

A RAPID MEANS OF APPROXIMATING BEAM SIZES.

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ARCHITECTURAL ENGINEERING THESIS

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For

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I. INTRODUCTION

The purpose of this series of graphs is to provide a rapid means for the rough sizing of beams, joists, and other spanning members. These graphs are not meant to be used for final structural calculations for critical members; however, they may prove to be of some value to students and professionals during preliminary design. Wood, steel, and concrete, materials commonly used in beams, are covered in these graphs.

The graphs for wood beams are all based on a rectangular cross section. These three types of loading are covered: an evenly distributed load, a point load at mid-span, and a point load at one quarter point. One graph is included to show the relationship between shear, moment, and deflection for a particular beam.

The graphs for the steel beams are all based on an evenly distributed loading condition. The structural shapes of the steel beams to which the graphs apply are those shapes that may be approximated by a box section. These include the wide flange, open web steel joists, channels back to back, a plate and angles, and the "I" beam. In approximating a box beam, the web areas were neglected for moment and deflection. Since the web area of a box beam is assumed to carry all shear, and this web area is an independent variable, values for shear were not computed. One graph is included for a rectangular section in steel. This graph was included primarily to show the relationship between steel and wood with the same cross section.

The concrete beam graphs are based on a rectangular balanced section singly reinforced. One graph is based on a beam with a simple span ($M = 1/8wL^2$), the other is based on a continuous beam ($M = 1/12wL^2$).

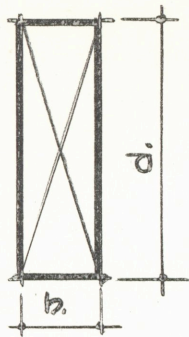
Formulas from basic mechanics for deflection, moment, and shear were used as a starting point for the method of calculation. In each case, the formula for the external action was set equal to the resisting internal reaction. In the resulting sets of equations, kL was set equal to d , where k is a percentage of L . In this manner, the dependant variable d and the independent variable L were eliminated from the equations. In the case of a point load, P/L (which has the same dimensions as w) was not eliminated by substituting $kL = d$.

From the resulting equations, k was then solved for in terms of the following independent variables:

1. The extreme fiber in bending (f) in psi.
2. The width of the beam (b) in inches.
3. The load (w) in pounds per linear feet of span.
4. The modulus of elasticity (E) in psi.
5. The unit stress (v) in psi.

By assuming a unit width beam ($b = 1$) the independant b values were eliminated. Next the k values for deflection, shear, and moment were set equal and the point of change between the values were calculated in terms of w . Substitutions were made into these equations for normal working ranges, and to show the points of change between deflection, moment and shear. These equations were then plotted with k versus w (or P/L in the case of a point load) with an independant variable of the extreme fiber in bending.

The numbers used to plot the graphs are to slide rule accuracy. Three assumptions were made in compiling the numbers for the graphs. All materials were assumed to be not stressed over their elastic limit, all beams were assumed to be laterally supported, and the limit for deflection was taken at $1/360$ of the span (the point where plaster cracks).



f = EXTREME FIBER IN PSI.
 L = LENGTH OF SPAN IN FEET
 v = 80 PSI
 E = 1.76×10^6 PSI
 Δ = $1/360$ OF THE SPAN
 b = 1"
 w = #/LIN. FT OF SPAN
 d = DEPTH OF BEAM IN IN.
 k = % OF L

NOTES ON THE WOOD BEAM GRAPHS

As an example for the use of the wood graphs assume a $w/b = 176$. This would be the equivalent of a 1" beam with a load of 176#/lin. ft. of span, or a 2" beam with a load of 352#/lin. ft. of span. Following this line across the sheet, the first intersection is with the shear line. This shows that shear governs for all f 's intersecting the shear line below this point. The corresponding k value for this intersection is 1.10. The depth of the wood beam required to carry this loading could be found by multiplying this k value (1.10) by the length of the required span. The next intersection of the $w/b = 176$ line is with the $f = 1200$ curve. With an $f = 1200$, $k = 1.15$ approximately. This k value could be multiplied by the span to find the beam depth. The same procedure for each remaining intersections of w/b and f curves would give corresponding beam depths.

Note that in graph I (wood with an evenly distributed load) the line for shear to control and the line for deflection to control meet at a point where $w/b = 137.5$, $k = .858$ when $f = 1750$. Since deflection and shear are not dependent on f , this shows that with the given set of conditions a beam with a higher f value than 1750 would have no greater load carrying capacity than the beam with an f value of 1750. This same condition is seen to be true in the graph of a point load at the $1/4$ point (graph 3) where the upper f value is 1900.

The intersections of the moment curves and either the shear line or the deflection curve is the point that the beam is efficient for both deflection and shear.

Graph 4 shows the relationship between shear, moment and deflection for any particular wood beam with an evenly distributed load, $E = 1.76 \times 10^6$ psi and $v = 80$ psi. The intersection of the shear, moment, and deflection at $f = 1650$ shows this to be most efficient f value for wood under the above conditions. If a higher f value is used, it is seen that the control areas for shear, moment and deflection do not change.

GRAPH 1

EXAMPLE #1

SHEAR LINE

DEFLECTION LINE

WOOD RECTANGULAR SECTION
EVENLY DISTRIBUTED LOAD

VALUES OF w/b IN #/LIN.FT./IN.

