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ECONOMIC TAXES *VS.* GOVERNMENT TAXES—AN ENGINEER'S VIEW OF TAXATION

BY LEWIS JEROME JOHNSON, MEMBER*

(Presented at a meeting of the Boston Society of Civil Engineers held on May 17, 1933)

TAXES are the charges which individuals must in any event carry in order to obtain the service of government; also the additional charges now forced upon them by the revenue-prompted demands of government.†

For taxes are now being levied by two different agencies: (1) economic law and (2) government.

Economic law, in this connection, means the body of requirements which the nature of society automatically imposes upon individuals in their getting and enjoying of a living; *i.e.*, in their production and consumption of goods and services. The levy of taxes by economic law is accomplished by the automatic working of the market in the purchase and sale of a certain basic government service, a share in which each individual in civilized life must constantly have and actually does constantly get. This service now, however, goes by various ill-fitting names, further discussed later, under the cover of which its true nature remains unperceived, as does also the fact that the pay for it is inherently public funds.

Government is humanity organized (1) for such non-automatic control or adjustment of its common affairs as it may at any time consider expedient; and (2) for providing itself with such other types of

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† Throughout this paper regulative and intentionally restrictive taxes are to be understood to be wholly outside the discussion.

service as it cannot get or prefers not to try to get from individual or private agencies.

Taxes levied by economic law may properly be called *economic taxes;* those levied by government may similarly be called *government taxes.**

Both kinds of taxes, government taxes as well as economic taxes, draw upon the same fund: namely, the fruits of production.

That is the only fund that exists, either for meeting the expenses of government, households or business, or for paying debts, or for meeting any other human need.

Economic taxes are simply the market-determined and market-exacted pay for the government service automatically attending lawful occupancy of a city lot or any other tract of land, the title to which (apart from improvements within its borders) has any value in the market. The essential feature of this service is protection against dispossession or displacement in occupancy of the tract. The occupancy may be for purposes of domicile, or for getting a living, or for recreation. An individual may be alone in his occupancy of a tract or lot; or he may, with the help of an apartment house or office building, be only one of many, perhaps many hundreds of, occupants of the same lot.

The *amount* of the tax which economic law levies upon each individual land-occupant, as such, and the amount of the payment which economic law is hence now securing in some form from him, is determined by the bidding of the market for the advantages and opportunities attending, but exclusive of works of man contained on or in, the particular tract or tracts of land, or part thereof, which he has the legal right to occupy. Some of these attending advantages are governmentally provided, like streets, roads, schools, waterworks and sewers; others of them, such as industrial plants and operations, railroad facilities, and places of religious worship, and attractive homes and door-yards, are more likely to be privately provided; some, like markets and social facilities, come of themselves by the mere presence of large numbers of people; still others, like water frontage, mineral deposits, natural fertility, and fine views, are provided by nature.

But however and by whomever provided, such share in these ad-

---

*In passing, we may note that the word "economic," by its derivation from the Greek, means in accord with the rules of housekeeping; in accord with the requirements of the safety and happiness of all the members of the household — therefore, in the best sense, expedient for the great household of humanity. A meaning worth reviving, and one which holds throughout this paper. Accordingly economic taxes and government taxes may and should be regarded as antithetical terms; for government taxes, though above so named because they are levied by government, are also, as will appear, anything but expedient in the best sense. Hence their nature as well as their origin debars them from the classification "economic."

vantages and neighborhood opportunities and attractions as are automatically bestowed upon him along with protection from dispossession constitutes the price-determining feature of his share in this basic service of government.

The government is the only agency which is in a position finally to collect economic taxes and disburse their vast yield in the interest of the productive forces, itself included, which are the sole human providers of all the considerations for which economic taxes are paid. Moreover, only by utilization of their government for that purpose can the forces of production, whether governmental or non-governmental, fully salvage and get the full enjoyment of their normally and actually ever-increasing *earnings*.

Hence, it is government which should ultimately get and have the spending of, in the interest of the whole body of producers (the people), what each individual as land-occupant is paying and must in any event pay for the government's basic service and every consideration whose market value is in excess of what is otherwise paid for it and which attends this basic service.

To this whole great and indispensable body of service we may ascribe the name co-service, or, more simply, *coservice*. By the use of this term, we shall constantly keep in view that the service so named is a service from society to individuals, underlying and in addition to the services exchanged between individuals deliberately and consciously in their many private capacities. It is therefore for coservice and for coservice alone that economic taxes are paid; and the payments for it are properly called taxes not only because of their compulsory character but also because of government's dominant share in the rendering of coservice, government's great direct share in provision of what gives coservice its money value and government's unique power (and hence responsibility) finally to collect and disburse in the public interest the inherently public fund paid solely for coservice. The word tax furthermore connotes the correct ultimate disposition of that great fund.

Unfortunately, however, the economic-tax-*bearing* individual commonly ascribes the name "land" to the considerations for which he makes his payment for coservice, and the payment itself, especially if periodic, he commonly and equally misleadingly calls by the confusing term "rent."*

* Among other occasionally met and equally uninformative or misinformative terms for considerations more or less like this portion of government service, or the pay for it, may be mentioned ground rent, rent of land, economic rent, land value, value of land, site value, site value of land, unearned increment, unearned increment of land value, or some kind of "surplus." Even a "surplus" may belong to him who produced it rather than to one who did not!

Government, *i.e.*, the organized tax-bearers, is thus led to overlook the fact that the vast aggregate pay for coservice thus and now being secured from its own individual membership by economic law is but a body of charges for, and consequently payments for, nothing but a combination of its own direct service and other service the pay for which it alone can justly spend. Misled by this oversight, government fails to collect its own and then jumps to the disastrously incorrect conclusion that, in order to get the needed public revenue, it must *itself* levy taxes, — taxes which in the nature of the case can be nothing but additional charges on these same persons, all of them already and in any event taxed and for the same service.

This mistake comes from failing to perceive that —

(1) Economic law levies taxes;

(2) Economic law does and in any event will levy taxes, not only to the extent that the service thus charged for commands a price in the market, but to the extent that (with occasional, emergency-bred but normally ever diminishing recourse to public borrowing) will secure for individuals this indispensable service;

(3) Economic law levies taxes more fairly, expediently and fruitfully than the wisest government can hope to do; and hence —

(4) The government's part, certainly a would-be democracy's part, in revenue-raising may and should diminish to a mere harvesting of the vast economic-tax fund;

(5) That fund, without government taxes and the misgovernment whence they spring and the further misgovernment which they breed, should yield a public revenue far more abundant than otherwise attainable (for government would then be less harmful and worth more), and the then normally large economic-tax fund would, like the present merely residual portion of it, be brought by economic law into plain sight and within the government's easy reach.

These findings result from taking due note as follows of the characteristics of economic taxes.

* * *

Economic taxes are natural, not artificial in their origin. They arise from the inherent nature of man and society. They are already in force. They are beyond the power of governments either to enact or repeal. Though their yield may be and is impaired by oppressive or incompetent use of governmental authority, their yield rises with citizens' and hence their government's growth in understanding, wisdom nd fair dealing.

Economic taxes inevitably bear upon everyone, rich or poor, who meets his own expenses. They are not and cannot be evaded by abstaining from production. They are not increased by one's success in one's own work, business or profession. Hence they do not discourage production, *i.e.*, do not discourage service to one's self or one's fellowmen. Hence, also, they do not discourage self-employment or the employment of one's fellowmen. Economic taxes, accordingly, do not hamper business; nor do they diminish the fund from which governmental and all other human needs are met. On the contrary, they encourage honest business and promote the enlargement of that fund.

Economic taxes are never based on inquiries into private or personal affairs. They levy on a man, not at all on the ground of what he has done for himself or for others, but only to collect the market-determined value of the service which the government actually puts and holds at his disposal. *Whether they go up or down, they are levied only when and because their payment commands complete market-determined recompense in service unconcealably held at the disposal of each of those on whom they ultimately fall.* Being thus requited in each case, they put no citizen at a disadvantage as compared with other men.

Thus also they reveal "ability-to-pay" as a notion inherently as irrelevant in taxation practice as it is already perceived to be in substantially all other business practice.

