A part of PROCEEDINGS OF THE AMERICAN CONCRETE INSTITUTE Vol. 40

JOURNAL
of the
AMERICAN CONCRETE INSTITUTE

Vol. 15 No. 1 7400 SECOND BOULEVARD, DETROIT 2, MICHIGAN September 1943

Planning for the Postwar Period

A report by the American Concrete Institute's Committee on Postwar Planning

MORTON O. WITHEY, Chairman

Roy W. Crum, Ben Moreell, John R. Nichols

Douglas E. Parsons, Harry F. Thomson, Stanton Walker

Harvey Whipple, Secretary

— A —

Believing that serviceable structures are achieved by planning, engineers welcome the challenge to contribute to plans for the creation of an orderly world from one in conflict and disorder, to help solve the problems of social and economic dislocation produced by war and to assist in the correction of those maladjustments from which wars gather their destructive force. In thinking beyond the sphere of its engineering specialization, there is assumed in American Concrete Institute membership a sense of the responsibility of all citizens for the general welfare—a responsibility made more general and more urgent by the magnitude of the tasks to be accomplished. To these ends it is recommended:

1) That the American Concrete Institute encourage and participate in the discussion of ways and means toward a better postwar world—first, to assist during the emergency of reconversion to peace economy, and second, to contribute to the ultimate goal of domestic and international relations in which an efficient and equitable economy will be general and permanent (Sections B and C).

2) That the American Concrete Institute rededicate itself to the task of increasing, correlating, and disseminating the special engineering knowledge of its chosen field, and of making such knowledge available in readily usuable form for prompt application to the projects of a postwar world; specifically, that:

a) Under a procedure to be inaugurated and directed by the Publications Committee with such special instructions as the Board of Direction may deem best, "Planning for the Postwar Period" be opened to discussion at the Institute's 40th Annual Convention.

b) The Advisory Committee be asked to give prompt consideration to the ACI technical committee activity for the next two years with these objects in view: (1) The inauguration, and prompt completion of assignments to tasks involving reports digesting and correlating needed information in reference to concrete design, construction and manufacture; (2) The completion, as rapidly as possible, of important assignments which will add to the Institute's recommended practices; (3) The encouragement of research undertakings which give promise of valuable contributions to the background of future correlations and recommendations.

c) The text of this report be published to aid the Institute in planning its own work, and in fostering cooperation with other agencies on general problems.

— B —

Inasmuch as the problems of the postwar world are so numerous, so complicated, and so far-reaching that we can hope to solve them only as the best organized thought is brought to bear on their manifold ramifications, it is further recommended:

1) That the Congress of the United States be urged to create at once a non-partisan national planning body of adequately diversified public representation, to gather, consider, and correlate information, to make public specific recommendations and to cooperate with planning agencies of state, county, city governments and of civic, industrial, professional, agricultural, labor, and other organizations, with respect to domestic and international problems, looking toward the crystallization of policies and the promulgation of measures to meet the emergencies of the postwar period and the long-time adjustment of social and economic relations;

2) That subdivisions of government and civic, industrial, professional, agricultural, labor and other organizations, be urged to create and support planning bodies for the purposes of initiating plans and implementing such plans as may be recommended;

3) That among the subjects, proposals and considerations that might come before such planning agencies study be given to (C).

— C —

The country is faced with the emergency problem of employment during the postwar period for: (a) men in uniform at the war's end, (b) government employees in excess of peace-time requirements, (c) employees of government-owned and privately-operated plants producing war material, (d) employees of privately-owned plants now producing war material, that can be reconverted to peace-time production (anticipating that during reconversion there may be an extended period of unemployment). To meet these emergency needs for postwar employment and to build more permanently for the general welfare, there are many possible solutions, among which are the following:

1) Encourage the development of private enterprise by every means consistent with the general good, including review of controls and fiscal policies applied as war-time measures.

2) Encourage all units of industry, large and small, to plan now for their type and scope of operation after the war. Many producers of war goods will return to their former production for civilian needs; others must convert to new lines and new products. Upon the thoroughness of industrial planning now, postwar employment and productivity will depend, especially in view of the prodigious character of postwar expansion required to equal war production.

