3. Design and Analysis

Experience and judgment are the foundation of all structural design which is basically a cut-and-try process. The first trial or preliminary design may be close to the final or far away, depending upon the ability of the designer to estimate (from experience and judgment) the sizes and proportions of the various structural elements. The final step in the design process is to check the design in all of its elements by an analysis of the structure to be certain that it will resist the loads that come to it without exceeding the permissible stresses. The designer's goal is to produce plans for an adequate, safe, and economical structure; analysis is but one step in the process and is important only as a check on the designer's judgment.

3.1 Fundamental Requirements. A structural designer must meet certain basic requirements of experience, knowledge, and ability. His value as a designer will increase as his experience grows; experience is gained both from doing and from reading about what others have done.

The basic principles of structural analysis are relatively few in number and, with a few exceptions, are relatively simple. The structural designer must have a thorough, clear, and complete knowledge and conception of equilibrium; force; moment; couple; the basic laws and propositions regarding the composition and resolution of forces, moments, and couples; the laws of statics; and the geometry of continuous frames. The basic theory is simple; the difficulties arise in applying the principles to the many types of structures and loading conditions encountered. It is important to realize that unless the basic principles are thoroughly understood, their application to actual structures can be exceedingly difficult and often erroneous. Frequent review of good texts on analytical mechanics and structural theory will help fix these principles in the mind.

The equations of statics are so important that they are listed below for emphasis. For planar structures they are:

$$\Sigma H = 0 \qquad (6.3\text{-}1)$$

$$\Sigma V = 0 \qquad (6.3\text{-}2)$$

$$\Sigma M = 0 \qquad (6.3\text{-}3)$$

In words, these equations say that for a body to be in equilibrium, (1) the algebraic sum of the horizontal components of all forces acting on the body must equal zero; (2) the algebraic sum of the vertical components of all forces acting on the body must equal zero; and (3) the algebraic sum of the moments of all the forces acting on the body about any point in the plane of the forces must equal zero. These equations are necessary and sufficient for the solution of any statically determinate planar structure.

Free Body Diagrams. One of the most powerful tools of structural analysis is the free body diagram. A good designer will develop skill in their preparation and use; he will know and be able to apply the following steps:

1. Isolate a portion of the structure by passing a section (not necessarily straight) that cuts the member or members in which unknown forces or stresses are to be found.

2. Draw the free body diagram and show carefully all of the forces both internal and external acting on this free body.

3. Compute the unknown forces from the equations of statics.

Free body diagrams are also of value in the determination of the correct sense of shears, moments, rotations, and deflections; they give credence to the proverb that "a picture is worth 1000 words."

The use of free body diagrams will be illustrated numerous times in other sections of this handbook that deal with the design of specific structures.

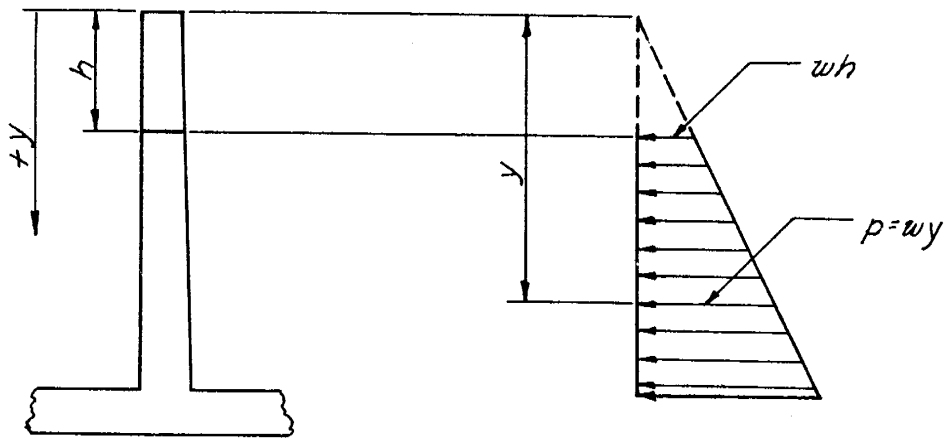
A designer's analytical ability can be lost through slovenly design notes and inadequate, sloppy engineering drawings. After a designer knows the fundamentals and how to apply them to specific problems, he must present his ideas in clear, neat, complete design notes and good drawings, or his effort and ability will not be recognized and appreciated. Anyone who has attempted to check a poorly prepared set of design notes or a carelessly prepared drawing will agree with the above comment. The reference value of cold, inadequately recorded engineering work is almost nil.

3.2 Shear and Moment Curves. Any of the modern textbooks on elementary structural theory and many books on strength of materials contain thorough discussions on the preparation of shear and moment curves and on the interrelationships between load, shear, and moment.

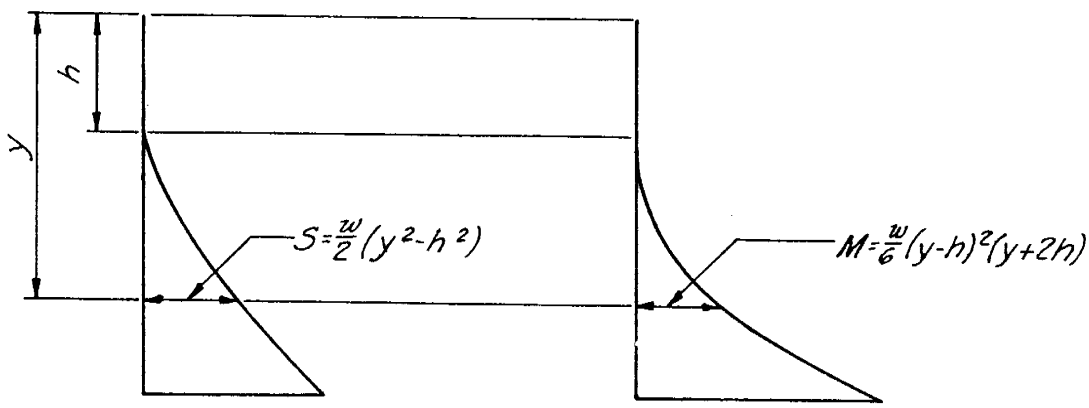
To aid in the computations involved in such work, several drawings have been prepared and included herein. Use of these drawings will facilitate the preparation of shear and moment curves on many of the cantilevers, beams, slabs, and rectangular frames encountered in soil conservation engineering. Your attention is especially directed to drawing ES-4, "Shear and Moments for Trapezoidal Load on Cantilever." The data contained in the three sheets of this drawing has found increasing use over the past 8 to 10 years since its original preparation.

Use of the following drawings will be illustrated in other sections of this handbook.

STRUCTURAL DESIGN: SHEAR AND MOMENTS FOR TRAPEZOIDAL LOAD ON CANTILEVER



CANTILEVER LOAD



SHEAR MOMENT

Consider one foot slice of cantilever.

h = depth of weir, height of surcharge, etc. in ft.
M = moment in ft.-lb. (for one foot slice).
p = pressure at depth y in lb. per sq. ft.
S = shear in lb. (for one foot slice)
w = weight of equivalent fluid in lb. per cu. ft.
y = vertical distance from top to any point in ft.

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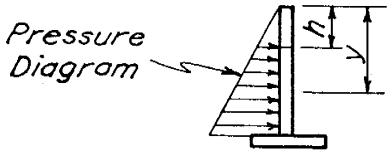
STRUCTURAL DESIGN: MOMENTS FOR TRAPEZOIDAL LOAD ON CANTILEVER



$$M = \frac{w}{6}(y-h)^2(y+2h)$$

$$w = 1$$

y \ h	0	1'-0"	1'-3"	1'-6"	1'-9"	2'-0"	2'-3"	2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	3'-9"	4'-0"	4'-3"	4'-6"	4'-9"	5'-0"
1'-0"	0.17	0																
1'-6"	0.56	0.15	0.04	0														
2'-0"	1.33	0.67	0.42	0.21	0.06	0												
2'-6"	2.60	1.69	1.30	0.92	0.56	0.27	0.07	0										
3'-0"	4.50	3.33	2.81	2.25	1.69	1.17	0.70	0.33	0.09	0								
3'-3"	5.72	4.43	3.83	3.19	2.53	1.89	1.29	0.77	0.36	0.10	0							
3'-6"	7.15	5.73	5.06	4.33	3.57	2.81	2.08	1.42	0.84	0.40	0.10	0						
3'-9"	8.79	7.25	6.51	5.70	4.83	3.96	3.09	2.28	1.54	0.91	0.43	0.11	0					
4'-0"	10.7	9.0	8.19	7.29	6.33	5.33	4.34	3.38	2.47	1.67	0.98	0.46	0.12	0				
4'-3"	12.8	11.0	10.1	9.14	8.07	6.96	5.83	4.72	3.66	2.67	1.79	1.05	0.49	0.13	0			
4'-6"	15.2	13.3	12.3	11.3	10.1	8.85	7.59	6.33	5.10	3.94	2.86	1.92	1.13	0.52	0.14	0		
4'-9"	17.9	15.8	14.8	13.6	12.4	11.0	9.64	8.23	6.83	5.49	4.22	3.06	2.04	1.20	0.55	0.14	0	
5'-0"	20.8	18.7	17.6	16.3	15.0	13.5	12.0	10.4	8.86	7.33	5.87	4.50	3.26	2.17	1.27	0.58	0.15	0
5'-3"	24.1	21.8	20.7	19.3	17.9	16.3	14.6	12.9	11.2	9.49	7.83	6.25	4.78	3.45	2.29	1.34	0.61	0.16
5'-6"	27.7	25.3	24.1	22.7	21.1	19.4	17.6	15.8	13.9	12.0	10.1	8.33	6.64	5.06	3.65	2.42	1.41	0.65
5'-9"	31.7	29.1	27.8	26.3	24.7	22.9	20.9	18.9	16.9	14.8	12.8	10.8	8.83	7.02	5.34	3.84	2.54	1.48
6'-0"	36.0	33.3	32.0	30.4	28.6	26.7	24.6	22.5	20.2	18.0	15.8	13.5	11.4	9.33	7.40	5.63	4.04	2.67
6'-3"	40.7	37.9	36.5	34.8	32.9	30.9	28.7	26.4	24.0	21.6	19.1	16.7	14.3	12.0	9.83	7.78	5.91	4.23
6'-6"	45.8	42.9	41.3	39.6	37.6	35.4	33.1	30.7	28.1	25.5	22.9	20.3	17.6	15.1	12.7	10.3	8.17	6.19
6'-9"	51.3	48.2	46.6	44.8	42.7	40.4	38.0	35.4	32.7	29.9	27.1	24.2	21.4	18.6	15.9	13.3	10.8	8.55
7'.0"	57.2	54.0	52.3	50.4	48.2	45.8	43.2	40.5	37.6	34.7	31.6	28.6	25.5	22.5	19.5	16.7	13.9	11.3
7'-3"	63.5	60.2	58.5	56.5	54.2	51.7	49.0	46.1	43.0	39.9	36.7	33.4	30.1	26.8	23.6	20.5	17.4	14.6
7'-6"	70.3	66.9	65.1	63.0	60.6	57.9	55.1	52.1	48.9	45.6	42.1	38.7	35.2	31.6	28.2	24.8	21.4	18.2
7'-9"	77.6	74.0	72.2	70.0	67.5	64.7	61.8	58.6	55.2	51.7	48.1	44.4	40.7	36.9	33.2	29.5	25.9	22.4
8'-0"	85.3	81.7	79.7	77.5	74.9	72.0	68.9	65.5	62.0	58.3	54.5	50.6	46.7	42.7	38.7	34.7	30.8	27.0
8'-3"	93.6	89.8	87.8	85.4	82.7	79.8	76.5	73.0	69.3	65.5	61.5	57.3	53.2	48.9	44.7	40.4	36.2	32.1
8'-6"	102.4	98.4	96.4	93.9	91.1	88.0	84.6	81.0	77.2	73.1	68.9	64.6	60.2	55.7	51.2	46.7	42.2	37.8
8'-9"	111.7	107.6	105.5	102.9	100.0	96.8	93.3	89.5	85.5	81.3	76.9	72.4	67.7	63.0	58.2	53.4	48.7	43.9
9'-0"	121.5	117.3	115.1	112.5	109.5	106.2	102.5	98.6	94.4	90.0	85.4	80.7	75.8	70.8	65.8	60.8	55.7	50.7
9'-3"	131.9	127.6	125.3	122.6	119.5	116.1	112.3	108.2	103.9	99.3	94.5	89.5	84.4	79.2	74.0	68.6	63.3	58.0
9'-6"	142.9	138.5	136.1	133.3	130.1	126.6	122.6	118.4	113.9	109.1	104.2	99.0	93.7	88.2	82.7	77.1	71.4	65.8
9'-9"	154.5	149.9	147.5	144.6	141.3	137.6	133.6	129.2	124.5	119.6	114.4	109.0	103.5	97.8	92.0	86.1	80.2	74.3
10'-0"	166.7	162.0	159.5	156.5	153.1	149.3	145.2	140.6	135.8	130.7	125.3	119.7	113.9	108.0	101.9	95.8	89.6	83.3
10'-3"	179.5	174.7	172.1	169.1	165.6	161.6	157.3	152.7	147.7	142.4	136.8	131.0	125.0	118.8	112.5	106.1	99.6	93.0
10'-6"	192.9	188.0	185.4	182.4	178.6	174.6	170.2	165.3	160.2	154.7	148.9	142.9	136.7	130.3	123.7	117.0	110.2	103.4
10'-9"	207.0	202.0	199.3	196.1	192.4	188.2	183.6	178.7	173.3	167.7	161.7	155.5	149.0	142.4	135.6	128.6	121.5	114.3
11'-0"	221.8	216.7	213.9	210.6	206.8	202.5	197.8	192.7	187.2	181.3	175.2	168.8	162.1	155.2	148.1	140.8	133.5	126.0
11'-3"	237.3	232.0	229.2	225.8	221.9	217.5	212.6	207.4	201.7	195.7	189.3	182.7	175.8	168.6	161.3	153.8	146.1	138.3
11'-6"	253.5	248.1	245.1	241.7	237.7	233.1	228.2	222.8	216.9	210.7	204.2	197.3	190.2	182.8	175.2	167.4	159.5	151.4
11'-9"	270.4	264.8	261.8	258.3	254.2	249.5	244.4	238.9	232.9	226.5	219.8	212.7	205.3	197.7	189.8	181.8	173.5	165.2
12'-0"	288.0	282.3	279.3	275.6	271.4	266.7	261.4	255.7	249.6	243.0	236.1	228.8	221.2	213.3	205.2	196.9	188.3	179.7
12'-3"	306.4	300.6	297.5	293.7	289.4	284.5	279.2	273.3	267.0	260.3	253.1	245.6	237.8	229.7	221.3	212.7	203.9	194.9
12'-6"	325.5	319.6	316.4	312.6	308.2	303.2	297.7	291.7	285.2	278.3	270.9	263.3	255.2	246.9	238.2	229.3	220.2	210.9
12'-9"	345.4	339.4	336.1	332.2	327.7	322.6	317.0	310.8	304.2	297.1	289.6	281.6	273.4	264.8	255.9	246.7	237.3	227.7
13'-0"	366.2	360.0	356.7	352.7	348.0	342.8	337.1	330.8	323.9	316.7	309.0	300.8	292.3	283.5	274.3	264.9	255.2	245.3
13'-3"	387.7	381.4	378.0	373.9	369.2	363.9	358.0	351.5	344.5	337.1	329.2	320.8	312.1	303.0	293.6	283.9	273.9	263.7
13'-6"	410.1	403.6	400.1	396.0	391.2	385.7	379.7	373.1	365.9	358.3	350.2	341.7	332.7	323.4	313.7	303.8	293.5	283.0
13'-9"	433.3	426.7	423.2	418.9	414.0	408.4	402.3	395.5	388.2	380.4	372.1	363.3	354.1	344.6	334.7	324.4	313.9	303.1
14'-0"	457.3	450.7	447.0	442.7	437.7	432.0	425.7	418.8	411.3	403.3	394.8	385.9	376.5	366.7	356.5	346.0	335.1	324.0
14'-3"	482.3	475.5	471.8	467.4	462.2	456.4	450.0	443.0	435.3	427.1	418.5	409.3	399.7	389.6	379.2	368.4	357.2	345.8
14'-6"	508.1	501.2	497.4	492.9	487.7	481.8	475.2	468.0	460.2	451.9	443.0	433.6	423.7	413.4	402.7	391.7	380.3	368.5
14'-9"	534.8	527.8	524.0	519.4	514.0	508.0	501.6	494.0	486.0	477.5	468.4	458.8	448.7	438.2	427.2	415.9	404.2	392.1
15'-0"	562.5	555.3	551.4	546.8	541.3	535.2	528.3	520.8	512.7	504.0	494.7	484.9	474.6	463.8	452.6	441.0	429.0	416.7

REFERENCE

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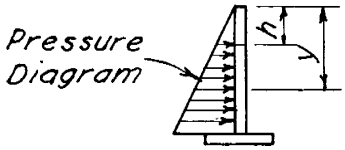
Revised 6-4-51

STRUCTURAL DESIGN: SHEAR FOR TRAPEZOIDAL LOAD ON CANTILEVER



$$S = \frac{w}{2}(y^2 - h^2)$$

$$w = 1$$

y \ h	0	1'-0"	1'-3"	1'-6"	1'-9"	2'-0"	2'-3"	2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	3'-9"	4'-0"	4'-3"	4'-6"	4'-9"	5'-0"
1'-0"	0.50	0																
1'-6"	1.13	0.63	0.34	0														
2'-0"	2.00	1.50	1.22	0.88	0.47	0												
2'-6"	3.13	2.63	2.34	2.00	1.59	1.13	0.59	0										
3'-0"	4.50	4.00	3.72	3.38	2.97	2.50	1.97	1.38	0.72	0								
3'-3"	5.28	4.78	4.50	4.15	3.75	3.28	2.75	2.16	1.50	0.78	0							
3'-6"	6.13	5.63	5.34	5.00	4.59	4.13	3.59	3.00	2.34	1.63	0.84	0						
3'-9"	7.03	6.53	6.25	5.90	5.50	5.03	4.50	3.90	3.25	2.53	1.75	0.90	0					
4'-0"	8.00	7.50	7.22	6.88	6.47	6.00	5.47	4.88	4.22	3.50	2.72	1.88	0.97	0				
4'-3"	9.03	8.53	8.25	7.90	7.50	7.03	6.50	5.90	5.25	4.53	3.75	2.90	2.00	1.03	0			
4'-6"	10.1	9.63	9.34	9.00	8.59	8.13	7.59	7.00	6.34	5.63	4.84	4.00	3.09	2.13	1.09	0		
4'-9"	11.3	10.8	10.5	10.2	9.75	9.28	8.75	8.16	7.50	6.78	6.00	5.16	4.25	3.28	2.25	1.16	0	
5'-0"	12.5	12.0	11.7	11.4	11.0	10.5	9.97	9.38	8.72	8.00	7.22	6.38	5.47	4.50	3.47	2.38	1.22	0
5'-3"	13.8	13.3	13.0	12.7	12.3	11.8	11.3	10.7	10.0	9.28	8.50	7.66	6.75	5.78	4.75	3.66	2.50	1.28
5'-6"	15.1	14.6	14.3	14.0	13.6	13.1	12.6	12.0	11.3	10.6	9.84	9.00	8.09	7.13	6.09	5.00	3.84	2.63
5'-9"	16.5	16.0	15.8	15.4	15.0	14.5	14.0	13.4	12.8	12.0	11.3	10.4	9.50	8.53	7.50	6.40	5.25	4.03
6'-0"	18.0	17.5	17.2	16.9	16.5	16.0	15.5	14.9	14.2	13.5	12.7	11.9	11.0	10.0	8.97	7.88	6.72	5.50
6'-3"	19.5	19.0	18.8	18.4	18.0	17.5	17.0	16.4	15.8	15.0	14.3	13.4	12.5	11.5	10.5	9.41	8.25	7.00
6'-6"	21.1	20.6	20.3	20.0	19.6	19.1	18.6	18.0	17.3	16.6	15.8	15.0	14.1	13.1	12.1	11.0	9.84	8.63
6'-9"	22.8	22.3	22.0	21.7	21.3	20.8	20.3	19.7	19.0	18.3	17.5	16.7	15.8	14.8	13.8	12.7	11.5	10.3
7'-0"	24.5	24.0	23.7	23.4	23.0	22.5	22.0	21.4	20.7	20.0	19.2	18.4	17.5	16.5	15.5	14.4	13.2	12.0
7'-3"	26.3	25.8	25.5	25.2	24.8	24.3	23.8	23.2	22.5	21.8	21.0	20.2	19.3	18.3	17.3	16.2	15.0	13.8
7'-6"	28.1	27.6	27.3	27.0	26.6	26.1	25.6	25.0	24.3	23.6	22.8	22.0	21.1	20.1	19.1	18.0	16.8	15.6
7'-9"	30.0	29.5	29.3	28.9	28.5	28.0	27.5	26.9	26.3	25.5	24.8	23.9	23.0	22.0	21.0	19.9	18.8	17.5
8'-0"	32.0	31.5	31.2	30.9	30.5	30.0	29.5	28.9	28.2	27.5	26.7	25.9	25.0	24.0	23.0	21.9	20.7	19.5
8'-3"	34.0	33.5	33.3	32.9	32.5	32.0	31.5	30.9	30.3	29.5	28.8	27.9	27.0	26.0	25.0	23.9	22.8	21.5
8'-6"	36.1	35.6	35.3	35.0	34.6	34.1	33.6	33.0	32.3	31.6	30.8	30.0	29.1	28.1	27.1	26.0	24.8	23.6
8'-9"	38.3	37.8	37.5	37.2	36.8	36.3	35.8	35.2	34.5	33.8	33.0	32.2	31.3	30.3	29.3	28.2	27.0	25.8
9'-0"	40.5	40.0	39.7	39.4	39.0	38.5	38.0	37.4	36.7	36.0	35.2	34.4	33.5	32.5	31.5	30.4	29.2	28.0
9'-3"	42.8	42.3	42.0	41.7	41.3	40.8	40.3	39.7	39.0	38.3	37.5	36.7	35.8	34.8	33.8	32.7	31.5	30.3
9'-6"	45.1	44.6	44.3	44.0	43.6	43.1	42.6	42.0	41.3	40.6	39.8	39.0	38.1	37.1	36.1	35.0	33.8	32.6
9'-9"	47.5	47.0	46.8	46.4	46.0	45.5	45.0	44.4	43.8	43.0	42.3	41.4	40.5	39.5	38.5	37.4	36.3	35.0
10'-0"	50.0	49.5	49.2	48.9	48.5	48.0	47.5	46.9	46.2	45.5	44.7	43.9	43.0	42.0	41.0	39.9	38.7	37.5
10'-3"	52.5	52.0	51.8	51.4	51.0	50.5	50.0	49.4	48.8	48.0	47.3	46.4	45.5	44.5	43.5	42.4	41.3	40.0
10'-6"	55.1	54.6	54.3	54.0	53.6	53.1	52.6	52.0	51.3	50.6	49.8	49.0	48.1	47.1	46.1	45.0	43.8	42.6
10'-9"	57.8	57.3	57.0	56.7	56.3	55.8	55.3	54.7	54.0	53.3	52.5	51.7	50.8	49.8	48.8	47.7	46.5	45.3
11'-0"	60.5	60.0	59.7	59.4	59.0	58.5	58.0	57.4	56.7	56.0	55.2	54.4	53.5	52.5	51.5	50.4	49.2	48.0
11'-3"	63.3	62.8	62.5	62.2	61.8	61.3	60.8	60.2	59.5	58.8	58.0	57.2	56.3	55.3	54.3	53.2	52.0	50.8
11'-6"	66.1	65.6	65.3	65.0	64.6	64.1	63.6	63.0	62.3	61.6	60.8	60.0	59.1	58.1	57.1	56.0	54.8	53.6
11'-9"	69.0	68.5	68.3	67.9	67.5	67.0	66.5	65.9	65.3	64.5	63.8	62.9	62.0	61.0	60.0	58.9	57.8	56.5
12'-0"	72.0	71.5	71.2	70.9	70.5	70.0	69.5	68.9	68.2	67.5	66.7	65.9	65.0	64.0	63.0	61.9	60.7	59.5
12'-3"	75.0	74.5	74.3	73.9	73.5	73.0	72.5	71.9	71.3	70.5	69.8	68.9	68.0	67.0	66.0	64.9	63.8	62.5
12'-6"	78.1	77.6	77.3	77.0	76.6	76.1	75.6	75.0	74.3	73.6	72.8	72.0	71.1	70.1	69.1	68.0	66.8	65.6
12'-9"	81.3	80.8	80.5	80.2	79.8	79.3	78.8	78.2	77.5	76.8	76.0	75.2	74.3	73.3	72.3	71.2	70.0	68.8
13'-0"	84.5	84.0	83.7	83.4	83.0	82.5	82.0	81.4	80.7	80.0	79.2	78.4	77.5	76.5	75.5	74.4	73.2	72.0
13'-3"	87.8	87.3	87.0	86.7	86.3	85.8	85.3	84.7	84.0	83.3	82.5	81.7	80.8	79.8	78.8	77.7	76.5	75.3
13'-6"	91.1	90.6	90.3	90.0	89.6	89.1	88.6	88.0	87.3	86.6	85.8	85.0	84.1	83.1	82.1	81.0	79.8	78.6
13'-9"	94.5	94.0	93.8	93.4	93.0	92.5	92.0	91.4	90.8	90.0	89.3	88.4	87.5	86.5	85.5	84.4	83.3	82.0
14'-0"	98.0	97.5	97.2	96.9	96.5	96.0	95.5	94.9	94.2	93.5	92.7	91.9	91.0	90.0	89.0	87.9	86.7	85.5
14'-3"	101.5	101.0	100.8	100.4	100.0	99.5	99.0	98.4	97.8	97.0	96.3	95.4	94.5	93.5	92.5	91.4	90.3	89.0
14'-6"	105.1	104.6	104.3	104.0	103.6	103.1	102.6	102.0	101.3	100.6	99.8	99.0	98.1	97.1	96.1	95.0	93.8	92.6
14'-9"	108.8	108.3	108.0	107.7	107.3	106.8	106.3	105.7	105.0	104.3	103.5	102.7	101.8	100.8	99.8	98.7	97.5	96.3
15'-0"	112.5	112.0	111.7	111.4	111.0	110.5	110.0	109.4	108.7	108.0	107.2	106.4	105.5	104.5	103.5	102.4	101.2	100.0

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

ENGINEERING STANDARDS UNIT

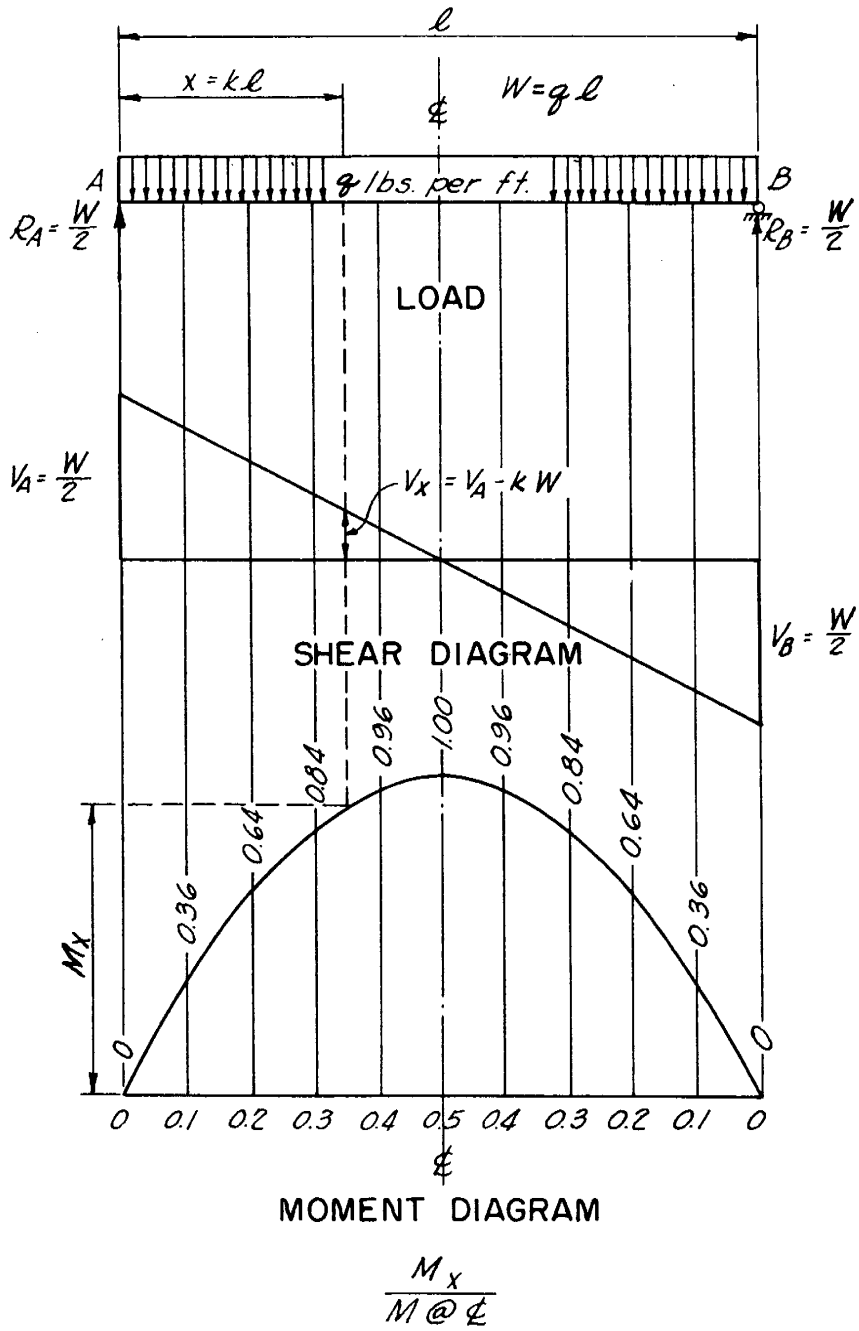
STANDARD DWG. NO.
ES - 4
SHEET 3 OF 3
DATE 11-1-49

USDA-SCS-HYATTSVILLE MD 1967 Revised 6-4-51

STRUCTURAL DESIGN: SIMPLE BEAM MOMENTS FOR UNIFORMLY DISTRIBUTED LOAD

$$M_x = M_{k\ell} = \frac{q\ell^2}{2} k(1-k) = \frac{W\ell}{2} k(1-k)$$

$$\text{or } M_x = CW\ell, \text{ where } C = \frac{k}{2}(1-k)$$



k	C	$\frac{M_x}{M@℄}$
0.01	0.00495	0.0396
0.02	0.00980	0.0784
0.03	0.01455	0.1164
0.04	0.01920	0.1536
0.05	0.02375	0.1900
0.06	0.02820	0.2256
0.07	0.03255	0.2604
0.08	0.03680	0.2944
0.09	0.04095	0.3276
0.1	0.04500	0.3600
0.11	0.04895	0.3916
0.12	0.05280	0.4224
0.13	0.05655	0.4524
0.14	0.06020	0.4816
0.15	0.06375	0.5100
0.16	0.06720	0.5376
0.17	0.07055	0.5644
0.18	0.07380	0.5904
0.19	0.07695	0.6156
0.2	0.08000	0.6400
0.21	0.08295	0.6636
0.22	0.08580	0.6864
0.23	0.08855	0.7084
0.24	0.09120	0.7296
0.25	0.09375	0.7500
0.26	0.09620	0.7696
0.27	0.09855	0.7884
0.28	0.10080	0.8064
0.29	0.10295	0.8236
0.3	0.10500	0.8400
0.31	0.10695	0.8556
0.32	0.10880	0.8704
0.33	0.11055	0.8844
0.34	0.11220	0.8976
0.35	0.11375	0.9100
0.36	0.11520	0.9216
0.37	0.11655	0.9324
0.38	0.11780	0.9424
0.39	0.11895	0.9516
0.4	0.12000	0.9600
0.41	0.12095	0.9676
0.42	0.12180	0.9744
0.43	0.12255	0.9804
0.44	0.12320	0.9856
0.45	0.12375	0.9900
0.46	0.12420	0.9936
0.47	0.12455	0.9964
0.48	0.12480	0.9984
0.49	0.12495	0.9996
0.5	0.12500	1.00

REFERENCE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

ENGINEERING STANDARDS UNIT

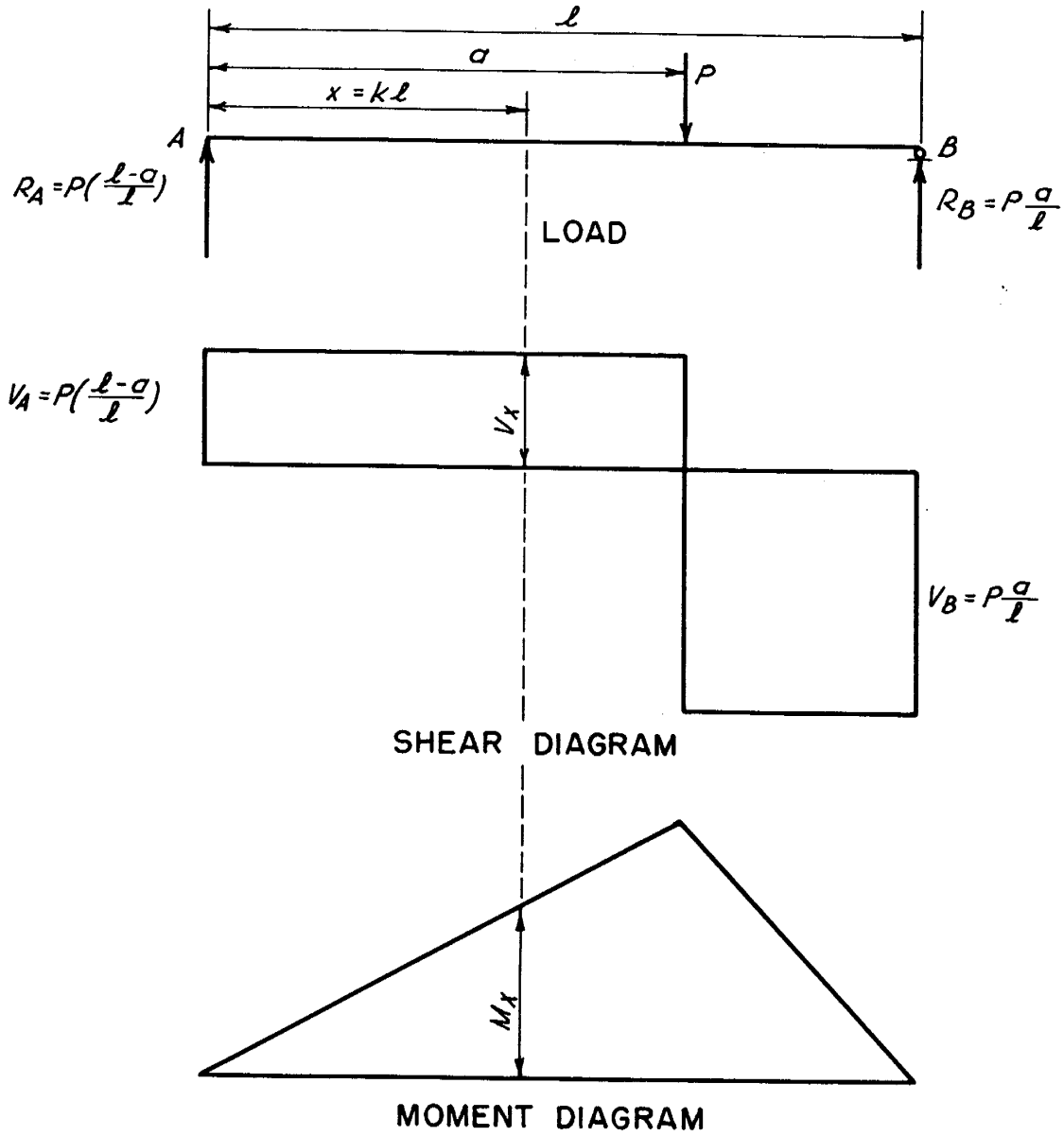
STANDARD DWG. NO. ES - 1

SHEET 1 OF 1

DATE 10 - 26 - 49

REVISED 3-30-50

STRUCTURAL DESIGN: SIMPLE BEAM MOMENTS FOR CONCENTRATED LOAD



$M_x = P(\ell - a)k$, when $k\ell < a$; $M_x = Pa(1-k)$ when $k\ell > a$

$$M_{max} = P(\frac{\ell - a}{\ell})a$$

When load (P) is at ℄ of beam ($a = \frac{\ell}{2}$)

$R_A = R_B = \frac{P}{2}$; $V_{max} = \frac{P}{2}$

$M_x = \frac{P}{2}k\ell$; $M_{max} = \frac{P\ell}{4}$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-2 SHEET 1 OF 1 DATE 11-1-49

STRUCTURAL DESIGN: SIMPLE BEAM MOMENTS FOR TRAPEZOIDAL LOAD

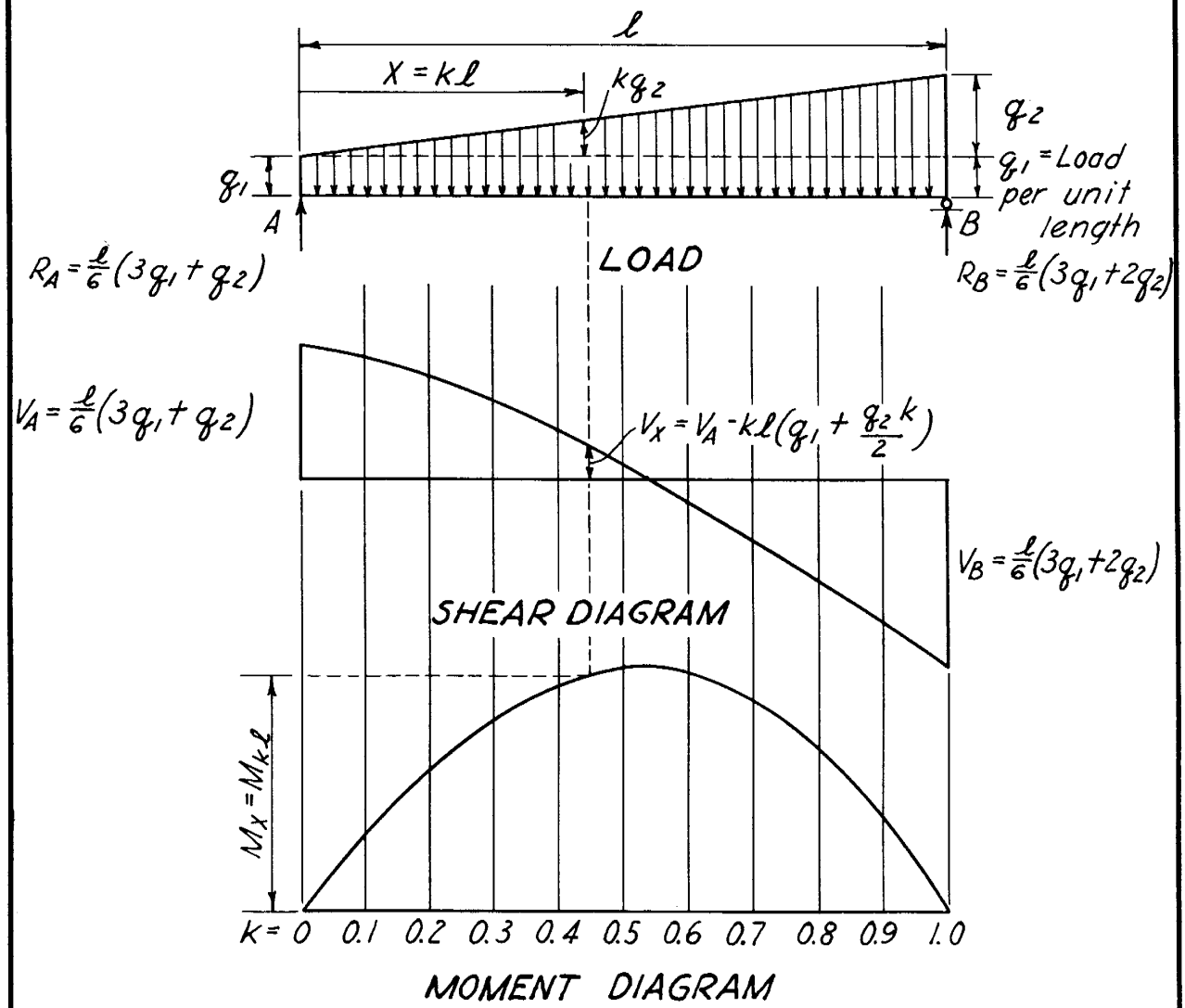
$$M_x = M_{k\ell} = \frac{q_1 \ell^2}{6} \cdot D(E + C)$$

where $C = \frac{q_2}{q_1}$, $D = k(1-k^2)$, $E = \frac{3}{1+k}$

M max. when $k = \frac{1}{c}\left[-1 + \sqrt{\frac{c^2+3c+3}{3}}\right]$

NOTE: Ordinarily it is not necessary to compute the maximum moment. It can usually be determined from the moment diagram with sufficient accuracy. The maximum moment will occur between $k = 0.500$ and $k = 0.577$

k	D	E
0.1	0.099	2.727
0.2	0.192	2.500
0.3	0.273	2.308
0.4	0.336	2.143
0.5	0.375	2.000
0.6	0.384	1.875
0.7	0.357	1.765
0.8	0.288	1.666
0.9	0.171	1.579



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-3 SHEET 1 OF 1 DATE 11-1-49

FED 3-30-5

STRUCTURAL DESIGN: SIMPLE BEAM MOMENTS FOR TRIANGULAR LOAD

$$M_x = M_{k\ell} = \tfrac{1}{6} q \ell^2 (k - k^3) = \tfrac{1}{3} W \ell (k - k^3)$$

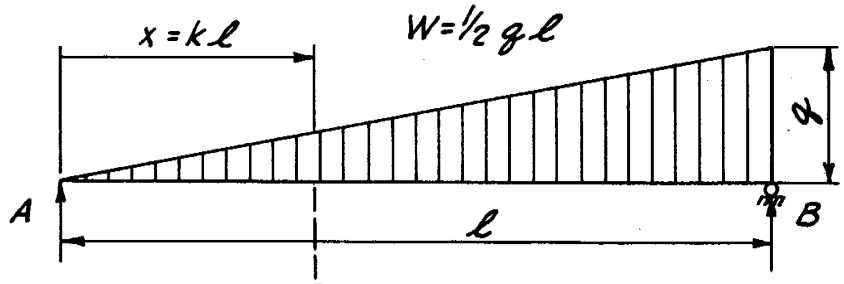
$$C = \tfrac{1}{3}(k - k^3)$$

$$M_{k\ell} = CW\ell$$

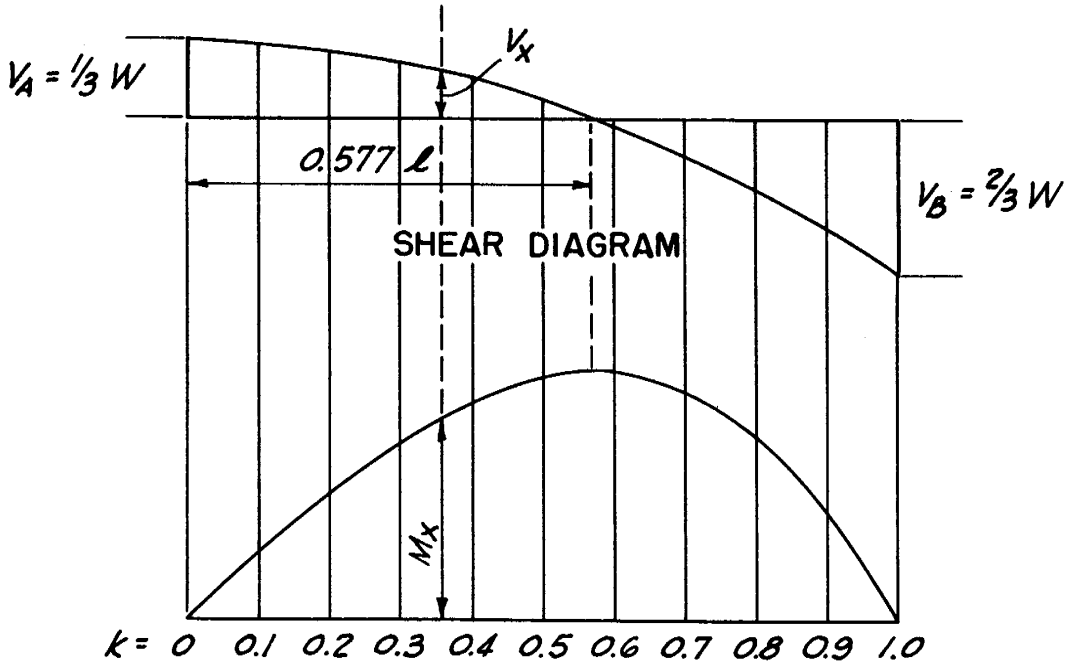
M is maximum when $k = 0.577$

$$V_x = V_{k\ell} = W(\tfrac{1}{3} - k^2)$$

k	C
0.1	0.033
0.2	0.064
0.3	0.091
0.4	0.112
0.5	0.125
0.577	0.1283
0.6	0.128
0.7	0.119
0.8	0.096
0.9	0.057



LOAD DIAGRAM



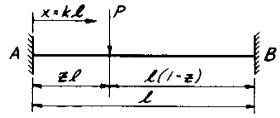
SHEAR DIAGRAM

MOMENT DIAGRAM

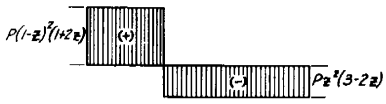
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	STANDARD DWG. NO.
Continuity in Concrete Building Frames, Third Edition, Portland Cement Association.	ENGINEERING STANDARDS UNIT	ES-23
		SHEET 1 OF 1
		DATE 4-1-50

STRUCTURAL DESIGN: FIXED ENDED BEAM MOMENTS FOR CONCENTRATED LOAD, UNIFORMLY DISTRIBUTED LOAD, AND HYDROSTATIC LOAD ON PRISMATIC BEAMS

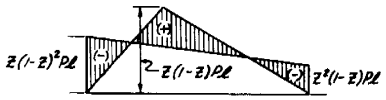
CONCENTRATED LOAD



Load Diagram



Shear Diagram



Moment Diagram

MOMENT AT ANY POINT kℓ FROM A

For $0 \le k \le z$

$M_x = M_{k\ell} = (1-z)^2(k+2zk-z)P\ell$

For $z \le k \le 1$

$M_x = M_{k\ell} = z^2(2zk-z+2-3k)P\ell$

MAXIMUM POSITIVE MOMENT (k = z)

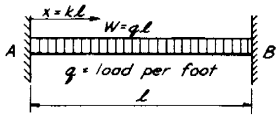
$M_{z\ell} = 2z^2(1-z)^2 P\ell$

FIXED END MOMENTS (Negative)

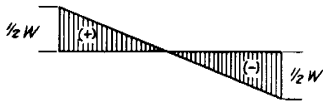
$M^F_{AB} = z(1-z)^2 P\ell$

$M^F_{BA} = z^2(1-z)P\ell$

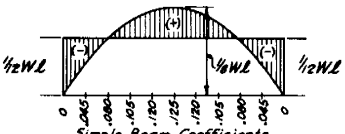
UNIFORMLY DISTRIBUTED LOAD



Load Diagram



Shear Diagram



Simple Beam Coefficients at tenth points in M = CWℓ

Moment Diagram

SHEAR AT ANY POINT kℓ FROM A

$V_x = V_{k\ell} = \frac{1}{2}(1-2k)W$

MOMENT AT ANY POINT kℓ FROM A

$M_x = M_{k\ell} = \frac{1}{12}(6k-6k^2-1)W\ell$

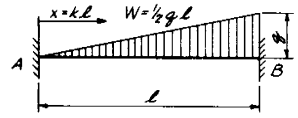
MAXIMUM POSITIVE MOMENT (k = ½)

$M_{\frac{1}{2}\ell} = \frac{1}{24}W\ell$

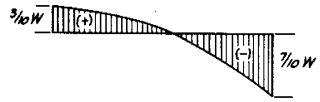
FIXED END MOMENTS (Negative)

$M^F_{AB} = M^F_{BA} = \frac{1}{12}W\ell$

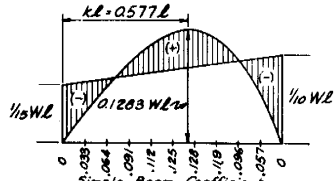
HYDROSTATIC LOAD



Load Diagram



Shear Diagram



Simple Beam Coefficients at tenth points in M = CWℓ

Moment Diagram

SHEAR AT ANY POINT kℓ FROM A

$V_x = V_{k\ell} = \frac{1}{10}(3-10k^2)W$

MOMENT AT ANY POINT kℓ FROM

$M_x = M_{k\ell} = \frac{1}{30}(9k-2-10k^3)W\ell$

MAXIMUM POSITIVE MOMENT (k = 0.5477)

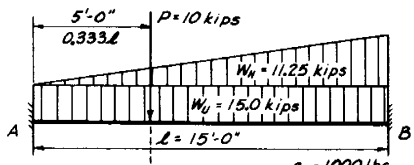
$M_{0.5477\ell} = 0.0429\,W\ell$

FIXED END MOMENTS (Negative)

$M^F_{AB} = \frac{1}{15}W\ell$

$M^F_{BA} = \frac{1}{10}W\ell$

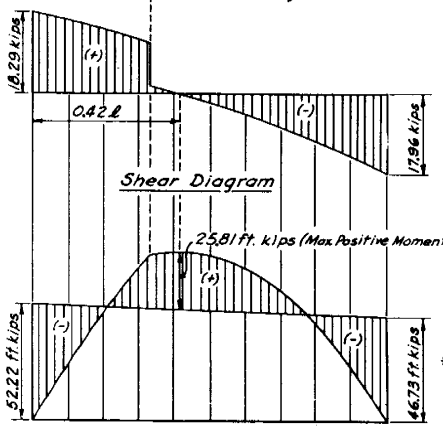
EXAMPLE



Load Diagram

$q_U = 1{,}000$ lbs.

$q_H = 1{,}500$ lbs.



