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by

P. J. Sereda and H. F. Slade

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PREFACE

This is a further progress report on the work being done by the Division of Building Research at the request of Central Mortgage and Housing Corporation and in co-operation with the Forest Products Laboratories of the Department of Northern Affairs and National Resources, in connection with the problem of asphalt shingles on wooden roofs.

Field observations are also being made into the performance of asphalt shingles on roofs constructed with different widths of boards, the original inquiry having arisen because of questions relating to CMHC standards regarding such board widths.

A previous report on work in this project was DBR Report No. 84, "The Effect of Moisture on Asphalt Shingles". Other reports will be issued to describe other phases of the work. Comments on the contents of the present report will be welcomed.

Ottawa,
October 1956.

R.F. Legget,
Director.

BUCKLING OF ASPHALT SHINGLES

by

P. J. Sereda and H. F. Slade

Although the buckling of shingles on wood roof decks has been observed and reported, little has been done to establish the factors responsible for this problem and to suggest solutions. The asphalt shingle industry has contended that the use of boards no wider than 6 inches would minimize this problem. It was of importance to the lumber industry to show that the width of boards was not the only pertinent factor. As a result the Forest Products Laboratories and the Division of Building Research were asked by all the parties concerned to investigate the relationship between the buckling of shingles and the width of roof boards.

In a recent report (1) it has been shown that asphalt shingles are not dimensionally stable when exposed to conditions of wetting and drying. The dimensional instability of wood caused by changes in moisture content is well known. From the existing information about shingles and boards, it was possible to analyse the expected movements of an assembly of boards and shingles under extreme conditions. It was of interest to demonstrate experimentally whether the predicted movements in the boards and the shingles did occur. The following experiments were designed to provide this information.

Experimental Procedure and Samples

This investigation was concerned with 3-tab 210-lb. asphalt shingles only. An apparatus was designed to measure the height of buckle produced in a dry asphalt shingle for various relative movements of the shingle nails at 5-inch centres as would occur when the wood deck swells or shrinks with changes in moisture content. This apparatus consisted of an assembly of four rows of shingles with 5-inch exposure on two pieces of ¾-inch plywood. In the test assembly (Fig.1) the two plywood decks could be moved horizontally relative to each other. Shingles were nailed on the plywood deck first, in the manner followed in practice, with the shingle tabs staggered; then a new assembly was nailed with the tabs vertically aligned. As the break between the two plywood decks was located between the second and third row of nails, relative movement of these two decks produced a buckle in the second row of shingles. The height of buckle was measured in the slot between the tabs. The measurement was made with a dial gauge adapted for this purpose (Fig.1).

Assemblies of asphalt shingles on wood decks served as samples. Lumber used for these samples consisted of 1-inch pine boards, 6 and 12 inches wide. These were nailed to 2- by 4-inch spruce rafters on 16-inch centres. Two nails were used for the 6-inch boards and three for the 12-inch boards. Five rows of 3-tab 210-lb. asphalt shingles were nailed on these prepared wood decks exposing 5 inches of the shingles to the weather. The shingle nail positions were marked and indicators were placed at the contact between boards and rafters to indicate the movement of that point of the board relative to the rafter. The indicators consisted of a needle the end of which was held in a tiny hole provided by a stud driven into the board. The needle had a pivot point consisting of a hole $\frac{1}{4}$ inch from the board through which a nail was driven into the rafter. The other end of the 3-inch needle indicated the movement of the board multiplied 12 times. The manner of installation is shown in photographs (Fig.2).

Reference points consisting of brass round-head nails having a 1/64-inch hole drilled into the heads were driven into the boards at 2-inch centres to enable the measurement of dimensional changes due to wetting or drying. A dial gauge was adapted to serve as an extensometer.

Two sample assemblies consisting of 6- and 12-inch wide boards were made after the boards had been conditioned in a room controlled at 50 per cent relative humidity. Two other assemblies consisting of 6- and 12-inch wide boards were made after the boards had been conditioned in the humid room controlled at 100 per cent relative humidity. The conditions of moisture content of the boards and shingles are given in Table 1.

The samples were cycled between conditions in one room controlled at 50% RH and 73°F. and another room controlled at 100% RH and 73°F. The samples were kept at each condition for about one month and each sample was given three complete cycles or seven changes of conditions. Measurements were made at the beginning and the end of each half cycle. The moisture content of samples of the shingles was determined after the last cycle.

Results and Discussion

The data from the experiment designed to show the relationship between the movement of shingle nails and the corresponding size of buckle are presented in Fig.3. These show a considerable variation between the first cycle and subsequent cycles. This can be accounted for by the fact that after the first cycle a plane of weakness was developed in the shingle along the line where the shingles bent the most.

TABLE I

SUMMARY OF DATA ON CONDITIONS OF BOARDS AND SHINGLES FOR THE FIRST CYCLE

Sample No.	Width of boards (inches)	Cycle	M.C. of boards (%)	Dimensional change of boards (%)	M.C. of shingles exposed to weather	M.C. of shingles contact to wood
12a	6	dry	8	0		
	"	wet	24	2.13		
	"	dry	10	0.38	1.0	.95
12b	6	dry	8	0		
	"	wet	23	1.6	1.9	3.8
	"	dry	10	0.45		
13a	12	dry	8	0		
	"	wet	24	2.6		
	"	dry	10	0.55	1.0	1.0
13b	12	dry	8	0		
	"	wet	21	2.65	2.0	3.0
	"	dry	9	0.46		

During subsequent cycles therefore the shingle would bend sharply along this centre line and would show a higher buckle for the same relative movement of the nails. This effect was not observed in the samples under study when the shingles buckled due to wetting or drying.

