted floor in the control houses. Geurin related further that it required 140 pounds more feed per 100 pounds of gain in the winter for hogs on slotted flooring than for those on solid concrete; again the tests were conducted in the same building. He also related that the hogs on slotted floors were surrounded by a cooler air temperature than those on solid concrete, but the hogs on slotted floors had a higher respiration rate. This indicated that lying on a solid concrete floor had a cooling effect.

An enclosed building for confinement use should be insulated and must be mechanically ventilated. Winter drafts must be prevented and temperatures regulated for small pigs. The build-up of manure and urine under the slotted floor produces methane and carbon dioxide gases that may be harmful to hogs and man. Spillman (22) reported that with dry manure storage Europeans recommended that the pit under the slats be air tight so that air will not be exchanged above and below

the slats but did not say how this was accomplished. England (18) pointed out that his first two groups of hogs used over a lagoon presented no problem in that it was not necessary to empty the lagoon or clean the slats. But with any type of confinement feeding system, the removal of odors and gases may be more of a problem with a slotted floor than with a solid concrete floor, since the manure is not removed as often. Bond (2) had this in mind when he indicated that the ventilating system should conserve animal heat while removing the moisture and odor produced. Roth (20) added also that the ventilating system should be of variable capacity and automatically controlled to aid in accomplishing the required ventilation. The ventilation requirement is increased to some extent by the heat, moisture, and gases resulting from bacterial digestion of the animal wastes under the slotted floor. In winter the cold air drawn in should be mixed with the warmer air in the building before coming in contact with the animal. The circulation should be 5 to 8 cubic feet per minute per animal for a 200 pound hog, but in summer the ventilation capacity may need to be as high as 100 cubic feet per minute, according to Roth (19). Some air outlet below the floor level would prevent a harmful accumulation of carbon dioxide, which is heavier than air.

One method, used by a company (1) offering a complete swine finishing building with slotted floors, brings in outside air through the roof down under slotted floors, and exhausts the air through a duct back out the top for winter

ventilation. But in the summer, air is brought in through the sides of the building rather than the top, and then circulated in the building and exhausted out through the roof duct that connects the air space above the manure pit to the outside. However, Spillman (22) reported that not all ventilating factors for slotted floors are known and that heating will not be needed as a general rule if the entire building is insulated.

With the reduced space per hog, management becomes an even more important part of swine handling. Environment control is critical and temperature control is especially important with young pigs; drafts should be eliminated. Jensen (13) suggested that additional hogs should not be added to a group already on a slotted floor because of the greater possibility of injuries to the feet and legs during the adjustment period.

Under crowded conditions tail biting, skin abrasion, and leg injuries will be more common. If slotted floors mean less space per hog, stress could make hogs more susceptible to certain infections and disease spreading would be more likely. Tail biting can be avoided by hanging an old tire in the pen for hogs to chew on. Colored plastic bottles and various other items have been used to reduce the damage of ear chewing and tail biting. If a sick animal is observed it should be removed from the slotted floor pen immediately because the other animals will tend to

molest it more here than in a less crowded area.

Regardless of the flooring material used, the slotted floors should be so designed that weight, initial cost, ease of cleaning and animal discomfort are kept to a minimum. With the exception of quarry screen, each type of material offers about equal animal comfort as far as has been determined. Cleaning required of each type slotted floor is about the same for the same width opening, with the most satisfactory slot being 3/4 to 1 inch wide, with 1 inch being used when each slat is more than three inches wide. This size opening appears to be satisfactory for baby pigs as well as large animals.

Some Kansas farmers have reported that the manure freezes on the slats in an open pen in an extremely cold spell similar to that of late January, 1963. In one case the manure piled up to a depth of 4 to 6 inches before the weather warmed up enough to thaw it out. However, the operator was not concerned about this because the slats were self cleaning until this extreme cold weather came. Freezing of the manure could in part be prevented in open pens by stacking bales of hay or straw around the pen.

As a whole, farmers have been well pleased with slotted floors because of the ease of cleaning and the cleanliness of the hogs. Most investigators agree that slotted floors do not increase the rate of gain or reduce the amount of feed needed per pound of gain. Therefore, the added cost of

EXPLANATION PLATE III

A total slotted floor in a finishing unit.

(Source: Nation's Agriculture)

Plate III

slotted floors will have to be balanced by reduction of labor and less floor space per animal.

OBSERVATION OF SWINE IN A PORTABLE FINISHING UNIT WITH A SLOTTED FLOOR

A 12 x 20 foot portable unit was constructed by the Farm Building Construction class in the fall of 1962. This unit is to be used as a demonstration unit on the Kansas State University Swine Farm to determine the feasibility of a portable unit with slotted floors. Dr. Berl Koch of the Animal Husbandry Department furnished the funds for construction and C. O. Jacobs of the Agricultural Engineering Department supervised the construction with P. N. Stevenson assisting. The general design was obtained from a plan published by the Engineering Extension Service.

One unique feature of this unit is its mobility when the manure needs to be disposed of, rather than having to remove the manure from under the pen. Most of the waste is trampled through the slotted floor, reducing the cleaning necessary, giving another saving in labor. The flexibility of this portable unit is demonstrated by the fact that the hinged sides can be raised or lowered as the season demands. In the winter the sides can be closed to aid in keeping the animals warm and when the weather warms up the sides can be raised to provide additional shade and increase natural ventilation. Because the manure is in the open, natural ventilation should be sufficient without additional mechanical

ventilation being required.