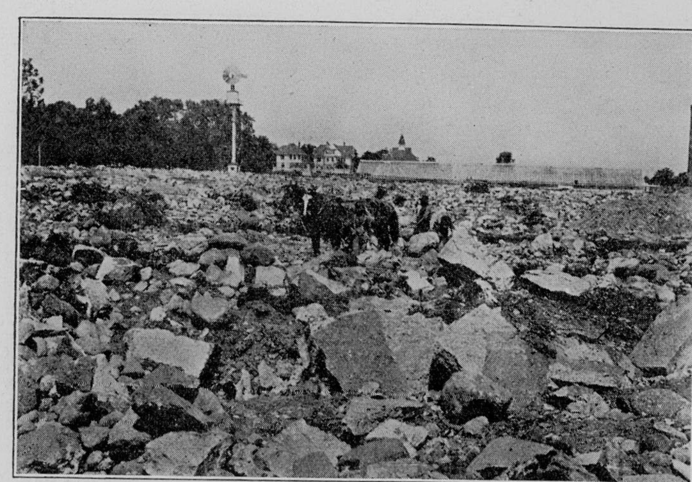
The amount which economic taxes require each person to pay is fixed by the impersonal agency of the market; not by public officials induced by man's statutes to attempt a task which is not only superfluous but beyond human power to do justly.

Economic taxes are the most easily, certainly and cheaply collectible of taxes — not only from the point of view of those now unofficially collecting them, but also from the point of view of the government, which, in order to get the funds, has only to require those always on public record as actually or legally first-hand collectors of them to turn them in.

Economic taxes operate powerfully to establish that equality of opportunity, with security in enjoyment of the fruits of one's own efforts, which has ever been the aspiration of democracy, and without the achievement of which political democracy is dangerously exposed to risk of discredit and even scorn.

* * *

Government taxes are of opposite character in all of these respects. Government taxes include all the taxes which are "shifted," "passed on," or "dodged." They are the only taxes which increase the difficulty



Clearing a boulder-strewn pasture in Massachusetts despite the annual government taxes imposed, nominally at least in perpetuity, on the farmer and his heirs and assigns for so doing. This particular extension of his garden area was made about twenty-five or thirty years ago.

The same tract after being thus transformed into a celery garden. The buildings in the distance are the residences, stable and greenhouse of the enterprising family who made this improvement. These buildings are the results of success in previous ventures of the same kind. It is pleasant to record that this courageous group is still able to meet the taxes and get a living out of this small truck farm. It is an example of success in self-employment in the face of obstacles that were great enough without the addition of government taxes. And what additional expense did this clearing the land impose on the government?

of earning a living, and which increase, without requital, the cost of living. They are far worse than useless, even for their own professed purposes. They are but an evil inheritance from the ancient despotisms, and survive with us because we have been slow to perceive their needlessness as well as their incompatibility with fair dealing and economic order.

Hence government not only may but should abstain from *levying* taxes.

Instead, government should, by adopting the practice of substantially all other great agencies for service, merely gather in the charges for its service, now and always levied upon and collectible from every one by economic law.* Though now collectible under that authority, only a portion of the yield of these charges now reaches the public treasury, the rest being intercepted by their unofficial collectors — to the heavy net financial injury of the vast majority of even those, all of them landowners, who are now doing and should continue to do this collecting. Small, indeed, is the proportion of landowners whose interceptions are their *predominant* interest.

* * *

Production, if it is to thrive normally, must not permit itself to be despoiled of its own earnings, wealth. Production must also see that there is no interference with just distribution of its proceeds. To do this, it must, as a first essential, assert and keep its right of way over interception of economic-tax moneys as the incentive for owning land, whether in city or in country.

Government, as one of humanity's chief productive agencies, must accordingly get into line with normal business practice and prevent the interception of the pay for its own services. This it must do if it hopes either to reduce its expenses to a tolerable level or to raise enough public revenue to meet its present swollen obligations. This it must do if it is ever to fulfill the first requirements of a democratic régime. Among these requirements are the establishment and maintenance of the fairest and hence the most favorable opportunities for production, *i.e.*, for all legitimate business, including government itself. For thus and only thus can arise the best conditions for consumption which is an interest of every human being. With production of all sorts and grades enjoying free and fair play, consumption will look out for itself. Accordingly,

* Though careless accounting often overlooks the thus caused overhead borne by the occupant of land, particularly in cases when he is also owner of the land which he occupies.

a consistent working out of democracy requires the removal of man-made obstacles to just distribution of wealth, *i.e.*, to just apportionment of the fruits of production among all those of all grades who do the producing. Interception of economic taxes and the thus bred extortions, such as government taxes and rack-renting in its various other forms, are among the most disastrous of such obstacles.

* * *

The basic objection to government taxes, along with their superfluousness, is that they take private property for public purposes without equality of compensation.

Moreover, the payment of government taxes is somewhat optional, — that is, the payment of government taxes can be avoided to a considerable extent by refraining from production, by curtailing or declining to carry on business; hence, as a rule, the heavier the government taxes the less the business likely to be done; and therefore the less revenue likely to be had from any source for any purpose. Meanwhile the demand for government expenditures grows and intensifies. Government by thus breaking down private enterprise increases its own burdens and lessens its own ability to bear burdens. It thus produces "depressions" and impedes "recovery." It thus defeats its own purposes.

* * *

Economic taxes, not being levied in response to governmental enactment, cannot be repealed by government nor do they require governmental enactment to be set in operation. They, as above stated, are always fully requited, the accuracy and richness of the compensation increasing with elimination of government taxes and other increases of wisdom in our control of our government.

* * *

The chief reason, already intimated, why we have not long since required our governments to discontinue the practice of levying taxes is a misunderstanding, due largely if not wholly to certain traditional misuses of words.

For instance, the terms "land" and "value of land" as customarily used in discussing taxation do not actually mean land or value of land at all.

"Land," in such discussion, whenever spoken of as having market value, means, even when used with closest approach to accuracy, nothing but the coservice automatically attending lawful occupancy of land. This service is now and always rendered to and hence paid for by occupants, as such, of land, *i.e.*, by every one who meets his own living expenses.* Often, additionally misleading, the term "land" includes, lumped under that one word, land improvements, — a mistake of maximum importance, of course, in farming and suburban districts. Such improvements (among them orchards, cared-for woodlots and timber lots and the results of clearing, draining, tilling, grading, planting, etc.) are not land any more than the buildings upon the land or the just-referred-to coservice attending land. Buildings, land improvements and coservice are the only items on, in, or attending land which are due to any human agency, and are the only things in "land" that actually have any market value. Presence of minerals or other natural advantages, such as command of a fine view, merely increases the market value of the coservice attending the land so favored, but only so long as it continues to be so favored; for minerals can be exhausted and views shut off or spoiled. Minerals in order to acquire market value must be transformed into wealth by removal from their nature-made position.

Coservice is no more to be confounded with the land which it attends than a painting is to be confounded with the canvas to which it adheres. Land, accurately speaking, has and can have no market value whatever, any more than air. On the other hand, coservice ranges in market value from little or nothing in remote or farming regions to hundreds of thousands of dollars per acre per year in the business districts of cities.

* * *

"Value of land" and "land value" are misleading terms often used for the interceptible portion (expressible either as an annual or as a capitalized sum) of the market value of the coservice attending the land in question. Apparently this is the meaning of the term "land rent" as used in the following statement responsibly but unofficially published in 1932: "The land rent (not counting rent for buildings or

* The appropriateness of the term coservice lies in the fact that the service in question is not only a true service rendered by human beings to one another, but it is a service in the rendering of which producers automatically, and to some extent even unwittingly, co-operate. In serving what they are accustomed to regard as their own legitimate ends, they are often serving also one another and beyond what they now get paid in cash. The precise term, coservice, is of importance primarily because we are so pitifully negligent about what becomes of what is paid for this part of our service to one another. Few, indeed, seem to be aware that anything is paid for it. Its meaning will be further worked out in what follows.

other improvements) of the United States is $13,600,000,000 annually, or 15 per cent of our national income." How this figure* was arrived at was not stated, but the connection carried no incentive to an overestimate. In any event, the term "land rent" (or "rent of land") as thus used ordinarily means that portion of the country's total annual payment for coservice which is now legally intercepted each year and hence lost each year to the public treasury and hence to the productive forces of society. If producers now get any of it back, they can do so ordinarily only by earning it over again. *That is not restitution; that is earning it two or more times in order to get it once.*

* * *

In Massachusetts, the familiar official term "assessed value of land" still unfortunately means the sum of two radically different items: (1) the capitalization of that portion of the economic taxes (coservice charge) now abandoned to legal interception, and (2) the assessed capital value of land improvements other than buildings. The first is a portion of governmental or public earnings; the second is a portion of individual or private earnings. The protection of government requisite for producing or enjoying the second is the occasion for economic taxes and the erroneously supposed occasion for government taxes.

