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16. Abstract

The Texas State Department of Highways and Public Transportation (TSDHPT) uses two types of guardrail posts: a circular wood post and a steel W6 x 8.5 post. The posts are embedded into soil and rock depending upon the site in which the guardrail system is to be constructed. This research study was concerned only with the wood post embedded in rock. When located in rocky terrain, the current plans and specifications require the wood post to be placed in a drilled hole in the rock 18 in. deep and backfilled with soil or concrete as required by the engineer. If concrete is required, the guardrail system becomes expensive. The research study reported herein was conducted to determine whether a soil backfill would develop the required strength for the post to perform satisfactorily as a traffic barrier system.

A series of static load tests was conducted on such posts using backfills of clay, sand, decayed limestone and concrete. The results of these tests indicate that the wood guardrail post embedded 18 in. in rock will perform satisfactorily whether backfilled with clay, sand, decayed limestone or concrete. The cohensionless soil (sand or decayed limestone in this case) is recommended because it is economical and easier to place or tamp around the post.

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STRENGTH OF GUARDRAIL POST IN ROCK

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DISCLAIMER

KEY WORDS

Guardrail, Post, Safety, Barriers

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute (TTI), the State Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration (FHWA). Mr. Ralph K. Banks (Supervising Field Engineer, SDHPT) and Mr. Harold D. Cooner (Supervising Designing Engineer, SDHPT) were closely involved in all phases of the study.

IMPLEMENTATION STATEMENT

The results of this study are being implemented by the Highway Design Division, D-8, of SDHPT.

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INTRODUCTION

USES AND APPLICATIONS OF HIGHWAY GUARDRAILS

The primary function of guardrails and median barriers is to safely redirect errant vehicles. Guardrail installations on shoulders prevent vehicle access to steep embankments or fixed objects, whereas median barriers are used between the roadways of divided highways to prevent "across-the-median" collisions with opposing traffic. Properly designed installations accomplish the redirection of errant vehicles in such a manner as to minimize the vulnerability of vehicle occupants as well as the involvement of following and adjacent traffic. Other desirable guardrail and median barrier system characteristics include minimal damage to vehicles and barrier systems and economy in construction, installation, and maintenance.

When a vehicle in motion collides with a guardrail, a substantial portion of its energy is absorbed by the guardrail. The lateral forces carried by the guardrail are transmitted to the ground through the guardrail posts. This research study was conducted to determine if a wood post embedded in rock using soil for the backfill material would absorb as much energy as a wood post embedded just in soil.

WOOD POSTS AS GUARDRAILS

The State Department of Highways and Public Transportation current specifications require the wood post to have a minimum diameter of 7 in., a minimum embedment depth of 38 in. in soil and 18 in. in rock. Wood posts with domed tops have a minimum overall length of 69 in. A length of 66 in. is required if the top of the wood post is beveled. When the

guardrail is located in rocky terrain, usually the posts are placed in a 12 in. diameter by 18 in. deep hole that is drilled into the rock. The hole is backfilled with soil or concrete as required by the engineer. When concrete is required, the guardrail system becomes more expensive to construct. To date, no experimental work has been performed to determine whether the concrete fill is required in order for the wood post guardrail system to perform satisfactorily as a traffic barrier in rocky terrain.

SCOPE OF STUDY

The 7 in. diameter wood post embedded into 38 in. of soil has performed adequately as a traffic barrier. These guardrail systems have successfully redirected errant vehicles. Any guardrail system that performed similarly to the system using wood posts embedded in soil would be considered as performing satisfactorily. With this in mind, this study was conducted to determine whether concrete fill or soil is required for the wood guardrail posts to perform satisfactorily when embedded 18 in. in rock. The procedure used in conducting this study was:

1. Static field load tests were performed on the wood guardrail post embedded 18 in. into rock. Four different types of backfill were used -- sand, decayed limestone, clay, and concrete.
2. The results from these static tests were compared with the results of a wood post embedded 38 in. in cohesive and cohensionless soil.

STATIC LOAD TEST

The static guardrail post tests that were conducted using different types of soils and concrete as the fill material are summarized in

Table 1. Also in Table 1 are two tests reported in TTI Research Report No. 343-1 (2). These tests used a wood post embedded 38 in. in cohesive and cohensionless soil. Tests 1-4 are embedded 18 in. into concrete in order to simulate rocky terrain. Three different soil types were used to set the wood guardrail post. A test using concrete as the fill material was also performed.

In order to model rocky terrain, a concrete block was constructed. A 12 in. diameter hole is located in the middle of the block to simulate a hole augered through rock. The hole reaches to a depth of 18 in., which is the current requirement set by SDHPT. This reinforced 3 ft x 5 ft concrete block is shown in Figures 1 and 2.

Since only 18 in. of embedment depth is required when the guardrail system is located in rocky terrain, 20 in. of the standard 69 in. wood post had to be cut off the bottom. Because of the steel framed testing apparatus, a portion of the top (approximately 3 in.) was cut off in order to ease the placement of the post inside the hole. These cuts are shown in Figure 3, and the testing apparatus is shown in Figures 4 and 5. For the first three tests, soils were used to set the post in place. The soil was poured into the hole in 6 in. layers and tamped around the post. For the fourth test, concrete was poured into the hole until it was full. After the concrete was poured and vibrated, a period of two weeks was allowed for curing.

EQUIPMENT AND INSTRUMENTATION

In order to conduct these tests, it was necessary to develop a loading system capable of (1) applying a horizontal force to the post at a uniform

displacement rate, (2) measuring the load acting on the post at known displacements, and (3) measuring the displacement of the post at ground level and at 21 in. A hydraulic loading device was used to apply the lateral force to the post. The loading system is illustrated in Figures 4 and 5.

The load applied to the post was measured by means of a force transducer attached between the post and the hydraulic cylinder, as shown in Figures 4 and 5. The transducer was calibrated up to a maximum load of 15,000 lb. The force transducer was constructed of a metal bar instrumented with a full bridge of strain gages. The output from these strain gages was measured with a digital microvoltmeter calibrated to read the load directly. For the four static load tests, the post deflection at the ground surface was measured. This was done by attaching a metal rod to the center of the post and placing a tape with 1/2 in. increments to the concrete block, as shown in Figure 6. In order to locate the pivot point of the post, a second measurement was taken at 23 in. from ground level, as shown in Figure 7. For energy absorption comparison, the measured horizontal deflections at 23 in. were converted graphically to deflections at 21 in. The energy is transmitted from the guardrail to the post at a height of approximately 21 in. during the impact of the vehicle.

TEST PROCEDURE

A specially constructed loading bracket was attached to the post at the height of 21 in. above the top of the concrete block. This bracket, shown in Figure 8, assured the pull to be horizontal and eliminated the development of stress concentrations in the post itself. The hydraulic cylinder was bolted to the steel frame at a height of 21 in. from the top of the concrete block in order to keep the weight of the equipment from

applying an initial load. The load transducer was then calibrated and zeroed. The load was read off the digital voltmeter at every 1/2 in. of movement of the post at 23 in. until the post failed. The tests were terminated after the hydraulic cylinder had traveled the entire stroke length.