Shear Diagram

Moment Diagram

SHEAR IN KIPS

	0	0.1ℓ	0.2ℓ	0.3ℓ	0.333ℓ	0.4ℓ	0.5ℓ	0.6ℓ	0.7ℓ	0.8ℓ	0.9ℓ	ℓ
Conc. Load	+7.41	+7.41	+7.41	+7.41	+7.41 / -2.59	-2.59	-2.59	-2.59	-2.59	-2.59	-2.59	-2.59
** U.L = ½(1-2k)W_U	+7.50	+6.00	+4.50	+3.00	+2.50	+1.50	0	-1.50	-3.00	-4.50	-6.00	-7.50
** H.L = 1/10(3-10k²)W_H	+3.38	+3.26	+2.92	+2.36	+2.13	+1.58	+0.56	-0.68	-2.14	-3.83	-5.74	-7.87
Total	+18.29	+16.67	+14.83	+12.77	+12.04 / +2.04	+0.49	-2.03	-4.77	-7.73	-10.92	-14.33	-17.96

FIXED END MOMENTS

Conc. Load - $M_A = z(1-z)^2 P\ell = 0.333(0.667)^2 10 \times 15 =$ 22.22 ft. kips

Unif. Load - $M_A = \frac{1}{12} W_U \ell = \frac{1}{12} \times 15 \times 15 =$ 18.75 ft. kips

Hyd. Load - $M_A = \frac{1}{15} W_H \ell = \frac{1}{15} \times 11.25 \times 15 =$ 11.25 ft. kips

Total $M^F_{AB} =$ 52.22 ft. kips

Conc. Load - $M_B = z^2(1-z)P\ell = (0.333)^2(0.667)10 \times 15 =$ 11.11 ft. kips

Unif. Load - $M_B = \frac{1}{12} W_U \ell = \frac{1}{12} \times 15 \times 15 =$ 18.75 ft. kips

Hyd. Load - $M_B = \frac{1}{10} W_H \ell = \frac{1}{10} \times 11.25 \times 15 =$ 16.87 ft. kips

Total $M^F_{BA} =$ 46.73 ft. kips

SIMPLE BEAM MOMENTS IN FT. KIPS

	0	0.1ℓ	0.2ℓ	0.3ℓ	0.333ℓ	0.4ℓ	0.5ℓ	0.6ℓ	0.7ℓ	0.8ℓ	0.9ℓ	ℓ
Conc. Load	0	10.00	20.00	30.00	33.33	30.00	25.00	20.00	15.00	10.00	5.00	0
** U.L = C_U W_U ℓ	0	10.13	18.00	23.63	25.00	27.00	28.13	27.00	23.63	18.00	10.13	0
** H.L = C_H W_H ℓ	0	5.57	10.80	15.36	16.67	18.90	21.10	21.60	20.10	16.20	9.62	0
Total	0	25.70	48.80	68.99	75.00	75.90	74.23	68.60	58.73	44.20	24.75	0

* See ES-1, ES-2, and ES-23

** The Uniform load and Hydrostatic load can be combined and ES-3 used.

REFERENCE Continuity in Concrete Building Frames, Third Edition, Portland Cement Association.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

ENGINEERING STANDARDS UNIT

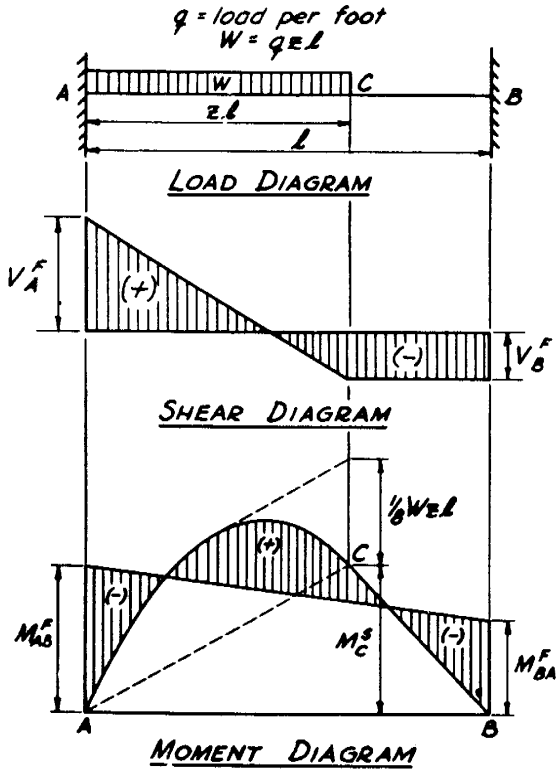
STANDARD DWG. NO. ES-17

SHEET 1 OF 1

DATE 4-11-50

Revised 6-4-51

STRUCTURAL DESIGN: FIXED ENDED BEAM MOMENTS FOR PARTIAL UNIFORMLY DISTRIBUTED LOAD— PRISMATIC BEAMS



FIXED END MOMENTS

$M_{AB}^F = \frac{1}{12} l z (6 - 8z + 3z^2) W$

$M_{BA}^F = \frac{1}{12} l z^2 (4 - 3z) W$

SIMPLE BEAM REACTIONS

$R_A^S = V_A^S = \frac{1}{2} W (2 - z)$

$R_B^S = V_B^S = \frac{1}{2} W z$

FIXED END REACTIONS

$$R_A^F = V_A^F = R_A^S + \frac{(M_{AB}^F - M_{BA}^F)}{l}$$

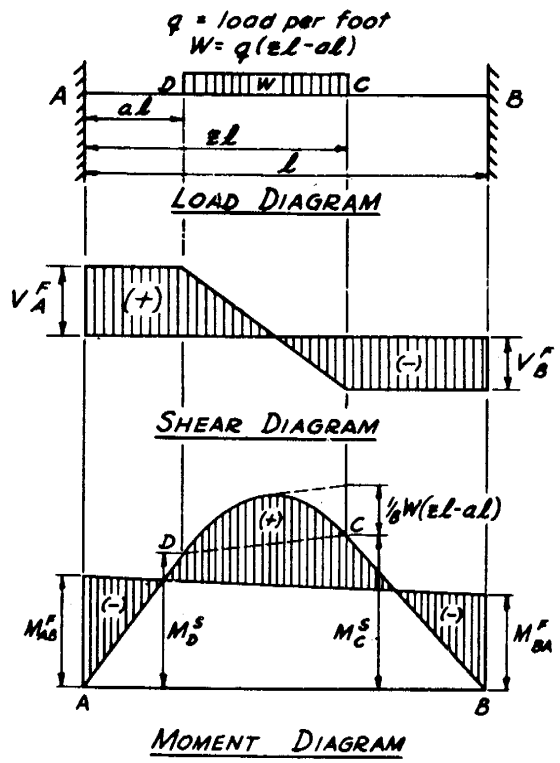
$$R_B^F = V_B^F = R_B^S - \frac{(M_{AB}^F - M_{BA}^F)}{l}$$

SIMPLE BEAM MOMENT AT C

$M_C^S = R_B^S (l - zl)$

PLOTTING MOMENT DIAGRAM

1. Plot M_C^S at C
2. Plot simple beam moment diagram for span (zl) and load (W) vertically above line AC (See ES-1)
3. Plot M_{AB}^F at A
4. Plot M_{BA}^F at B



FIXED END MOMENTS

$M_{AB}^F = \frac{1}{12} l [z(6 - 8z + 3z^2) q z l - a^2 (6 - 8a + 3a^2) q l]$

$M_{BA}^F = \frac{1}{12} l [z^2 (4 - 3z) q z l - a^3 (4 - 3a) q l]$

SIMPLE BEAM REACTIONS

$R_B^S = V_B^S = \frac{1}{2} W (a + z)$

$R_A^S = V_A^S = \frac{1}{2} W (2 - a - z)$

FIXED END REACTIONS

$$R_A^F = V_A^F = R_A^S + \frac{(M_{AB}^F - M_{BA}^F)}{l}$$

$$R_B^F = V_B^F = R_B^S - \frac{(M_{AB}^F - M_{BA}^F)}{l}$$

SIMPLE BEAM MOMENTS AT C & D

$M_C^S = R_B^S (l - zl)$

$M_D^S = R_A^S (al)$

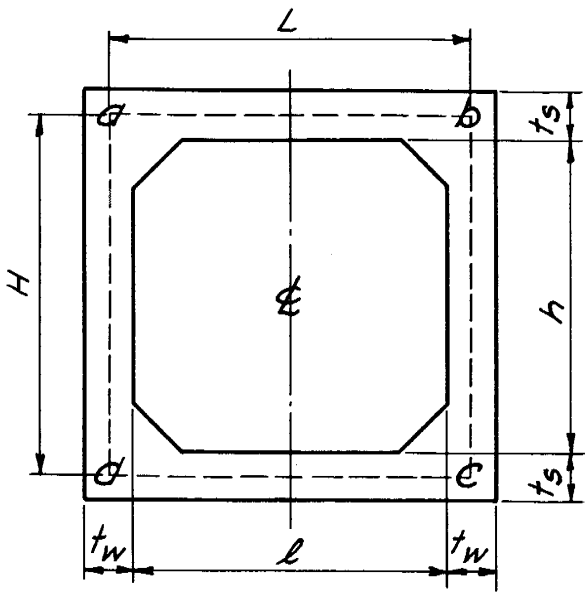
PLOTTING MOMENT DIAGRAM

1. Plot M_C^S at C
2. Plot M_D^S at D
3. Plot simple beam moment diagram for span ($zl - al$) and load (W) vertically above line CD (See ES-1)
4. Plot M_{AB}^F at A
5. Plot M_{BA}^F at B

REFERENCE Continuity in Concrete Building Frames, Third Edition, Portland Cement Association.	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-32 SHEET 1 OF 1 DATE 5-26-50

Revised 6-4-51

STRUCTURAL DESIGN: MOMENTS IN SINGLE BARREL



Assumptions -

1 - Loads and frame are symmetrical about center line of frame.

2 - The analysis is based on center line dimensions.

3 - The effect of small fillets is neglected.

$$H = h + t_s$$

$$L = \ell + t_w$$

$$\frac{K_s}{K_w} = C = \left(\frac{t_s}{t_w}\right)^3 \cdot \frac{H}{L}$$

$$p = \frac{C}{(C+2)^2 - 1}$$

$$q = C + 2$$

$$U_a^F = M_{ab}^F + M_{ad}^F$$

$$U_c^F = M_{cd}^F + M_{cb}^F$$

$$M_{ab} = M_{ab}^F - p(U_c^F + q\,U_a^F)$$

$$M_{dc} = M_{dc}^F + p(U_a^F + q\,U_c^F)$$

$$M_{dc} + M_{da} = 0$$

$$M_{ab} + M_{ad} = 0$$

Sign convention - A moment acting in a clockwise direction on a joint is positive.

Caution: Use proper sign of fixed end moments when substituting them in the given equations.

Nomenclature:

M_{ab} = Moment at end "a" of member "ab".

M_{ab}^F = Fixed end moment at end "a" of member "ab".

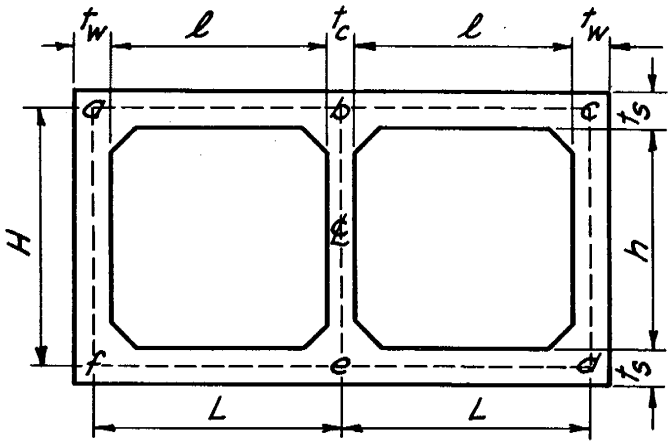
U_a^F = Algebraic sum of fixed end moments at a = unbalanced fixed end moment at a.

K_w = Stiffness of wall.

K_s = Stiffness of slab.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-28 SHEET 1 OF 1 DATE 5-23-50

STRUCTURAL DESIGN: MOMENTS IN DOUBLE BARREL



Assumptions:

1. - Loads and frame are symmetrical about center line of frame.
2. - The analysis is based on center line dimensions.
3. - The effect of small fillets is neglected.

$$M_{ab} = M_{ab}^F + 2m\left(U_f^F - nU_a^F\right)$$
$$M_{ba} = M_{ba}^F + m\left(U_f^F - nU_a^F\right)$$
$$M_{ef} = M_{ef}^F + m\left(U_a^F - nU_f^F\right)$$
$$M_{fe} = M_{fe}^F + 2m\left(U_a^F - nU_f^F\right)$$
$$M_{ab} + M_{af} = 0;\ M_{fa} + M_{fe} = 0;$$
$$M_{be} = M_{eb} = 0.$$

$$H = h + t_s$$

$$L = \ell + \frac{t_w}{2} + \frac{t_c}{2}$$

$$\frac{K_s}{K_w} = C = \left(\frac{t_s}{t_w}\right)^3 \cdot \frac{H}{L}$$

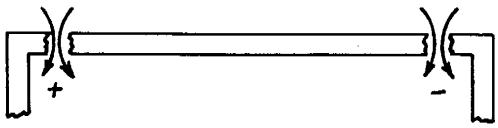
$$m = \frac{C}{4(C+1)^2 - 1}$$

$$n = 2(C+1)$$

$$U_f^F = M_{fa}^F + M_{fe}^F$$

$$U_a^F = M_{ab}^F + M_{af}^F$$

Sign Convention - A moment acting in a clockwise direction on a joint is positive.



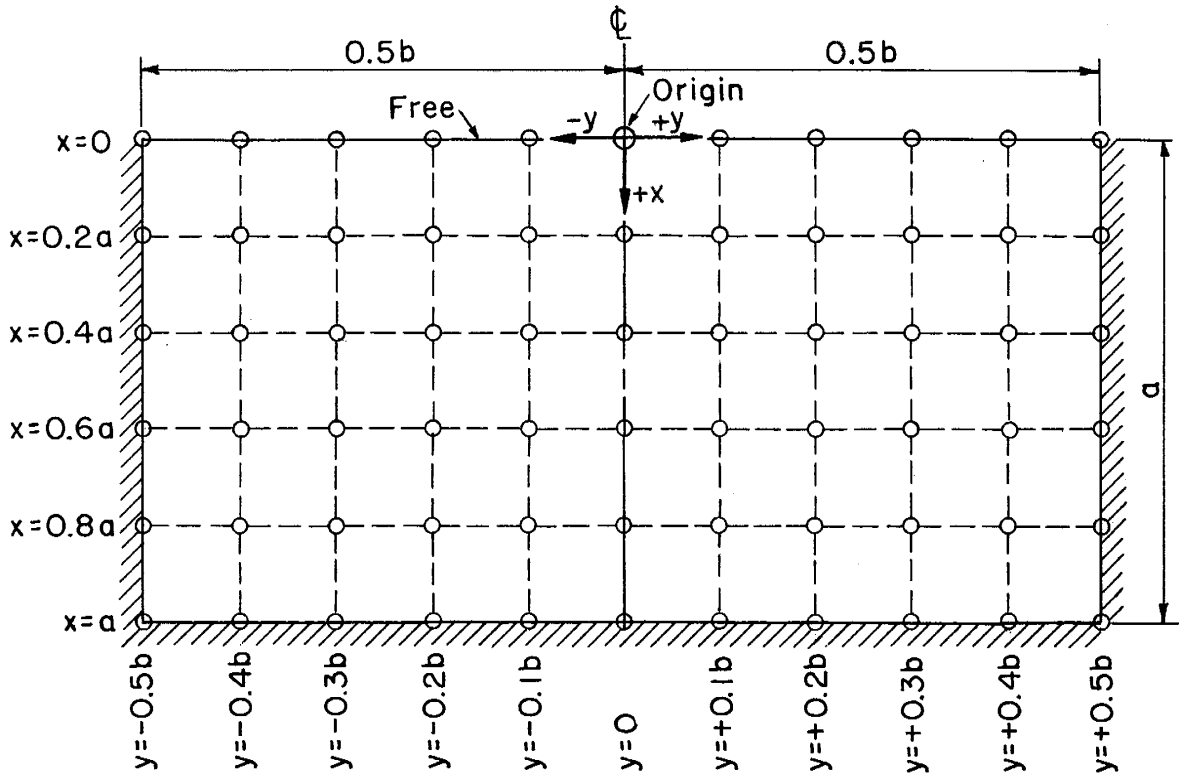
Caution: Use proper sign of fixed end moments when substituting them in the given equations.

Nomenclature:

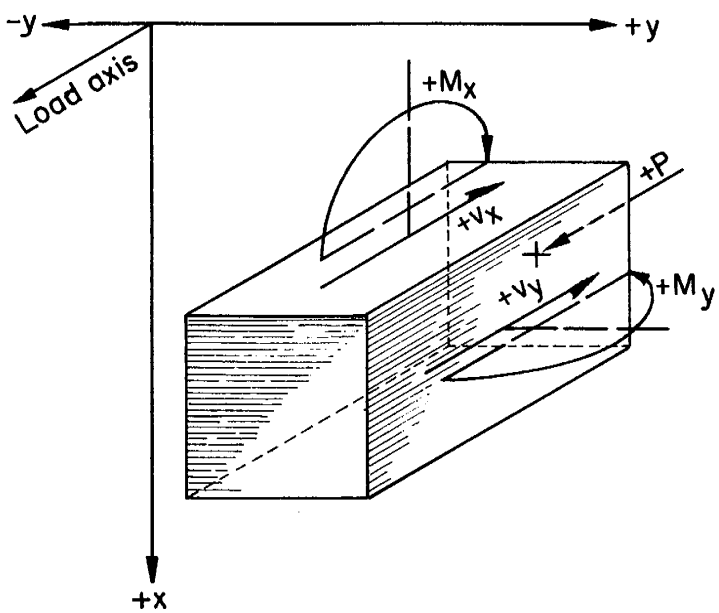
M_{ab} = Moment at end "a" of member "ab".
M_{ab}^F = Fixed end moment at end "a" of member "ab".
U_a^F = Algebraic sum of fixed end moments at joint a = unbalanced fixed end moment at a.
K_w = Stiffness of wall.
K_s = Stiffness of slab.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-29 SHEET 1 OF 1 DATE 5-25-50

STRUCTURAL DESIGN : Cartesian grid point designation system, positive sign convention, symbols and nomenclature



CARTESIAN GRID POINT DESIGNATION SYSTEM



POSITIVE SIGN CONVENTION

SYMBOLS AND NOMENCLATURE

a = vertical dimension of fixed slab, ft

b = horizontal dimension of fixed slab, ft

M_x = vertical moment, lb ft/ft

M_y = horizontal moment, lb ft/ft

p = intensity of pressure, lbs/ft^2

v = shearing reactions per unit length acting normal to the plane of the slab, lbs/ft

w = weight, lbs/ft^3

x,y = rectangular coordinates in the plane of the slab

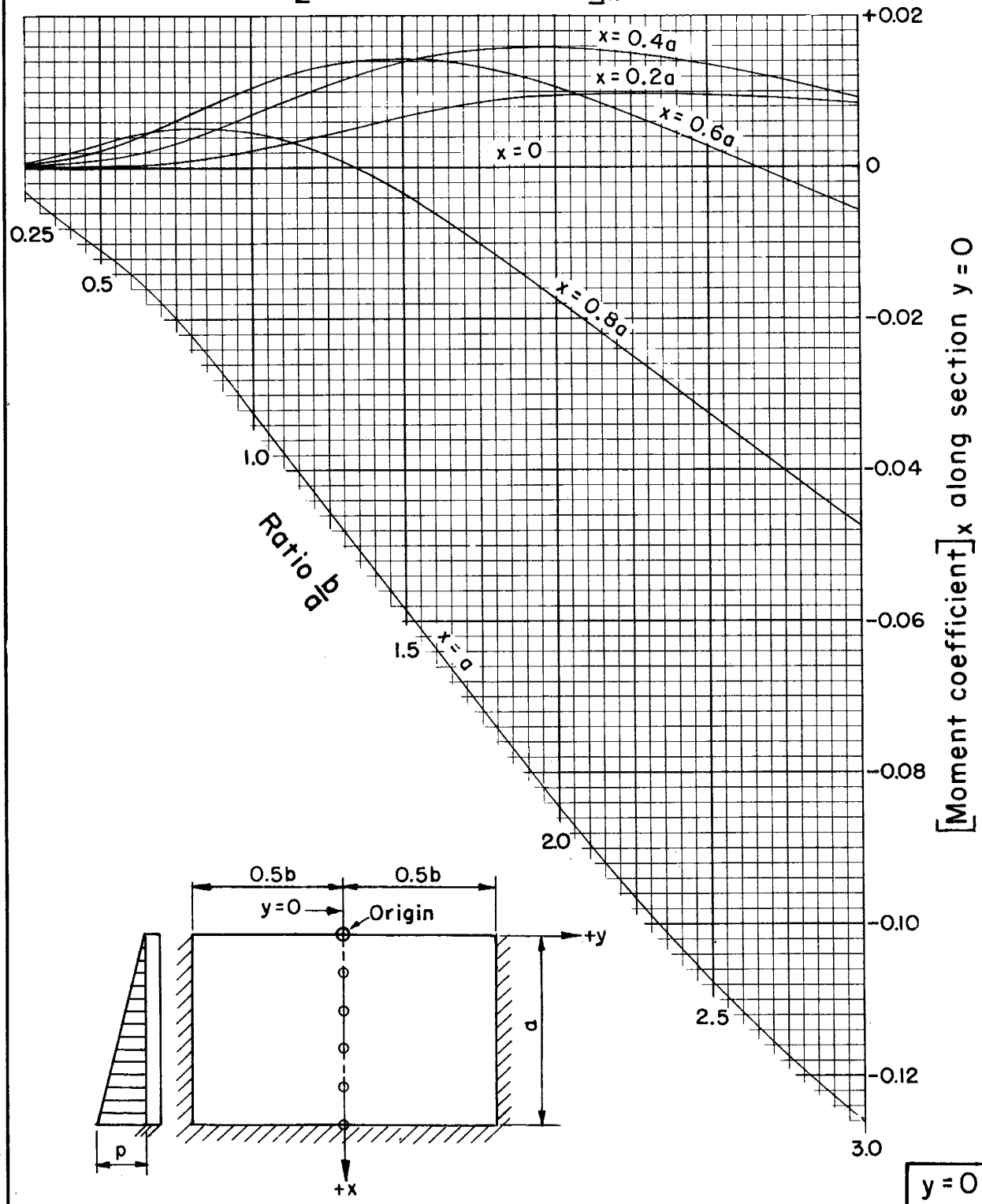
= fixed edge

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION-DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 1 OF 85 DATE 4-13-56

STRUCTURAL DESIGN : Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = 0$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \; pa^2$$

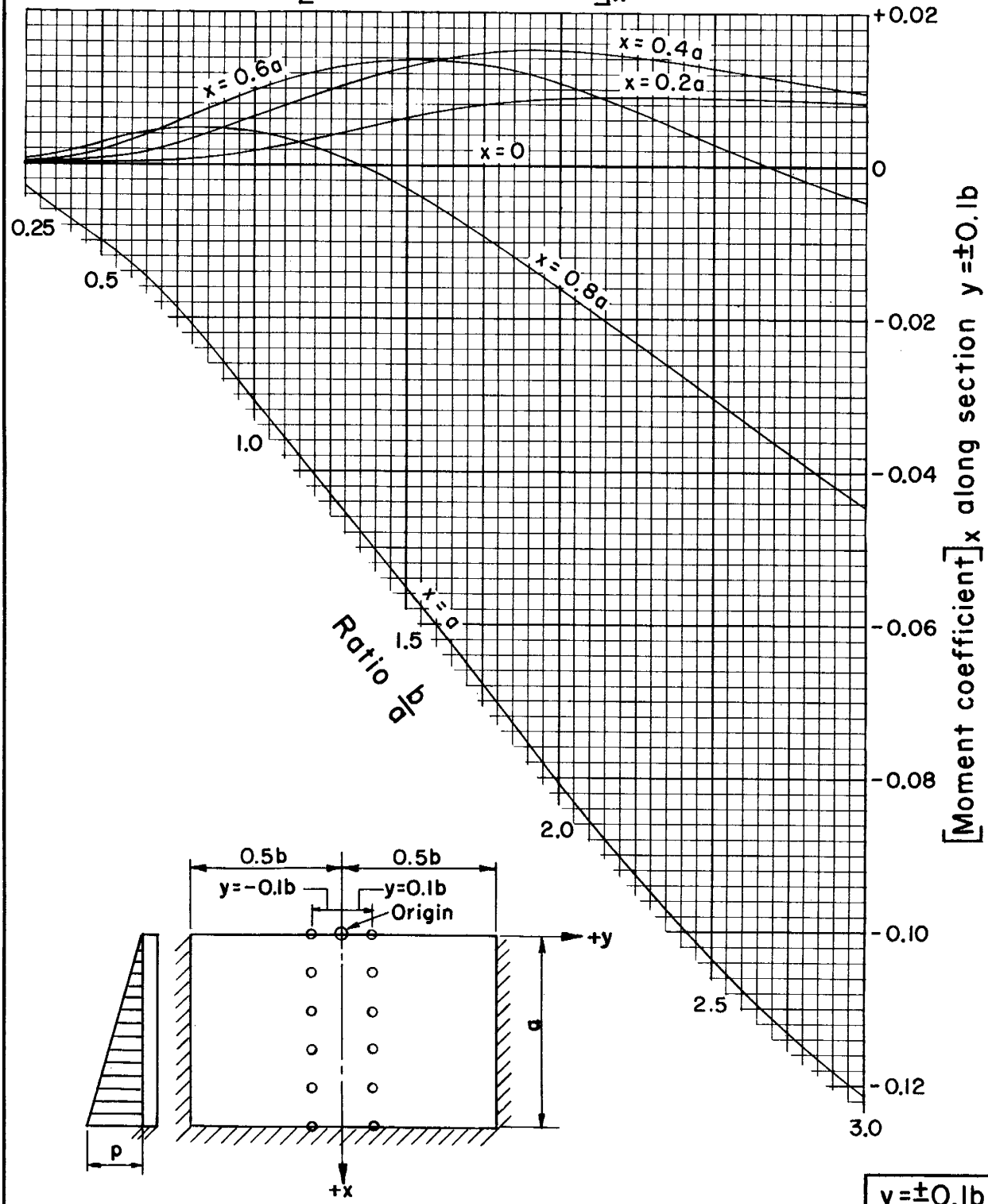


REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 2 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.1b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$



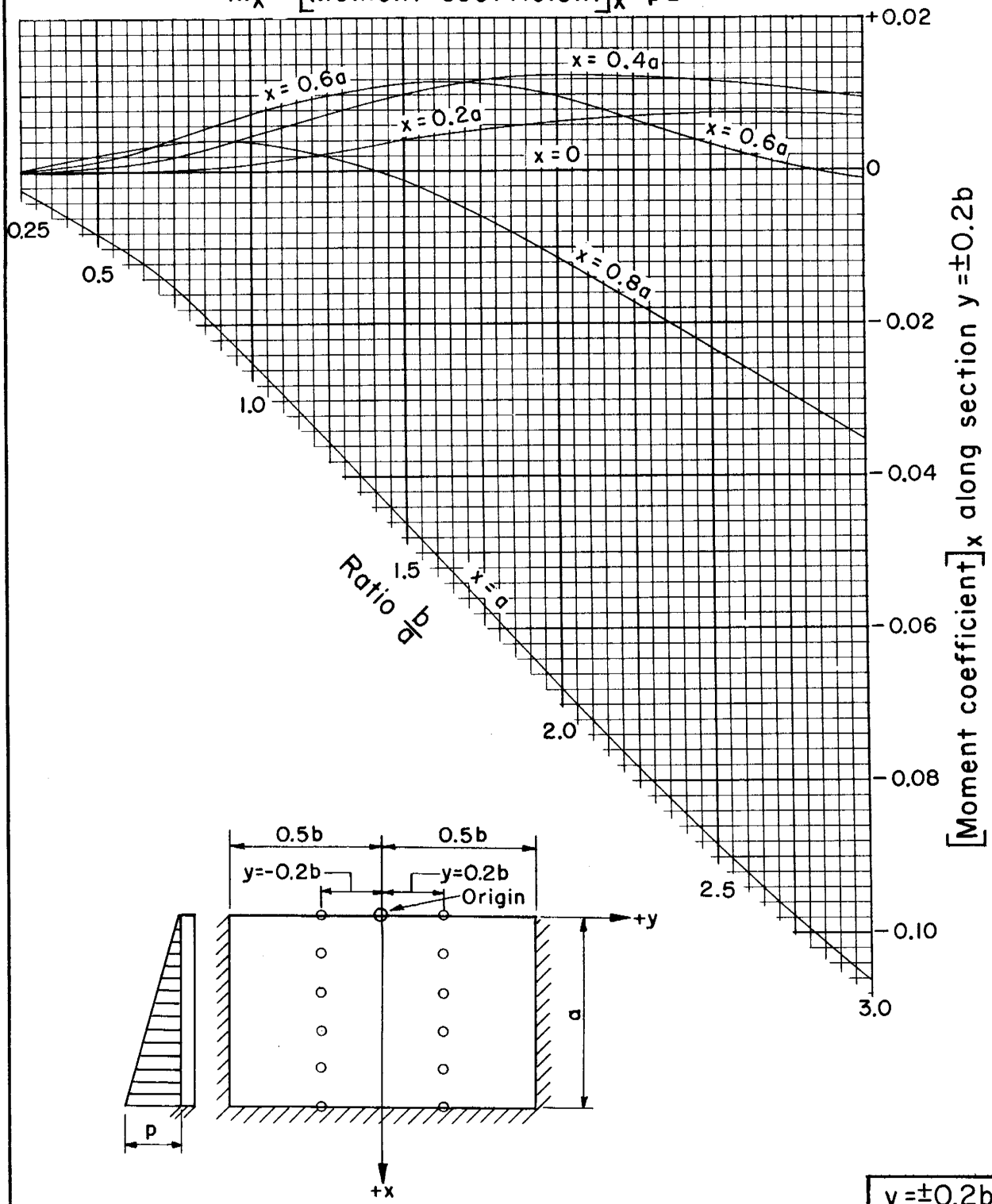
$y = \pm 0.1b$

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 3 OF 85 DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.2b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$



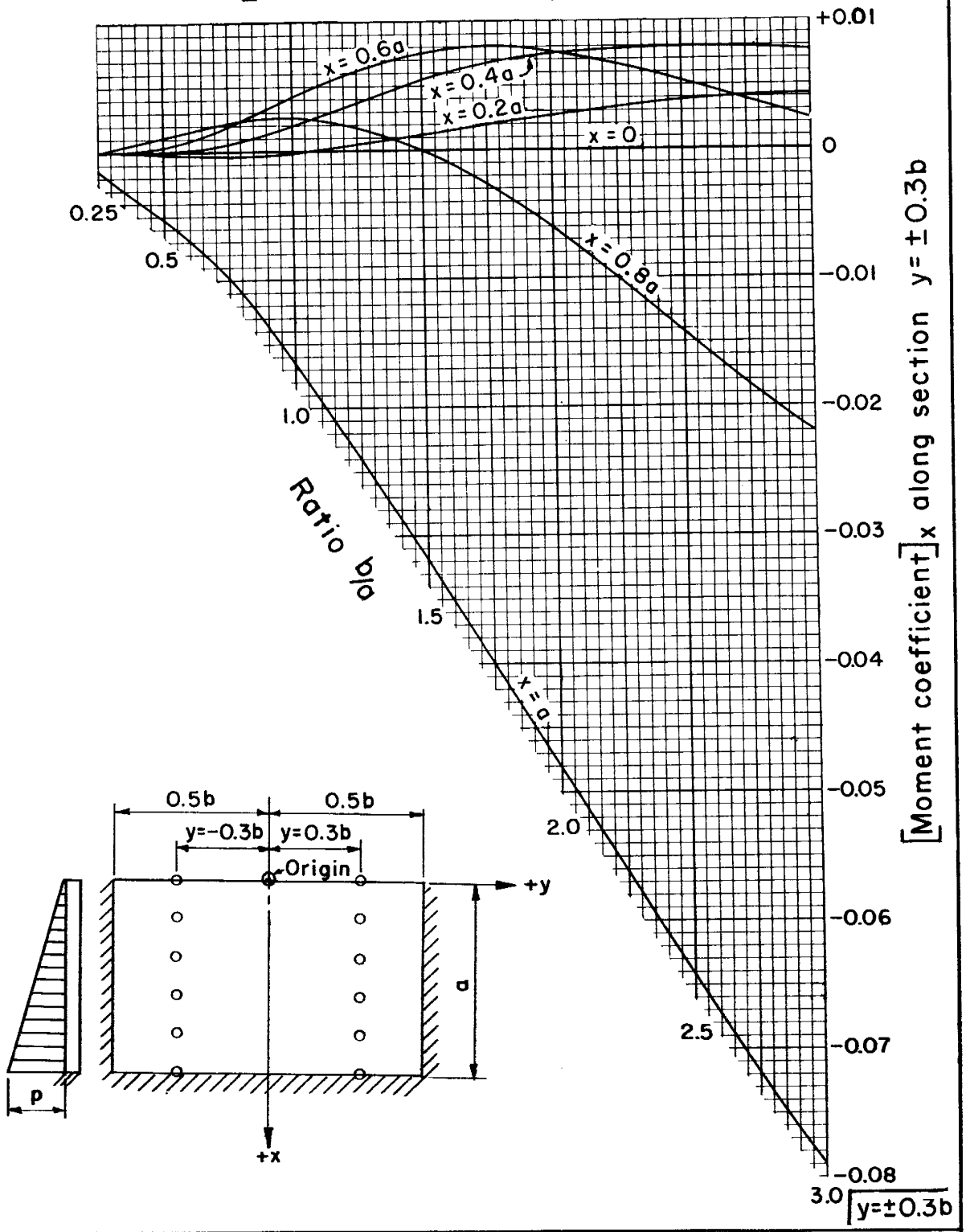
$y = \pm 0.2b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 4 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.3b$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \; pa^2$$

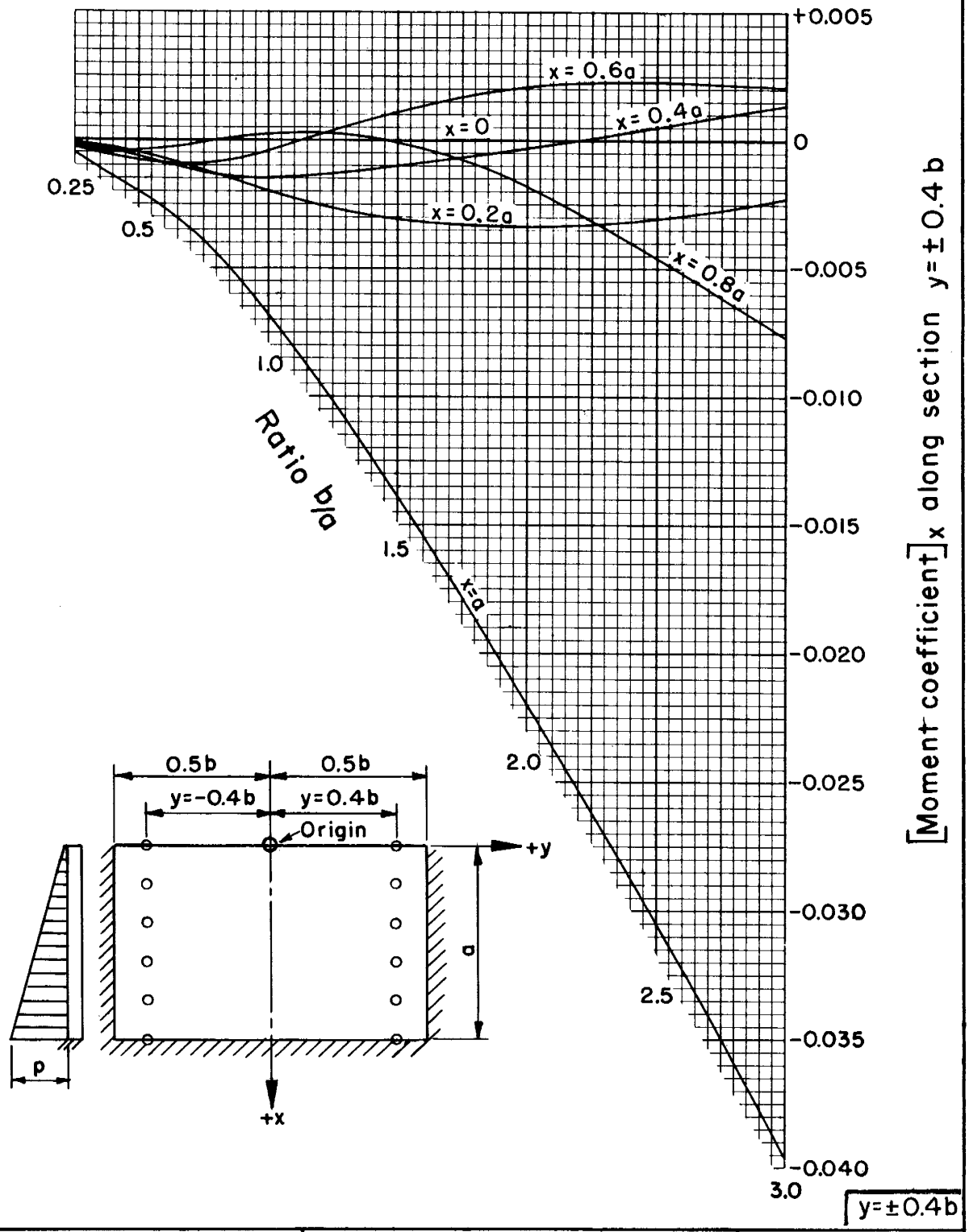


REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 5 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.4b$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \; pa^2$$

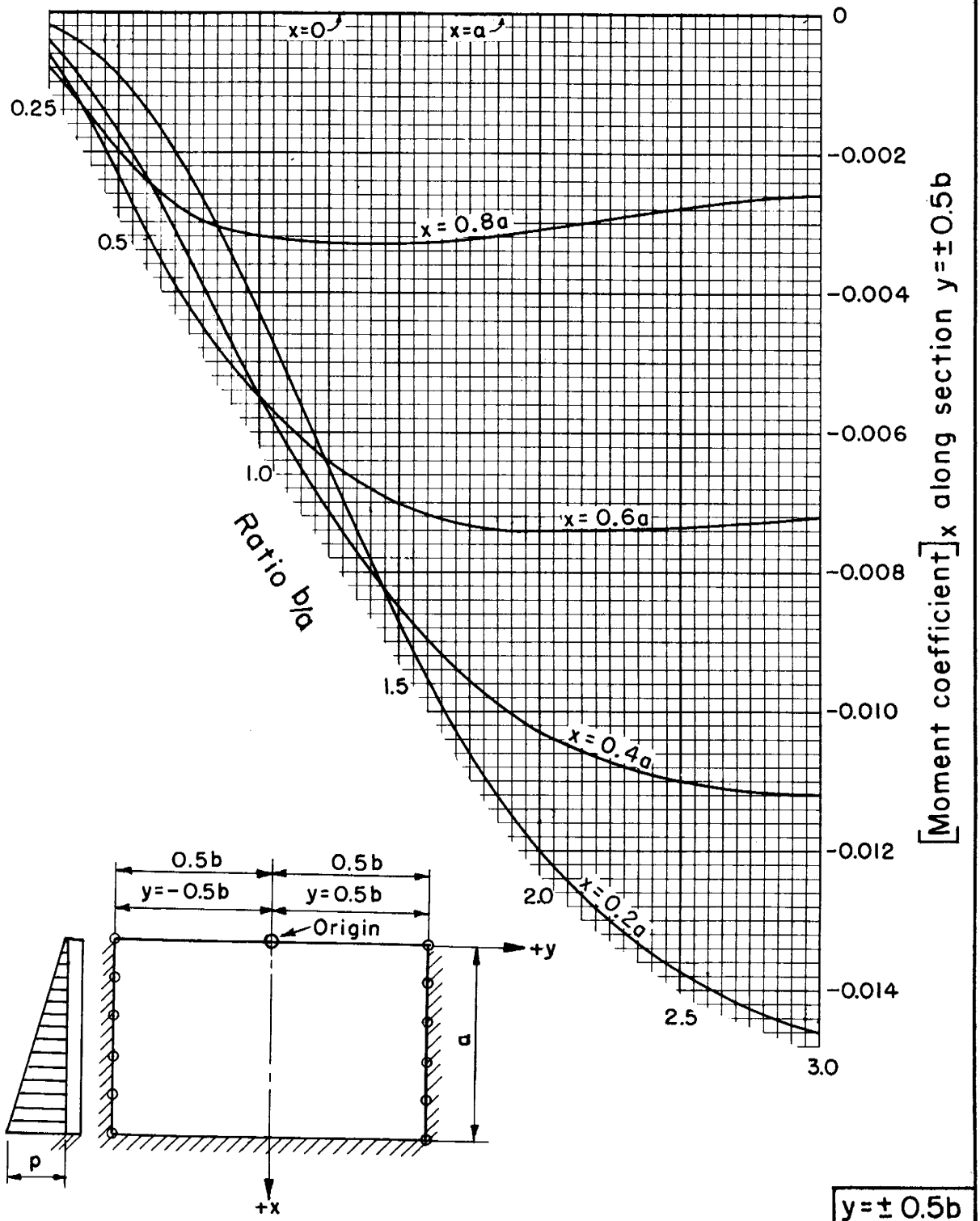


REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 6 OF 85 DATE 8-1-55
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954		

STRUCTURAL DESIGN : Rectangular slabs with hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.5b$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \; pa^2$$



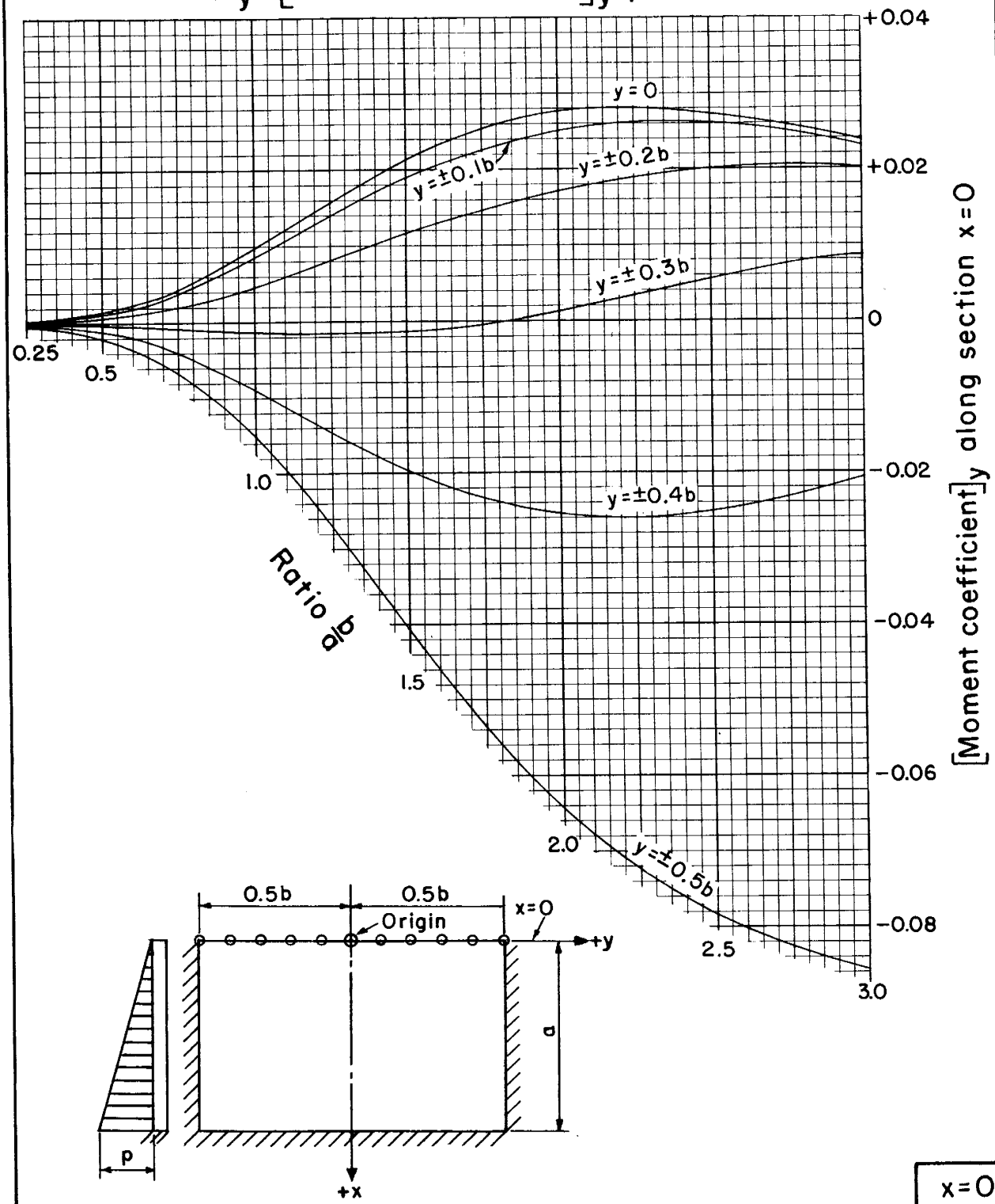
$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 7 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice. x=0

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$



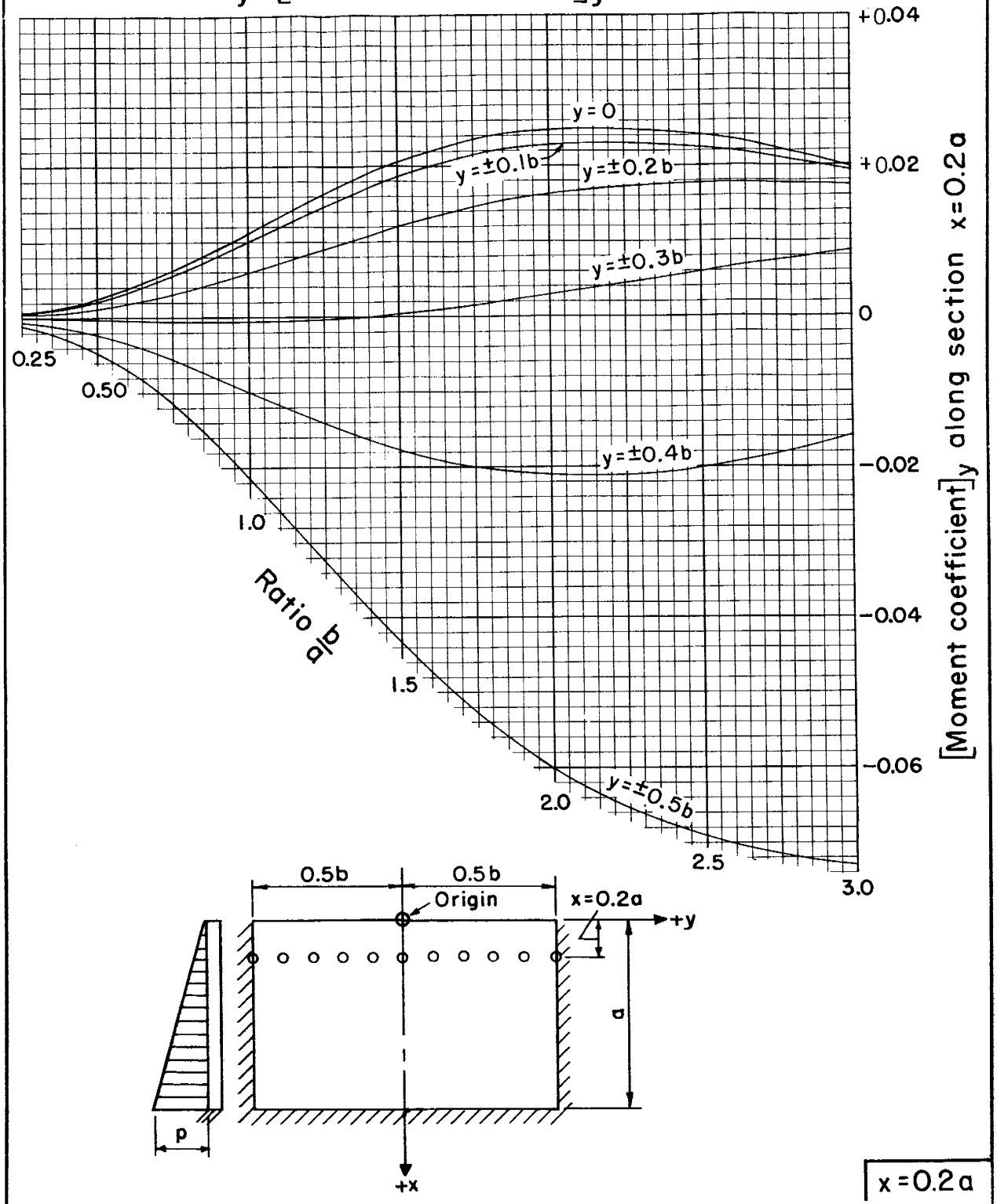
x=0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 8 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice. x = 0.2a

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$



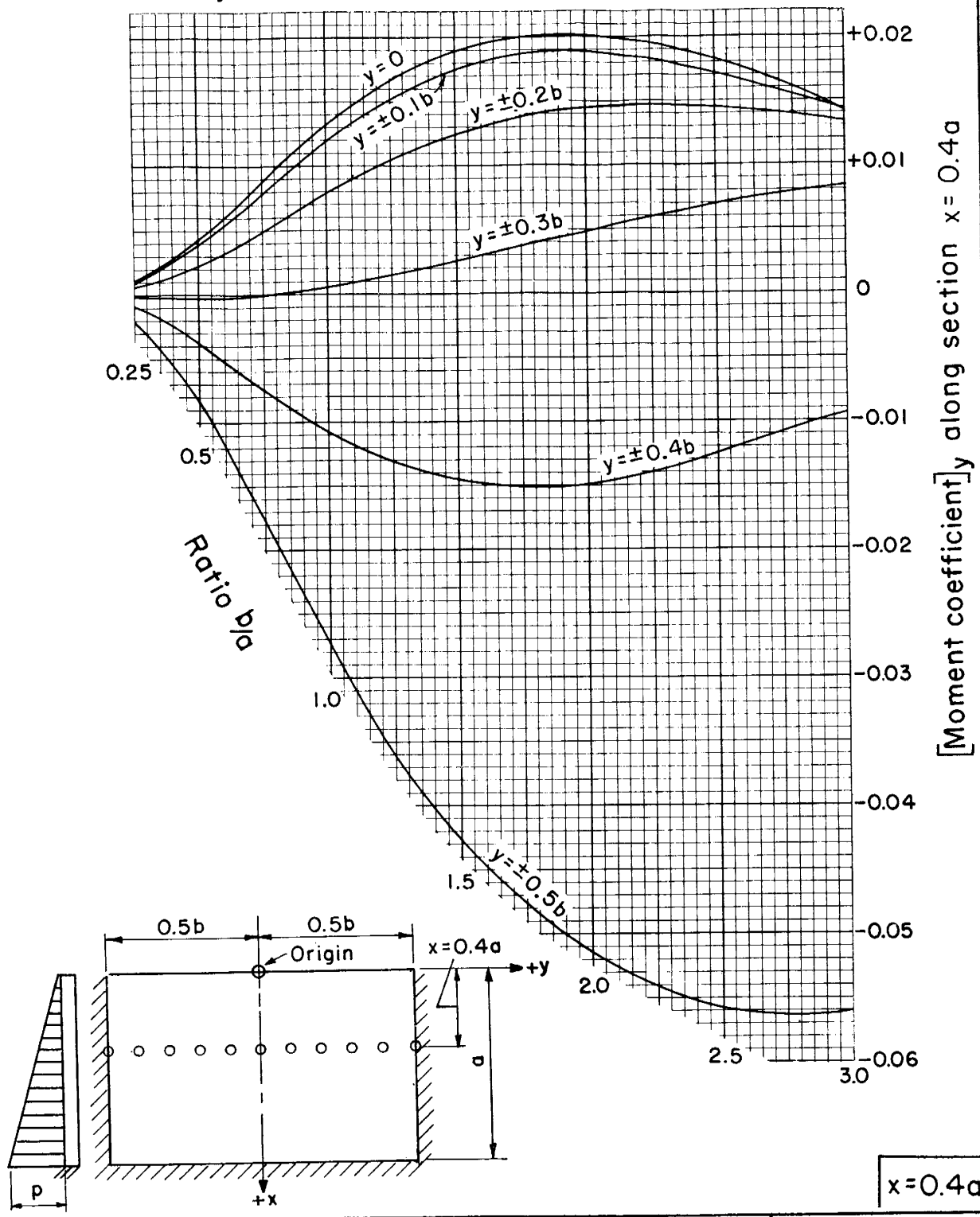
x = 0.2a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 9 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice. x= 0.4a

