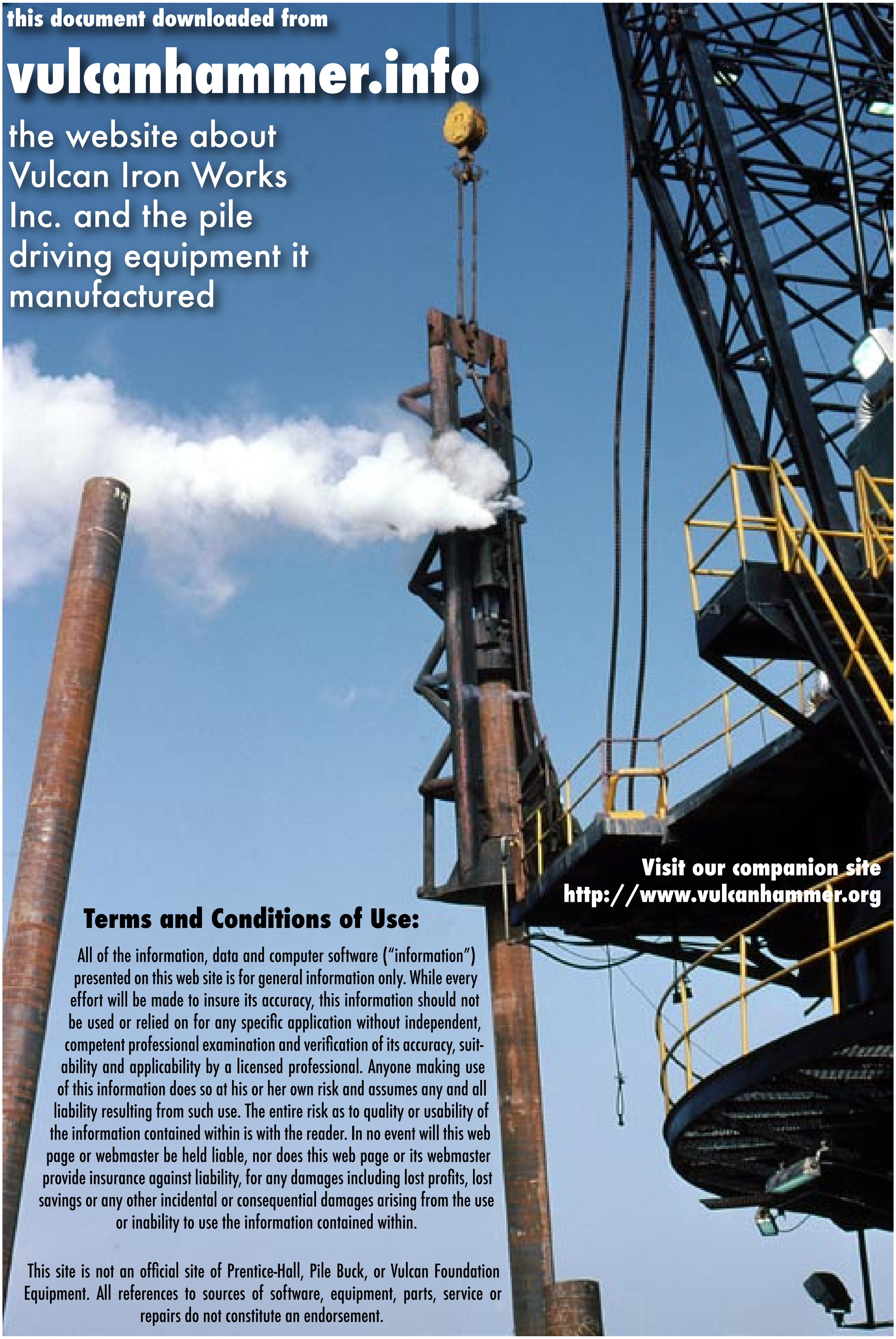

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# THE EFFECTS OF MATERIAL DAMPING ON WAVE EQUATION ANALYSIS OF PILE-DRIVING

By

Rick Corder
George Cozart
Jim Field

CE 686
Offshore and Coastal Structures
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# INTRODUCTION

Adequate information on the effects of including material damping in the wave equation analysis has not previously been available. It was recognized that material damping might have a significant influence on driving long piles although experience with short piles indicated that the exclusion of a damping coefficient or the inclusion of any reasonable value of damping had little effect. However, the current use of very long piles in the offshore area required further consideration of the effects of material damping.