TEST RESULTS

The results of the static guardrail post tests are presented in Figures 10 to 14 and in Table 2. The load-deflection curves for each different fill material are given in Figures 10 to 13. The load-deflection curves from these three tests along with results from test Nos. 1 and 4 of TTI Research Report No. 343-1 (2) are plotted in Figure 14. Maximum load values and dissipated energy values for all tests are presented in Table 2.

CONCLUSIONS

From the results of these static post tests, it is clear that the wood guardrail post embedded 18 in. into rock using soil for the backfill absorbs more energy than if concrete is used for the fill material. The energy dissipated by the posts in rock is equal to or less than the energy dissipated by a post embedded 38 in. in soil.

The maximum lateral load capacity for all the static tests in rock was much greater than for the tests on posts embedded 38 in. in soil. The load capacities were much higher because when embedded in rock the post breaks instead of soil failure.

The 7 in. diameter wood guardrail post embedded 18 in. in rock should perform satisfactorily with any of the backfill materials used here -- sand, decayed limestone, clay, and concrete. The cohesionless soil backfill is recommended because it is economical and easy to place.

TABLE 1. SUMMARY OF STATIC TEST

TEST NO.	GENERALIZED FILL DESCRIPTION	UNIT WEIGHT (pcf)	HEIGHT OF LOAD (in.)	SOIL TYPE
1B	Dark Red, Stiff Clay	82.35	21	Red Clay Cohesive
2B	Poorly Graded Crushed Limestone Gravel	104.80	21	Georgetown Cohesionless
3B	Well Graded Sand	112.60	21	Pit-Run Sand Cohesionless
4B	Ready-Mix Concrete	150	21	--
1*	Dark Grey, Stiff Clay	124.50	21	Grey Clay Cohesive
4*	Decayed Limestone	119	21	Cohesionless

*Test results were taken from TTI Research Report No. 343-1 (Test No. 1).

TABLE 2. SUMMARY OF RESULTS

TEST	TYPE OF FILL	EMBEDMENT DEPTH (in.)	MAXIMUM FORCE (kips)	ENERGY ABSORBED** (ft-kips)
1B	Red Clay	18	11.38	4.2
2B	Georgetown	18	8.43	2.8
3B	Pit-Run Sand	18	8.44	3.3
4B	Concrete	18	9.40	2.7
1*	Embedded in soil - clay	38	3.7	4.2
4*	Embedded in soil - cohensionless	38	3.2	4.4

*Same as Table 1.