VALUES OF K $KL=d$

$w/b=5.3$ $K=.622$

$w/b=29.6$ $K=.515$

$w/b=21.5$ $K=.455$

$w/b=102$ $K=.774$

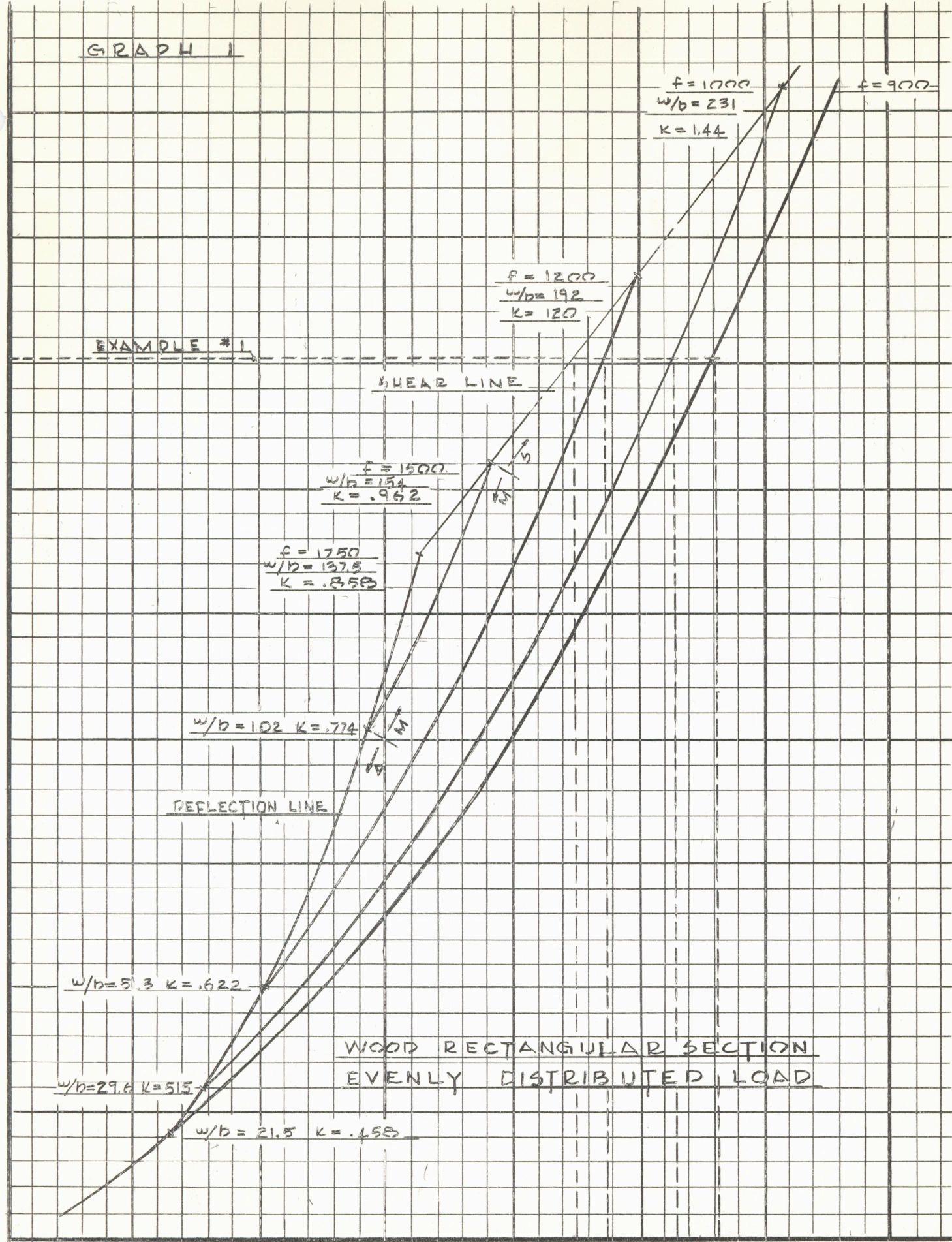
$f=1750$
 $w/b=137.5$
 $K=.858$

$f=1500$
 $w/b=154$
 $K=.962$

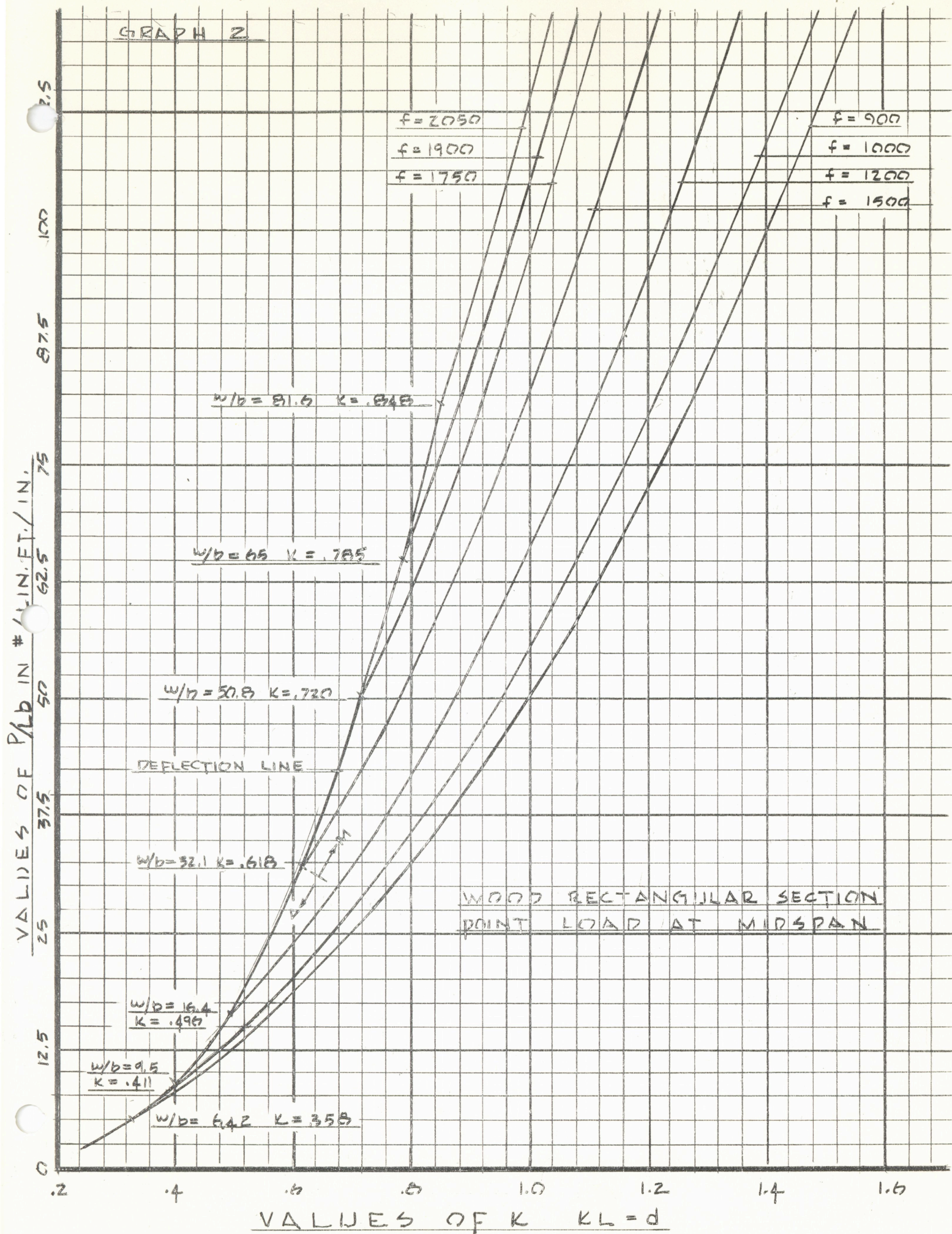
$f=1200$
 $w/b=192$
 $K=1.20$

$f=1000$
 $w/b=231$
 $K=1.44$

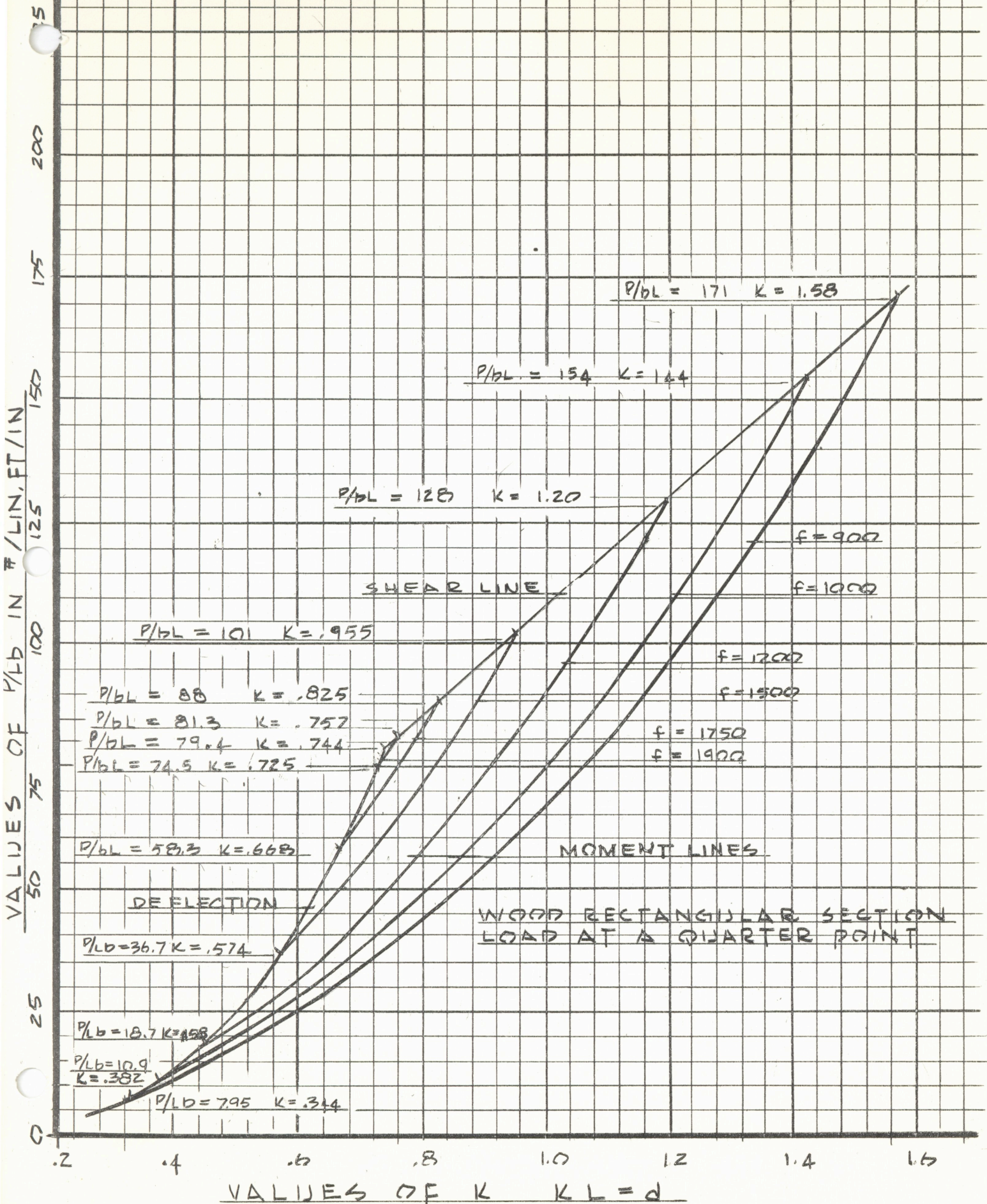
$f=900$

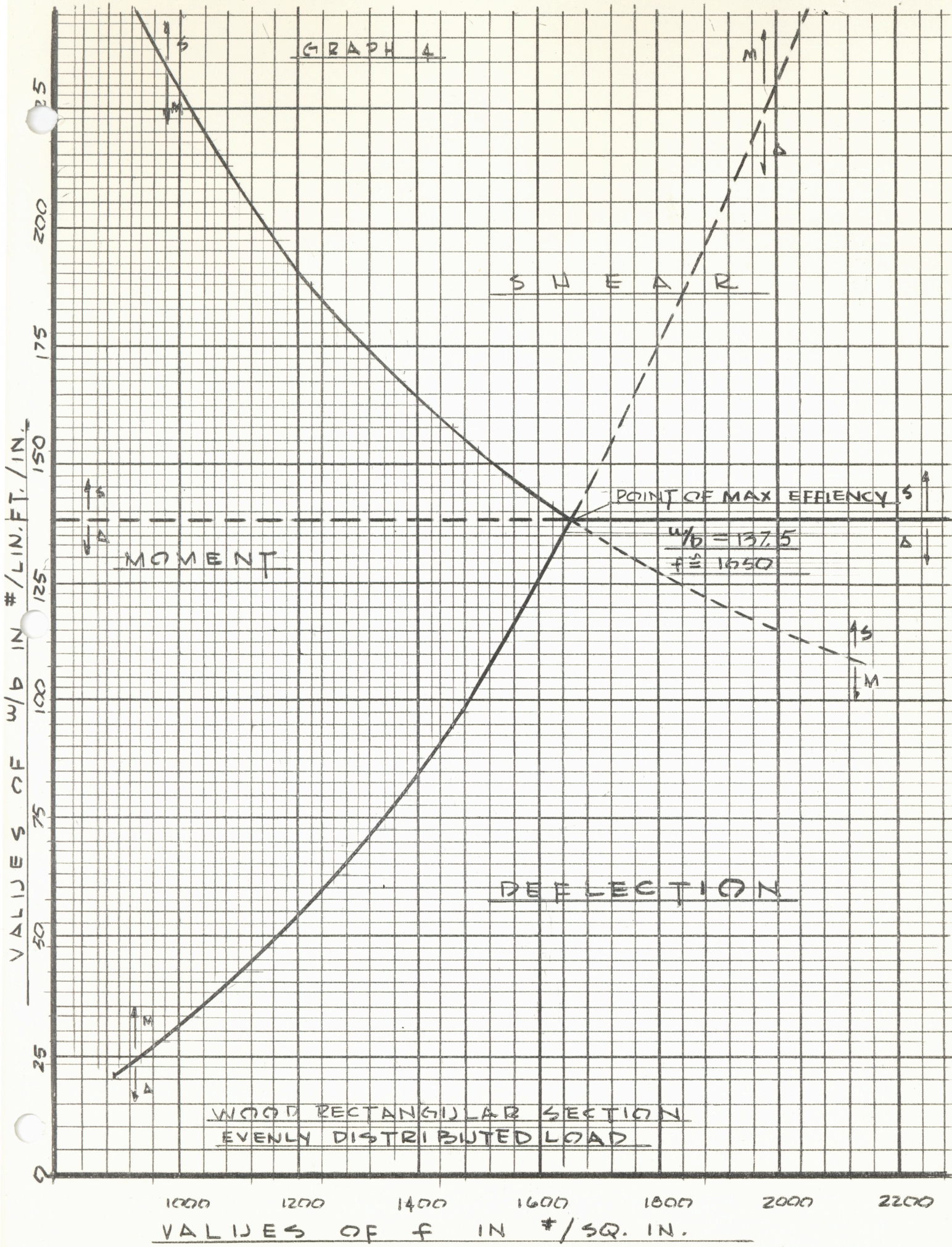


