NATIONAL BUREAU OF STANDARDS REPORT

5989

INSULATING CONCRETES
(Tests of Reinforced Perlite Concrete Slabs)

Interim Report No. 2

by

T. W. Reichard and D. Watstein

Report to
the Departments of
the Air Force, the Army, and the Navy

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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A description is given of a series of transverse tests of perlite concrete slabs reinforced with welded wire fabric. The purpose of the tests was to determine the properties of such slabs subjected to short-term and long-term loads. The effect of the reinforcement and the formboard normally used with roof slabs of perlite concrete was investigated.

In the short-term tests the slabs were loaded to complete failure, whereas the specimens subjected to the long-term test were loaded with one-half of the estimated maximum load. The results indicate that the minimum concrete strength must be about 400 psi in order to develop the full strength of the 4- by 4-in. 12/12 ga welded wire fabric used in the 3-in. thick slabs tested on 36-in. span.

The slabs tested under a sustained load for 200 days showed increases over the instantaneous deflections of about 280 and 350 percent for the 230 psi and the 665 psi concrete, respectively, although the instantaneous deflections of the two slabs were nearly equal.

1. INTRODUCTION

During the past two years the National Bureau of Standards has been engaged in a study of insulating concretes initiated as a Tri-Service Project.1/ In view of the current interest in the use of insulating concretes in reinforced roof slabs, the Bureau was asked to include some tests of perlite and vermiculite concrete slabs under short-term and sustained loads in the study of insulating concretes.

This report presents the data developed in the tests on perlite concrete slabs reinforced with welded wire fabric. The investigation included the study of the behavior of slabs under short-term and sustained loads.

1/ Tri-Service Projects are sponsored jointly by the Departments of Army, Navy, and the Air Force.

2. PREPARATION OF SPECIMENS

The test slabs were 24- by 48- by 3-in. slabs and were designed to be tested as simply supported one way slabs with a 36-in. span. They were reinforced with 4- by 4-in. welded wire fabric of 12 ga wire. The fabric was spaced 0.2 in. from the bottom of the slabs.

The slabs were cast on 1 in. formboard in a plywood form. Slab Nos. 5, 9, 10, 11, 12, and 13, were cast with cellophane between the slab and the formboard to prevent any bond between them. Slab Nos. 2, 9, 10, 11, 12, and 13 were tested without the formboard.

Slab Nos. 6 and 7 had the wire fabric anchored to 2- by 3-in. galvanized steel angles at each end to prevent slipping of the reinforcement through the concrete while under test.

The concrete used was a 1:5 perlite mix for all slabs except Nos. 9, 12, and 13, which was a 1:4 perlite mix. Type I cement was used in slab Nos. 1, 2, and 3. Type III cement was used in all other slabs.

The two slabs fabricated for the sustained load tests had steel inserts cast in the top surface as gage points for deflection measurements. All slabs and the 6- by 12-in. control cyclinders were left in the form for one day covered with vapor barrier paper. The concrete made with Type I cement was cured for three days under damp burlap following removal of the form. The concrete made with Type III cement was damp cured one day after removal of the form. The concrete was then air-dried until tested at 28 days for the Type I cement specimens, or 7 days for the Type III cement specimens.

The formboard for all slabs except No. 8 was a 1-in. thick, asphalt coated, vegetable fiberboard commonly used as rigid insulating roof board. The modulus of rupture of the formboard was 230 psi as determined by flexure tests. The tensile strength of the board was about 110 psi.

The formboard used for slab No. 8 was a 1-in. thick asphalt impregnated fiberboard. This formboard is made up of two 1/2-in. thick sheets cemented together to make up the 1-in. thickness. The modulus of rupture was about 380 psi and the tensile strength was about 260 psi.

3. TEST PROCEDURE

All slabs were simply supported on two 2-in. diameter steel pipes spaced 36 in. on centers (see figure 1). The 2-in. pipes were seated on a rigid supporting frame and were free to rotate in the direction of the span. Bearing plates, 2-in. wide and 1/4-in. thick were placed between the supports and the slabs.

3.1 Short-term tests

For the short-term tests the slabs were loaded in a hydraulic testing machine equipped with a rigid loading beam centered under a spherically-seated head. The loading beam was designed to apply the load at the quarter points of the slab through 2-in. diameter steel pipes. Leather belting was placed between these pipes and the top of the slabs.

The load was applied at a rate that would allow deflection readings to be taken without interrupting the application of the load. Center deflections of the slabs were measured with 0.001 in. dial gages until the initial failure.

3.2 Sustained load tests

For the sustained load tests the slabs were loaded by placing cast iron weights 4 ft long directly on 2-in. diameter steel pipes at the quarter points of the slabs. The total load for slab Nos. 11 and 13 was 808 lb and 1008 lb, respectively. These loads were approximately half the estimated maximum loads.

The humidity and temperature in the test room were not controlled, but throughout most of the test period remained at 40 ± 10% R.H. and 72° ± 4° F, (Fig. 6). However, after the test had been in progress about 200 days, the humidity and temperature rose to about 60% R.H. and 80° F. This increase was due to a room, directly under the test room, being filled with steam.

Changes in the dimensions of the portable deflectometer were compensated for by the use of standard surfaces installed on a steel channel.

4. RESULTS

4.1. Type of failure

4.1.1. Composite slabs (concrete and formboard)

When the eight composite slabs were tested, two distinct failures occurred in each slab. The initial failure occurred when the formboard ruptured. The load at this point was the maximum observed for the test.

The deflection of the composite slab was then continued until a secondary failure occurred. In all composite slabs except Nos. 6 and 7, the secondary failure was caused by failure of the bond between the steel wire fabric and the concrete.

