INTERIM REPORT NO. 1

PAVEMENT DESIGN AND PERFORMANCE STUDY

Phase B: Deflection Study

Evaluation of Pavement Design in Virginia Based on Layer Deflections, Subgrade and Its Moisture Content

by
N. K. Vaswani
Highway Research Engineer

Virginia Highway Research Council
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SUMMARY

In this investigation, the optimum structural strength contributed by a material to the overall strength of the pavement was studied for cases applicable to Virginia. The variables were (a) the modulus of elasticity or the thickness equivalency of the material, (b) the thickness of the material in the layer, (c) the location of the material with respect to other layers containing stronger or weaker materials and in varying thicknesses, and (d) the effect of the total pavement thickness and the depth of the material from the top of the pavement.

The investigation consisted of two parts: (a) a study of the thickness equivalencies of the materials on interstate, primary, secondary and subdivision roads in Virginia, and (b) a model study. The evaluation of the highway system was quantitative, while that of the model study was qualitative only.

This investigation showed that the structural strength of a pavement is decreased when a weaker layer is placed over a stronger layer or when a weaker layer is sandwiched between two strong layers. The investigation also showed that when the bottom of the top layer does not bend, the stress distribution is bulb type; and when the bottom bends, the stress distribution is fan type. Each case would therefore need a different mathematical treatment for design.

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INTRODUCTION

In Virginia and other states, flexible pavement design has undergone a change from the old concept of designing each successive layer stronger than the layer underneath it. Nowadays materials having a high modulus of strength, e. g. , soil cement, soil lime, and cement treated aggregate, are commonly used. These materials are placed in subgrades or bases, and at various depths and at varying positions in relation to other layers having a low modulus of elasticity. Because of this, the structural strength contributed by a given material is affected by the arrangement of the other materials in relation to the material under consideration.

In this investigation, the manner and the degree of strength contributed by a material in such pavement systems, with respect to the strength of other materials, have been studied. Two types of studies were made as stated below.

(1) Determinations of the optimum thickness equivalency values of the materials used on primary, interstate, secondary and subdivision roads in Virginia. The thickness equivalency values are based on the location of the materials in the structure of the flexible pavement.

(2) A model study for qualitative evaluation of the effect of thickness and modulus of strength of a given layer with respect to the thickness and modulus of strength of the other layers in the pavement system.

The thickness equivalency values of the materials with respect to their location in the structure were determined. The effect of the location of a given material in a pavement with respect to the other materials in the pavement system was determined, along with stress distribution patterns.

PURPOSE

The main purpose of this study was to determine the structural behavior and the optimum use of a given material in a layered pavement system. It was proposed to determine the behavior and strength of the given material with respect to the modulus of strength and thickness of other layers in the system.

THICKNESS EQUIVALENCY VALUES OF
PAVEMENTS IN VIRGINIA

The thickness equivalency value, a, is an index of the load carrying capacity of a material and could be defined as the ratio of the strength of a one inch thickness of the material to that of one inch of asphaltic concrete or any other specified material.

In Virginia, different design standards are established for (a) primary and interstate roads, and (b) secondary and subdivision roads. In the case of primary roads, the design is based on the subgrade CBR value and on traffic in terms of 18-kip equivalents. In the case of secondary and subdivision roads, the design is based mostly on traffic in terms of vehicles per day. The evaluations of thickness equivalency values for these roads were carried out as discussed below.

Primary and Interstate Roads

The evaluation of thickness equivalency values in this case was based on (a) the adoption of soil support values (based on CBR and soil resiliency), which would account for the regional factor, (b) traffic in terms of 18-kip equivalents, and (c) deflections. The thickness equivalency values have been reported previously.(1, 2) These values were determined by multiple regression analysis.

A study of cement treated aggregate subbases was carried out in this investigation and their thickness equivalency values, along with all the others previously determined, are given in Table 1. (Table and figures are appended.)

Secondary and Subdivision Roads

The evaluation of the thickness equivalency values in this case was based mainly on traffic in terms of vehicles per day. The values determined by regression analysis were based on the present design practice in Virginia, by correlating daily traffic with the thickness index $D = a_1h_1 + a_2h_2 + \ldots.$(3) in the equation $\log D = P + Q \log \text{vpd.}$, where

D = Thickness index $= a_1h_1 + a_2h_2 + \ldots.$

vpd = the number of vehicles per day

$h_1, h_2, \ldots.$ = thickness in inches of different layers

$a_1, a_2, \ldots.$ = thickness equivalency of the materials with thicknesses $h_1, h_2, \ldots.$ respectively, and $a_1 = 1$.

P and Q = constants of the equation.

The following equation was obtained: $\log D = 0.2 + 0.24 \log \text{vpd}$ from 12 mean values. The correlation coefficient was found to be 0.99 and the standard error of estimate 0.02. These values indicated a very high degree of correlation.

Effect of Depth of Cover and Pavement Thickness on Thickness Equivalency Values

The primary and interstate roads usually carry high volumes of traffic while the secondary and subdivision roads carry comparatively low volumes of traffic. The primary and interstate roads are therefore stronger and thicker than the secondary and subdivision roads.

Examination of the thickness equivalency values in Table I for the two sets of design procedures reveals the following:

(a) The thickness equivalency of untreated aggregate in the base is 0. 35 for primary and interstate roads, and 0. 60 for secondary and subdivision roads.

(b) Similarly, the thickness equivalency values of the materials in the subbase for primary and interstate roads is lower than the values for secondary and subdivision roads.

(c) In the case of primary and interstate roads the thickness equivalency for the cement treated aggregate for the base course is 1. 0, and for the subbase course 0. 6.

The reason for the above mentioned differences in the thickness equivalency values is the depth of the cover. In the case of primary and interstate roads, the surfacing, binder, and base courses over the untreated aggregate would consist of asphaltic concrete varying in thickness from 4. 5 to 10. 5 inches. Further, an intermediate layer of about six inches of cement treated aggregate is sometimes provided between the untreated aggregate base and the asphaltic concrete mat, which further increases the cover thickness. As compared to this thickness of cover, the cover thickness of asphaltic concrete over the untreated aggregate base for secondary and subdivision roads varies from zero to five inches. The reduction in thickness equivalency with an increase in cover thickness has also been pointed out by Foster. (4)

In some cases it has also been found that as the thickness of the pavement decreases the thickness equivalencies of the materials increase. This is evident from Table 1, wherein the thickness equivalency values of the subbase materials in secondary and subdivision roads are higher than those of similar materials in primary and interstate roads.

Figure 1 has been drawn on the basis of AASHO Road Test Results.(3) This figure shows that as the depth of the pavement increases the thickness index required decreases. For example with the 20,000 lb. axle load shown in the figure the thickness index decreases from 3.31 to 3.14 when the pavement thickness increases from 7 +10.4 = 17.4 inches to 7 +16.8 = 23.8 inches.

In spite of the effect of the depth of cover and pavement thickness on the thickness equivalencies of the materials, it is found that the equation of thickness index, $D = a_1h_1 + a_2h_2 + \ldots.$ holds good. This equation is applicable if the thickness equivalencies of the materials are determined according to their quality or strength and their location in the pavement system. However, during study of the flexible pavements in Virginia certain observations were made which, due to lack of data, could not be clarified. Therefore, model studies were conducted to investigate these observations. This study is discussed in the following paragraphs.