The floor consisted of 84 square feet of solid plywood and 144 square feet of wood slats. The slotted floor was of commercial oak slats in 2 x 6 foot sections with a 3/4 inch dowel holding them in place. The slats are 24 inches off the ground and the unit is mounted on a double 2 1/2 inch I. D. pipe runner on each side. A picture of the unit and slats is shown in Plate IV.

Twenty-six feeder pigs with an average weight of 62 pounds were placed on this floor on February 23, 1963. A wood panel was used to partition off part of the shed to encourage the animals to go out on the slotted floor to dung. Workmen at the farm also installed a 4 x 8 foot sheet of plywood across the front to reduce the drafts in the shed. This wind break reduced the opening into the shed to less than four feet, which was so small that the hogs dunged on the floor rather than climbing over those lying in the doorway to go outside. It was evident that the wind break was unsatisfactory; it was removed after two and one-half weeks. The floor dried up in a reasonable time after the plywood wind break was removed and has remained dry since. The plywood floor had solid board insulation under it to conserve body heat while the animals lay on the floor.

One section of wood slats was replaced by concrete slats on March 7, 1963, to observe the effect of a partial concrete slotted floor. The sections of wood slats had been

EXPLANATION PLATE IV

The portable unit used for observation study.

Close-up view of the wood slats with protective coating.

Plate IV

covered with various types of plastics and epoxy resins before animals were placed in the pen.

Literature investigated revealed that no data were available concerning recommended types of protective coatings for wood slats. However, as previously mentioned, wire mesh has been used to protect wood slats, but it corrodes very rapidly and can become very dangerous to the animal when the wire breaks. Since the rapid wearing away of wood slats is one main disadvantage, Professors Jacobs and Stevenson suggested that several types of plastics and epoxy resins be applied to some of the wood slats to see if the useful life could be increased.

Several companies were contacted about their products to be applied to the slats; some reported that their product was unsuitable for such purposes while others sent samples for this test. The main considerations taken into account when selecting products to use were method of application, adhesive qualities to wood, wear resistance, and resistance to absorption of liquid (urine and water).

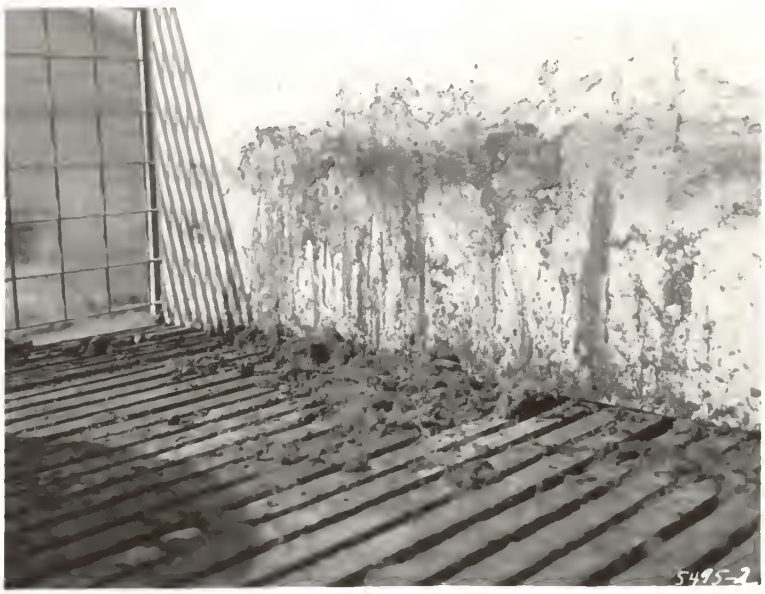
The wood slats were first sanded with a No. 1 sand paper to remove foreign materials and also to give a smooth surface. Unless otherwise indicated, each material was used to cover two slats on two different sections, or a total of four six-foot slats. See Figure 6 for the exact location. Surface preparation was completed as nearly as possible, according to the manufacturers' recommendations, before the

EXPLANATION PLATE V

Note the dirtiness of the hogs as a result of the plywood wind break.

A favorite dunging area behind the plywood wind break.

Plate V



material was applied.

Application of Protective Coatings

Metacrete[1], the first material applied to the wood slats, consisted of two ingredients, each in a separate container. One of the cans contained sand already mixed. The mixing directions of the manufacturer were followed and the red, grainy, paste-like substance was applied to the wood with a putty knife. Although care was exercised, it was difficult to obtain a uniform covering when applying the paste in this manner. However, when dry it produced a very hard, durable finish with a good bond to wood. Since this coating test concerns only a part of this paper it was not felt that additional time or money could be spent in devising a means of applying a uniform rate of application for such a small area.

As can be seen in Figure 6, next to the metacrete a Ren plastic compound was brushed on two slats in each section. Immediately a fine aluminum oxide was sprinkled on the surface of two slats and coarse aluminum oxide on the other two slats. A second coat of plastic was applied over the coarse oxide. Again the ingredients came in two separate cans and they were mixed together immediately before using. The purpose of the aluminum oxide was to reduce slippage and also to increase wear resistance. This product when dry has

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[1]Name and address of each manufacturer will be given in the Appendix.

a very hard, bright gray finish and also produces a good bond to wood.