**Energy dissipated after 18 in. or less (if post broke) of horizontal deflection.

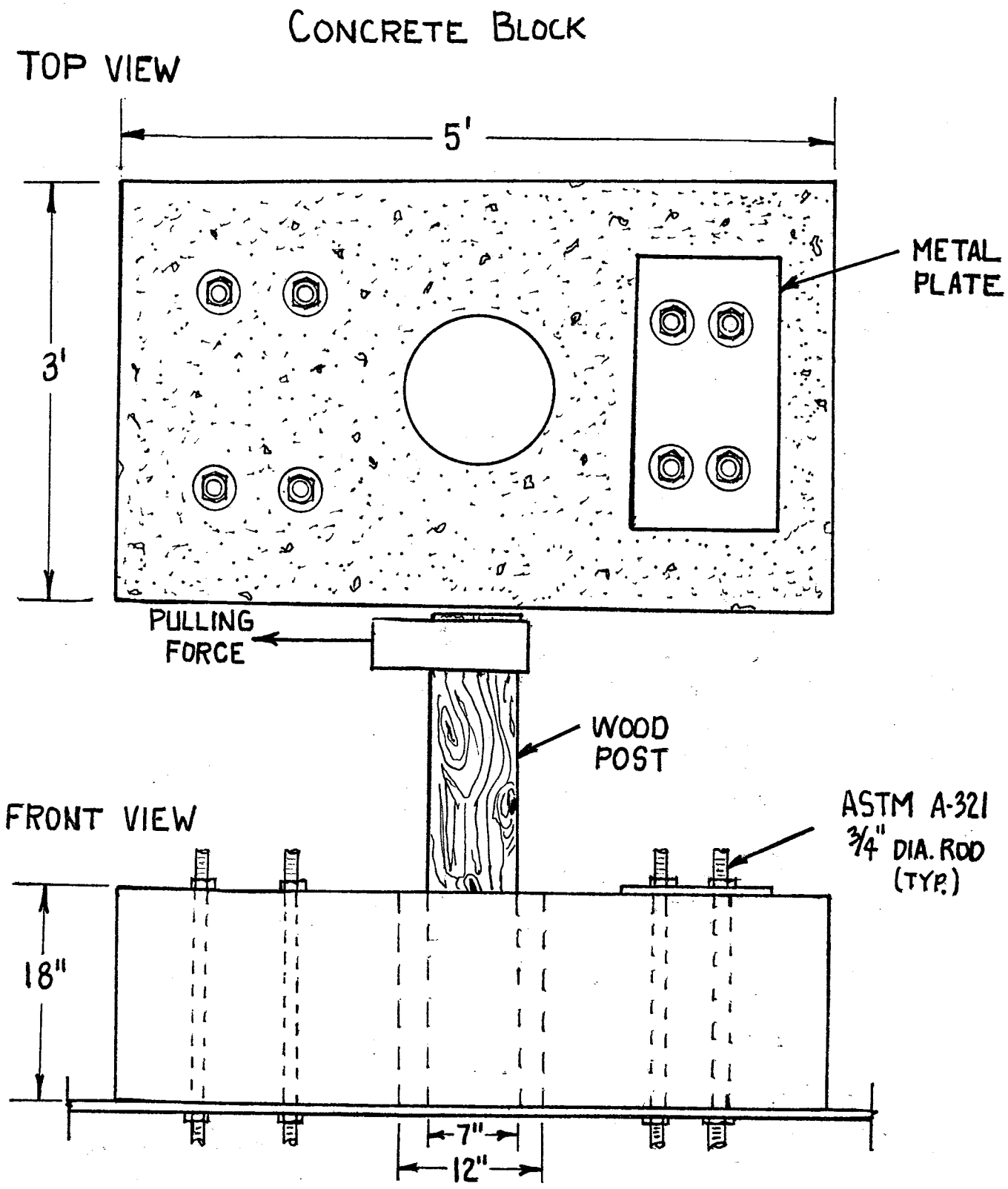


FIGURE 1. CONCRETE BLOCK TO SIMULATE ROCK

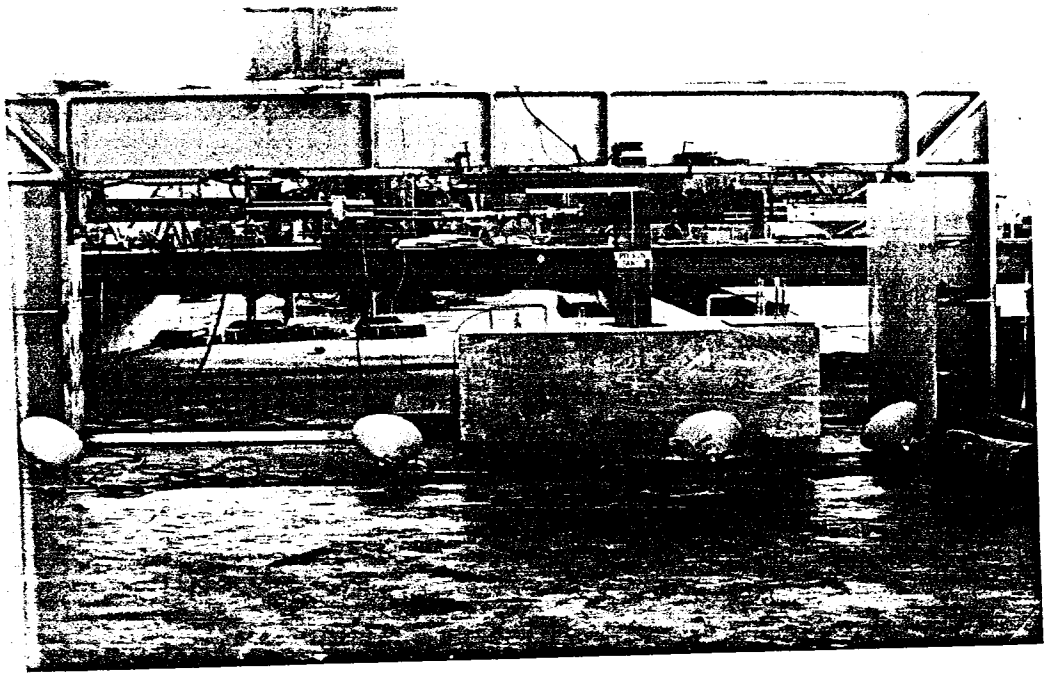


FIGURE 2. TEST SETUP

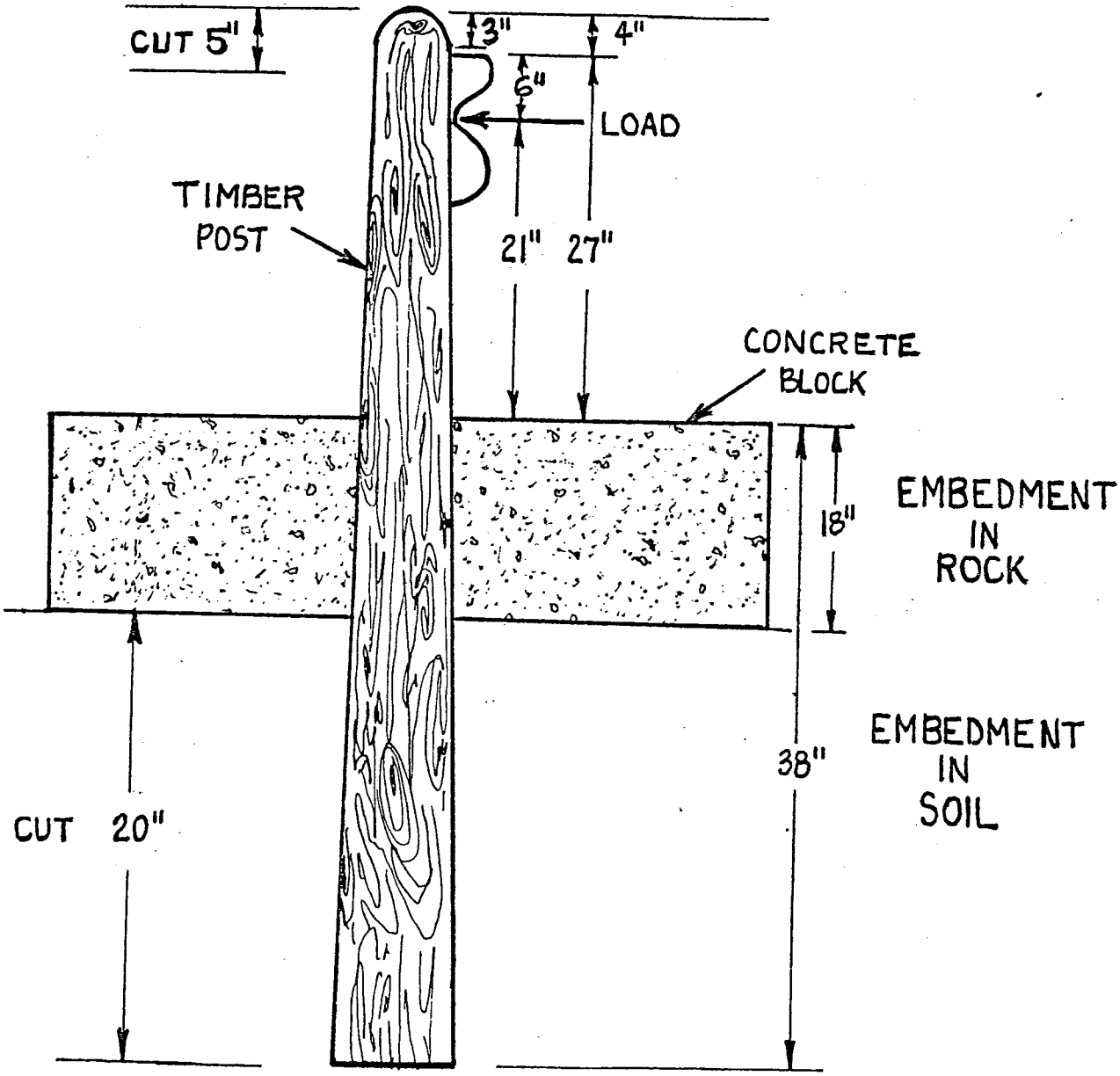


FIGURE 3. POST CUTS

