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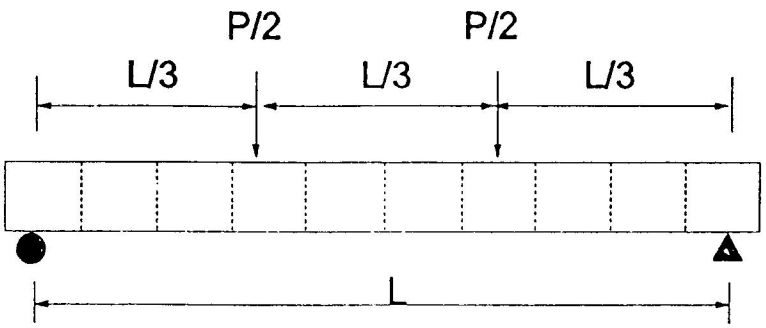
Structural Testing of AMT Prototype Columns

January 1995



Phase I-B
final

report

Engineering Research Institute
Iowa State University

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STRUCTURAL TESTING OF AMT PROTOTYPE COLUMNS

Introduction

During December, 1994, several tests were performed to determine the flexural load capacity of prototype composite/ceramic structural columns manufactured by AlphaGen Materials Technologies, Inc. The specimens tested were CMU columns of various sizes, reinforcement configurations, and composite/ceramic coating options. These preliminary tests were conducted at Iowa State University's Structural Engineering Laboratory as Part B of the initial Phase I Research Plan Proposal under the auspices of the Engineering Research Institute.

Test Specimens, Procedure, and Results

Specimens were subjected to flexural loading in a simply supported configuration as shown in Figure 1. The specimens were instrumented with position transducers for measuring deflection at the midspan. Observations were made during the tests regarding the behavior of each specimen under load. All specimens were tested to ultimate failure on December 20, 1994. The largest remaining sections (following the tests to ultimate) of both of the unreinforced columns were re-tested on December 22, 1994. Results of the testing will be discussed for each specimen in the sections below.

Specimen 1

Specimen Construction/Applied Loading

The first column specimen was constructed from 8" x 8" x 8" nominal CMU block, with a column length of 10 blocks. The specimen weight was determined to be 230 lbs. The section was reinforced with a 5/8" deformed reinforcing bar at the tension surface, as shown in Figure 1. The

span of the simply supported section measured 69 3/8". A concentrated load was applied at the mid-span of the section, directly over the center joint between CMU blocks (see Figure 1). The ceramic coating applied to the compression surface was approximately 1/8" thick. The ceramic/fiberglass/ceramic coatings on the tension surface and the other two sides of the specimen were approximately 1/16" thick for each of the three layers.

Test to Ultimate

Specimen 1 was tested to a maximum effective load of 11,004 lbs. This was not the maximum load carried by the specimen, but rather the maximum load attained before the specimen lost significant load. This concentrated load caused a maximum moment at the midspan of 15.9 ft-kips. The column deflection at the maximum load was measured to be 0.51 in. The first "major event" prior to the maximum load occurred at a load of 8252 lbs., corresponding to the delamination of the top ceramic coating (compression surface) at the first CMU joint away from the load point in one direction. Delamination of the top ceramic coating at the first CMU joint in the opposite direction constituted the second "major event", which occurred at 9872 lbs. Vertical cracking along the sides of the specimen was then observed immediately prior to the achievement of maximum effective load, in addition to further separation of the ceramic coating along the compression surface. Following the attainment of the maximum effective load, the specimen lost approx. 2500 lbs. of load and then the load began to increase again. The specimen carried additional load up to a level of 11,219 lbs., at which time deflections began to increase with a slight drop in load. The specimen then lost load again, as the CMU blocks crushed in compression near the load point area. The test was then terminated, as the specimen failed to carry any increased loading. See Figure 2 for a plot of load v. deflection at the midspan of Specimen 1. Note that this plot shows nearly perfect linear load v. deflection behavior prior to the first "major event".

Specimen 2

Specimen Construction/Applied Loading

The construction of Specimen 2 was intended to be identical to that of Specimen 1, except that no reinforcing steel was provided. The specimen weight was determined to be 230 lbs. The span of the simply supported section measured 69 1/8". Concentrated loads were applied at the third points of the simply supported span. Load was applied in this manner to create a constant moment region over the two center blocks of the specimen. Refer to Figure 1 for a schematic of the test setup.