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$



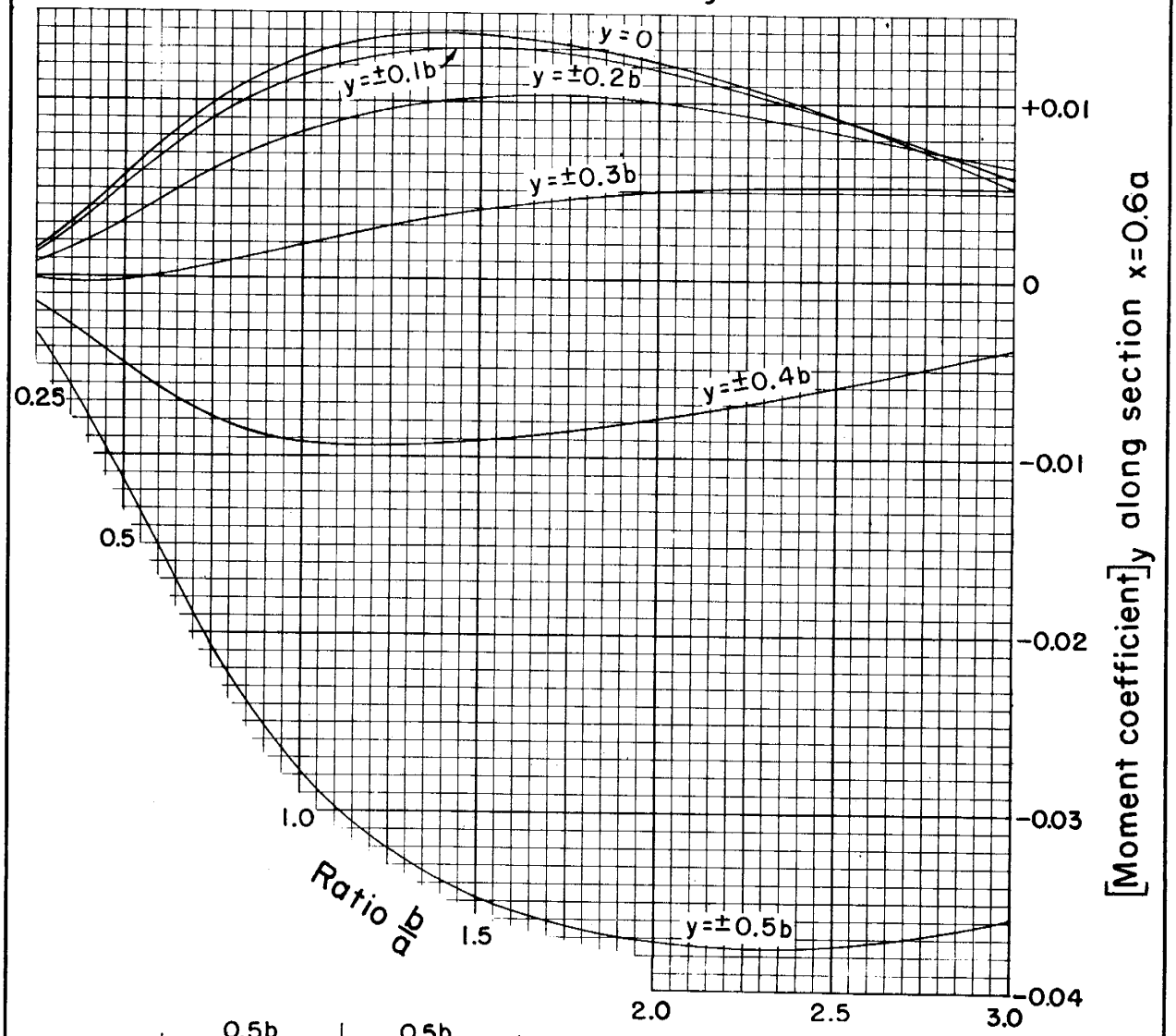
x=0.4a

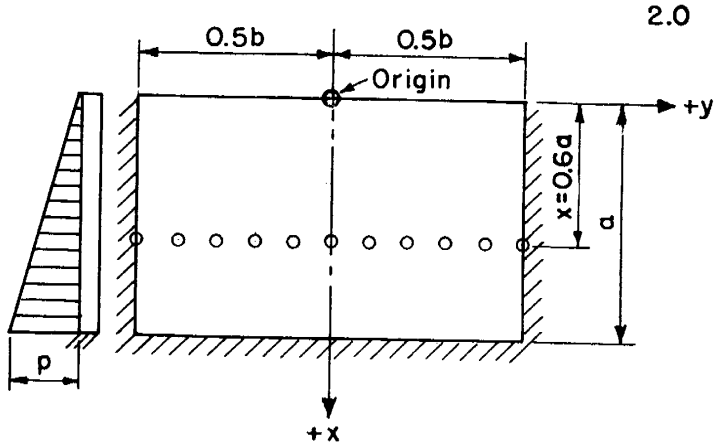
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 10 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice. x = 0.6a

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$





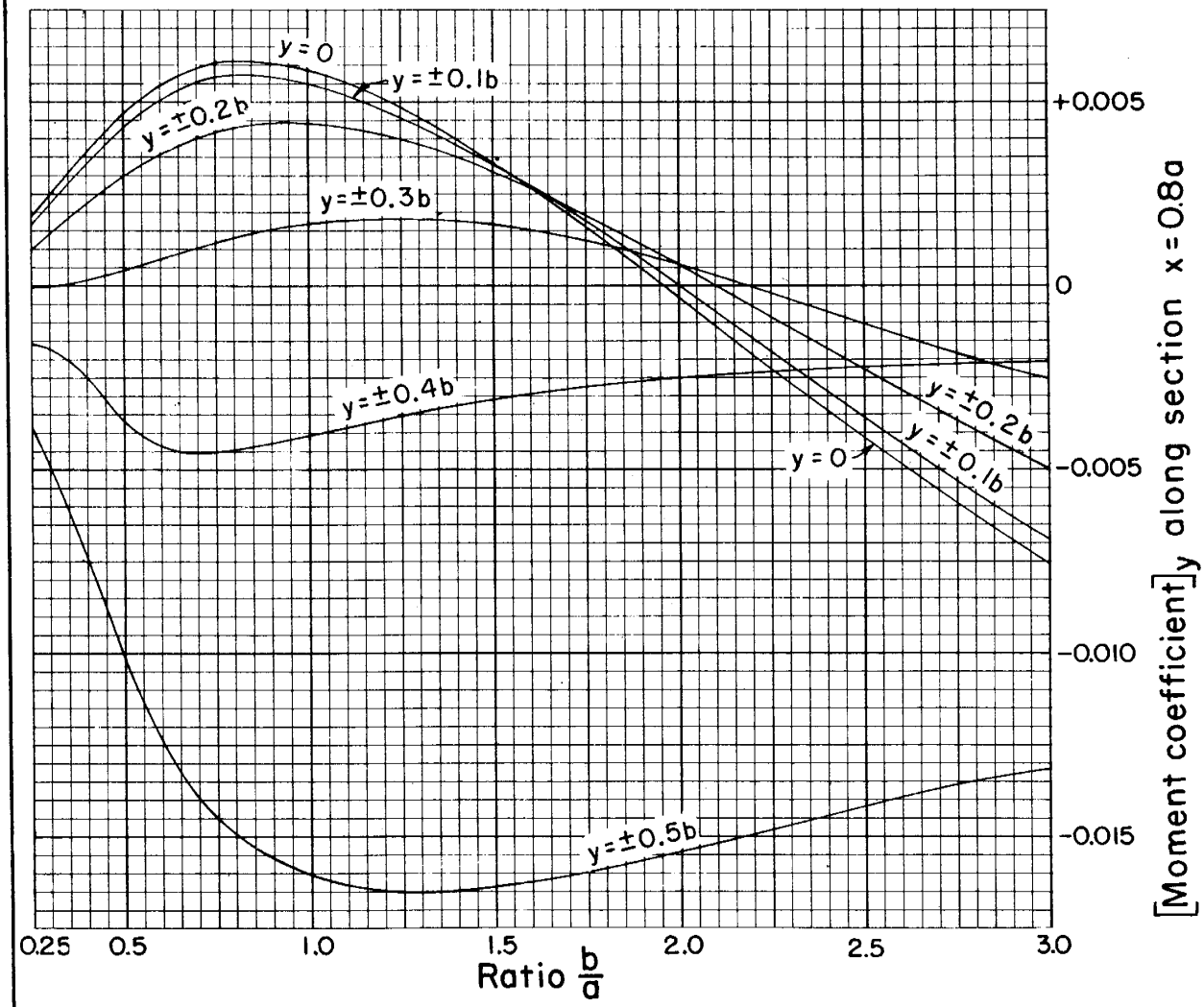
x = 0.6a

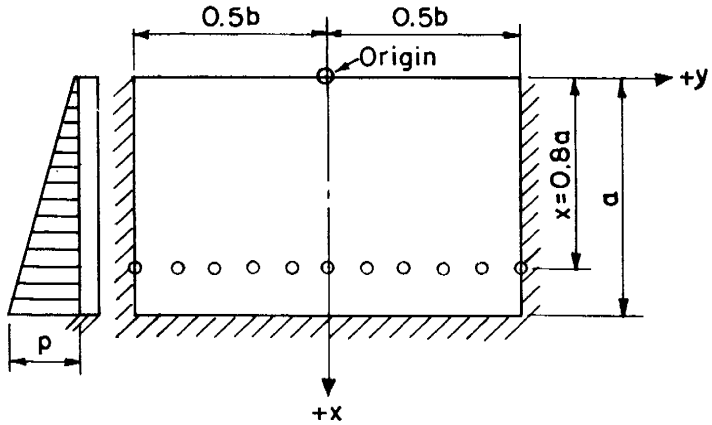
REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 11 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.8a

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$





x=0.8a

REFERENCE
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

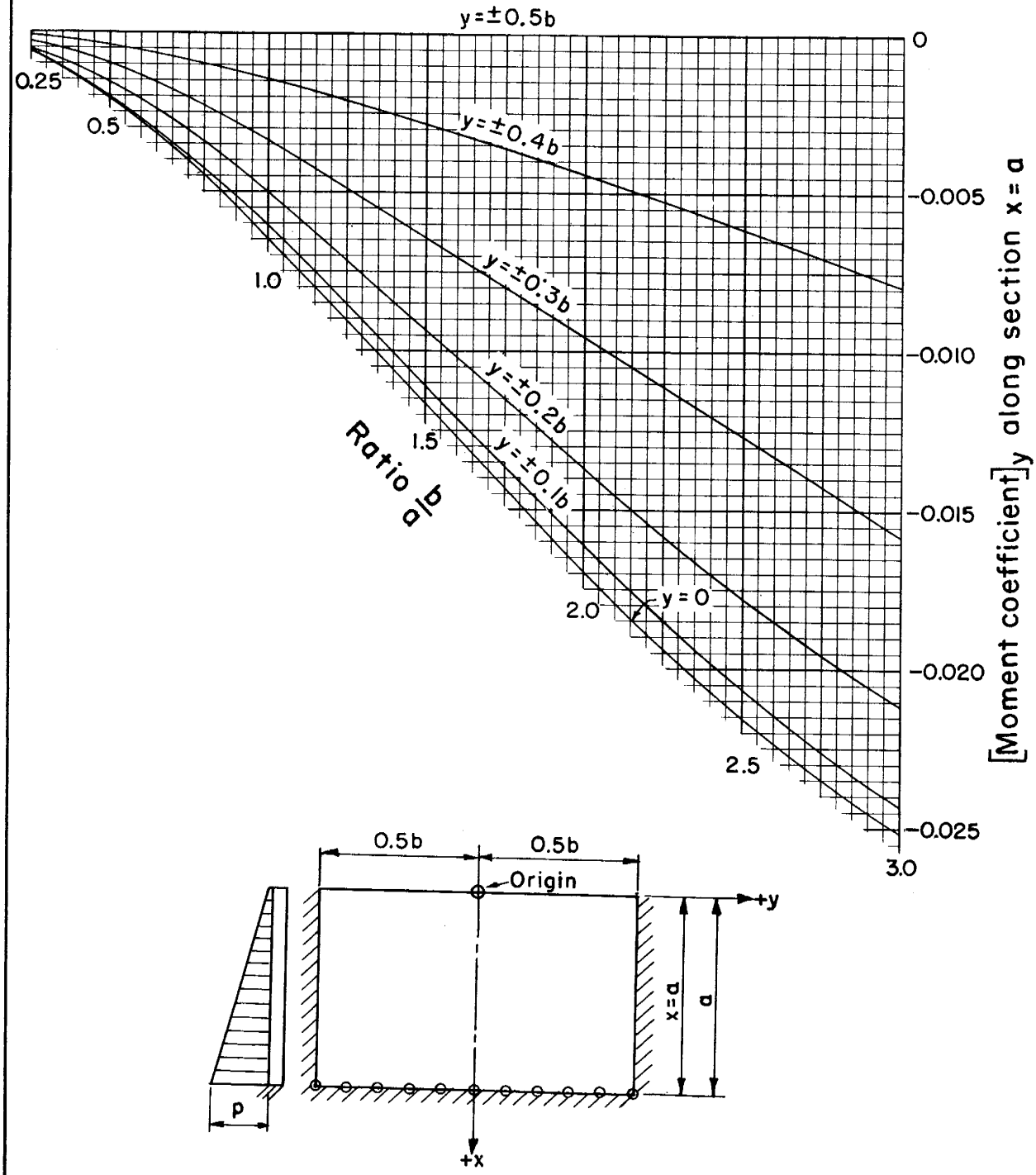
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-104
SHEET 12 OF 85
DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = a

Horizontal moment determines tension in horizontal steel

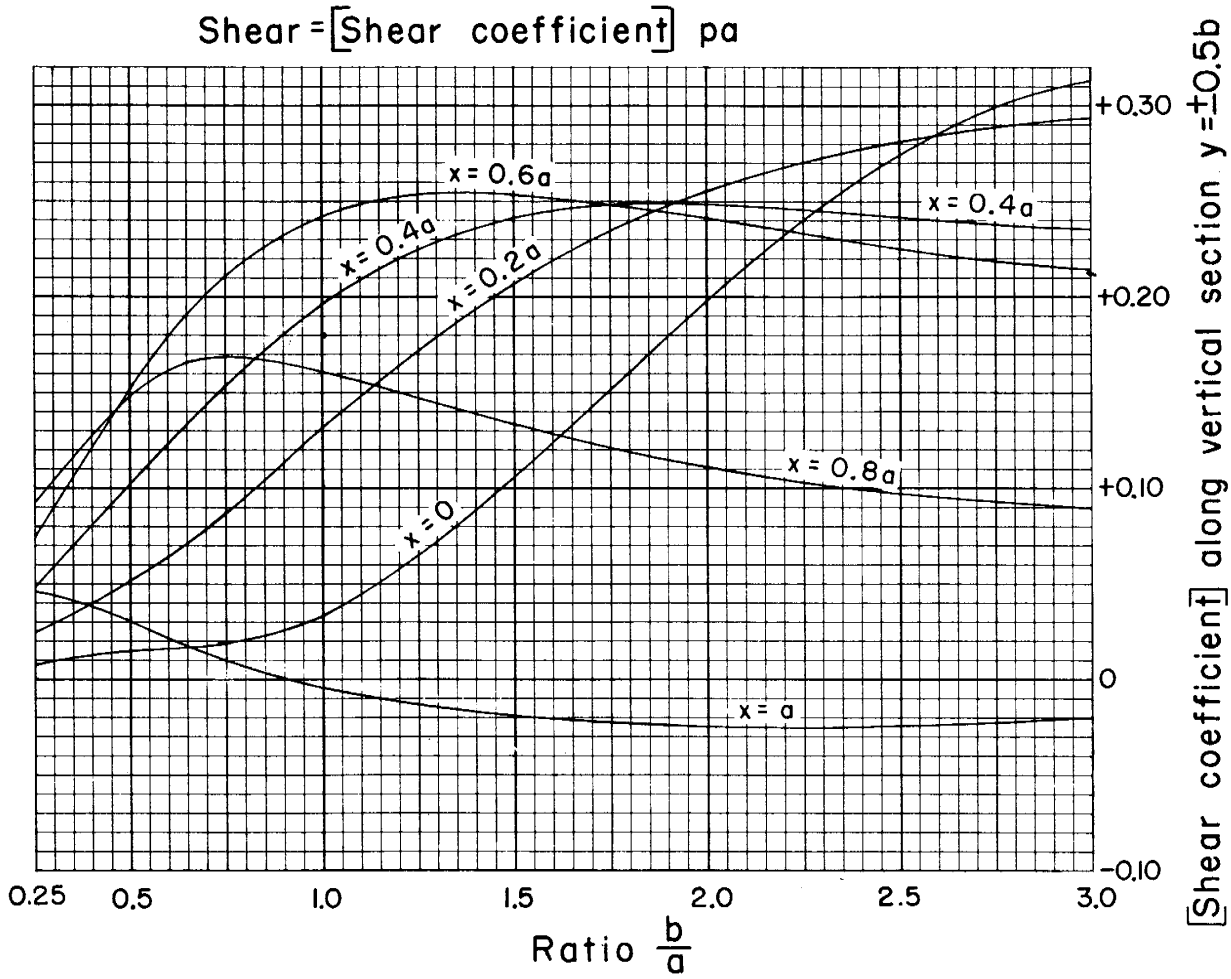
$$M_y = [\text{Moment coefficient}]_y \, pa^2$$

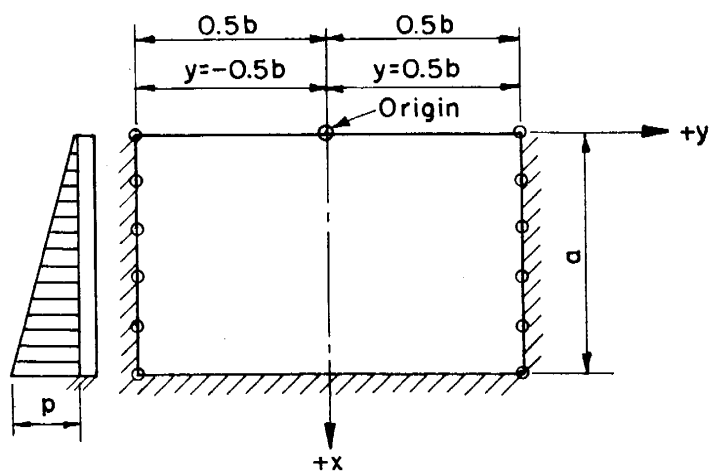


x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 13 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with hydrostatic load; coefficients for shear at fifth points on fixed side edges $y = \pm 0.5b$



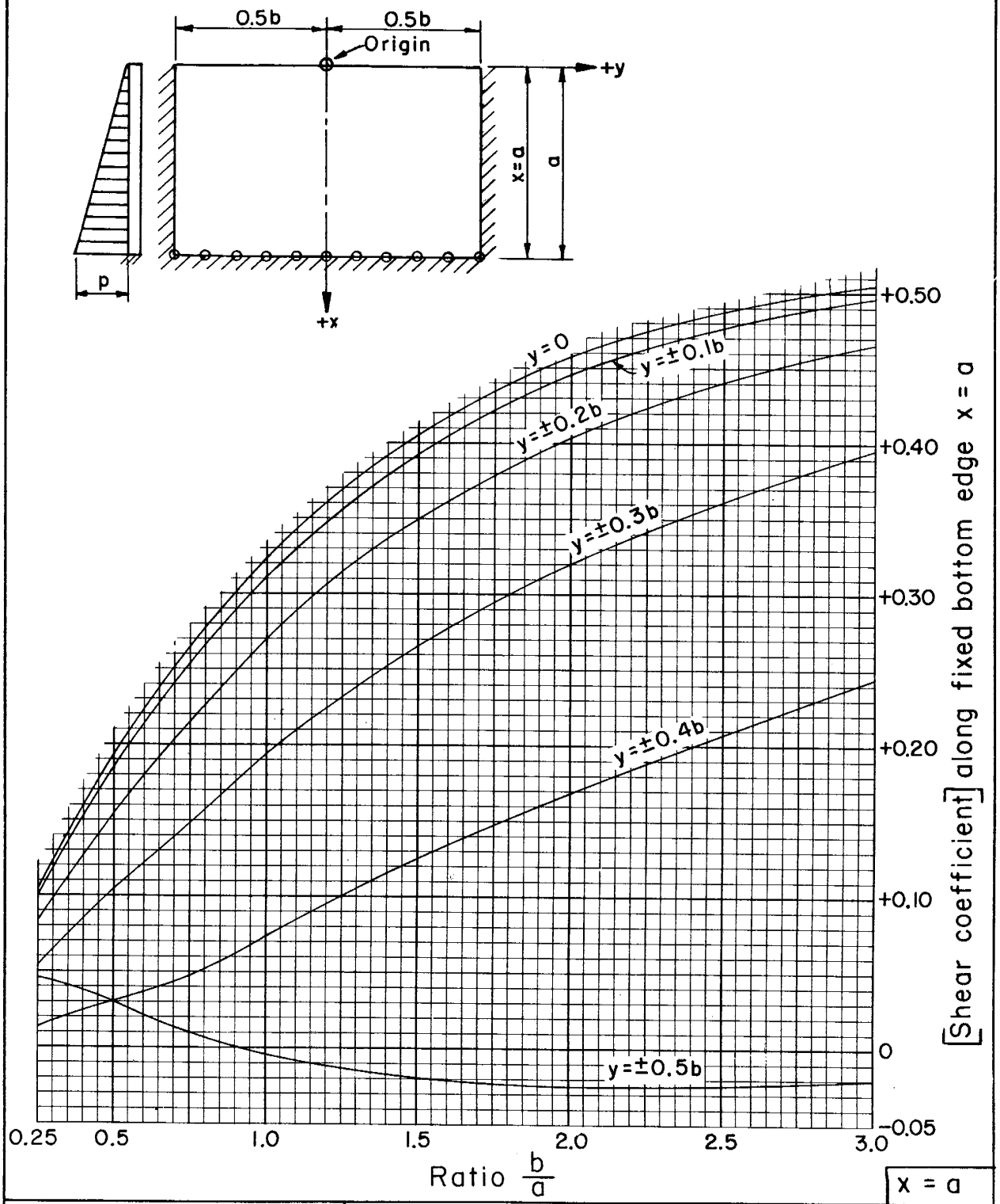


$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 14 OF 85 DATE 8-1-55
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954		

STRUCTURAL DESIGN : Rectangular slabs with hydrostatic load; coefficients for shear at tenth points on fixed bottom edge x = a

Shear = [Shear coefficient] pa



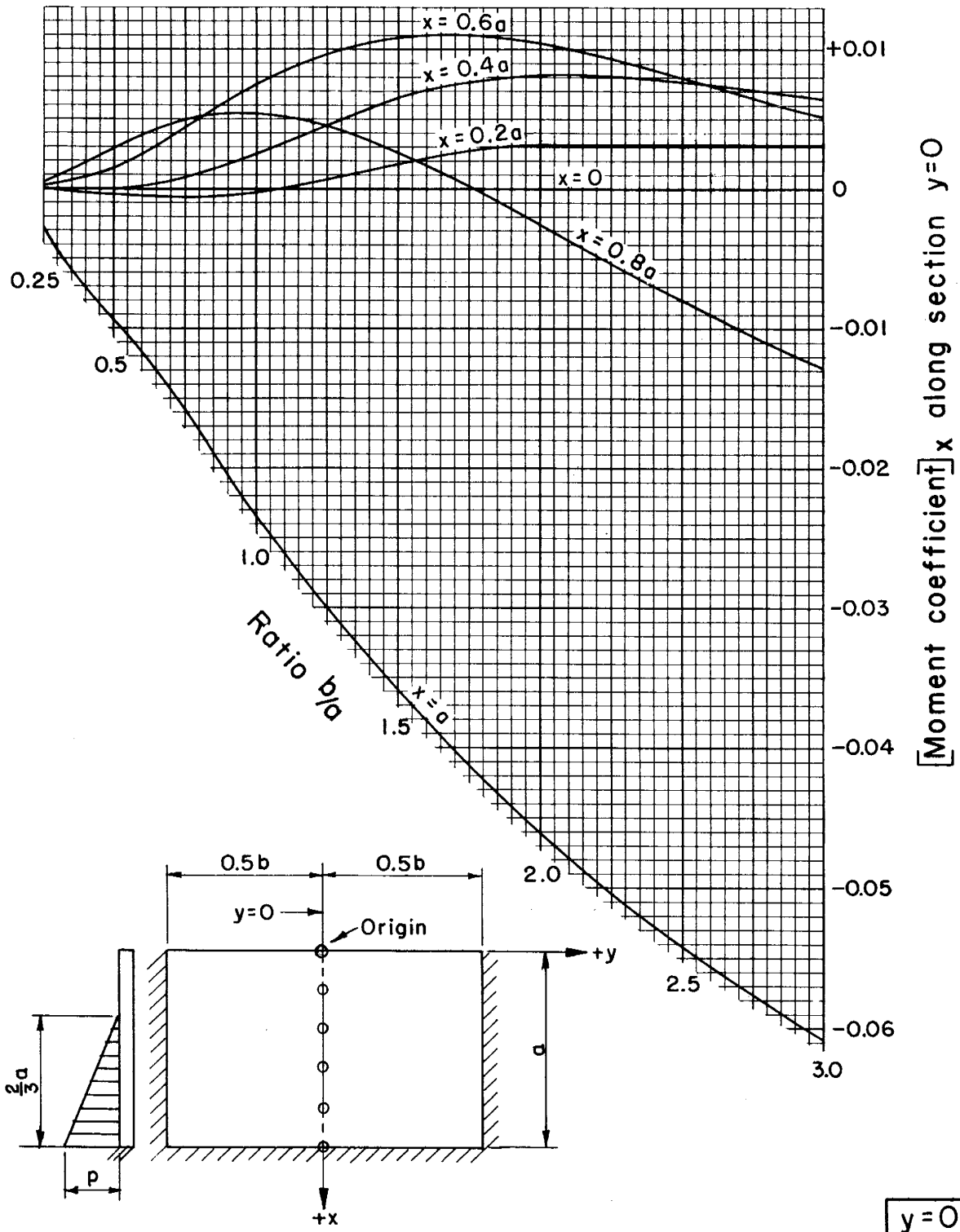
x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 15 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = 0$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \, pa^2$$



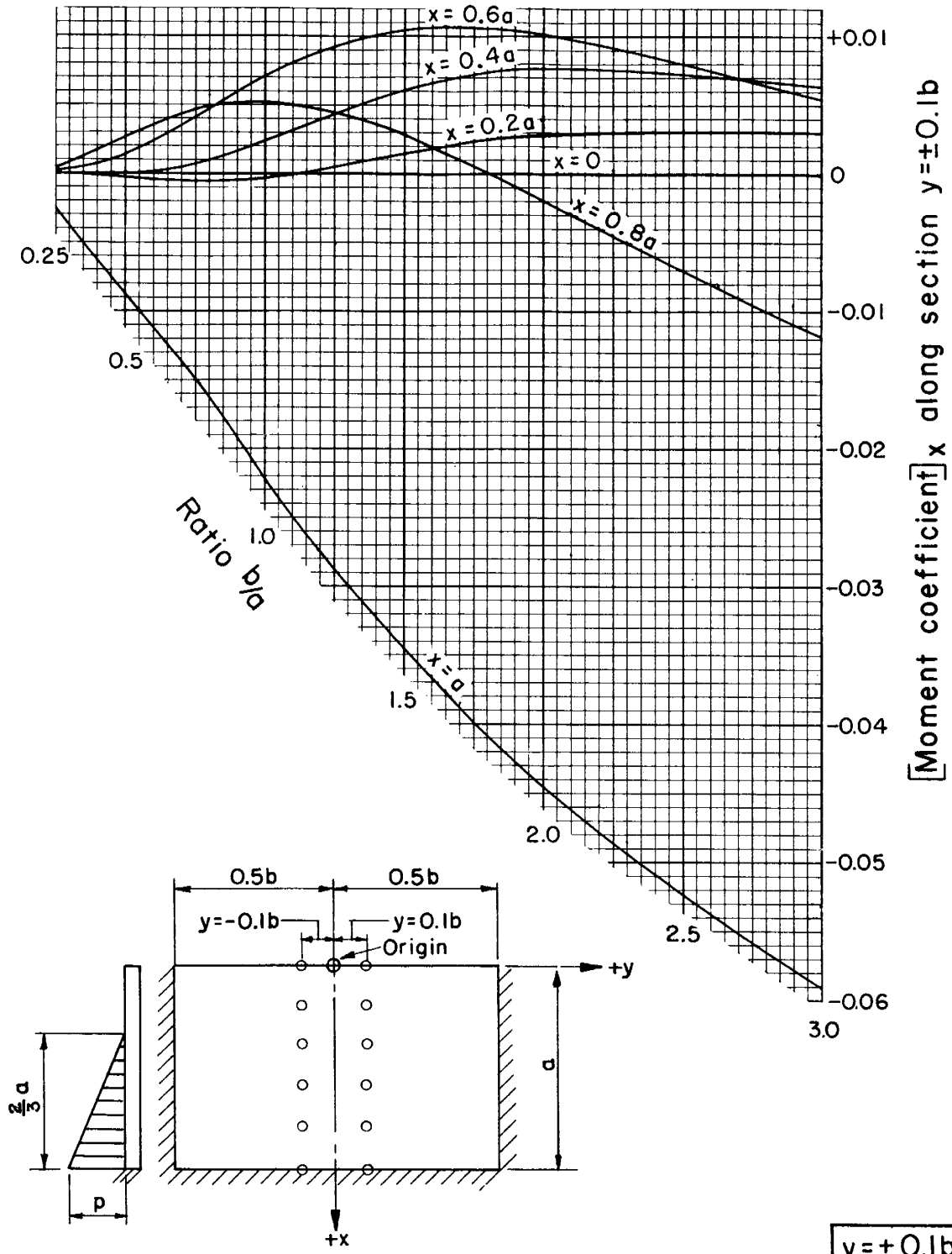
y = 0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 16 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.1b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



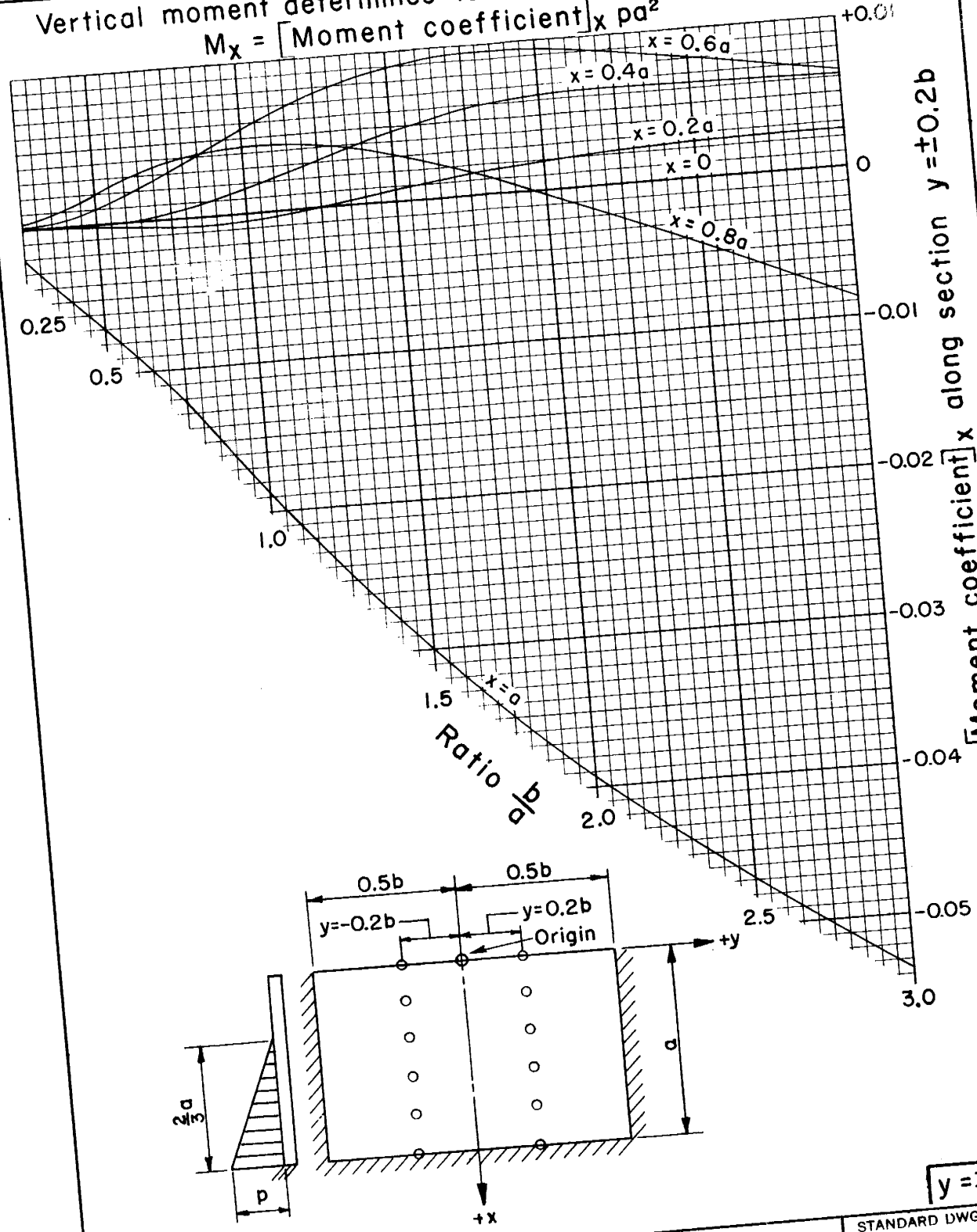
$y = \pm 0.1b$

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 17 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.2b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



$y = \pm 0.2b$

REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

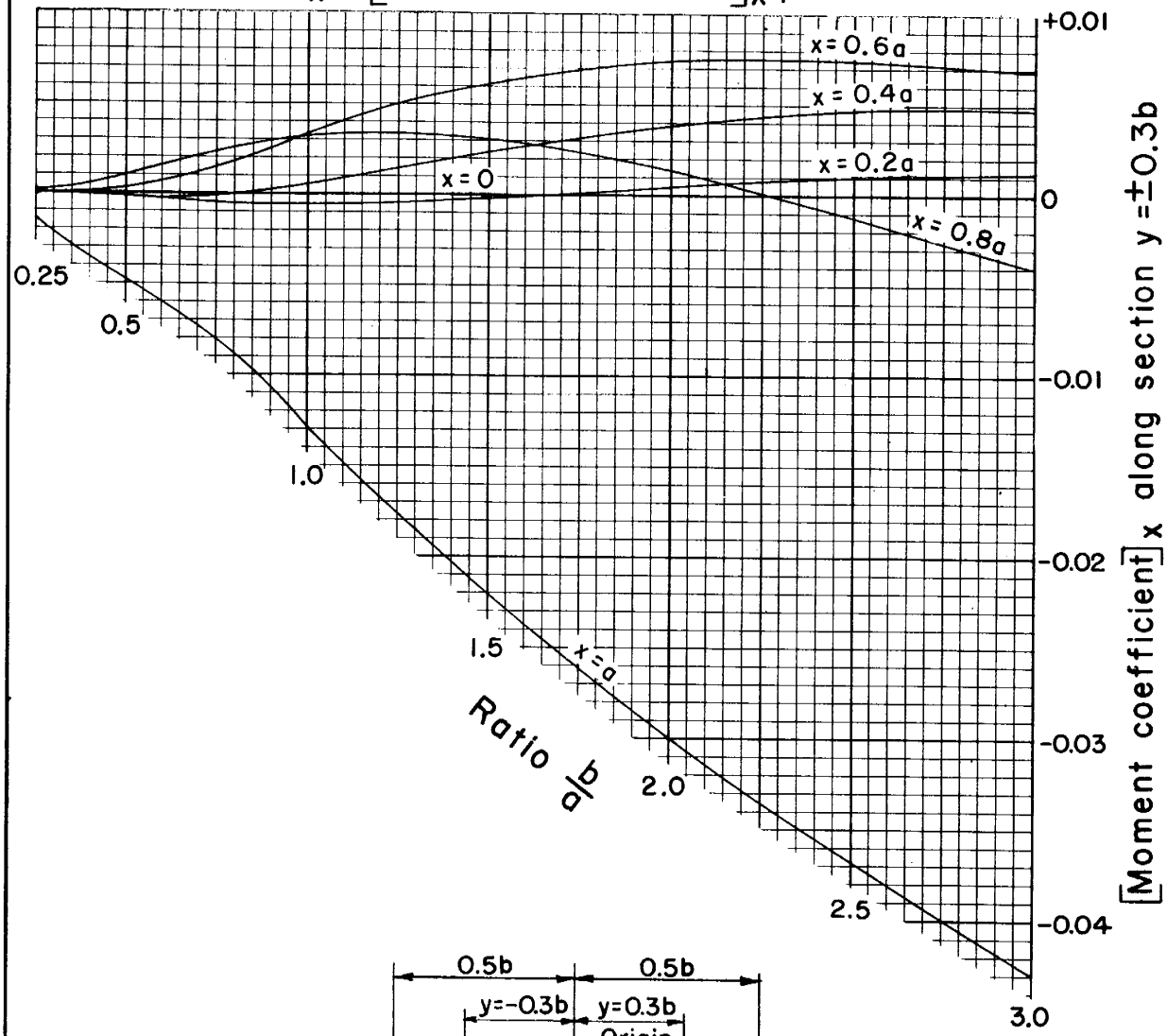
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

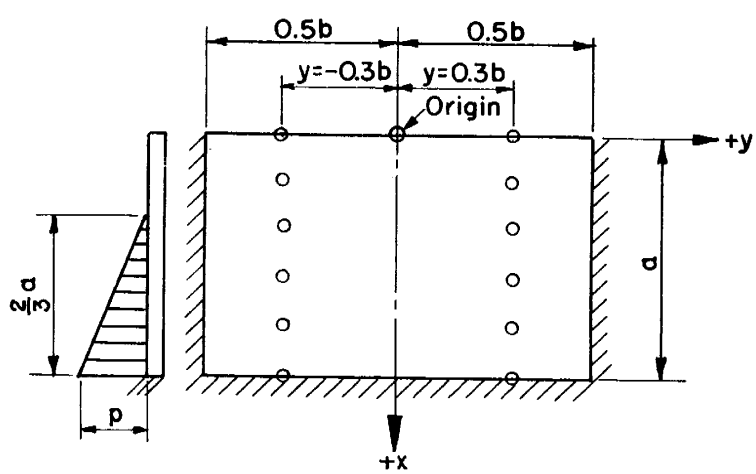
STANDARD DWG. NO.
ES-104
SHEET 18 OF 85
DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.3b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$





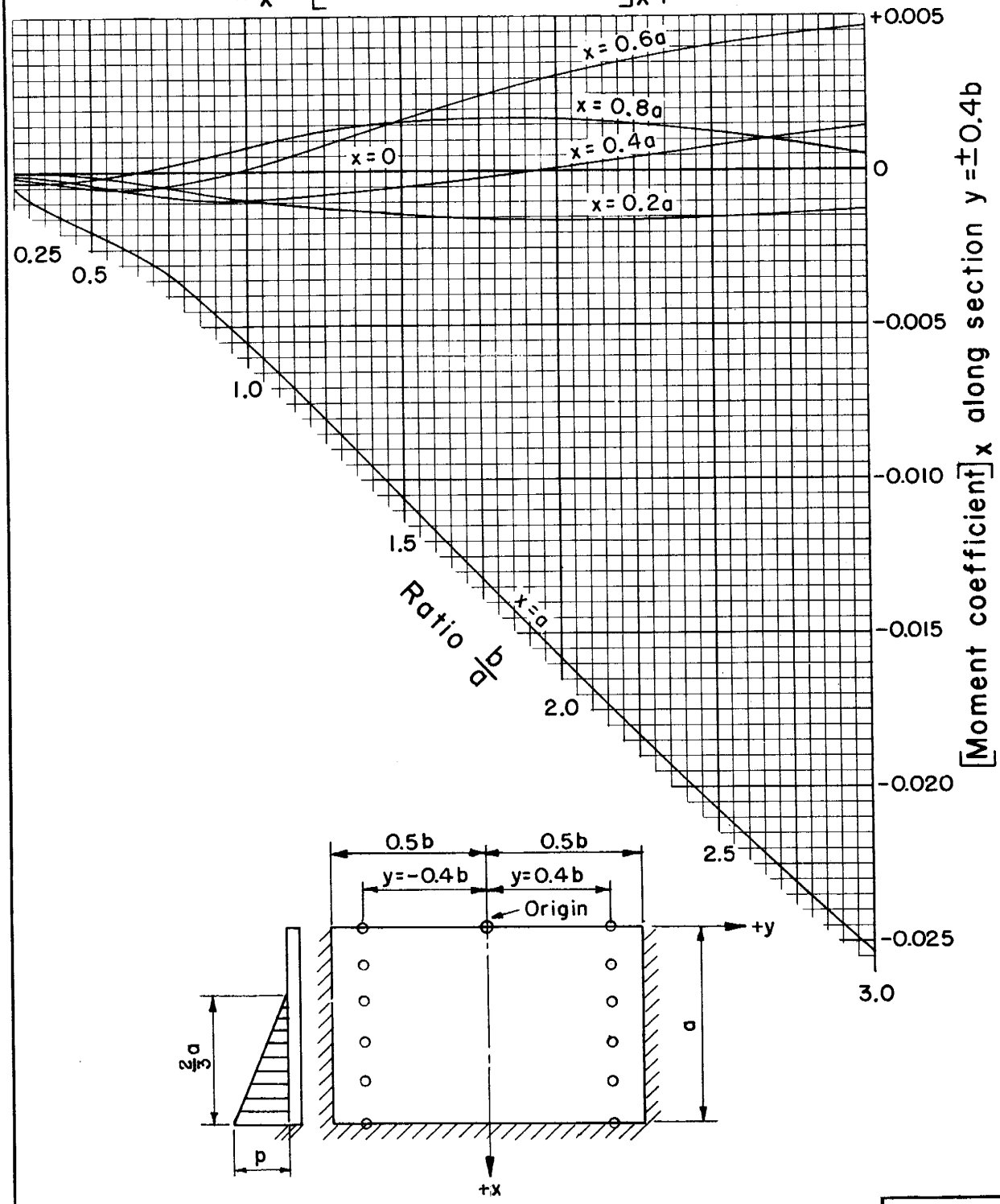
$y = \pm 0.3b$

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 19 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.4b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



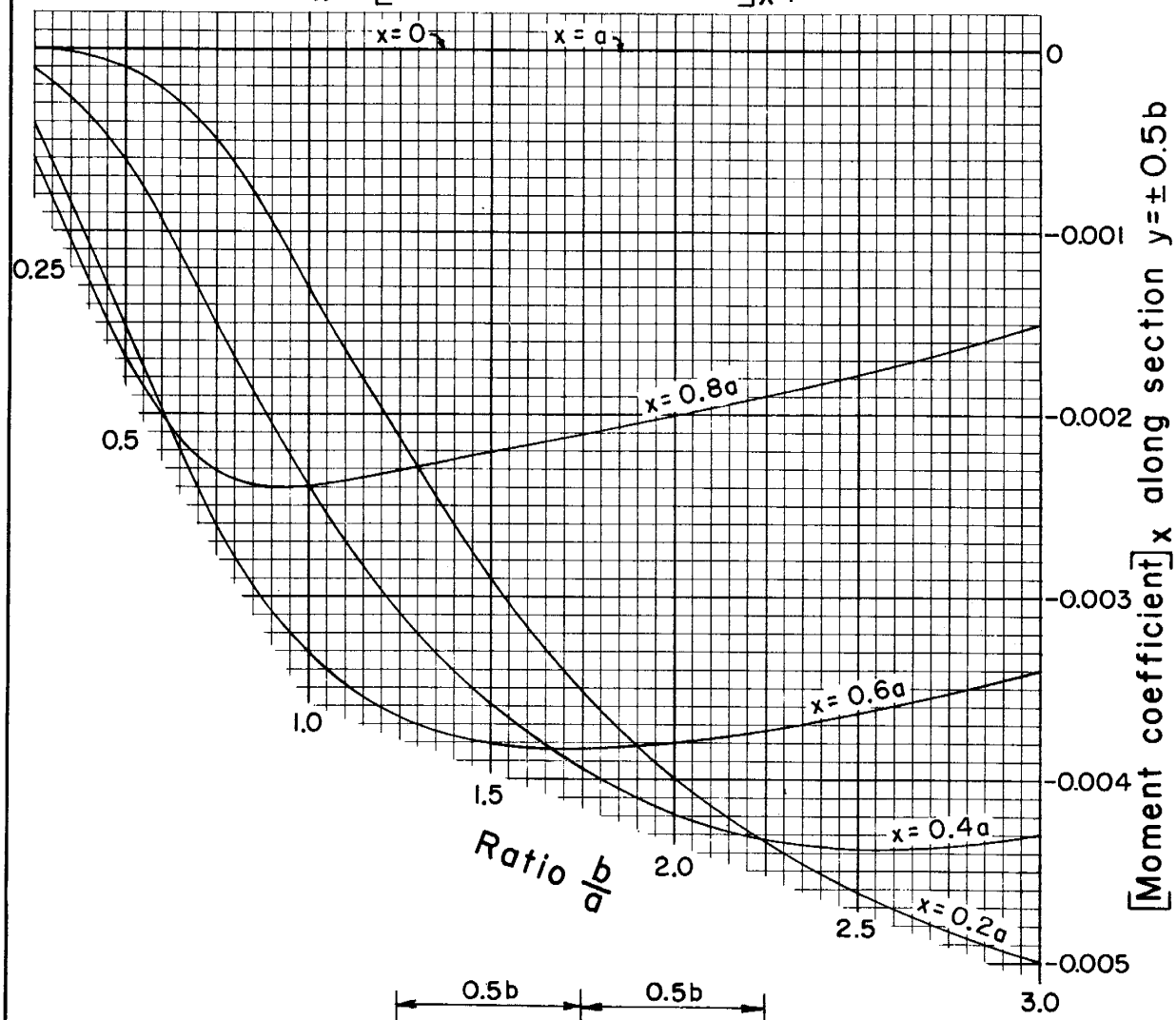
$y = \pm 0.4b$

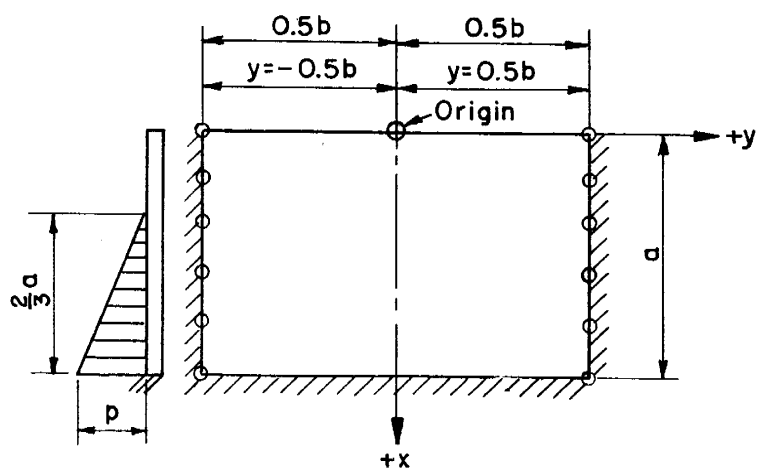
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 20 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.5b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$





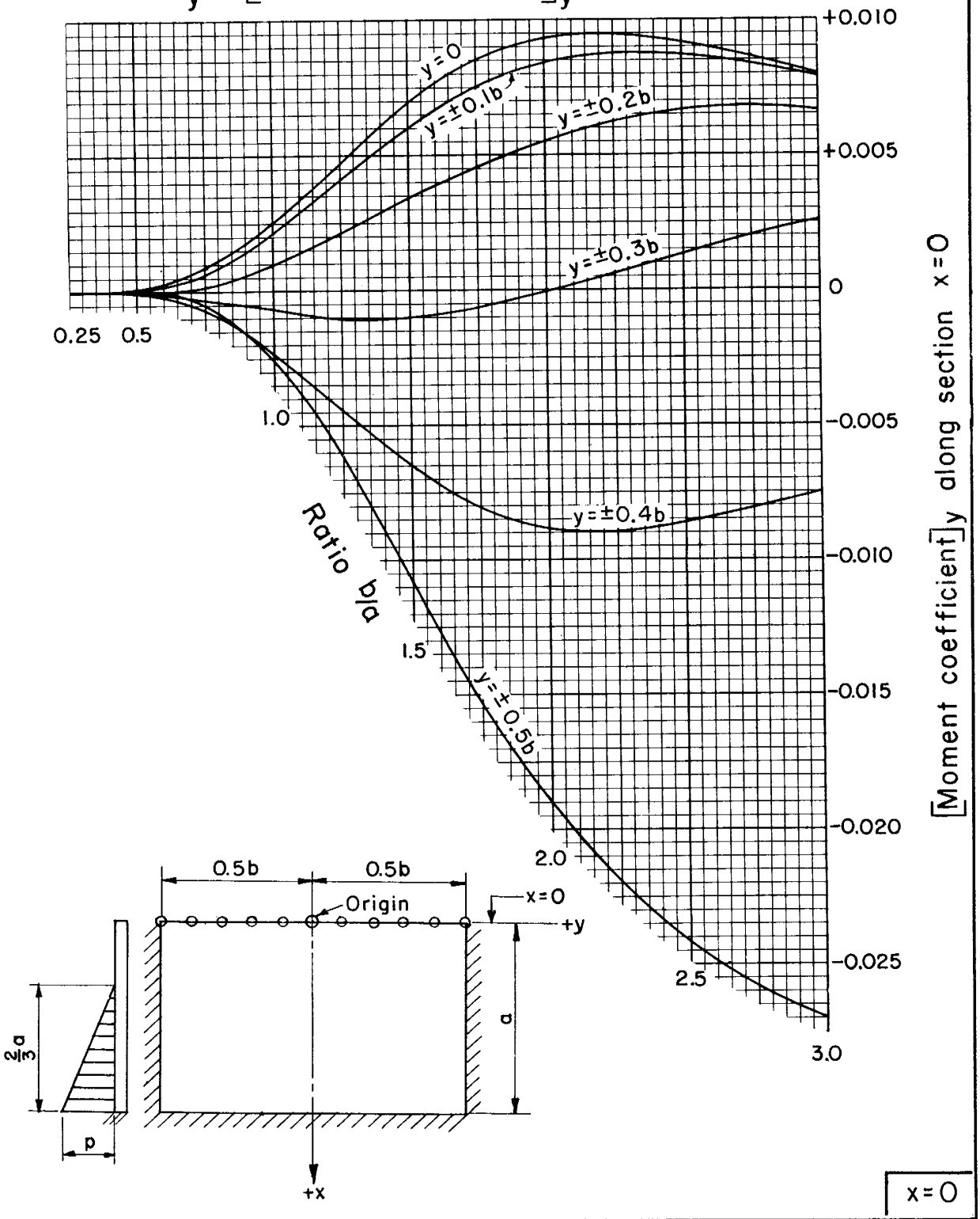
$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 21 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



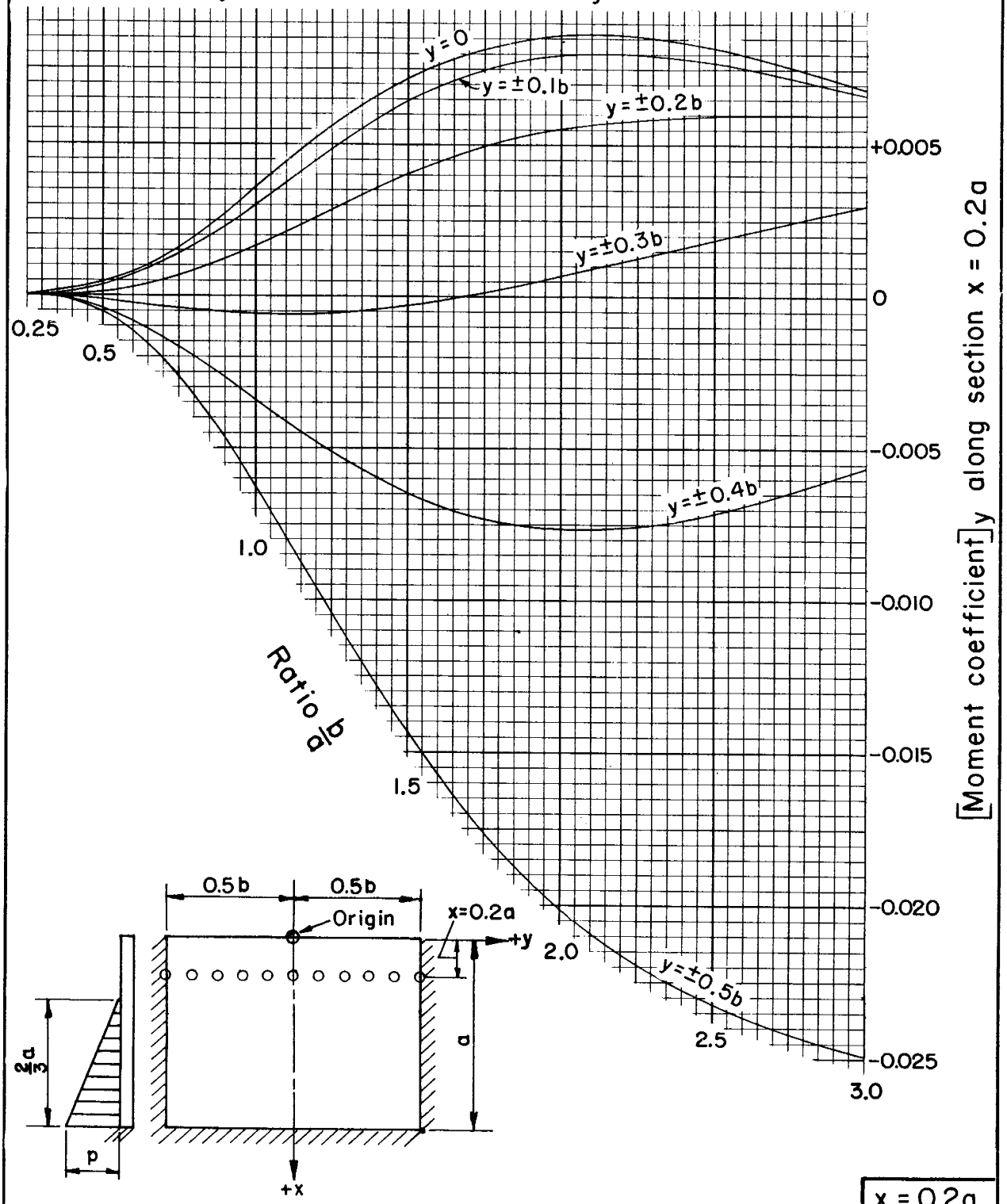
x = 0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES- 104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 22 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice $x = 0.2a$