The third material tried was pavement patching compound which The Fuller Company recommends for concrete and wood. In this case the entire contents of both containers, a clear, syrup-like substance and a black, tar-like material, were mixed together with a small bag of sand that was furnished, and applied with a putty knife to about 1/8 inch thickness. When it hardened, this application resembled cold roofing tar.

Next to the Fuller Material a slat was left untreated for a check, but the next slat was coated with Rez-Zin, a four-minute plastic filler. It was a plastic base containing some fiberglass which required a hardener to be mixed with it. No ratio for mixing was given except to add all of the blueish-green liquid in the small tube to the black jelly in the pint can. After being mixed, it had characteristics of putty and was applied with a putty knife. The Rez-Zin was very difficult to spread in a uniform layer, but a 1/8 inch coat was recommended.

In place of the Rez-Zin, on the second slat section a Devcon epoxy floor patch was applied. It consisted of a clear syrup-like substance that had to be mixed with a clear jelly. To this mixture was added about an equal volume of fine sand furnished by the manufacturer. Due to the small amount of material sent by the manufacturer only 1/4 of a slat could be treated, so it is not a true comparison to

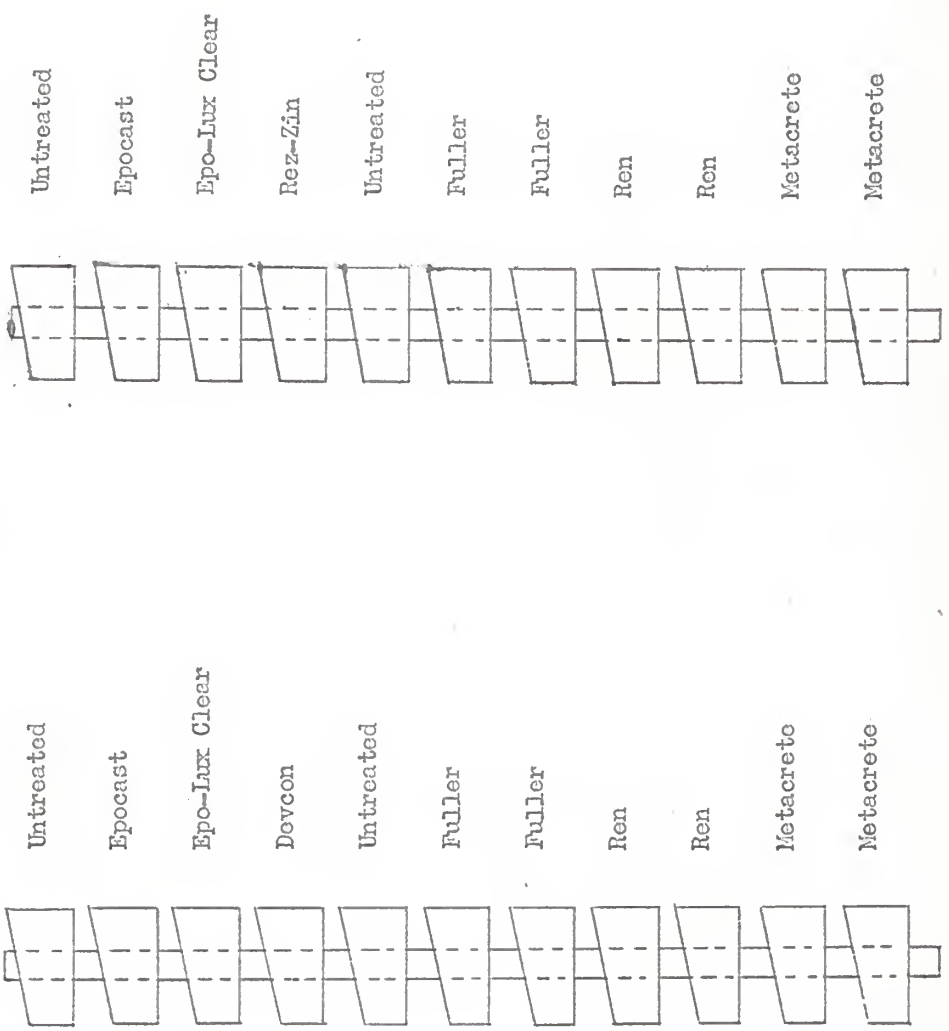


Figure 6. Location of protective coatings on wood slats.

the other materials. A first coat was applied by brush before the sand was added; then a second and final coat was applied with a putty knife.

Epo-Lux-Clear, which was applied with a brush, looked and brushed very much like varnish. It was a 100% solid epoxy plastic which required two coats for adequate protection, according to the manufacturer. Here again two liquids had to be mixed to cause hardening; both were similar to varnish in appearance. It was easy to spread butran off the edges if applied too thickly.

The last material applied was another varnish-like product which required a primer coat to be brushed on the wood. The second coat was mixed with 1 1/2 parts sand to 1 part Epocast and spread on with a putty knife. The first coat was allowed to become dry to the tacky stage before the second coat was applied. The sand was added to reduce slippage and increase wear resistance.