Slab Nos. 6 and 7 had positive anchorage for the wire fabric at each end which prevented excessive slipping of the reinforcement through the concrete. The secondary failure in slab No. 6 was by fracture of the wire fabric, while in slab No. 7 secondary failure was by crushing of the concrete.

4.1.2. Slabs without formboard

The initial failure of the four slabs tested to failure without formboard was similar to the secondary failure of the composite slabs. Slab Nos. 2 and 10 failed through slippage of the fabric through the concrete. The steel fabric failed in slab No. 9 which was cast from 885 psi compressive strength concrete. Slab No. 12 which was made from 400 psi concrete appeared to fail simultaneously by bond through excessive slip and fracture of the reinforcement.

4.2. Bond between formboard and concrete

Table 1 gives a summary of the data and figures 2 and 3 show the load-deflection curves for the slabs. With the load applied at the quarter points, the performance of the slab is nearly the same as would be expected with a uniformly distributed load totalling the same as the applied machine load. The deflections given in Table 1 for an equivalent distributed load of 150 lb per sq ft indicate that the amount of bond between the formboard and the concrete may affect the stiffness of the composite slabs to some extent although the strength of the concrete appears to be the main factor.

4.3. Bond between concrete and steel wire fabric

The loads at initial failure for slab Nos. 2, 9, 10, and 12, and the secondary failure load for the composite slabs give an indication of the effectiveness of the steel reinforcement. From the data available, it appears that the concrete strength should be about 400 psi in order to have sufficient bond between the 4- by 4-in. 12/12 welded wire fabric and the concrete to develop the full strength of the steel.

4.4. Sustained load tests

Figures 4 and 5 show the time-deflection curves for the two sustained load tests. The instantaneous deflections caused by application of the test load were about the same for the two slabs but the increase in deflection with time was greater for slab No. 11.

Both slabs appeared to have stopped moving at about 200 days although there is some doubt as to the reason. It was at this time that the humidity and temperature in the test room had increased above the normal. From a study of the data it is apparent that changes in the relative humidity affect the deflection of these slabs. The slight drop in the deflection above the 200 day period coincides with an increase in relative humidity to 60 percent. It is possible that the moisture picked up by the concrete had caused the concrete to expand somewhat, thus causing the deflection to decrease slightly. It is probable that the deflections will continue to increase after the ambient relative humidity returns to normal.

5. PROPOSED TESTS

It is planned to make sustained load tests on vermiculite concrete slabs. No formboard will be used and the same amount of reinforcement will be used as in the perlite concrete slabs.

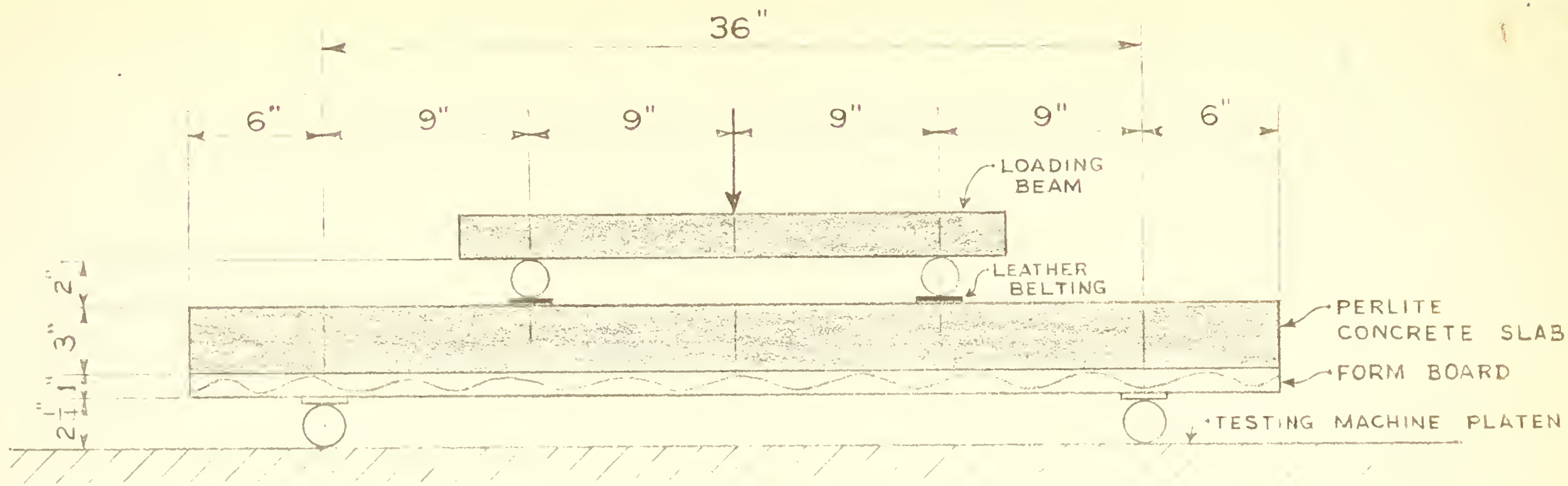
Table 1. Properties of Perlite Concrete Slabs.