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



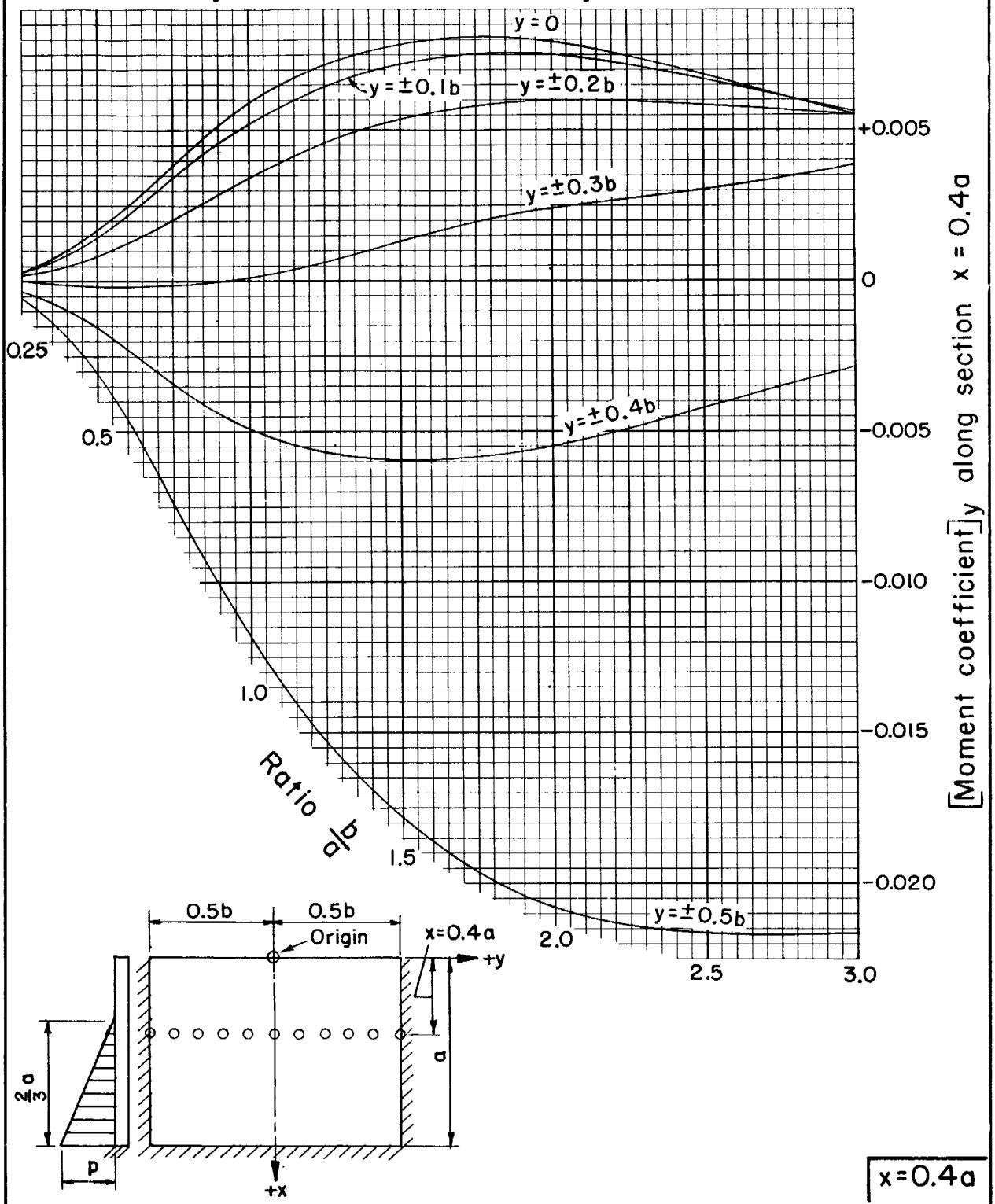
x = 0.2a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES- 104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 23 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice $x = 0.4a$

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



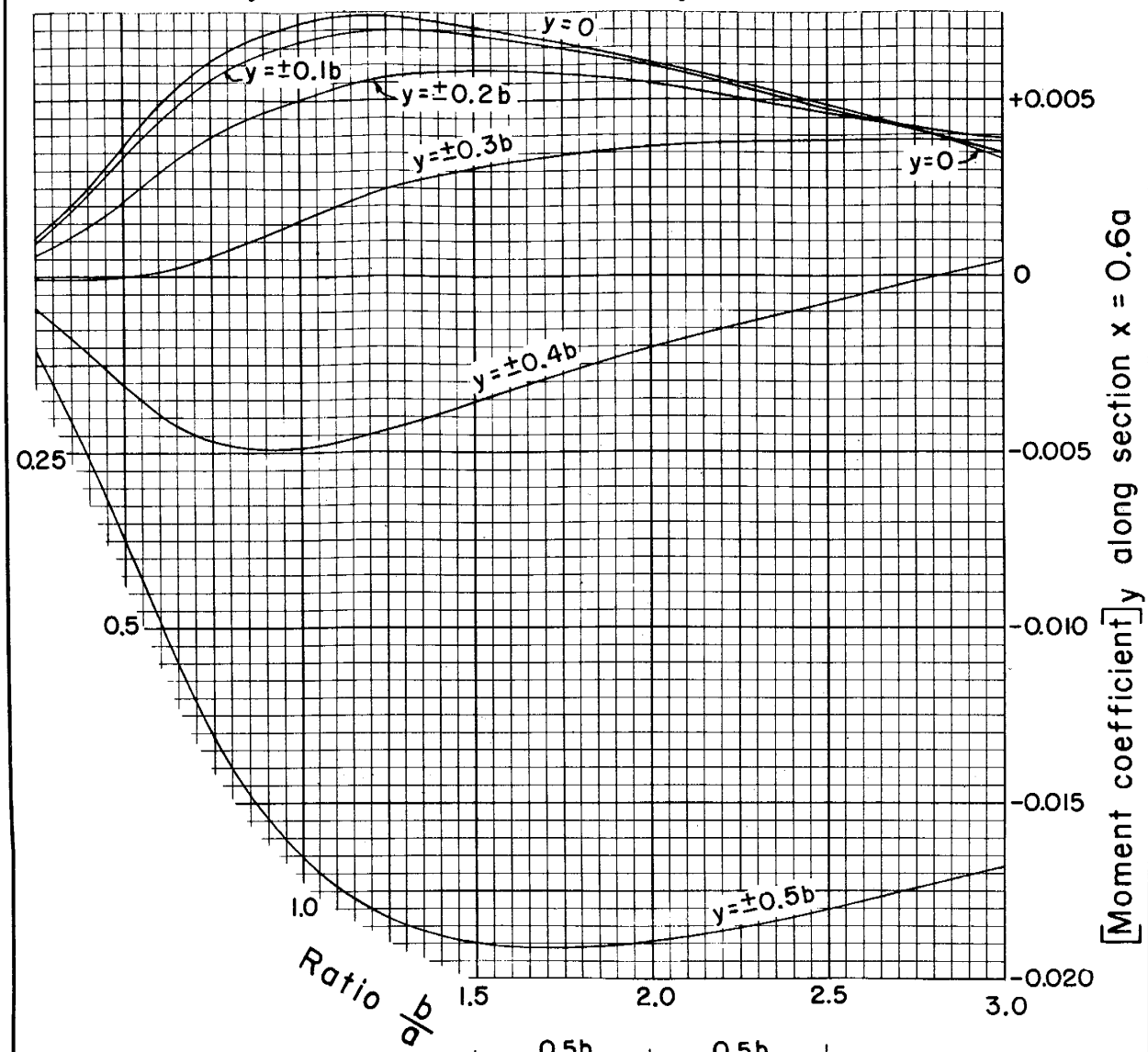
x=0.4a

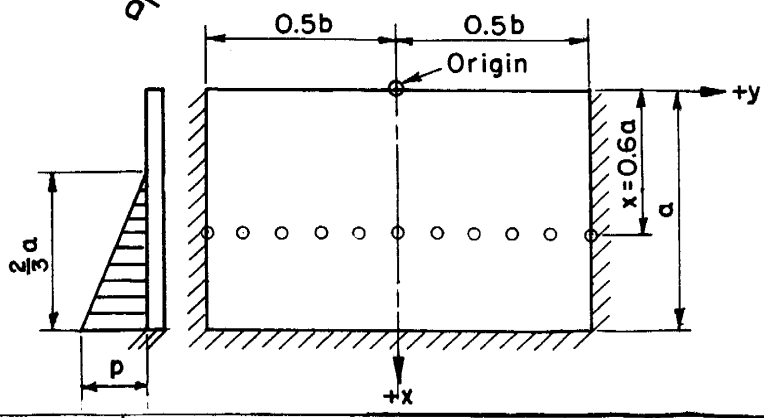
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES- 104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 24 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.6a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2





x = 0.6a

REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

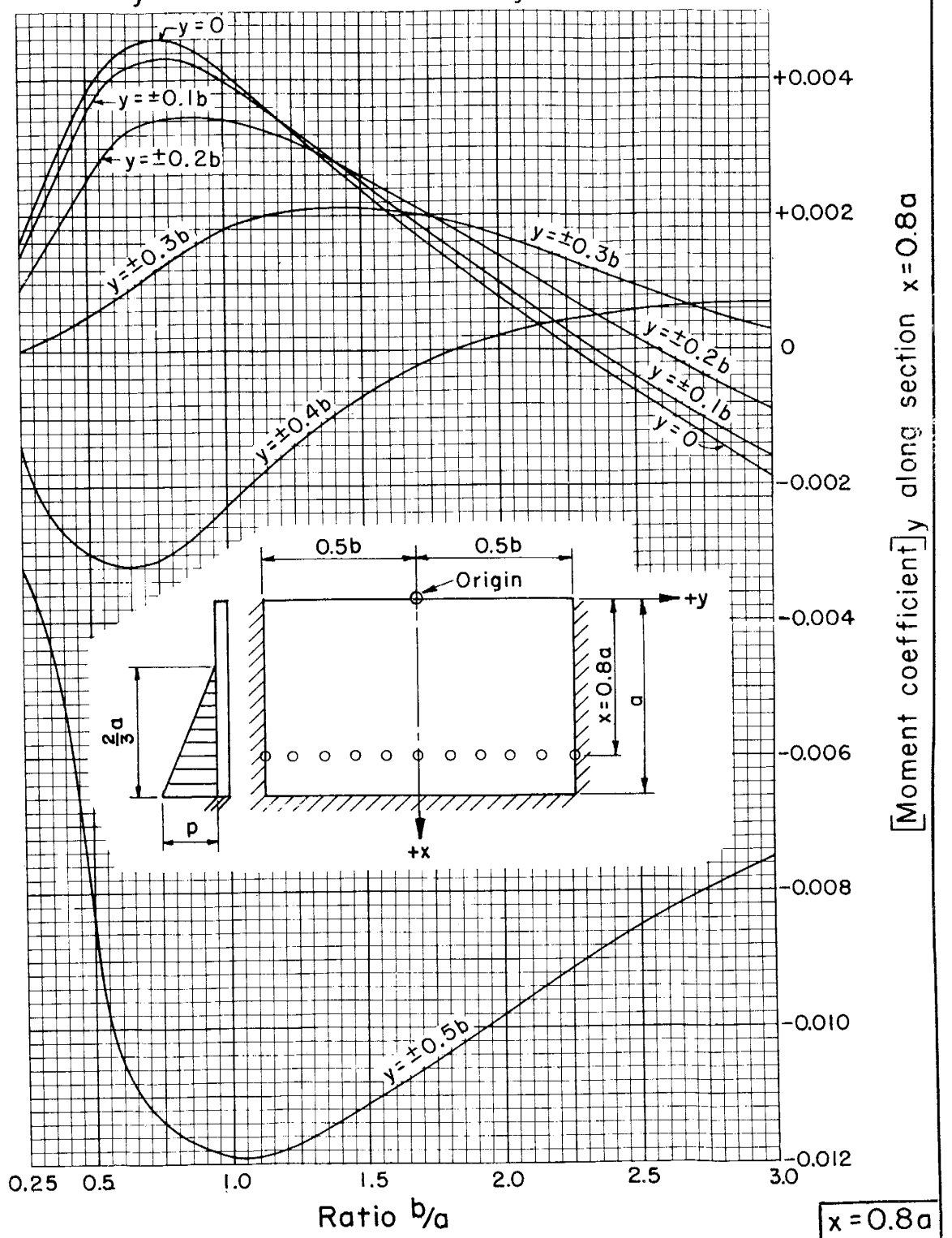
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 104
SHEET 25 OF 85
DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.8a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2



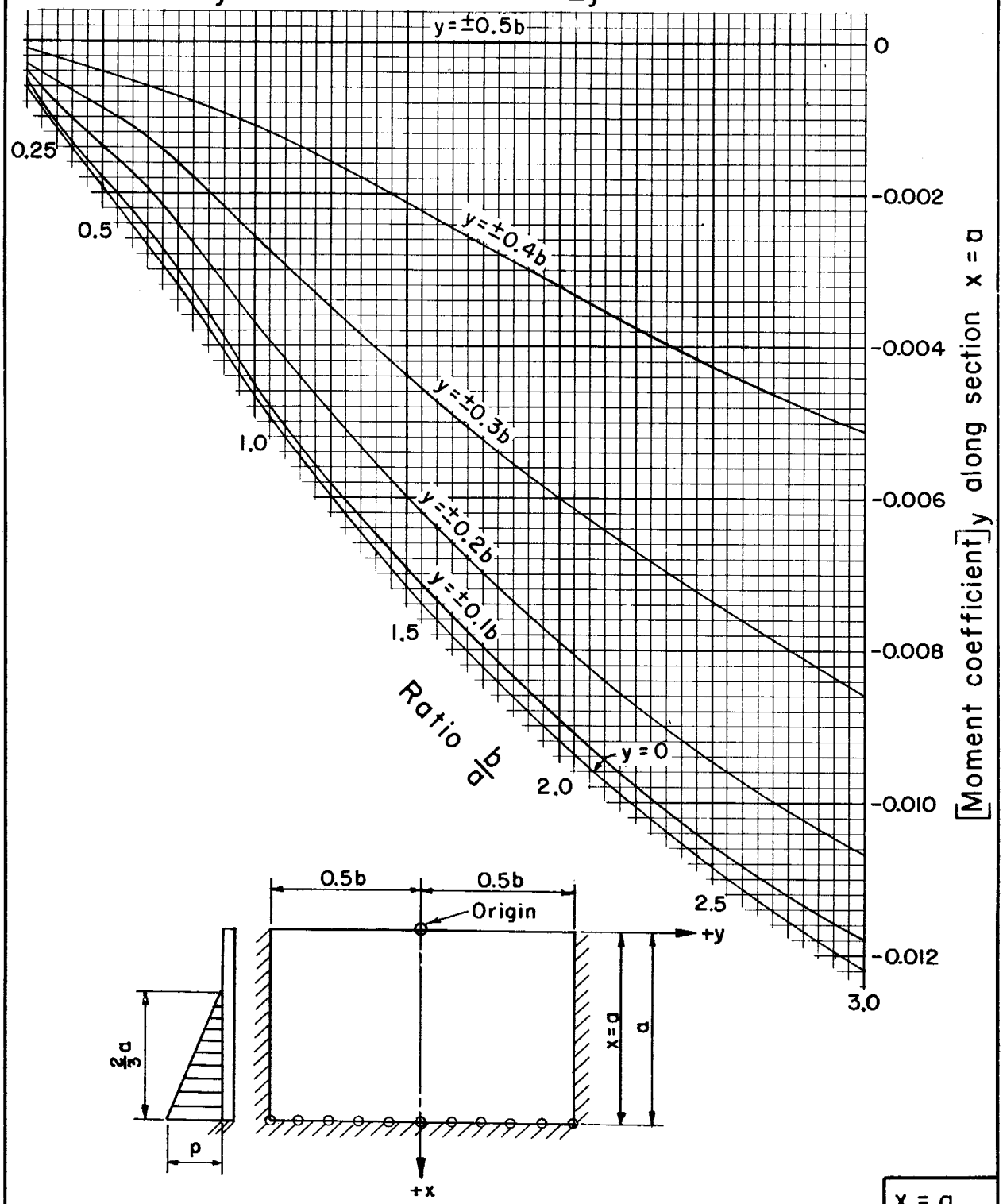
x = 0.8a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES- 104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 26 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = a

Horizontal moment determines tension in horizontal steel

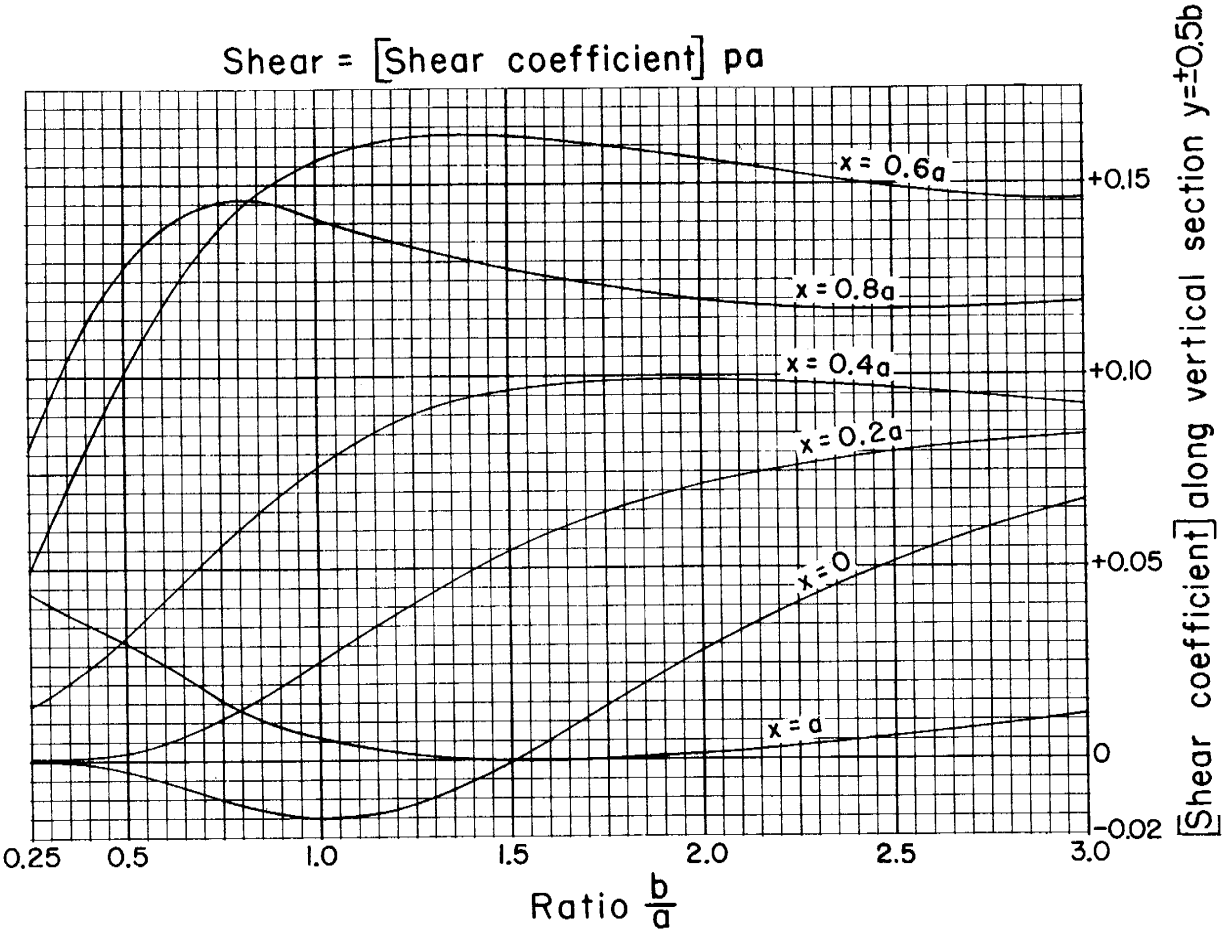
$$M_y = [\text{Moment coefficient}]_y \, pa^2$$

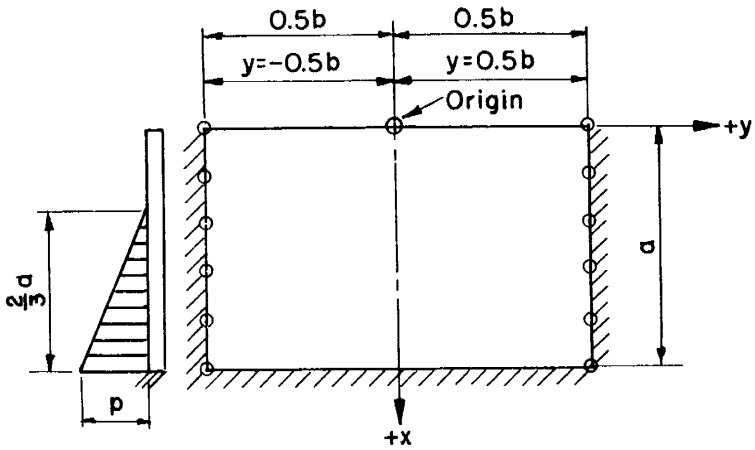


x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES- 104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 27 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with 2/3 hydrostatic load; coefficients for shear at fifth points on fixed side edges $y = \pm 0.5b$



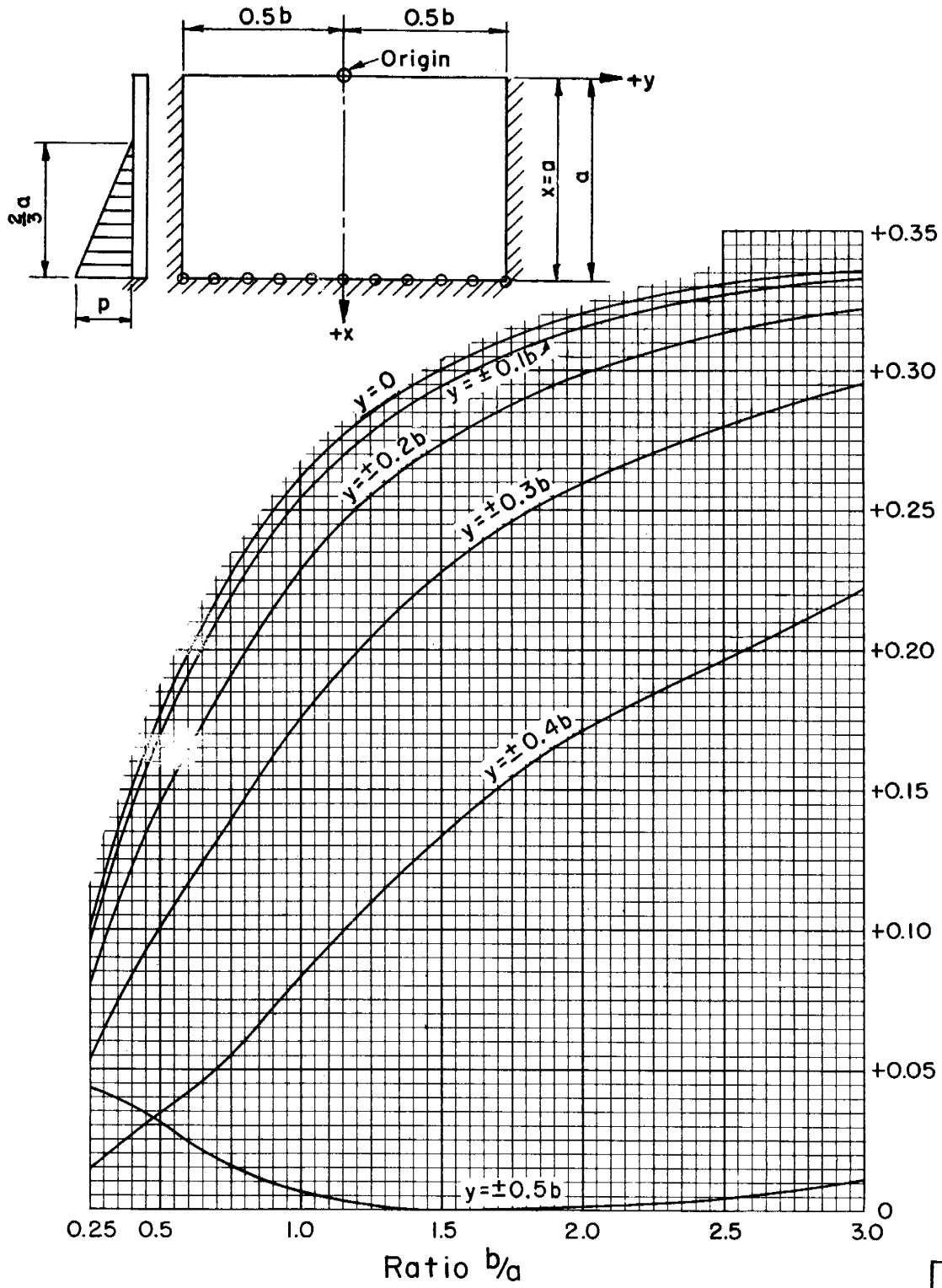


$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 28 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ hydrostatic load; coefficients for shear at tenth points on fixed bottom edge x = a

Shear = [Shear coefficient] pa



x = a

REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

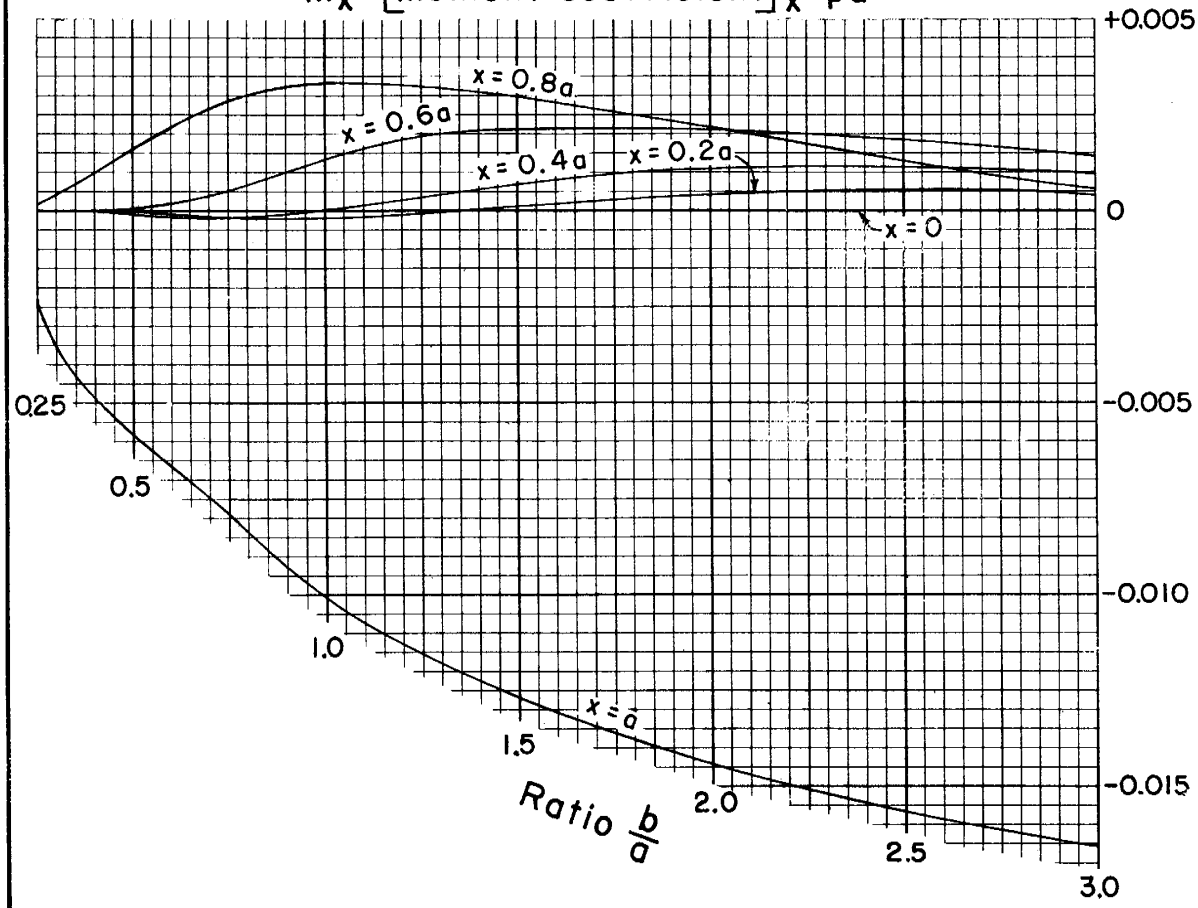
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

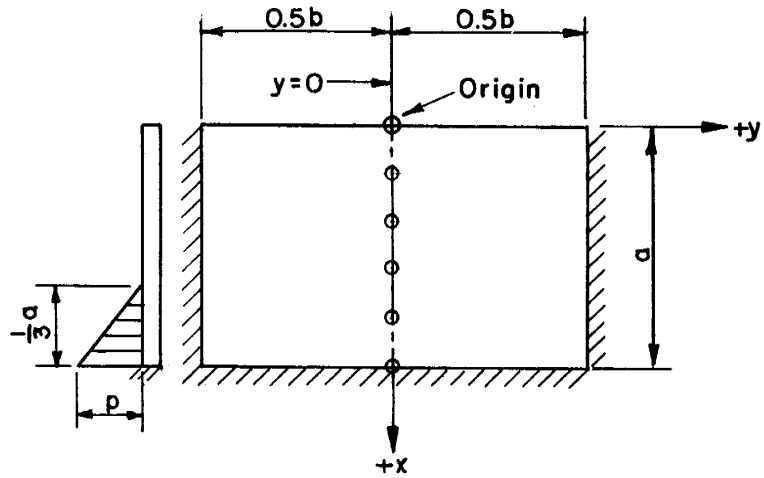
STANDARD DWG. NO.
ES-104
SHEET 29 OF 85
DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice y = 0

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$





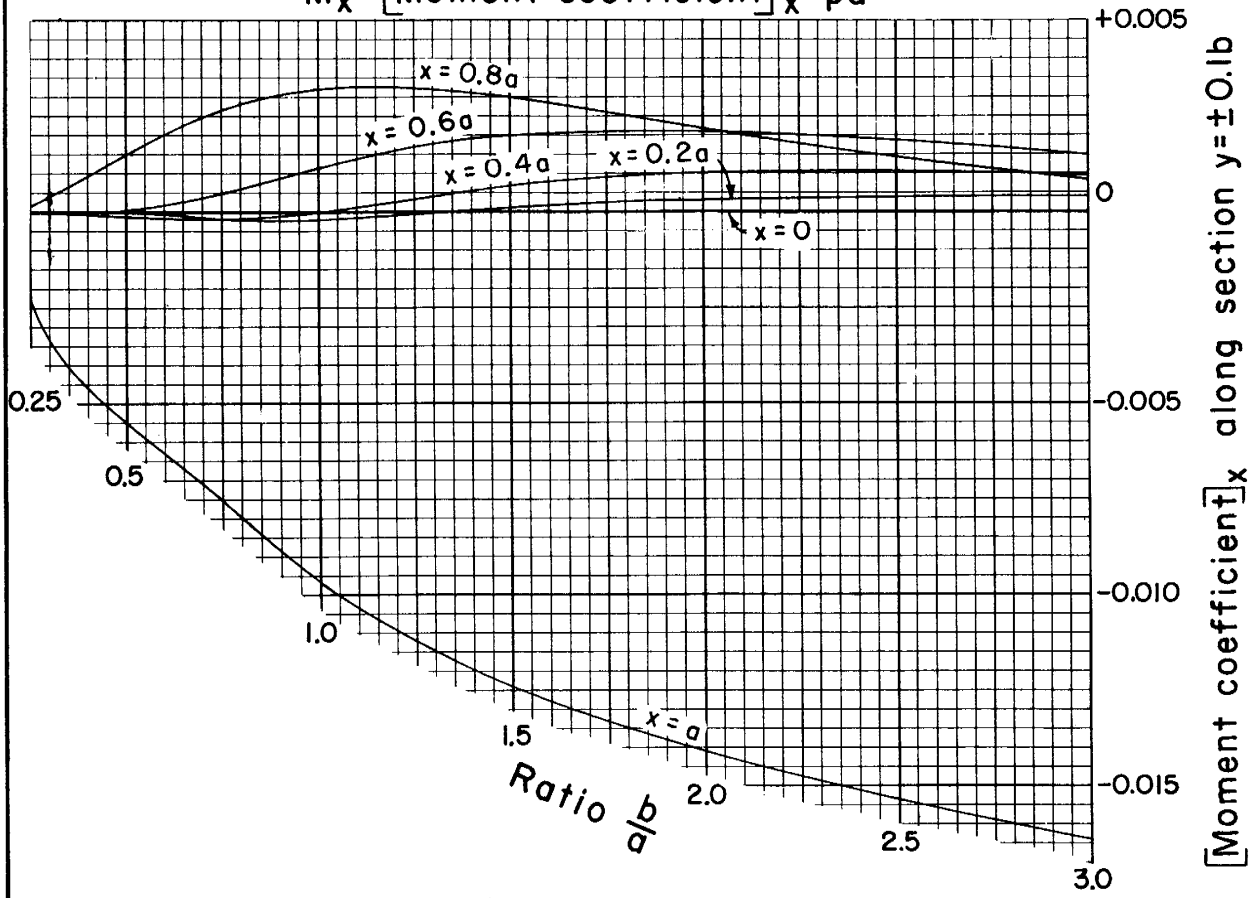
y = 0

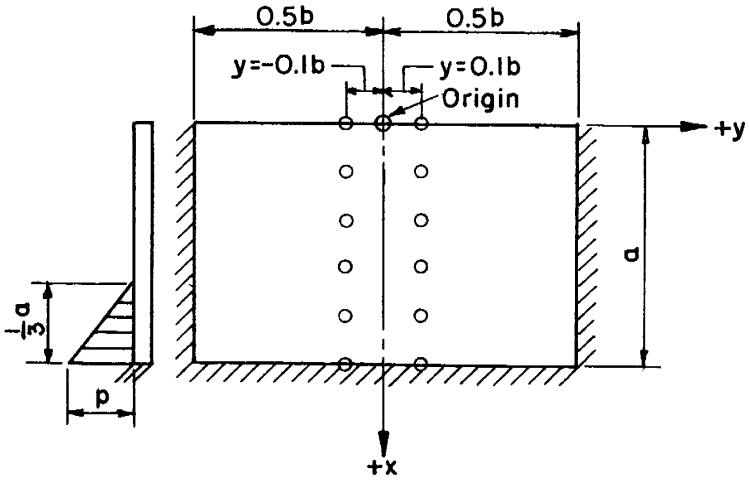
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 30 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.1b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$





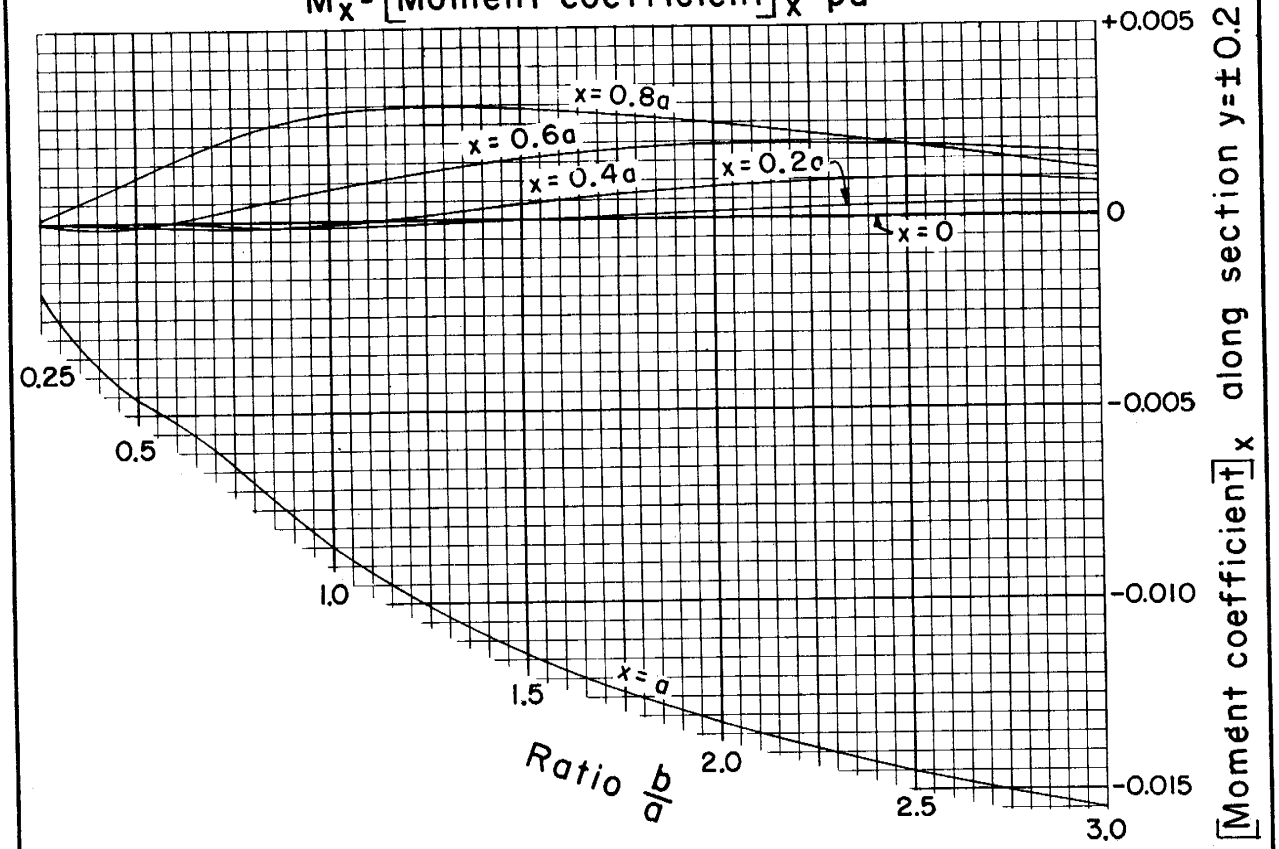
$y = \pm 0.1b$

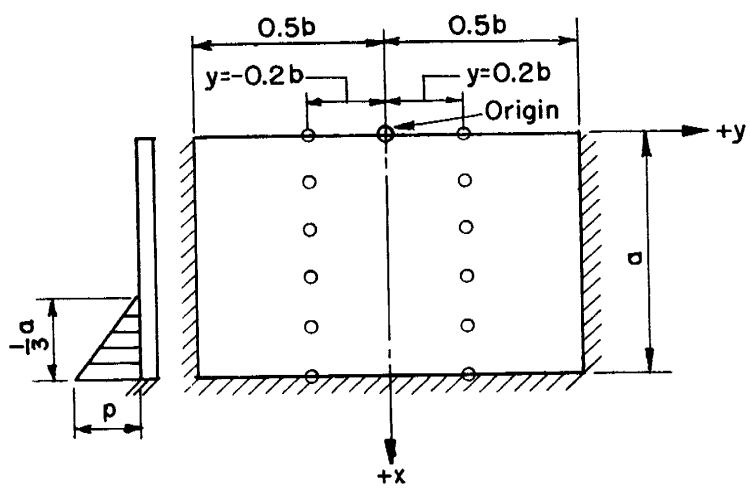
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 31 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.2b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$





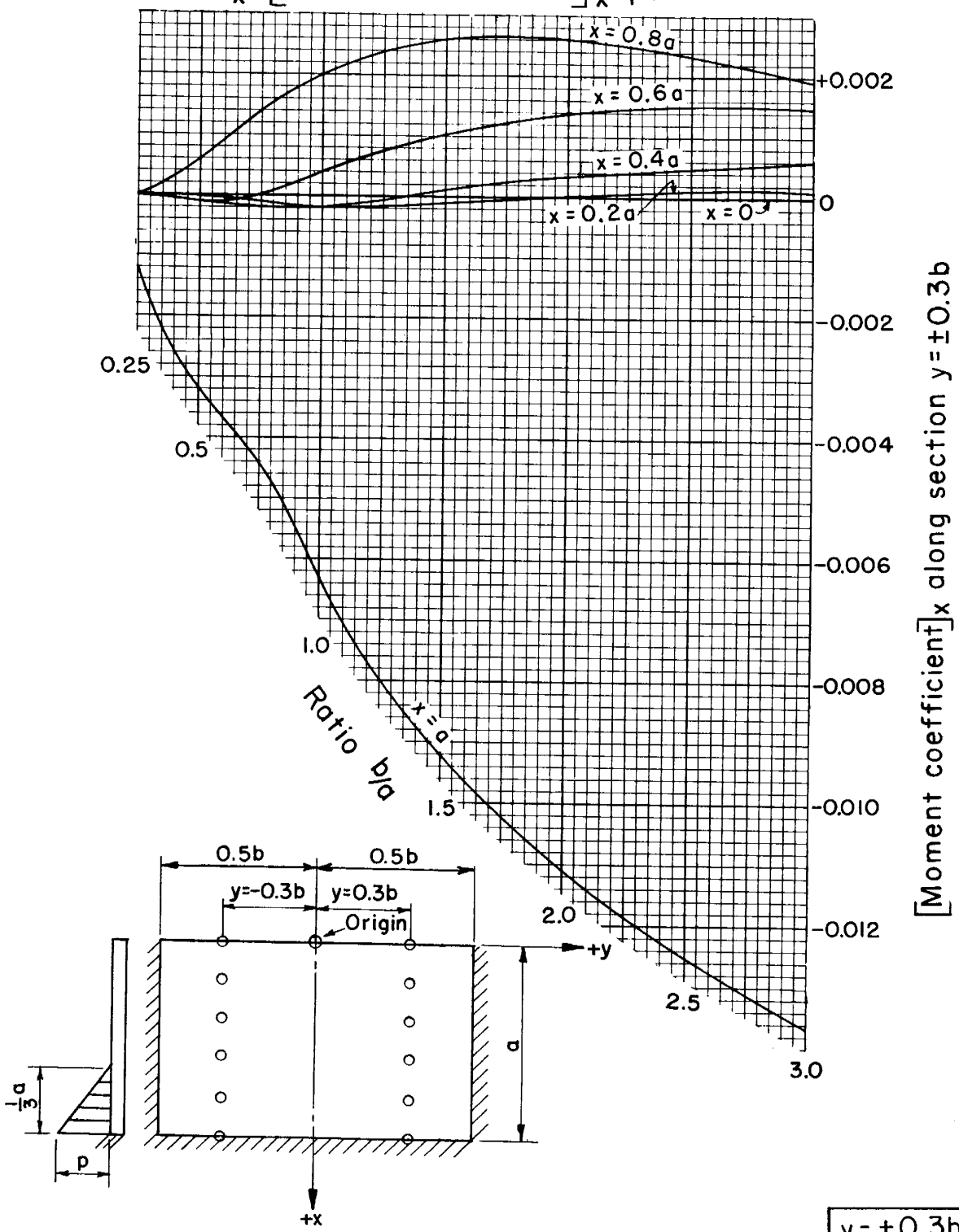
$y = \pm 0.2b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 32 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.3b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



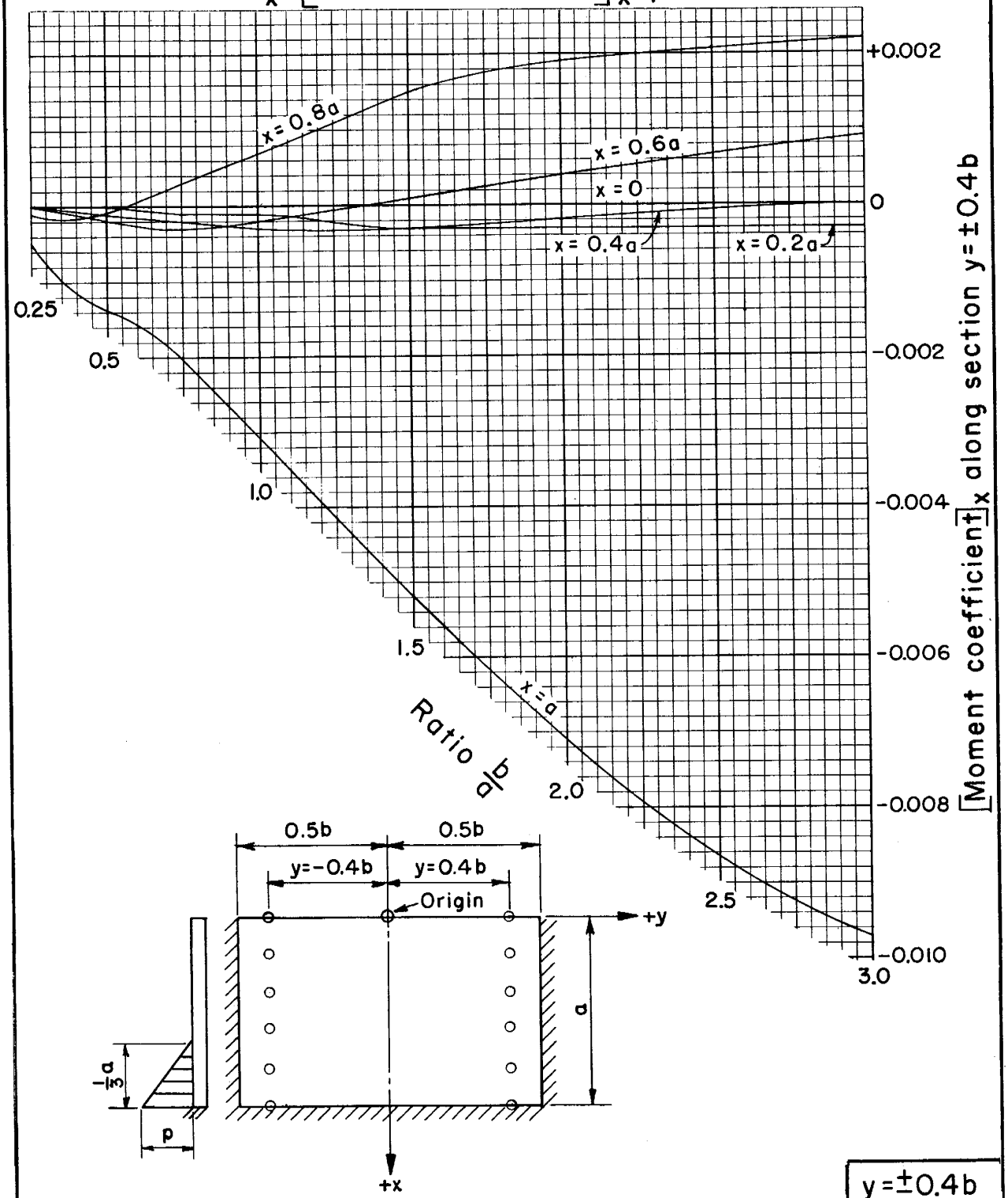
$y = \pm 0.3b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 33 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.4b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$



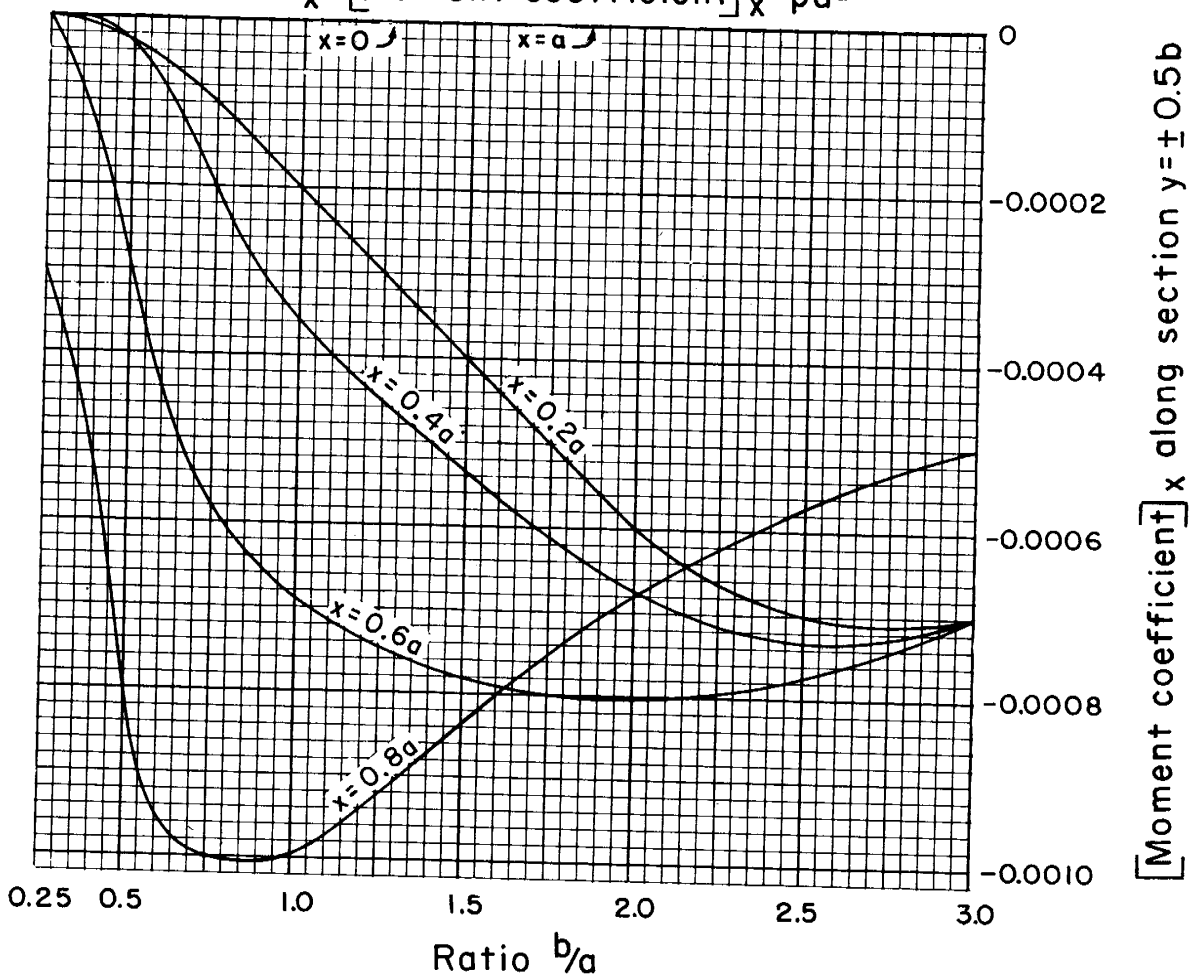
$y = \pm 0.4b$

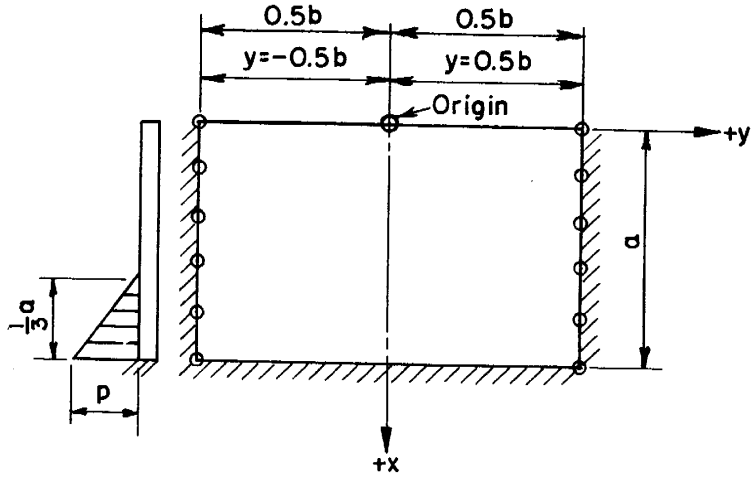
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 34 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN : Rectangular slabs with 1/3 hydrostatic load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.5b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \; pa^2$