MODEL STUDIES

The study of pavements in Virginia indicated that when the organization of the layered system deviated from that of the usual system, there was a change in the load versus thickness index relationship.

It was not possible to make any theoretical verification of this fact beyond certain limits. Theoretical evaluations made on pavements in Virginia are given in the 1969 publication.(2) The method of verification by models was therefore employed. The object of the model studies was to obtain a qualitative evaluation of the behavior of the pavement. No quantitative or numerical evaluation was proposed or should be assumed, though numerical values are given for clarity.

In all the studies mentioned herein the models consisted of two, three, or four layers of materials arranged in varied order and in varied depths. The lowest layer consisted of a specified material — called the subgrade — having a modulus of elasticity = 1,000 psi for an infinite depth. The infinite depth of the subgrade was obtained by increasing the thickness of the subgrade layer until the load deflection ratio on the subgrade only remained almost constant. Some of the different combinations adopted are described below. All materials in the models were homogenous, isotropic and elastic within the testing range of load and time. All models whose results are reported herein were two dimensional on a three dimensional subgrade. The models were of a specified width and depth to permit proper distribution of load. The depth of each layer varied. The load was applied in the center of the model and maximum deflections measured. The loading system on the two and three demensional models is shown in Figures 2(a) and 2(b).

Two Layers — Single Layer Over the Subgrade

In a two layer system, the modulus of elasticity of the top layer is always higher than that of its subgrade; e.g., an untreated stone or soil cement, asphaltic mat, etc., over a weaker soil subgrade.

In this investigation, three photoelastic materials having moduli of elasticity values E = 30,000; 340,000; and 450,000 psi were independently loaded while resting on a weaker subgrade having an E = 1,000 psi.

A graph of load versus deflection was drawn for each of the materials with different thicknesses of the top layer resting on the given subgrade. All these graphs were straight lines passing through the origin. The slopes of the graphs differed from one another depending upon the modulus of elasticity and the thickness of the top layer. From each of the graphs, deflection per unit load was determined. Based on the data so obtained, a graph of deflection per unit load versus thickness of the top layer was drawn for each of the materials with a given modulus of elasticity. (Deflection per unit load was adopted to enable evaluation for any given load.) Three such graphs, one each for E = 30,000; 340,000 and 450,000 psi of the top layer, are shown in Figure 3.

To correlate the thickness equivalency of each of these three materials, the thickness equivalency of the material with E = 340,000 psi was taken as $a_1 = 1.0$. For different values of deflection, ratios of the thickness of the layer of material with E = 30,000 psi to the thickness of the material with E = 340,000 psi were determined from Figure 3. There was very little difference between these ratios. The general trend was a slight decrease in the values of the ratios with an increase in the thickness of the layer or a decrease in deflection. An average value of this ratio was found to be 0.27. Thus, this ratio is the thickness equivalency value, a_3, of the material having $E_3 = 30,000$ psi. In the same manner, the thickness equivalency value of the material having $E_2 = 450,000$ psi was found to be $a_2 = 1.44$. The thickness equivalency value of the material with $E_2 = 450,000$ psi decreased very little with an increase in the thickness of the layer, as was observed for the material with $E_3 = 30,000$ psi, and hence this difference is ignored and the average value accepted.

Thus, the following values for different materials were accepted for further tests:

for E_1 equal to 340,000 psi, a_1 is 1.0;

for E_2 equal to 450,000 psi, a_2 is 1.44;

for E_3 equal to 30,000 psi, a_3 is 0.27, and

for E_4 equal to 1,000, a_4 was not determined, because the E value of the subgrade was also 1,000 psi.

Three Layers — Two Layers Over a Subgrade

In the three layer system the top layer could be either stronger than the bottom layer, e.g., an asphaltic concrete mat overlying an untreated stone base; or the top layer could be weaker than the bottom layer, e.g., stone aggregate lying over a cement treated subbase or an asphaltic mat lying over a portland cement concrete pavement.

The model tests showed that when a stronger layer lies over a weaker layer, the equation of $\log d = M + N (a_1h_1 + a_2h_2 + \dots)$ based on AASHO Road Test Results and as adopted in the report$^{(5)}$ is applicable where d = deflection; M and N = constants of the equation, and a_1, a_2, h_1, h_2 have the same meaning as described before.

In Figure 4, thickness index versus deflection has been drawn for the three layer system and the two layer system. The values of the three layer system were obtained directly from load tests, while the values of the two layer system were obtained from the curves in Figure 3, which were drawn from the load test data. Excluding the very low values of thickness index, say up to a maximum of D = 2, the graph of deflection, d, versus thickness index, D, would be a straight line. Lower values of D are ignored because pavement designs with such low values would be impractical. However, the straight line graph shown in Figure 4 is based on a simple regression analysis of all points shown in the graph. A high degree of correlation (R = -0. 97) exists between these two variables, deflection and thickness.

With $a_1 = 1.0$ for the upper layer as determined from the two layer system discussed above, it was found that the thickness equivalency of the lower layer with a lower strength modulus increases as its thickness decreases, as shown in Figure 5. The increase is from a value of 0. 27 as determined in the two layer system to 0. 48 for the minimum thickness adopted. This tendency has been observed in pavements in Virginia. H. B. Seed, et al(6) have shown that resilient deformation per inch of granular base is smaller for an eight inch base than for a twelve inch base. Resilient deformation is an inverse function of the thickness index, and hence an inverse function of the thickness equivalency. Thus, the investigation by Seed, et al also shows that the thickness equivalency of the lower layer increases as its thickness decreases.

We could, therefore, conclude that the optimum thickness value for the lower layer is the minimum thickness that could be economically provided.

In the model study, when a stronger layer was laid under a weaker layer — as shown in Figure 6 — the model did not exactly fit the equation $\log d = M + N (a_1h_1 + a_2h_2 + \ldots.)$ as it offered less resistance to deflection. Assuming $a_2 = 0.27$ for the upper layer as determined from the two layer system discussed above, it was found that as the thickness of the top layer increases, the thickness equivalency contributed by the lower layer decreases. This is shown in Figure 6. The reduction in the value of the thickness equivalency of the lower layer depends upon the ratio of the modulus of the two layers and also on their thicknesses. This figure also shows that the thickness equivalency of the lower layer increases as its thickness increases.

Figure 6 thus shows that the strength equivalency value, a_1, of the stronger lower layer decreases from 1.0 to 0.6 dependent upon layer thickness if a_2 is taken as 0.27. Thus, we find that the materials in this system remain below their optimum strengths.

Four Layers — Three Layers Over a Subgrade

In this system, if the modulus of elasticity decreased from top to bottom no change was noticed from the fundamentals discussed in the three layered system with the stronger layer over the weaker layer, i.e., $\log d = a + b (a_1h_1 + a_2h_2 + \ldots.)$

The system discussed herein, and which sometimes is found in practice, is when a weaker layer is sandwiched between two stronger layers. Two systems of sandwiched layers are discussed. In one case the sandwiched layer had an $E_4 =$ 1,000 psi with the sandwiching layers having an $E_1 = 340,000$ psi as shown in Figure 7.