Smith's formula for the force exerted by the idealized springs, includes a modification factor for material damping. A value of 0.0002 was suggested pending the availability of more complete experimental data. Research was conducted at Texas A & M University to provide such data. Once a value of the damping coefficient had been obtained, the effects of including material damping in the wave equation analysis could be studied.

In order to determine the value of the damping coefficient for materials other than steel, laboratory tests will have to be conducted on piles made of these other materials.

# THE EFFECTS OF MATERIAL DAMPING ON WAVE EQUATION ANALYSIS OF PILE DRIVING

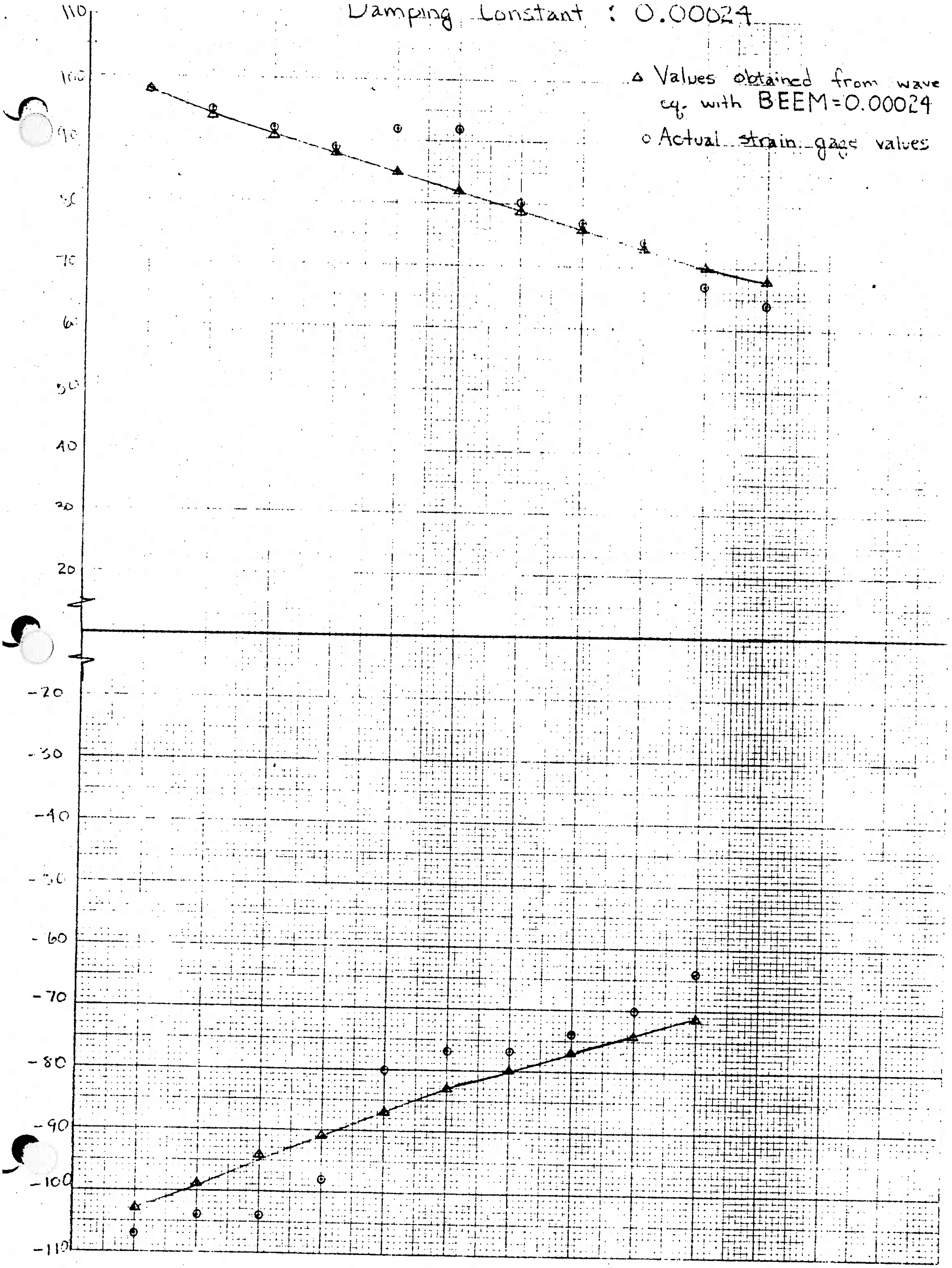
## Experimental Tests

In order to obtain data with which to determine the effects of damping, tests were run on a 100 ft. long steel wide flange beam. The beam was suspended horizontally in the lab, and straing gages were placed at various locations along the beam. A large spring was placed at one end of the beam to keep the beam from swinging too far when struck by the hammer.

variation with time was accurately reproduced. Therefore, in order to compare the strain gage values with the values given by the computer analysis, the value of the first peak as given by the strain gage was adjusted to correspond to the first peak in the computer analysis. The remaining strain gage values were adjusted so as to be consistent with the first strain gage reading. Thus, the values given by the strain gages could be compared to the values computed by the wave equation.

For each assumed value of the damping coefficient, the results given by the strain gages and by the computer analysis were plotted on the same scale. The peaks were assumed to occur at constant time intervals. Plots for six different assumed values of the damping coefficient are shown in Figues 1 - 6.

The reason for the jump in the strain gage values near the beginning of each plot is unclear. The damping effect is cumulative, errors in the assumed values of the damping coefficient are most readily detected after several time intervals have elapsed, i.e., toward the end of each plot. From these plots, a material damping coefficient of B = 0.00027 in.sec./ft. was chosen as being most accurate for steel piles.