Each time that sand was mixed with a coating material it was according to the manufacturer's recommendation and, as previously mentioned, sand was furnished by several companies for mixing purposes.

Union Carbide Company sent material that appeared to have the qualities that are desirable in a wood coating material, but it was not used because it had to be applied by dipping, followed by baking for two hours. If it should be suitable, some commercial company might apply this

coating before selling the slats.

Designing A Concrete Slat

In order to evaluate properly the wear of unprotected wood and protected wood slats, six individual concrete slats were used to replace one section of the slotted wood floor on March 7, 1963. As the slats were six feet long and a hog is 13.4 inches wide, then 5.4 or 6 pigs are the most that could stand on each slat at a time. If we assume a top width of three inches, bottom width of two inches, and a depth of four inches for each slat, then the dead load is about 10.5 pounds per foot.

The critical loading for cattle given by Burgener (10) is the uniform live load plus an additional 1/2 animal weight. If we assume the same loading conditions for hogs, then the maximum shear will occur when 1/2 animal weight is at one support and maximum bending moment will occur when the extra load is placed symetrically with the center of the beam.

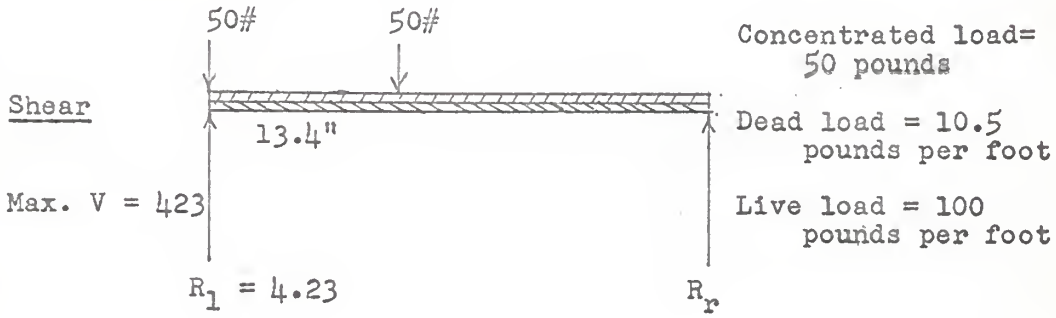
Reference to the concrete slat design problem on page 36 will show how the 3 x 2 x 4 1/2 inch slat design was arrived at. The 3 x 2 x 4 1/2 inch cross section is assumed to be equivalent to a 2 1/2 x 4 1/2 inch section. It is realized this is in error, but due to the small size of the beam the error can be neglected. The specific mix of concrete was 7 1/2 bags per cubic yard with five gallons of water per bag of cement. A compression strength of 3750

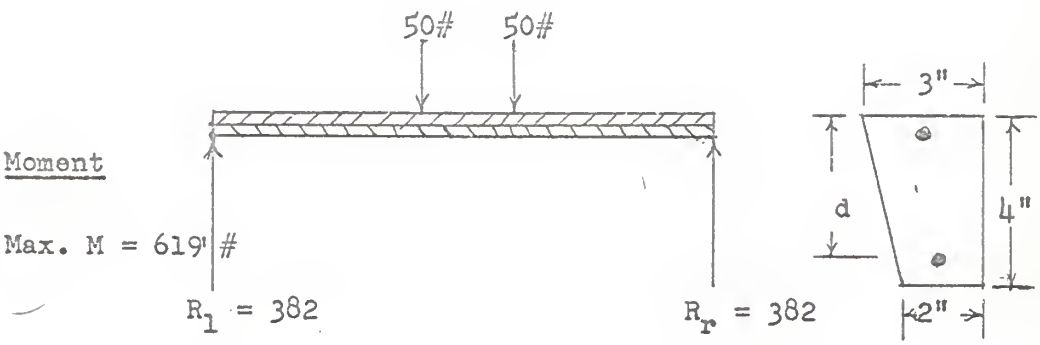
CONCRETE SLAT DESIGN PROBLEM

Stresses:

Concrete 3,000 psi = fc, and fc^1 = 45% of fc (22, 23)

Steel 18,000 psi = fs





$$K = \frac{fc}{\frac{fs}{n} + fc} = \frac{(3000)(.45)}{\frac{18000}{10} + (3000)(.45)} = .428$$

$$J = 1 - 1/3\ K = 1 - \frac{.428}{3} = .857$$

$$d^2 = \frac{2M}{fckjb} = \frac{(2)\ (12)\ (619)}{(1350)(.428)(.857)(2.5)} = 12"$$

$$d = 3.46"$$

$$A_s = \frac{740}{(.857)(3.45)(18000)} = .139 \text{ square inches or \# 4 bar}$$

Use #2 bar in top for handling purposes only.

pounds per square inch was the design requirement and only fine sand was used for the aggregate because of the limited distance between the concrete form and reinforcing bars.

No actual weight of the finished slats was obtained, but from the materials used it is estimated that they had a weight of about 75 pounds each. The concrete was mixed by hand using a mortar box and hoe, with the cement and sand being mixed thoroughly before water was added, after which the concrete was mixed continuously for ten minutes. The reinforcing bars were put in the forms before the concrete was placed in the forms. Then the forms were vibrated with an electric vibrator to increase the density and reduce honeycombing. No attempt was made to smooth the top surface except by limited use of a wood float. If the entire floor is to be concrete slats, then the edges should be rounded rather than being left square to prevent possible injury to the animals' feet.