Slab No.	Cement content per cu yd concrete	Water per bag cement	Wet density	Oven dry density	Compressive strength 6" x 12" cylinders	Machine load at initial failure	Machine load at secondary failure	Center deflection at 150 ps load	Estimated bond between formboard and concrete	Type of failure in slab
	bags	lb	pcf	pcf	psi	lb	lb	in.	% of total area	
1	4.35	118	40.7	24.4	185	2530	1680	.057	15	Bond
2	4.61	118	43.0	25.5	200	1440	--	.091	No board	Bond
3	4.96	104	43.8	28.2	235	3000	2000	.049	60	Bond
4	4.75	92	39.0	26.2	230	2620	1800	.061	35	Bond
5	5.13	94	43.3	29.6	260	2200	1700	.084	0	Bond
6 1/	5.59	94	48.4	32.6	420	3180	2380	.044	4	Tensile
7 1/	4.75	92	39.9	26.9	260	2680	1860	.062	5	Compressive
8 2/	5.11	94	43.5	29.9	290	3280	2180	.057	0	Bond
9	8.52	76	63.5	47.5	885	2280	--	.030	No board	Tensile
10	3.94	94	39.4	26.0	215	1634	--	.095	No board	Bond
11	3.94	94	39.4	25.9	230	sustained load test			No board	Test in progress
12	6.14	76	45.8	33.4	400	2036	--	.082	No board	Bond and tensile
13	7.30	76	54.4	38.4	665	sustained load test			No board	Test in progress

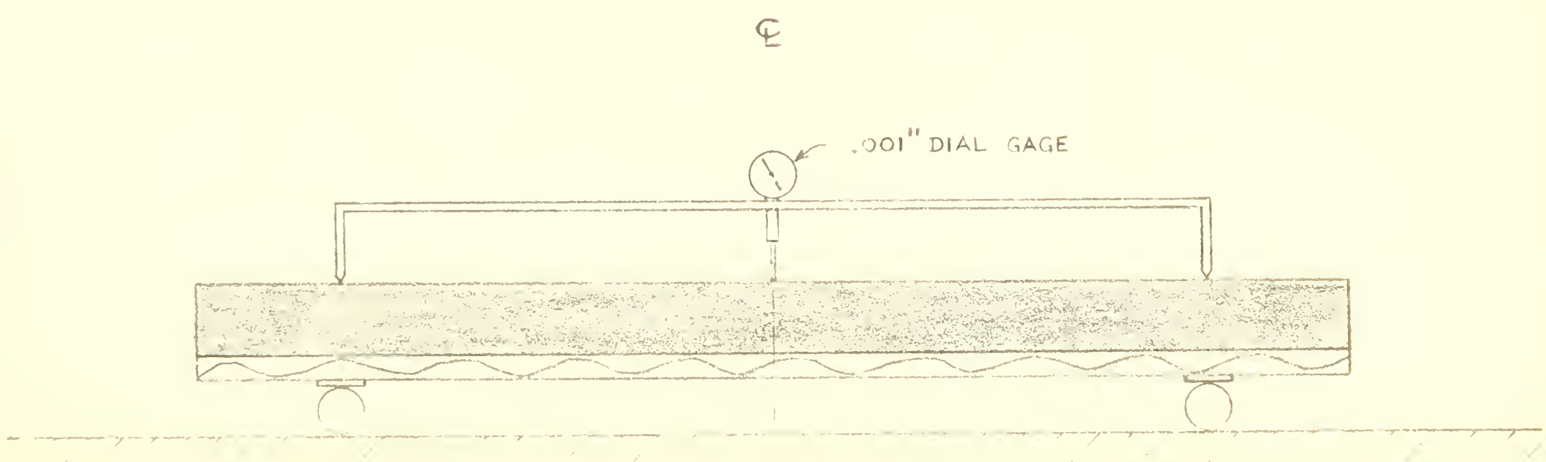
1/ Slab Nos. 6 and 7 had wire fabric welded to 2- by 3-in. 18 ga GI angles at both ends of slabs.

2/ Formboard used for slab No. 8 was the stronger asphalt impregnated type.