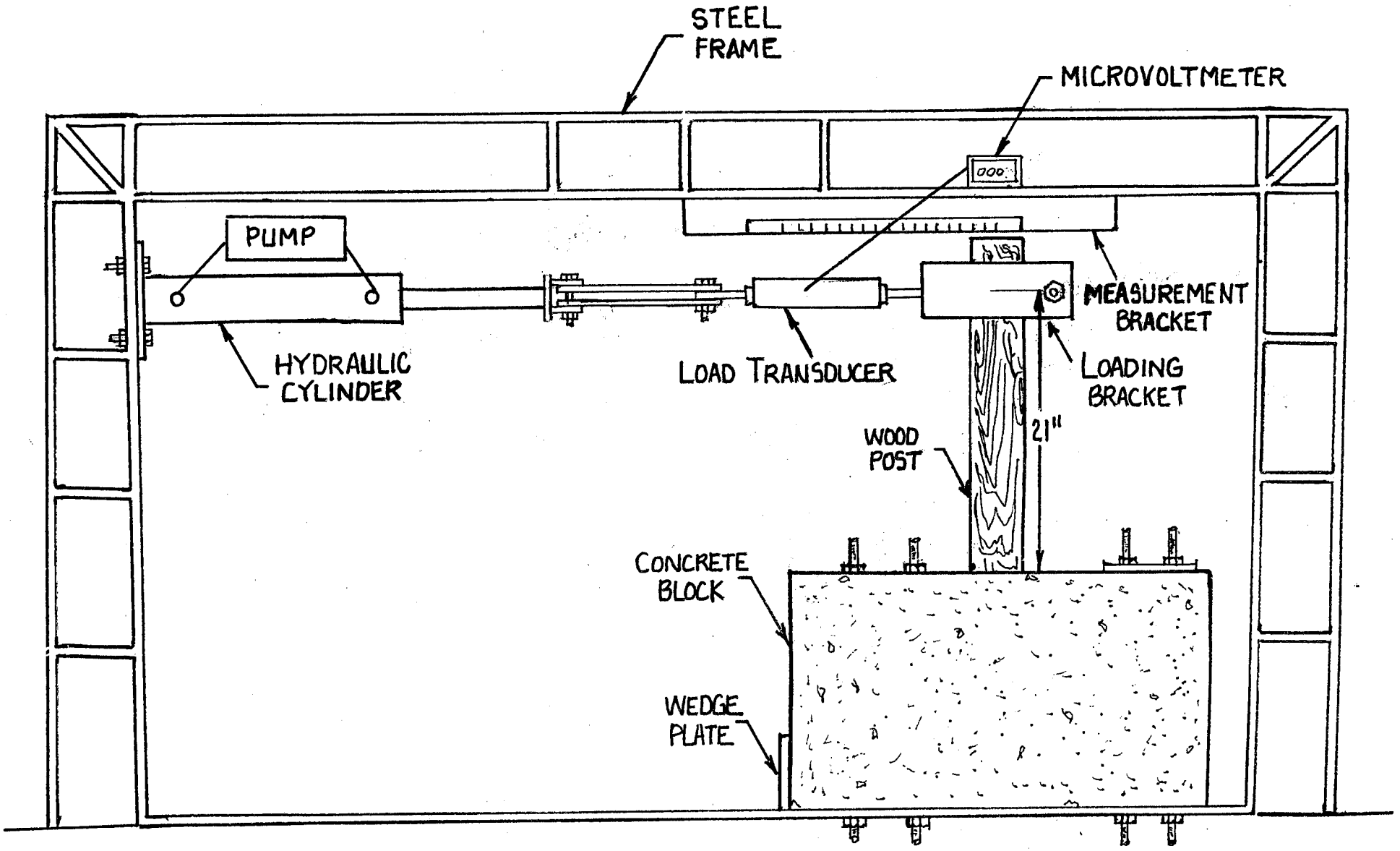


FIGURE 4. DRAWING OF TESTING APPARATUS

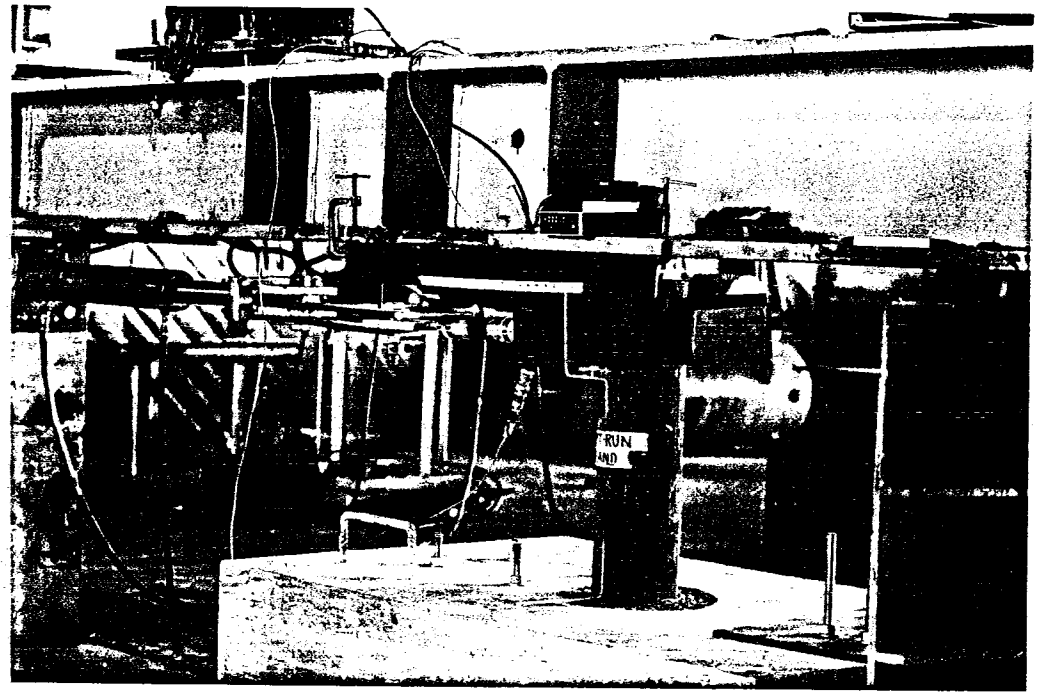


FIG. 5. ACTUAL TESTING APPARATUS

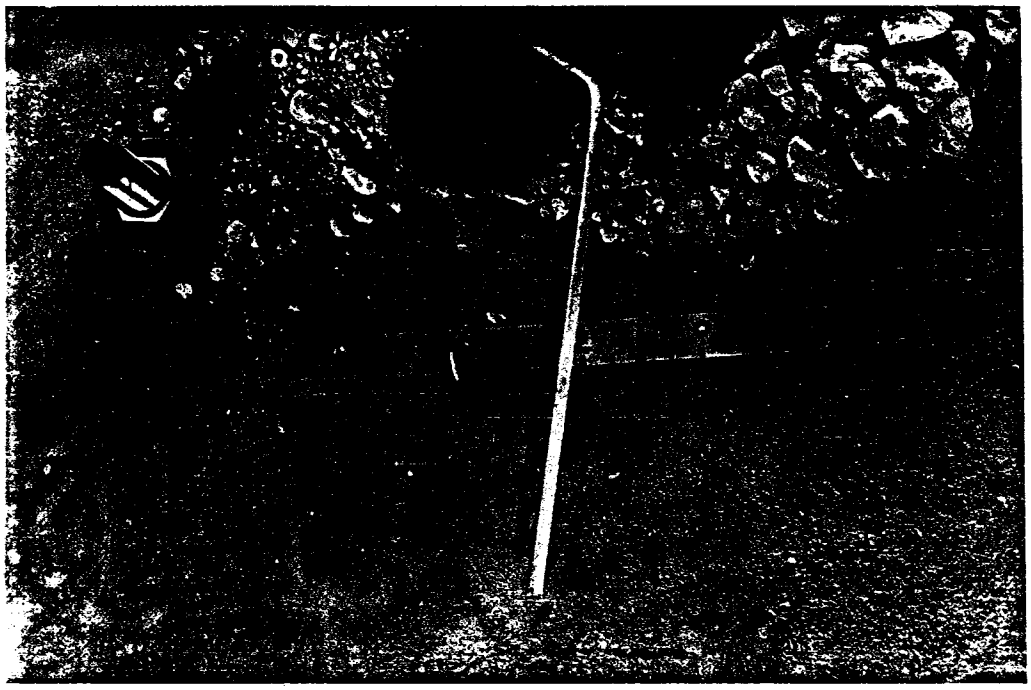


FIGURE 6. GROUND DEFLECTION MEARUREMENT

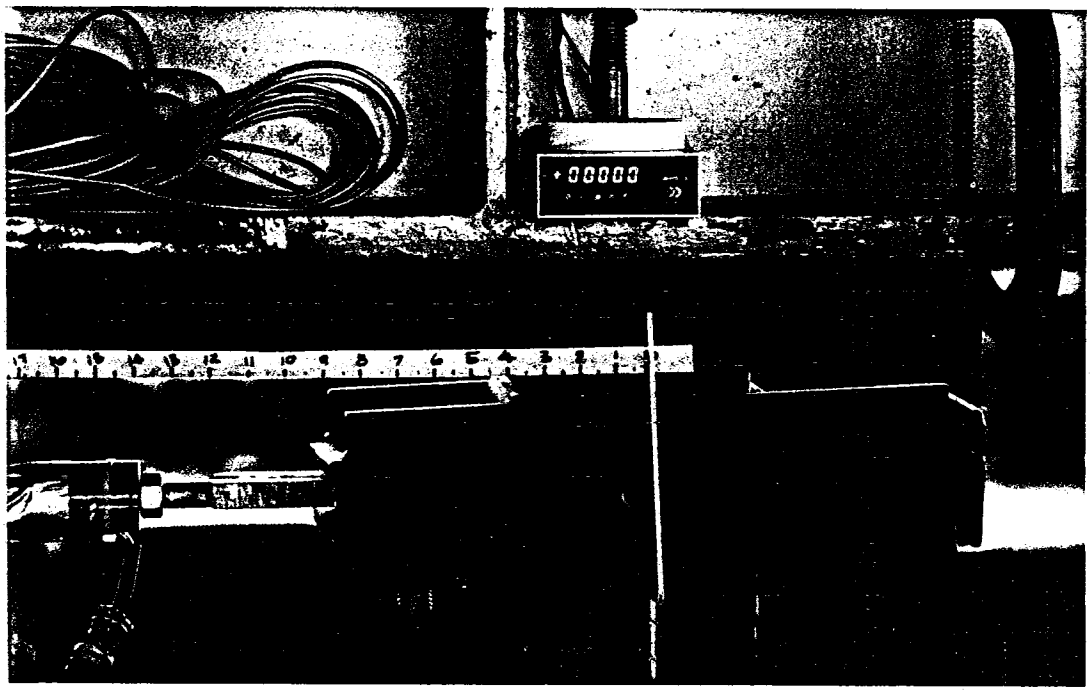