In the other case the sandwiched layer had an $E_3 = 30,000$ psi with the sandwiching layers having an $E_1 = 340,000$ psi or 450,000 psi. The case of the sandwiched layer with an $E_3 = 30,000$ psi and sandwiching layers with an $E_1 = 340,000$ psi is shown in Figure 8.

In both cases the model did not exactly correspond to the equation $\log d = M + N (a_1h_1 + a_2h_2 + \ldots.)$ and the following was observed:

(a) Assuming the normal thickness equivalency value $a_1 = 1.0$ for the sandwiching layers with an $E = 340,000$ psi, the strength contributed by the weaker sandwiched layer (i.e., the values of a_4 or a_3) decreased with an increase in thickness of the sandwiching layers. See Figures 7 and 8.

(b) By decreasing the modulus of elasticity of a sandwiched layer, the strength contributed by the sandwiched layer considerably decreases as compared to its normal strength and is even sometimes negative. See Figures 7 and 8.

The negative thickness equivalency value shows that the pavements are not reinforced by the sandwiched layer, but that, on the contrary, they decrease in total strength. This same behavior was observed on an experimental project in Virginia where a select soil material was sandwiched between soil cement underneath it and stone base or cement treated aggregate and asphaltic concrete over it. The deflections as related to supposedly comparable projects were higher and it is believed that if this layer was not introduced the deflections of the pavement would have been lower. In other words, the thickness equivalency of this sandwiched material was negative, thus giving a higher deflection.

This negative thickness equivalency value could be explained by the observation made on the stress distribution for weak sandwich layers in the following paragraph. In this paragraph, it is shown that the angle of spread of load increases with a decrease in the modulus of elasticity of the sandwiched material. It is obvious, therefore, that the introduction of a weaker sandwiched layer provides two effects. (1) It spreads the load over a larger area and thus transmits very little load intensity to the underlying layer, and (2) the variation in thickness of the sandwiched layer does not seem to affect the system much, as long as the sandwich layer remains in compression only.

Use could be made of these two effects in the optimum design of pavements. For example when the subgrade is weak or resilient a sandwich layer system could be utilized to spread the load over a larger area. Since the load intensity transmitted to the underlying layer is small the choice of material and thickness design of the underlying layer could be such as to provide more rigidity than strength. Further, the thickness of the sandwich layer need not be increased beyond a certain minimum.

The reduction in the overall structural strength of this type of sandwich system does not eliminate its use. There are cases in which this flexible sandwich layer helps in other respects, e.g. by preventing reflection cracks in the bottom sandwiching layer from traveling into the top sandwiching layer.

Stress Distribution in Layered Systems

By means of a polariscope, the stress distributions in layered systems were determined. The stress distributions were mainly of two types, (a) the bulb type as shown in Figure 9(a), and (b) the fan type as shown in Figure 9(b).

Bulb Type Distribution

The bulb type distribution was found in the following cases. The amount of stress and the degree of distribution depended upon the thickness and the modulus of elasticity of the materials in the layered system.

(a) Two layer system — The underlying layer was a subgrade of infinite depth having an $E = 30 \times 10^6$ psi. The overlying layer consisted of varying depths of 0.5 inch and above and the modulus of elasticity was equal to 1,000; 30,000; 340,000; or 450,000 psi.

(b) Three layer system — The underlying layer was of infinite depth having an $E = 1,000$ psi. The overlying two layers consisted of the top layer of thickness 0.5 inch or more and an $E = 1,000$ or $30,000$ psi. The layer below the top layer had a thickness of 0.5 inch or more and an $E = 340,000$ or $450,000$ psi, i.e., a modulus of elasticity much higher than that of the material above it. An example of this is shown in Figure 9(a). The bulb type distribution is clearly defined in the topmost layer only when the underlying layer or the layered system is very rigid.

From this it is evident that when a weaker layer, such as untreated aggregate or a combination of thin asphaltic concrete over untreated aggregate, lies over a stronger layer, such as a good quality soil cement or cement treated aggregate, the stress distribution will be bulb type. In other words it may be stated that when the lower layer prevents bending of the bottom side of the top layer, the stress distribution will be of the bulb type, and Boussinesq's theory, or theories based on Boussinesq's evaluation, could be applied.

Fan Type Distribution

The fan type stress pattern was found in the following cases. The amount of stress and the degree of distribution depended upon the thickness and the modulus of elasticity of the materials in the layered system.

(a) Two layer system — The underlying layer was a subgrade of infinite depth having an E = 1,000 psi. The overlying layer consisted of varying depths and had an E = 1,000; 30,000; 340,000; or 450,000 psi.

(b) Three layer system — Various combinations in thicknesses of two layers over a subgrade material of infinite depth with an E = 1,000 psi were found to give a fan type distribution in the top layer. These combinations were as follows: The lower layer had an E = 30,000 psi and the upper layer had an E = 340,000 or 450,000 psi; or the lower layer had an E = 340,000 psi and the upper layer had an E = 450,000 psi. An example of this is shown in Figure 9(b).

(c) Four layer system — In all the systems tried, the sandwiched layer was weaker than that of the other two layers. In almost all cases a fan type distribution was observed in the top layer. In a few cases, when the ratio of the modulus of the sandwiching layers and the sandwiched layer was low and the thickness of the sandwiched layer was also low, a combination of bulb and fan type stress distribution was observed.

From the above observations, it could be concluded that when the layer underlying the top layer has a low modulus of elasticity and the overlying layer has the same or a higher modulus of elasticity, fan type distribution takes place in the top layer. In other words, it may be stated that when the bottom side of the top layer bends, the stress distribution will be fan type and the design of the top layer should be based on the avoidance of failure along the shear plane as recommended by McLeod(7) and by others based on this principle.

Effect of Deep Strength

The stress distribution pattern in two layers of the same modulus and varying depths lying over a subgrade layer was carried out with partial bond between the two layers that could slide over their contact surface after a certain amount of load was applied. The pattern of stress distribution in the top and lower layers was always of the form shown in Figure 10. This shows that when a certain depth of a specified material is laid in more than one layer and there is no perfect bond between the two layers the structural behavior is different as compared to that of one deep layer. The difference in the strength contributed depends upon the thickness of the two layers and the modulus of elasticity of the material in each. The overlying layer in combination with the underlying layer provides less structural strength than when laid in one depth.

Effect of Weak Sandwiched Layers

Figure 11 shows the stress distribution for three cases of a four layered system. In Figures 11(a) and (b) the sandwiched layer consists of material with an E = 1,000; but the thickness of the sandwiched layer in Figure 11(b) is half the thickness of the sandwiched layer in Figure 11(a).

No stress lines are noticed in the sandwiched layers in Figures 11(a) and (b); instead, three horizontal bands are noticed in Figure 11(a). The two bands near the contact surfaces with the top and bottom layers were deep brown in color, while the central band was light brown. In the case of thinner sandwiched layers, as shown in Figure 11(b), the color was uniformly deep brown. Both figures, 11(a) and (b), therefore indicate uniform stress of compression with higher stresses near the contact surface. This uniform stress of compression indicates an increase in the spread of the load over the top of the sandwiched layer. Thus, it is concluded that the angle of spread of the load increases with a decrease in the modulus of elasticity of the material of the sandwiched layer.

Comparing Figures 11(a) and (b), we find that under the same load there is no change in the stress distribution in the lower sandwiching layer, except in the sandwiched layer itself. This shows that the thickness of the sandwiched layer does not affect the system below the top sandwiching layer.