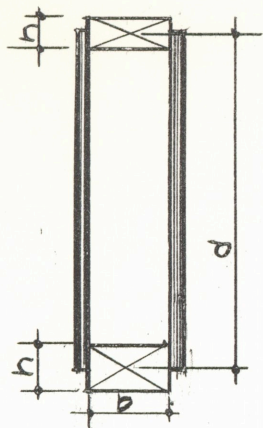
GRAPH 2



GRAPH 3







$f = 20 \times 10^3$ PSI
 $L =$ LENGTH OF SPAN IN FT.
 $U = 13 \times 10^3$ PSI
 $E = 30 \times 10^6$ PSI
 $\Delta = 1/360$ OF SPAN
 $b = 1''$
 $W = \#/\text{LIN FT OF SPAN}$
 $D =$ DEPTH OF BEAM IN IN.
 $K = \% \text{ OF } L$
 $h =$ HT OF FLANGE IN IN.
 $K' = h/L$

NOTES ON THE STEEL BEAM GRAPHS

Example number 2 as shown on graph 5 starts with the assumption of a value of $w/b = 52 \#/\text{lin. ft.}/\text{in.}$ This is comparable to a load of $52 \#/\text{lin. ft.}$ with a beam width of $1''$. This w/b value's intersection with the k_{Δ} curve shows the point that deflection controls the beam design. At this point of intersection $1/k' =$ approximately 35, or L in ft. over h in inches = 35. For a span of 35 feet $h = 1''$. This intersection