FIGURE 7. DEFLECTION MEASUREMENT AT 23 IN. HEIGHT

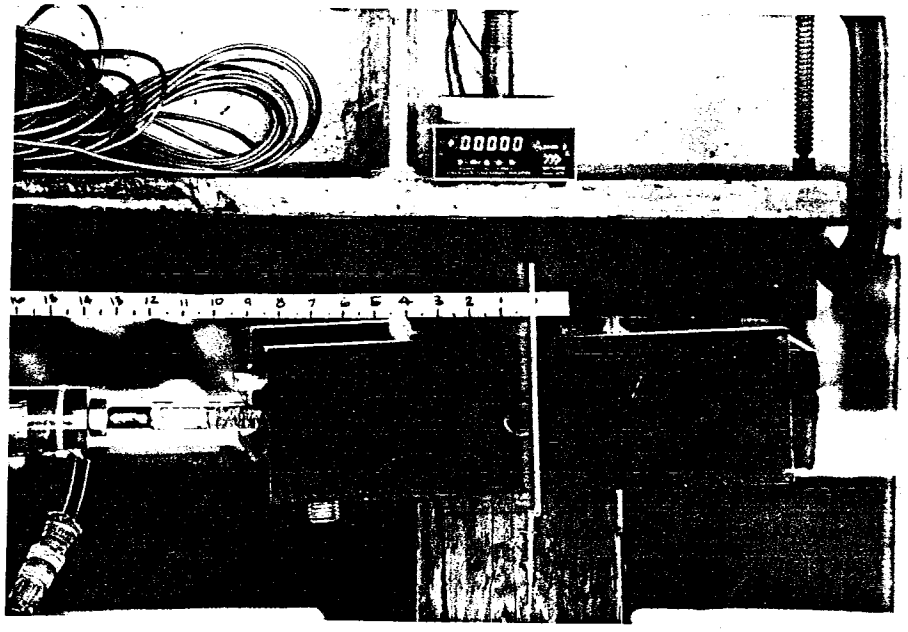


FIG. 8. LOADING BRACKET

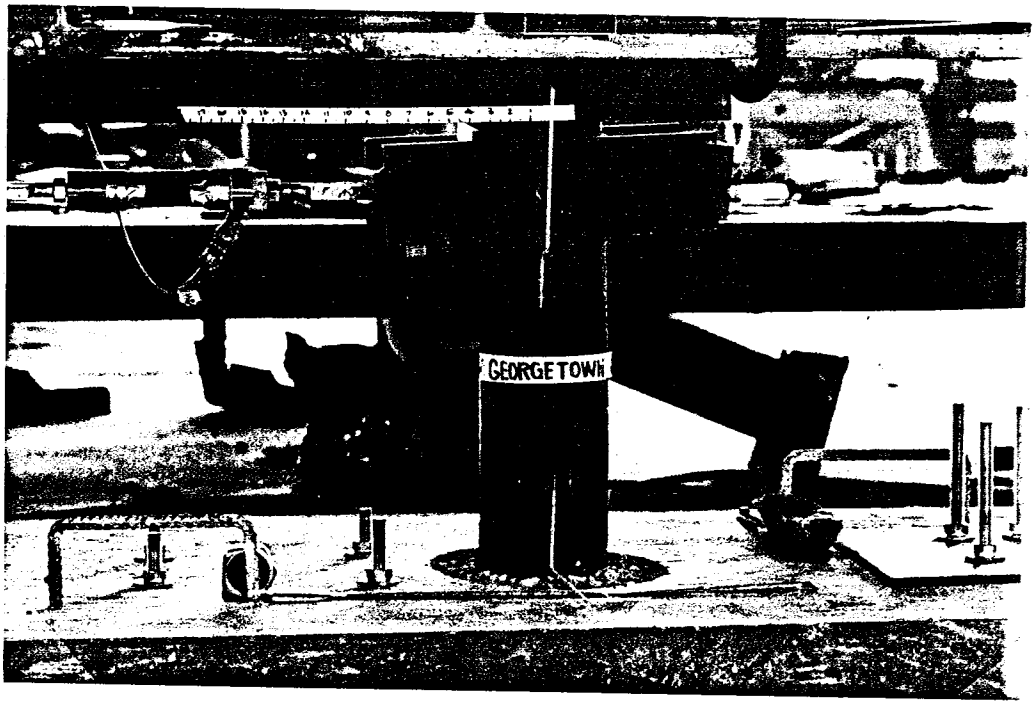


FIG. 9. RODS USED FOR MEASURING DISPLACEMENTS

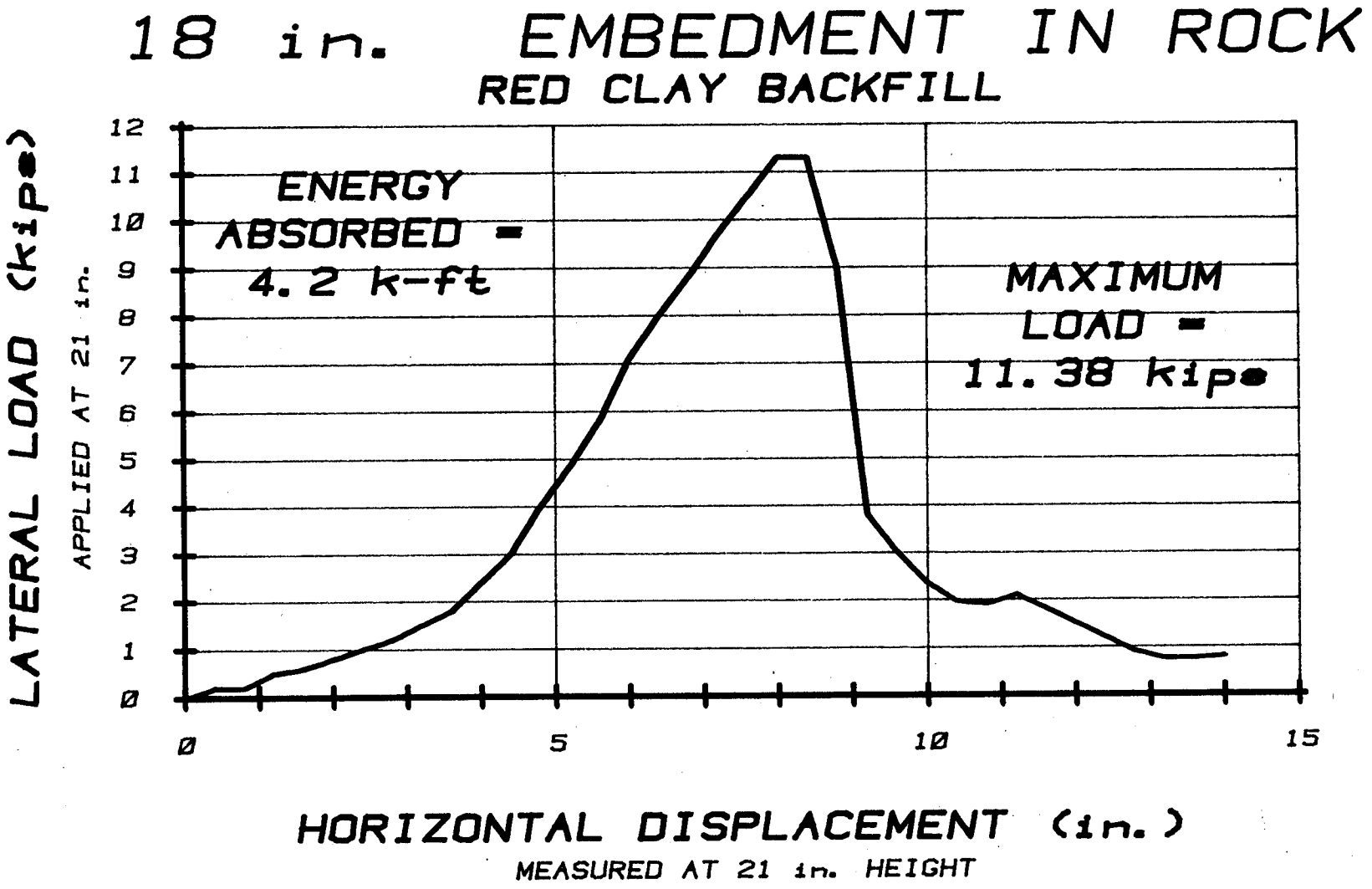


FIG. 10. LATERAL LOAD VS. DEFLECTION FOR TEST 1