Figure 11(c) shows a sandwiched layer with a higher modulus of elasticity, as compared to that in Figures 11(a) and (b). Stress lines are visible in the sandwiched layer, and the load transfer to its underlying layer is greater than for a weaker sandwiched layer. Thus it shows that as the modulus of elasticity of the sandwiched layer decreases, the transfer of load through the lower sandwiching layers decreases.

CONCLUSIONS

1. Investigations of satellite pavements on primary and interstate roads of Virginia, the secondary and subdivision road designs for Virginia, and the model studies have shown that:
   - (a) The strength contributed by a pavement could be represented by a thickness index of $D = a_1h_1 + a_2h_2 + \ldots.$ as given by the AASHO Road Test Results. The thickness equivalency value of the material depends upon its strength and location in the pavement system.
   - (b) The thickness equivalency value of the material decreases as the thickness of the cover increases and vice versa.
2. The following conclusions are drawn from the model studies.
   - (a) In the case of a single layer resting on a subgrade, the thickness equivalency of the material in the layer decreases very little with an increase in depth, and hence this variation could be ignored.

(b) In a three layered system, when a stronger layer lies over a weaker layer (e.g., an asphaltic concrete mat over a stone base) the optimum thickness of the weaker layer is the minimum thickness one could provide economically.

(c) In a three layered system, when a weaker layer lies over a stronger layer (e.g., untreated aggregate over treated aggregate) the structural strength of the pavement, or resistance to deflection, is less compared to when the layers are reversed.

(d) When a weaker layer lies over a stronger layer and if this underlying strong layer prevents bending in the bottom side of the top layer, the stress distribution is bulb type. In such a case Boussinesq's theory, or theories based on Boussinesq's evaluation, can be applied.

(e) When a stronger layer lies over a weaker layer or over a layer of the same strength the underlying layer permits bending in the bottom side of the top layer, and the stress distribution will be fan type. In such a case the design of the upper layer should be based on the avoidance of failure along the shear plane.

(f) In the case of a four layered system with a weaker material sandwiched between two layers of stronger materials, if the sandwich layer contributes any strength to the pavement system, this strength contributed by the sandwiched layer decreases with an increase in the thickness of the sandwiching layers.

(g) The strength contributed by the sandwiched layer decreases, and even becomes negative, with a decrease in its modulus of elasticity.

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TABLE 1

THICKNESS EQUIVALENCY VALUES OF MATERIALS IN FLEXIBLE PAVEMENT SYSTEM

Serial Number	Location and Material	Notation	Value of "a"	
			Primary and Interstate Roads	Secondary and Subdivision Roads
1	Surface — Asphaltic Concrete	A.C.	1.0	1.0
2	Base —			
	(a) Asphaltic Concrete	A.C.	1.0	1.0
	(b) Cement treated aggregate over dense graded aggregate base or soil cement or soil lime and under A.C. mat.	CTA	1.0	1.0
	(c) Dense graded aggregate crushed or uncrushed	Agg.	0.35	0.60
	(d) Select material I (Va. specifications) directly under A.C. mat. and over a subbase of a good quality.	Agg.	0.35	—
	(e) Select material cement treated	Sel. mat. C	—	0.80
3	Subbase — Select Material type I, II & III (Va. specifications)	Sel. Mat.		
	(1) In Piedmont Area		0.0	0.0
	(2) In Valley & Ridge area and Coastal Plain		0.2	0.50
	Soil Cement	S.C.	0.4	0.60
	Soil Lime	S.L.	0.4	0.55
	Sel. Mat. Cement treated	Sel. mat. C	0.4	0.80
	Cement treated aggregate directly over subgrade	CTA	0.6	—

(Based on Figure 36 of AASHO Road Test SR 61E)

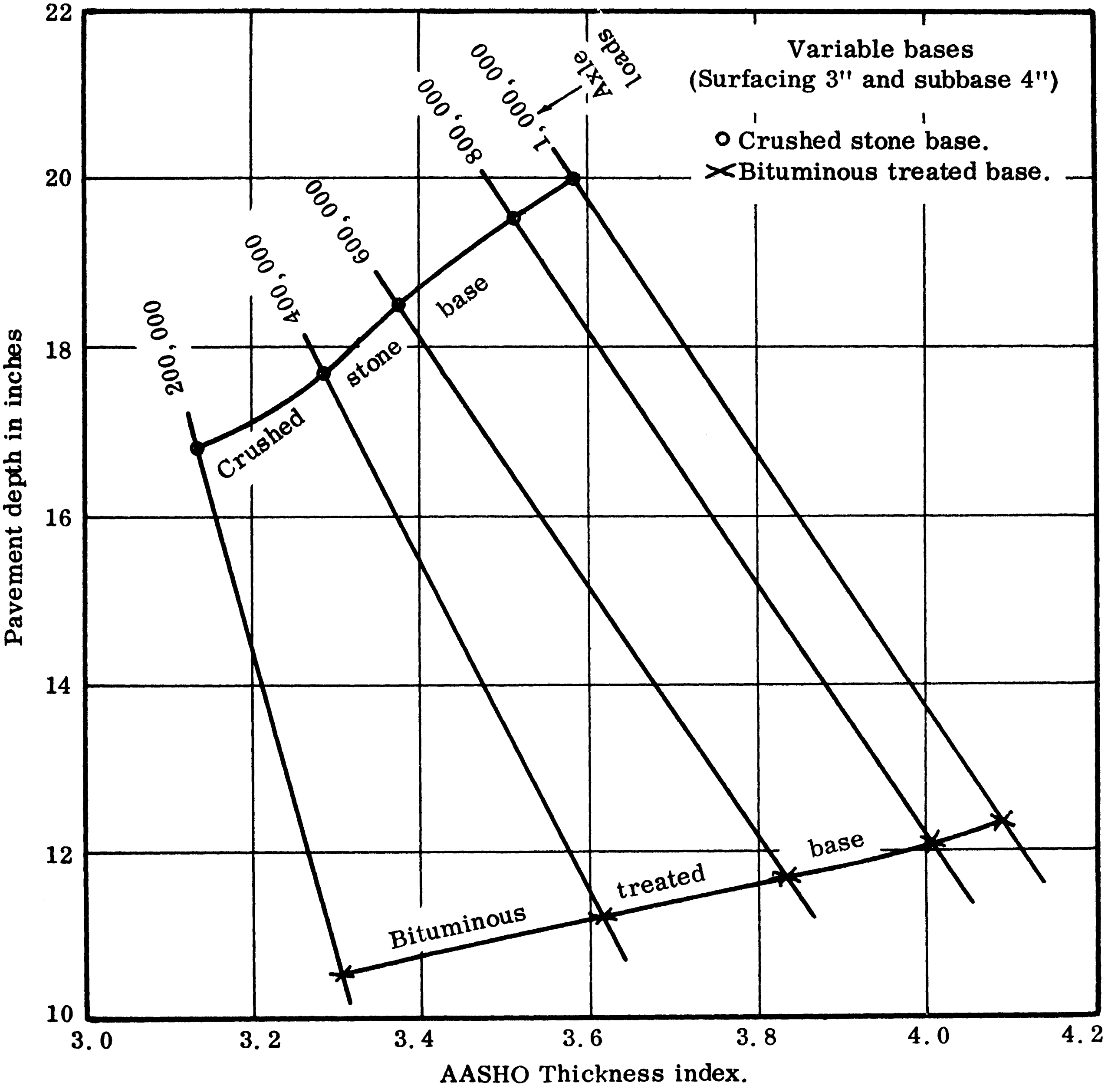


Figure 1. Thickness index versus pavement depth (AASHO Tests).