After the removal of each slat from the form it was cured for minimum of fourteen days before being put into use. Extreme care was exercised not to crack the concrete slat, which would have allowed liquid to reach the reinforcing bars and start corrosion.

The only structural member of the unit that should be fully loaded is the center cross beam that supports the slats. To check for its load we can assume a 200 pound hog occupies about four square feet, the beam is 12 foot long;

and the slats are six feet long. The total weight that the beam will be carrying can be obtained as shown below:

12' long x 6' wide x 50 pounds per square foot = 3600 pounds

or 300 pounds per foot for live weight, plus 104 pounds for dead weight, which is a uniform load of 404 pounds per foot total. With this information in mind, the next problem is to design the beam.

Designing of Center Cross Beam

Uniform load = 404 lbs/ft

Dead load = 300 lbs/ft
Live load = 104 lbs/ft

Because this is a simple beam with uniform load, maximum bending moment will occur at the center, and is: $\frac{w\,l^2}{8}$

Where:

w = 404 pounds per foot

l = 12 feet

then: $M_m = \frac{(404)(11.5)(11.5)}{8}$

$= 6750$ foot pounds

$= 80400$ pound inches

Then using the flexure formula:

S = 1700 psi

$C = \frac{7.5}{2} = 3.75"$

$I = \frac{b\,h^3}{12} = \frac{(2)(1.625)(7.5)^3}{12}$

$= 114$ inches^4

Then, rearranging and substituting in the flexure formula:

$$M = \frac{(1700)(114)}{3.75}$$

$$= 51,700 \text{ inch pounds}$$

The 51,700 inch pounds is considerably below the design calculation of 80,400 inch pounds needed, but the design was based upon the entire slotted floor being concrete slats rather than wood slats, which were used. Therefore, the two 2 x 8 inch beams should be sufficient as the maximum live load may never be reached.

Objectional Environmental Factors

The cold of winter and heat of summer will have a more harmful effect in an open pen than in an enclosed shed. As can be seen from Plate IV the roof of the shed covered less than one-half of the floor space. Due to the discomfort caused by hot sunshine on hogs, the entire pen should be under shade for summer use. Tests performed by Bond et al (3) in California showed that an aluminum roof with a white top and black plastic shade is recommended for use over the pen. The reflective ability of the galvanized roof over the shed could be increased by painting it with white paint or whitewash, thus increasing comfort for the animals.

To reduce the effect of winter, baled hay could be stacked around the pen to serve as a wind break and reduce drafts under the slotted floor. Providing a false ceiling

of 25/32 inch rigid insulation sheathing on a framework so that provisions could be made to lower it close to the animals in cold weather would help conserve animal heat. Raising the ceiling would reduce temperature in the summer by restricting the radiant heat from the hot roof.

RESULTS OF OBSERVATIONS

Feeding Results

The twenty-six hogs observed included ten Duroc, ten Poland China, and six cross breeds. They were equally divided, thirteen barrows and thirteen gilts. At the end of the 40-day observation period the twenty-six hogs had eaten 5,278 pounds of feed and gained a total of 1872 pounds, or an average of 72 pounds each. The average daily gain was 1.79 pounds with a feed conversion of 2.84 pounds feed for each pound of gain. The highest daily gain was 2.125 pounds, with the lowest being only 1.2 pounds. (This animal was operated on for prolapse.)

This type of performance compares very favorably with tests from the University of Illinois in which hogs gained only 1.49 and 1.40 pounds per day on concrete and wood slats respectively. Results from Michigan State University indicated the maximum gain was 1.78 pounds per day on solid concrete floor, which was better than the 1.60 pounds on concrete slats.

No adverse damage to feet or legs was noticed on the

animals, even though some had knots on the rear legs below the hock. As a general rule, the hogs were extremely clean throughout the test and no ear or tail chewing was observed. Occasionally the animals were observed eating some of the waste on the floor; to discourage this, rocks were placed on the floor for the animals to root around. In conference, Dr. Koch indicated that he was well pleased with animal performance and cleanliness.

Results of Protective Coatings

The wood slats that were covered with a protective coating showed little evidence of wear at the end of the 40-day trial; although the wear of the unprotected wood slats was small, it was visible. Because of the glazed surface of Metacrete, the slats covered with it stayed cleaner than any of the other covering materials; however, it was the only surface that was slippery when wet.

The solid plywood floor was damaged severely by animal wear and chewing. To lessen any further damage, an epoxy compound was brushed on the plywood floor at the end of the trial.

In order to evaluate properly the wear resistances, the epoxy coverings should be applied at a uniform rate and tested for a longer period of time.

SUMMARY

Slotted floors are not new, but it has been within recent years that hog raisers have used them extensively. This popularity has been stimulated by the savings in labor for cleaning and by improved sanitation.

Tests at the University of Illinois showed that pigs on slotted floors and solid floors gained at comparable rates when space allowances were identical. This fact was also proved by several hog farmers in different states.

One objection to slotted floors is the removal of waste from under the slotted floor, and then what to do with it after it is removed. To overcome this objection wet pits, dry pits, and lagoons have been tried.