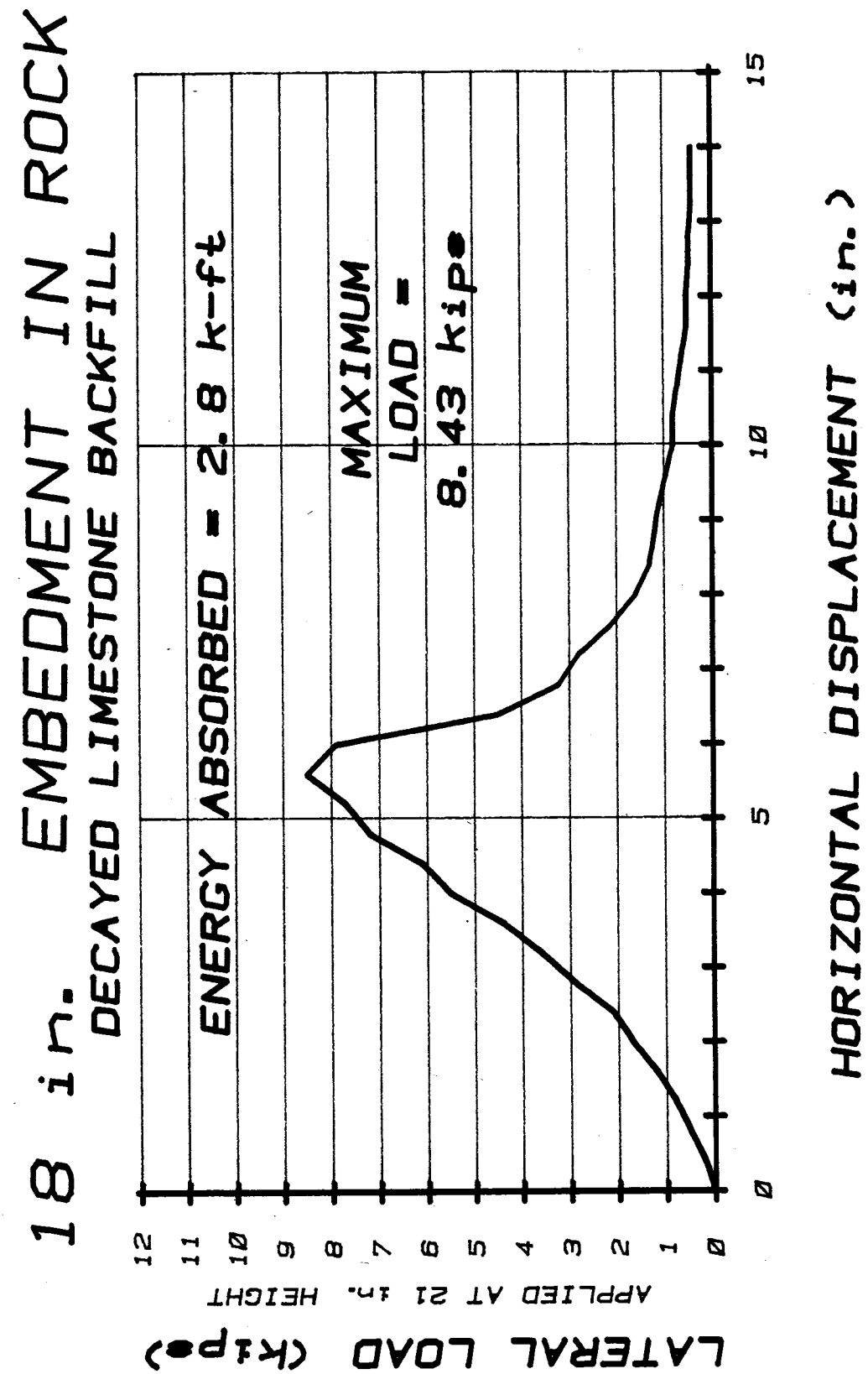


FIG. 11. LATERAL LOAD VS. DEFLECTION FOR TEST 2

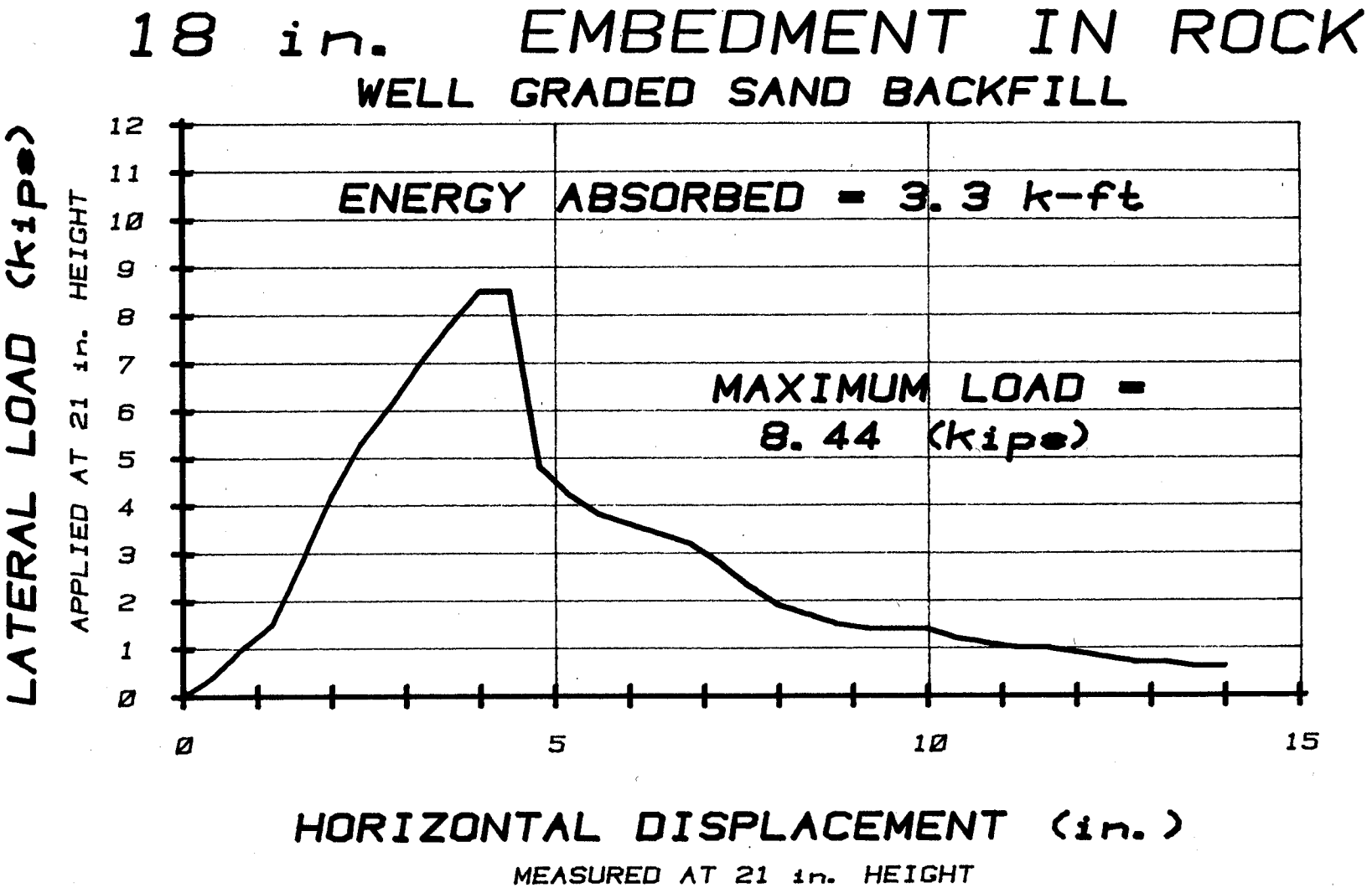


FIG. 12. LATERAL LOAD VS. DEFLECTION FOR TEST 3

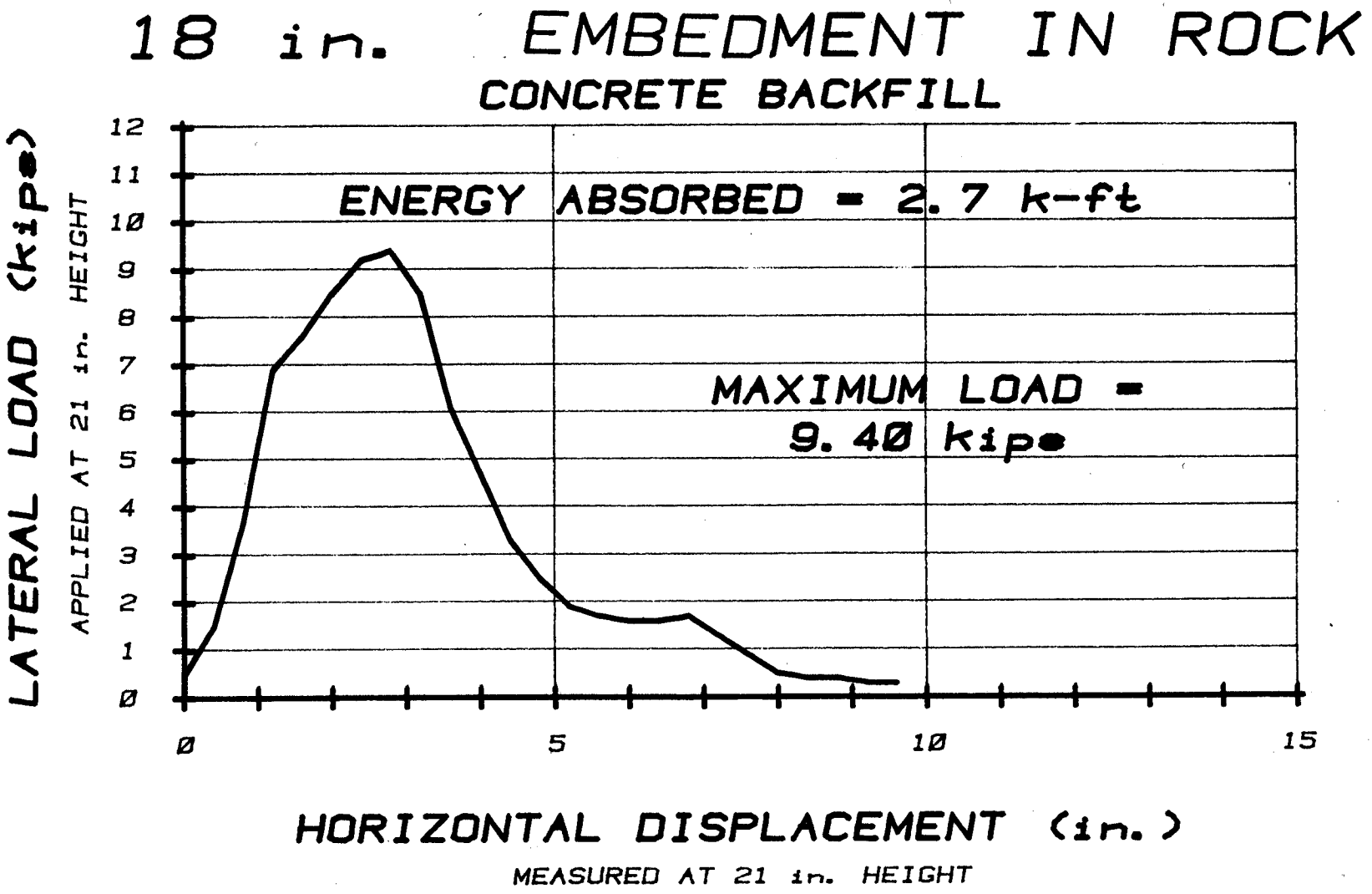


FIG. 13. LATERAL LOAD VS. DEFLECTION FOR TEST 4