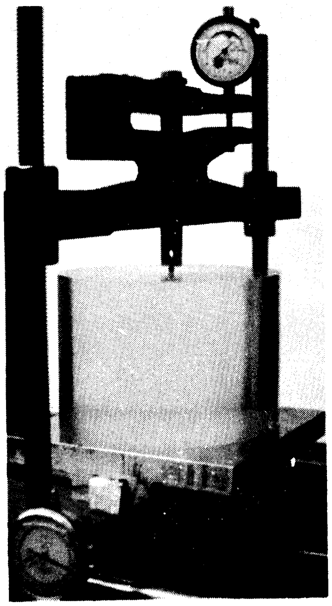


Figure 2(a). Loading system for three dimensional model.

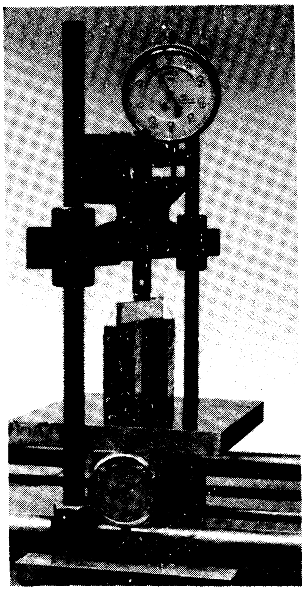


Figure 2(b). Loading system for two dimensional model.

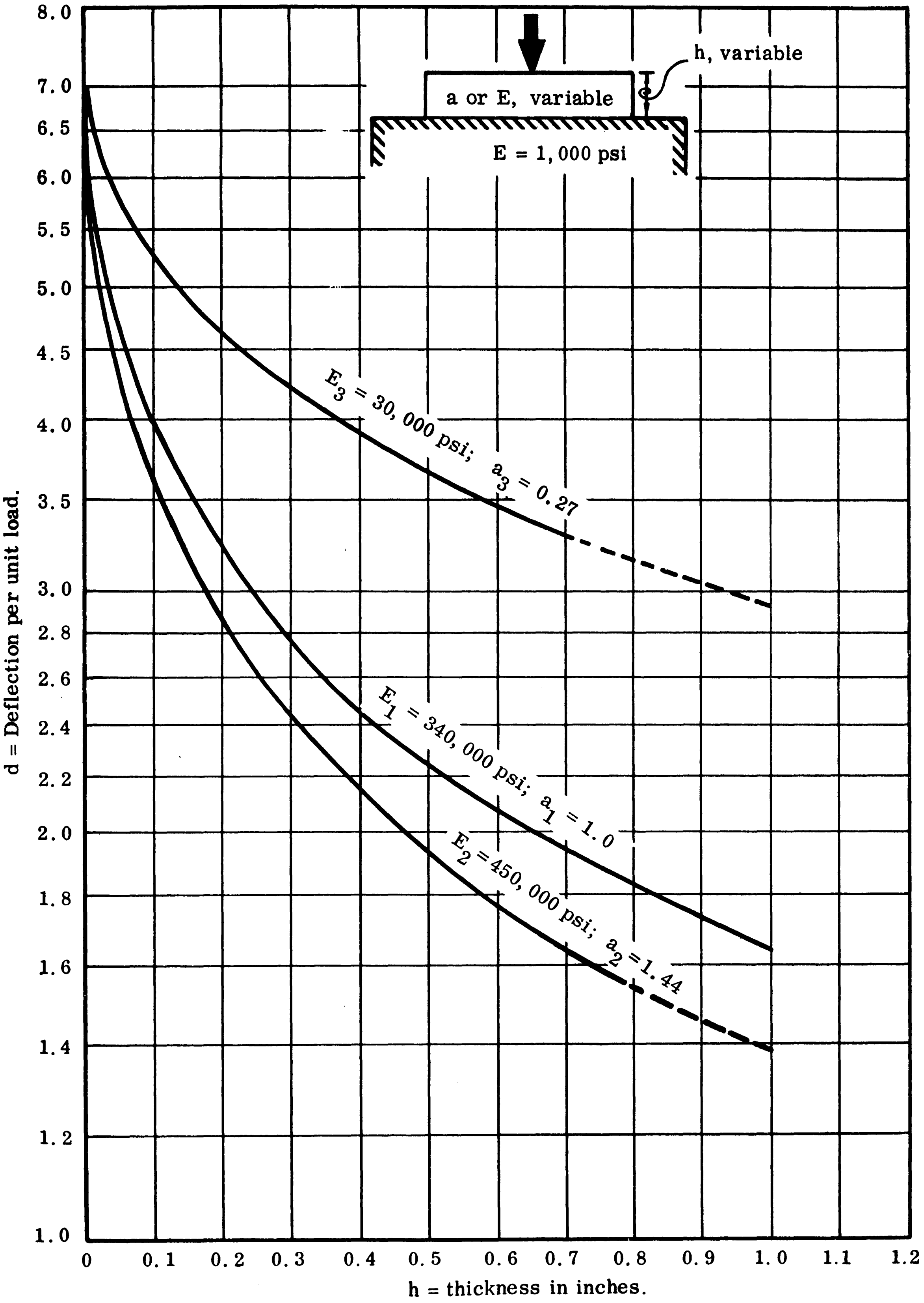


Figure 3. Deflection v/s thickness (two layer system).