Test to Ultimate

Specimen 2 was tested to an ultimate failure load of 9527 lbs. This concentrated load caused a maximum moment of 9.1 ft-kips over the two center CMU blocks. The column deflection at the ultimate load was measured to be 0.52 in. No "major events" were observed prior to the failure of the specimen. The specimen failed suddenly at the CMU joint between the centerline of the specimen and one of the load points. One of the CMU blocks at the failure joint was discovered to have a key-out for utility access. The ceramic coating separated from the block as the specimen failed, but the block showed no other signs of distress at the failure region. The failure mode appeared to be shear failure of the ceramic coating on the compressive surface of the specimen. Post-test observations indicated that the inside ceramic coating on the sides of the specimen was slightly thicker than the intended 1/16", and that the overall thickness of the three coatings had slight variations. See Figure 3 for a plot of load v. deflection at the midspan of Specimen 2. Note the nearly perfect linear behavior prior to the ultimate failure load.

Retest of Largest Remaining Section

The failure of Specimen 2 along the CMU joint resulted in two remaining sections; one four blocks long and one six blocks long. The six block section was retested to determine its load-carrying capacity in flexure. The span of the simply supported remaining section was 42", and two concentrated loads were applied 11" off center in each direction. The retest of Specimen 2 gave an ultimate failure load of 15,279 lbs. This concentrated load gave a maximum moment of 6.4 ft-kips over the two center CMU blocks. The deflection at the ultimate failure load was measured to be 0.15 in. At the ultimate failure load, cracking was noted at one corner of the CMU at one end of the specimen. As additional load was attempted to be applied to the specimen, further cracking at other corners was observed. The end where the cracking occurred corresponded to the failed end from the previous test, where the ceramic coating had "popped off" during the failure of the specimen. The opposite end of the specimen was noted to have coatings partially covering the CMU block at the end, and showed no signs of damage. Post-test observations indicated that the top of the CMU block at the failed end had crushed in compression during the testing, and that the ceramic/fiberglass/ceramic coating had separated along the sides of the CMU as the block failed. See Figure 4 for a plot of load v. deflection at the midspan of the retested section of Specimen 2. Again note the linear behavior prior to ultimate.

Specimen 3

Specimen Construction/Applied Loading

The construction of Specimen 3 was intended to be identical to that of Specimen 1, except that a 5/8" smooth reinforcing bar was provided in place of a deformed bar. The specimen weight was determined to be 230 lbs. The span of the simply supported section measured 68". Concentrated loads were applied at the locations indicated on Figure 1, which were fairly close to the third points of the simply supported span. Load was applied in this manner to create a constant moment region over the two center blocks of the specimen.

Test to Ultimate

Specimen 3 was tested to an ultimate failure load of 7197 lbs. This concentrated load gave a maximum moment of 5.4 ft-kips over the two center blocks of the specimen. The column deflection at the ultimate load was measured to be 0.16 in. No "major events" were observed prior to the ultimate failure load. At the ultimate failure load, a crack was observed on the tension side near one of the load points. This crack spanned fully across the tension surface and widened as load was attempted to be applied to the specimen following the attainment of the ultimate failure load. The width of the crack was measured to be 1/4" at this time. Following a drop in load to approx. 4000 lbs., the specimen gained load up to approx. 5300 lbs., where the load remained fairly constant (5300-6000 lbs.) as the crack widened and the CMU at one end cracked and began failing in compression at the support. The test was then terminated, as it was determined that the additional load-carrying capability of the specimen was limited. Post-test measurement of the tension side crack gave its size as 9/16". See Figure 5 for a plot of load v. deflection at the midspan of Specimen 3. Again note the linear behavior prior to ultimate.

Specimen 4

Specimen Construction/Applied Loading

The fourth column specimen was constructed from 8" x 8" x 16" nominal CMU block, with a column length of 10 blocks. The weight of the specimen was determined to be 320 lbs. The section had no reinforcing steel provided, and was coated only with a ceramic coating on the tension and compression surfaces, and none on the sides. As shown in Figure 1, the span of the simply supported section was 66 1/2" and concentrated loads were applied close to the third points of the simply supported span. Load was applied in this manner to create a constant moment region over the two center blocks of the specimen.