* * *

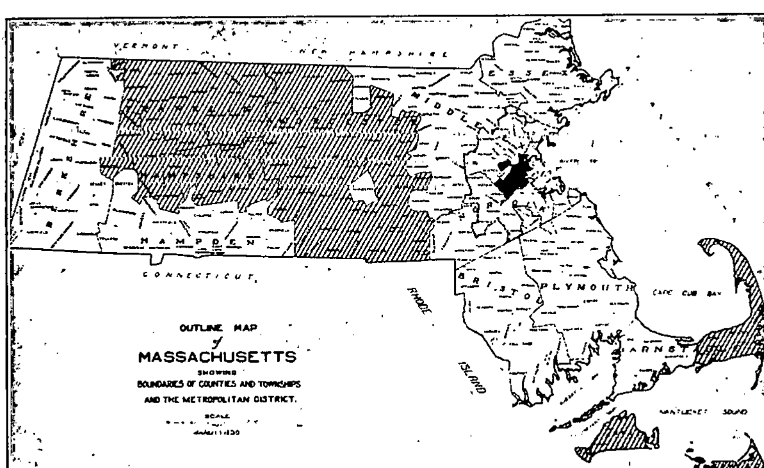
Coservice is rendered exclusively by producers, partly in their non-governmental capacity and partly by the same producers in their all-inclusive, organized capacity, — government.

The portion of coservice rendered by individuals in their non-governmental capacity includes all activities of individuals which make any tract desirable for occupancy to a marketable degree beyond what an occupant must pay for such activities directly. Such activities include, among many others, the building of a bridge, the provision of good telephone or railroad service; also, and by no means least, friendly, law-abiding and public-spirited individual conduct.

A share in this whole great body of service is held at the disposal of each occupant of a city lot or other tract of land (as against any one who would displace him in occupancy) directly and exclusively by government, and in the same sense that telephone service is directly and exclusively rendered to its individual patrons by the telephone company.

* A sum slightly exceeding current estimates of the total annual cost of government in this country, national, state and local combined; a sum also in excess of the present total outstanding principal of the war debts owed the United States.

Shaded areas are (*a*) Massachusetts, large enough to afford individual housing with some 8,000 square feet of land per family for every family of the 120,000,000 population of the United States, and leave adequate room for streets; (*b*) Texas, with Illinois, or five Belgiums, taken out of it, is equal in area to European Germany before the war, in which some sixty million people, despite bad economic management much like our own, were able to get a living. The reader can readily check these assertions for himself.



The aggregate shaded areas, including land improvements other than buildings, were at that time required to equal in assessed valuation the more than half of the taxable land area of municipal Boston reported or indicated in 1914 by the city assessors as vacant; slum-covered and shack-ridden land of course counted as occupied. The solid black area shows the area of municipal Boston, taxable and untaxable land combined. Thus do government taxes and interception-motivated land ownership militate against the normal development and use of much of the most valuable of the residential and business opportunities of the Commonwealth.

The government, like the telephone company, should get what is paid for its services, and for the same reason and for the same purpose. This is none the less true because the government is, in final analysis, all of us, while the telephone stockholders, bondholders and employees are only some of us.

Government, of course, makes a contribution to coservice quite apart from, and in addition to, its basic service of protecting land-occupants from dispossession. This additional or secondary contribution is a miscellaneous one and includes fire and police protection, water supply, sewers, parks, schools, streets, etc., — a body of service closely akin to that which can be, and more or less of which often is, rendered by non-governmental agencies.

Anything, whether the activity of individuals or of government, which makes the city or town a better place to live in or do business in makes the coservice more valuable, whether it increases its price or not. In so far as it does increase its price it increases either the total sum automatically available for public purposes (*i.e.*, for the producers' advantage) or the total losses by producers through interception, according as the producers themselves may be wise enough to direct.

So far as the sums paid for (or carried as an overhead for) coservice are abandoned to interception, as they now so largely are, the economic effect on the tax-bearers (producers) is the same as an equivalent increase of the bonded public debt; except for the radical difference that for the debt the public has presumably been furnished an equivalent by the bondholders. But the public is furnished nothing by the interceptors, as such, of the coservice fund; for the producers themselves furnish the coservice, and no human agency furnishes the land which it attends. Moreover, public debt and interest have an upper limit controlled by conscious governmental act. Capitalized interception and attending charges have not — so long, at least, as producers, rich and poor, permit the interception of the pay for their services to go on; and so long as, by improving their skill, machinery and management, producers continually increase the amounts which they themselves put within the reach of interception. This ever-mounting burden is imposed on and has to be carried by producers only because of their own increase of their own ability to bear it, and, of course, because of their continuing submission to such losses. The remedy is, of course, not that producers stop improving their methods, but that they stop permitting the interception of the major part of their normal earnings.

We should carefully keep in mind: (1) that the governmentally rendered service which consists of protection against displacement from a city lot or other tract of land is the essential and controlling item of coservice, for without it one gets none of the rest of the coservice; with it one gets *all* the rest of the coservice; (2) that those who render the coservice, or any part of it, are all of them, without important exception, constituent members of organized society, *i.e.*, government; and (3) that only by use of their government to that end can these productive forces rescue from interception and secure for themselves what is paid, or carried as overhead, by land occupants, as such, for this great part of their (the producers') immensely valuable service.

For the three reasons just stated, it follows that producers should direct their government to prevent the interception of this now-paid sum, and to utilize it, in their own behalf, for defraying its own, *i.e.*, a large and now increasing part of *their* own, expenses. Thus only, whatever else they may do, can they open the way for fair returns and constant security of outlook for business, which includes the business of all producers, those of humble station and those of high station alike. Thus only can business establish the free run in a fair field which is all that honest business can desire, and which it has never yet had, particularly in our larger communities.

* * *

The less the taxes in a given locality "on" ("on," because, accurately speaking, taxes can be levied on nothing but persons) improvements, incomes, inheritances, etc., *i.e.*, the less the taxes levied on a man on the pretext of his having successfully served himself or others, the better that locality is for producers to live in, work in and do business in; and the more the coservice is thus made worth, the more the producer will cheerfully pay for his share of the service of a government so enlightened.

The present total coservice charge, *i.e.*, the sum now paid by producers, rich and poor, for nothing but coservice, is the vast aggregate of all the taxes now levied, economic taxes and government taxes combined. It includes what actually reaches the government plus the useless costs and wastes attending the collection of government taxes, plus the part of economic taxes which gets intercepted or wasted. Besides being needlessly inflated by these interceptions and wastes, the cost of government is disastrously unfairly apportioned and made intolerably hard to bear by the direct and indirect effects of government taxes. Yet this whole misarranged burden is now being borne exclusively by *occupants* of land, as such, and with no help from land *owners*, as such;

for landowners, as such, are not producers. They are, instead, consumers, — intermediate consumers of the coservice of which the ultimate consumers are the land occupants, as such. Land occupants, in their turn, of course, can and do pay for the coservice only because they are also producers or in the favor of producers.

The government's noting and gathering in of economic taxes would reduce the total charge upon producers by eliminating the interception of economic taxes and its attending wastes; and the elimination of government taxes, besides doing away with their heavy attending wastes, would permit economic law to establish fairness of apportionment of taxation. That means market-established equality of compensation to all who *bear* taxes, *i.e.*, to all who meet their own expenses.

The people are now carrying, for no purpose save that of getting coservice, the present inflated and cruelly misapportioned total tax levy. They can get better government than they have ever had yet for less than the present tax levy by at least the vast aggregate of the present interceptions of economic taxes, to say nothing of attending wastes. They who now bear the larger burden could bear the then smaller charge, and do it more willingly because then fairly apportioned, and, in the case of each tax-bearer, fully compensated.

* * *

The market will in any event set the coservice charge high enough to secure the coservice. For without coservice one cannot, in our modern life, have security of tenure of the landed opportunities essential for home, business or recreation. Coservice is one thing which all persons falling within the scope of the taxation problem must have.

Economic taxes will therefore, as above intimated, suffice to meet the expenses of an honest, intelligent and worth-while government.

Government under which the market fails to set the coservice charge high enough to meet the governmental expenses is thereby proved to be misgovernment, the worst feature of which may be the very prevalence of government taxes, and the interceptions which breed them. Extortions such as government taxes as a corrective for low automatic yield from coservice are on a par with grit as a corrective for overheated bearings in an engine.

The foregoing once perceived, it again stands forth that the levy of taxes by government can and must be discontinued.