gives a k value of .132, or for a 35 ft. span the depth of the beam would be $.132 \times 35 \text{ ft.} = 3.62''$.

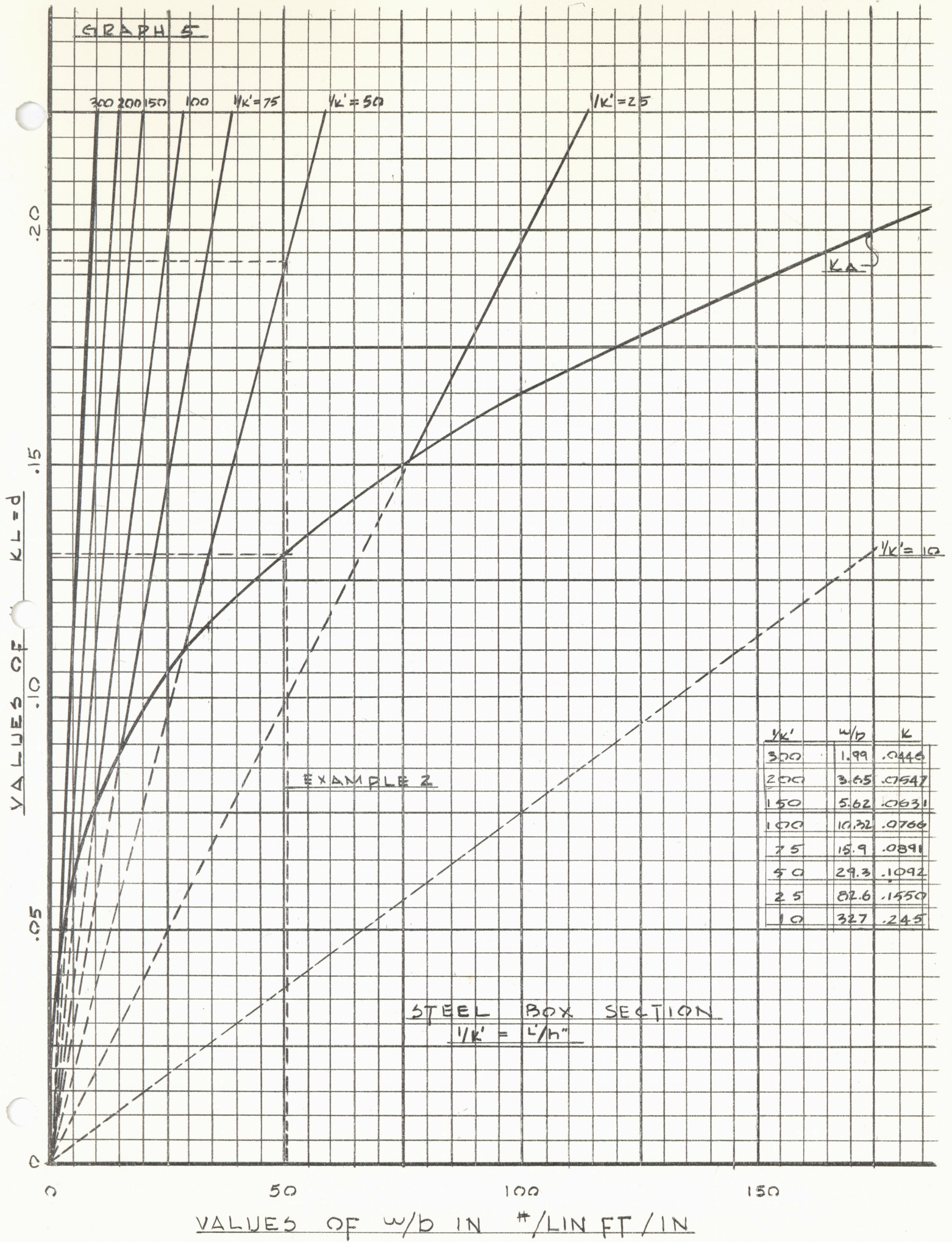
If the $w/b = 52$ value is carried up to its intersection with the $1/k = 50$ line, the corresponding depth of the beam would be $.194 \times 35 \text{ ft.} = 5.89''$. For a span of 35 ft. the $1/k' = 50$ value would yield an h value of $.7''$.