Damping Constant : 0.00024

Fig. 2

Damping Constant: 0.00028

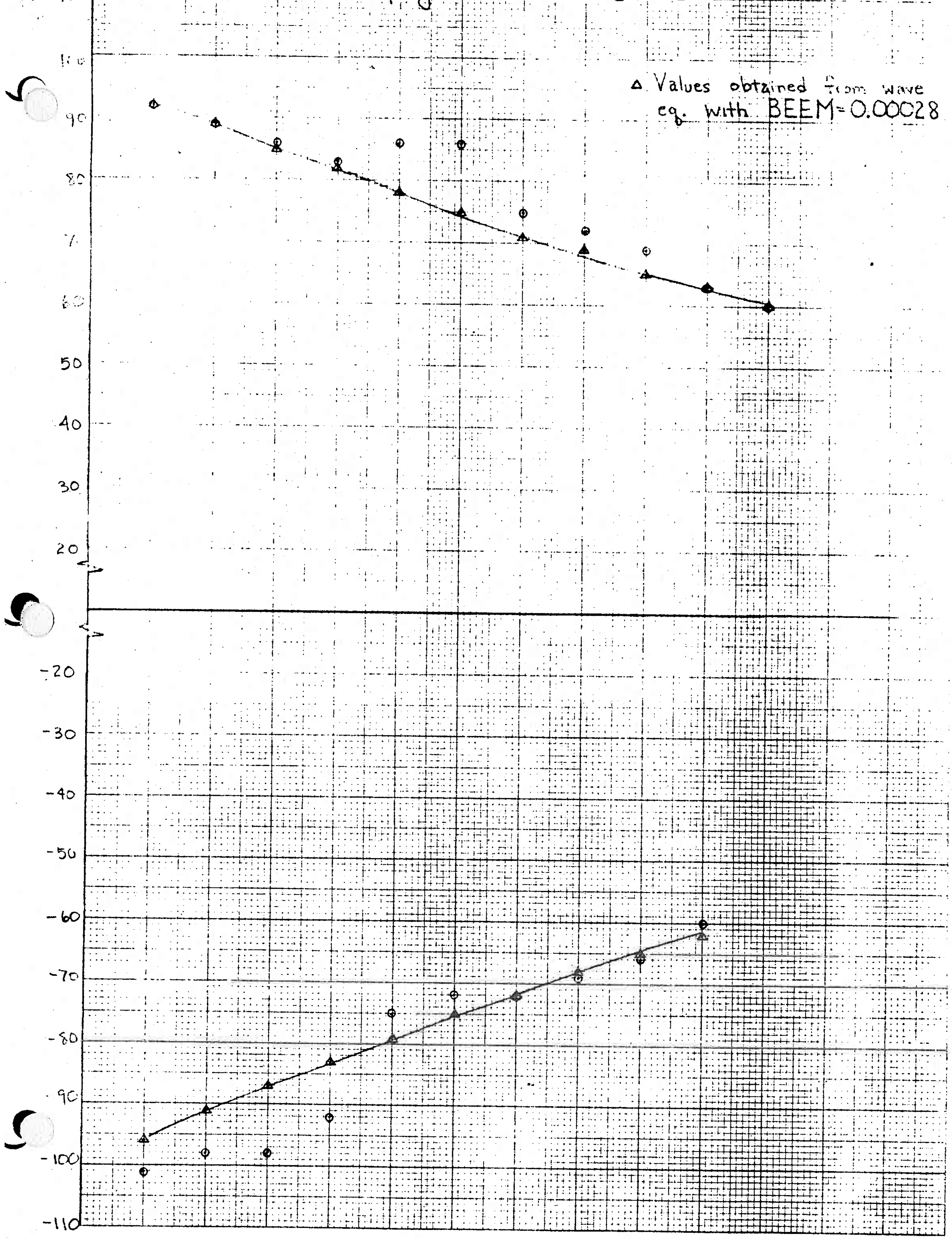


Fig. 4

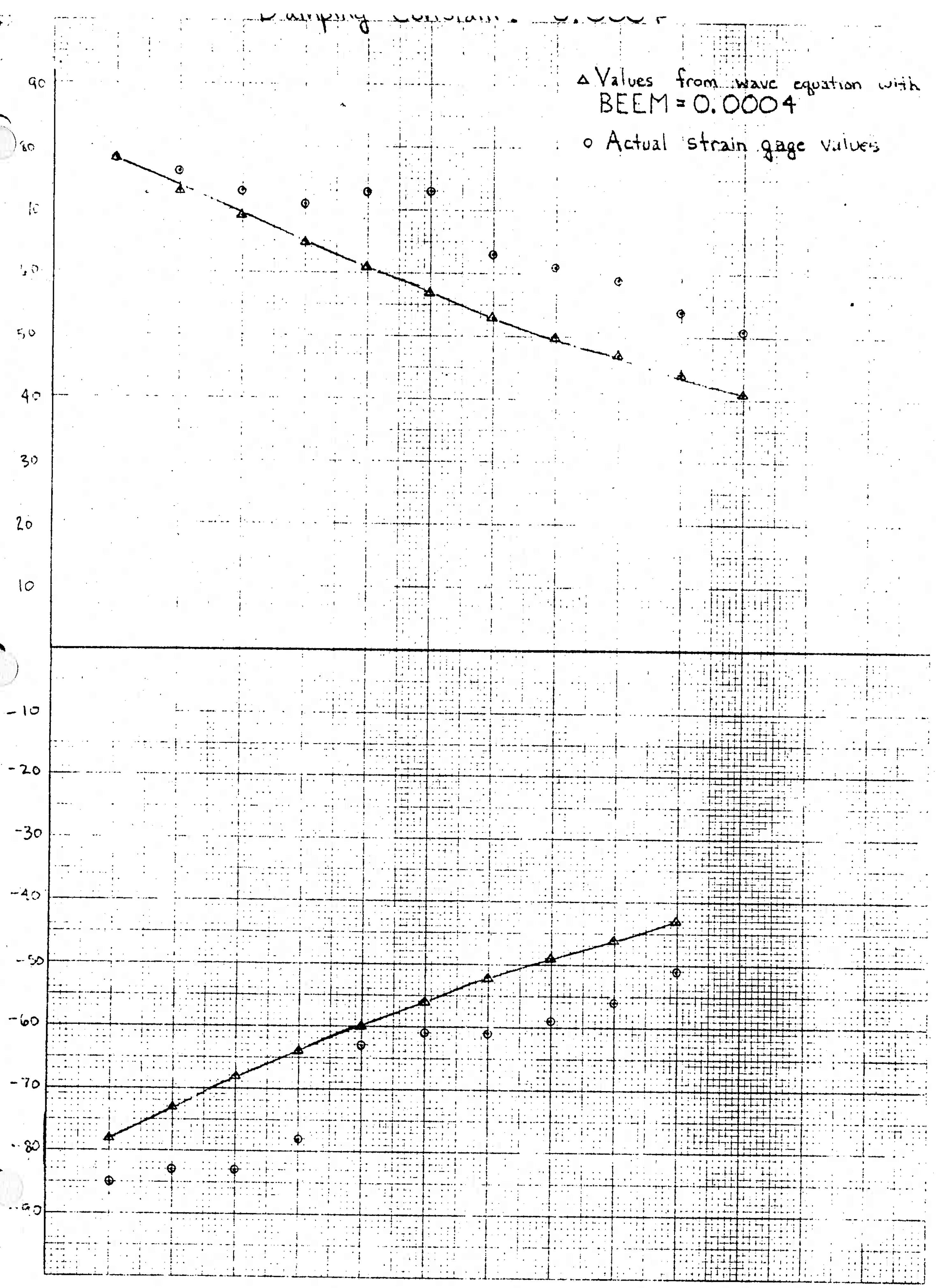

Damping Constant: 0.0004
△ Values from wave equation with BEEM = 0.0004
○ Actual strain gage values
90
80
70
60
50
40
30
20
10
-10
-20
-30
-40
-50
-60
-70
-80
-90