Thus only can government clear the way for economic taxes to do their beneficent work unimpeded by the deranging influence of government taxes.

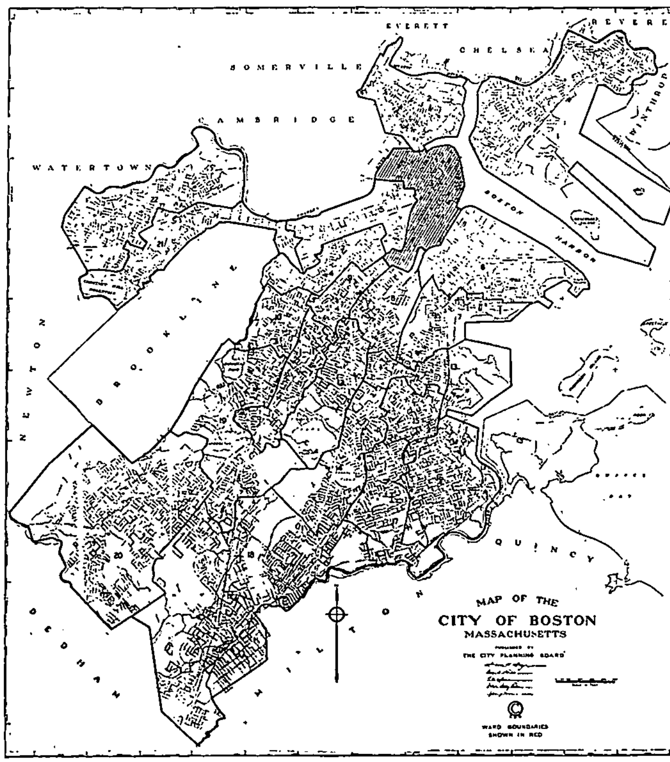
* * *

Valuation. Land and Buildings, by Wards, 1931.

Wards.	Value Land.	Value Buildings.	Total Value.
1....................	$19,060,900	$29,075,600	$48,136,500
2....................	21,545,500	25,192,400	46,737,900
3....................	459,277,800	218,044,400	677,322,200
4....................	59,443,300	55,461,700	114,905,000
5....................	118,792,500	114,045,400	232,837,900
6....................	41,025,700	51,069,000	92,094,700
7....................	9,199,600	16,875,900	26,075,500
8....................	15,594,300	16,854,800	32,449,100
9....................	15,355,000	18,432,400	33,787,400
10....................	5,608,400	17,378,900	22,987,300
11....................	7,391,400	19,573,600	26,965,000
12....................	9,188,200	29,943,900	39,132,100
13....................	6,889,200	18,091,600	24,990,800
14....................	9,483,200	40,625,300	50,108,500
15....................	4,712,900	17,822,200	22,535,100
16....................	8,666,700	25,982,700	34,649,400
17....................	8,110,300	27,558,000	35,668,300
18....................	11,103,800	32,939,000	44,042,800
19....................	9,804,600	25,842,900	35,647,500
20....................	9,633,500	37,477,000	47,110,500
21....................	21,760,300	63,662,200	85,422,500
22....................	10,353,400	30,828,900	41,182,300
Totals............	$882,010,500	$932,777,800	$1,814,788,300

Photographic reproduction of page 15 of the "Report of the Assessing Department of the City of Boston for 1931." Note in what part of the city the "land" (really the capitalized intercepted portion of the residual economic tax explained in page 313 of this paper) exceeds the buildings in assessed valuation, and by how much. Of course, in the suburban wards the "land" assessment in many cases includes land with an appreciable portion of its value attributable to improvements, due to filling, grading, planting; in Ward 3 and even Wards 4 and 5 perhaps *relatively* much less so. The taxable area of Ward 3 is about 525 acres; of the whole city, 18,767 acres. Thus Ward 3, with only 2.8 per cent of the taxable area of the city, commands 52 per cent of the coservice; and even the present coservice enjoyed in that ward is assessed at more than double the value of the buildings of that most heavily built-up region.

Fiduciary interests should help bring about the change on the ground of the greater prosperity at once to be expected for their and all other borrowers, and of better conditions for the non-interceptive portion of their securities and greater and healthier demand for loans. It should be feasible, and, with their co-operation, easy, to find an



Municipal Boston in 1931, showing location of Ward 3 (shaded) and its gross area relative to that of the whole city.

acceptable way, even in the period of change, to prevent harm to any legitimate interest of theirs.

It should also be feasible to ease acceptably through the period of change the small percentage of landowners whose practices are now *predominantly* interceptive.

The period of change should no more be dreaded than any other period of recovery from chronic and occasionally nearly complete paralysis. All ex-interceptors should then find business and investment openings fairer than any now or hitherto open to the producers from whom present-day interceptors are now getting their support.

The period of change should be short. The new régime with its unparalleled blessings should be permanent.

* * *

The government's revenue system, then and thus for the first time made completely economic, would consist, as it should, and as is the case with all other great service agencies, of merely noting and gathering in its own earnings. In thus getting its own earnings, government would have the aid as at present of a type of unofficial tax-collectors (landowners), whose actual and correct economic function is only now beginning to be perceived. But the commissions which we now thoughtlessly allow to such tax-collectors, commonly amounting to 50 to 60 per cent or more of their collections or potential collections, would be reduced to nullity, for the inherent and unrivaled convenience to the landowner — as well as to the public interest — of private property in land would still suffice to secure from landowners the collection service desired and which they are in a position to render more acceptably and more economically than any other possible agency.

* * *

This governmental collection of the coservice yield could, of course, be waived then as now — and even more completely than now — in special cases, such as those of charitable, religious or educational institutions. Thus, and with the abolition of government taxes, these institutions could for the first time become truly "tax exempt"; for they would then be freed from the tax charges now included in their pay rolls and in the cost of their buildings and supplies; they would also be freed from the inroads of income taxes and inheritance taxes into the non-interceptive fortunes, or at least non-interceptively invested fortunes, of donors and testators.

* * *

Requirements upon unofficial collectors of economic taxes to turn in the tax-moneys which our governmental law properly directs into their hands are not taxes upon such tax-collectors, or upon anybody else, any more than similar requirements upon official tax-collectors to turn in the tax-moneys which we direct into their hands are taxes upon those officers of the government, or upon anybody else.

The legal enforcement of this requirement upon these unofficial tax-collectors should hence be feasible without technically invoking the taxing authority of government. This requirement, since it is not taxation,* should be capable of being carried into effect without violation of existing constitutional limitations on the taxing authority. So far as I am aware, our constitutional authorizations of governmental levy of taxes are always permissive or restrictive — never mandatory requirements that the government *shall* levy taxes. Hence, the discontinuance of the governmental levy of taxes should be feasible by merely statutory changes. Such changes would repeal the worse than superfluous governmental taxes and set up the machinery for noting and securing from each unofficial tax-collector the market value of the share of the government service distributed through him to one or more occupants, as such, of his land, among whom he himself, of course, may or may not be included.

The lighter the government taxes, the larger, *other things being equal,* will be these unofficial tax-collectors' interceptions; with their interceptions stopped, however, the greater would then be the amount of wealth left in the control of the producers, either as their individual property or as property applicable in their own interest by their governments — very likely both. We should then hear more of progress with increasing plenty, and less of progress with persisting poverty.

* * *

Practically all persons who own land are producers besides being landowners. Often they are also owners of real estate other than land, and of personal property as well. Hence most persons who own land are as individuals losing heavily, both in cash and in security of outlook, by the prevalent misunderstanding of the term "land" and the consequently prevalent failure to perceive and turn to account the normal function of landowners as unofficial tax-collectors.

The correction of these mistakes, thus abolishing the hardships which these mistakes are now inflicting on the multitudes of owners of land who are producers as well as landowners, and on the perhaps even greater multitude of producers who are not also landowners, is an achievement within the power as well as the purpose of popular self-government, and is now long overdue.

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* The only taxation involved is levied by economic law and is so levied as an operation obviously antecedent to its collection, and *two* steps antecedent to the topic of this paragraph, viz., the disposal of its proceeds as between its unofficial collectors and the public till.

The fairer conditions thus obtainable for all producers and would-be producers should open the way to our becoming once more, and this time permanently, a nation of landowners and home owners, with a better prospect than ever before of making a creditable showing in our effort for democracy.