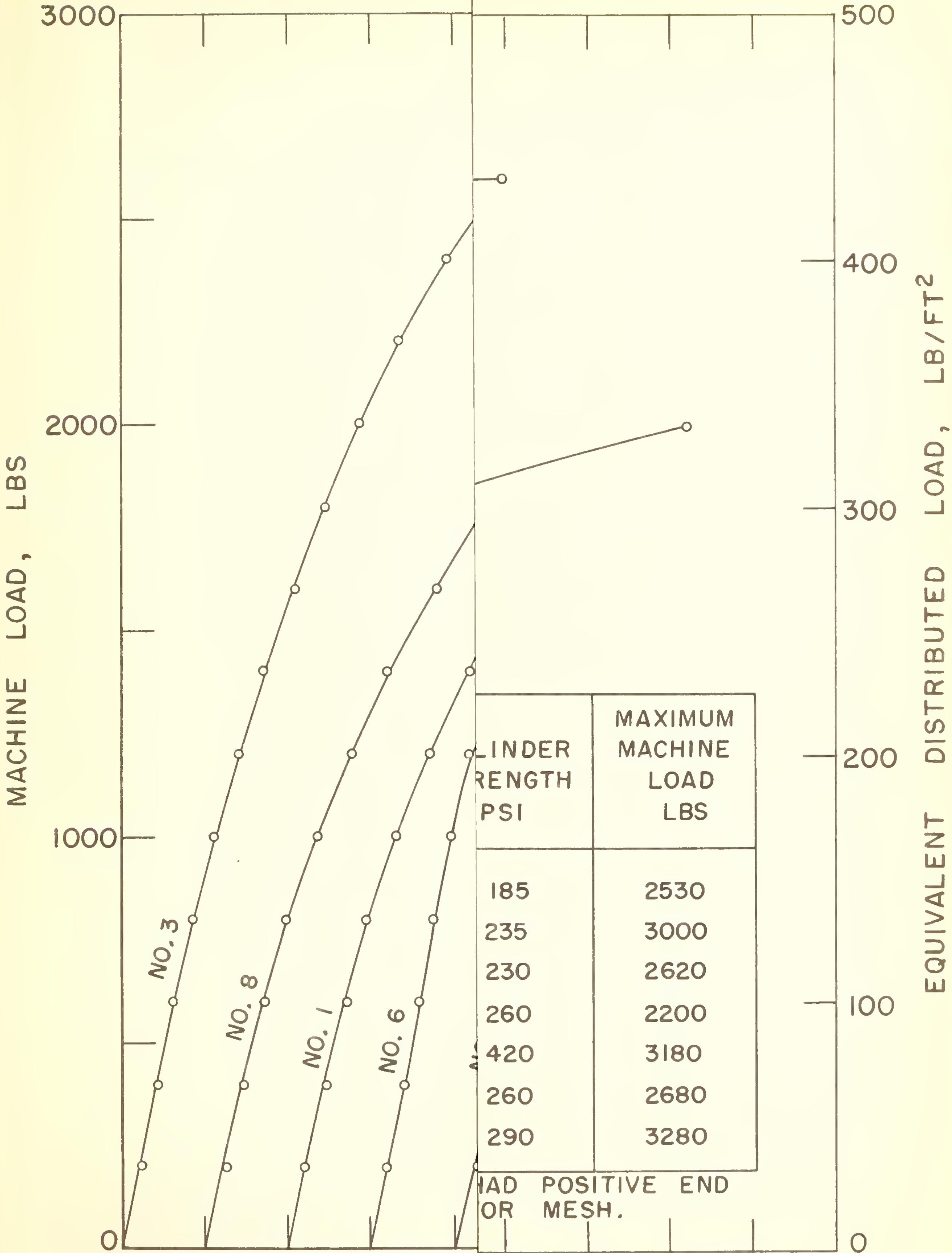
FIG. 1 LOADING ARRANGEMENT FOR SHORT TERM TESTS