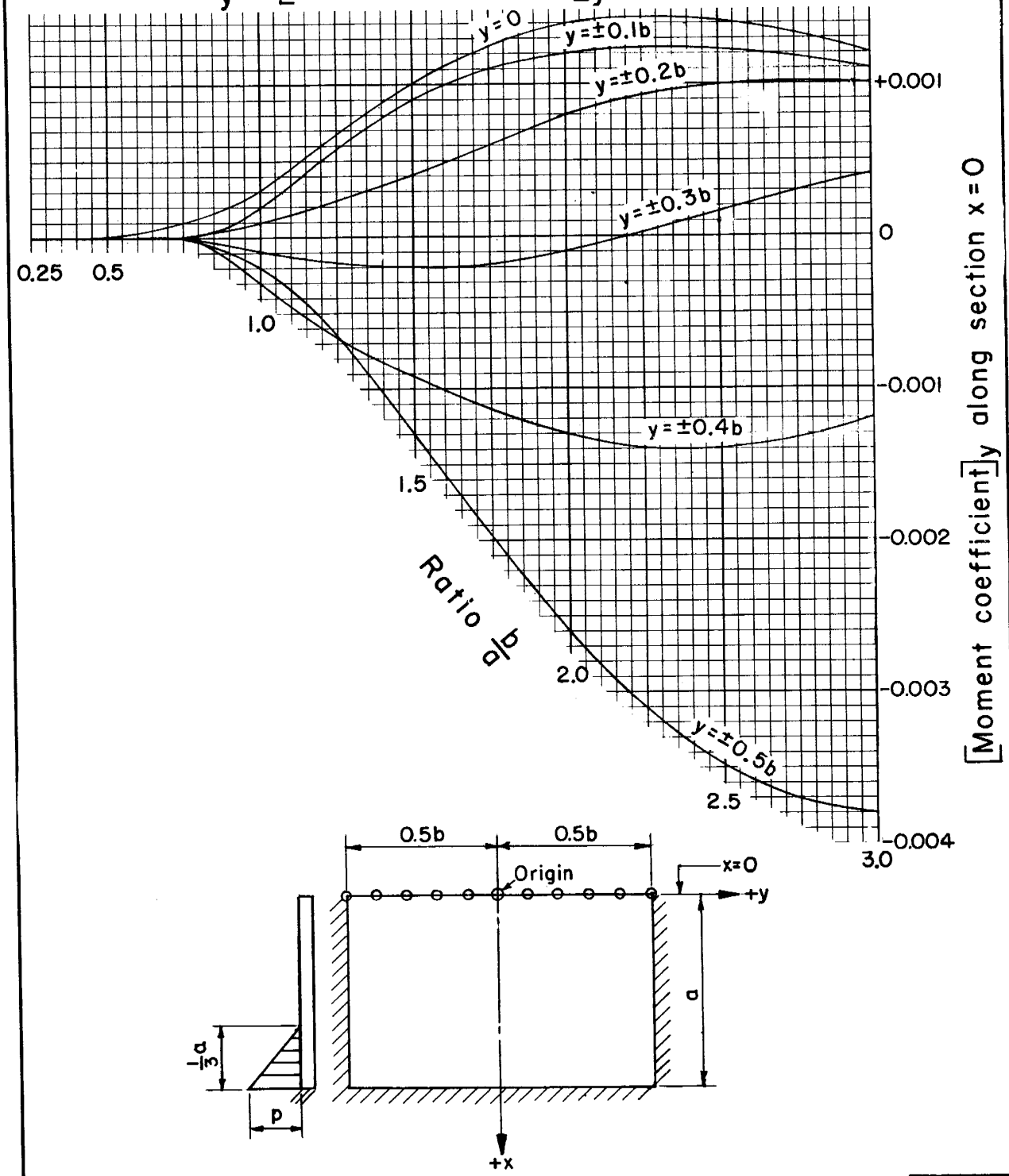
$y = \pm 0.5b$

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 35 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2



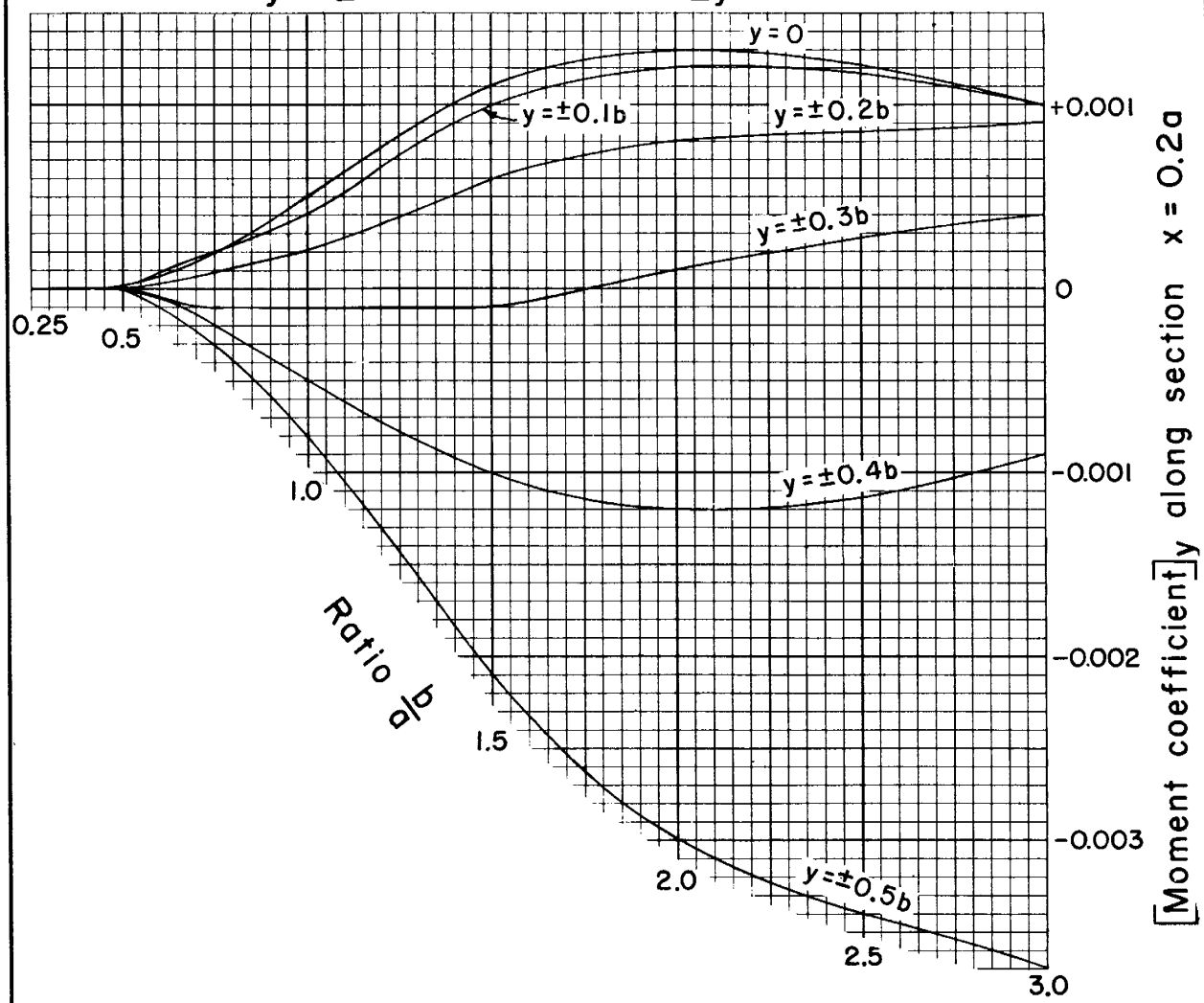
x = 0

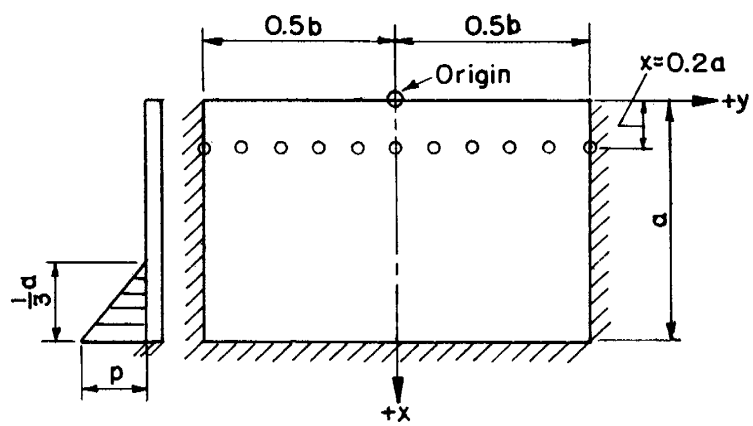
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 36 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.2a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2





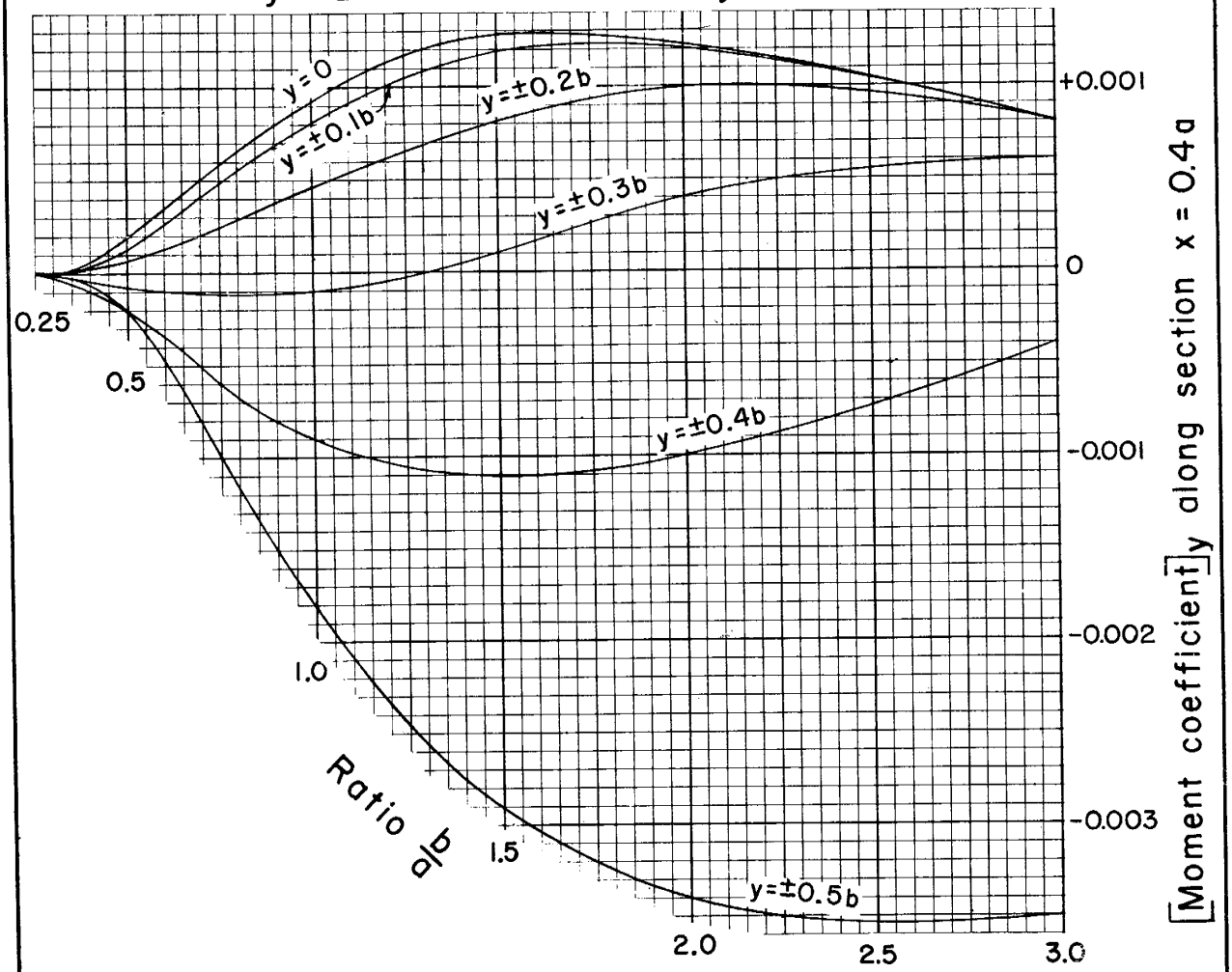
x = 0.2a

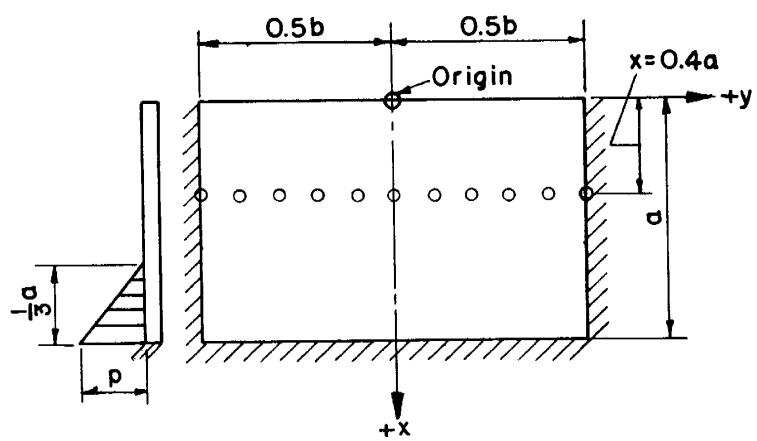
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 37 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with ⅓ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.4a

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$





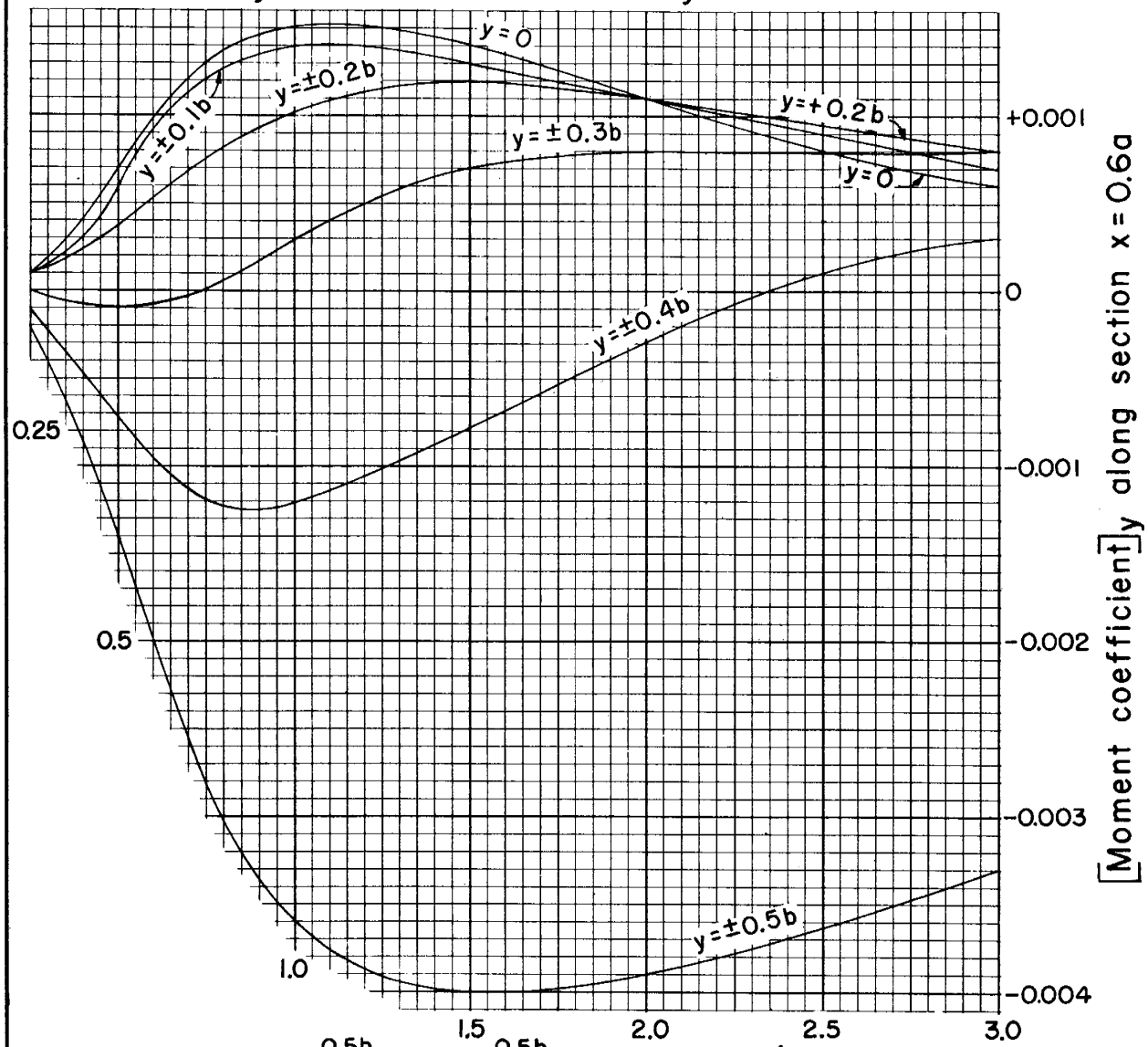
x = 0.4a

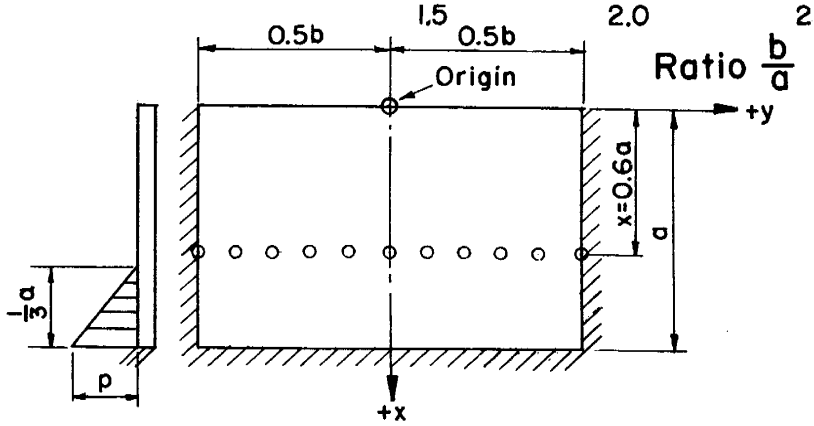
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 38 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.6a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2





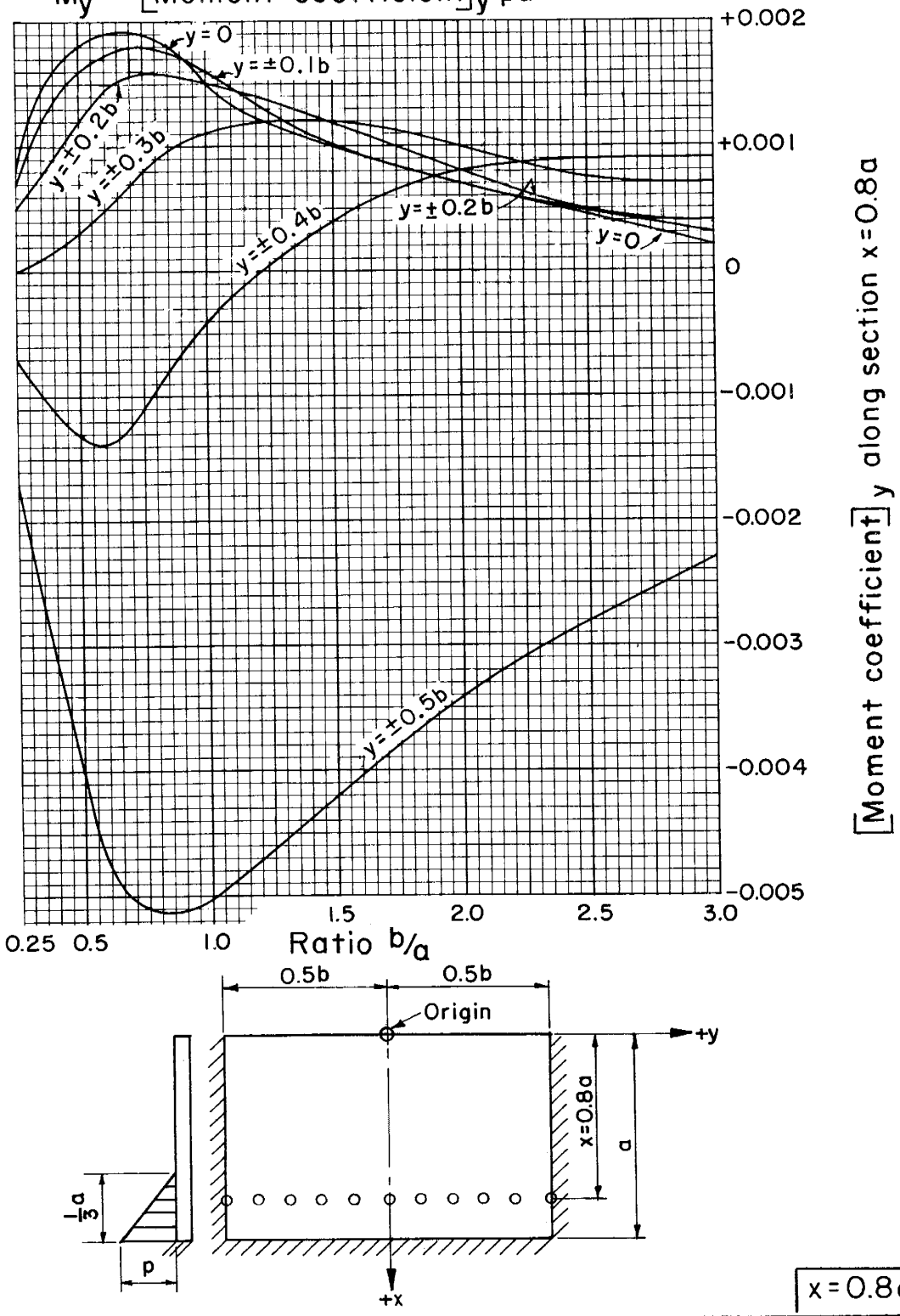
x = 0.6a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 39 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.8a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2



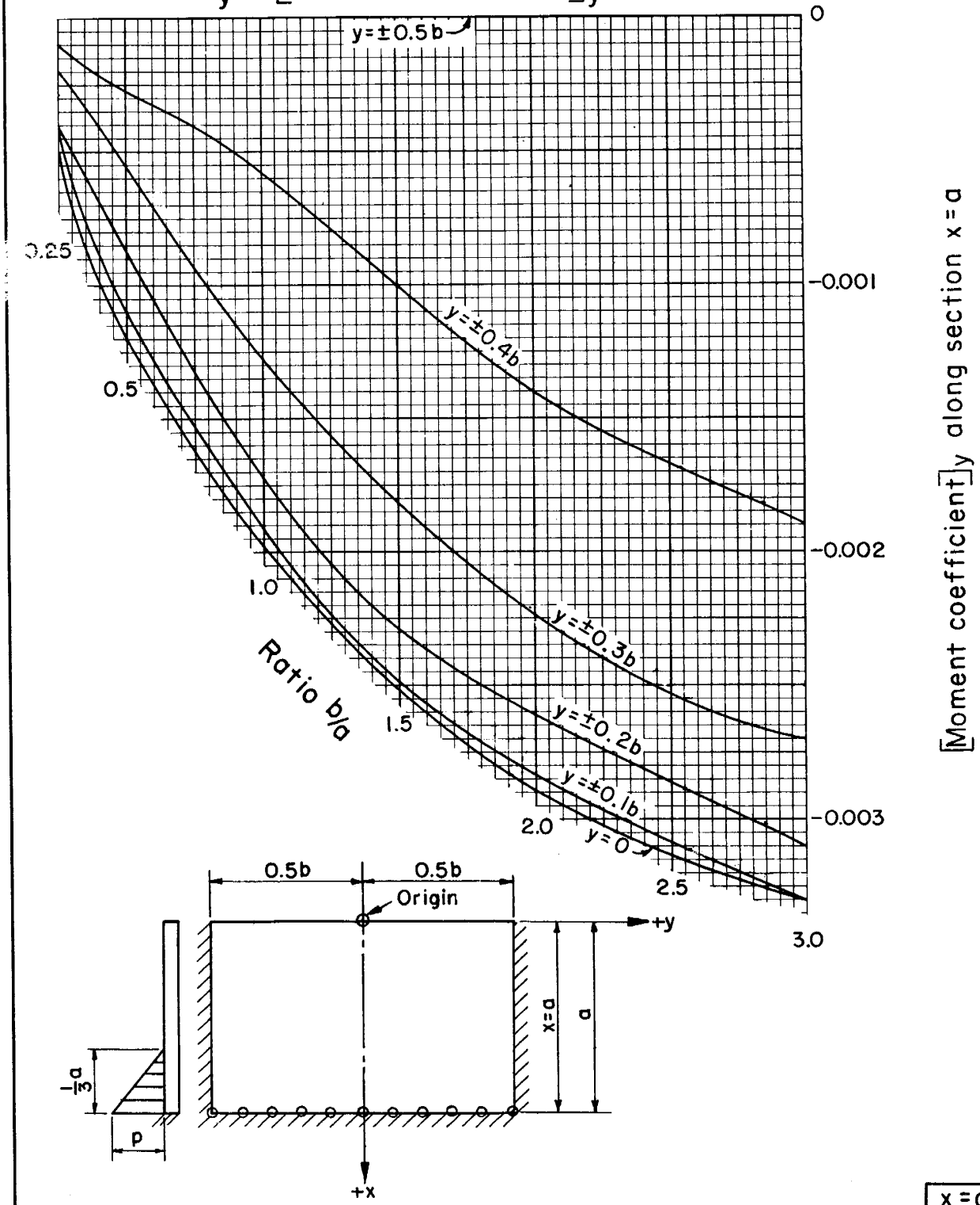
x = 0.8a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 40 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with ⅓ hydrostatic load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = a

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 41 OF 85
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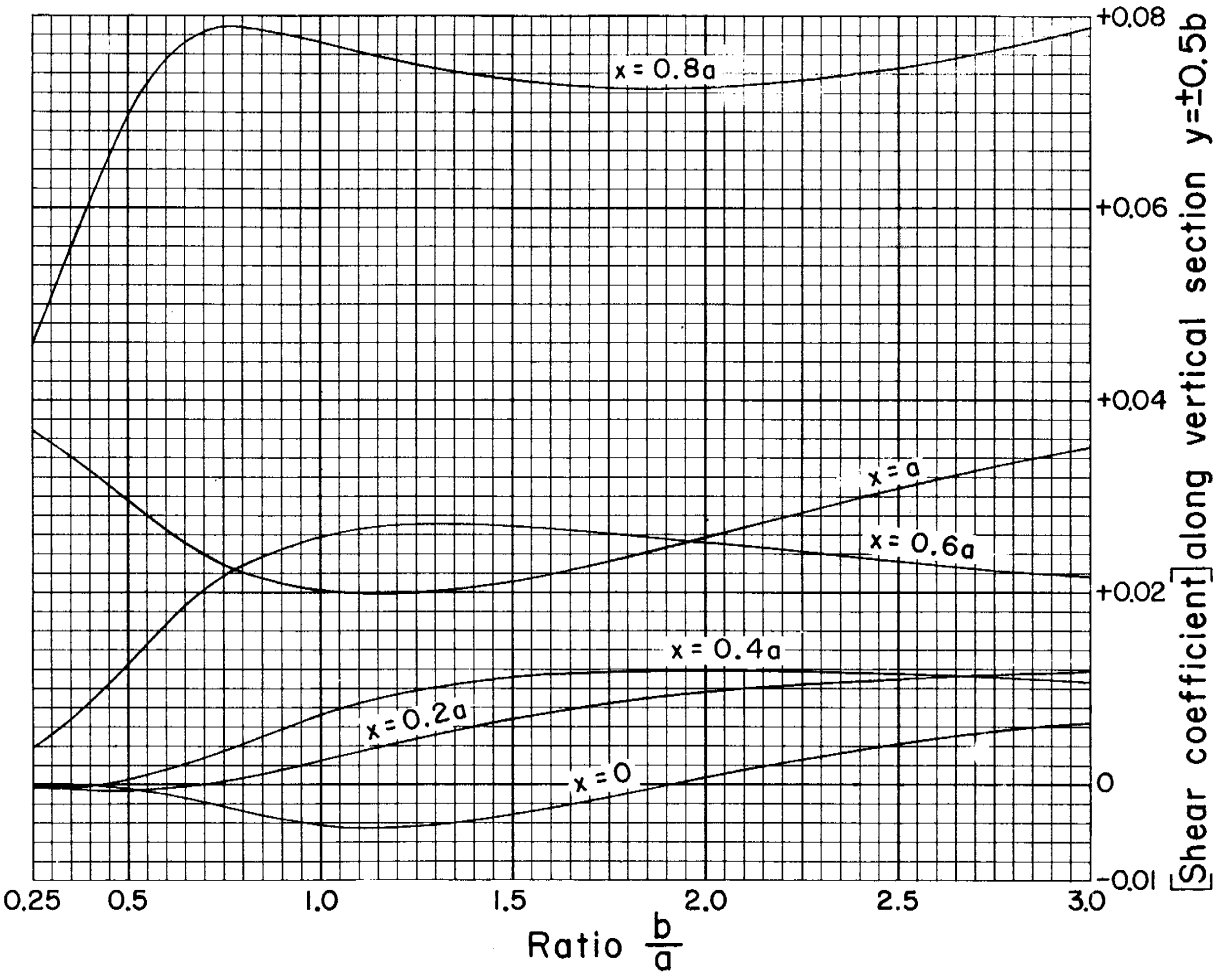
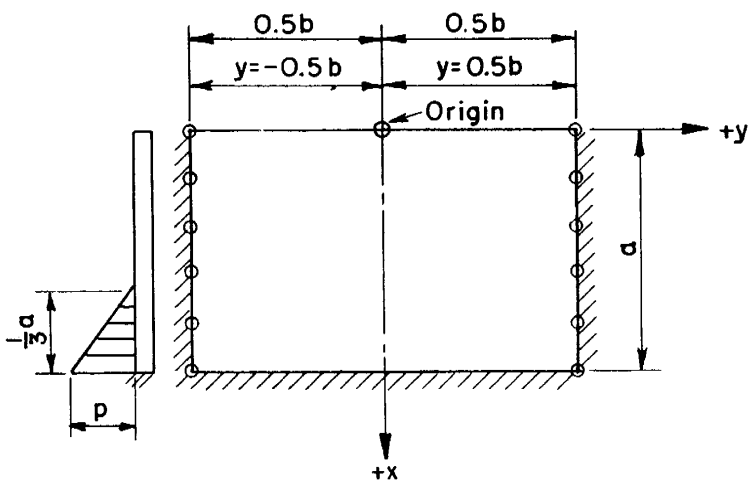
STRUCTURAL DESIGN: Rectangular slabs with 1/3 hydrostatic load; coefficients for shear at fifth points on fixed side edges y = ±0.5b

Shear = [Shear coefficient] pa





y = ±0.5b

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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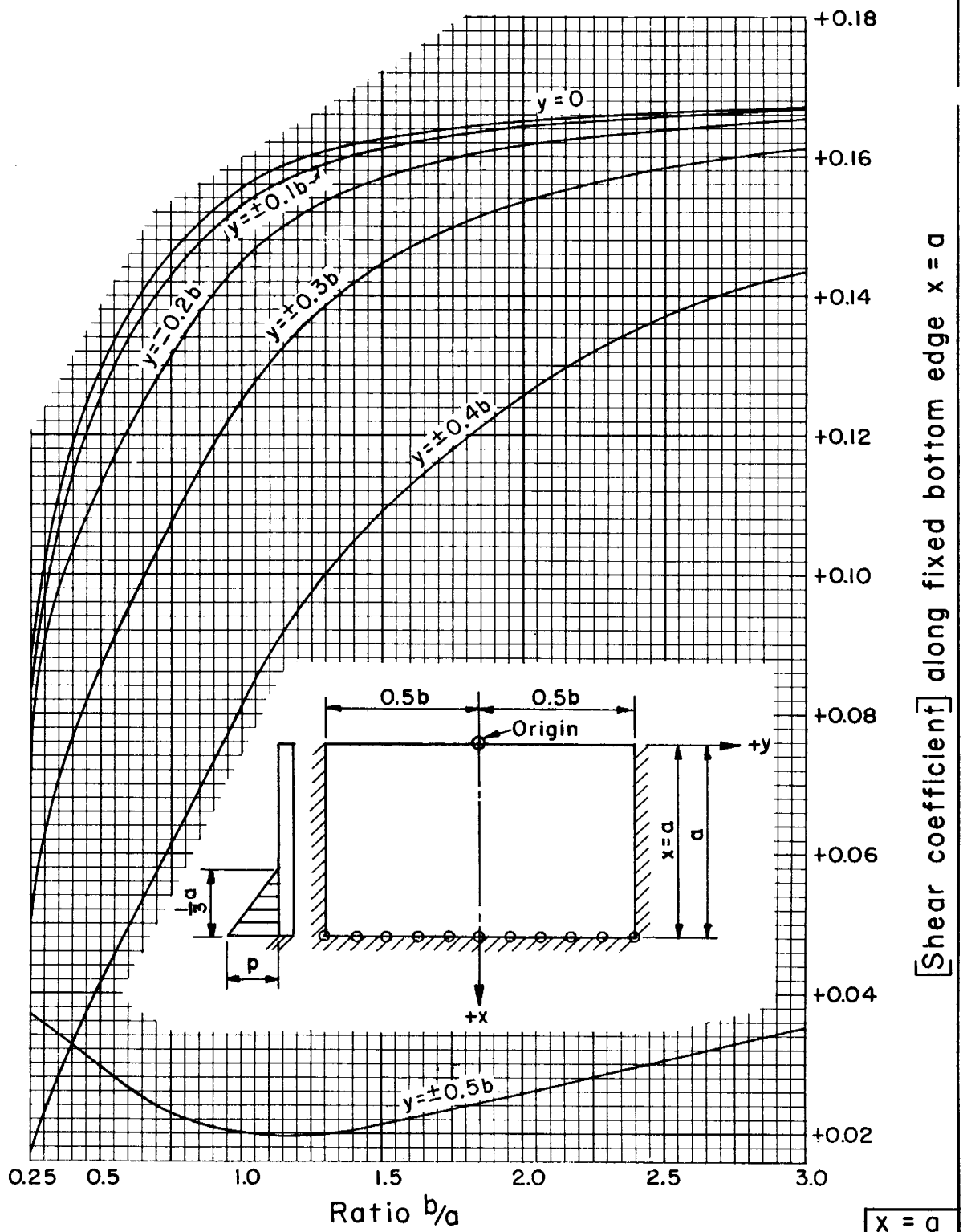
STRUCTURAL DESIGN: Rectangular slabs with ⅓ hydrostatic load; coefficients for shear at tenth points on fixed bottom edge x = a

Shear = [Shear coefficient] pa



x = a

REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

U. S. DEPARTMENT OF AGRICULTURE
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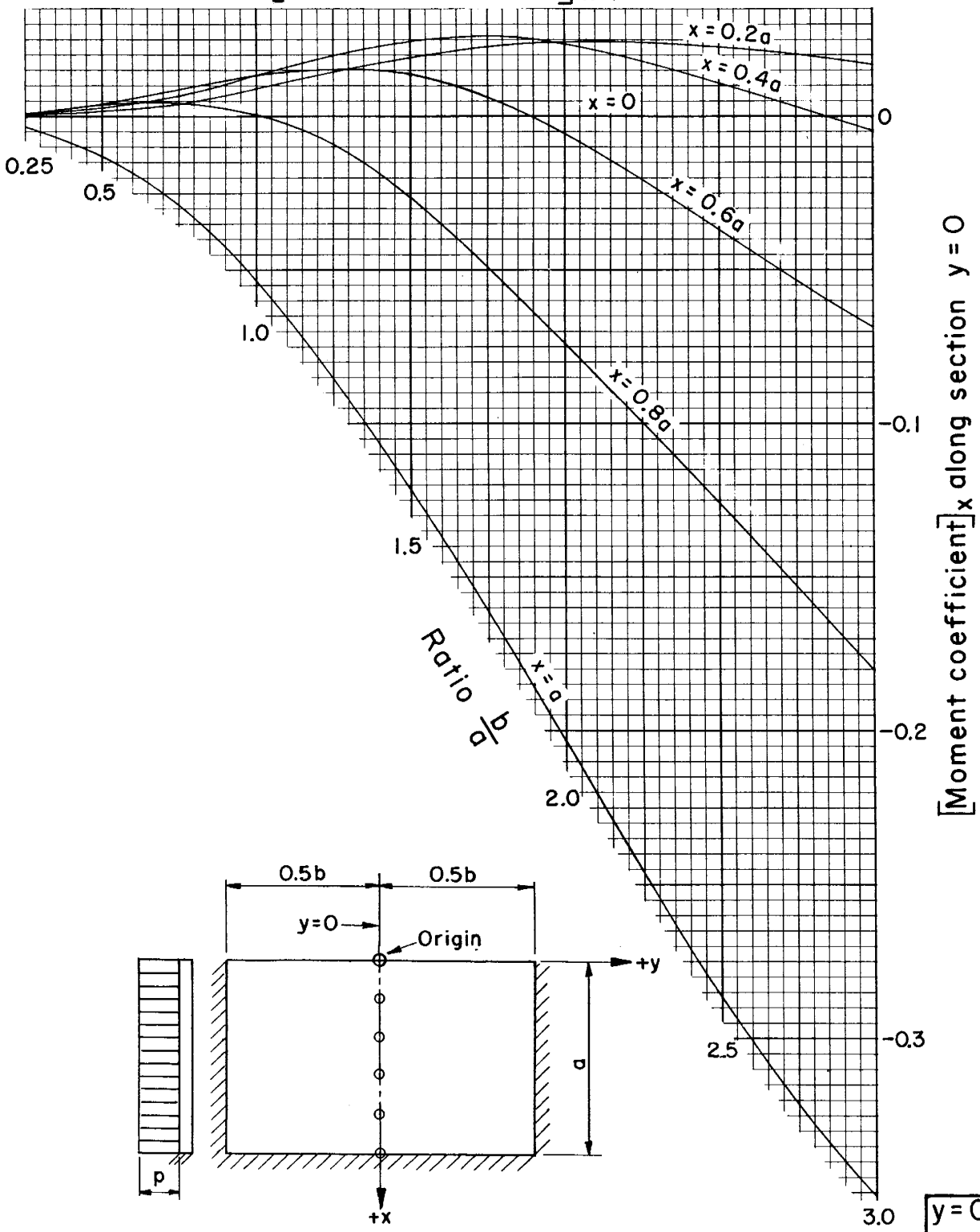
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice y = 0

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



y = 0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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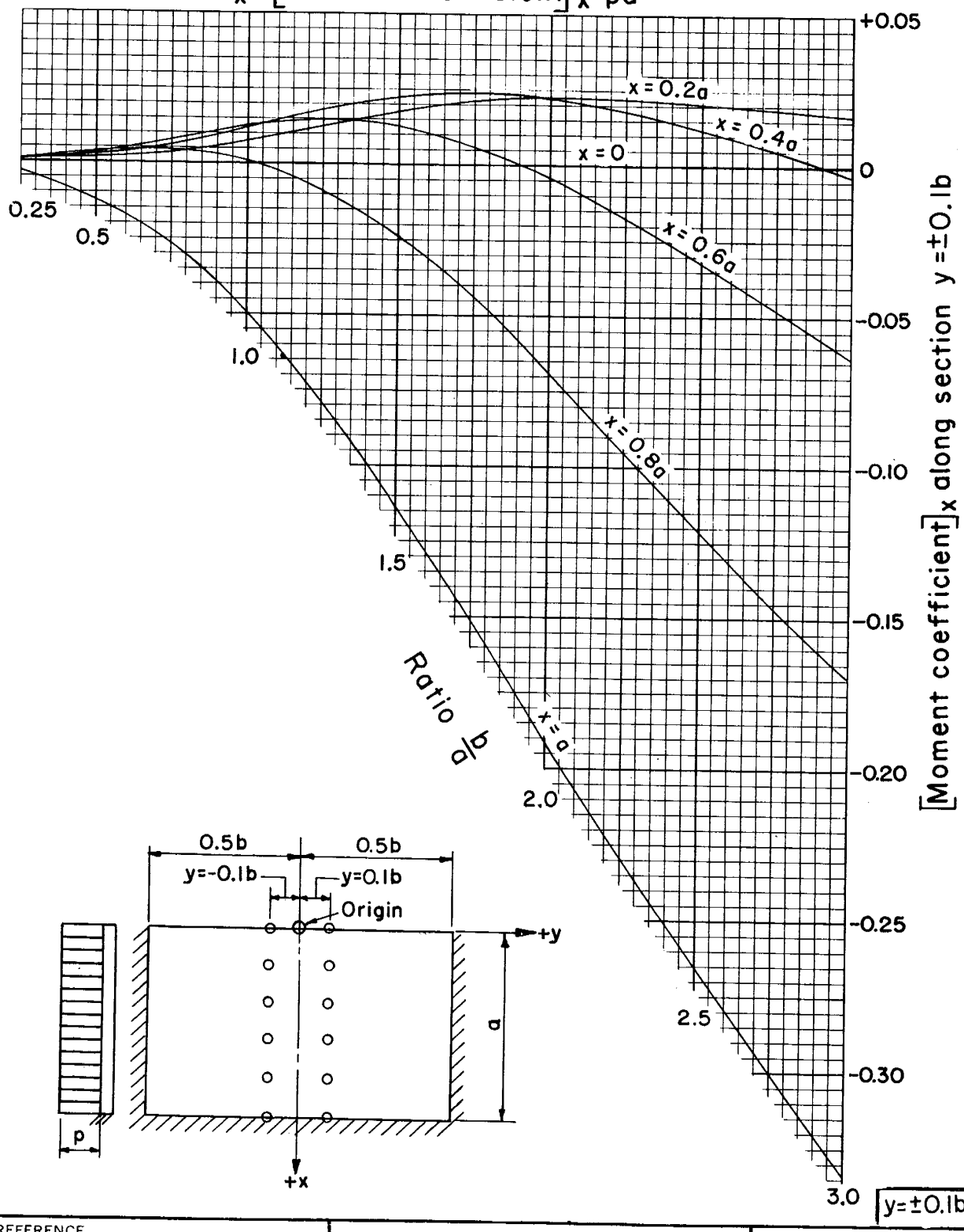
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.1b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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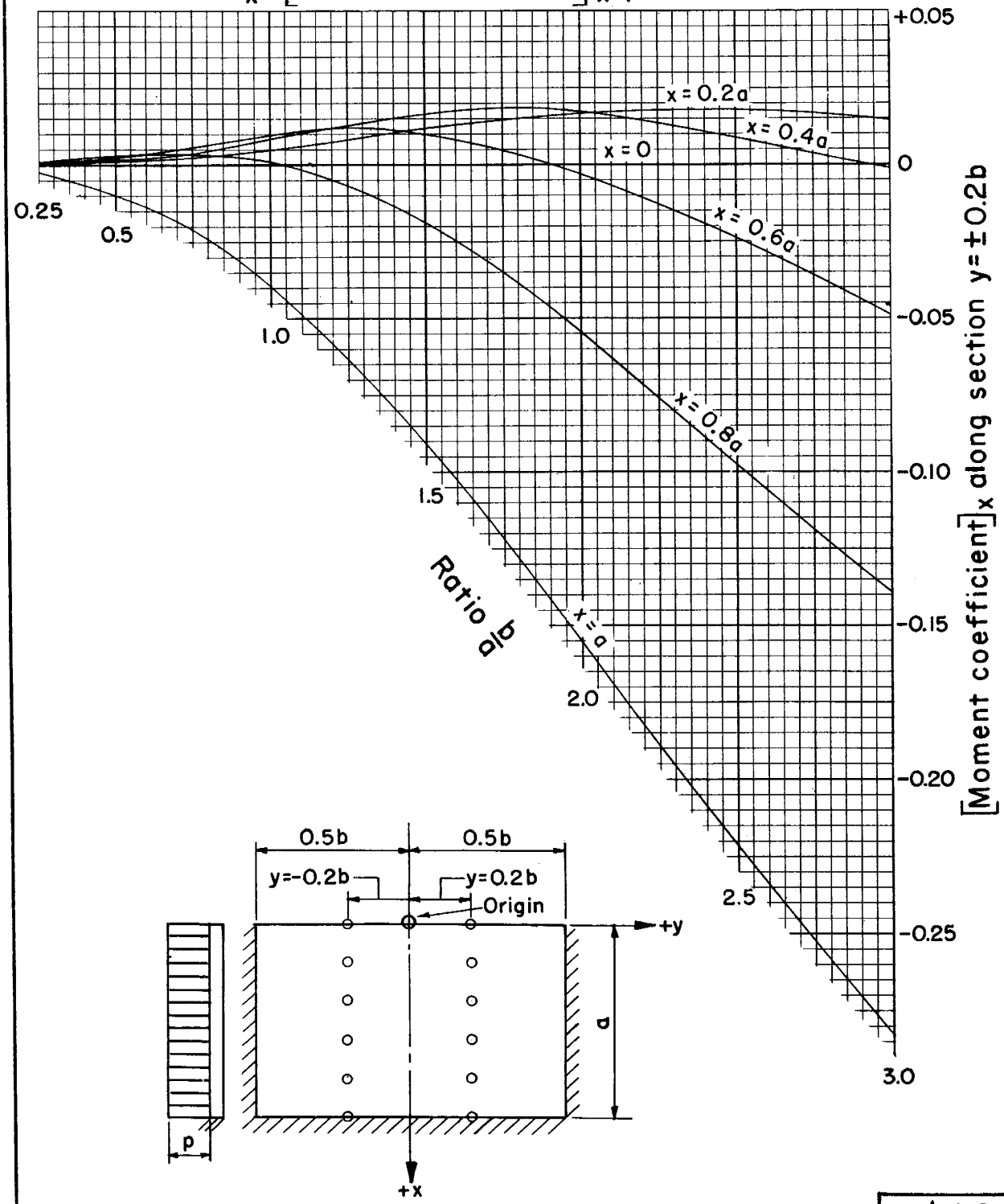
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.2b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



$y = \pm 0.2b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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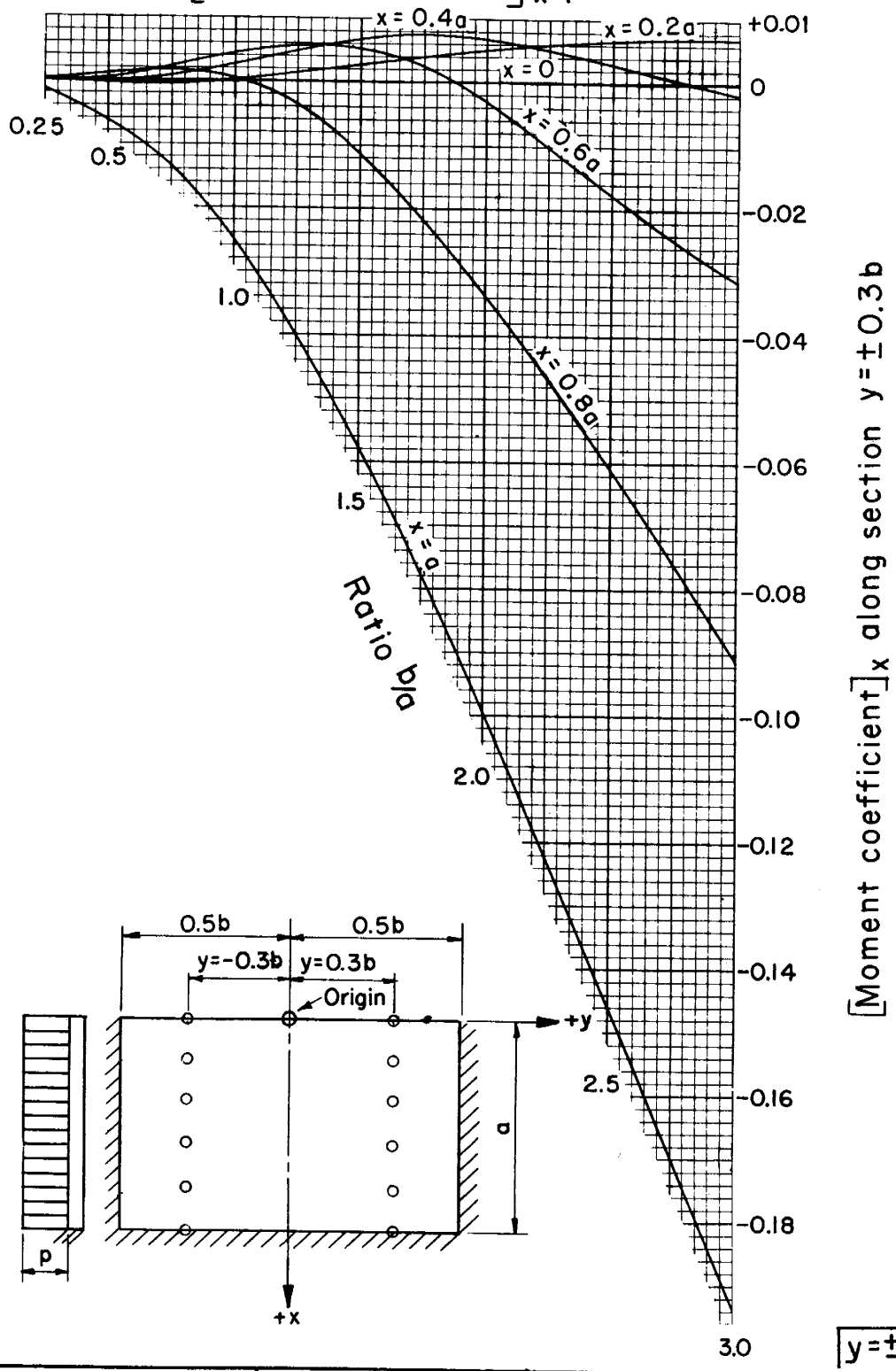
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.3b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