Test to Ultimate

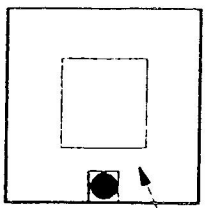
Specimen 4 was tested to an ultimate failure load of 5068 lbs. This concentrated load caused a maximum moment of 4.5 ft-kips over the two center CMU blocks. The column deflection at the ultimate load was measured to be 0.051 in. No "major events" were observed prior to the failure of the specimen. The specimen failed suddenly at a CMU joint, splitting the column into two sections; one seven blocks long and one three blocks long. The failure mode appeared to be shear failure of the ceramic coating. Post-test observations indicated that the thickness of the ceramic coating was 1/16" thick on the compressive surface of the specimen and 1/8" thick on the tension surface, with some variations. See Figure 6 for a plot of load v. deflection at the midspan of Specimen 4. Again note the linear behavior.

Retest of Largest Remaining Section

The seven block section was retested to determine its load-carrying capacity in flexure. The span of the simply supported remaining section was 45", and two concentrated loads were applied 8" off center in each direction. The retest of Specimen 4 gave an ultimate failure load of 3610 lbs. This concentrated load caused a maximum moment of 2.2 ft-kips over the two center CMU blocks. The deflection at the ultimate load was measured to be 0.054 in. At the time of ultimate failure, the CMU block sitting on one of the supports separated from the rest of the specimen. The top ceramic coating separated at the joint between the end CMU block and the adjacent block at that time. See Figure 7 for a plot of load v. deflection at the midspan of the retested section of Specimen 4. Again note the linear behavior prior to ultimate.

Figure 1: Specimen Descriptions & Loading Configurations

Specimen 1

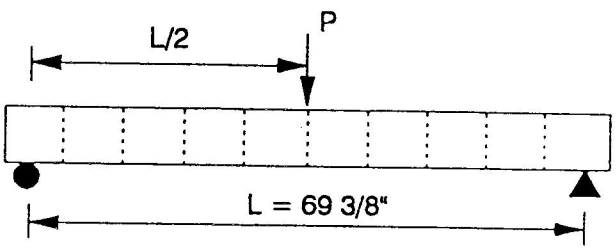


Ceramic/Fiberglass/Ceramic ———

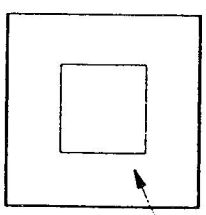
Ceramic Only ———

8" x 8" x 8" Nominal CMU

5/8"
Deformed Bar



Specimen 2



Ceramic/Fiberglass/Ceramic ———

Ceramic Only ———

8"x 8" x 8" Nominal CMU

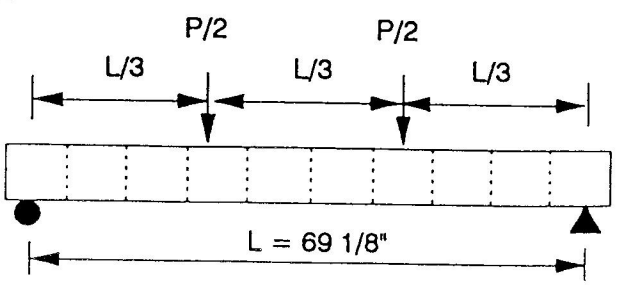
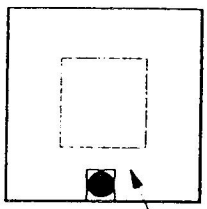


Figure 1: Specimen Descriptions & Loading Configurations
(Cont'd)