Data presented in Fig. 3 were obtained with dry shingles subjected to rapid relative movement of the deck. Therefore these data should not be applied directly to predict the buckle height corresponding to a given movement in the deck when the movement is caused by wetting or drying involving a slow rate of change and when the shingles are at other than the dry state. Only large movements caused a fairly reproducible buckle.

Table 1 presents the experimental data of the moisture content changes and dimensional changes of the boards and the shingles in the samples during first cycle of wetting and drying. It should be noted that there was considerable variation in dimensional changes of boards. The fact that the part of the shingle next to the boards picked up more moisture than the part exposed to the air is significant. This may justify the use of 15-lb. asphalt felt under the shingles.

Figure 4 presents the data from the first experiment demonstrating the swelling of asphalt shingles on wetting. In this experiment the shingles were nailed to a metal base so that no movement of shingle nails was possible and then the assembly was left in a room conditioned to 100 per cent relative humidity for a month. The buckling of the shingles is shown graphically and corresponds roughly to the swelling of the shingle by 0.05 inch in 5 inches or the equivalent of 2 per cent change in a board 2.5 inches wide.

The experimental and computed data giving the movements of the shingle nails with the wood deck and the corresponding buckling or tearing of shingles are presented in graphical form in Figures 5, 6, 7 and 8.

Figures 5 to 8 are drawn to show to scale the positions of the shingles and their nails designated (a), (b), (c), (d), and (e) with respect to the boards and their centre lines designated 1, 2, 3, 4, and 5. The positions A, B, C, and D on the shingles denote the lines between the shingle nail positions along which buckling was measured and are represented on the vertical scale at the extreme left as the height of the buckle in inches. The changes in the height of the buckle during repeated cycles are represented by successive lines displaced to the right and numbered 1 to 3. At the right of the diagram are shown multiple graphs which represent the movements of the shingle nail positions (a), (b), (c), (d), and (e) with respect to their initial positions and with respect to each other. Thus at any cycle the vertical movement of the shingle at A, will be determined by the direction and amount of movement of nail positions (a), and (b), with respect to the initial position shown as zero. Similarly the behaviour of shingles at B, C, and D, can be predicted from the corresponding movements of the appropriate two shingle nail positions (b)(c), (c)(d), and (d)(e).

In general the changes occurring on the first half cycle were large in comparison to those in subsequent cycles. These changes represented irreversible shifts of position due to uneven yielding of nails or cracks developing in the boards. The direction of movement during the first half cycle was very important and often determined the future behaviour of the sample. For example, if the movement during the first half cycle was one of separation of the two rows of shingle nails, this caused the tearing of the nail holes in the shingle and on the reverse cycle the movement could take place without affecting the shingle.

In reality this was not always the case possibly because the nail holes were not enlarged sufficiently during the first half cycle, when stretching of the shingle took place, to allow free movement of the nail in the nail hole on the reverse cycle and thus some buckling was observed in most of such cases.

The instances where small movements in the wood deck were accompanied by a buckle of considerable size are further evidence that the dimensional changes in the shingle itself contributed to the buckling.

When calculating the predicted movements of the shingle nail positions in the wood deck the assumption was made that all movements of the board would occur symmetrically about the centre line of the board. The extent of the movement was based on the measured dimensional changes that occurred in the boards during the cycling. From the data presented in Fig. 5 it is evident that shingle nail positions (d) and (e) did not move as predicted but rather shifted position resulting in a large buckle at D where a buckle of the size shown at A and B should have occurred. For the same reason no buckle occurred at C although it should have been the same as at A and B.

Examination of the model of the assembly of shingles on 6-inch wide boards shows that the relative movement between any two rows of shingle nails will equal the movement caused by swelling or shrinking of one-inch width of board. In every sixth row of shingles, however, the relative movement will correspond to the movement due to the swelling or shrinking of 5-inch width of board because two rows of shingle nails will be located in the same board.

The results from sample 13a presented in Fig. 7 show the large movements of shingle nail positions which are possible when 12-inch wide boards are being wetted from the dry state. Positions (a) and (b), also (c) and (d) undergo a relative movement corresponding to the change in dimension due to swelling of a 7-inch wide board. This amounted to about 0.2 inch and produced a buckle of almost ½ inch. The movements and the buckling in this case were approximately as predicted. The large relative separation of nail positions (b) and (c), also (d) and (e) in Fig. 7 caused by swelling of 5-inch width of board caused a tearing of the shingle nail holes by about 1/8 inch.

The results from sample 13b as shown in Fig. 8 illustrate that the shrinkage of boards that are nailed when wet can cause cracks to develop with the result that movements of shingle nail positions can be very different from what they are predicted to be. A good example is the shingle nail positions (b) and (c) in Fig. 8 where a large buckle at B should have occurred. The board cracked at about the mid-position causing little movement at the shingle nail positions. There should not have been buckling of shingles at A and C as is shown. This buckling at A and C can only be explained by considering that part of it is due to the swelling of the shingle and part due to the gripping of the nail in the shingle at the new extended position corresponding to the first half cycle.

Summary and Conclusions

These experiments have demonstrated that asphalt shingles will buckle as a result of the relative movement due to swelling or shrinking of the boards to which the shingles are nailed and also as a result of swelling of the shingle itself when the moisture content is changed.