Still another problem is determining which type of building material is best for slats. At the present concrete, wood, steel, and masonite are being used to answer this problem. Comparable gains have been obtained from wood and concrete, but concrete lasts longer.

No conclusive evidence was available as to the discomfort caused an animal from heat and cold on a slotted floor as compared to a solid floor. This suffering may take the form of slower gain or poor feed conversion, or both. However, tests from Ralston Purina Company indicate that the animal on a slotted floor was affected more from the extreme cold and excessive heat than the animal on a solid floor.

Decay of the waste under the slats will produce methane

and carbon dioxide gases, additional heat, and moisture; therefore, the ventilation must be mechanical and of variable capacity to meet varying conditions.

The operator must decide on a total or partially slotted floor that best fits his needs. Although the total slotted floor will require less cleaning, it will cost more; while partially slotted floor requires more cleaning, it will reduce the initial cost of the building.

Due to the crowded conditions on a slotted floor, leg and foot injury, as well as ear chewing and tail biting, may be more common. Also the animals may chew the floor if it is wood. To reduce this molesting, old tires or such may be put in the pen for the hogs to chew on.

When the results of the 40-day feeding test were compared to the results of tests performed by Michigan State University, it is evident that comparable gains can be obtained on slotted and solid floors.

Determining the value of plastic coating on wood slats will require a longer test than was possible with this portable unit. Although these coatings showed some advantages, the extent of the advantage was not determined.

ACKNOWLEDGMENTS

The author is deeply indebted to his wife, Lou, for the encouragement and devoted assistance which she gave during the preparation of this report. He is also indebted to his Major Professors, P. N. Stevenson and C. O. Jacobs for their sincere and attentive direction and constructive criticism offered.

Thanks are also due to Associate Professor R. I. Lipper of the Department of Agricultural Engineering and to Dr. Berl Koch, of the Department of Animal Husbandry.

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APPENDICES

Name and Address of Suppliers
of Protective Coatings observed
in this study

1. Epocast

   Furane Plastic, Inc.
   4516 Brazile Street
   Los Angeles 39, California

2. Epo-Lux Clear

   Steel-Cote Manufacturing Co.
   3418 Gratiot
   St. Louis 3, Missouri

3. Devcon material

   Devcon Corporation
   Danves, Massachusetts

4. Fuller material

   The H. B. Fuller Co.
   2000 Funston Road
   Kansas City, Kansas

5. Metacrete

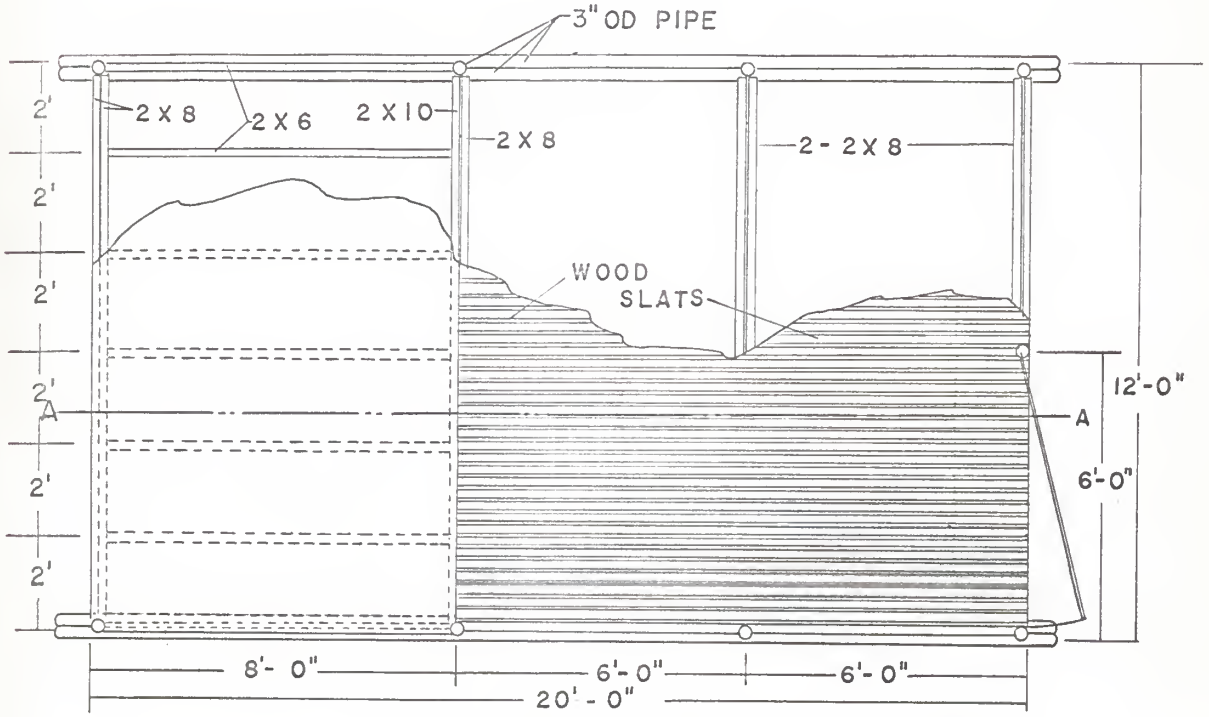
   American Metaseal Corporation
   18666 Fitzpatrick
   Detroit 28, Michigan