* * *

In 1931, the charge upon the people of Boston for government service was, on the score of property in Boston alone, not only the $62,000,000 officially reported as their total state, county and city tax, but some $35,000,000 * additional, — now being intercepted, — a total of nearly $100,000,000; not to mention federal taxes, motor vehicle excise, the state income tax, inheritance taxes, taxes "on" gasoline, etc., borne in addition by occupants of Boston land.

Occupants of land in Cambridge are similarly carrying for government service some 35 per cent more than the total nominal municipal tax levy. Instances of this kind could be multiplied indefinitely.

* * *

Producers, in addition to bearing all the government taxes, have to provide the funds absorbed by these interceptions. Hence we can hardly wonder that producers and would-be producers, despite their vast increase in the past century or two of their own ability to produce, are still short in purchasing power; and that anxiety prevails among them all, by no means excluding such of them as are owners or managers of manufacturing, transportation, agricultural and other service-rendering undertakings.

* * *

Interceptors are those who stand in the channels of wealth distribution and intercept wealth which would otherwise reach and remain with those who have a superior economic and moral right to it, sometimes a superior legal right to it as well.

Interceptor, be it noted, is not synonymous with middleman. It is far broader than that. A middleman, a jobber, is not necessarily an interceptor at all, any more than any other dealer in merchandise.

Interception of economic tax-moneys is the key log in the jam of interceptions which now, as throughout history, is all that does or can prevent just distribution of wealth. (See Appendix I.)

* Being 4 per cent on the officially reported "assessed value of land" of Boston.

Economic (Local) System; Resulting Savings (by wards) to Occupants of Boston Land.

Ward	1 Nominal "Total Tax, Polls and Property" (Personal, B'ld'gs and Land) State, County, City $31.50 per $1000	2 Assessed "Value of Land" (Capitalization of Legal Interceptions)	3 Annual Legal Interceptions (4% of Col.2)	4 Actual Total Tax Charge (Annual) (Col.3 + Col.1)	5 Tax Charges which would Yield Present Nominal "Total Tax," Apportioned acc. to coservice distribution shown by Col 2	6 Annual Savings to Occupants of Boston Land by Salvaging the Interceptions recorded in Col. 3. (Col.4 - Col.5)
1	$ 1,602,652	$ 19,060,900	$ 762,436	$ 2,365,088	$ 1,343,329*	$ 1,021,759
2	1,555,660	21,545,500	861,820	2,417,480	1,518,432	899,048
3	23,867,147	459,277,800	18,371,112	42,238,259	32,367,886	9,870,373
4	3,688,797	59,443,300	2,377,732	6,066,529	4,189,310	1,877,219
5	8,606,534	118,792,500	4,751,700	13,358,234	8,371,975	4,986,259
6	3,086,316	41,025,700	1,641,028	4,727,344	2,891,311	1,836,033
7	868,507	9,199,600	367,984	1,236,491	648,347	588,144
8	1,085,573	15,594,300	623,772	1,709,345	1,099,017	610,328
9	1,115,704	15,355,000	614,200	1,729,904	1,082,153	647,751
10	758,499	5,608,400	224,336	982,835	395,255	587,580
11	903,558	7,391,400	295,656	1,199,214	520,914	678,300
12	1,266,556	9,188,200	367,528	1,634,084	647,544	986,540
13	816,870	6,899,200	275,968	1,092,838	486,225	606,613
14	1,624,052	9,483,200	379,328	2,003,380	668,334	1,335,046
15	739,691	4,712,900	188,516	928,207	332,144	596,063
16	1,130,558	8,666,700	346,668	1,477,226	610,791	866,435
17	1,186,172	8,110,300	324,412	1,510,584	571,578	939,006
18	1,480,755	11,103,800	444,152	1,924,907	782,547	1,142,360
19	1,162,237	9,804,600	392,184	1,554,421	690,985	863,436
20	1,521,790	9,633,500	385,340	1,907,130	678,927	1,228,203
21	2,747,013	21,760,300	870,412	3,617,425	1,533,570	2,083,855
22	1,345,592	10,353,400	414,136	1,759,728	729,662	1,030,066
	$62,160,233	$882,010,500	$35,280,420	$97,440,653	$62,160,236	$35,280,417

* $\frac{19,060,900}{882,010,500} \times 62,160,233 = 1,343,329$

Compiled from the Annual Report of the Assessing Department of the City of Boston - 1931

Note that the sums recorded in Cols. 2, 3, 5 and 6 are based upon the yield of the present or merely Residual Economic Tax defined in footnote on page 312. Col. 4 indicates the total cash yield of the combination of local government and Residual Economic Tax. The indirect burdens imposed by this excessive and misdirected charge and bringing income to neither the government nor anyone else are such that their elimination should materially increase all the figures in Col. 6.

The interests common to all the productive forces of society, rich and poor, in high station and in low station, call for recognition of this elemental fact. Legal interception is as harmful in our republic as it was in the old despotisms when it drifted down to us. Other oppressive practices of the old monarchies we have tried to correct, and with some success. But large-scale legal interception of economic-tax moneys has survived, and even today is generally unheeded.

Prevention of the interception of economic-tax moneys and discontinuance of government taxes are two steps essential to the beginning of Economic Order.

With the start thus accomplished and the outlook thus clarified; with the task of government thus reduced and simplified; and with the individual thus given new freedom, new understanding, and new faith, the requisite further progress should prove to be within human powers.

* * *

Petrarch's time brought the Revival of Learning.

The time of Watt brought Mechanical Power.

The time of Bell and Marconi brought Instantaneous World-Communication.

Our time should bring Economic Order.

Appendix I

Present Distribution of Fruits of Production

- Fruits of production
  - Earnings (the pay for one's *own* services)
    - Ordinary earnings *
      - Agriculturists
      - Employees of private enterprise
      - Government officials and employees
      - Laborers, skilled and unskilled
      - Managers
      - Merchants
      - Professional men
    - Deferred earnings †
      - Providers (*i.e.*, owners) of —
        - Buildings
        - Machinery
        - Ships
        - Rolling stock
        - Mine workings
        - Stocks in trade
        - Live stock
        - Orchards
        - Growing timber
        - Land improvements, such as —
          - Clearing
          - Grading
          - Fencing
          - Draining
          - Fertilizing
          - Tilling, etc.
  - Interceptions (the pay for *other* people's services)
    - Legal . . Interception of economic tax moneys ‡ by their unofficial collectors
    - Twilight . . Extortion; "high finance;" "high pressure" selling; "honest" graft; "profiteering:" certain holding company operations, speculative manipulation of the market, betrayals of trust, etc.
    - Criminal . . Embezzlement, swindling, blackmail, etc.

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* Called, also, wages, salaries, profits and incomes.

† Called, also, interest, dividends, rent, incomes and profits; the right to such earnings is properly transferable through sale, gift or bequest of the property in question, and without tax interference.

‡ Called, also, dividends, or, quite improperly, interest; and, thoroughly misleadingly, rent; also profits and incomes.

Appendix II

Illustrative Example of Economic System. In Such a Town as Wakefield, Mass. (Pop. 16,000)

Ratio of "Assessed Value of Land" to assessed value of Bldgs. and Personal Estate about 0.21. Same ratio in Mass. as a whole is 0.44. Figure 1 is based upon Assessor's Report of 1931. Figures 2 and 3 are illustrative **only.**

The tract shown represents $\frac{1}{2500}$ of the total assessed area of the town and also $\frac{1}{2500}$ of the total of the "assessed value of land", buildings, and personal property.

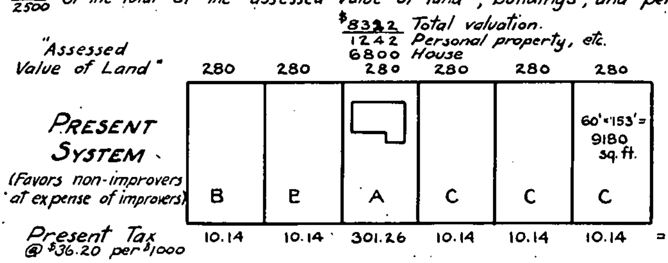

Fig 1

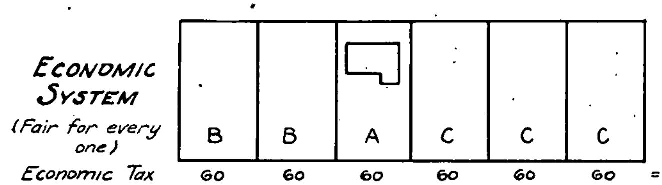

Fig. 2.