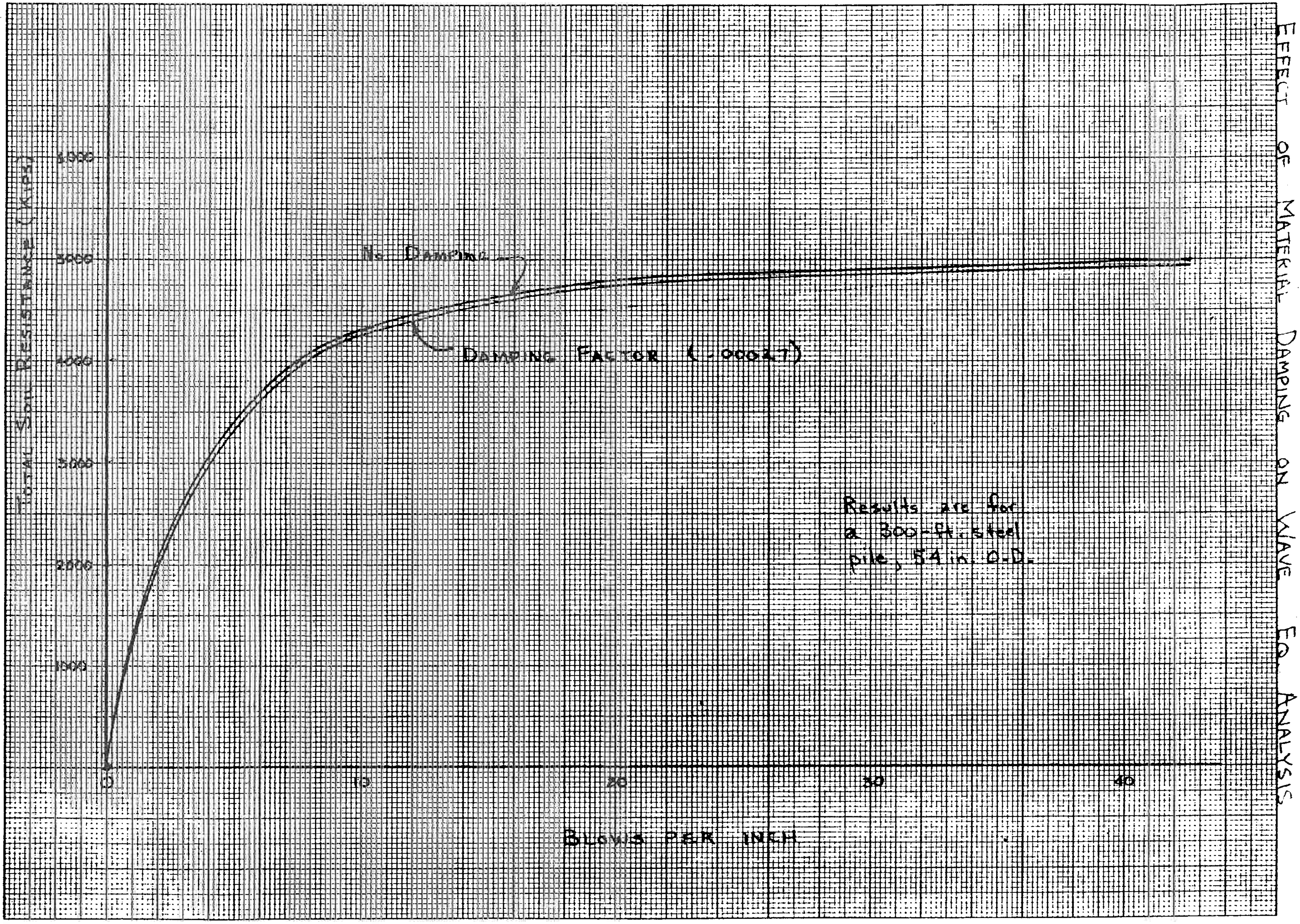
Fig. 6

## Effect of the Damping Constant on Wave Equation Analysis

In order to study the effects of including material damping in the wave equation analysis, three different piles were analyzed both with and without material damping. (See Figure 1). The first pile was a 300 foot long steel pipe with 54 in. O.D., 2 inch wall thickness, and 200 feet of penetration. The second pile was a 600 ft. long steel pipe pile having a 54 inch O.D., driven to 300 feet of penetration, and having wall thicknesses of 2 inches for the top 50 feet, 1.5 inches for the next 100 feet, and 0.75 inches for the remainder of the pile. The third pile was a 1,200 ft. long steel pipe pile with a 54 in. O.D., 2 in. wall thickness, and 500 feet of penetration. The hammer used in each case was a Vulcan 3100, with a 5.5 inch thick asbestos cushion and a pile cap weighing 55.6 kips. The energy output of the hammer was 300,000 ft.-lbs., and the efficiency used was 80%. In each case 10% of the total soil resistance was assumed to act at the point of the pile, and the remaining 90% was assumed to be distributed uniformly along the side of the pile. The soil damping constant along the side of the pile was taken as 0.2 sec./ft., and the soil damping constant at the point was assumed to be 0.05 sec./ft.

Each pile was analyzed under one blow of the hammer using the wave equation analysis and assuming no material damping was present. A plot of total soil resistance versus blows per inch was made for each pile. Then each pile was analyzed at a specific total soil resistance, and a material damping coefficient of B = 0.00027 in.sec./ft. was used in the analysis. The point thus obtained was plotted on the corresponding graph for the undamped case. The results are shown in the Figures 8 - 10. As can be seen from these results, the effect of material damping is to cause a slight increase in the