3) Encourage the complete readiness for use, by private enterprise and by all levels of government, of a true "shelf" of postwar construction projects for which there are authorizations, surveys, plans and specifications, with financing provided:

(a) Let there be special provision for a repair, maintenance, replacement and new work program that emphasizes jobs long deferred by war, and that can be set in motion with the least loss of time at war's end, to tide over employment for the period in which large projects are got under way. By thorough advance planning provide work in reference to public need, avoiding "made" work that might otherwise be hastily improvised and uneconomically executed without attaining maximum public service.

(b) Let long range construction planning for continuing programs and large projects be with reference to public need and employment demand and be reconciled with construction potentialities, the national economy in general, and the wartime backlog of demand for many consumer goods. Consider the overall construction program with a view to maximum employment consistent with construction needs and a balanced economy. With an assumed national income of $110 billion, $14 billion might be spent for construction, of which four or five billion might be for public works. If construction, other than that for war, continues at war's end at $1.5 billion, large possibilities for employment will depend upon the acceleration of the construction program. If this program attains an annual acceleration of $3.8 billion (the war-time peak) an annual construction total of $14 billion would be attained only by the fourth year. In this is further emphasis of the need that a so-called "shelf" of construction projects consist not in projects merely "proposed" but in those advanced to the point of getting under way at once when men return from the military and industrial war-fronts. Assuming that $5,000 for construction hires one man on-site and 1.5 men off-site in shops, mines, transportation, and so forth, for one year, $14 billion would employ 2.8 million men on-site and 4.2 million off-site, 7 million in all of which 2.5 million might be on public works. Although not eliminating unemployment, such a program would be a substantial contribution from the construction industry toward that end.*

4) Consider employment possibilities in dismantling surplus military installations.

5) Plan and schedule demobilization of the armed forces so far as practicable, to return men to civil pursuits as and where employment becomes available—some regions being ready sooner than others, some skills more in demand than others. Such scheduled demobilization might be made feasible by a reversal of the war training program, refitting men in uniform for return to peace-time occupations. The great military training stations and the established educational institutions, both of

*For the figures in (3) reference is made to public releases of the National Resources Planning Board.

which play such important parts in special training for war, might be used for postwar courses in the manual arts, academic subjects, languages, history and so forth, including political economy and the duties and responsibilities of citizens—often less well understood and practiced than the citizen's civil rights.

6) Consider universal military service first for national safety and also in reference to employment problems. One year of such service for boys will not solve the problem of unemployment but will remove some employment competition.

7) Study opportunities for greater coordination of agriculture with industrial and chemical uses of farm products.

8) Apply a lesson of this war in measures to maintain adequate stockpiles of selected raw materials.

9) Seek a solution of continuing problems of social security as related to unemployment and old age benefits.

10) Continue the study of conservation measures for agricultural and forest lands.

11) Encourage the preparation of master plans for cities, and for metropolitan and regional areas by which a more logical arrangement of their development may be laid down, including provisions for adequate housing, streets, parks, facilities, playgrounds, and means of transportation and for the elimination of slums and blighted areas.

12) Effect international agreements for the elimination of financial and legal obstructions to trade between nations.

13) Encourage that expansion of private enterprise necessary for full employment by measures to make the natural resources of the country more easily available. Give thorough study to the best plans not only for conserving natural resources but for their utilization for the public good.

14) Consider the revision of laws and regulations for the greater freedom of commerce between states of the United States, including the most efficient use of all transportation facilities.

15) Study the possibilities of greater safeguards to the public welfare: (a) in patent law revision that, while giving incentive to invention, would prevent undue delays in the use of new ideas and processes; (b) in such revision of anti-trust laws that, without sacrifice of essential safeguards against uneconomic and monopolistic practices, would encourage efficient production and distribution; (c) in the enactment of laws to discourage the restriction of production for the maintenance of high profit margins; (d) through the cooperation of labor in the elimination of practices that increase costs of production and construction without compensating contributions to the general welfare of labor and the public.

A part of PROCEEDINGS OF THE AMERICAN CONCRETE INSTITUTE Vol. 40

JOURNAL
of the
AMERICAN CONCRETE INSTITUTE

Vol. 15 No. 1 7400 SECOND BOULEVARD, DETROIT 2, MICHIGAN September 1943

Charts and a Direct Method for Design of Cantilever Retaining Walls*

By WILLIAM A. JONES†
Member American Concrete Institute

SYNOPSIS

This paper describes and illustrates a method for the design of retaining walls with special reference to the highway field. Included is a suggested classification of walls. It touches lightly upon the selection of wall types and of earth pressure formulas and factors, and discusses and illustrates briefly the preparation of charts.