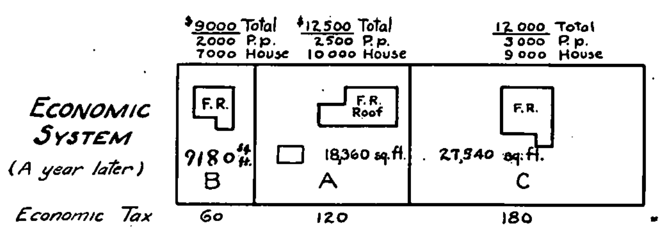

Fig 3.

With the Economic System come better conditions for improvers and fair inducements for non-improvers to become improvers. The new dwellings are the homes of people glad to move out of the more congested parts of the Town.

EXPLANATORY OF FIG. 1 ‡ (PRESENT CONDITIONS)

The imaginary but illustrative tract shown represents 1/2500 of the total assessed area of the town and also 1/2500 of the total of the assessed value of "land", buildings and personal property in the town. It covers also, in the "etc." of the $1,242 item, the same fraction (capitalized at the tax rate of 3.62 per cent) of the total annual levy of the town for polls, old age assistance and motor vehicle excise. This coverage amounts to $521 and constitutes about 5.36 per cent of the total tax charge for the tract.

The six lots in the tract are attended by coservice of uniform market value per lot; hence these six lots are all assessed at the same valuation, about three cents per square foot. That is also the *average* valuation for the town's *whole assessed area* of 3,175 acres. The *actual* valuations within the whole town range from $3.50 per square foot to about one-tenth of a cent per square foot, or from $152,460 per acre to $50 per acre. Economic taxes, if government taxes were done away with, would, of course, vary similarly in the different parts of the town.

The whole tract is owned by three men, A, B and C; and is divided among them as shown. A, as the only resident upon the tract, is assumed to be chargeable with the whole of the payment from the tract for motor vehicle excise, etc. It amounts to about 6.25 per cent of the total charge on him here shown.

"Assessed value" of each lot		$280 00
Annual carrying charge for each lot —		
"Tax" ($36.20 per thousand)	$10 14	
Interest (4 per cent on $280)	11 20	
		21 34

A owns and occupies one lot and the house.
B owns two lots, C three lots; both reside downtown.

Present annual municipal, state and county tax on the score of property in this tract alone totals, as shown		351 96*
Of which the items are —		
Government tax on A, over 93 per cent of it because he has saved, built, etc.	$291 12*	
Residual† Economic Tax, the portion thereof not now intercepted (6 × $10.14)	60 84	
		351 96*

* This figure includes, in addition to the usual total local property tax, 1/2500 of the total of poll taxes, old age assistance and motor vehicle excise of the town.

† Residual Economic Tax is the portion of the Economic Tax (on occupants of land) remaining annually collectible despite the depressing effect (on the market value of coservice) of government taxes.

‡ See page 311.

To this we must add —
Residual† Economic Tax, the portion thereof now intercepted (6 × 4 per cent of $280) $67 20

And so arrive at the
Total Annual Local Tax Charge (total of present annual local charges for coservice) on the score of property represented in Fig. 1 . . 419 16*

This total annual charge of $419.16 is now borne in return for nothing but the coservice attending equally all six of the lots. It amounts per lot to one-sixth of $419.16; *i.e.*, to $69.86 per lot. The equality of distribution of this coservice is the reason for the uniformity of the present "assessed value" of the lots.

A is now carrying, besides his annual $21.34 total Residual Economic Tax for his lot, an annual government tax of $291.12, mainly on account of his house and other savings, his having which subjects the government to trifling if any additional expense; and to no expense not inevitably covered by the undepressed charge for the coservice attending each lot.

Government taxes thus burden landowners, such as A, despite the fact that their utilization of their property does not add appreciably to the public expense. The removal of this handicap upon utilizers, we may reasonably assume, would permit the economic tax per lot to rise from $21.34 toward its normal undepressed figure, say to at least $60 per lot, for the present *unfairly* apportioned levy yields an average of $69.86 per lot. A uniform rate per lot should be paid by all three of these occupants, because the same coservice attends each one of those six lots; and individual owners letting coservice run largely or wholly to waste does nothing to lessen the cost of supplying the coservice. Least of all does the government's failure to collect from a vacant lot owner the full market value of the coservice held at his disposal justify the government's making up the thus caused deficit by piling arbitrary taxes on some one who *has*, and *because* he has, improved his property, *i.e.*, has engaged in production. For production is something which government is organized to protect, not to despoil. Moreover, production is the sole ultimate support of any government.

Owning land is not production, nor is it production to hold land idle. And land is idle to the extent that it is under-utilized either for buildings or for grounds, whether for agriculture, homes, business or recreation.

* This figure includes, in addition to the usual total local property tax, 1/2500 of the total of poll taxes, old age assistance and motor vehicle excise of the town.

† Residual Economic Tax is the portion of the Economic Tax (on occupants of land) remaining annually collectible despite the depressing effect (on the market value of coservice) of government taxes.

And obsolete buildings, often fire traps and shacks, are, in considering the state of development of a town or city, to be regarded as disguises for vacant lots rather than as *de facto* buildings. Overdevelopments, however, like some of our more extreme skyscrapers, are also wasteful, and owners should be freed from the influences which have been tempting them to put up such buildings.

Being provided with coservice, one should pay for it. If a man chooses to waste coservice, that is his affair; but the government should nevertheless get from him in pay for the coservice he wastes as much as the market stands ready to pay for that very same coservice.

Having bought potatoes a man does not have to pay extra if and because he eats them, instead of letting them rot. If eating potatoes were so discouraged, the purchase price of potatoes would be correspondingly depressed, just as Economic Taxes are now depressed; and for the same kind of reason. The purchase price of potatoes would then be merely a residual or preliminary price, just as present "Assessed Value of Land" in business centers of cities (or elsewhere, apart from land improvements) is merely a residual or preliminary price for coservice. Worse yet, the present "Assessed Value of Land" is a price still further depressed by the fact that government taxes force upon the producers or would-be producers, whose organization, the government, alone provides the coservice, the losses due to those who get the coservice allowing the coservice furnished them to run to waste, neither paying the government for it nor utilizing it themselves nor allowing any one else to utilize it.

Such practices would be absurd and ruinous in the potato business, both to potato raisers and potato eaters; they are none the less absurd and ruinous to the productive forces who alone provide coservice and for whose own activities coservice at a fair price is in turn a first essential.

Explanatory of Fig. 2,* Illustrating the Beginning of the Economic System locally

In Fig. 2, local government-taxes are supposedly no longer levied. Economic Taxes are supposedly not permitted either to be wasted with impunity or to be intercepted. Economic Taxes then automatically approach the level normal in such conditions. The Economic System is begun. Next should follow abolition of the rest of government taxes (federal and such of state or other taxes as are not collected municipally). Economic Taxes, then, fully relieved from their government-tax-caused depression, should automatically rise to a level ample for all legitimate needs of government.

* See page 311.

Consequent on the beginnings shown in Fig. 2, A pays $60 into the government treasury instead of $301.26; and B and C, similarly pay $120 and $180, respectively, in place of $20.28 and $30.42. The local revenue now secured is $360 in place of $351.96.

The new liberties and new motivations at once prompt all three of these landowners to action. They quickly see that it is to their interest to write off the $11.20 per year per lot which they had been intercepting and which B and C had been wasting. They can now safely build; they will not be locally taxed because they build, either in local direct tax charges or in such tax charges in the price of building materials, nor because they build a good building rather than a shack; and utilization is now the only means of profit from their property. A year later their property and local taxes are likely to appear as shown in Fig. 3, and for reasons which we may now more fully state.

EXPLANATORY OF FIG. 3,* ILLUSTRATIVE OF THE OPERATION OF THE ECONOMIC SYSTEM LOCALLY; A YEAR LATER

A, by the change, saves at once $241.26 per year, which at 4 per cent capitalizes at $6,031.50.

He proceeds to acquire (from B) one of the vacant lots, enlarges his house, builds a garage, puts on a fire resistant roof, and buys some long-needed additional furnishings. The cost of all his improvements and his current living costs are now free from local government-tax additions to prices of building materials and household supplies.

His local taxes (now wholly economic) become $120 per year, against the more than $452.50 which a continuance of Fig. 1 conditions would have imposed on him, a prospective overhead which had long been blocking his improvements.

His net savings capitalized at 4 per cent are $8,032.50.†

* * *

B sees a new and welcome opportunity. Not caring for large grounds, he gladly relinquishes one of his lots (and its attending economic tax obligation) to A, builds a moderate sized fire resistant house and moves into the pleasanter and quieter quarters he has long desired.