$y = \pm 0.3b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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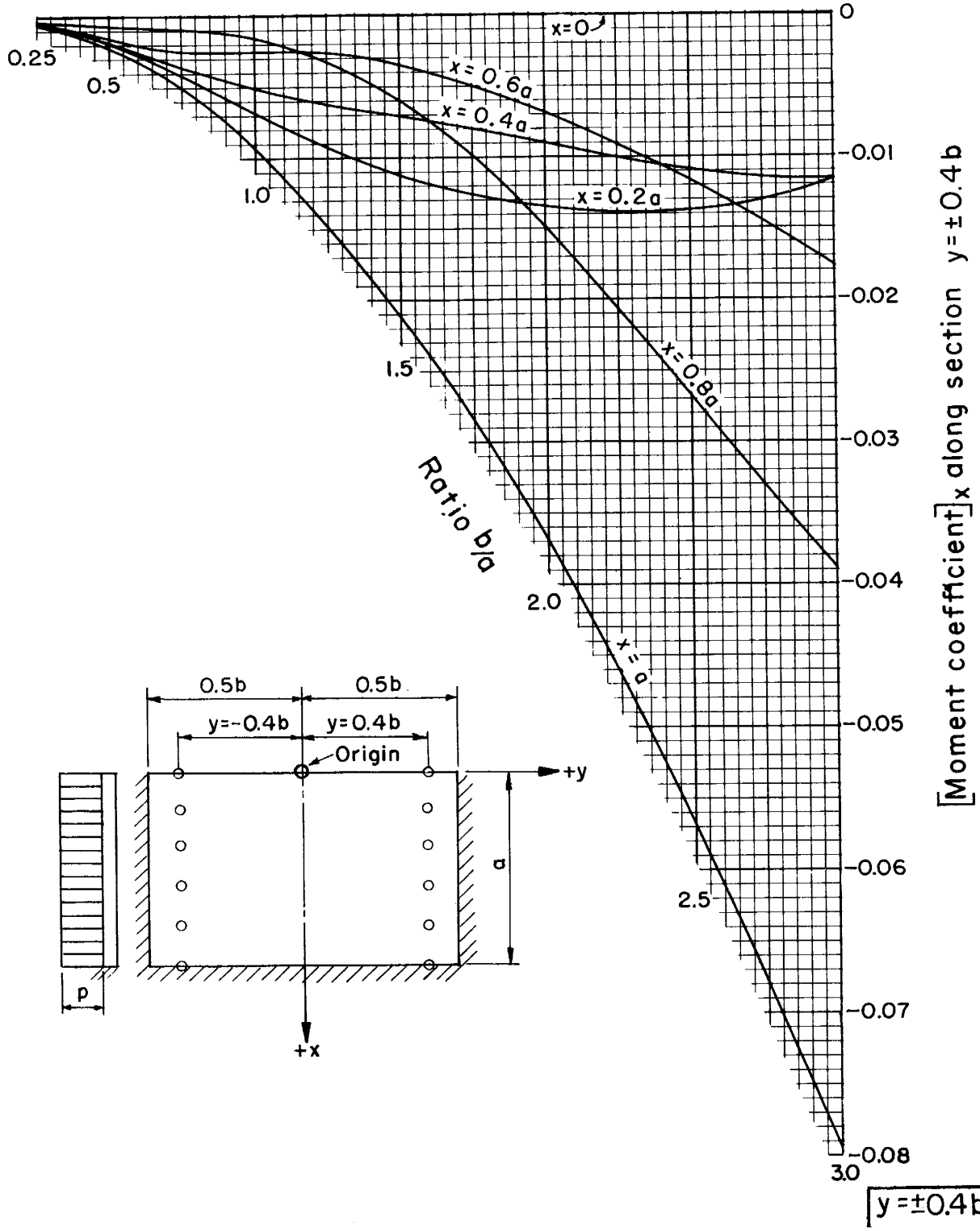
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.4b$

Vertical moment determines tension in vertical steel

$$M_x = [\text{Moment coefficient}]_x \, pa^2$$



$y = \pm 0.4b$

REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

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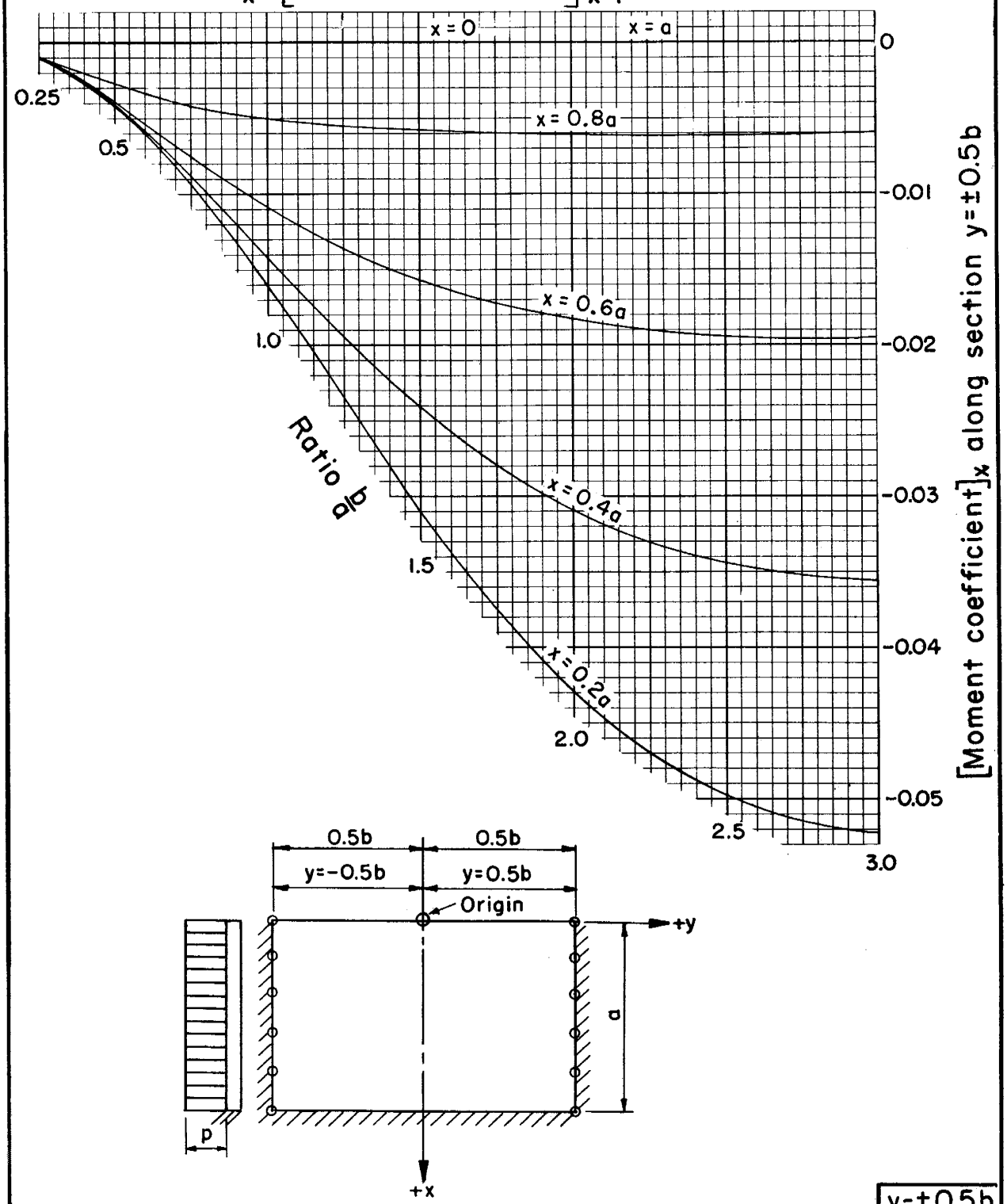
STRUCTURAL DESIGN : Rectangular slabs with uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.5b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \times pa^2$



$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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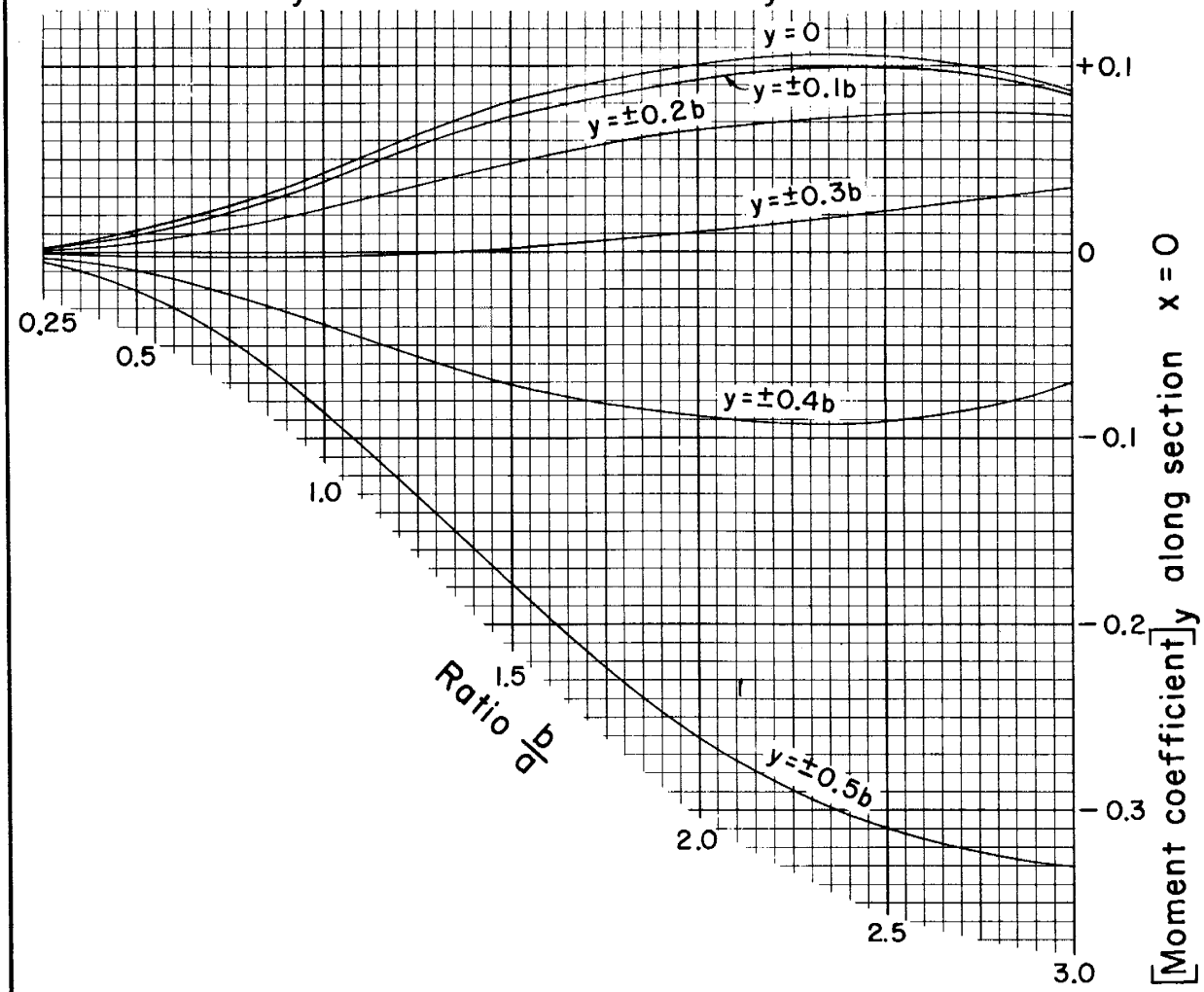
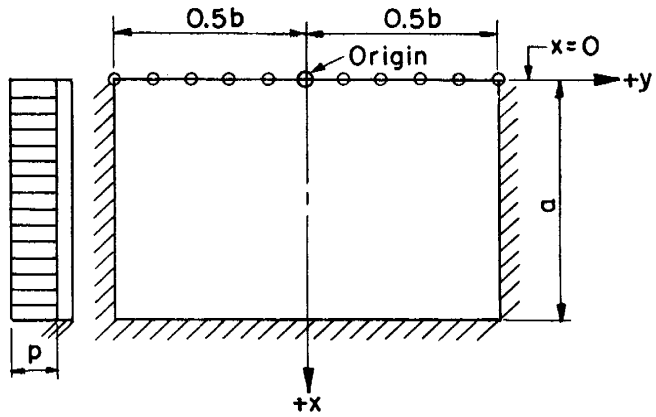
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$





x = 0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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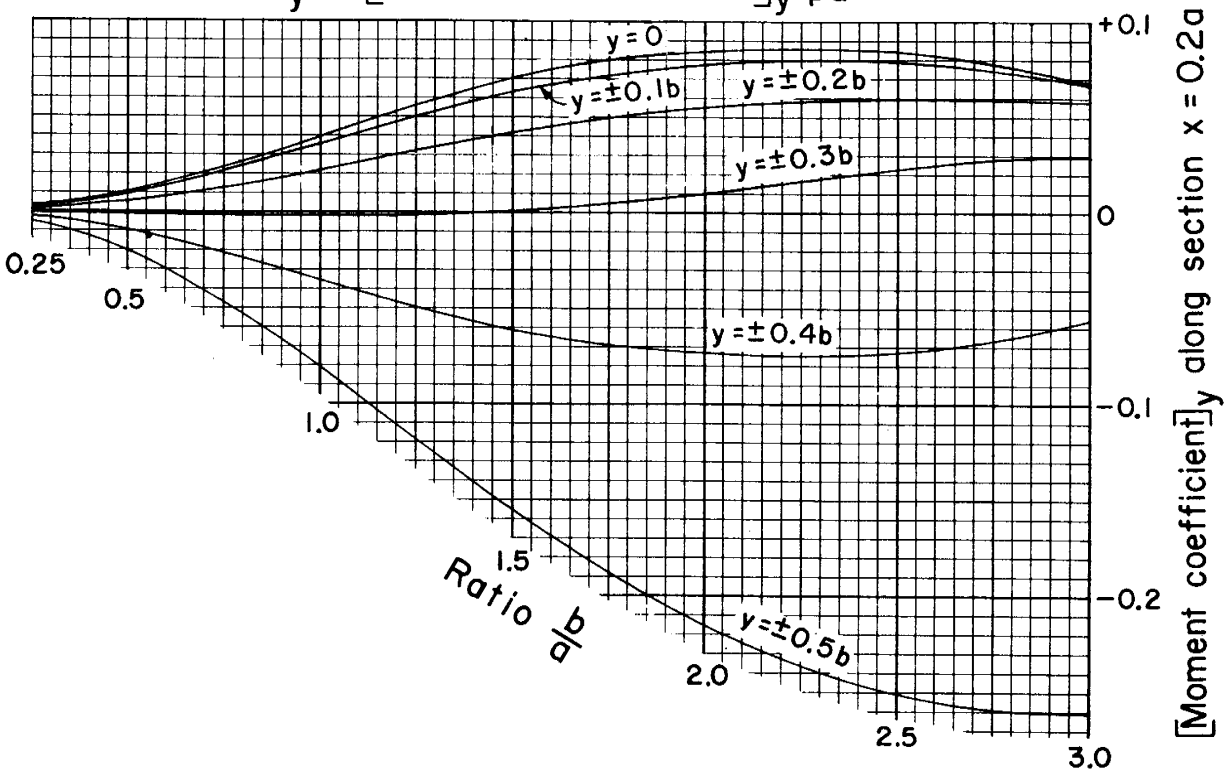
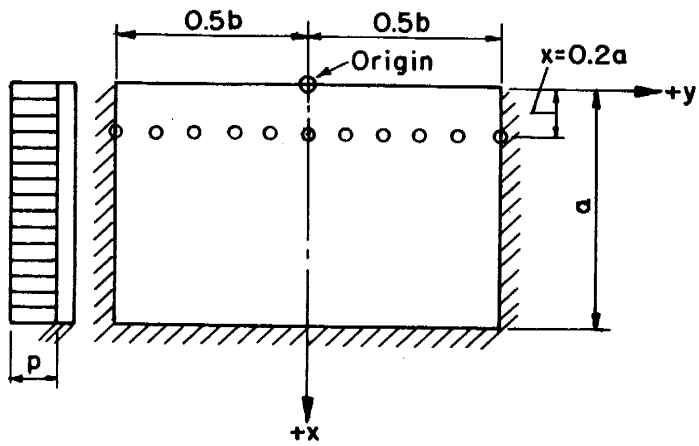
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.2a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2





x = 0.2a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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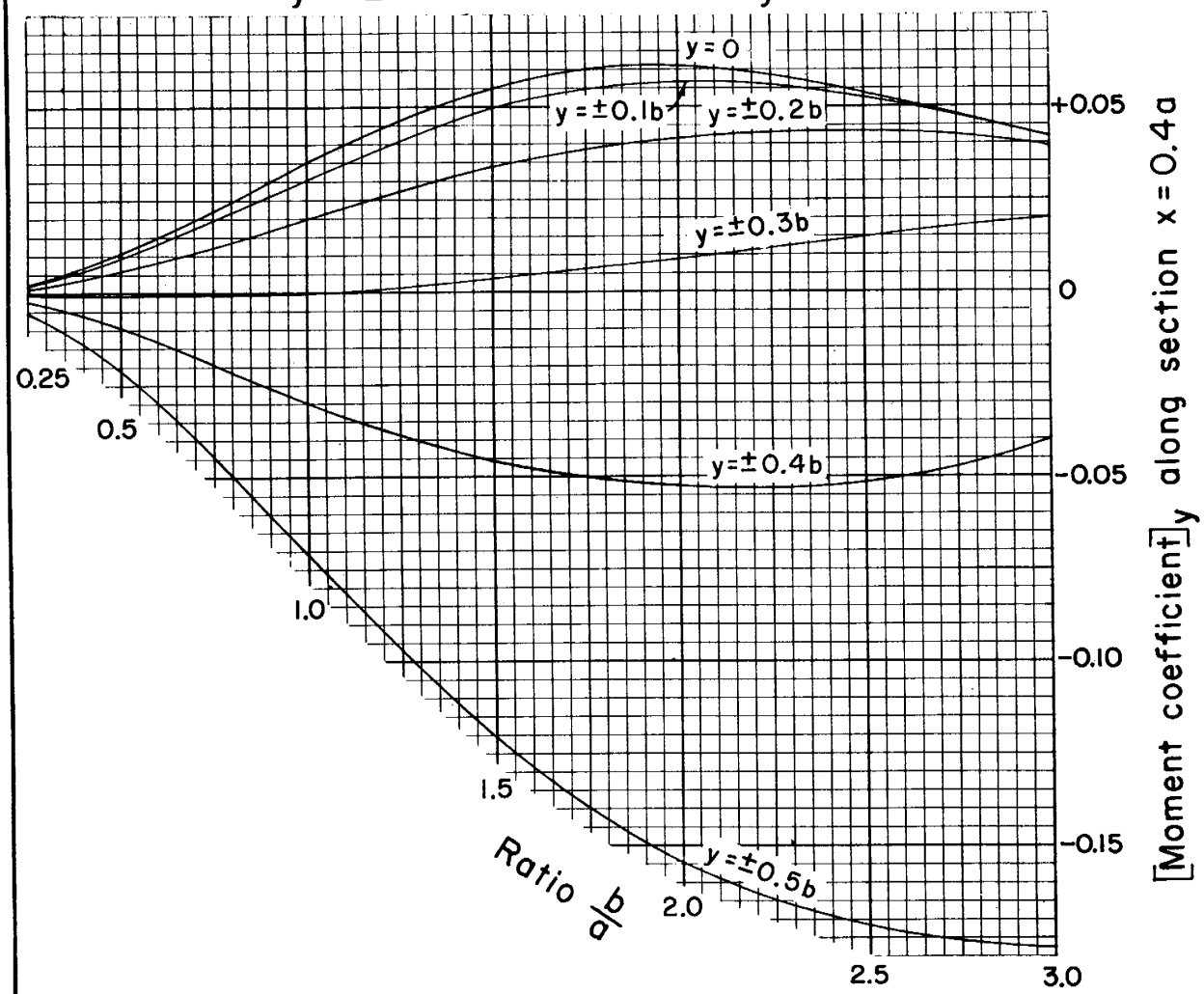
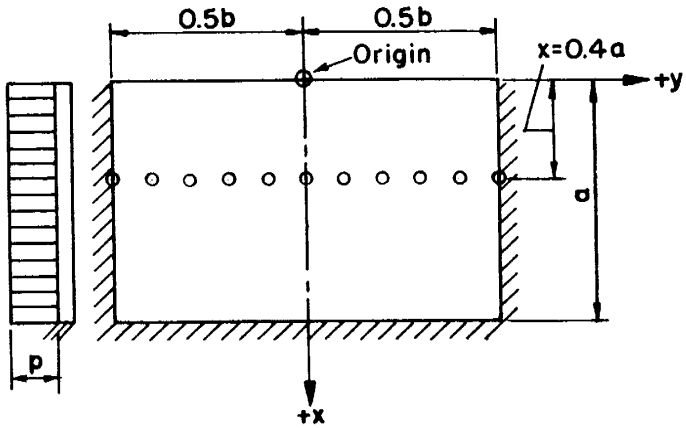
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice $x = 0.4a$

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$





$x = 0.4a$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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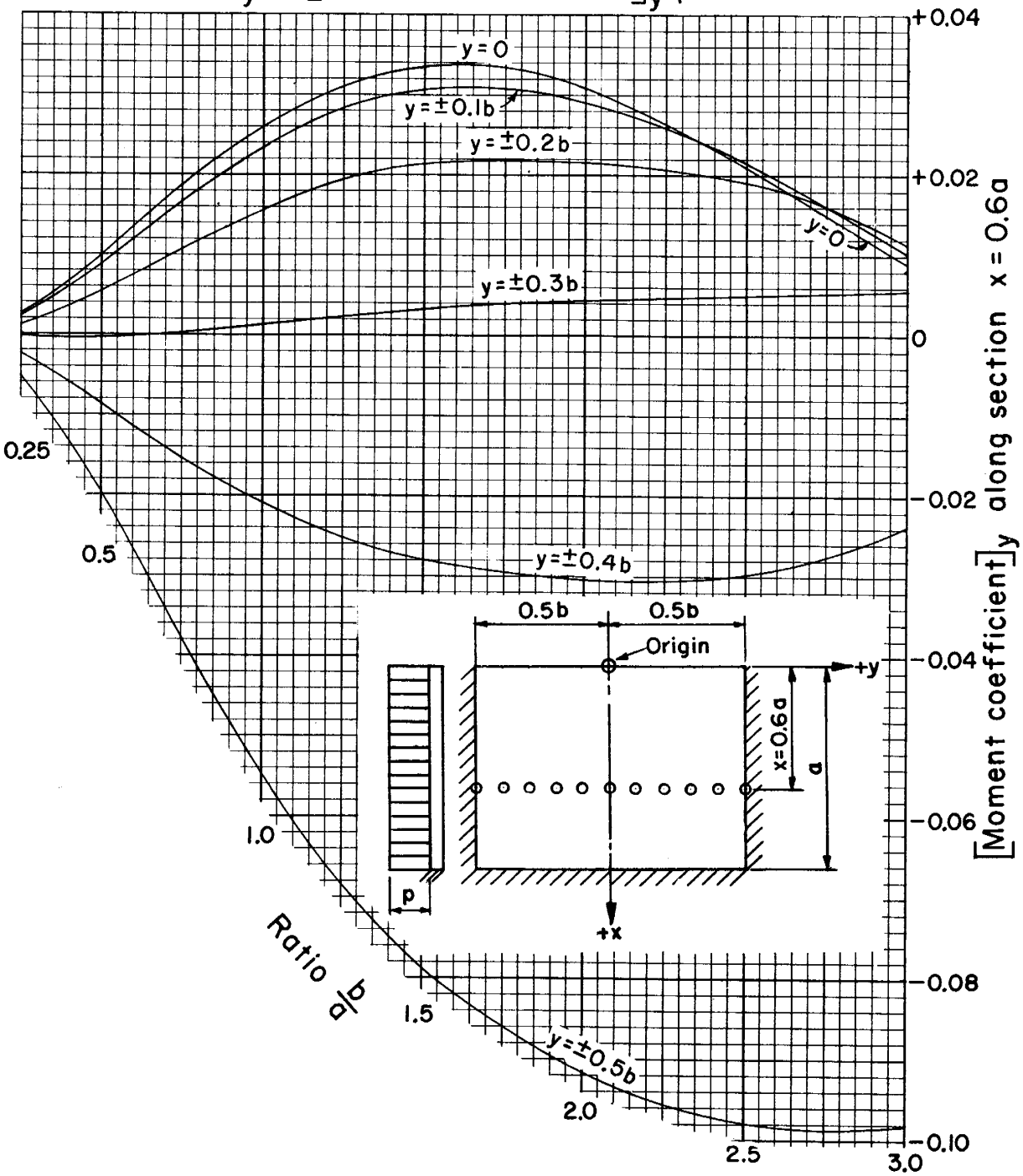
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice $x = 0.6a$

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$



x = 0.6a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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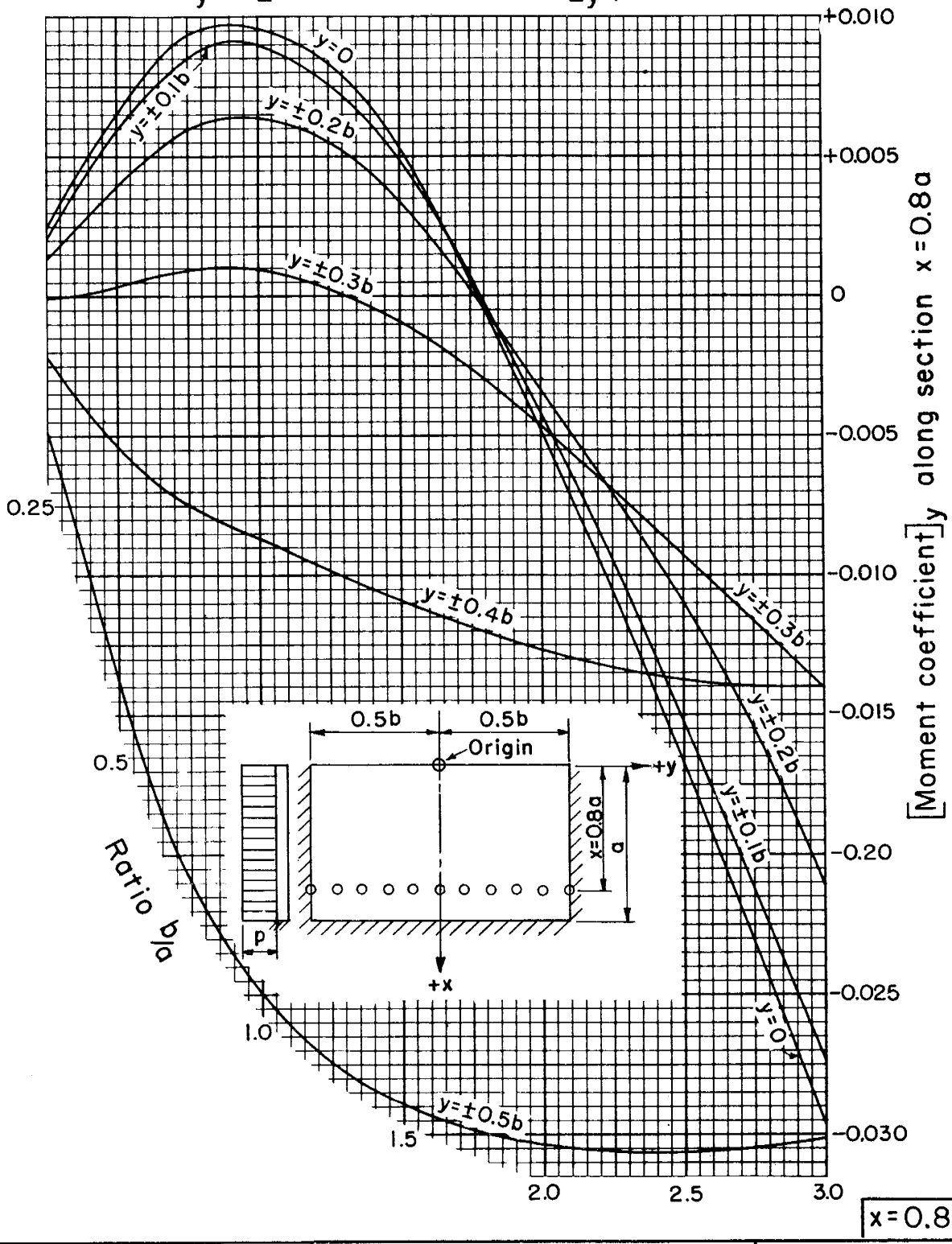
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice $x = 0.8a$

Horizontal moment determines tension in horizontal steel

$M_y = [\text{Moment coefficient}]_y \, pa^2$



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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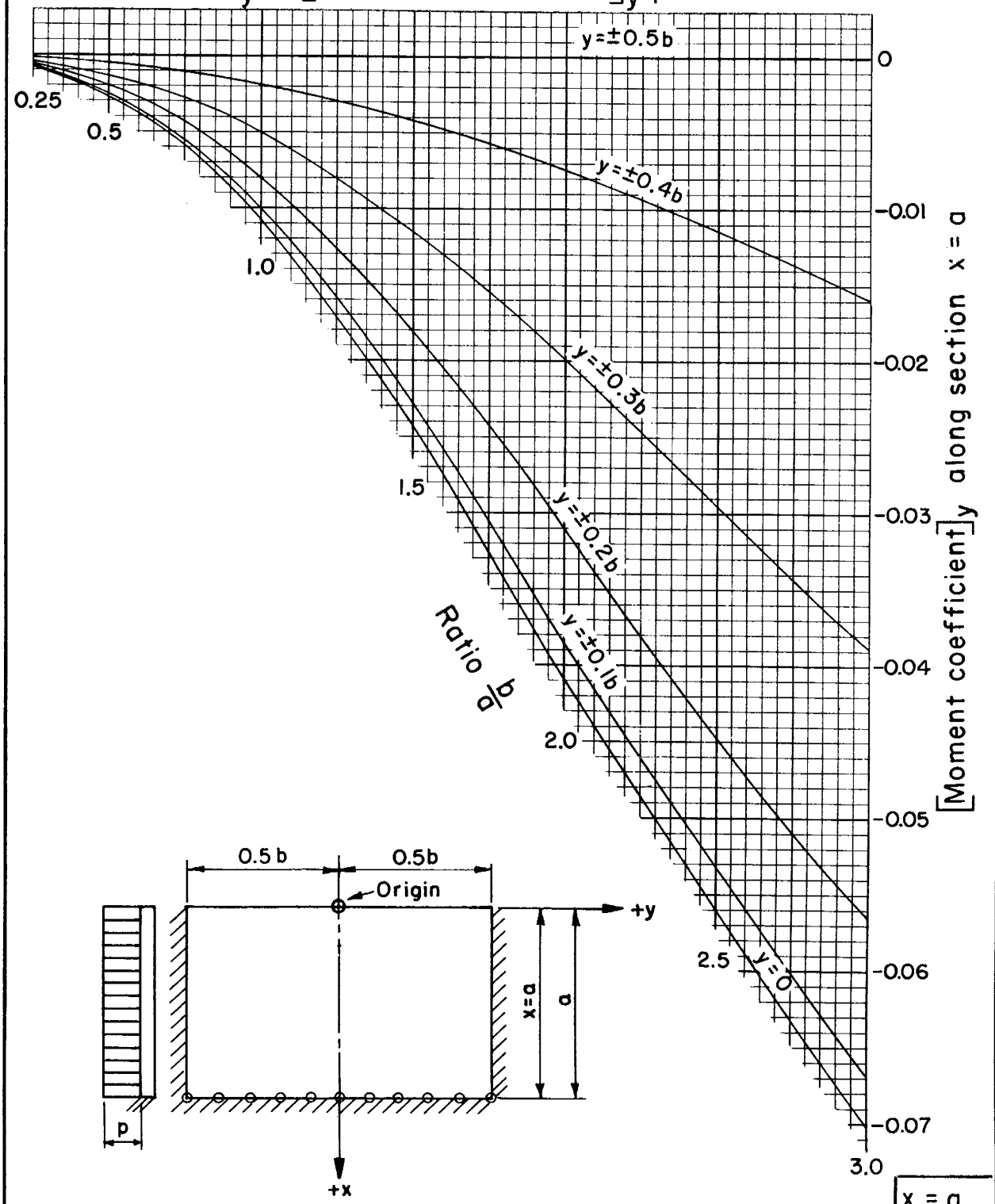
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2



x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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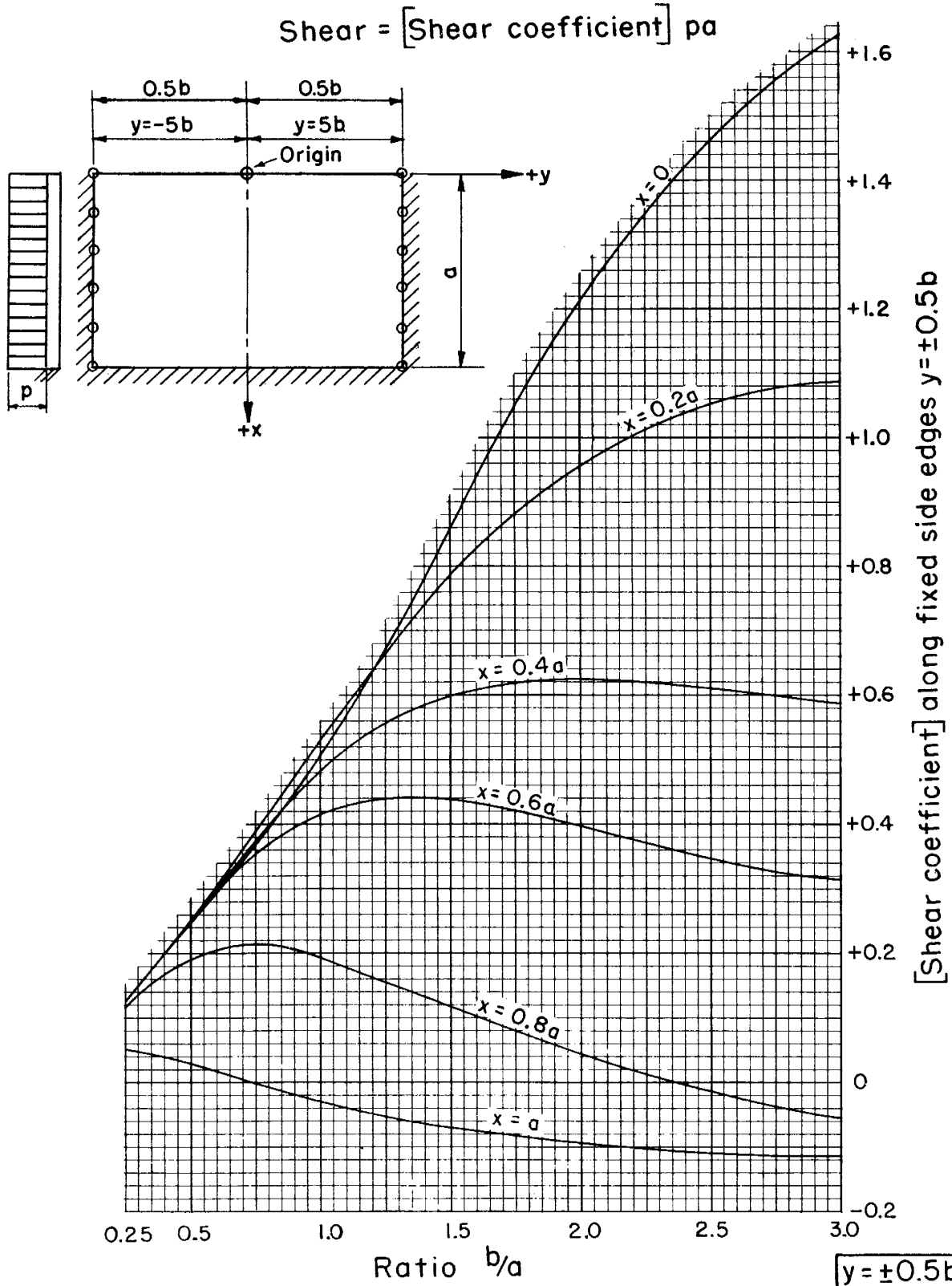
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for shear at fifth points on fixed side edges $y = \pm 0.5b$



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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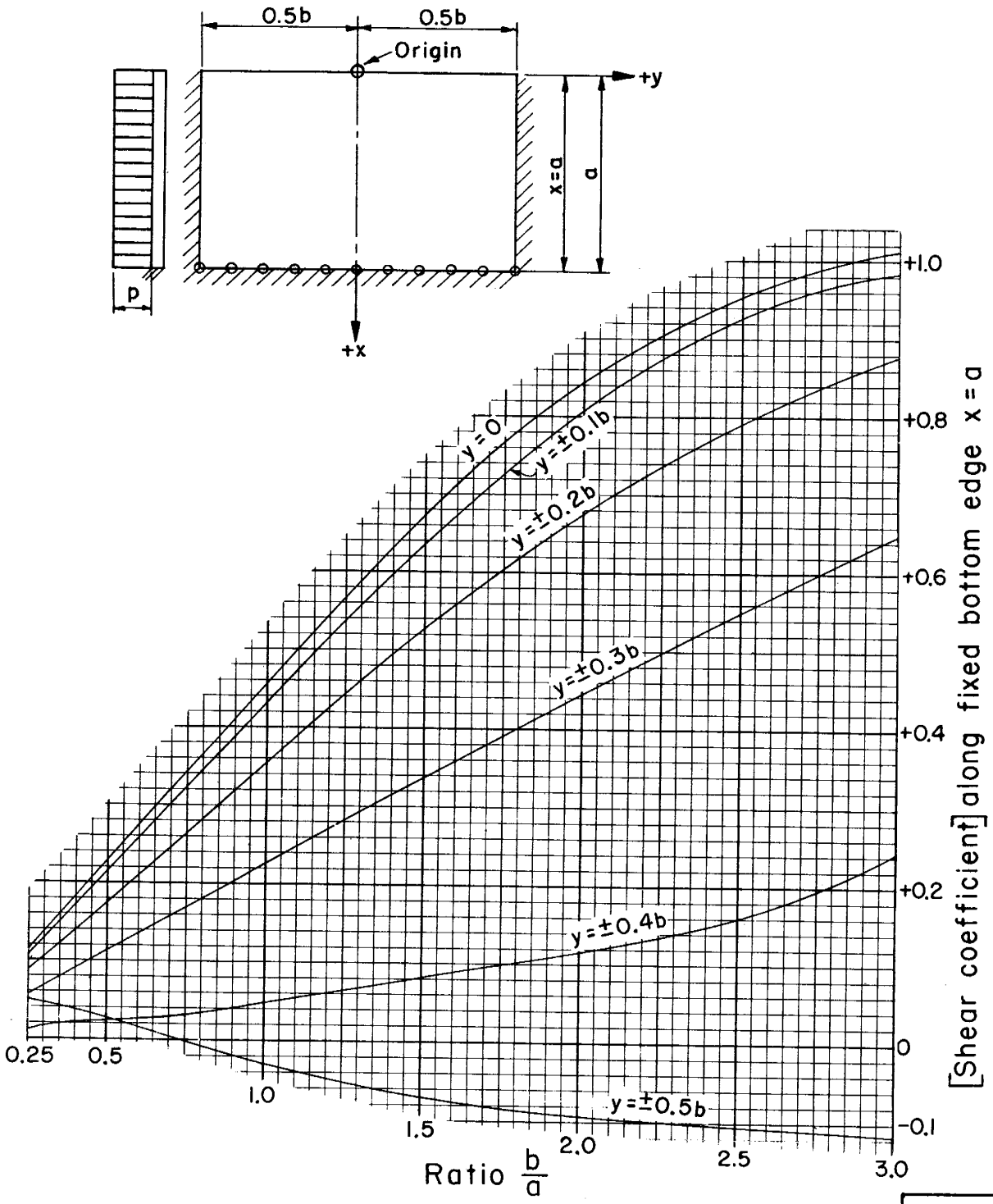
STRUCTURAL DESIGN: Rectangular slabs with uniform load; coefficients for shear at tenth points on fixed bottom edge x = a

Shear = [Shear coefficient] pa



x = a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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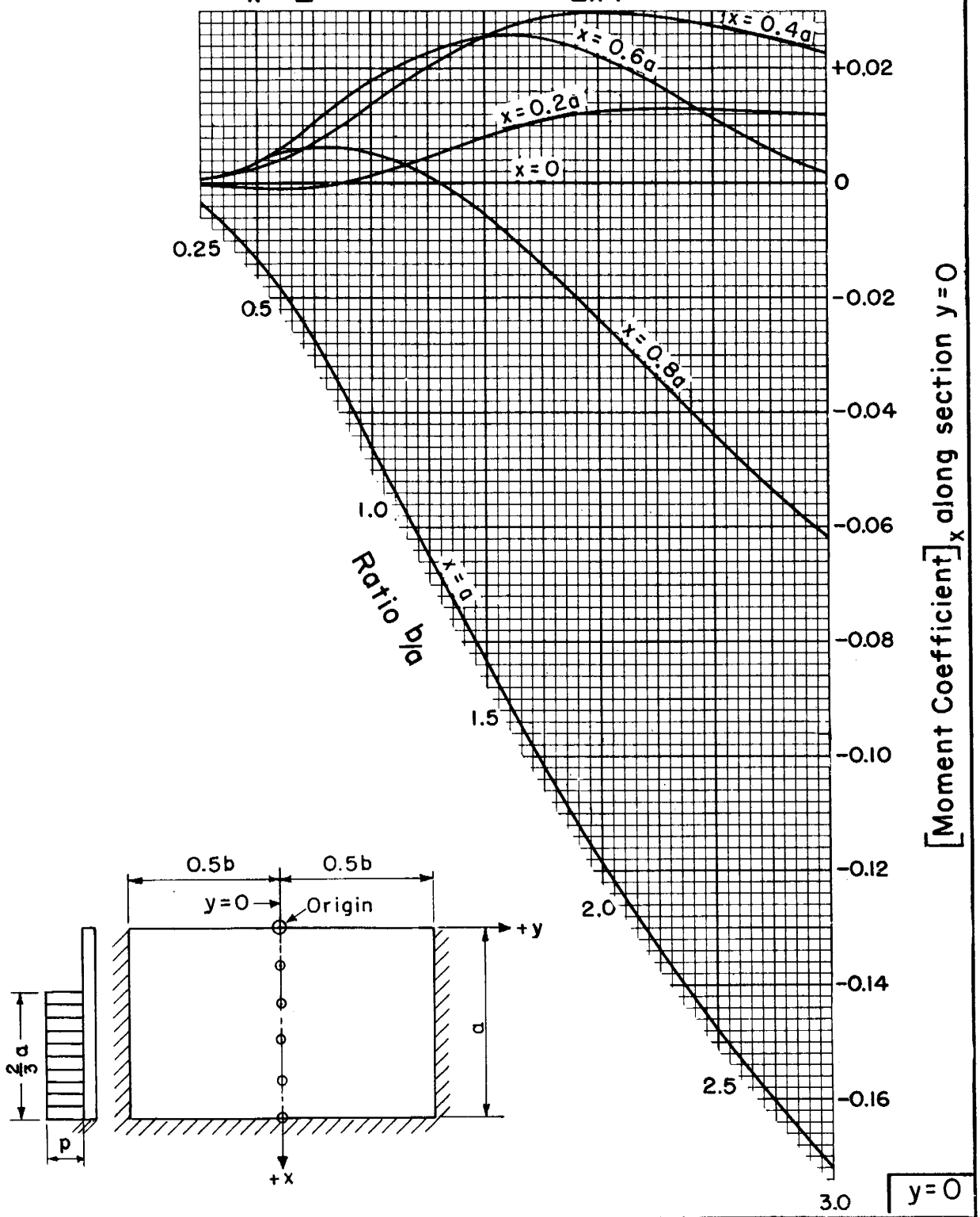
STRUCTURAL DESIGN: Rectangular slabs with $\frac{2}{3}$ uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = 0$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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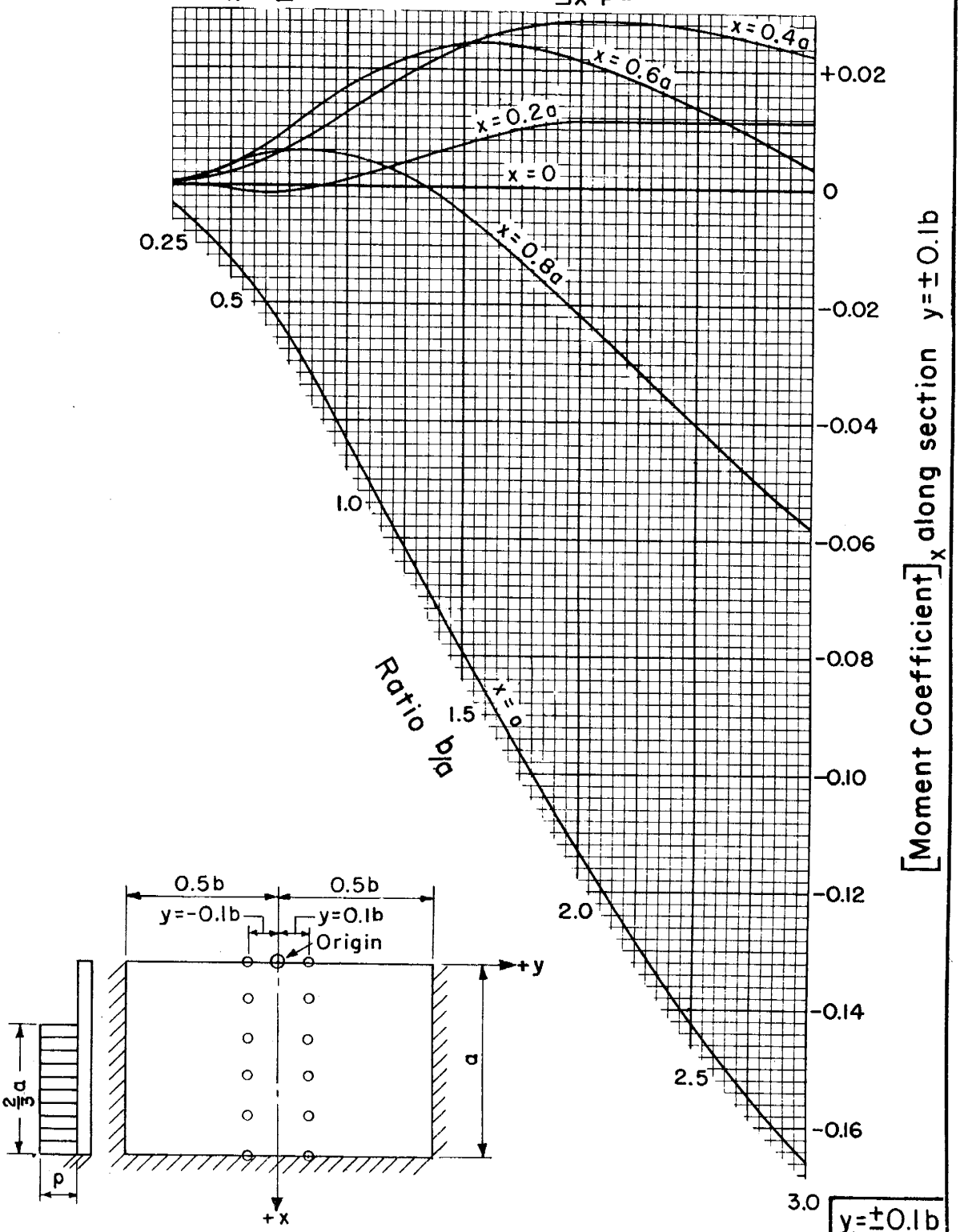
STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.1b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

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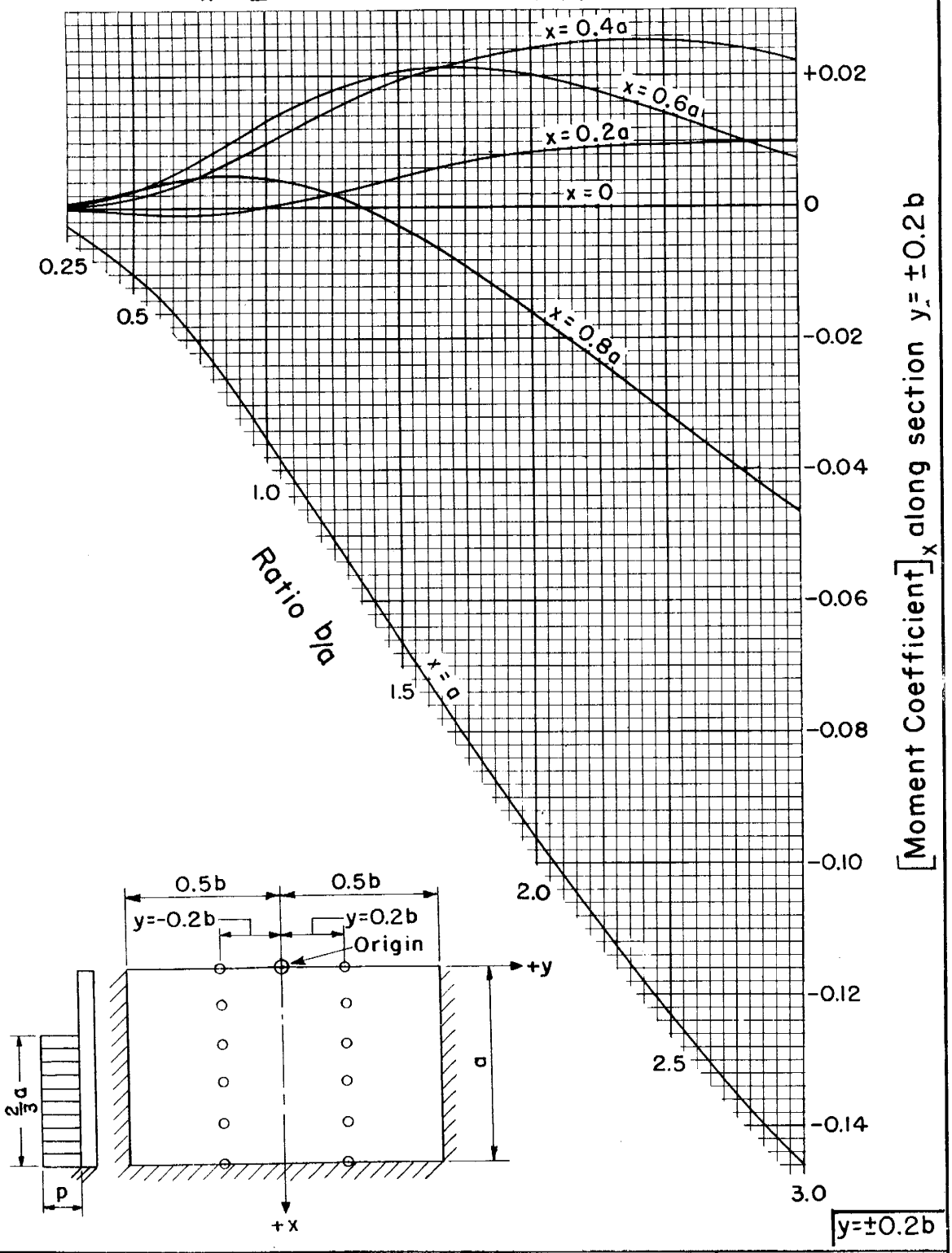
STRUCTURAL DESIGN: Rectangular slabs with $\frac{2}{3}$ uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.2b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