Both method and charts were developed and used by the author in a large bridge designing office and for the design of practically all wing walls of the numerous bridges of the new Pennsylvania Turnpike, thereby saving design cost and facilitating the intense design pace of the project.

INTRODUCTION

There is need for charts permitting easy and quick design of cantilever retaining walls.

In studying this need, consideration must be given at the very outset by each design office, to the various preliminary assumptions that accompany the design of any retaining wall: weights of earth and masonry, coefficients of friction, type and magnitude of superloads, use limitations, etc., and, conservatively safe values must be assigned to each of these variables. The study of these preliminary assumptions is not included in the scope of this paper.

Having established these values, a method of design that will lend itself to preparation of charts must be developed. The method should be direct; it should necessitate no further assumptions and should arrive at the answer that will fulfill the requirements most economically.

The subject is presented here primarily from the standpoint of the highway field or its equivalent as in that field design charts are probably

*Received by the Institute, Jan. 4, 1943.
†Stone & Webster Engineering Corp., Euclid, Ohio

most needed. In the building field and for railroad and highway bridge abutments, the additional superstructure loads encountered usually vary to such an extent that charts are impracticable. The method described in this paper however is general and will apply to all cases, bearing in mind, of course, that the resultant force referred to therein must first be combined with the additional superstructure loads. The reader will recognize throughout the paper details that are not new. These have been added to avoid any gap in the various design steps.

DESIGN METHOD—STEM AND FOOTING

Stem Design

Top thickness—Theoretically, the top thickness of the stem can be zero. Practically it must be sufficient to provide for pouring facility and strength to withstand impact and frost action. Pouring facility usually governs. For the purposes of this paper (walls up to 35 and 40 ft. high) 11 in. has been considered the minimum clear pouring width advisable and this width plus a 4-in. reinforcement cover at the rear face and 3-in. at the front face, gives a top thickness of 18 in. For lower walls of say 25 ft. and 15 ft. maximum height, this thickness might be reduced to 15 in. and 12 in. respectively. In each case, the design procedure remains exactly the same.

Height limit—35 ft. has been set as the upper height limit and, inasmuch as the upper height limit of economy for this type of wall is usually less than this height, this limit will embrace the majority of cantilever walls. To accommodate unusual and extreme cases, however, stem design charts have been carried up to 40 ft.

W and M^W_s—W is the total weight of the stem and retained material left of the vertical line f-f in Fig. 1.

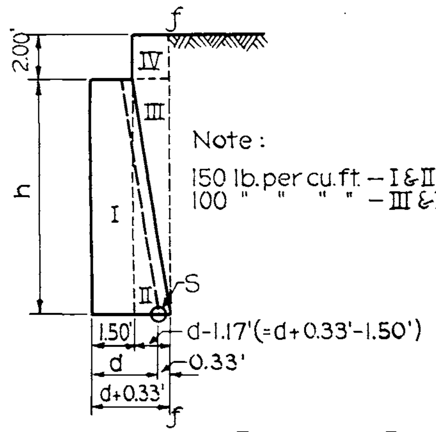
M^W_s is the moment of W about point s, the point where the reinforcement cuts the base.

The derivation of expressions for W and M^W_s is tabulated:

Part	Computation	Weight	Arm	Moment About Point s
I	$1.50h150$	$225h$	$d - 0.75$	$225hd - 169h$
II	$(d - 1.17)h\frac{1}{2}\ 150$	$75hd - 88h$	$.667d - 1.11$	$50hd^2 - 142.2hd + 97.7h$
III	$(d - 1.17)h\frac{1}{2}\ 100$	$50hd - 58h$	$.333d - 0.72$	$16.7hd^2 - 55.3hd + 41.8h$
IV	$(d - 1.17)(2)\ 100$	$200d - 234$	$.50d - 0.92$	$100d^2 - 302d + 216$

Summation for parts I to IV inclusive:

$W = 125\ hd + 79h + 200d - 234$ . . . . (a)