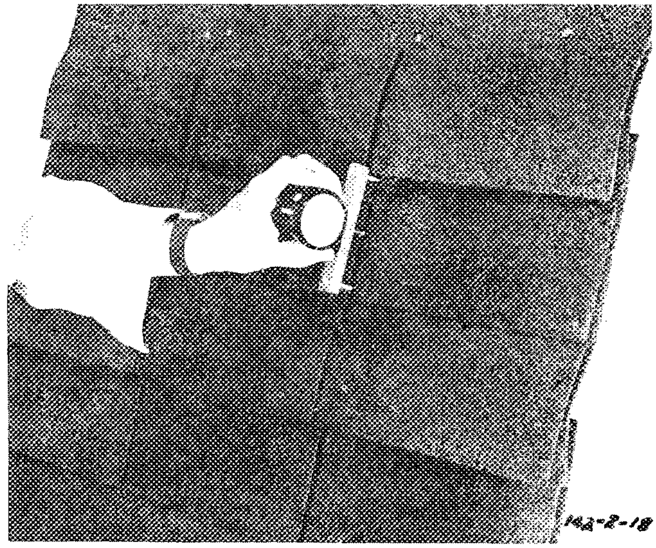
It has been shown that the chances of large buckles being produced are greater with 12-inch wide boards than with 6-inch wide boards. It is also evident when 12-inch wide boards are used and the first ½ cycle involves a drying of the initially wet boards (a case most likely to occur in practice) that there is a good chance the boards will crack longitudinally and will not produce the buckling that would be expected.

The results indicate that boards nailed to rafters with two or three nails cannot be expected to swell or shrink symmetrically about their centre lines. The longitudinal cracking and uneven yielding of nails contributes to this.

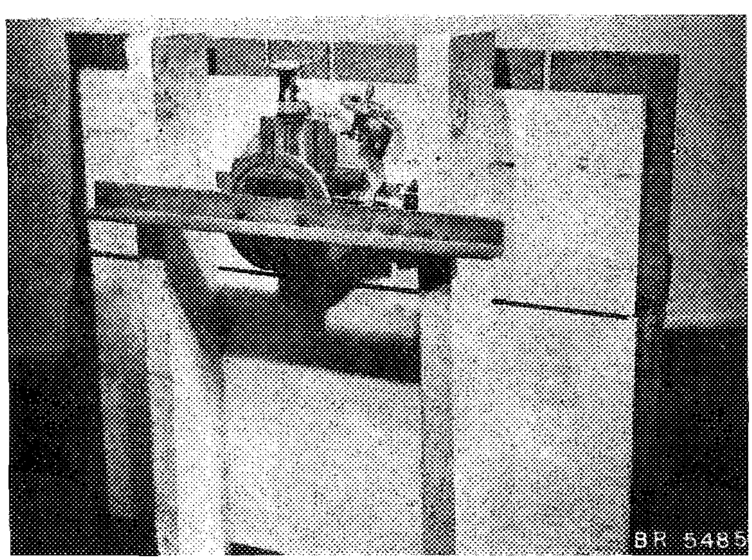
In conclusion it can be said that some degree of buckling of shingles is to be expected where the shingles are nailed with two rows of nails as long as both the shingle and the wood deck are dimensionally unstable with changes in moisture content.

References

(1) Ayukawa, M. and P.J. Sereda. The effect of moisture on asphalt shingles. National Research Council of Canada, Division of Building Research, Internal Report No. 84, May 1956. 11p.