LOADING ARRANGEMENT



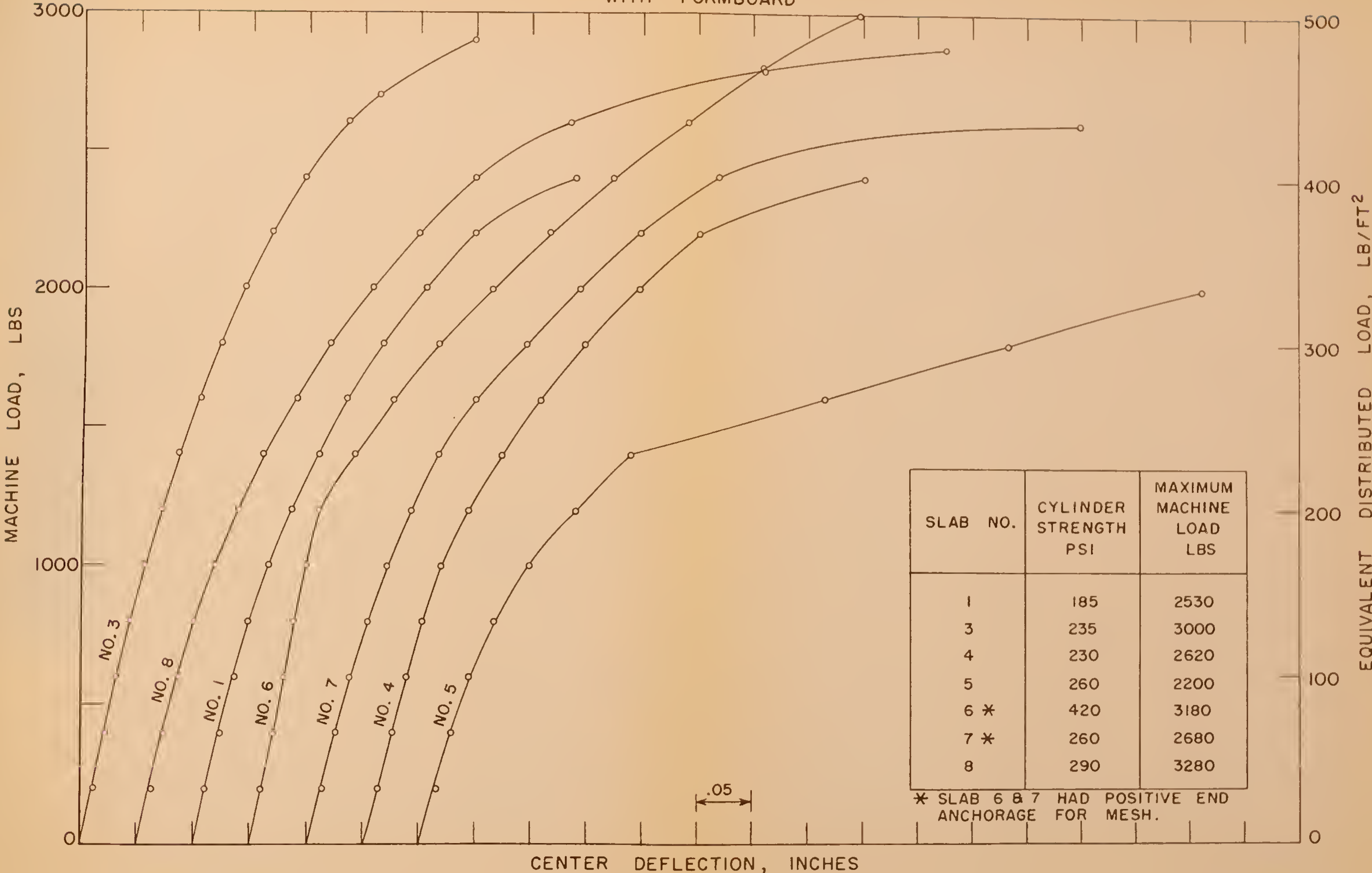
DEFLECTION MEASURING



LINDER RENGTH PSI	MAXIMUM MACHINE LOAD LBS
185	2530
235	3000
230	2620
260	2200
420	3180
260	2680
290	3280

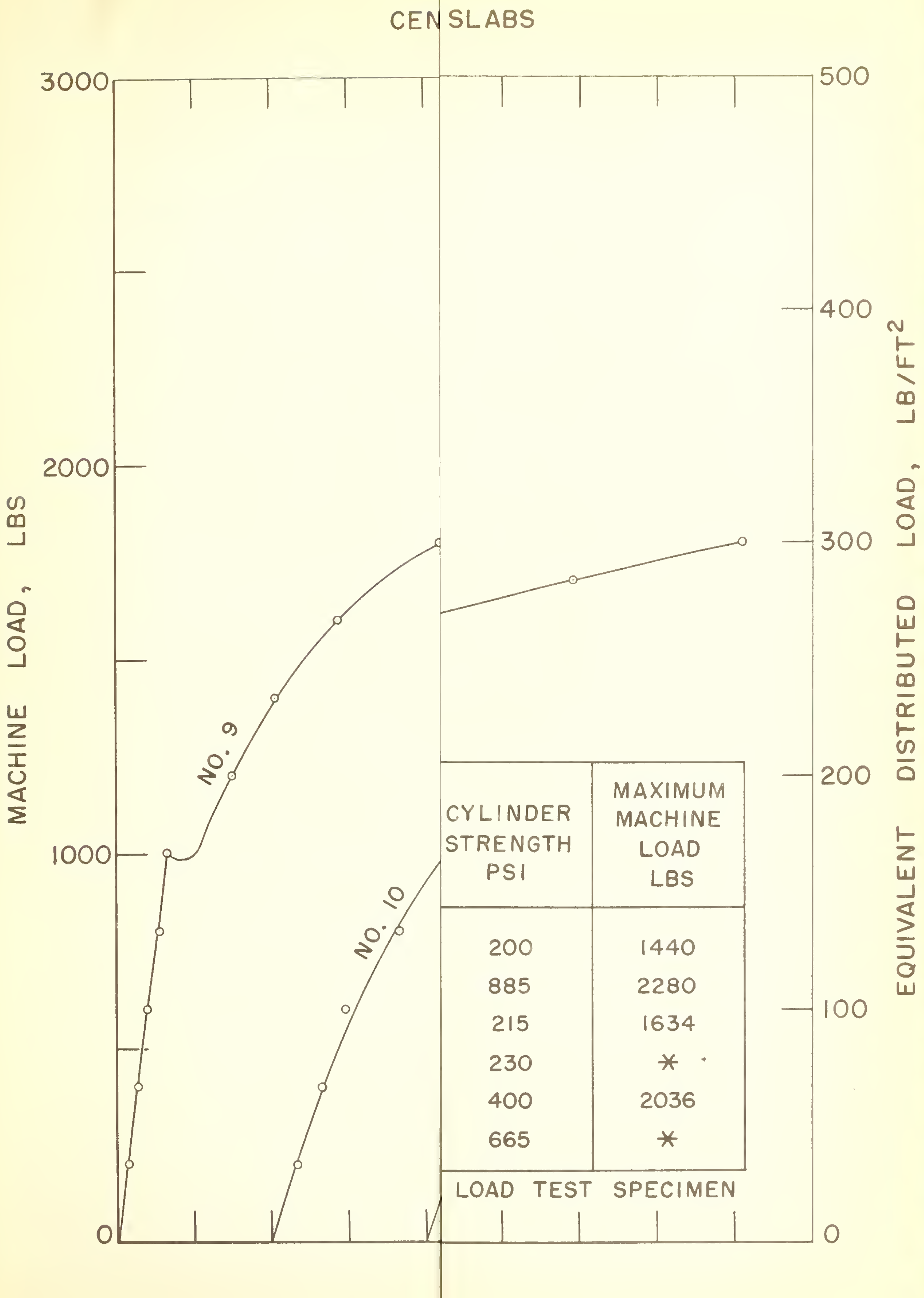
IAD POSITIVE END
OR MESH.