The $w/b = 52$ value crosses $1/k' = 25$ and $1/k' = 10$ before reaching the k_{Δ} curve; the two corresponding k values would not be applicable, for under the k_{Δ} curve deflection governs. The intersection of any particular w/b value with the k_{Δ} curve gives the minimum k value that is applicable to the particular w/b value.

The intersection of any particular w/b value with the $1/k'$ lines shows the relationship of h to the load applied to a beam. As $1/k'$ increases (h decreasing while L is constant), the beam, in effect, is growing lighter in section.

Graph 5a is an extension of graph f showing a greater range in w/b and k with lower $1/k'$ values. These lower $1/k'$ values would correspond to heavier beams in that if the length of span remains constant, h must increase for $1/k'$ to decrease.

GRAPH 5



GRAPH 5A

25

20

18

16

$1/K' = 14$

$1/K' = 12$

$1/K' = 10$

$1/K' = 8$

$1/K' = 5$

VALUES OF K KL=d

0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

$1/K'$	w/b	K
25	82.6	.1550
20	115.5	.1720
18	135.0	.1820
16	161.0	.1930
14	196.5	.207
12	248.0	.223
10	327.0	.245
8	458.0	.273
5	926.0	.345

STEEL BOX SECTION
 $1/K' = L'/h''$

VALUES OF w/b IN #/LIN FT. /IN

125

250

375

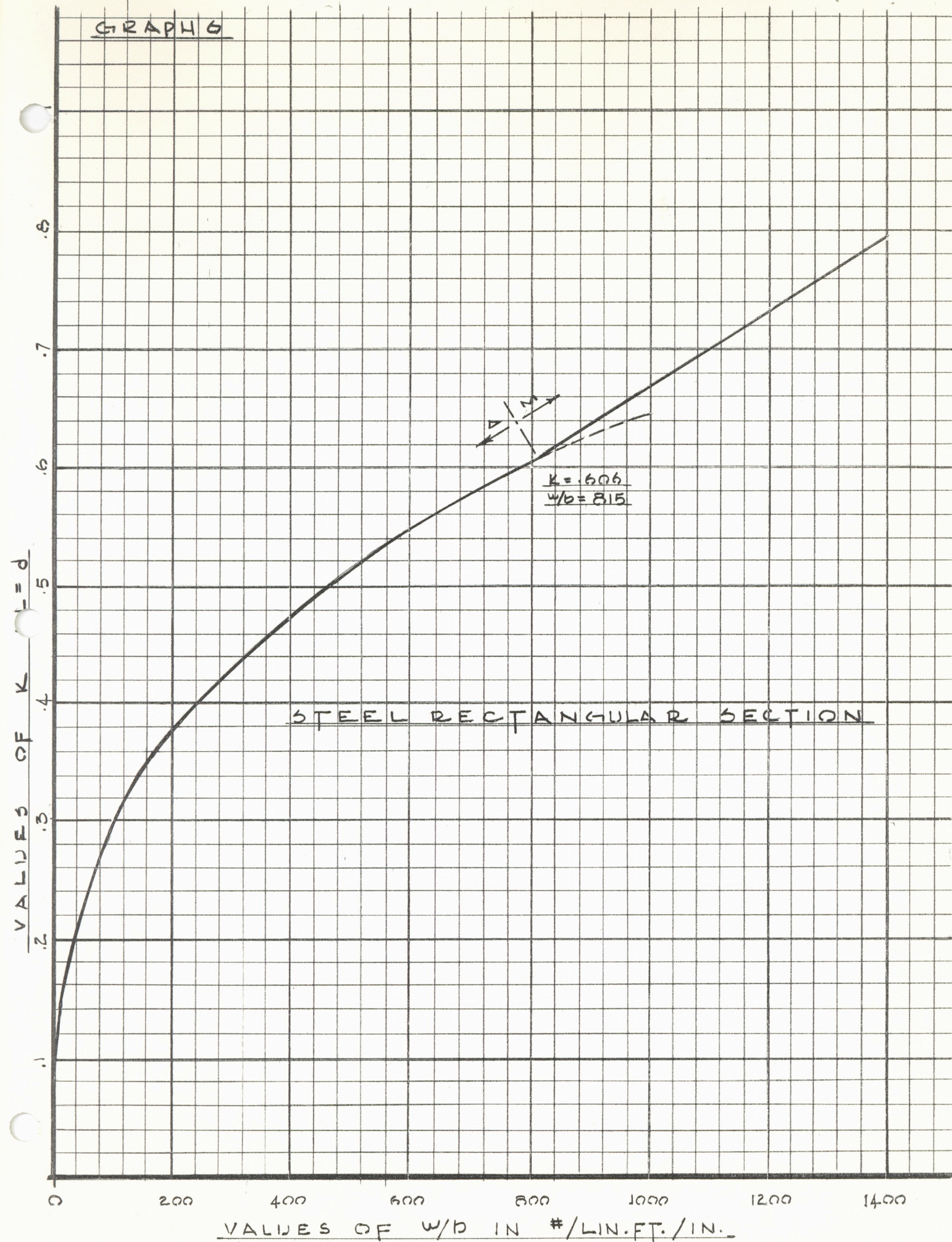
500

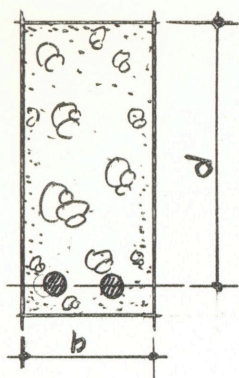
625

750

875

GRAPH 6





f'_c = COMP. STRENGTH OF CONC. IN PSI
 v = .03 & .12 f'_c IN PSI
 f_c = .45 f'_c IN PSI
 E = 1000 f'_c
 L = LENGTH OF SPAN IN FT.
 Δ = $1/360$ SPAN
 d = 1"
 w = #/LIN FT. OF SPAN
 d = DEPTH BEAM IN INCHES
 k = % OF L .

NOTES ON THE CONCRETE BEAM GRAPHS.

Example 3 on graph 8 starts with a value of 287#/lin. ft./in. for w/b . This would be equivalent to 2870#/lin. ft. for a 10 inch beam or 287#/lin. ft. for a 1 inch beam. This value intersects the moment curves for the various f'_c values. From these intersections, the various k values may be read. For example, the intersection of $w/b = 287$ with the $f'_c = 3000$ psi curve gives a k of 1.37. For a span of 20 feet, d then would equal 20×1.37 or 27.4". If the value of $w/b = 287$ is projected further to the right, it intersects the line of $.03 f'_c = v$. This line represents the maximum value for shear allowed by the A. C. I. section 305 for beams with no web reinforcement. At the intersection of $w/b = 287$ and $v = .03 f'_c$, a k value of 2.78 is read. For the span of 20 ft., the corresponding d value would equal 20×2.78 which equals 55.6 inches.

The value of $v = .12 f'_c$ is the maximum allowable by the A. C. I. It is for beams with longitudinal bars and a combination of stirrups and bent bars.

Deflection values are so negligible that they will govern only in the range of $w/b = .05$ #/lin. ft. /inch.