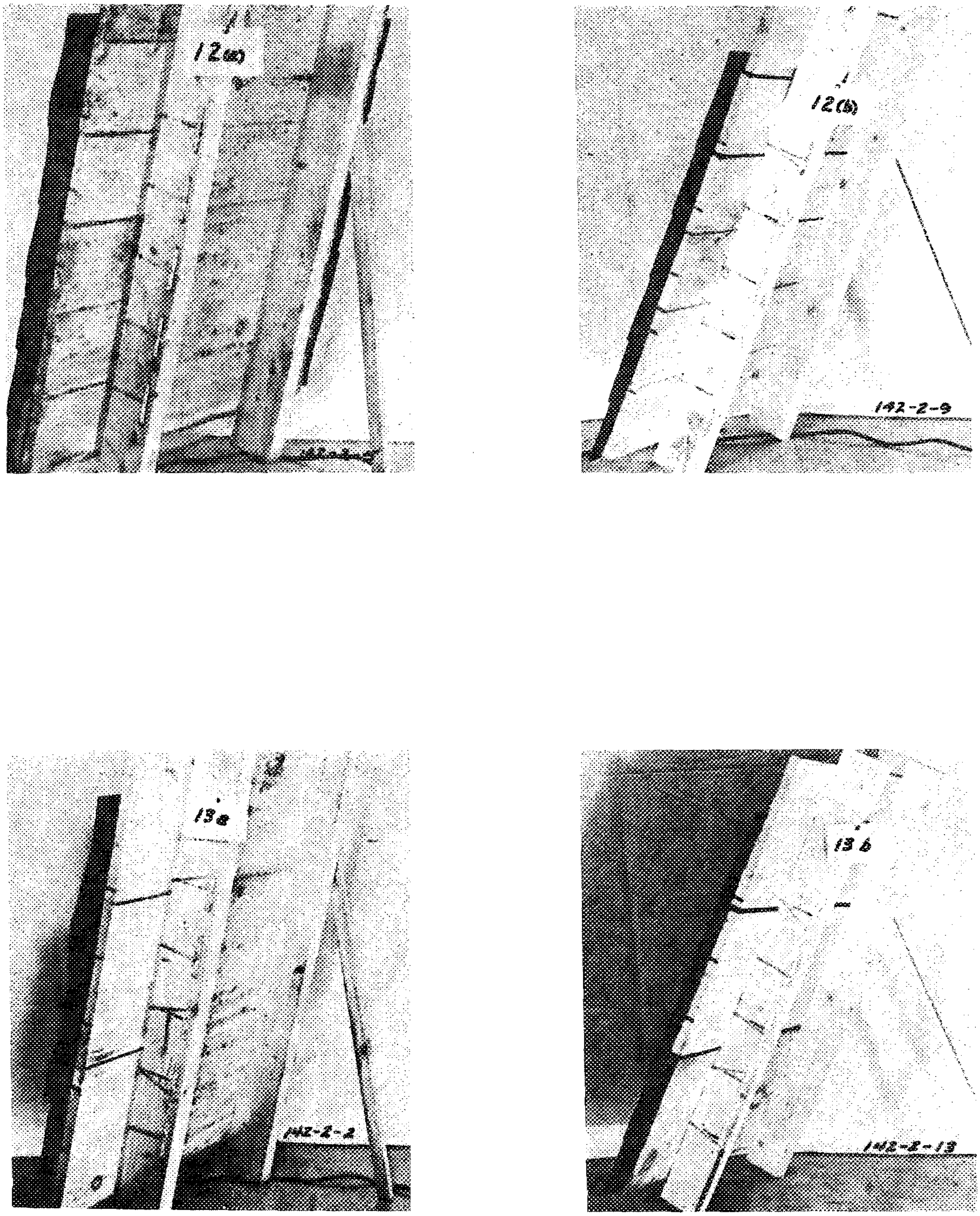


Dial gauge used for measuring the
buckle height.



Apparatus used for finding the relationship between buckle height and corresponding change in the 5-inch span between two rows of shingle nails.

FIGURE 1



Photographs showing the four assemblies used as samples and the indicators.

FIGURE 2

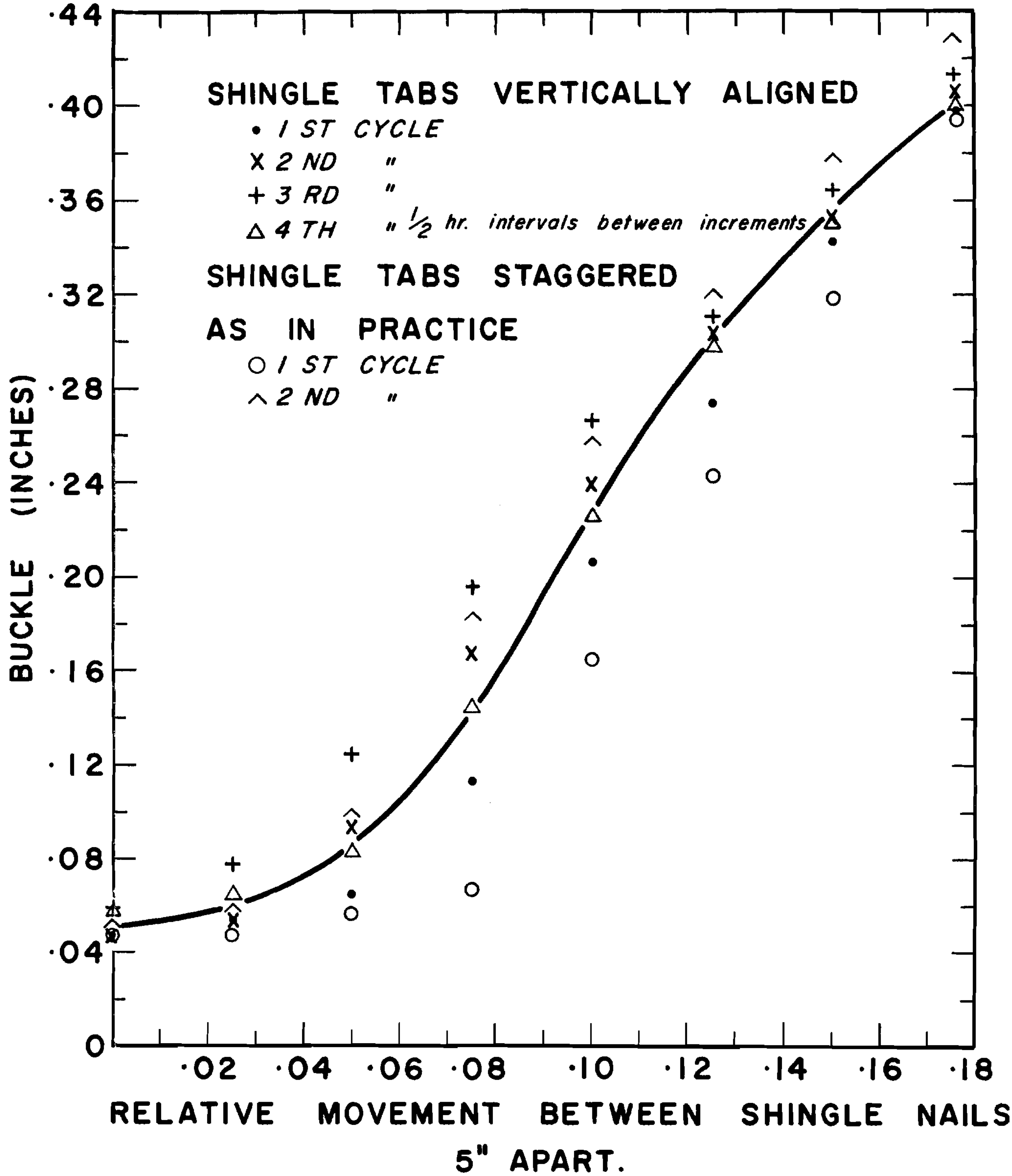


FIGURE 3

BUCKLING OF DRY ASPHALT SHINGLES DUE TO RELATIVE MOVEMENT OF SHINGLE NAIL POSITIONS.