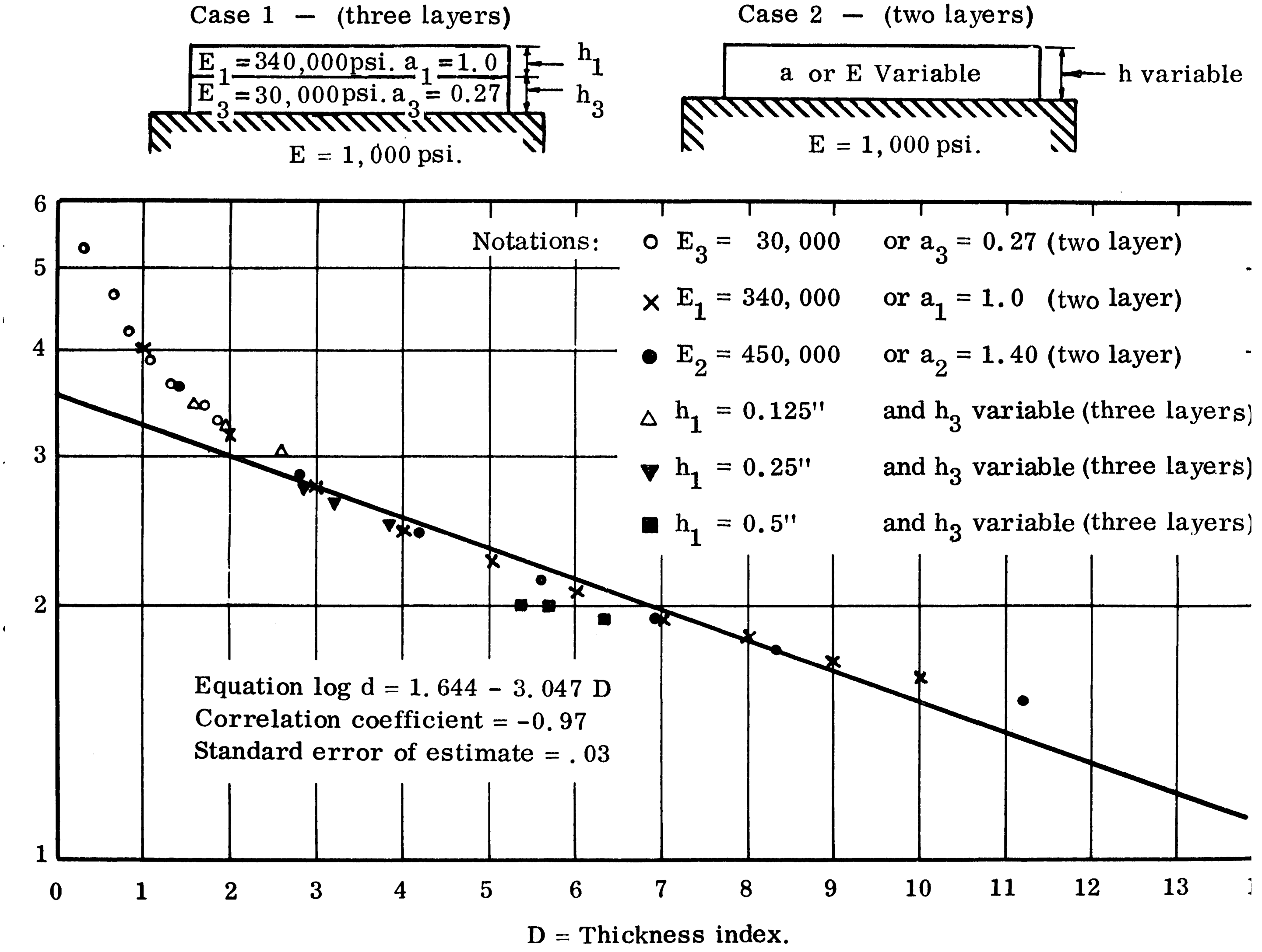


Figure 4. Deflection versus thickness index (model study)

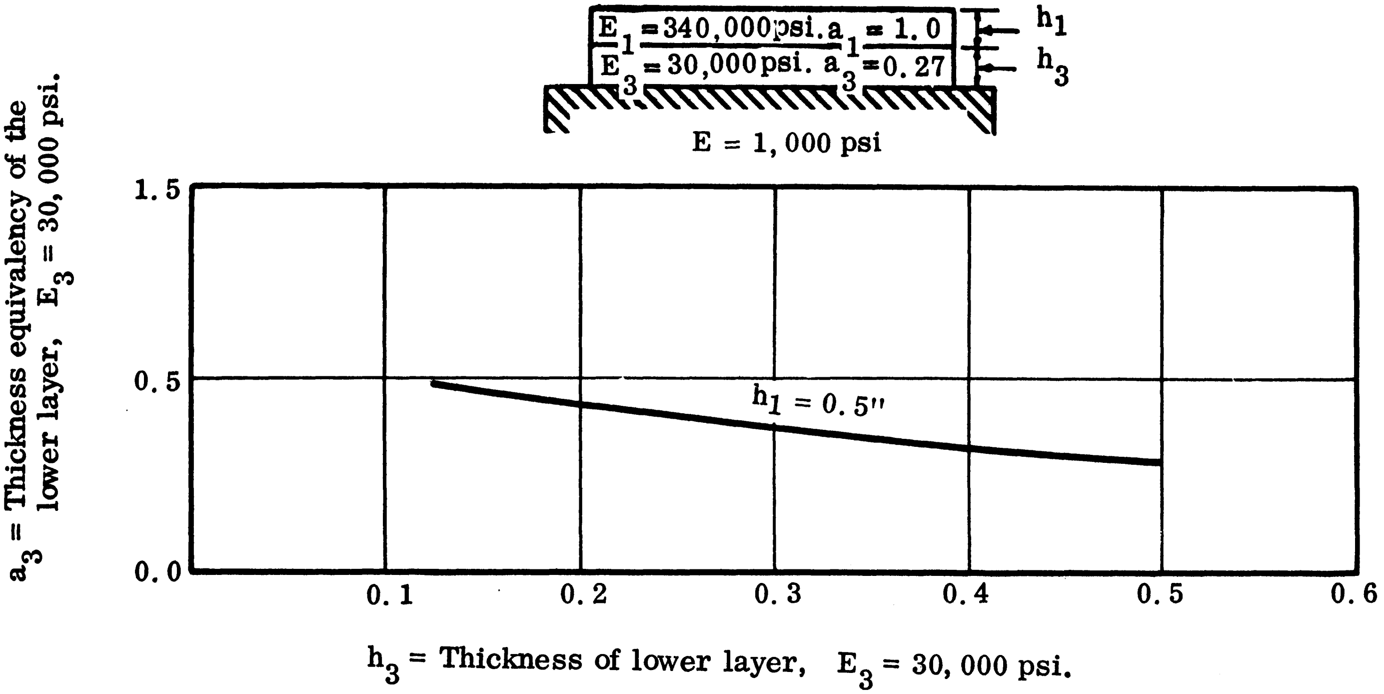


Figure 5. Weaker layers underneath a stronger layer.