6. Ren plastic

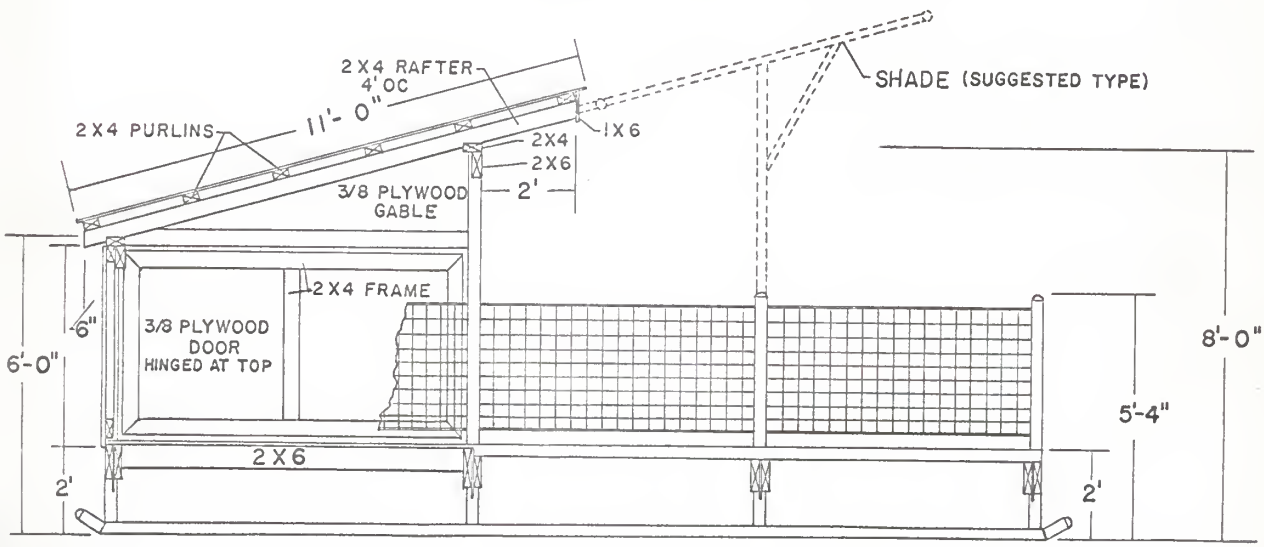
   Ren Plastics, Inc.
   South Cedar Annex Box 9337
   Lansing 9, Michigan

7. Rez-Zin

   Marson Corporation
   Revere, Massachusetts



PLAN VIEW



SECTION A-A

PORTABLE SWINE FINISHING UNIT	
AGRICULTURAL ENGINEERING KANSAS STATE UNIVERSITY	
DR BY- CJ	SCALE - 1/2" = 1'
TR BY- CJ	DATE - Mar. 1963

List of Materials

Lumber			
Joist	1 - 2" x 10" x 12'	No. 2 Common Fir	$ 3.00
"	7 - 2" x 8" x 12'	" " "	16.80
"	7 - 2" x 6" x 8'	" " "	8.40
Plates	2 - 2" x 6" x 12'	" " "	3.60
	2 - 2" x 4" x 12'	" " "	2.40
Rafter	4 - 2" x 4" x 12'	No. 1 Common Fir	5.20
Door Framing	9 - 2" x 4" x 8'	No. 2 Common Fir	7.20
" "	2 - 2" x 4" x 12'	" " "	2.40
Tie	2 - 2" x 4" x 8'	" " "	1.60
Facia	1 - 1" x 6" x 12'	No. 1 " "	.96
Doors & Gable	128 sq. ft. 3/8" CC Ext. Plywood		23.00
Floor	96 sq. ft. 3/4" CC Ext. Plywood		21.10
"	144 sq. ft. wood slats, white oak		80.64
Metal			
Runners, Framework	125 ft. 3" OD used pipe (Drill stem)		43.75
Fence	61 lin. ft. 3' height welded wire fencing		64.00
Roofing	6 sheets 11 ft. length 1 1/2 corr. galv.		15.73
Gusset Plates & ties	1/4" thickness scrap metal		3.00

Misc.

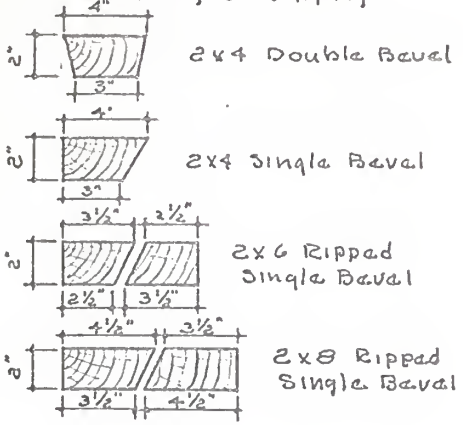
20 BR framing anchors	$2.00	24 3/8" x 4 1/2 carriage bolts	1.56
5# Casien glue	2.40	24 3/8" x 2 1/2 machine bolts	.96
5# 1 3/4" lead head galv. nails	1.65	1# 3/8 flat washer	.20
5# 6d common galv. nails	.80	10 5" Butt hinges	3.10
5# 4d common galv. nails	.80		