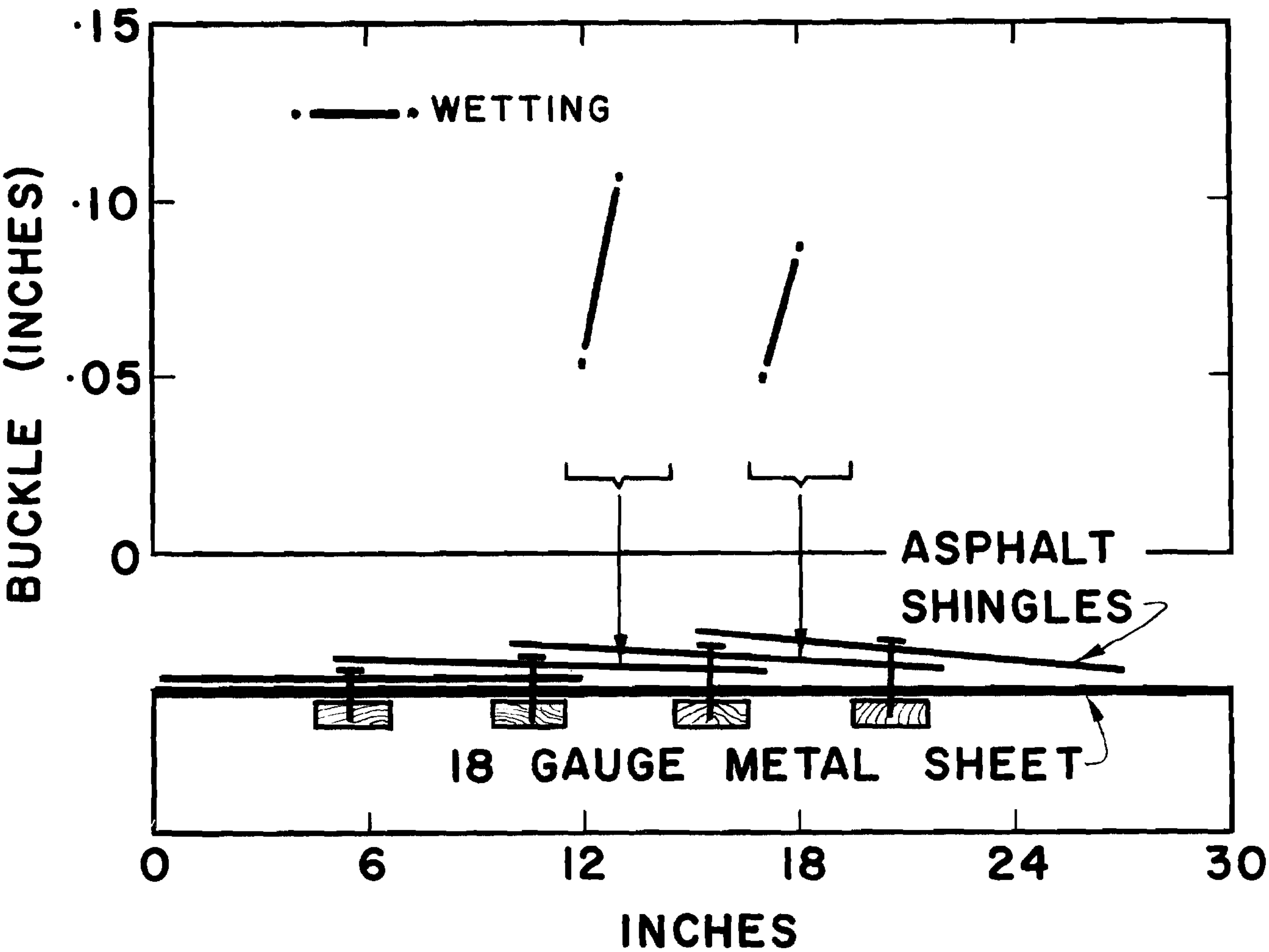
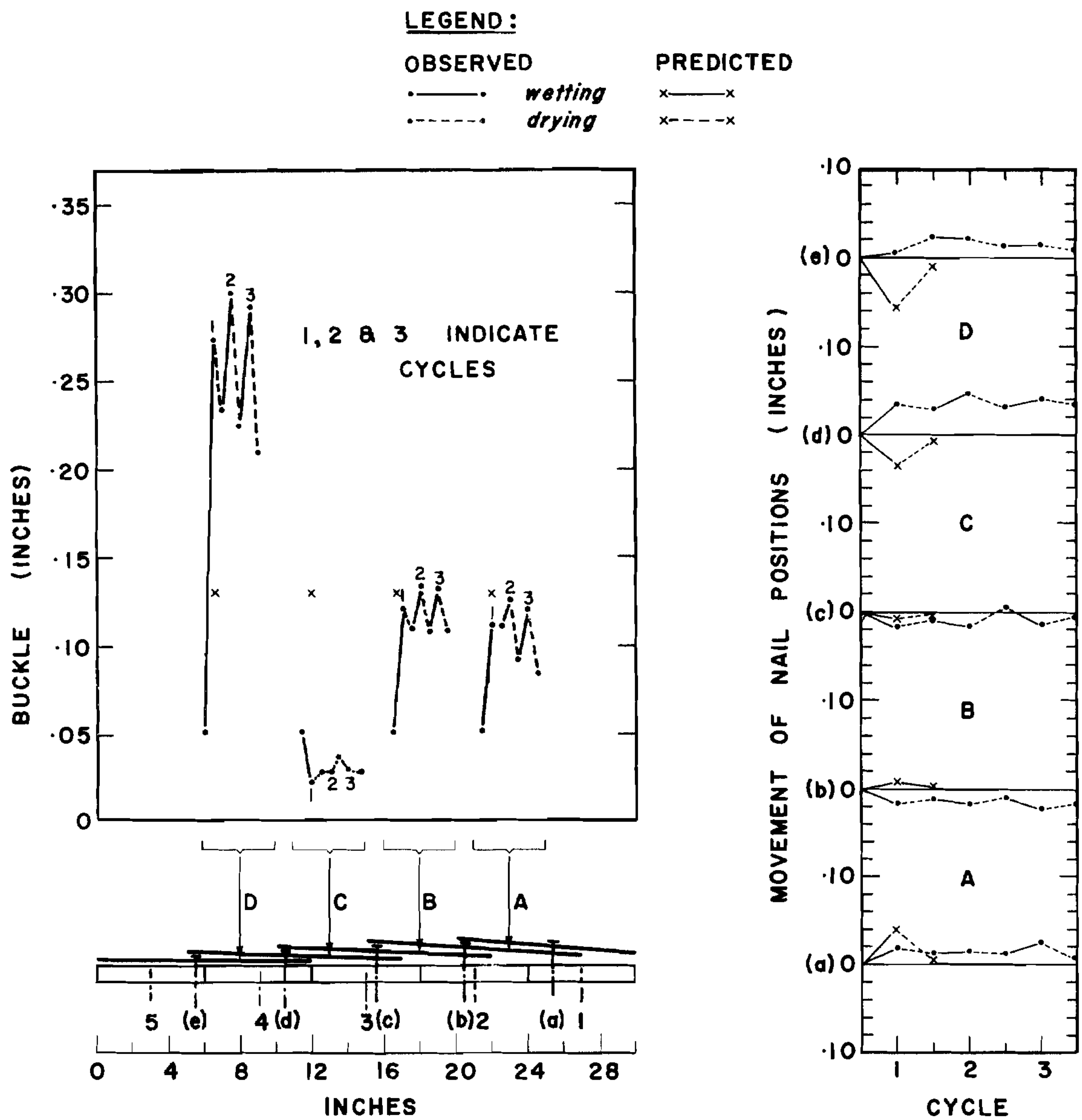