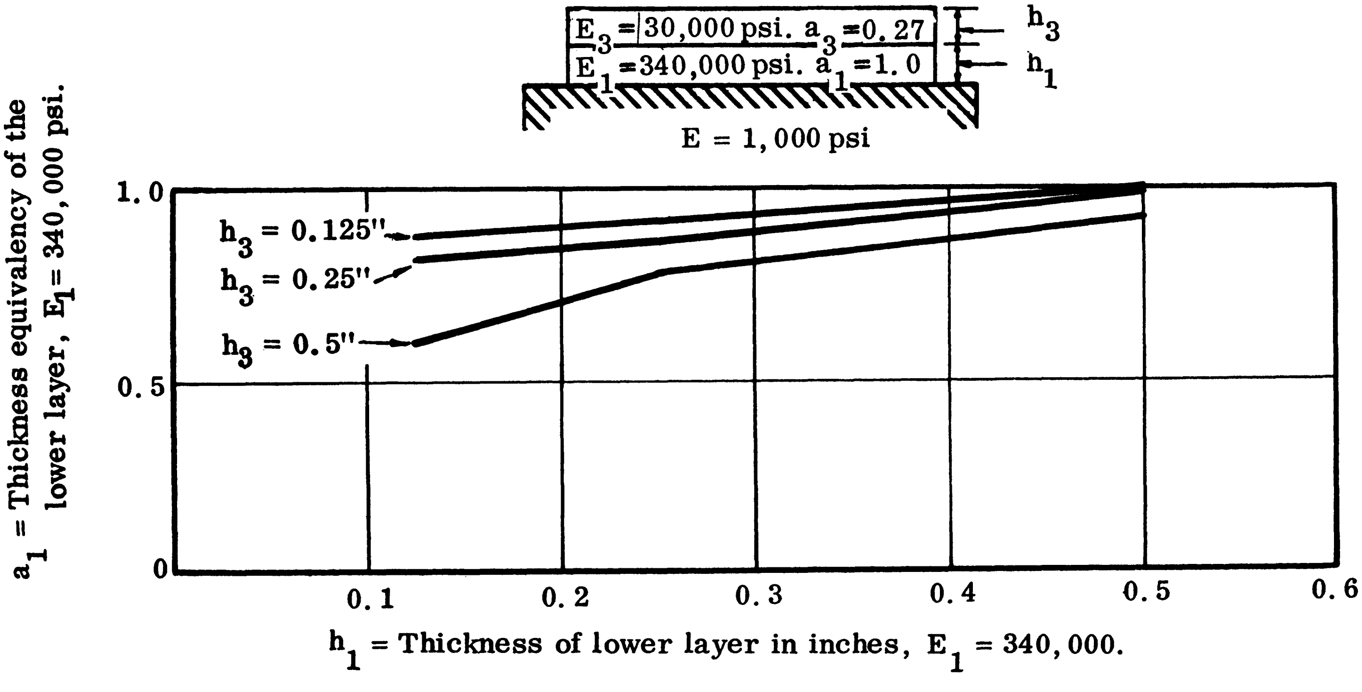


Figure 6. Stronger layer underneath a weaker layer.

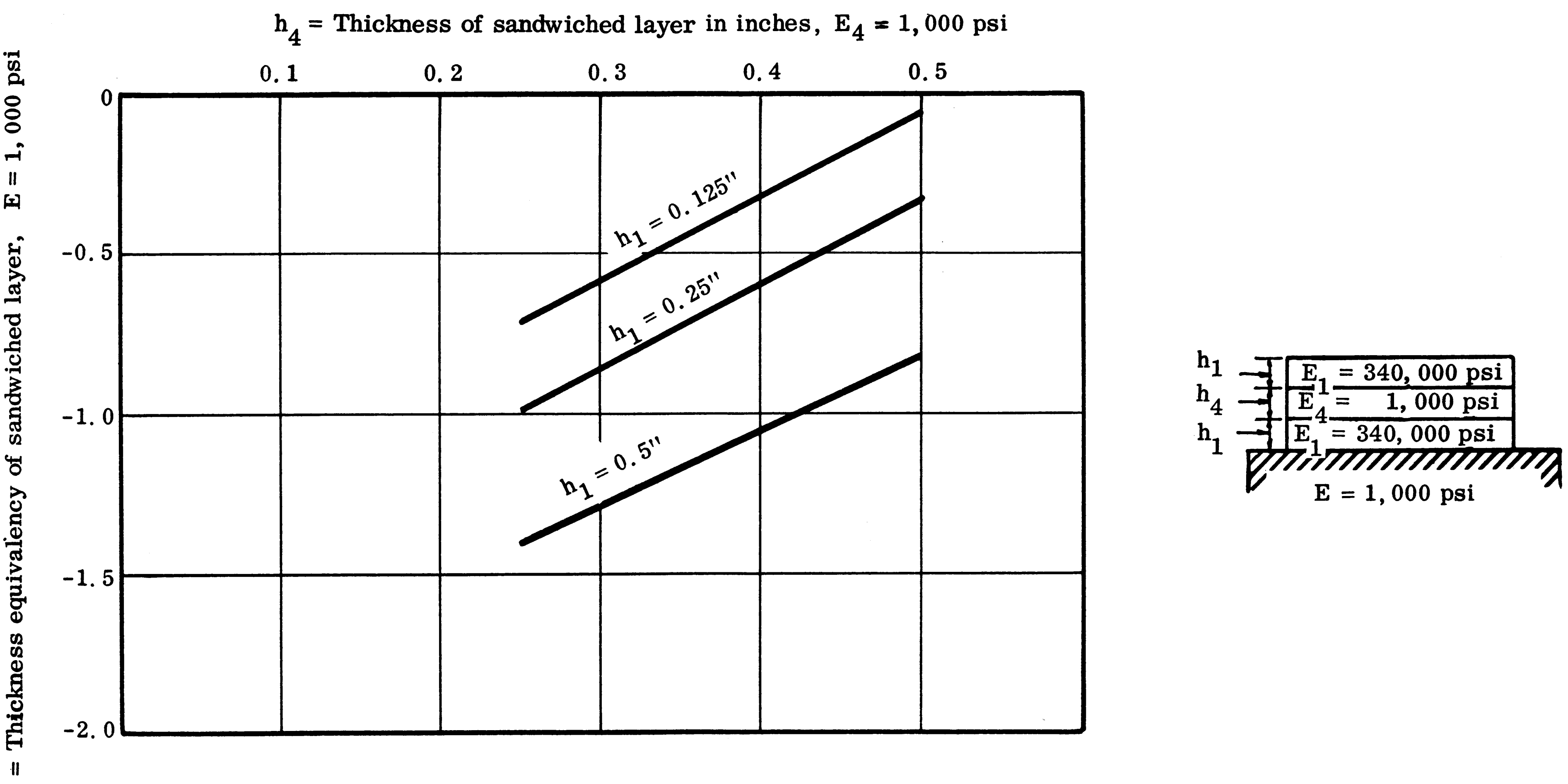


Figure 7. Weaker layer (E = 1,000 psi) sandwiched between two stronger layers.