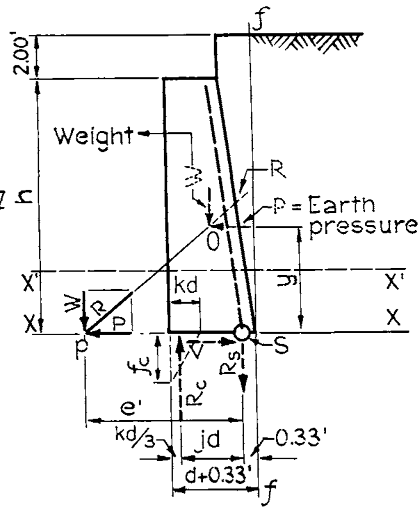


Fig. 1 (above)—$\left[W \text{ and } M_s^W \right]$

Fig. 2—(right) Forces

$$M_s^W = 66.67\, hd^2 + 27.5hd - 29.5h + (100d^2 - 302d + 216)$$

The terms in parentheses are never more than ⅓ of one per cent of the total moment acting on the structure; so, neglecting these terms:

$$M_s^W = 66.67hd^2 + 27.5hd - 29.5h \quad \text{(b)}$$

Bottom thickness—The bottom thickness is determined by applying the laws of statics and flexure to the forces acting on a horizontal section x-x at the base. (See Fig. 2.)

Study of Fig. 2 shows that the external force on section x-x may be regarded simply as a single force R sloping downward and cutting the base at point p, a distance e' from the reinforcement (point s). The moment of this force about point s, $M_s^R = We' = M_s^W + Py$ in which M_s^W is the moment about point s of the vertical component W acting at the center of gravity of the combined concrete and earth sections left of line f-f (i.e. through point o), and Py is the moment about the same point of the horizontal component P acting a distance y above the base.

$$M_s^R = We' = M_s^W + Py \quad \text{(c)}$$

This external force R acting on the horizontal section x-x (Fig. 2) is held in equilibrium by three internal forces:

(1) The compressive stress in the concrete R_c acting vertically upward (resisting the tendency of the front part of the wall to move downward).

(2) The tensile stress in the reinforcement R_s acting vertically downward, neglecting the batter, (resisting the tendency of the rear part of the wall to move upward).

(3) A horizontal stress in the concrete, V, acting horizontally to the right (resisting the tendency of the wall to move bodily to the left).

This force system has been isolated in Fig. 3.

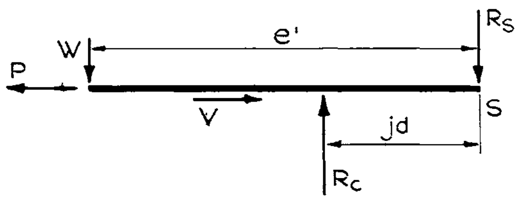


Fig. 3—Design of base

In Fig. 3 note that:

$R_c = \frac{1}{2} f_c kbd \qquad R_s = f_s pbd \qquad V = v\, b\, j\, d$

$W = 125\, hd + 79h + 200d - 234$

$We' = 66.67\, hd^2 + 27.5hd - 29.5h = M_S^W + Py.$

To obtain an expression for d, impose $\Sigma M = O$ about point s, i.e. $We' = R_c jd$; substitute for R_c and We' their values as given by the equations above; substitute the usual constant K for $\frac{1}{2} f_c kj$ and solve for d. The resulting expression, after compensating fully for two minor terms in the answer by introducing the term $+0.02$ ft. is as follows:

$$d = \sqrt{\frac{Py - 29.5h}{12Kb - 66.67h}} + .02 \text{ (ft.)} \qquad \text{(d)}$$

Py may be taken from whatever standard tables are in use in the office, or computed from earth pressure formulae based on theories of either Rankine, Coulomb, Boussinessque, Terzhagi, Spangler, Hogentoger, etc., or any other theory that experience has proven conservatively safe.

The following formulae are Rankine's for a retained material weighing 105 lb. per cu. ft.; a uniform level surcharge h', and an angle of repose of 33 deg. 42 min. They are given here for *no other reason* than that of convenience in establishing the values in the examples referred to below:

$$P = 15\,(h + 2h') \qquad \text{(e)}$$

$$y = \frac{h^2 + 3hh'}{3(h + 2h')} \qquad \text{(f)}$$

To find d substitute the foregoing values in equation (d).

For instance for $f_c = 1000$, $f_s = 18000$, $n = 12$, and $h = 30$ ft.