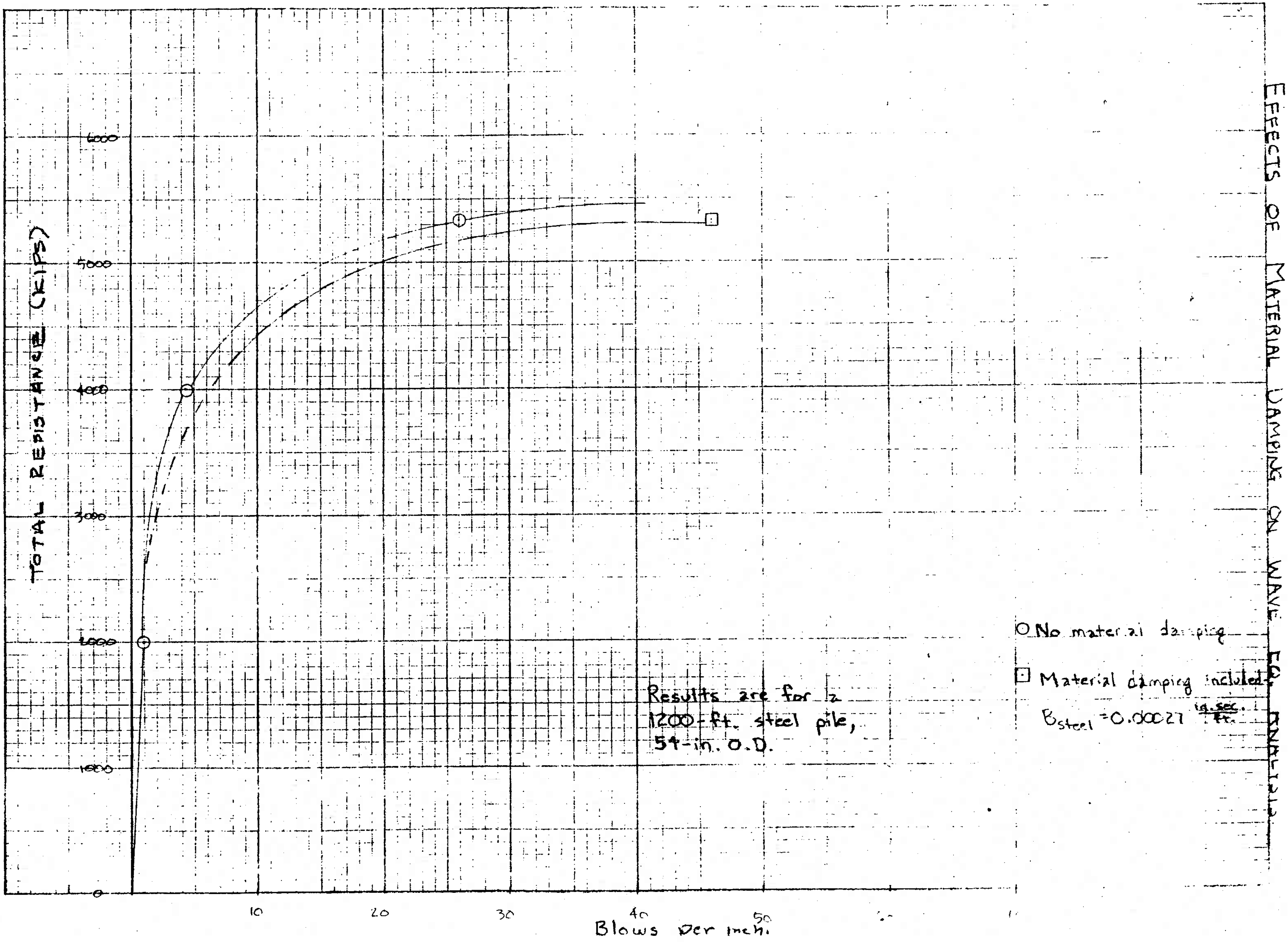
EFFECT OF MATERIAL DAMPING ON WAVE EQ. ANALYSIS



Results are for a 300-ft. steel pile, 54 in. O.D.

Fig. 8

# EFFECTS OF MATERIAL DAMPING ON WAVE EQ. ANALYSIS



○ No material damping

☐ Material damping included

$B_{steel} = 0.00027 \frac{in.sec.}{ft.}$

Results are for a 1200-ft. steel pile, 54-in. O.D.

Fig 10