FIGURE 4

BUCKLING OF ASPHALT SHINGLES ON SHEET METAL BASE DURING WETTING.

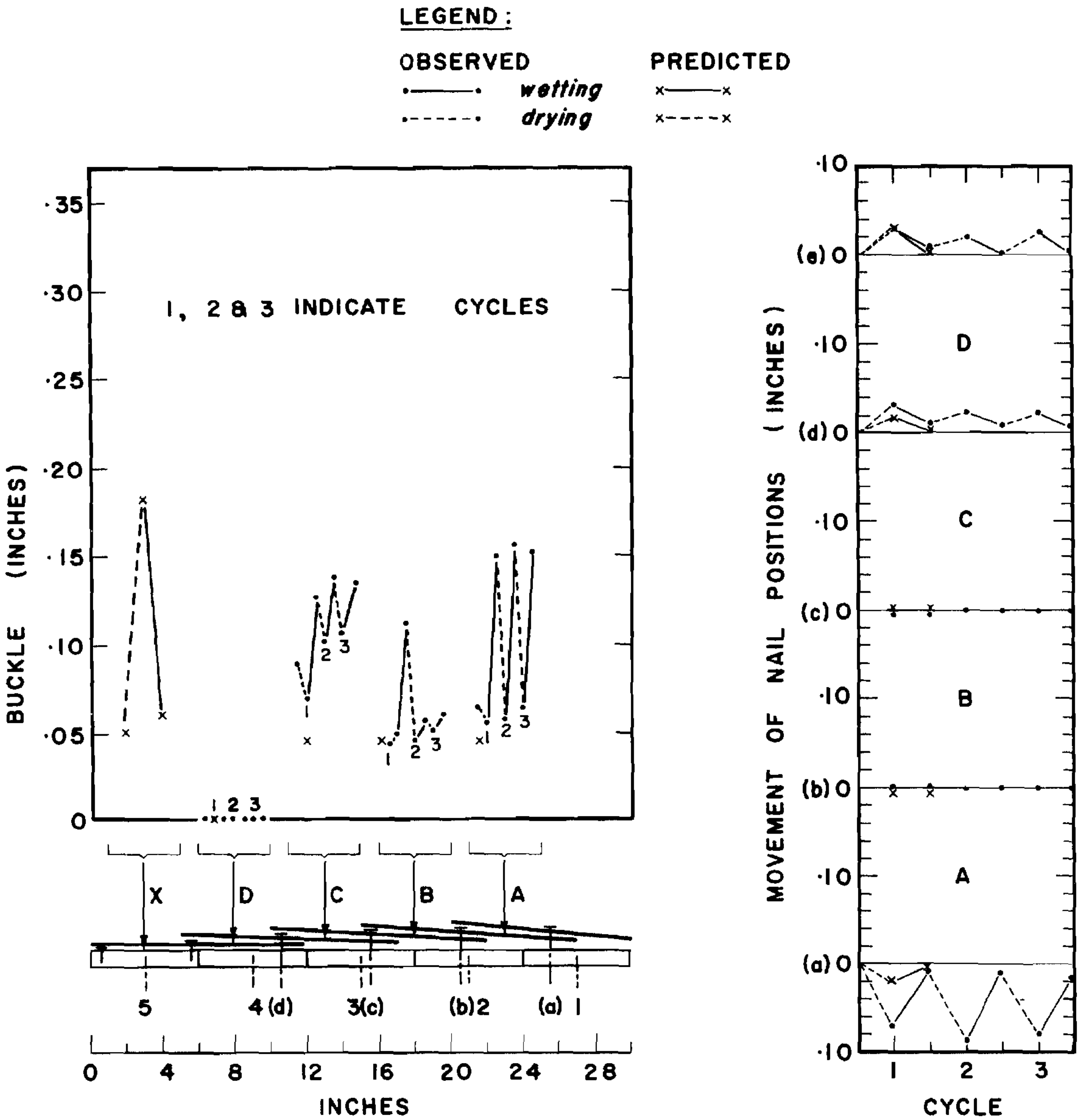


SHINGLE BUCKLE DURING 3 CYCLES

MOVEMENT OF SHINGLE NAIL POSITIONS IN WOOD DECK DURING 3 CYCLES

FIGURE 5

BUCKLING OF ASPHALT SHINGLES & MOVEMENTS IN WOOD DECK. DRY SHINGLES APPLIED ON DRY 6 INCH WIDE BOARDS.