FIG. 2 SHORT TERM TEST
CENTER DEFLECTION VS. APPLIED LOAD FOR PERLITE CONCRETE SLABS WITH FORMBOARD



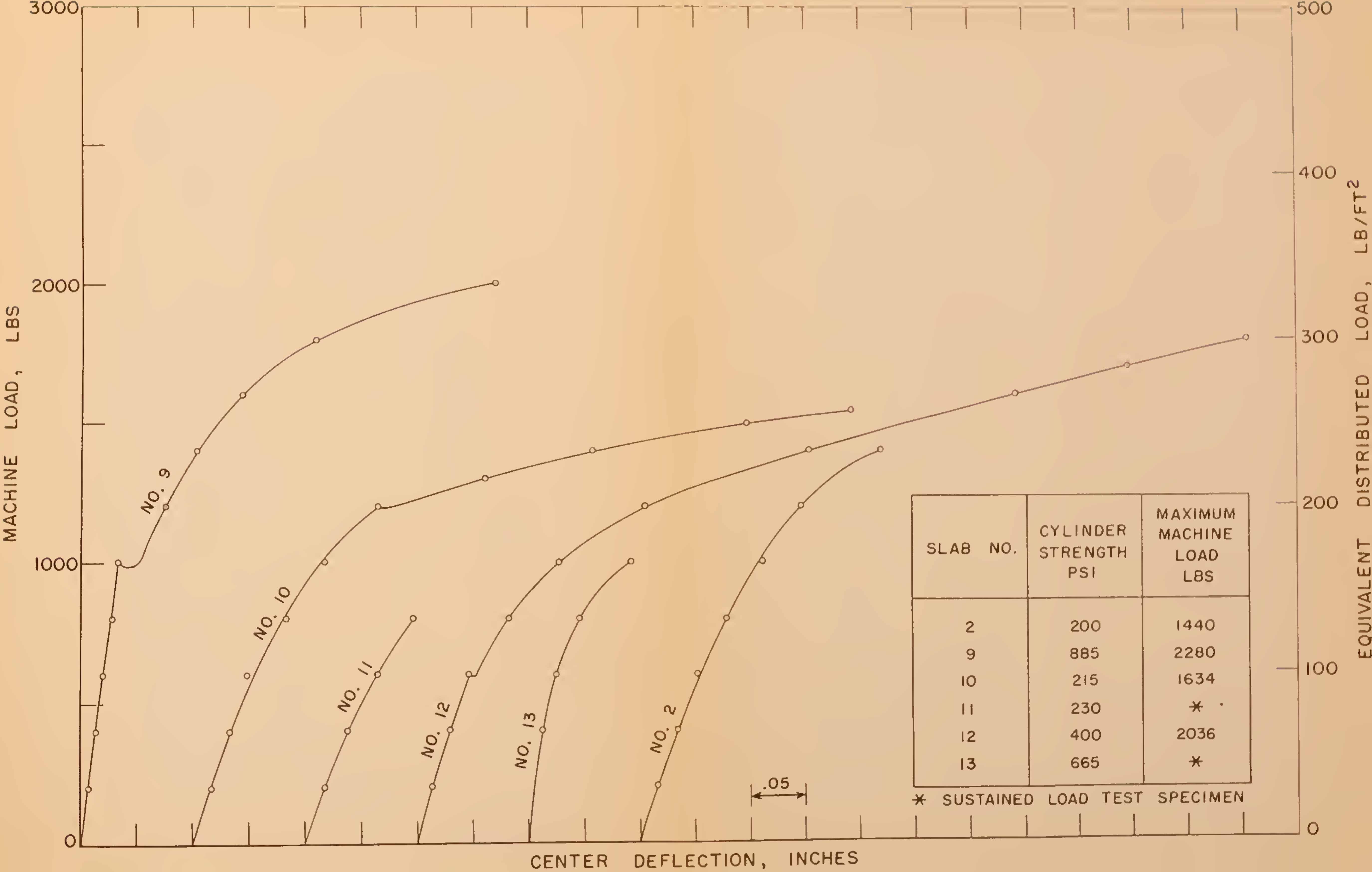
SLAB NO.	CYLINDER STRENGTH PSI	MAXIMUM MACHINE LOAD LBS
1	185	2530
3	235	3000
4	230	2620
5	260	2200
6 *	420	3180
7 *	260	2680
8	290	3280

* SLAB 6 & 7 HAD POSITIVE END ANCHORAGE FOR MESH.



CEN SLABS
MACHINE LOAD, LBS
EQUIVALENT DISTRIBUTED LOAD, LB/FT²
3000
2000
1000
0
500
400
300
200
100
0
NO. 9
NO. 10
CYLINDER STRENGTH PSI
MAXIMUM MACHINE LOAD LBS
200 1440
885 2280
215 1634
230 *
400 2036
665 *
LOAD TEST SPECIMEN