REFERENCE

U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

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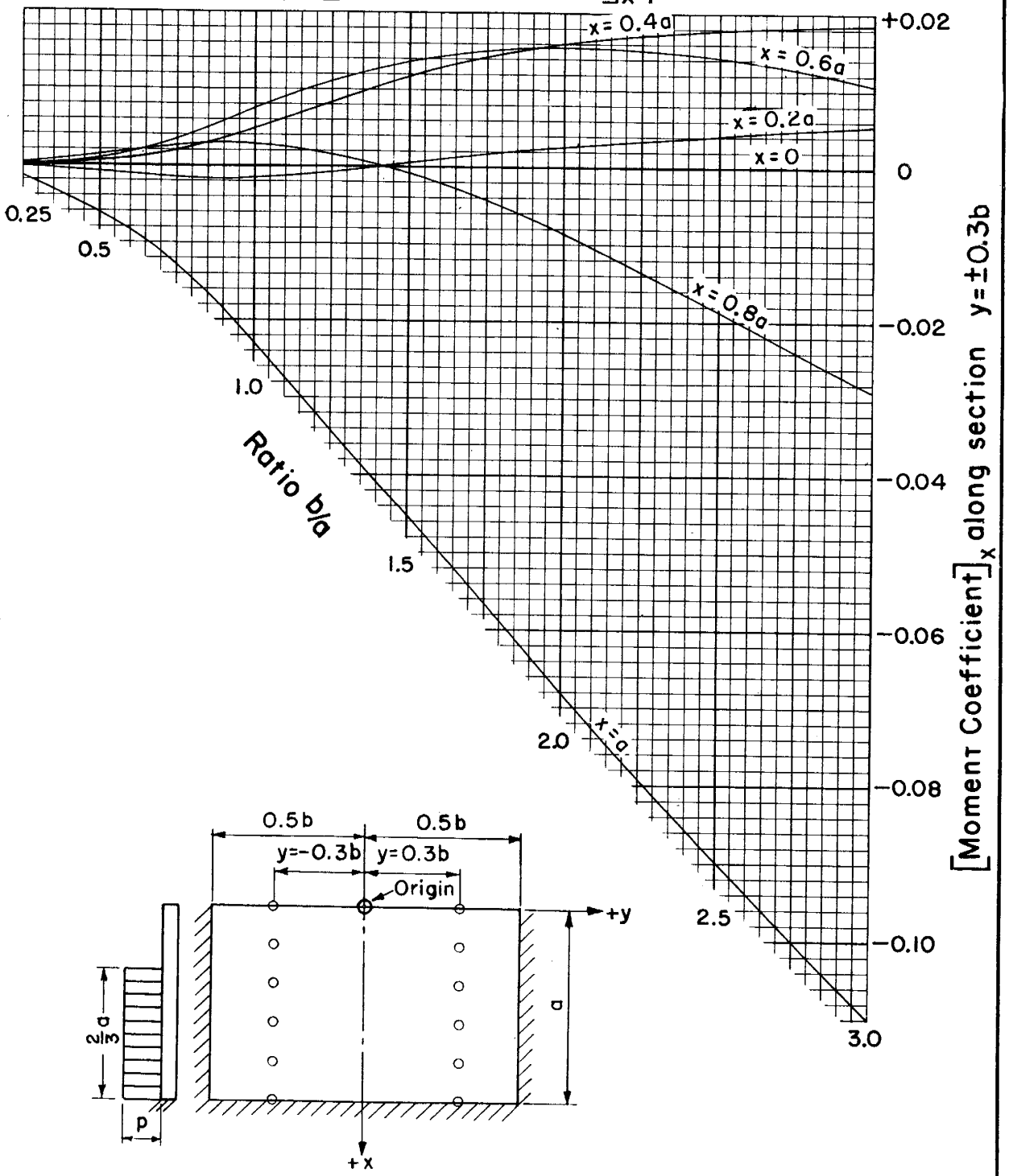
STRUCTURAL DESIGN: Rectangular slabs with $\frac{2}{3}$ uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.3b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



$y = \pm 0.3b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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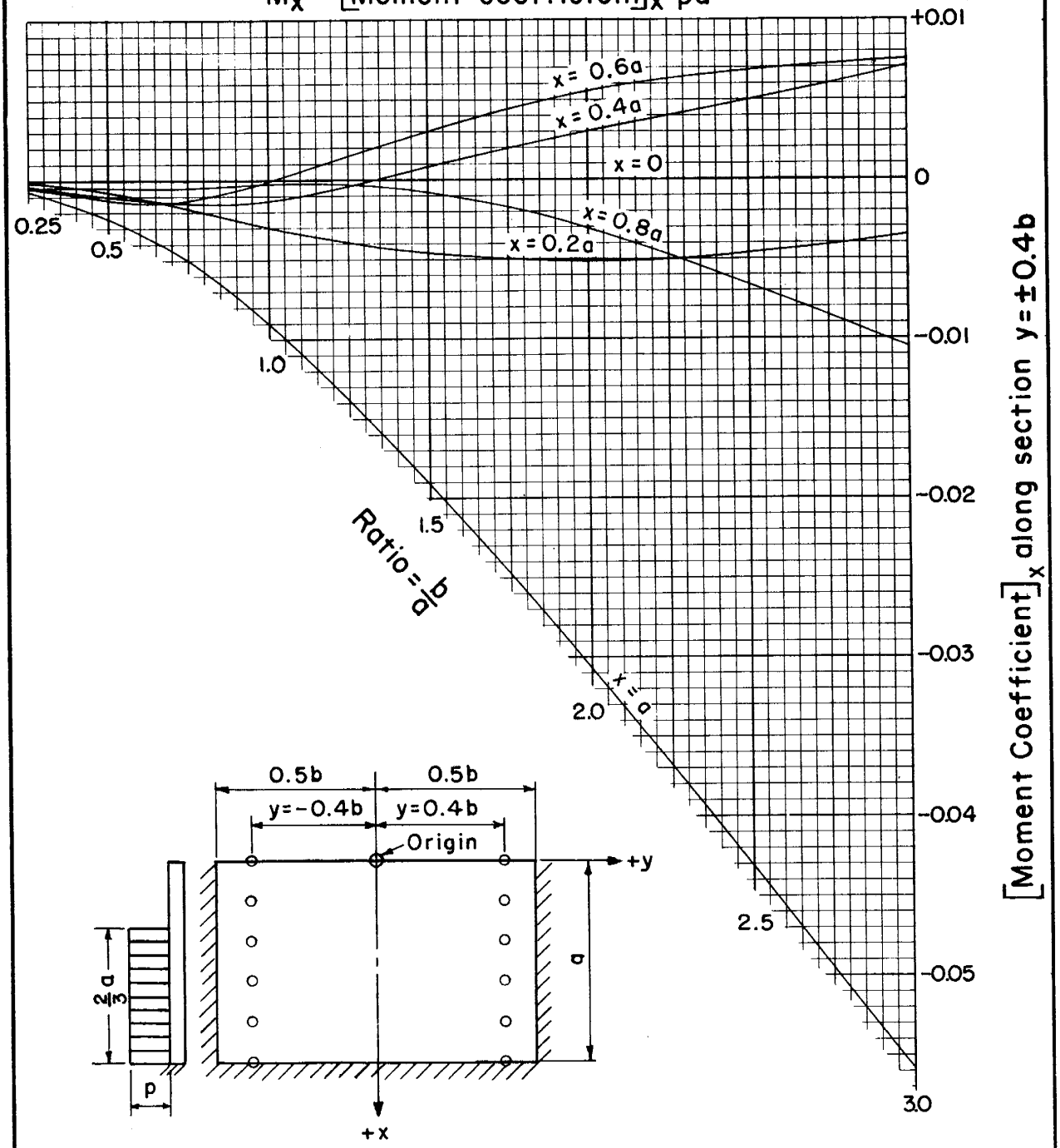
STRUCTURAL DESIGN: Rectangular slabs with $\frac{2}{3}$ uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.4b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



$y = \pm 0.4b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
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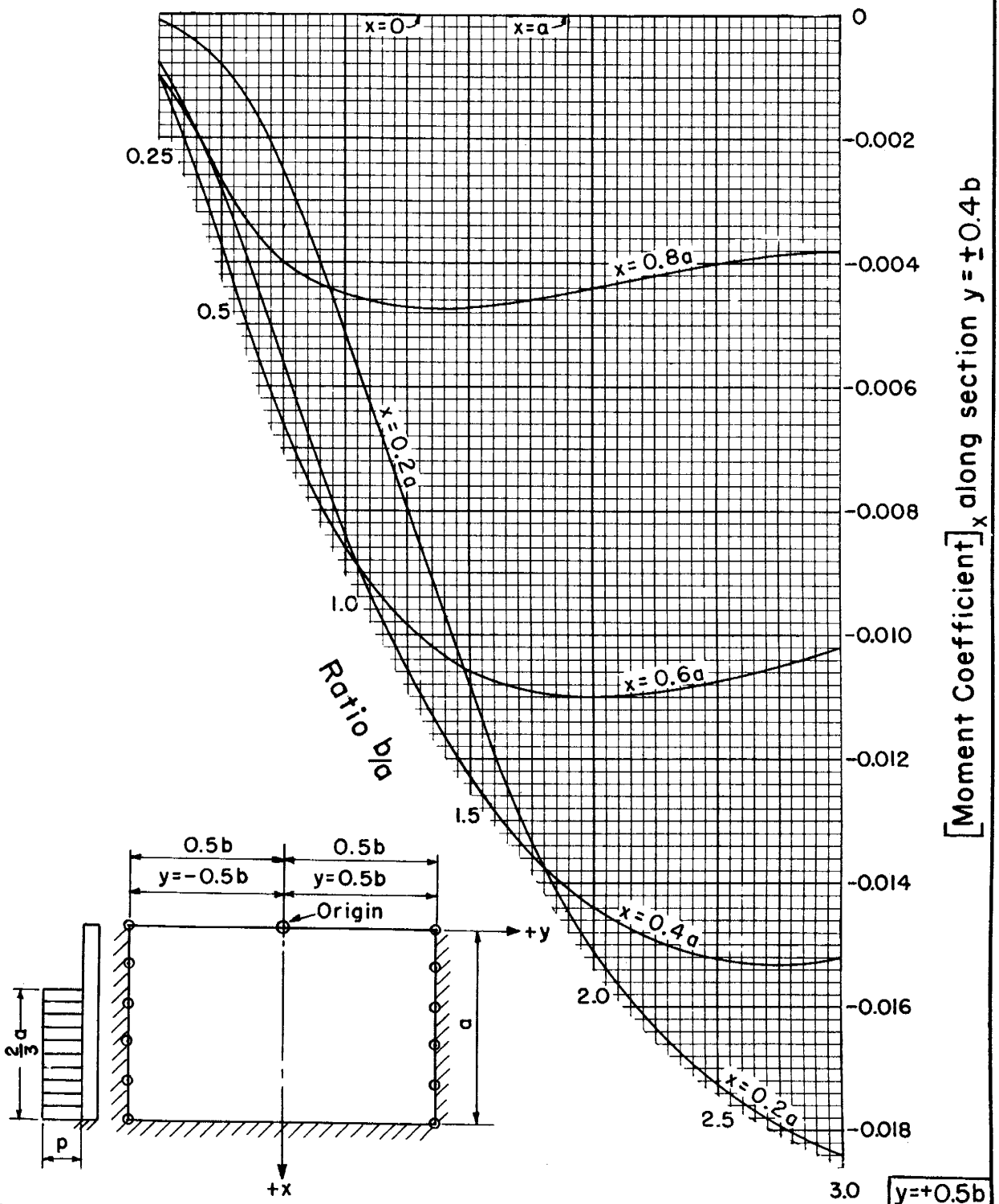
STRUCTURAL DESIGN: Rectangular slabs with $\frac{2}{3}$ uniform load; coefficients for vertical moment, M_x, at fifth points on vertical slice $y = \pm 0.5b$

Vertical moment determines tension in vertical steel

$M_x = [\text{Moment coefficient}]_x \, pa^2$



REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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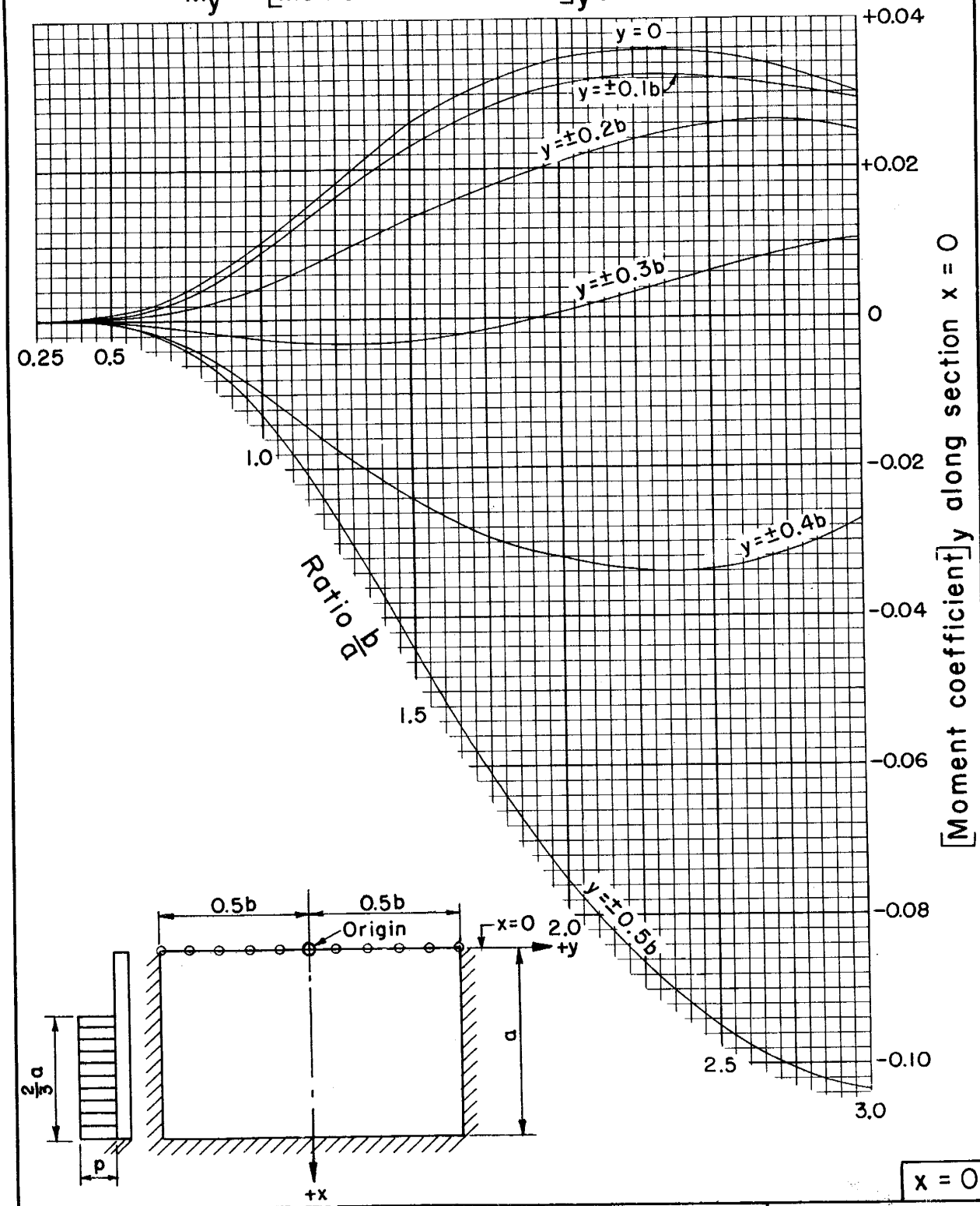
STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



x = 0

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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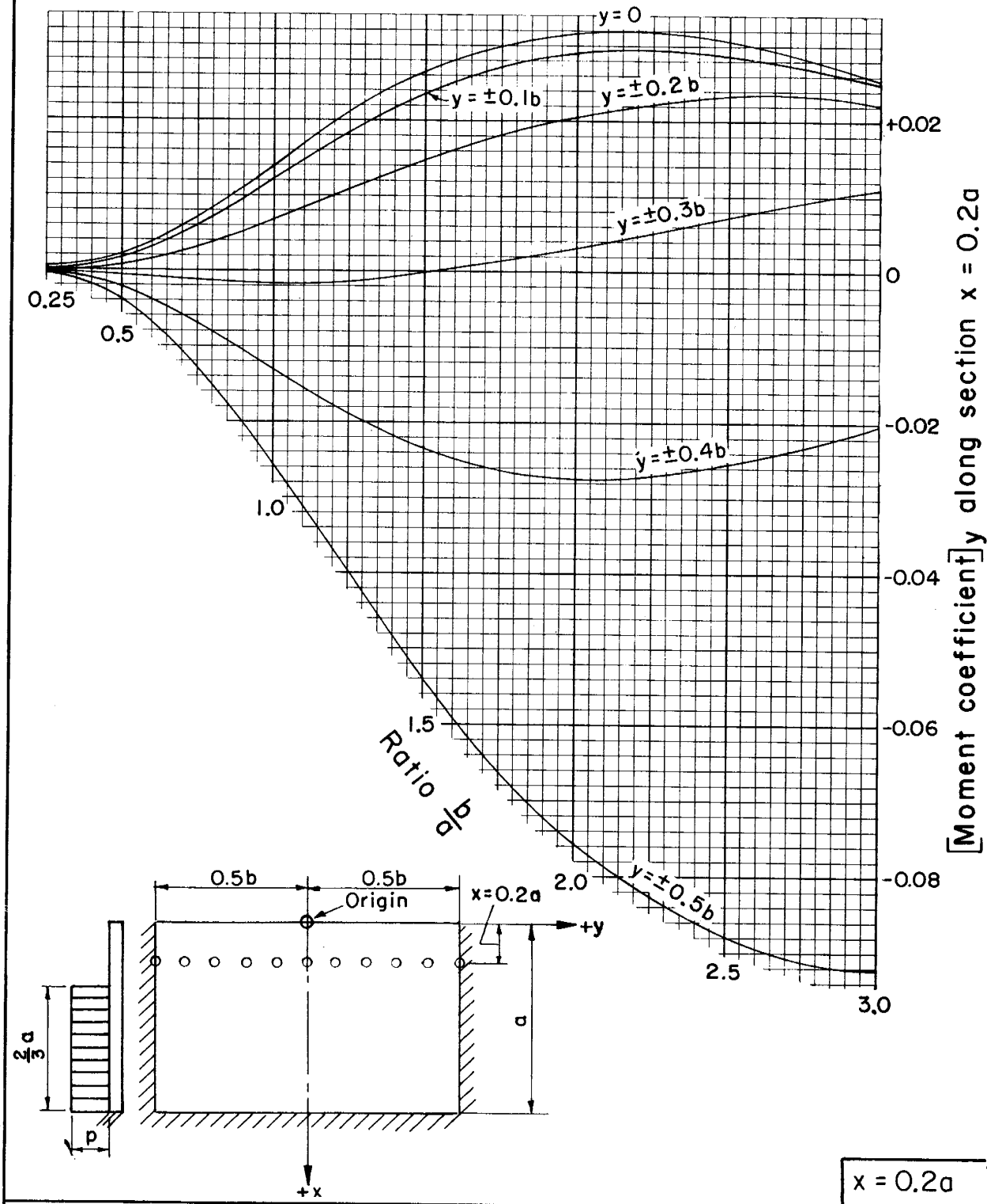
STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.2a

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



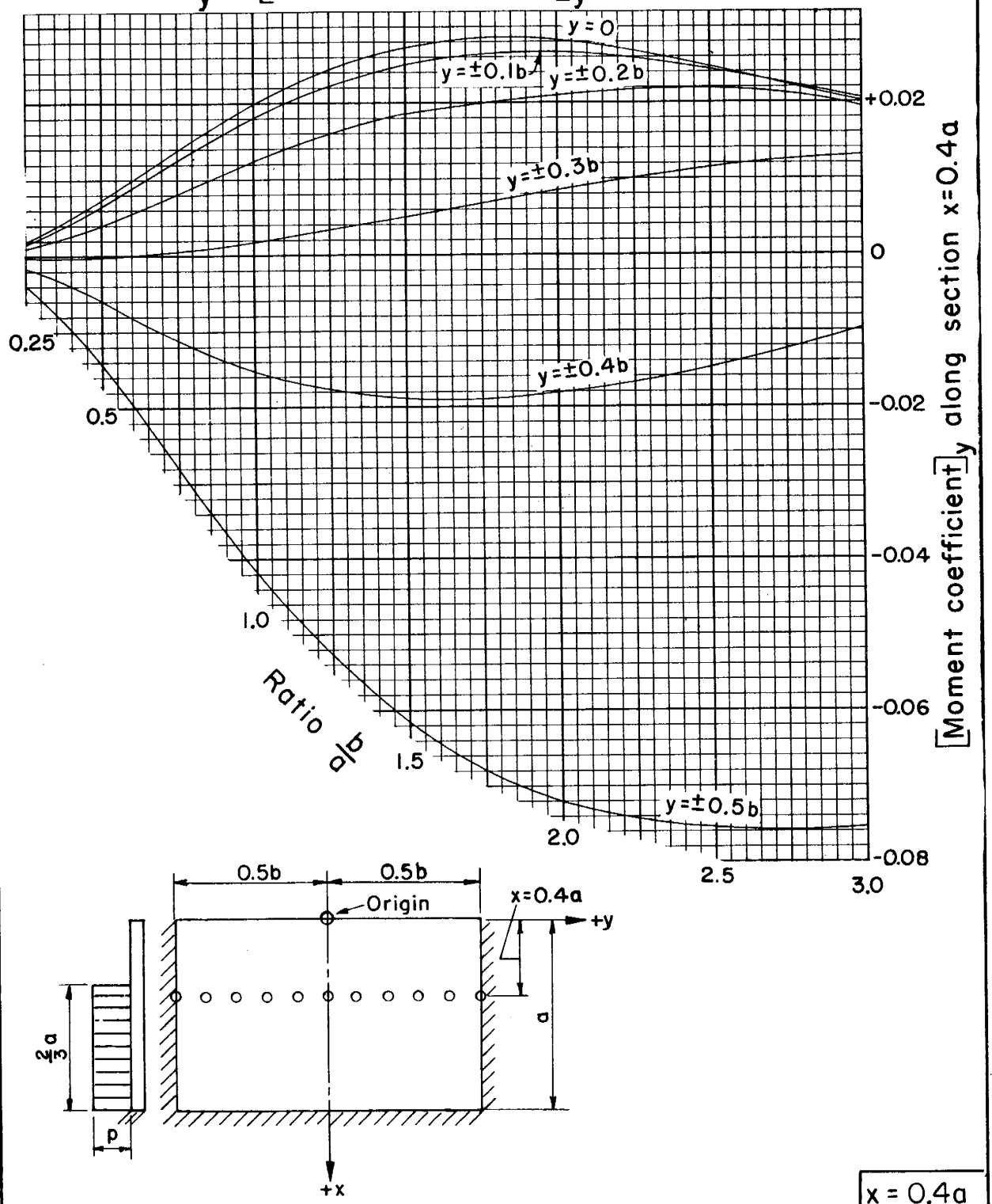
x = 0.2a

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 65 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.4a

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$



x = 0.4a

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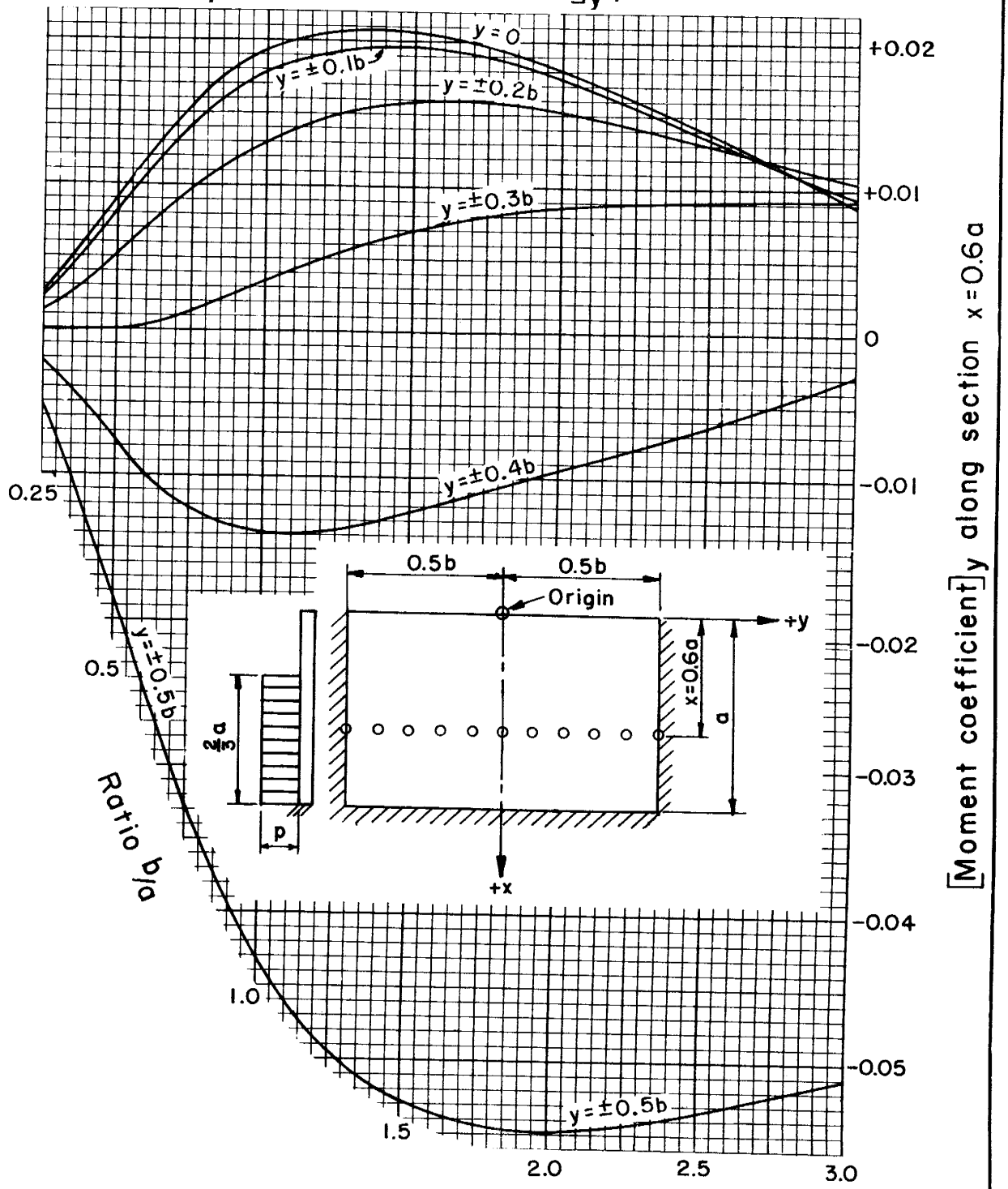
STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.6a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2



x = 0.6a

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
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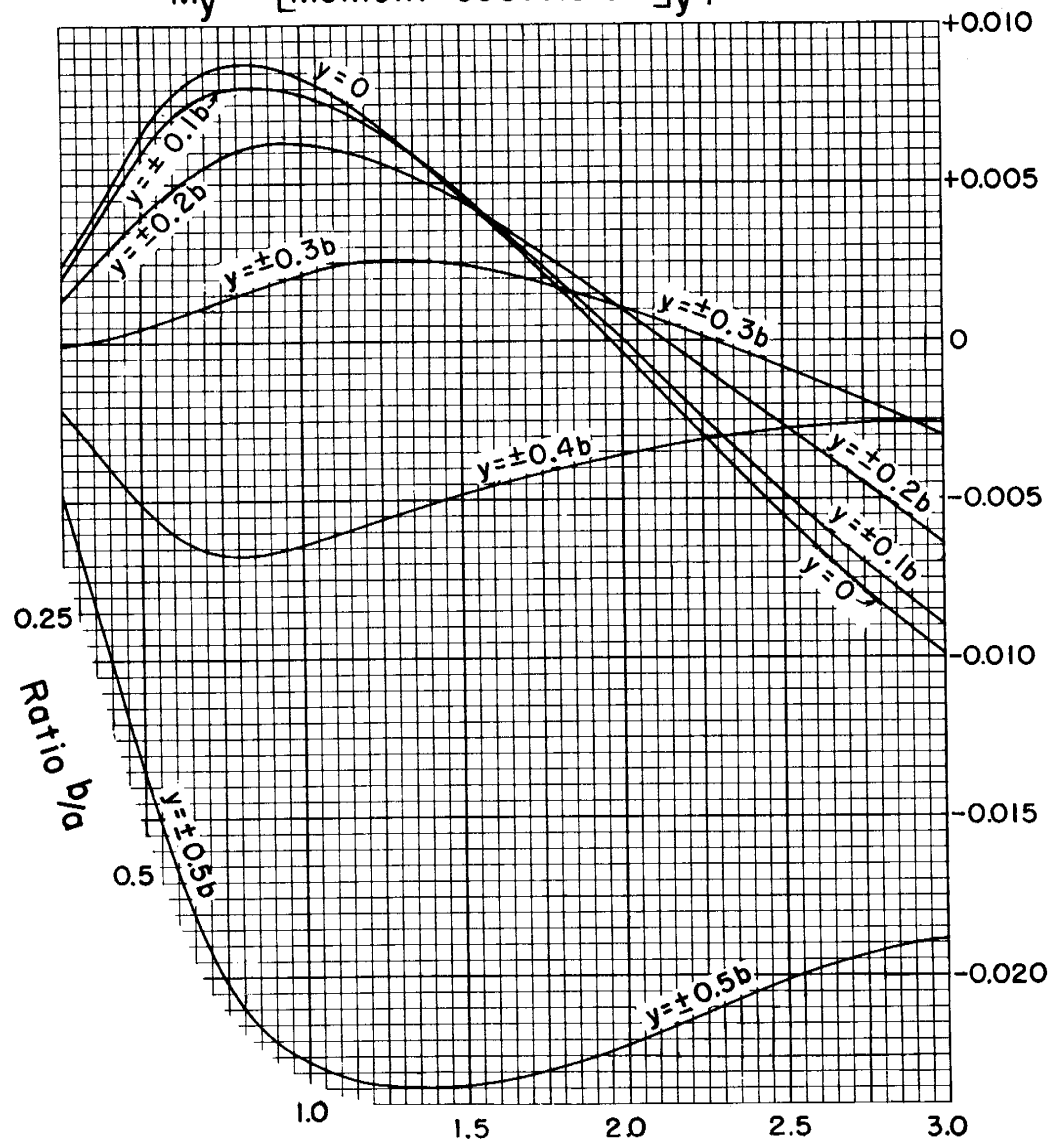
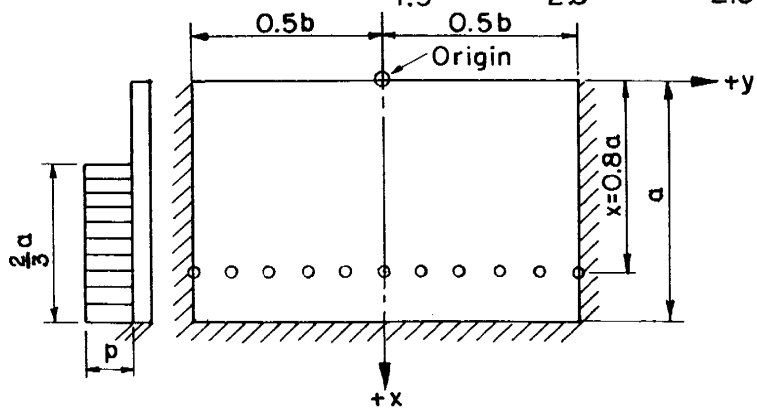
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 67 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = 0.8a

Horizontal moment determines tension in horizontal steel

M_y = [Moment coefficient]$_y$ pa^2





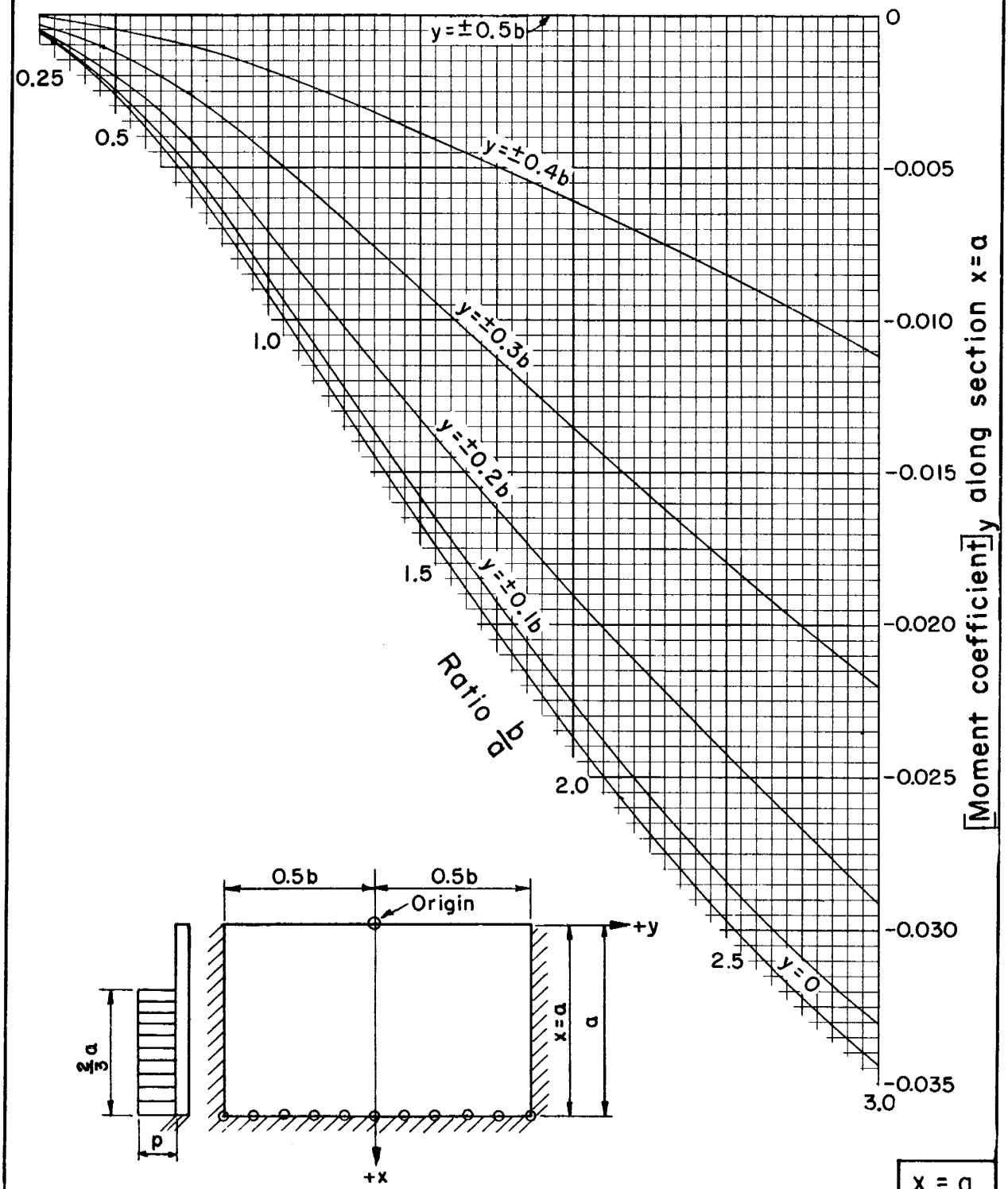
x=0.8a

REFERENCE Bureau of Reclamation photoelastic unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 68 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with $^2/_3$ uniform load; coefficients for horizontal moment, M_y, at tenth points on horizontal slice x = a

Horizontal moment determines tension in horizontal steel

$$M_y = [\text{Moment coefficient}]_y \, pa^2$$

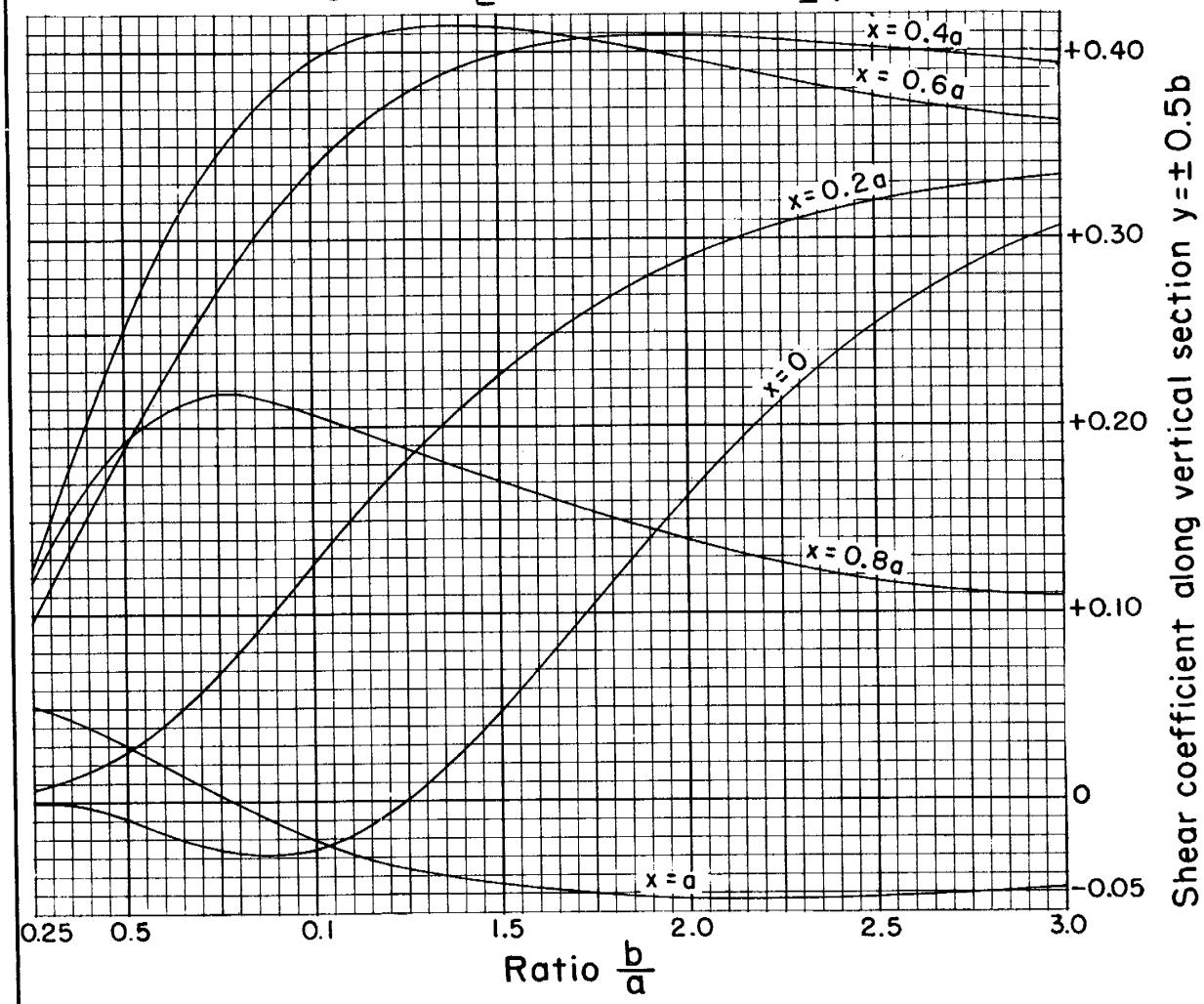


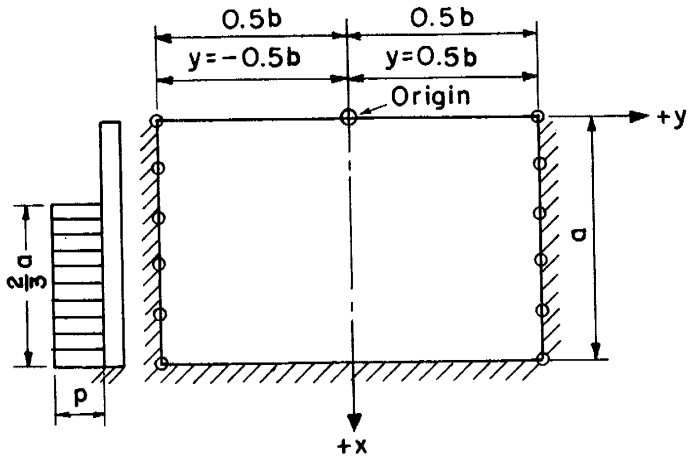
x = a

REFERENCE		
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 69 OF 85 DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; Coefficients for shear at fifth points on fixed side edges $y = \pm 0.5b$

Shear = [Shear coefficient] pa



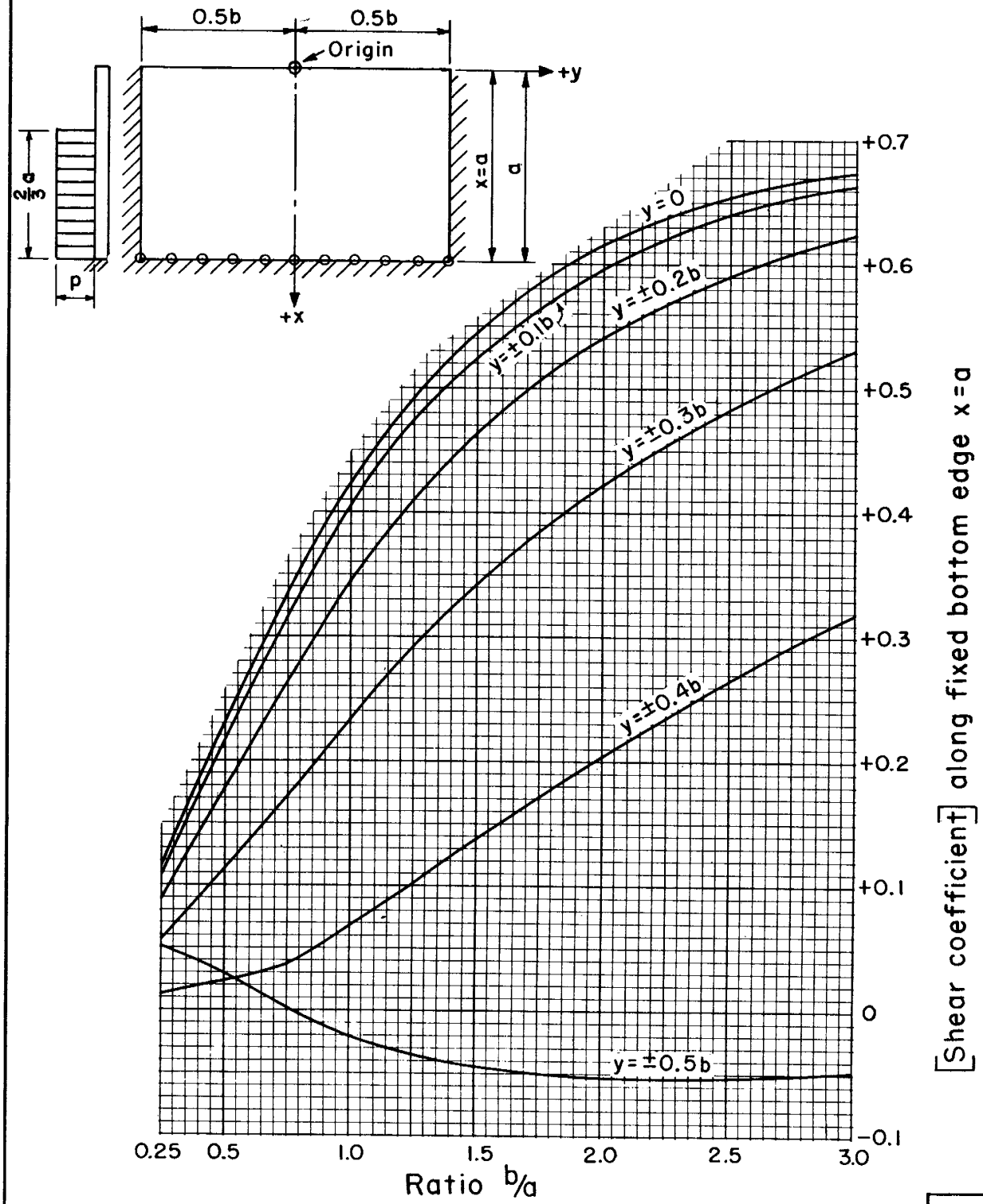


$y = \pm 0.5b$

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE	STANDARD DWG. NO.
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954	SOIL CONSERVATION SERVICE	ES-104
	ENGINEERING DIVISION - DESIGN SECTION	SHEET 70 OF 85
		DATE 8-1-55

STRUCTURAL DESIGN: Rectangular slabs with 2/3 uniform load; coefficients for shear at tenth points on fixed bottom edge x = a

Shear = [Shear coefficient] pa



x = a

REFERENCE
U. S. Bureau of Reclamation photoelastic analysis unit report No. 30, December 1954

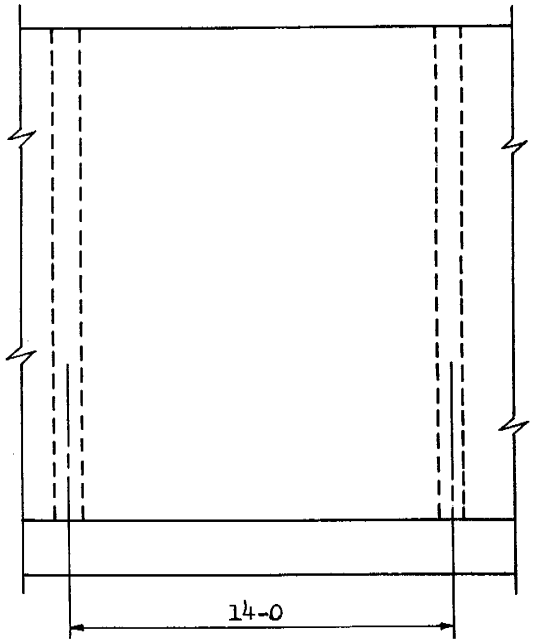
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-104
SHEET 71 OF 85
DATE 8-1-55

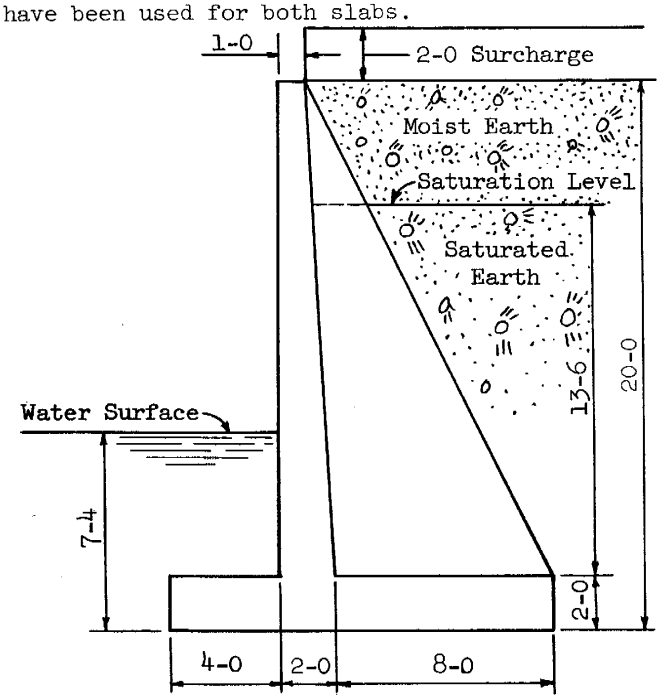
STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Dimensions and design loads

DESIGN EXAMPLE

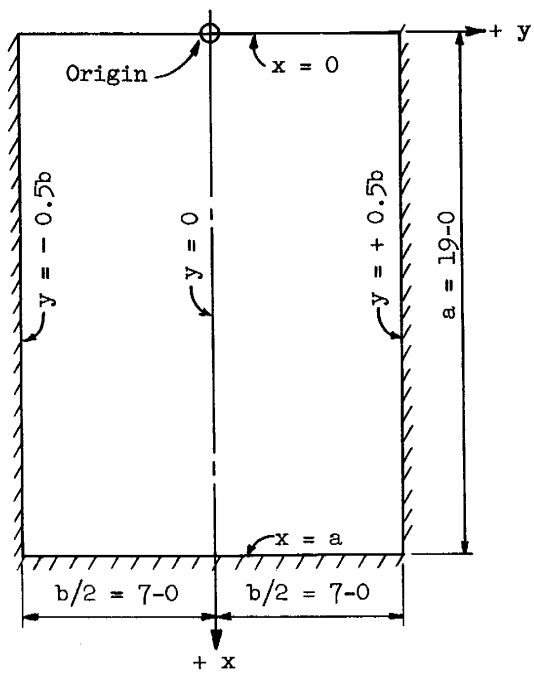
This is strictly an academic example and is only complete insofar as it illustrates the use of the Moment and Shear curves of ES-104. The following figure shows the essential dimensions and possible loads on the interior panel of a counterforted retaining wall. Both the wall slab and the heel slab approximate a plate fixed on three edges and free on the fourth. Center line dimensions have been used for both slabs.