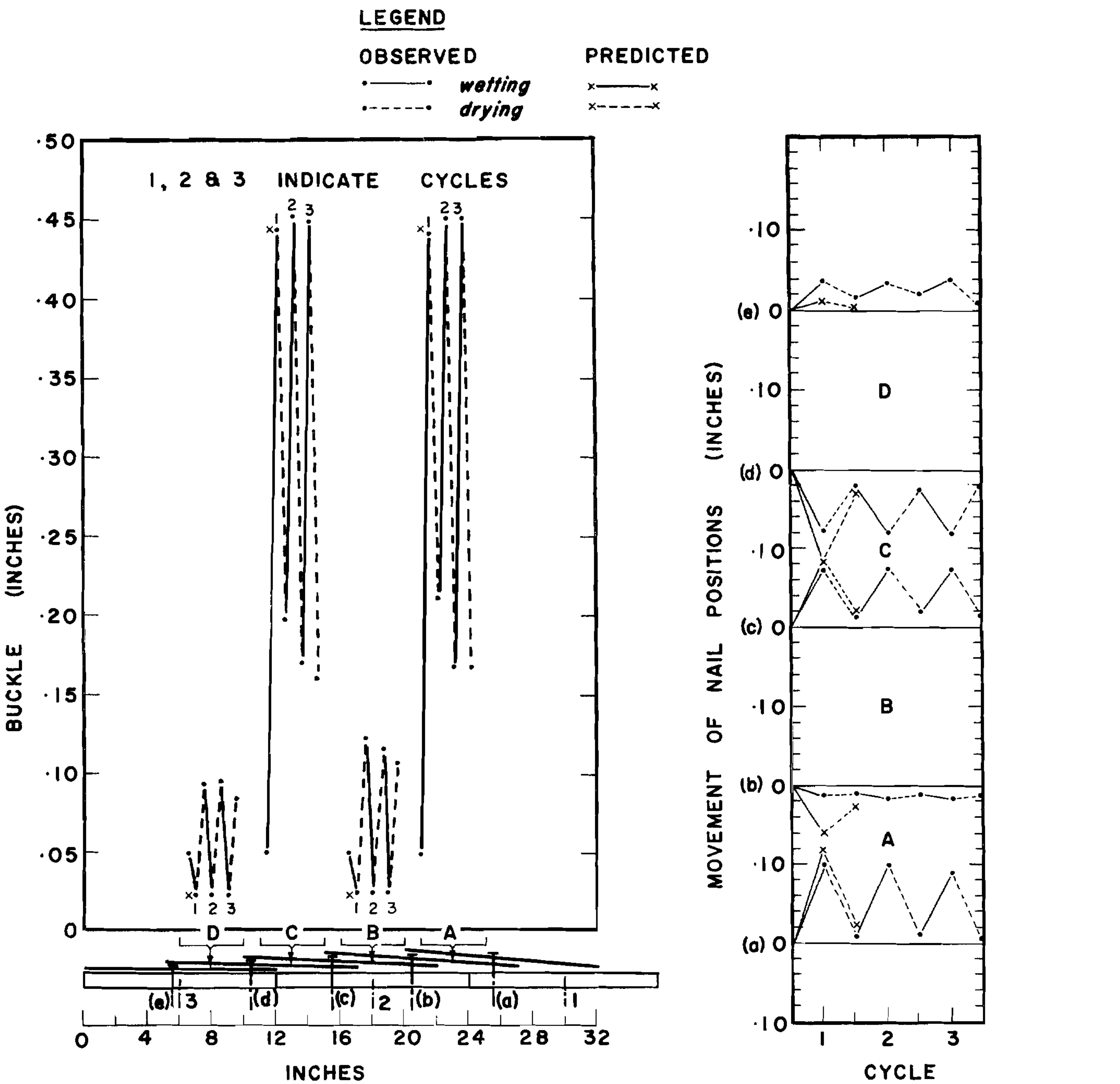


SHINGLE BUCKLE DURING 3 CYCLES

MOVEMENT OF SHINGLE NAIL POSITIONS IN WOOD DECK DURING 3 CYCLES

FIGURE 6

BUCKLING OF ASPHALT SHINGLES & MOVEMENTS IN WOOD DECK. DRY SHINGLES APPLIED ON WET 6 INCH WIDE BOARDS.