His local taxes (wholly economic) are now $60 per year, against the more than $352.80, for which he would have been liable under a continuance of the present system.

B's net savings, capitalized, are $6,085.†

* * *

* See page 311. † For derivation, see Cols. 6–11 of page 317.

C also grasps an opportunity. C likes larger grounds, but, otherwise like B, builds a fire-resistant house and moves into this more agreeable home.

His local taxes (wholly economic) are now $180 per year, instead of the more than $434.40 which he would have had to face under a continuance of our inherited system.

C's net savings, capitalized, are $5,520.*

* * *

The increased wealth is due to utilization of hitherto wasted opportunities, aided by the thawing of frozen assets or credits by improved conditions for production, *i.e.*, for business. Higher returns are coming to labor, including management; also to capital — not necessarily by higher interest rates, very likely lower, but because more capital is in existence and in use, hence rendering more service and in consequence getting more pay. Accompanying "losses" are losses of nothing but interceptive opportunities or prospects. Producers' enterprise has been freed from the burdens and obstructions imposed by the interception of economic taxes and the levy of government taxes.

* For derivation, see Cols. 6–11 of page 317.

COMPARISON OF ECONOMIC (LOCAL) SYSTEM (FIG. 3) WITH INHERITED SYSTEM (FIG. 1)

	INHERITED SYSTEM (FIG. 1)				ECONOMIC (LOCAL) SYSTEM (FIG. 3)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
OWNER.	"Total Valuation of Assessed Estate," "Personal and Real."	"Total Tax for State, County and City or Town Purposes, including Overlaying," (This is the sum secured by the government under our inherited system.)	Economic Tax borne by Each as Occupant and intercepted by Each as Unofficial Tax-Collector.	Total Local Tax Charge borne by Each as Occupant.	Total Value of Property in Fig. 3. (Increase of $25,458 Tangible Wealth.)†	Total Tax, by Inherited Methods and Old Rate, "on" Property of this Value.	Total Local Economic Tax of Fig. 3 — still adequate.	Annual Cash Advantage to Each Occupant after Introduction of Economic System.	Annual Loss to Each Present Owner as Interceptor of Economic Taxes.	Annual Net Saving to Each Present Owner as an Individual after Introduction of Economic System.	Capitalized Saving to Each Present Owner as an Individual. (Col. 10 at 4 Per Cent.)	Capitalized Saving to Each Occupant as Such. (Col. 8 at 4 Per Cent.)
A . .	$8,042 280*	$291 12 10 14	$11 20	$312 46	$12,500	$452 50	$120	$332 50	$11 20	$321 30	$8,032 50	$8,312 50
B . . .	560*	20 28	22 40	42 68	9,000	325 80	60	265 80	22 40	243 40	6,085 00	6,645 00
C . . .	840*	30 42	33 60	64 02	12,000	434 40	180	254 40	33 60	220 80	5,520 00	6,360 00
Totals .	$9,722	$351 96	$67 20	$419 16	$33,500	$1,212 70	$360	$852 70	$67 20	$785 50	$19,637 50	$21,317 50

* These three items are not wealth at all. They are merely assessed values of titles to interceptive opportunities, *i.e.*, of titles to places on the public pay roll. They are assets, as municipal bonds are assets to their *owners*—to A, B and C as land *owners;* liabilities, however, as municipal bonds are liabilities to the tax bearers, to A, B and C as *occupants* (*i.e.*, users), but without their ever having received the principal ($1,680) from those (always landowners *as such*) to whom the interest charge of $67.20 per year redounds. This leak of $67.20 per year, wholly a loss to producers, as such, is closed by the new system. Gone, also, is the government-tax obstruction which stood in the way of the production and enjoyment by its producers of the $25,000 worth of new tangible property of Fig. 3; in this case mainly real estate.

The closure of the $67.20 leak is more important than its magnitude in this instance would imply; for without its closure, the ending of government taxes, as, for example, by endowment of the municipality by a private philanthropy or bequest (like economy of government expenditure or any other civic improvement), might result in nothing but a heavy increase of the $1,680 liability on the producers, particularly if the area affected is small. Disastrous and needless as government taxes are, and often (as in this example) they may appear to be the major evil, interception of economic-tax-moneys is, nevertheless, the *basic* evil, *i.e.*, the one whose elimination is of primary importance. Its elimination is, indeed, essential for minimizing the cost of government, for maximizing its value to all but interceptive agencies, for establishing equality of opportunity and for thus opening the way to Economic Order.

† The starred items of Col. 1, aggregating $1,680, are not wealth. See preceding note.

REINFORCED CONCRETE SLABS SUPPORTED ON FOUR SIDES

By Eugene Mirabelli,* Member

Synopsis

Present practices in designing two-way slabs and their supporting beams are based on rules which lead to safe designs, but which do not express the true distribution of stresses and loads, because the effect of "plate action" is omitted. The economy inherent in this type of construction is not manifested by such practices, and its use, therefore, has been considerably restricted.

By studying results based on precise analysis for a number of cases, it has been possible to develop simple, approximate equations which may serve as a basis for safe and economical design. In this paper these equations are presented, together with a general discussion of "plate action." Results obtained by use of the approximate equations are compared with those obtained by use of more precise methods and by use of current methods of design. The cases considered are for uniformly distributed load only, and for adjacent spans of the same size or nearly the same size.

Introduction

The usual current methods for design are based on an imaginary division of the slab into a number of independent strips parallel to the sides of the panel, such as strips EF and GH, shown in Fig. 1. Distribution of the load in the long and short directions is a function of the ratio of the lengths of sides for the panel, and is made according to certain equations. The part of the load transmitted in each direction is then assumed to be carried by the slab acting as an ordinary beam in the corresponding direction.

Examination of Fig. 1 shows that the assumed independent action of strips does not exist. Deflection of the strip GH causes twisting in the strip EF, as shown in Section XY. The strip EF tends to resist twisting, and consequently tends to reduce deflection and bending mo-

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ment in strip GH. Bending moment in one element is partially relieved by torsional resistance of the elements at right angles. Ordinary methods for evaluating bending moments will result in quantities which are larger than the actual. The torsional resistance of mutually perpendicular strips contributes, in large part, to "plate action."

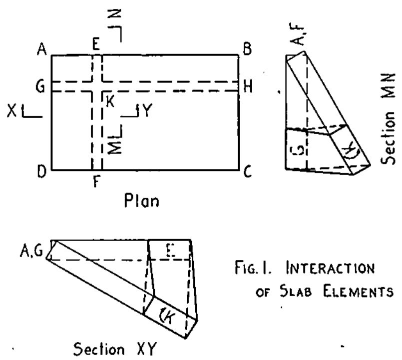

FIG. 1. INTERACTION OF SLAB ELEMENTS

A secondary effect of the twisting moments is a tendency for the corners of the slab to be raised off the supports, as indicated in Fig. 2 (*a*). A twist in the element EK or GK, in the directions shown in Fig. 1, tends to raise the point A. Actual raising of the corners occurs only when the supports AB, BC, etc., are of great stiffness, such as would be provided by masonry walls or by relatively large beams, and consequently are subject to comparatively small deflections. Shallow

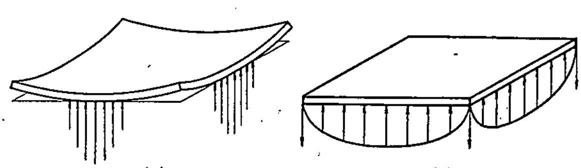

FIG. 2. SLAB REACTIONS

or flexible supporting beams may deflect sufficiently to cause slab and beams to remain in contact throughout.

The greatest benefit from "plate action" is obtained when the sides of the slab remain straight, that is, when supports are rigid and corners are anchored against uplift. Negative bending moments will occur near the corners on sections parallel to the direction GE (Fig. 1), and positive bending moments on sections parallel to the direction AK.

If the corners are not anchored, there are indications that, with uniformly distributed loading, the effect of torsional resistance is reduced about 50 per cent. The indications are supplied in loading tests described by Dr. E. Mörsch * and in the analysis given by C. Bach.†

There have been made a number of mathematically precise solutions for bending moments in rectangular slabs for particular cases by application of the theory of elasticity, and they have been based on the assumption that the sides remain straight. In applying the results of such analyses to practical design, consideration must be given to the flexibility of the supporting beams and the consequent reduction in the strength of the slab.