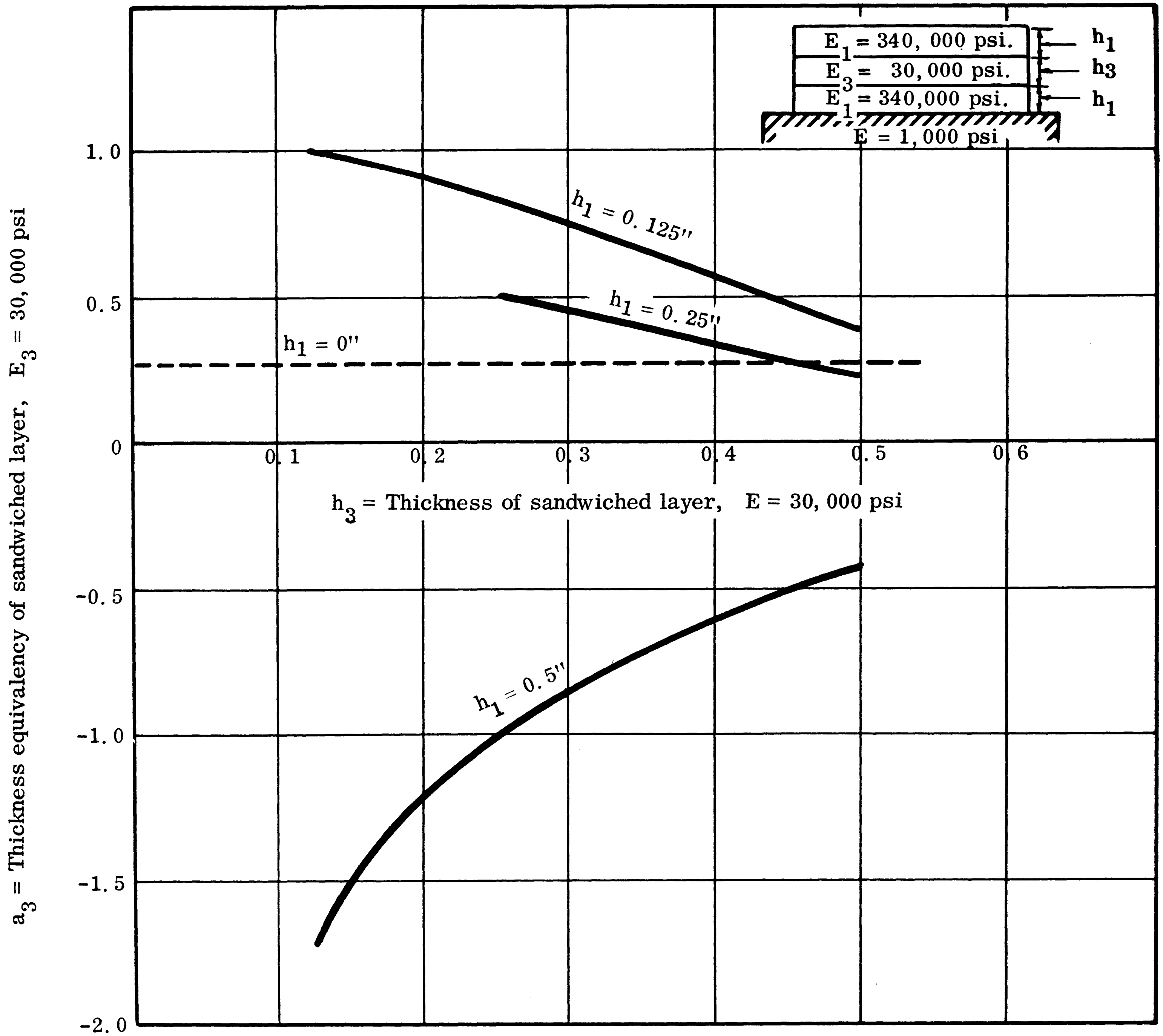
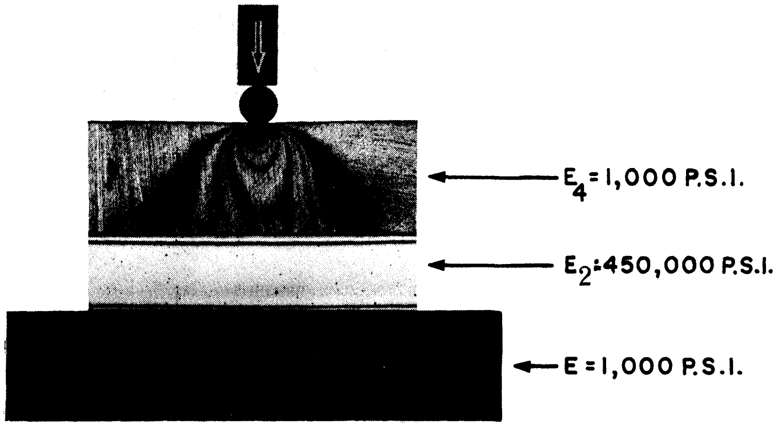
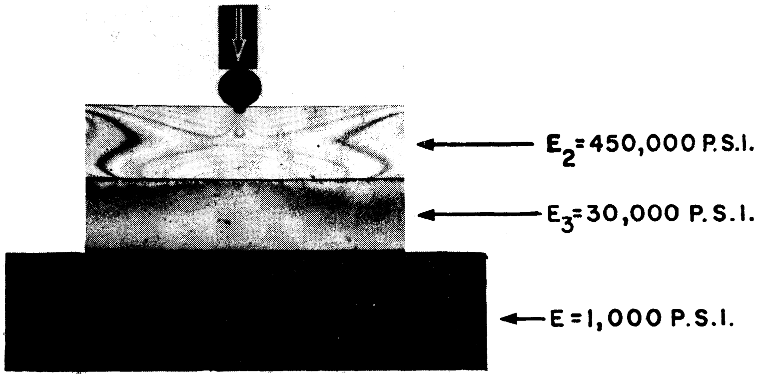


Figure 8 Weaker layer (E = 30, 000 psi) sandwiched



(a)



(b)

Figure 9(a). Stress distribution when a weaker layer lies over a stronger layer.

Figure 9(b). Stress distribution when a stronger layer lies over a weaker layer.

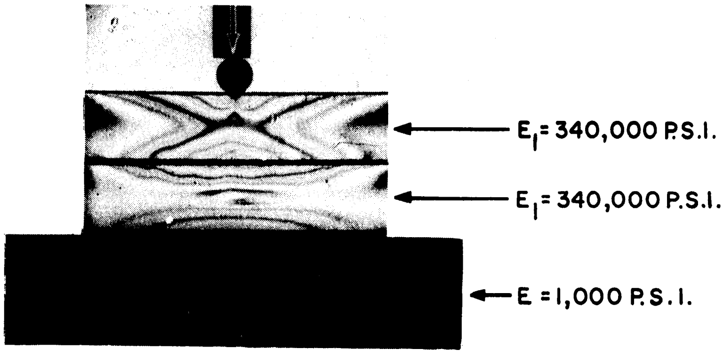


Figure 10. Effect of joint between two layers — in this case of the same modulus.

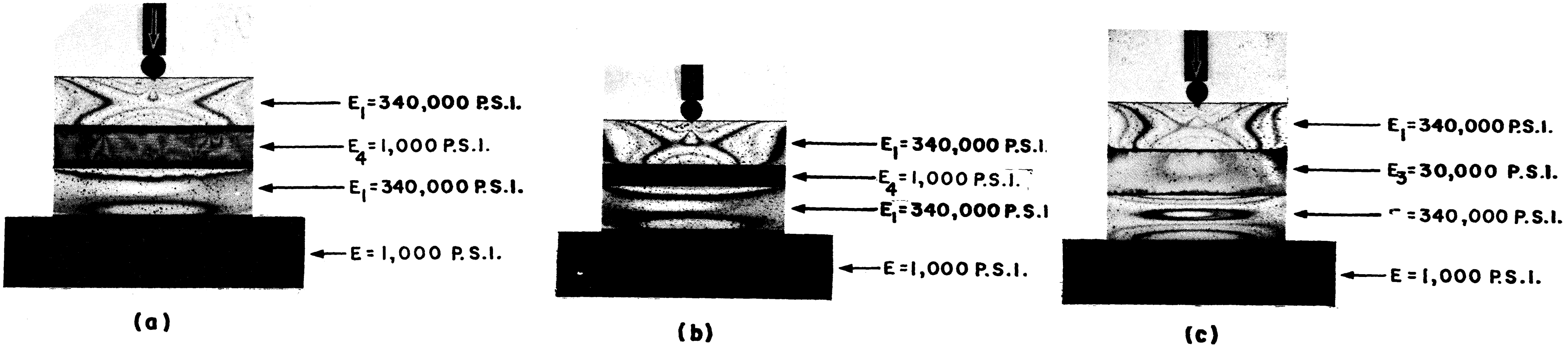


Figure 11. Weaker layer sandwiched between two strong layers.

(a) and (b) — E = 1, 000 PSI for sandwiched layer.
(c) — E = 30, 000 PSI for sandwiched layer.