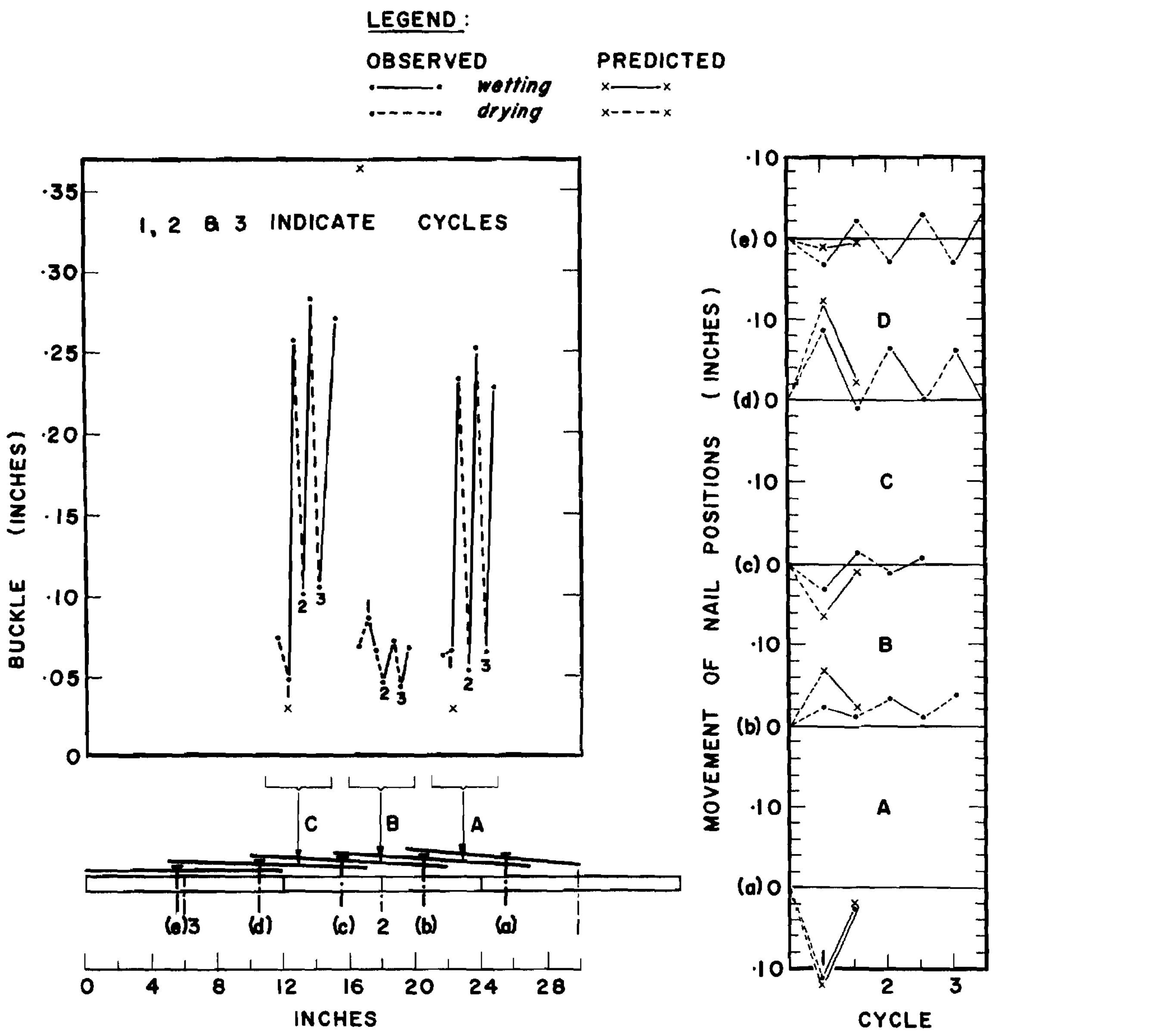


SHINGLE BUCKLE DURING 3 CYCLES

MOVEMENT OF SHINGLE NAIL POSITIONS IN WOOD DECK DURING 3 CYCLES

FIGURE 7

BUCKLING OF ASPHALT SHINGLES & MOVEMENTS IN WOOD DECK. DRY SHINGLES APPLIED ON DRY 12 INCH WIDE BOARDS.



SHINGLE BUCKLE DURING 3 CYCLES

MOVEMENT OF SHINGLE NAIL POSITIONS IN WOOD DECK DURING 3 CYCLES

FIGURE 8

BUCKLING OF ASPHALT SHINGLES & MOVEMENTS IN WOOD DECK. DRY SHINGLES APPLIED ON WET 12 INCH WIDE BOARDS.