Specimen 3

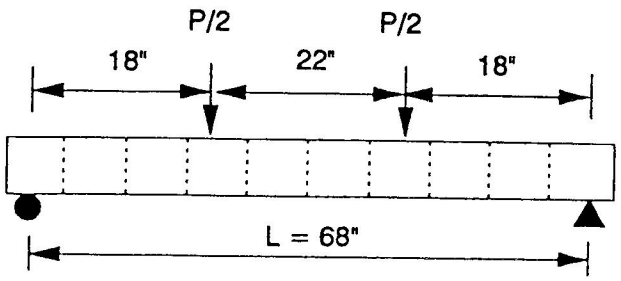
Ceramic/Fiberglass/Ceramic ———

Ceramic Only ———



5/8" Smooth Bar

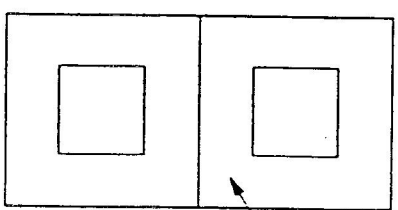
8" x 8" x 8" Nominal CMU



Specimen 4

Ceramic Only ———

No Coating ———



8" x 8" x 16" Nominal CMU

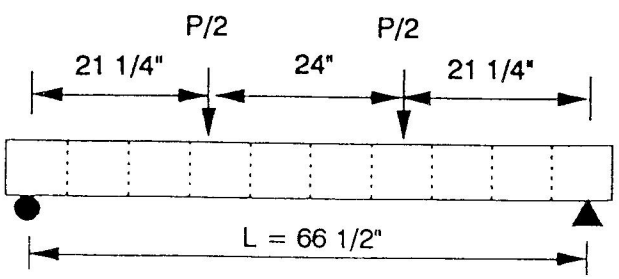


Figure 2: Specimen 1

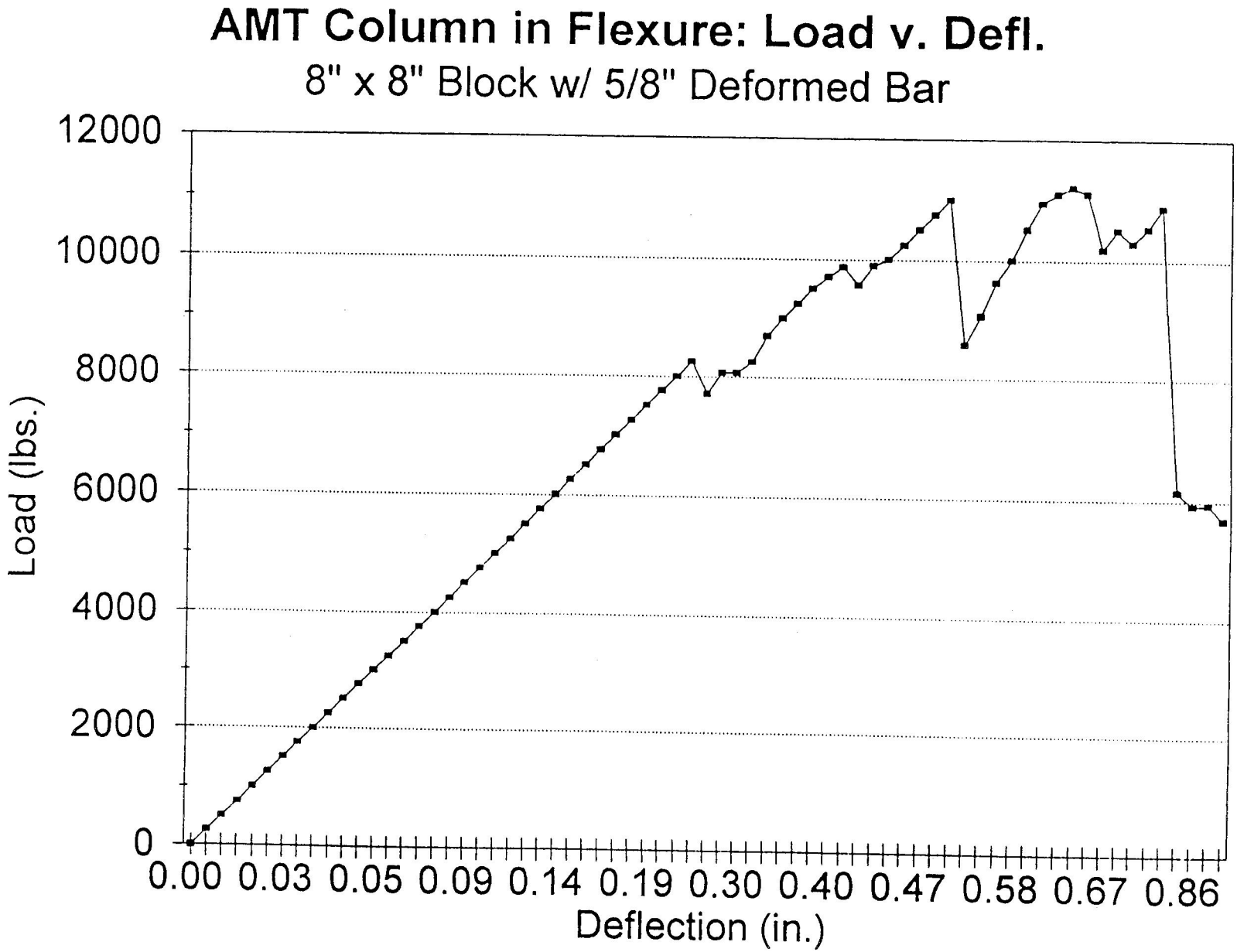


Figure 3: Specimen 2