FIG. 3 SHORT TERM TEST
CENTER DEFLECTION VS. APPLIED LOAD FOR PERLITE CONCRETE SLABS WITHOUT FORMBOARD

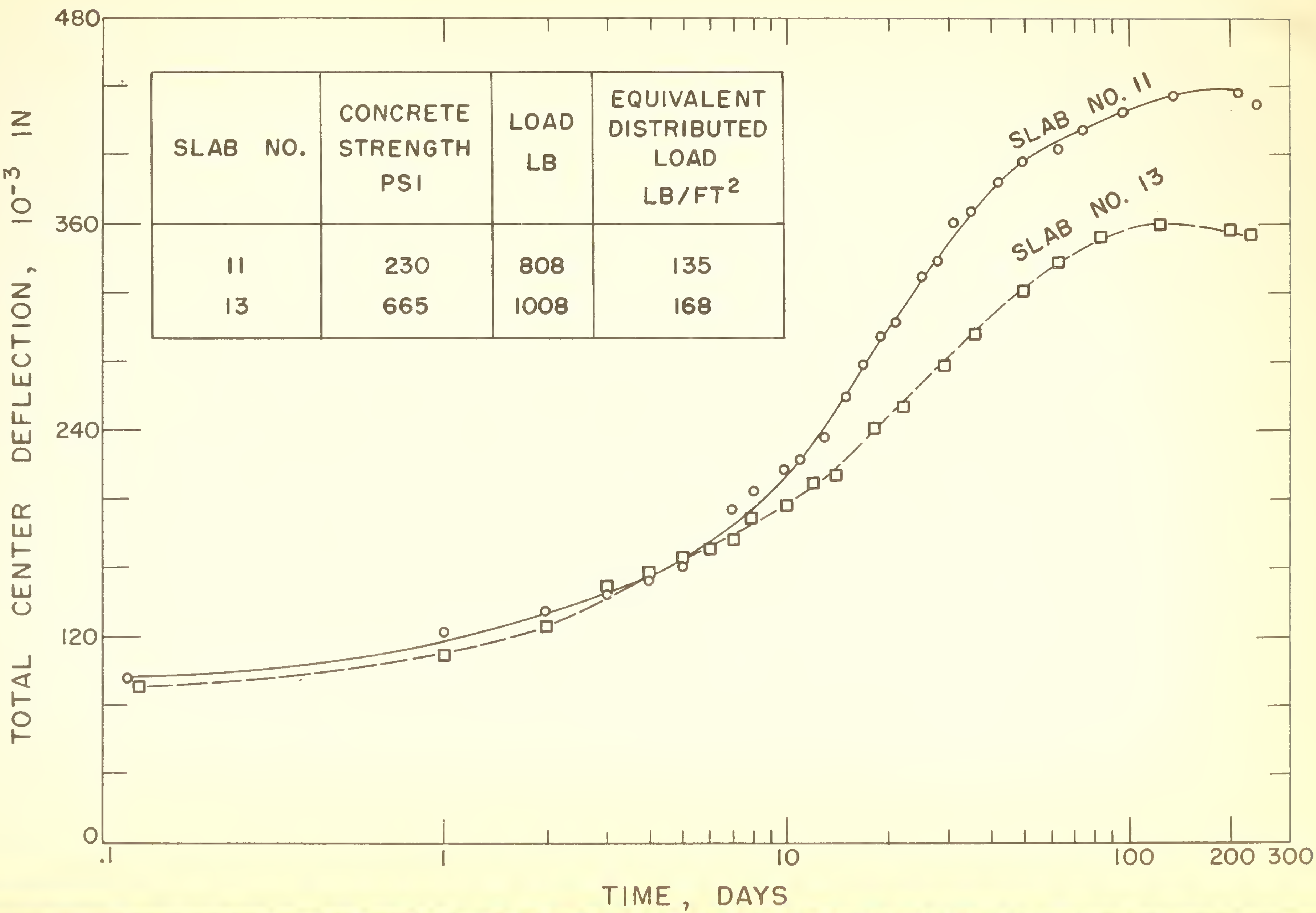


SLAB NO.	CYLINDER STRENGTH PSI	MAXIMUM MACHINE LOAD LBS
2	200	1440
9	885	2280
10	215	1634
11	230	*
12	400	2036
13	665	*

* SUSTAINED LOAD TEST SPECIMEN

FIG. 4 SUSTAINED LOAD TEST

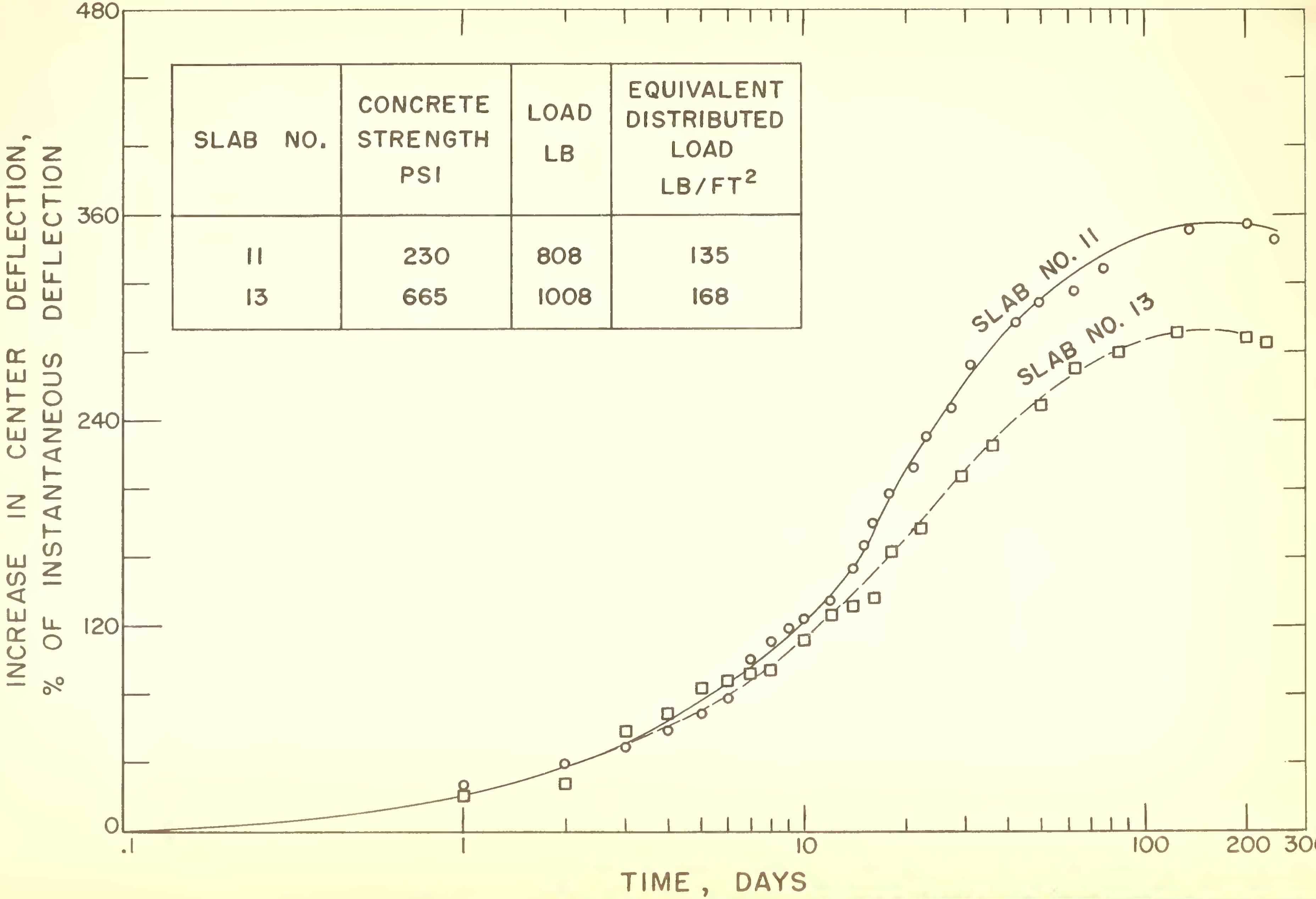
TIME VS. CENTER DEFLECTION FOR PERLITE CONCRETE SLABS