GRAPH 7

$$v = .12 f'_c$$

$$w/b = 2450$$

$$K = 3.94$$

$$f'_c = 5000$$

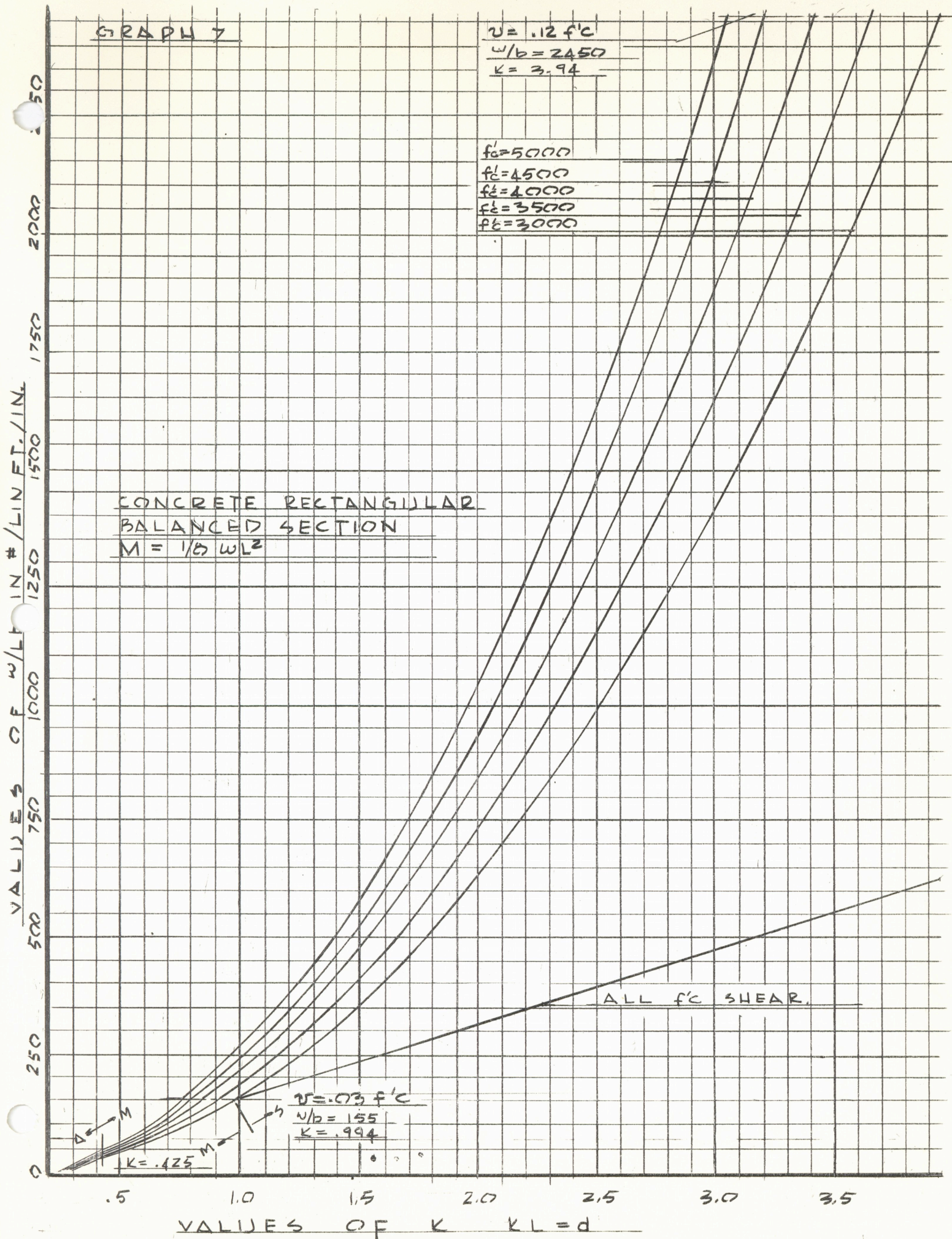
$$f'_c = 4500$$

$$f'_c = 4000$$

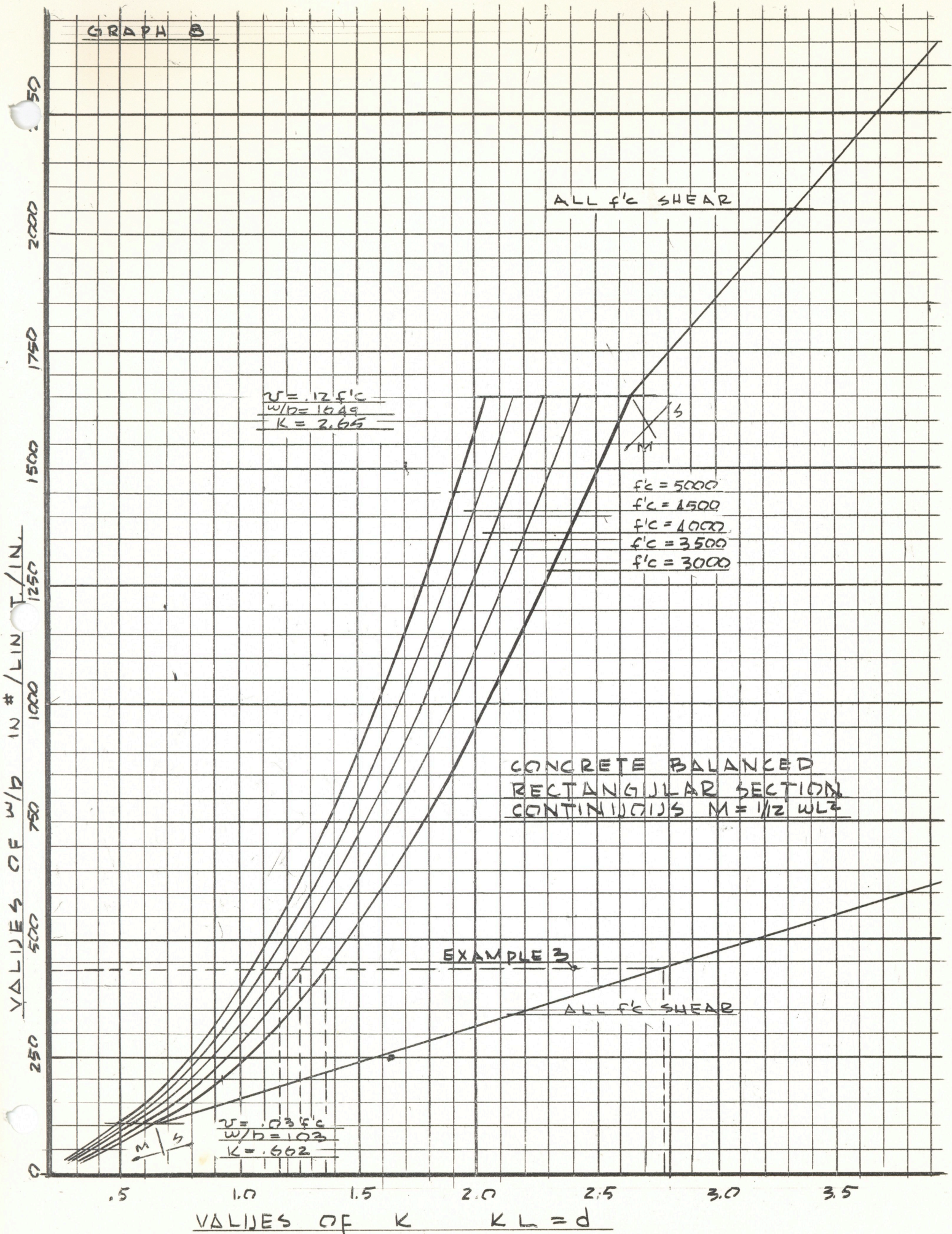
$$f'_c = 3500$$

$$f'_c = 3000$$

CONCRETE RECTANGULAR
BALANCED SECTION
 $M = 1/8 WL^2$



GRAPH B





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