Total Cost $316.25

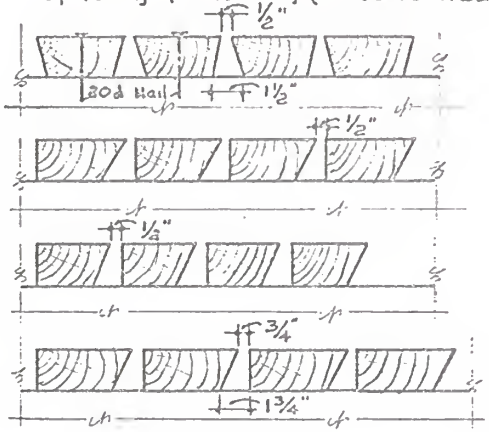
Cutting - Spacing - Placement - and Supporting Data

4' SLAT SPAN

Cutting or Shaping



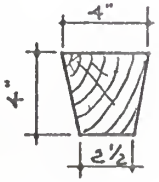
Spacing & Placing (Unseasoned)



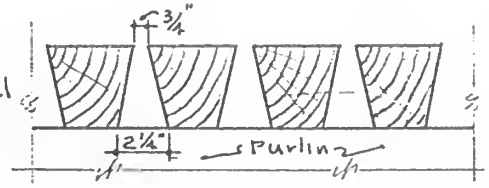
Wood Slat Support Purlins
Size for different purlin spans

4' span	—	2x6 single
6'-span	—	2x8 single
8' span	—	2-2x6's or 2x10 single
10' span	—	2-2x8's or 2x12 single
12' span	—	2-2x10's

6' SLAT SPAN

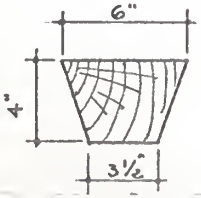


4x4 Double Bevel

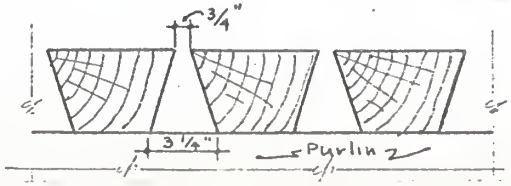


6' span	—	2-2x6's or 2x8 single
8' span	—	2-2x8's or 2x12 single
10' span	—	2-2x10's
12' span	—	2-2x12's

8' SLAT SPAN



4x6 Double Bevel



8'-span	—	2-2x10's
10'-span	—	2-2x12's
12' span	—	2-2x12's

RESULTS OF FEEDING SWINE ON SLOTTED FLOORS

by

CARL V. CHUMNEY

B. S., Texas Agricultural and Mechanical College, 1957

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Farm Mechanics
Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

Slotted floors are an attempt to reduce the amount of labor required for cleaning and improve sanitation in a swine handling system. Farmers have used them in a rapidly increasing number within the last few years without knowing the answers to many of the problems created by using slotted floors.

Several manufacturers are making slats out of wood, steel, concrete, and masonite in an attempt to satisfy each farmer's desire. But no one material appears to be best under all conditions or to please every hog raiser.

Slotted floors are not new, for they have been used in Iceland for more than 200 years and in Norway for at least 30 years. The first extensive test of slotted floors was started by the University of Illinois in 1955.

Cleaning time is reduced, bedding is unnecessary and less floor space per animal is required when slotted floors are used; however, the slotted floor will cost more than a solid floor and present some additional management problems.

Animal performance on slotted floors compares favorably with performance on solid concrete floors, with no noticeable difference in feet and leg injury.

Ventilation requirements will be greater for a house with slotted floors than for one with a solid floor, due to the extra odors and gases produced under the slats. The waste can be stored in a wet pit, dry pit, or moved to a lagoon.

A hog house can have the entire floor of slats or only a part of it. Here again no one system suits each one, but most farmers prefer a partially slotted floor.

If an open pen is used, some protection must be provided to reduce the discomfort from cold or heat to reduce the stress on the hog. This stress may take the form of slower or less efficient gains, or both.

Farmers have been well pleased with slotted floors as a whole, because they are easier to clean and the hogs stay cleaner than on a solid floor. But the added cost of the slotted floors must be offset by a reduction of labor and less floor space per animal.

Twenty-six feeder pigs in a portable unit with slotted floors were observed for a 40-day period. As an extra study, some of the wood slats were covered with plastics and epoxy to see if the useable life could be extended. Metacrete, Ren plastic, Fuller pavement patching compound, Rez-Zin plastic filler, Devcon floor patch, Epocast, and Epo-Lux Clear were the materials used.

Six concrete slats were also used in place of one 2 x 6 foot wood slat section to observe the effects of concrete slats.

The cold of winter can be reduced in this portable unit by stacking baled hay around the pen, while the radiant heat of the sun can be reduced in the summer by building a plastic shade over the pen and also painting the galvanized roof white.

For a 40-day trial the hogs gained 1.79 pounds per day and required only 284 pounds of feed for 100 pounds of gain, which is very good under any condition.

Due to the short duration of the test the protective coatings showed little difference in wear.