FRONT ELEVATION



SIDE ELEVATION



IDEALIZED WALL SLAB DIMENSIONS

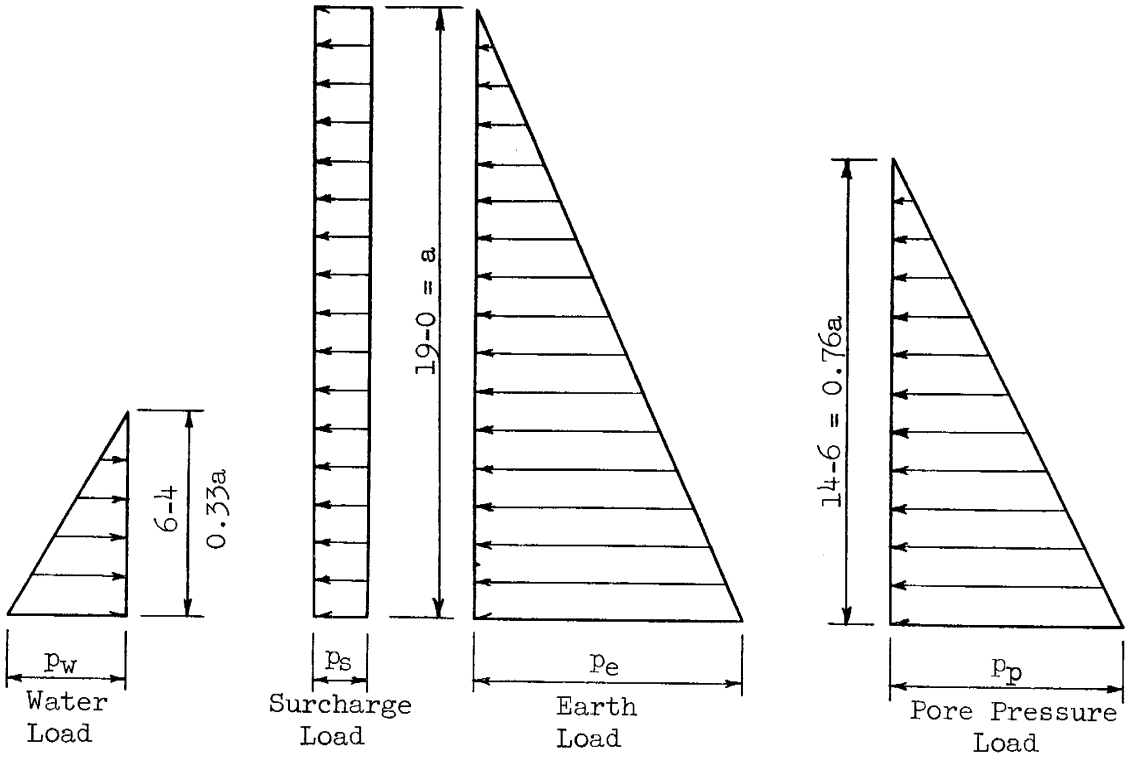
Unit Weights

Concrete	150 lbs/ft^3
Moist Earth	125 lbs/ft^3
Saturated Earth	140 lbs/ft^3
Water	62.4 lbs/ft^3

Equivalent Fluid Weights

Moist Earth	65 lbs/ft^3
Saturated Earth	85 lbs/ft^3

STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Component wall slab loads



COMPONENT WALL SLAB LOADS

$p_w = wh = (62.4)(6.33) = 395 \text{ lbs/ft}^2$

$p_s = wh = (65)(2) = 130 \text{ lbs/ft}^2$

$p_e = wh = (65)(19) = 1235 \text{ lbs/ft}^2$

$p_p = wh = (20)(14.5) = 290 \text{ lbs/ft}^2$

$p_w a = (0.395)(19) = 7.5 \text{ kips/ft}$

$p_s a = (0.130)(19) = 2.5 \text{ kips/ft}$

$p_e a = (1.235)(19) = 23.5 \text{ kips/ft}$

$p_p a = (0.290)(19) = 5.5 \text{ kips/ft}$

$p_w a^2 = (0.395)(19)^2 = 142.6 \text{ ft kips/ft}$

$p_s a^2 = (0.130)(19)^2 = 46.9 \text{ ft kips/ft}$

$p_e a^2 = (1.235)(19)^2 = 445.8 \text{ ft kips/ft}$

$p_p a^2 = (0.290)(19)^2 = 104.7 \text{ ft kips/ft}$

$\frac{b}{a} = \frac{14}{19} = 0.737$

STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Vertical moments (M_x) in wall slab

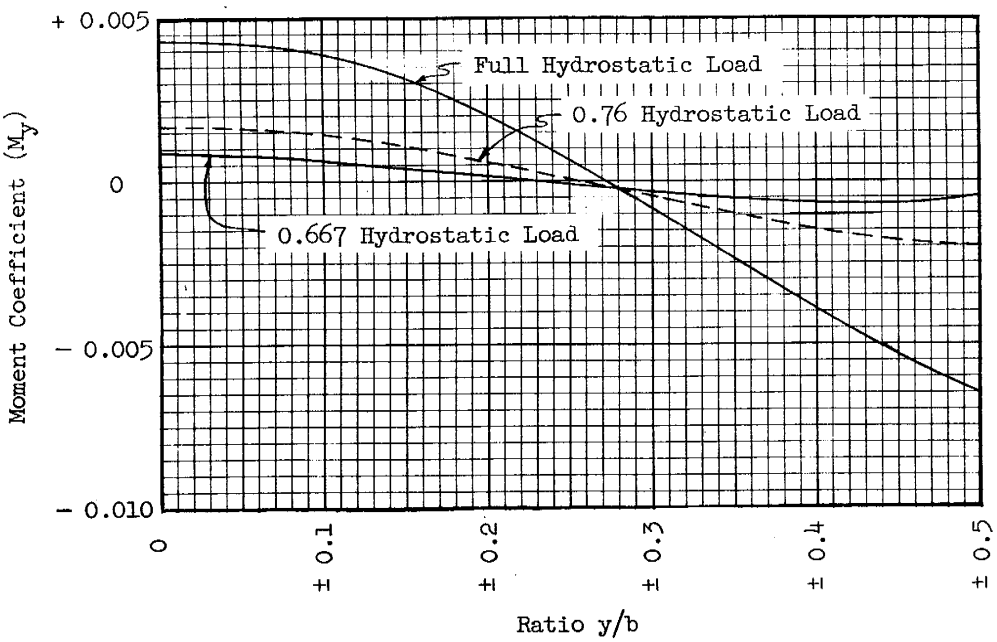
Values		Moment Coefficients				Moments (ft kips)				Total Moment (ft kips)
$pn^2 \rightarrow$		− 142.6	46.9	445.8	104.7					
$\pm \frac{y}{b}$	$\frac{x}{a}$	p_w	p_s	p_e	p_p	M_w	M_s	M_e	M_p	
0	0	0	0	0	0	0	0	0	0	0
0	0.2	− 0.0001	+ 0.0045	+ 0.0008	− 0.0004	+ 0.01	+ 0.21	+ 0.36	− 0.04	+ 0.54
0	0.4	− 0.0002	+ 0.0065	+ 0.0030	+ 0.0013	+ 0.03	+ 0.30	+ 1.34	+ 0.14	+ 1.81
0	0.6	+ 0.0005	+ 0.0085	+ 0.0060	+ 0.0049	− 0.07	+ 0.40	+ 2.67	+ 0.51	+ 3.51
0	0.8	+ 0.0028	+ 0.0048	+ 0.0053	+ 0.0051	− 0.40	+ 0.23	+ 2.36	+ 0.53	+ 2.72
0	1.0	− 0.0078	− 0.0280	− 0.0200	− 0.0170	+ 1.11	− 1.31	− 8.92	− 1.78	− 10.90
± 0.1	0	0	0	0	0	0	0	0	0	0
± 0.1	0.2	− 0.0001	+ 0.0040	+ 0.0007	− 0.0003	+ 0.01	+ 0.19	+ 0.31	− 0.03	+ 0.48
± 0.1	0.4	− 0.0002	+ 0.0055	+ 0.0026	+ 0.0013	+ 0.03	+ 0.26	+ 1.16	+ 0.14	+ 1.59
± 0.1	0.6	+ 0.0005	+ 0.0080	+ 0.0058	+ 0.0045	− 0.07	+ 0.38	+ 2.59	+ 0.47	+ 3.37
± 0.1	0.8	+ 0.0026	+ 0.0045	+ 0.0048	+ 0.0047	− 0.37	+ 0.21	+ 2.14	+ 0.49	+ 2.47
± 0.1	1.0	− 0.0075	− 0.0251	− 0.0185	− 0.0160	+ 1.07	− 1.18	− 8.25	− 1.68	− 10.04
± 0.2	0	0	0	0	0	0	0	0	0	0
± 0.2	0.2	− 0.0001	+ 0.0020	+ 0.0001	− 0.0004	+ 0.01	+ 0.10	+ 0.04	− 0.04	+ 0.11
± 0.2	0.4	− 0.0002	+ 0.0030	+ 0.0019	+ 0.0008	+ 0.03	+ 0.14	+ 0.85	+ 0.08	+ 1.10
± 0.2	0.6	+ 0.0003	+ 0.0060	+ 0.0040	+ 0.0033	− 0.04	+ 0.28	+ 1.78	+ 0.35	+ 2.37
± 0.2	0.8	+ 0.0022	+ 0.0030	+ 0.0038	+ 0.0038	− 0.31	+ 0.14	+ 1.69	+ 0.40	+ 1.92
± 0.2	1.0	− 0.0063	− 0.0200	− 0.0150	− 0.0130	+ 0.90	− 0.94	− 6.69	− 1.36	− 8.09
± 0.3	0	0	0	0	0	0	0	0	0	0
± 0.3	0.2	− 0.0001	− 0.0005	− 0.0003	− 0.0004	+ 0.01	− 0.02	− 0.13	− 0.04	− 0.18
± 0.3	0.4	− 0.0002	+ 0.0010	+ 0.0005	+ 0.0001	+ 0.03	+ 0.05	+ 0.22	+ 0.01	+ 0.31
± 0.3	0.6	0	+ 0.0021	+ 0.0019	+ 0.0016	0	+ 0.10	+ 0.85	+ 0.17	+ 1.12
± 0.3	0.8	+ 0.0014	+ 0.0019	+ 0.0021	+ 0.0022	− 0.20	+ 0.09	+ 0.94	+ 0.23	+ 1.06
± 0.3	1.0	− 0.0044	− 0.0130	− 0.0095	− 0.0085	+ 0.63	− 0.61	− 4.24	− 0.89	− 5.11
± 0.4	0	0	0	0	0	0	0	0	0	0
± 0.4	0.2	− 0.0001	− 0.0041	− 0.0012	− 0.0007	+ 0.01	− 0.19	− 0.53	− 0.07	− 0.78
± 0.4	0.4	− 0.0002	− 0.0036	− 0.0013	− 0.0009	+ 0.03	− 0.17	− 0.58	− 0.09	− 0.81
± 0.4	0.6	− 0.0003	− 0.0026	− 0.0009	− 0.0006	+ 0.04	− 0.12	− 0.40	− 0.06	− 0.54
± 0.4	0.8	+ 0.0003	− 0.0010	− 0.0001	+ 0.0001	− 0.04	− 0.05	− 0.04	+ 0.01	− 0.12
± 0.4	1.0	− 0.0020	− 0.0050	− 0.0038	− 0.0035	+ 0.29	− 0.23	− 1.69	− 0.37	− 2.00
± 0.5	0	0	0	0	0	0	0	0	0	0
± 0.5	0.2	− 0.0001	− 0.0092	− 0.0022	− 0.0010	+ 0.01	− 0.43	− 0.98	− 0.10	− 1.50
± 0.5	0.4	− 0.0002	− 0.0087	− 0.0034	− 0.0021	+ 0.03	− 0.41	− 1.52	− 0.22	− 2.12
± 0.5	0.6	− 0.0006	− 0.0072	− 0.0042	− 0.0031	+ 0.09	− 0.34	− 1.87	− 0.32	− 2.44
± 0.5	0.8	− 0.0010	− 0.0040	− 0.0028	− 0.0024	+ 0.14	− 0.19	− 1.25	− 0.25	− 1.55
± 0.5	1.0	0	0	0	0	0	0	0	0	0

STRUCTURAL DESIGN ; DESIGN EXAMPLE ;
Horizontal moments (M_y) in wall slab

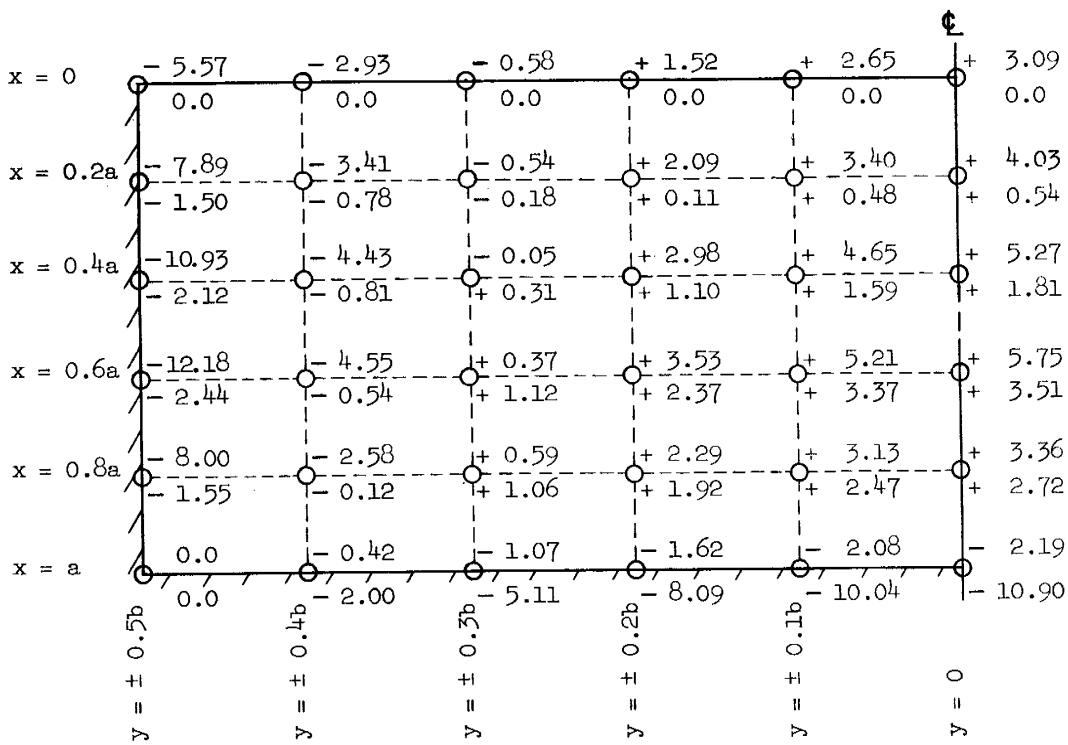
Values		Moment Coefficients				Moments (ft kips)				Total Moment (ft kips)
$pa^2 \rightarrow$		− 142.6	46.9	445.8	104.7					
$\frac{x}{a}$	$\pm \frac{y}{b}$	p_w	p_s	p_e	p_p	M_w	M_s	M_e	M_p	
0	0	+ 0.0001	+ 0.0240	+ 0.0040	+ 0.0018	− 0.01	+ 1.13	+ 1.78	+ 0.19	+ 3.09
0	± 0.1	0	+ 0.0200	+ 0.0035	+ 0.0014	0	+ 0.94	+ 1.56	+ 0.15	+ 2.65
0	± 0.2	0	+ 0.0120	+ 0.0020	+ 0.0007	0	+ 0.56	+ 0.89	+ 0.07	+ 1.52
0	± 0.3	0	− 0.0020	− 0.0010	− 0.0004	0	− 0.09	− 0.45	− 0.04	− 0.58
0	± 0.4	0	− 0.0210	− 0.0040	− 0.0016	0	− 0.98	− 1.78	− 0.17	− 2.93
0	± 0.5	0	− 0.0470	− 0.0070	− 0.0024	0	− 2.20	− 3.12	− 0.25	− 5.57
0.2	± 0	+ 0.0002	+ 0.0230	+ 0.0060	+ 0.0030	− 0.03	+ 1.08	+ 2.67	+ 0.31	+ 4.03
0.2	± 0.1	+ 0.0002	+ 0.0200	+ 0.0050	+ 0.0025	− 0.03	+ 0.94	+ 2.23	+ 0.26	+ 3.40
0.2	± 0.2	+ 0.0001	+ 0.0130	+ 0.0030	+ 0.0014	− 0.01	+ 0.61	+ 1.34	+ 0.15	+ 2.09
0.2	± 0.3	− 0.0001	− 0.0010	− 0.0010	− 0.0005	+ 0.01	− 0.05	− 0.45	− 0.05	− 0.54
0.2	± 0.4	− 0.0002	− 0.0200	− 0.0050	− 0.0026	+ 0.03	− 0.94	− 2.23	− 0.27	− 3.41
0.2	± 0.5	− 0.0003	− 0.0480	− 0.0115	− 0.0053	+ 0.04	− 2.25	− 5.13	− 0.55	− 7.89
0.4	0	+ 0.0006	+ 0.0220	+ 0.0085	+ 0.0052	− 0.09	+ 1.03	+ 3.78	+ 0.54	+ 5.27
0.4	± 0.1	+ 0.0005	+ 0.0190	+ 0.0075	+ 0.0047	− 0.07	+ 0.89	+ 3.34	+ 0.49	+ 4.65
0.4	± 0.2	+ 0.0002	+ 0.0120	+ 0.0048	+ 0.0030	− 0.03	+ 0.56	+ 2.14	+ 0.31	+ 2.98
0.4	± 0.3	− 0.0001	− 0.0010	0	− 0.0001	+ 0.01	− 0.05	0	− 0.01	− 0.05
0.4	± 0.4	− 0.0006	− 0.0180	− 0.0072	− 0.0045	+ 0.09	− 0.84	− 3.21	− 0.47	− 4.43
0.4	± 0.5	− 0.0010	− 0.0450	− 0.0176	− 0.0106	+ 0.14	− 2.11	− 7.85	− 1.11	− 10.93
0.6	0	+ 0.0013	+ 0.0183	+ 0.0097	+ 0.0073	− 0.19	+ 0.86	+ 4.32	+ 0.76	+ 5.75
0.6	± 0.1	+ 0.0012	+ 0.0163	+ 0.0088	+ 0.0067	− 0.17	+ 0.76	+ 3.92	+ 0.70	+ 5.21
0.6	± 0.2	+ 0.0007	+ 0.0104	+ 0.0060	+ 0.0045	− 0.10	+ 0.49	+ 2.67	+ 0.47	+ 3.53
0.6	± 0.3	0	0	+ 0.0007	+ 0.0006	0	0	+ 0.31	+ 0.06	+ 0.37
0.6	± 0.4	− 0.0012	− 0.0150	− 0.0077	− 0.0056	+ 0.17	− 0.70	− 3.43	− 0.59	− 4.55
0.6	± 0.5	− 0.0028	− 0.0370	− 0.0207	− 0.0154	+ 0.40	− 1.74	− 9.23	− 1.61	− 12.18
0.8	0	+ 0.0019	+ 0.0093	+ 0.0060	+ 0.0050	− 0.27	+ 0.44	+ 2.67	+ 0.52	+ 3.36
0.8	± 0.1	+ 0.0018	+ 0.0084	+ 0.0056	+ 0.0048	− 0.26	+ 0.39	+ 2.50	+ 0.50	+ 3.13
0.8	± 0.2	+ 0.0016	+ 0.0058	+ 0.0042	+ 0.0036	− 0.23	+ 0.27	+ 1.87	+ 0.38	+ 2.29
0.8	± 0.3	+ 0.0008	+ 0.0008	+ 0.0012	+ 0.0012	− 0.11	+ 0.04	+ 0.53	+ 0.13	+ 0.59
0.8	± 0.4	− 0.0011	− 0.0074	− 0.0045	− 0.0036	+ 0.16	− 0.35	− 2.01	− 0.38	− 2.58
0.8	± 0.5	− 0.0051	− 0.0210	− 0.0145	− 0.0123	+ 0.73	− 0.98	− 6.46	− 1.29	− 8.00
1	0	− 0.0016	− 0.0059	− 0.0040	− 0.0034	+ 0.23	− 0.28	− 1.78	− 0.36	− 2.19
1	± 0.1	− 0.0015	− 0.0055	− 0.0038	− 0.0032	+ 0.21	− 0.26	− 1.69	− 0.34	− 2.08
1	± 0.2	− 0.0013	− 0.0043	− 0.0030	− 0.0026	+ 0.19	− 0.20	− 1.34	− 0.27	− 1.62
1	± 0.3	− 0.0009	− 0.0027	− 0.0020	− 0.0017	+ 0.13	− 0.13	− 0.89	− 0.18	− 1.07
1	± 0.4	− 0.0004	− 0.0010	− 0.0008	− 0.0007	+ 0.06	− 0.05	− 0.36	− 0.07	− 0.42
1	± 0.5	0	0	0	0	0	0	0	0	0

STRUCTURAL DESIGN : DESIGN EXAMPLE ;

Example of interpolation, horizontal and vertical moments in wall slab



EXAMPLE OF INTERPOLATION OF MOMENT COEFFICIENT (M_y)
FOR 0.76 HYDROSTATIC LOAD ALONG SECTION x = 0

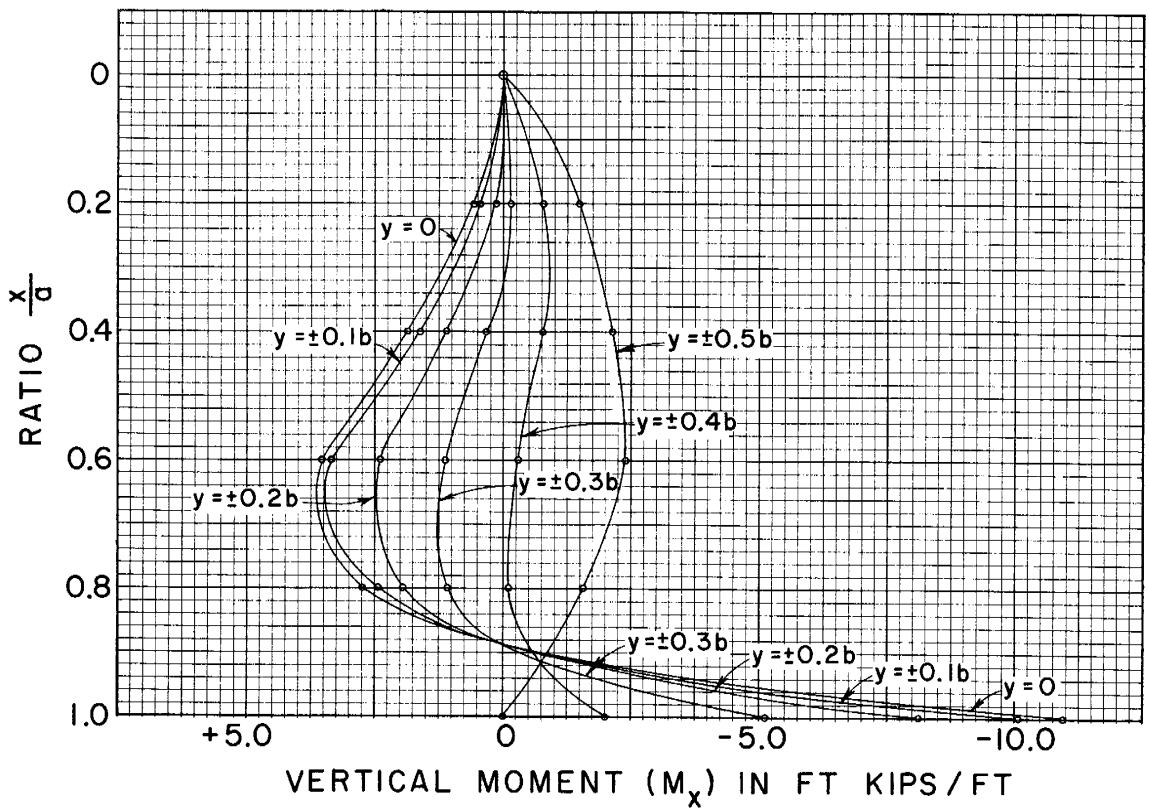


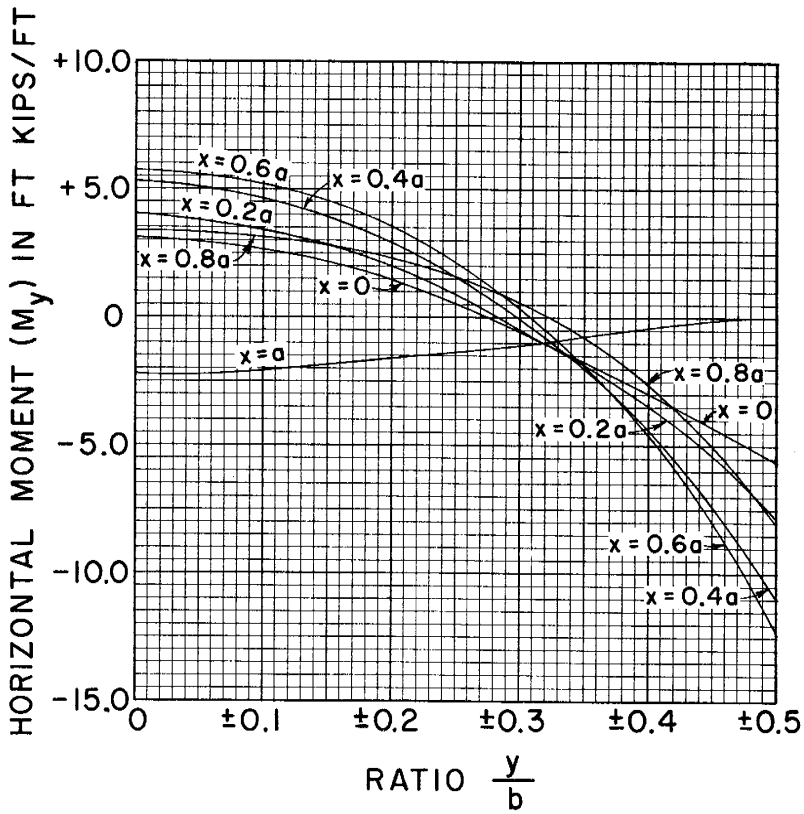
HORIZONTAL AND VERTICAL MOMENTS IN ft kips/ft IN WALL SLAB

Horizontal Moment
Vertical Moment

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES- 104 SHEET 76 OF 85 DATE 4 - 13 - 56

STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Vertical and horizontal moments in wall slab





REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 77 OF 85 DATE 4 13 56

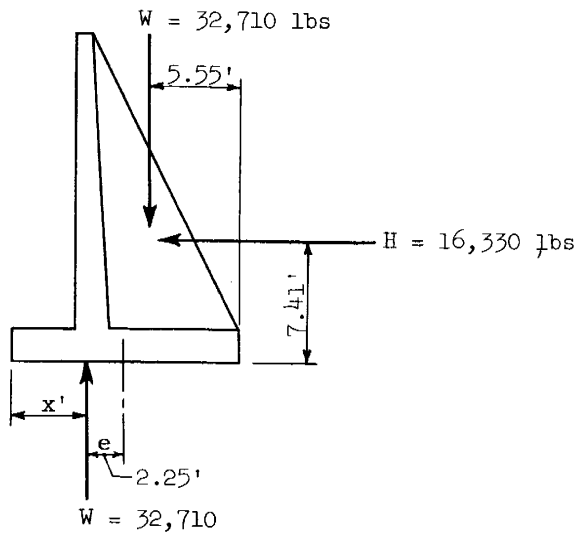
STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Shears in wall slab

Values		Shear Coefficients				Shear (kips/ft)				Total Shear
pa →		− 7.5	2.5	23.5	5.5					
$\frac{x}{a}$	$\pm \frac{y}{b}$	p_w	p_s	p_e	p_p	s_w	s_s	s_e	s_p	$\frac{kips}{ft}$
0	± 0.5	− 0.0021	+ 0.3650	+ 0.0190	− 0.0020	+ 0.02	+ 0.91	+ 0.45	− 0.01	+ 1.37
0.2	± 0.5	+ 0.0001	+ 0.3900	+ 0.0850	+ 0.0305	0.0	+ 0.98	+ 2.00	+ 0.17	+ 3.15
0.4	± 0.5	+ 0.0035	+ 0.3700	+ 0.1500	+ 0.0773	− 0.03	+ 0.93	+ 3.53	+ 0.43	+ 4.86
0.6	± 0.5	+ 0.0215	+ 0.3500	+ 0.2100	+ 0.1570	− 0.16	+ 0.88	+ 4.94	+ 0.86	+ 6.52
0.8	± 0.5	+ 0.0780	+ 0.2150	+ 0.1690	+ 0.1515	− 0.59	+ 0.54	+ 3.97	+ 0.83	+ 4.75
1.0	± 0.5	+ 0.0230	0.0	+ 0.0100	+ 0.0144	− 0.17	0.0	+ 0.24	+ 0.08	+ 0.15
1.0	± 0.4	+ 0.0610	+ 0.0320	+ 0.0480	+ 0.0524	− 0.46	+ 0.08	+ 1.13	+ 0.29	+ 1.04
1.0	± 0.3	+ 0.1070	+ 0.1670	+ 0.1480	+ 0.1407	− 0.80	+ 0.42	+ 3.48	+ 0.77	+ 3.87
1.0	± 0.2	+ 0.1310	+ 0.2600	+ 0.2150	+ 0.1961	− 0.98	+ 0.65	+ 5.05	+ 1.08	+ 5.80
1.0	± 0.1	+ 0.1425	+ 0.3200	+ 0.2510	+ 0.2263	− 1.07	+ 0.80	+ 5.90	+ 1.24	+ 6.87
1.0	0	+ 0.1460	+ 0.3400	+ 0.2640	+ 0.2356	− 1.10	+ 0.85	+ 6.20	+ 1.30	+ 7.25

SHEAR ALONG FIXED EDGES x = a AND y = ± 0.5b IN WALL SLAB

The magnitude and location of the maximum shear may readily be obtained from the above table.

HEEL SLAB



Determine the total vertical load W.

			Weight	x	lever arm	=	Moment
Wall Stem	= 1 x 18 x 150	=	2,700	x	9.5	=	25,650
	= 0.5 x 18 x 150	=	1,350	x	8.67	=	11,705
Footing	= 2 x 14 x 150	=	4,200	x	7	=	29,400
Moist Earth	= 8 x 20 x 125	=	20,000	x	4	=	80,000
	= 0.5 x 18 x 125	=	1,125	x	8.33	=	9,370
	= 1 x 2 x 125	=	250	x	8.5	=	2,125
Saturated Earth	= 8 x 13.5 x 15	=	1,620	x	4	=	6,480
	= 0.38 x 13.5 x 15	=	75	x	8.25	=	620
Counterfort	$= \frac{1 \times 4.5 \times 25}{14}$	=	10	x	8.17	=	80
	$= \frac{5 \times 13.5 \times 10}{14}$	=	50	x	5.50	=	275
Water	= 4 x 5.33 x 62.4	=	1,330	x	12	=	15,960
		ΣW =	32,710			ΣM =	181,665

$$x = \frac{\Sigma M}{\Sigma W} = \frac{181,665}{32,710} \quad 5.55 \text{ ft}$$

Determine the horizontal load H.

			Weight	x	lever arm	=	Moment
Water	$= -\frac{7.33^2 \times 62.4}{2}$	=	− 1,675	x	2.44	=	− 4,090
Surcharge	= 130 x 20	=	2,600	x	10	=	26,000
Earth Load	$= \frac{20^2 \times 65}{2}$	=	13,000	x	6.67	=	86,710
Pore Pressure Load	$= \frac{15.5^2 \times 20}{2}$	=	2,405	x	5.17	=	12,435
		ΣW =	16,330			ΣM =	121,055

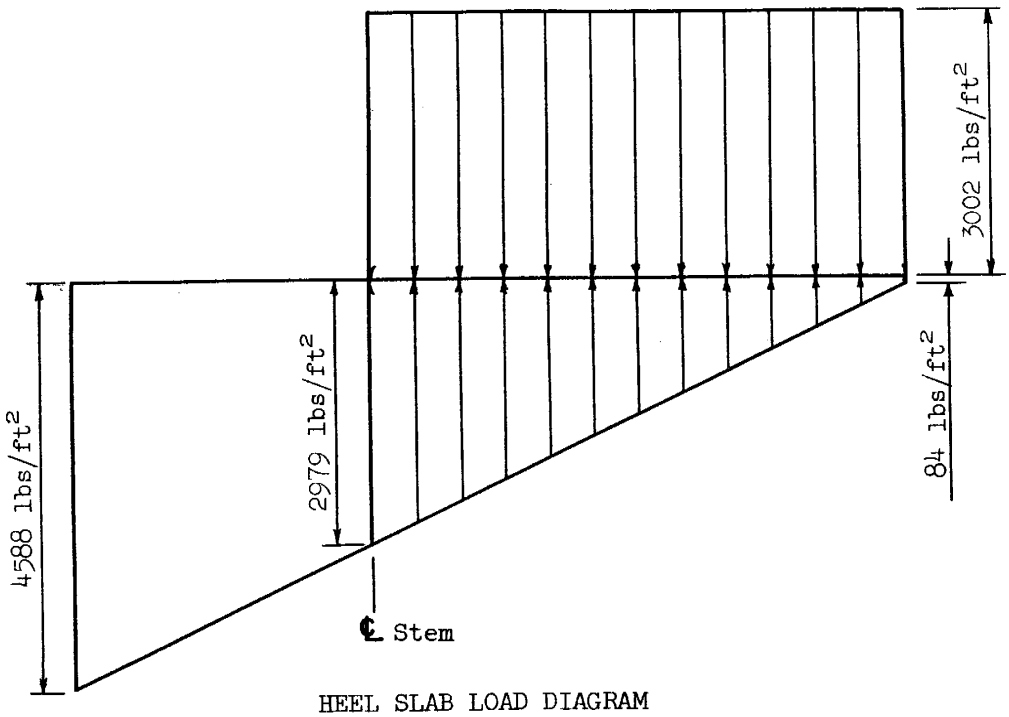
$$x' = \frac{(32,710)(8.45) - (16,330)(7.41)}{32,710} = 4.75 \text{ ft}$$

$$e = 7.00 - 4.75 = 2.25 \text{ ft}$$

STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Heel slab dimensions and component loads

$$\text{Max Pressure} = \left(\frac{W}{b}\right)\left(1 + \frac{6e}{b}\right) = \left(\frac{32,710}{14}\right)\left(1 + \frac{(6)(2.25)}{14}\right) = 4588 \text{ lbs/ft}^2$$

$$\text{Min Pressure} = \left(\frac{W}{b}\right)\left(1 - \frac{6e}{b}\right) = \left(\frac{32,710}{14}\right)\left(1 - \frac{(6)(2.25)}{14}\right) = 84 \text{ lbs/ft}^2$$



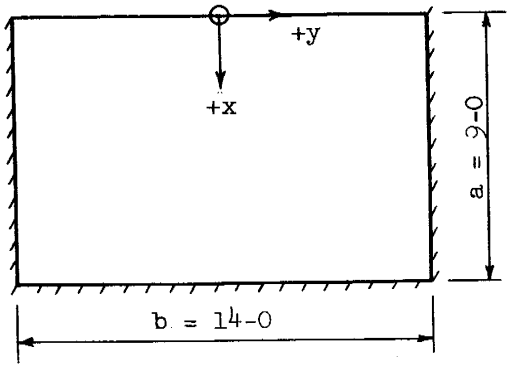
HEEL SLAB LOAD DIAGRAM

$$p_v = (4588 - 84)\left(\frac{9}{14}\right) = 2895 \text{ lbs/ft}^2$$

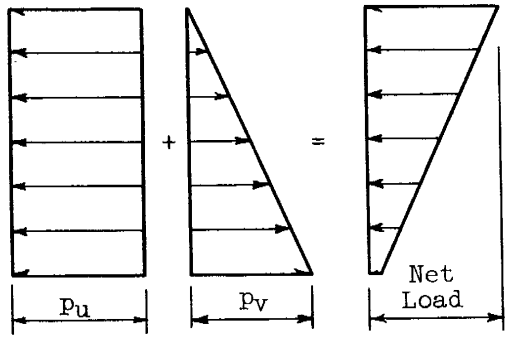
$$p_u = (20)(125) + (13.5)(15) + (2)(150) - 84 = 2918 \text{ lbs/ft}^2$$

$$p_v a^2 = (2.895)(9)^2 = 234.5 \text{ ft kips/ft}$$

$$p_u a^2 = (2.918)(9)^2 = 236.4 \text{ ft kips/ft}$$



IDEALIZED HEEL SLAB DIMENSIONS



COMPONENT HEEL SLAB LOADS

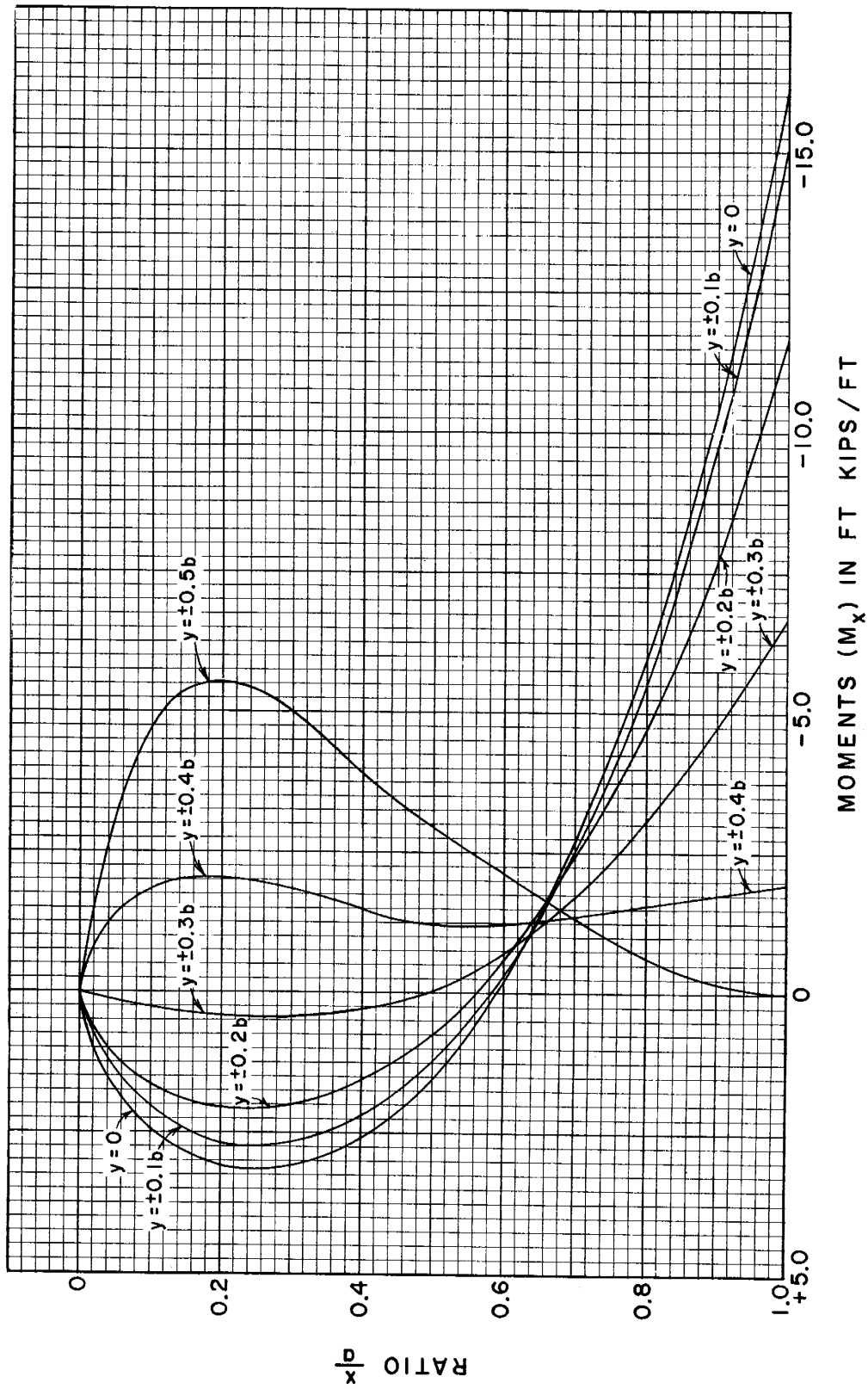
STRUCTURAL DESIGN : DESIGN EXAMPLE ; Moments (M_x) in heel slab

Values	$pa^2 \rightarrow$	Moment Coefficient		Moment (ft kips)		Total Moment ft kips
		236.4	− 234.5			
$\pm \frac{y}{b}$	$\frac{x}{a}$	p_u	p_v	M_u	M_v	
0	0	0	0	0	0	0
0	0.2	+ 0.0200	+ 0.0070	+ 4.73	− 1.64	+ 3.09
0	0.4	+ 0.0250	+ 0.0142	+ 5.91	− 3.33	+ 2.58
0	0.6	+ 0.0130	+ 0.0142	+ 3.07	− 3.33	− 0.26
0	0.8	− 0.0300	− 0.0048	− 7.09	+ 1.13	− 5.96
0	1.0	− 0.1290	− 0.0610	−30.50	+14.30	−16.20
± 0.1	0	0	0	0	0	0
± 0.1	0.2	+ 0.0180	+ 0.0067	+ 4.26	− 1.57	+ 2.69
± 0.1	0.4	+ 0.0230	+ 0.0138	+ 5.44	− 3.24	+ 2.20
± 0.1	0.6	+ 0.0120	+ 0.0133	+ 2.84	− 3.12	− 0.28
± 0.1	0.8	− 0.0275	− 0.0041	− 6.50	+ 0.96	− 5.54
± 0.1	1.0	− 0.1210	− 0.0575	−28.60	+13.48	−15.12
± 0.2	0	0	0	0	0	0
± 0.2	0.2	+ 0.0130	+ 0.0043	+ 3.07	− 1.01	+ 2.06
± 0.2	0.4	+ 0.0170	+ 0.0105	+ 4.02	− 2.46	+ 1.56
± 0.2	0.6	+ 0.0090	+ 0.0117	+ 2.13	− 2.74	− 0.61
± 0.2	0.8	− 0.0220	− 0.0020	− 5.20	+ 0.47	− 4.73
± 0.2	1.0	− 0.0970	− 0.0482	−22.93	+11.30	−11.63
± 0.3	0	0	0	0	0	0
± 0.3	0.2	+ 0.0030	+ 0.0013	+ 0.71	− 0.30	+ 0.41
± 0.3	0.4	+ 0.0070	+ 0.0059	+ 1.65	− 1.38	+ 0.27
± 0.3	0.6	+ 0.0048	+ 0.0078	+ 1.13	− 1.83	− 0.70
± 0.3	0.8	− 0.0133	− 0.0005	− 3.14	+ 0.12	− 3.02
± 0.3	1.0	− 0.0615	− 0.0335	−14.54	+ 7.86	− 6.68
± 0.4	0	0	0	0	0	0
± 0.4	0.2	− 0.0117	− 0.0031	− 2.77	+ 0.73	− 2.04
± 0.4	0.4	− 0.0072	− 0.0009	− 1.70	+ 0.21	− 1.49
± 0.4	0.6	− 0.0038	+ 0.0012	− 0.90	− 0.28	− 1.18
± 0.4	0.8	− 0.0068	− 0.0002	− 1.61	+ 0.05	− 1.56
± 0.4	1.0	− 0.0225	− 0.0145	− 5.32	+ 3.40	− 1.92
± 0.5	0	0	0	0	0	0
± 0.5	0.2	− 0.0323	− 0.0091	− 7.64	+ 2.13	− 5.51
± 0.5	0.4	− 0.0249	− 0.0088	− 5.89	+ 2.06	− 3.83
± 0.5	0.6	− 0.0160	− 0.0071	− 3.78	+ 1.66	− 2.12
± 0.5	0.8	− 0.0058	− 0.0033	− 1.37	+ 0.77	− 0.60
± 0.5	1.0	0	0	0	0	0

STRUCTURAL DESIGN : DESIGN EXAMPLE ; Moments (M_y) in heel slab

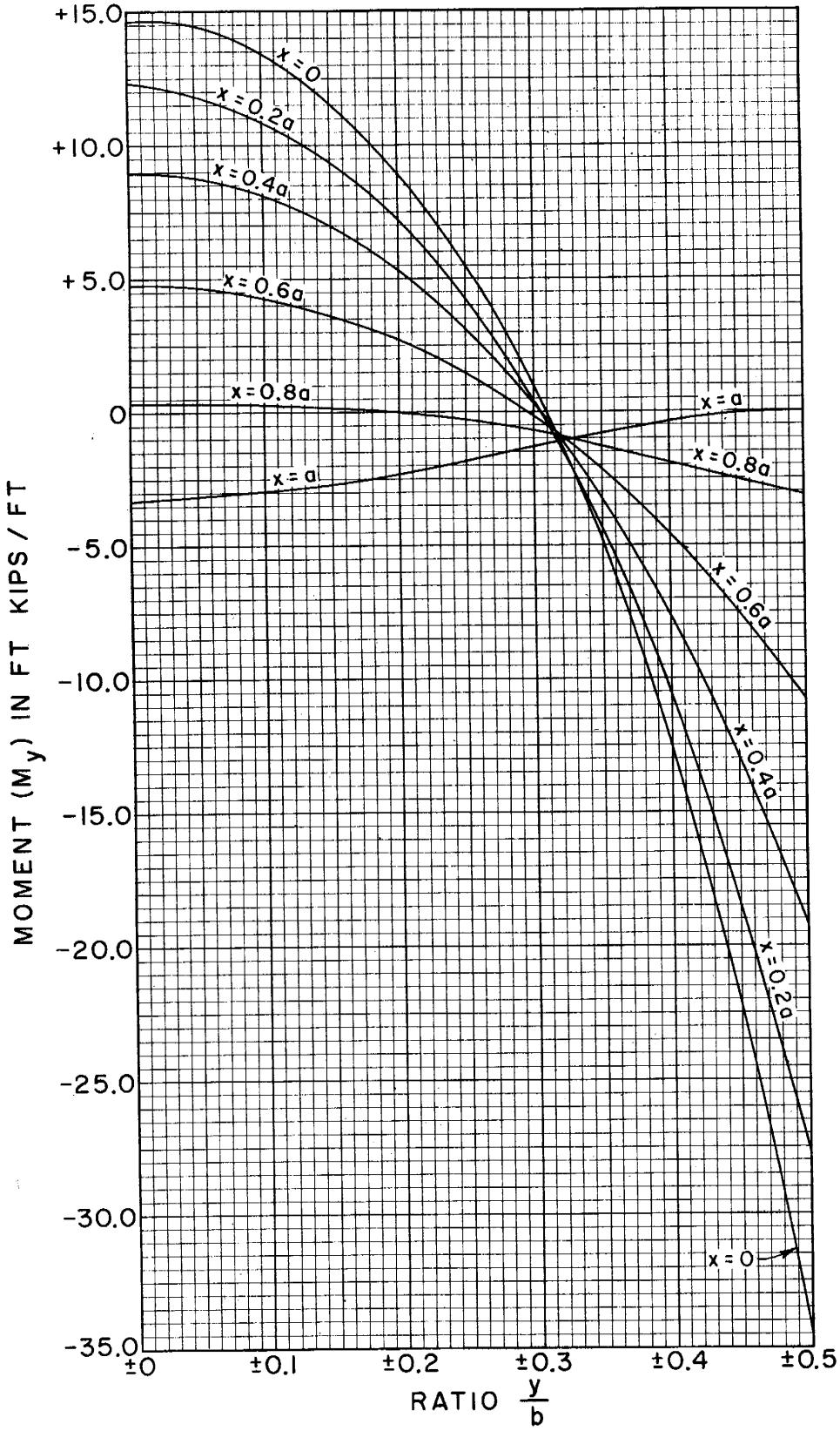
Values		Moment Coefficient		Moment (ft kips)		Total Moment ft kips
	$pa^2 \rightarrow$	236.4	− 234.5			
$\frac{x}{a}$	$\pm \frac{y}{b}$	p_u	p_v	M_u	M_v	
0	0	+ 0.0840	+ 0.0225	+ 19.86	− 5.28	+ 14.58
0	± 0.1	+ 0.0760	+ 0.0195	+ 17.97	− 4.57	+ 13.40
0	± 0.2	+ 0.0500	+ 0.0125	+ 11.82	− 2.93	+ 8.89
0	± 0.3	+ 0.0030	− 0.0013	+ 0.71	+ 0.30	+ 1.01
0	± 0.4	− 0.0740	− 0.0206	− 17.49	+ 4.83	− 12.66
0	± 0.5	− 0.1880	− 0.0430	− 44.44	+ 10.08	− 34.36
0.2	0	+ 0.0730	+ 0.0212	+ 17.26	− 4.97	+ 12.29
0.2	± 0.1	+ 0.0650	+ 0.0192	+ 15.37	− 4.50	+ 10.87
0.2	± 0.2	+ 0.0430	+ 0.0126	+ 10.17	− 2.95	+ 7.22
0.2	± 0.3	+ 0.0020	+ 0.0007	+ 0.47	− 0.16	+ 0.31
0.2	± 0.4	− 0.0630	− 0.0182	− 14.89	+ 4.27	− 10.62
0.2	± 0.5	− 0.1620	− 0.0452	− 38.30	+ 10.60	− 27.70
0.4	0	+ 0.0570	+ 0.0192	+ 13.47	− 4.50	+ 8.97
0.4	± 0.1	+ 0.0520	+ 0.0178	+ 12.29	− 4.17	+ 8.12
0.4	± 0.2	+ 0.0350	+ 0.0127	+ 8.27	− 2.98	+ 5.29
0.4	± 0.3	+ 0.0040	+ 0.0028	+ 0.94	− 0.66	+ 0.28
0.4	± 0.4	− 0.0470	− 0.0147	− 11.11	+ 3.45	− 7.66
0.4	± 0.5	− 0.1250	− 0.0439	− 29.55	+ 10.29	− 19.26
0.6	0	+ 0.0335	+ 0.0137	+ 7.92	− 3.21	+ 4.71
0.6	± 0.1	+ 0.0308	+ 0.0130	+ 7.28	− 3.05	+ 4.23
0.6	± 0.2	+ 0.0215	+ 0.0104	+ 5.08	− 2.44	+ 2.64
0.6	± 0.3	+ 0.0035	+ 0.0040	+ 0.83	− 0.94	− 0.11
0.6	± 0.4	− 0.0285	− 0.0090	− 6.73	+ 2.11	− 4.62
0.6	± 0.5	− 0.0805	− 0.0352	− 19.03	+ 8.25	− 10.78
0.8	0	+ 0.0045	+ 0.0030	+ 1.06	− 0.70	+ 0.36
0.8	± 0.1	+ 0.0041	+ 0.0030	+ 0.97	− 0.70	+ 0.27
0.8	± 0.2	+ 0.0028	+ 0.0028	+ 0.66	− 0.66	0
0.8	± 0.3	− 0.0012	+ 0.0016	− 0.28	− 0.38	− 0.66
0.8	± 0.4	− 0.0112	− 0.0030	− 2.65	+ 0.70	− 1.95
0.8	± 0.5	− 0.0292	− 0.0163	− 6.90	+ 3.82	− 3.08
1.0	0	− 0.0260	− 0.0122	− 6.15	+ 2.86	− 3.29
1.0	± 0.1	− 0.0242	− 0.0116	− 5.72	+ 2.72	− 3.00
1.0	± 0.2	− 0.0193	− 0.0097	− 4.56	+ 2.27	− 2.29
1.0	± 0.3	− 0.0123	− 0.0067	− 2.91	+ 1.57	− 1.34
1.0	± 0.4	− 0.0045	− 0.0030	− 1.06	+ 0.70	− 0.36
1.0	± 0.5	0	0	0	0	0

STRUCTURAL DESIGN : DESIGN EXAMPLE ;
Moments (M_x) in heel slab



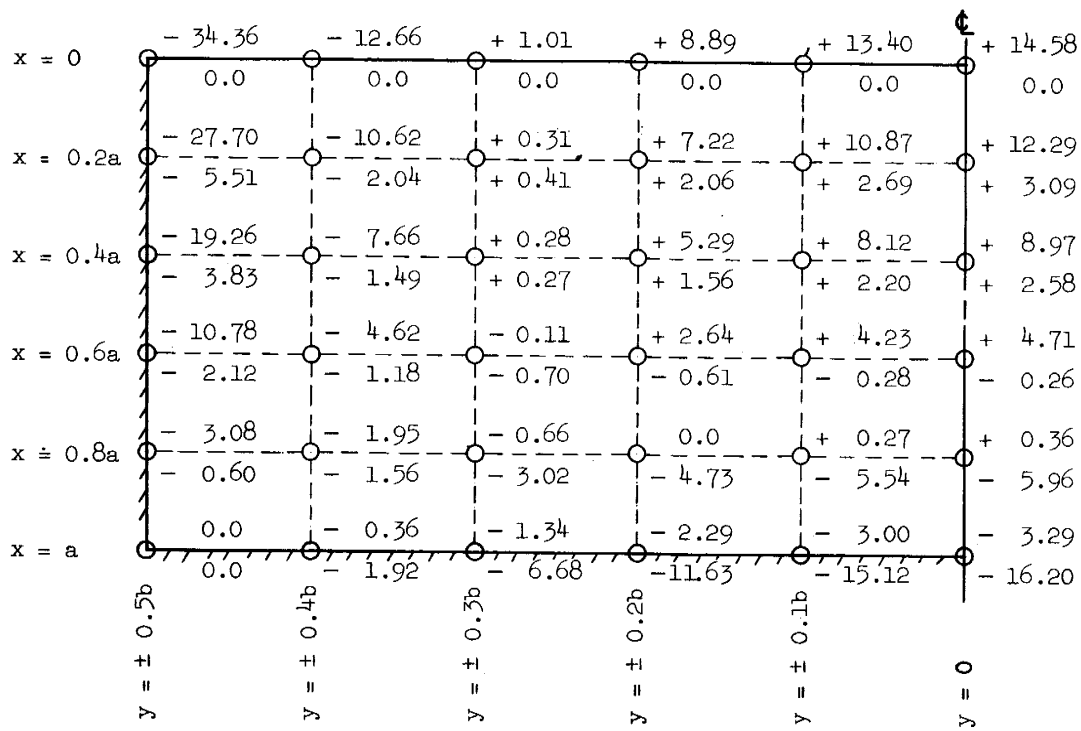
REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES- 104 SHEET 83 OF 85 DATE 4-13-56

STRUCTURAL DESIGN : DESIGN EXAMPLE ; Moments (M_y) in heel slab

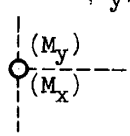


REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-104 SHEET 84 OF 85 DATE 4-13-56

STRUCTURAL DESIGN ; DESIGN EXAMPLE ;
Moments and shears in heel slab



MOMENTS (M_y) AND (M_x) IN ft kips/ft IN HEEL SLAB



Values pa →		Shear Coefficient		Shear kips/ft		Total Shear kips/ft
		26.3	- 26.1			
$\frac{x}{a}$	$\pm \frac{y}{b}$	p_u	p_v	s_u	s_v	
0	± 0.5	+ 0.90	+ 0.114	+ 23.7	- 3.0	+ 20.7
0.2	± 0.5	+ 0.805	+ 0.213	+ 21.2	- 5.6	+ 15.6
0.4	± 0.5	+ 0.603	+ 0.243	+ 15.9	- 6.3	+ 9.6
0.6	± 0.5	+ 0.435	+ 0.252	+ 11.4	- 6.6	+ 4.8
0.8	± 0.5	+ 0.110	+ 0.130	+ 2.9	- 3.4	- 0.5
1.0	± 0.5	- 0.075	- 0.020	- 2.0	+ 0.5	- 1.5
1.0	± 0.4	+ 0.085	+ 0.130	+ 2.2	- 3.4	- 1.2
1.0	± 0.3	+ 0.346	+ 0.271	+ 9.1	- 7.1	+ 2.0
1.0	± 0.2	+ 0.542	+ 0.355	+ 14.3	- 9.3	+ 5.0
1.0	± 0.1	+ 0.655	+ 0.399	+ 17.2	- 10.4	+ 6.8
1.0	0.0	+ 0.692	+ 0.411	+ 18.2	- 10.7	+ 7.5

SHEAR ALONG FIXED EDGES x = a AND y = ± 0.5b IN HEEL SLAB

The magnitude and location of the maximum shear may be readily obtained from the above table.