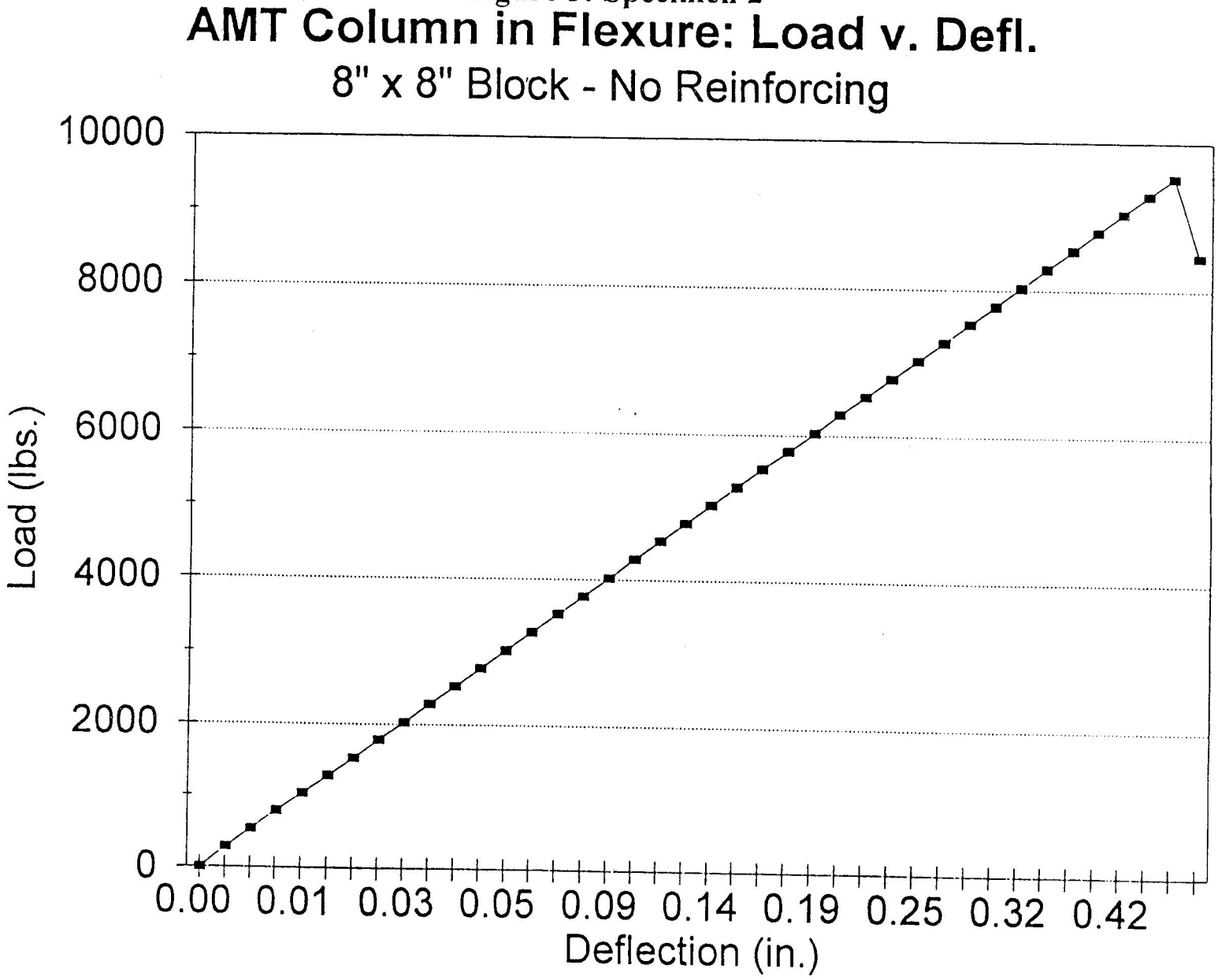


Figure 4: Specimen 2

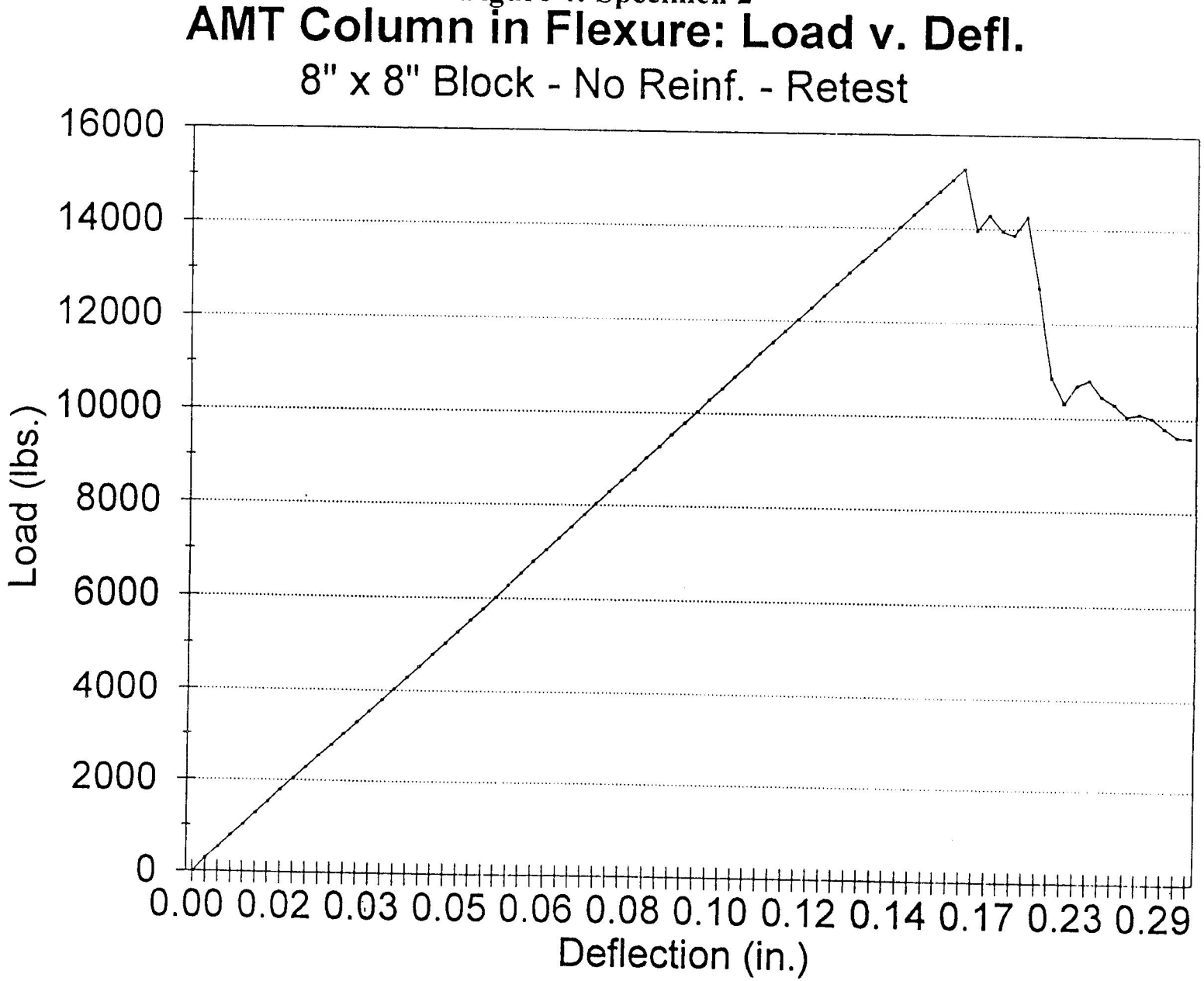


Figure 5: Specimen 3