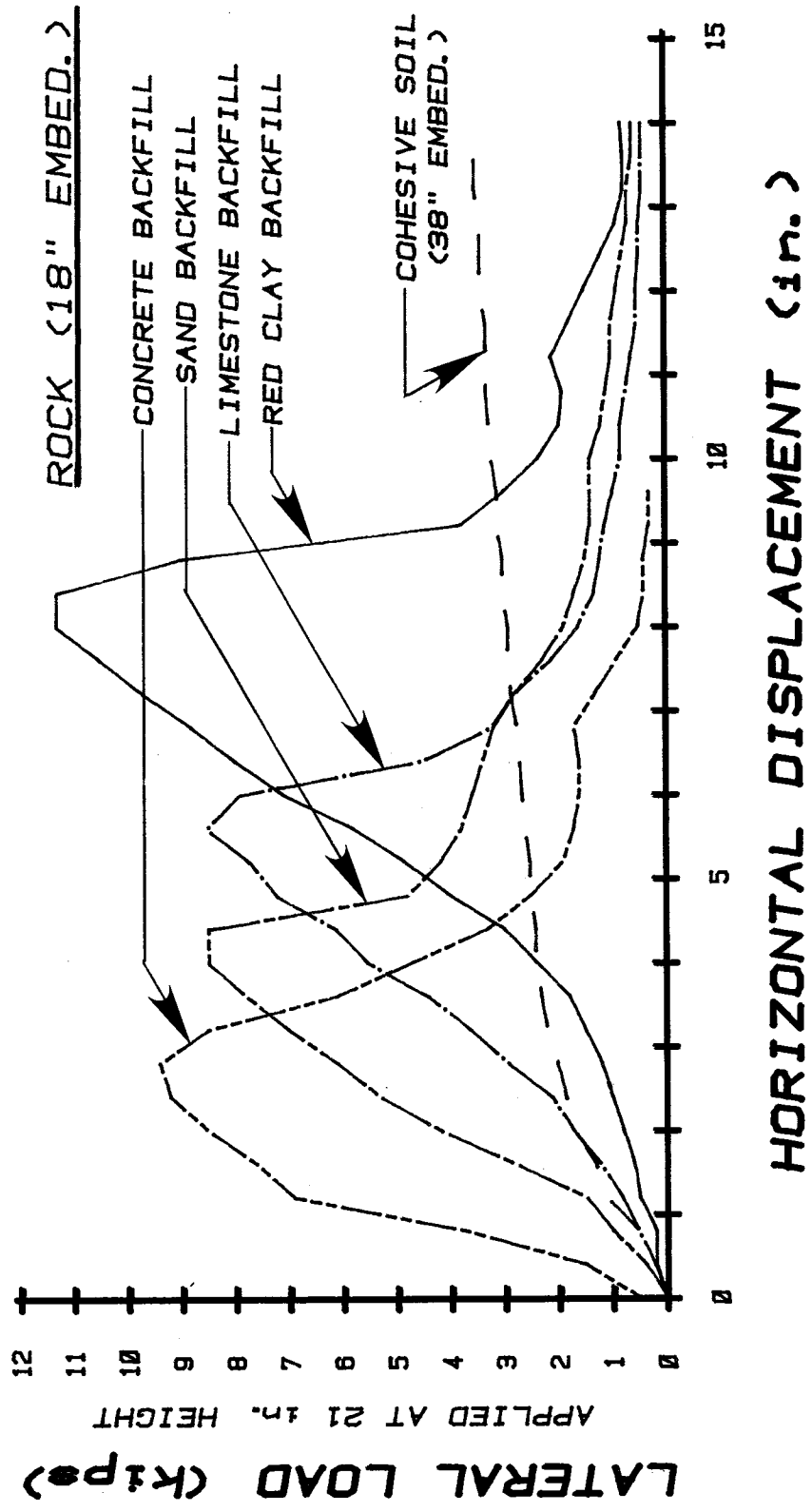


FIG. 14. LATERAL LOAD VS. DEFLECTION FOR ALL TESTS

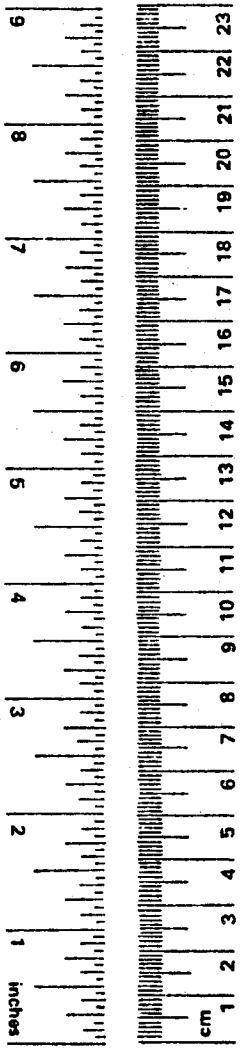
REFERENCES

1. Southwest Research Institute, "Response of Guardrail Post during Impact," Research Report No. 03-9051, October 1970.
2. Dewey, J. F., Jeyapalan, J. K., Hirsch, T. J., and Ross, H. E., "A Study of the Soil-Structure Interaction Behavior of Highway Guardrail Posts," TTI Research Report No. 343-1 to SDHPT, Austin, Texas, July 1983.

METRIC CONVERSION FACTORS

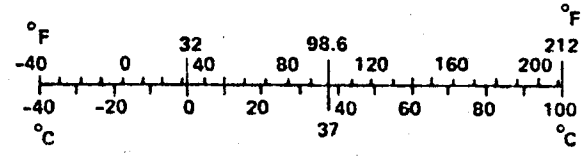
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.