$k = 0.400$, and $j = 0.867$, $K = 173$
$P = 15300$ lb., $Py = 162000$ ft. lb.
$12Kb = 12 \times 173 \times 12 = 24900$
$66.67h = 66.67 \times 30 = 2000$
$29.5h = 29.5 \times 30 = 885$

$$d = \sqrt{\frac{162000 - 885}{24900 - 2000}} + .02 = 2.67 \text{ ft.}$$

Reinforcement at base—Again, in Fig. 3, imposing $\Sigma V = 0$:
$R_s = R_c - W$

Substituting for R_s and R_c, their value given above under Fig. 3, and solving for p:

$$p = \frac{\frac{1}{2} f_c kbd - W}{f_s bd} \qquad \text{(g)}$$

Thus for the foregoing example:
$W = 125\ hd + 79h + 200d - 234$ (Eq. (a) above) $=$
$125 \times 30 \times 2.67 + 79 \times 30 + 200 \times 2.67 - 234 = 12670$
$\frac{1}{2} f_c kbd = \frac{1}{2} \times 1000 \times 0.400 \times 12 \times 2.67 \times 12 = 77000$
$f_s bd = 18000 \times 12 \times 2.67 \times 12 = 6{,}950{,}000$

$$p = \frac{77000 - 12670}{6950000} = .00926$$

$As = pbd = .00926 \times 12 \times 2.67 \times 12 = 3.56$ sq. in.

Shear, diagonal tension and bond—In Fig. 2, imposing $\Sigma H = 0$ at the base, the horizontal internal force in the concrete equals P and this value might be taken as the value of the external horizontal shearing force acting on that section. However, there is also acting vertically on that section the entire weight W, and before this horizontal shear could be developed, it would be necessary first to overcome the weight W. Moreover, compared to the horizontal force P, the vertical weight W is of considerable magnitude. Thus for the problem given above, it is 12670 lb., while the horizontal P value is 15300 lb. Therefore, the induced compression in the stem, analogous to that in an arch rib, will not permit the external shearing force to become fully effective. However, even under the assumption that the entire force P were unhampered in producing shearing stresses, shear would rarely govern the amount of reinforcement.

Diagonal tension and bond stresses depend upon external shear, hence the above remarks are also applicable to these stresses.

Design of any section above base—Using a straight rear face batter to the top, (Fig. 2), the thickness of any section x′-x′ above the base is computed by simple proportion. The thickness thus computed will be greater than that needed for balanced concrete and steel stresses because as the height decreases the external moment decreases as the cube of the height whereas the resisting moment of the stem itself decreases only as the square. Hence the design of any such section becomes merely a question of determining the amount of reinforcement needed and of computing other stresses merely for record. This may be done either by using Beards' Diagrams* or by direct computation, viz,

Using Beards' Diagrams—Compute d by proportion and in turn W (Eq. (a)); compute also M^W_S (Eq. (b)); Py; We' = Beards' $Ne' = M^W_S + Py$;

$$\text{Beards' } K = \frac{We'}{bd^2}; \text{ and } \frac{e'}{d} = \frac{We'}{Wd}$$

Enter Beards' Diagram with K value at bottom left; follow upward to intersect f_s curve and record f_c, thence horizontally to right to intersect the $\frac{e'}{d}$ curve, thence downward to bottom right and read p. Finally compute $As = pbd$.

By direct computation: (1) Compute d by proportion; also W (Eq. (a)); M^W_S (Eq. (b)); Py; $We' = M^W_S + Py$ and $L = \frac{We'n}{bd^2f_s}$. All these are given constants.

(2) Compute k i.e., $k = \sqrt{2.4L + 1.4\,L^2} - 1.18\,L$; f_c from $\frac{kf_s}{n\,(1 - k)}$ using the maximum allowable value for f_s; p from (Eq. (g)), i.e., $p = \frac{\frac{1}{2} f_c kbd - W}{f_s bd}$ and finally $As\ pbd$.

Shear, diagonal tesnion, and bond—any section above base—The comments concerning shear, diagonal tension, and bond stresses at a section at the base of the wall will apply here with even greater force, for as the height decreases the shear P decreases as the square of the height but the resistance to shear decreases only as the first power.

Two rear face batters—For long high walls it may be economical to use two rear face batters starting, for example, with say a 3-in. batter at the base of the stem and changing to say 2 in. per ft. after the height has sufficiently decreased. These batters and also the height at which the change is permissible may be readily determined from the chart entitled Rear Face Batters in this paper. The additional cost of reinforcement and form work must be considered before deciding to use two batters and consideration given to the fact that the single battered wall, being more massive, would have slightly greater inherent stability.

*See Bending & Direct Stress Diagrams, Case III, in Hool & Johnson's Concrete Engineers' Handbook.