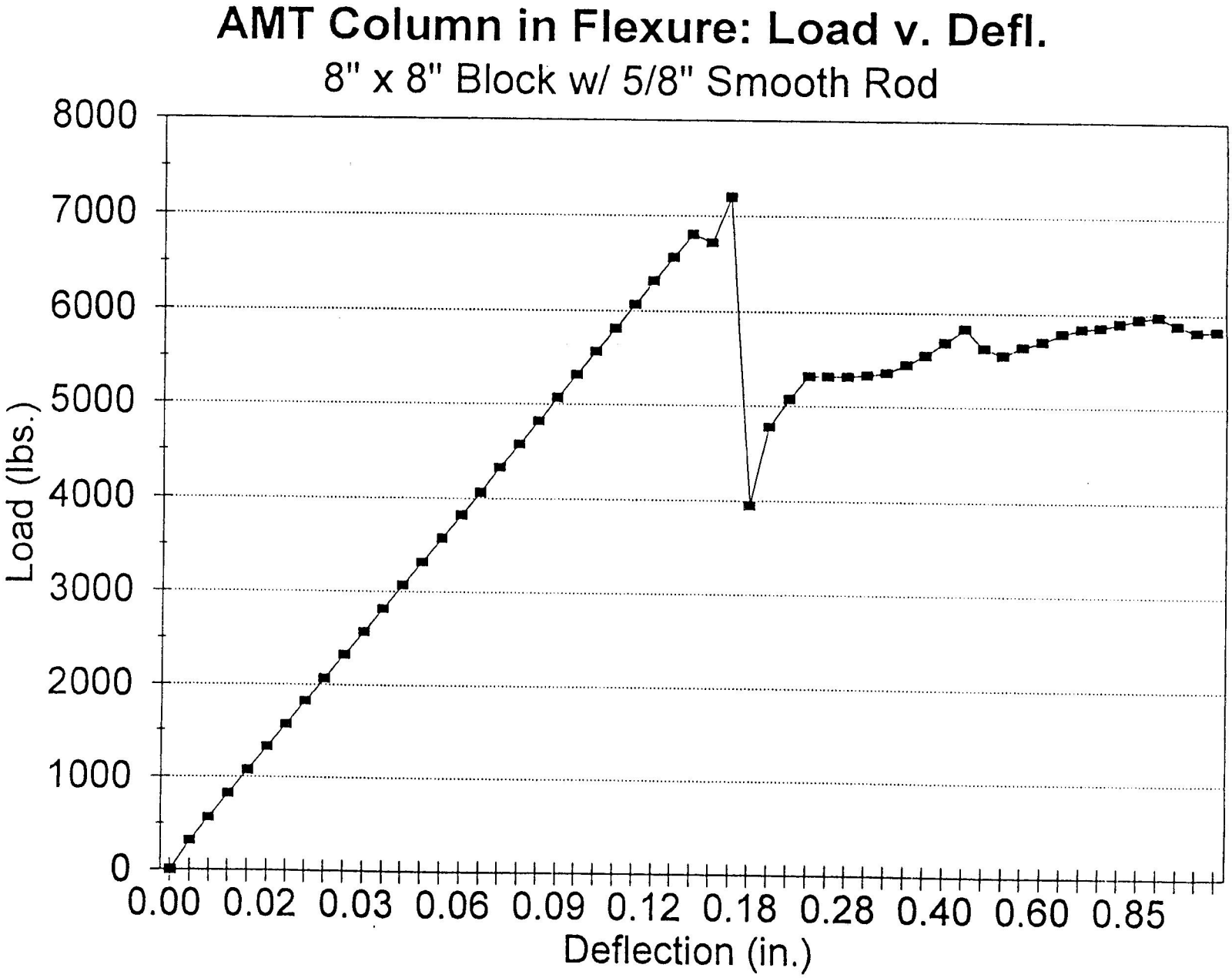


Figure 6: Specimen 4

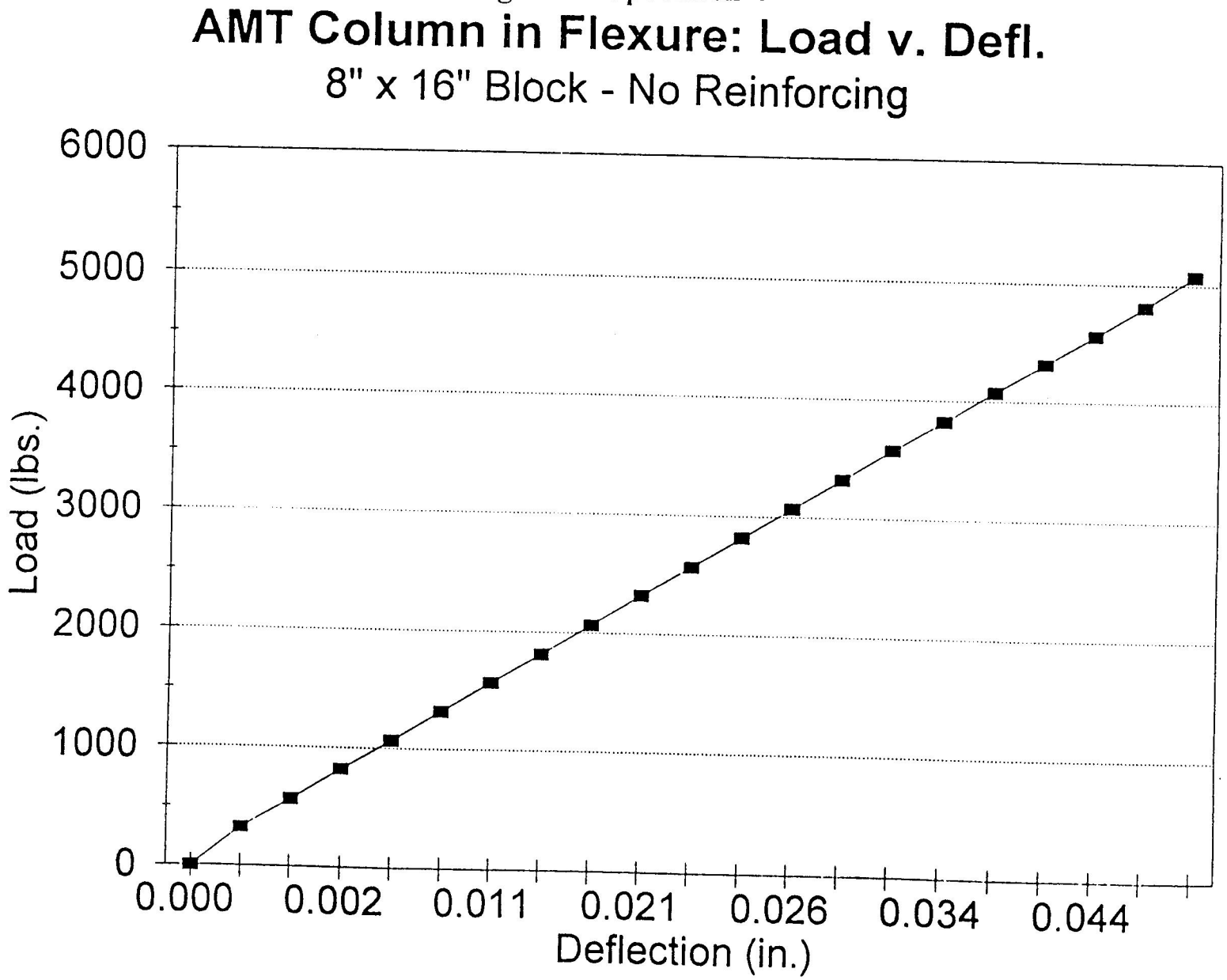


Figure 7: Specimen 4