SLAB NO.	CONCRETE STRENGTH PSI	LOAD LB	EQUIVALENT DISTRIBUTED LOAD LB/FT^2
11	230	808	135
13	665	1008	168

FIG. 5 SUSTAINED LOAD TEST

TIME VS. INCREASE IN CENTER DEFLECTION FOR PERLITE CONCRETE SLABS

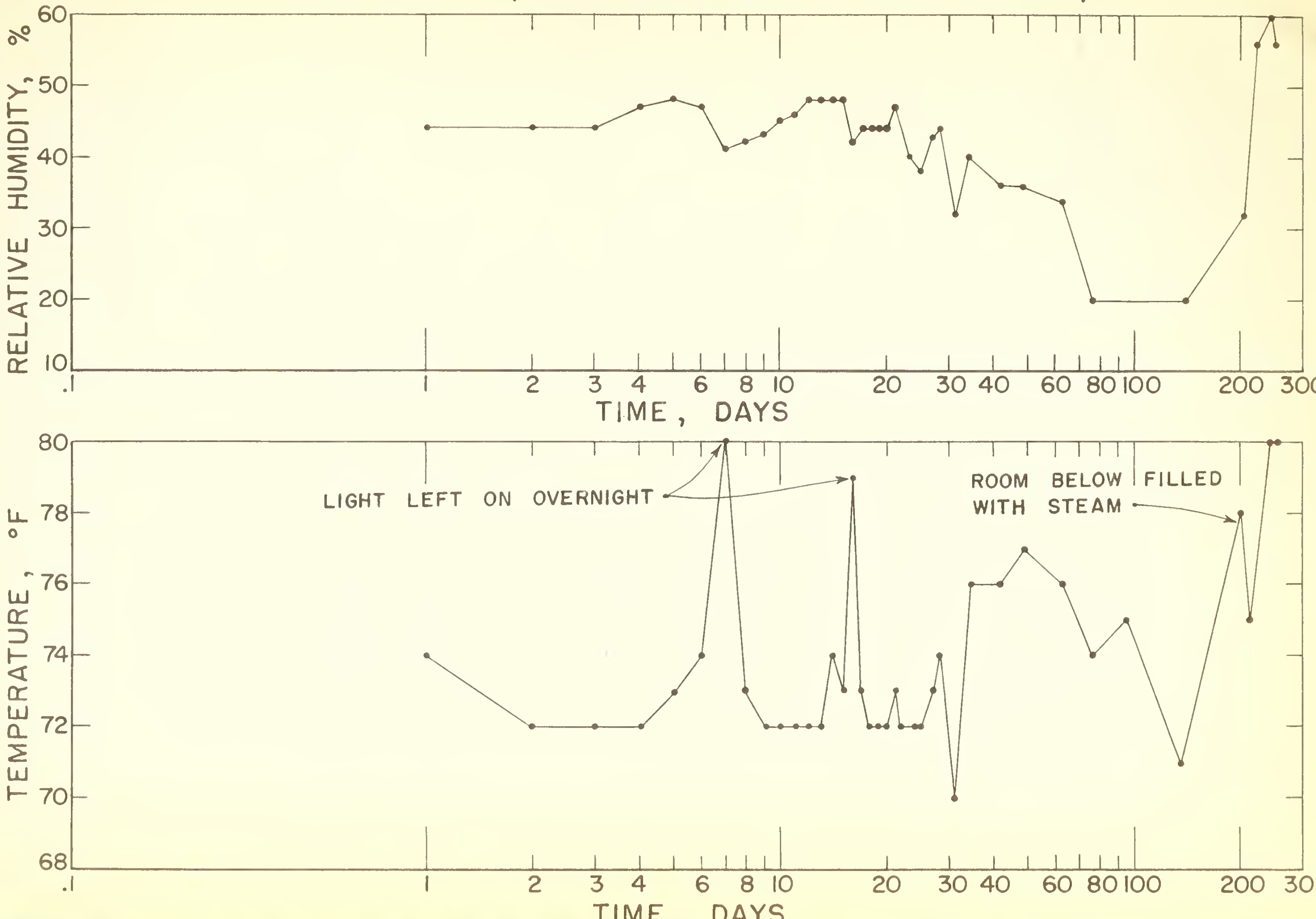


SLAB NO.	CONCRETE STRENGTH PSI	LOAD LB	EQUIVALENT DISTRIBUTED LOAD LB/FT^2
11	230	808	135
13	665	1008	168

FIG. 6 SUSTAINED LOAD TEST

TIME VS. RELATIVE HUMIDITY AND TEMPERATURE

SLAB NO. 11 (SLAB NO. 13 WAS 7 DAYS BEHIND)



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A. V. Astin, *Director*

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