It may be noted that the relative effect of torsional resistance is less for a slab in a restrained condition than for one which is freely supported, and also that negative bending moments at restrained edges are not affected to the same extent as are positive moments.

Although the effect of "plate action" in the slab is to reduce bending and make possible the use of a thinner section, the effect on the supporting beams is of the opposite character. If the corners are not anchored, there will be concentration of loading in the middle region of the beams equal and opposite to the slab reactions indicated in Fig. 2 (*a*). If the corners are held down and the supports are rigid enough to remain nearly straight, the shears along the periphery of the slab are shown by M. Pigeaud ‡ to vary roughly as the ordinates to an ellipse, for the case of uniform loading. The beam loading will have a similar variation and will be equal and opposite to the slab reactions indicated in Fig. 2 (*b*). The total beam loading will exceed the total slab loading by the amount of the downward forces at the corners.

Notation

L = length of short side of panel (ft.).
rL = length of long side of panel (ft.).
p = fraction of total panel load carried in short direction.
w = uniformly distributed panel load (lbs. per sq. ft.).
W = total uniformly distributed panel load (lbs.) $= wrL^2$.
M = bending moment (ft. lbs.).
M_a = maximum total bending moment in the slab on a section parallel to the long side (ft. lbs.).

* "Der Eisenbetonbau," by Dr. E. Mörsch, 6th Ed., Vol. I, Part II, Stuttgart, 1929, pp. 404–422.

† "Elastizität und Festigkeit," by C. Bach, 5th Ed., Berlin, 1905, p. 614.

‡ "Recherches sur les Plaques Rectangulaires Minces Appuyées a leur Pourtour," by M. Pigeaud, in Annales des Ponts et Chaussées, Paris, February, 1921.

M_b = maximum total bending moment in the slab on a section parallel to the short side (ft. lbs.).
M_l = maximum bending moment in supporting beam on long side of panel (ft. lbs.).
M_s = maximum bending moment in supporting beam on short side of panel (ft. lbs.).
K, K_a, K_b, K_l, K_s = bending moment coefficients.
a = number of restrained short sides in a panel (0, 1, or 2).
b = number of restrained long sides in a panel (0, 1, or 2).
V_l = shear in slab per unit length at middle of long side (lbs. per ft.).
V_s = shear in slab per unit length at middle of short side (lbs. per ft.).
C_l, C_s = coefficients for shears in slabs.
R_c = downward reaction at one corner of a freely supported slab (lbs.).
S_l = end shear in beam on long side of panel (lbs.).
S_s = end shear in beam on short side of panel (lbs.).

Present American Practices

Present practices regarding the distribution of loads in the two directions of a rectangular slab, as expressed by the requirements of building codes, standard specifications for the design of reinforced concrete, and methods given in textbooks on concrete construction are represented by the following equations:

$$p=\frac{r^4}{r^4+1} \tag{1}$$

$$p=\frac{r^3}{r^3+1} \tag{2}$$

$$p=r-0.5 \tag{3}$$

Equation (1) is known as Grashof's Equation, or the Fourth Power Distribution Equation, and is derived in standard textbooks * by equating the deflection of the intersection point for mutually perpendicular center strips. The deflections are evaluated for a uniformly distributed load, and no other interaction of elements is considered. Equation (2), which is sometimes called the Third Power Distribution Equation, may be developed in a similar manner, except that a concentrated load is used instead of the distributed load, and is applied at the intersection of

* "Reinforced Concrete Design," by Sutherland and Clifford, 1926, p. 195.

strips. Equation (3) appears to have no mathematical basis and is entirely arbitrary. It is obviously inapplicable beyond the ratio, $r=1.5$.

The bending moments resulting from any of these assumed distributions may be determined by using the usual moment factors and may be expressed in the form —

$$M=K\,w\,L^3 \tag{4}$$

For slabs which are freely supported on all sides —
Equation (1) leads to —

$$M_a=\frac{r^5}{8\,(r^4+1)}w\,L^3 \tag{5}$$

$$M_b=\frac{r^2}{8\,(r^4+1)}w\,L^3 \tag{6}$$

Equation (2) results in —

$$M_a=\frac{r^4}{8\,(r^3+1)}w\,L^3 \tag{7}$$

$$M_b=\frac{r^2}{8\,(r^3+1)}w\,L^3 \tag{8}$$

and Equation (3) gives* —

$$M_a=\frac{r\,(r-0.5)}{8}w\,L^3 \tag{9}$$

$$M_b=\frac{r^2\,(1.5-r)}{8}w\,L^3 \tag{10}$$

For slabs which are continuous or restrained, Equations (5) to (10) are modified by replacing the factor 1/8 with the usual moment factors which allow for restraint.

The supporting beams, ordinarily, are assumed to take the part of the load as determined by Equations (1), (2) or (3), applied as uniformly distributed. A modification of this procedure appears in the Building Law of the city of Boston which requires the beam loading ". . . to vary in accordance with the ordinates of a parabola having its vertex at midspan." Another common method is that specified in the United

* When $r > 1.5$, $M_a=\frac{r}{8}w\,L^3$ and $M_b=0$.

States Navy Department Standards of Design* which states that the distribution of slab load to the beams may be assumed as indicated in Fig. 3. The beam AB takes the load on the area ABFE, and the beam AC takes the load on the area ACE.

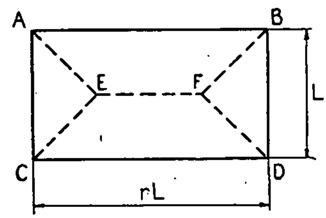

FIG. 3. LOAD DISTRIBUTION TO BEAMS

SOME FOREIGN PRACTICES

The German Regulations† of 1925 prescribe the method of H. Marcus which, for freely supported slabs, provides for a load distribution according to Equation (1). For restrained slabs, the load distribution is based on equal deflection of mutually perpendicular center strips at their intersection, the effect of restraint on the deflections being taken into consideration. The bending moments are corrected for "plate action" by use of modifying factors which vary with the number and location of restrained sides, and which are applicable only if the corners are anchored against uplift. In the absence of such anchorage the factor is equal to one. In slabs which are freely supported on all sides, the equations for moments are —

$$M_a = \frac{r^5}{8\,(r^4+1)} \cdot \left(1 - \frac{5}{6} \cdot \frac{r^2}{r^4+1}\right) w\,L^3 \qquad (11)$$

$$M_b = \frac{r^2}{8\,(r^4+1)} \cdot \left(1 - \frac{5}{6} \cdot \frac{r^2}{r^4+1}\right) w\,L^3 \qquad (12)$$

The method of H. Marcus is also being recommended for approximately square panels by the advisory committee reporting on amendments to the London Building Act.‡

* "Standards of Design for Concrete," No. 3Yb of United States Navy Department, Bureau of Yards and Docks, November, 1929, paragraph 7-04.

† "Der Eisenbetonbau," p. 499. See footnote* on page 320.

‡ Concrete and Constructional Engineering, London, February, 1934, p. 118.

The French Government Rule* provides for the following moments in freely supported slabs —

$$M_a = \frac{r^5}{8\,(r^4+2)}\,w\,L^3 \tag{13}$$

$$M_b = \frac{r^2}{8\,(2r^4+1)}\,w\,L^3 \tag{14}$$

The Official Italian Regulations † of 1927 specify the method of Grashof, that is, Equations (1), (5) and (6).

Some Precise Solutions

M. Pigeaud,‡ working with precise methods, has constructed curves for evaluating bending moments in freely supported slabs for both concentrated and distributed loads for a value of Poisson's ratio, $\frac{1}{m}=0$. The use of Poisson's ratio for slabs seems to be a debatable point. Pigeaud recommends a value of $\frac{1}{m}=0.15$. Other investigators use $\frac{1}{m}=0$.

Timoshenko and Lessells § have brought together the results of a number of precise solutions and give a table of constants from which bending moments may be calculated for simply supported rectangular plates for Poisson's ratio, $\frac{1}{m}=0.3$.

H. M. Westergaard,|| by collecting the results of many mathematical solutions and of load tests, and combining these with knowledge of the general behavior of concrete and of flat slabs, has made a very complete tabulation of probable bending moments for a number of conditions of continuity. The tabulation includes moments in both slabs and supporting beams. The equations for freely supported slabs are —

$$M_a = \frac{r^4}{8\,(r^3+2.75)}\,w\,L^3 \tag{15}$$

$$M_b = \frac{r+1}{60r}\,w\,L^3 \tag{16}$$

* Concrete and Constructional Engineering, London, May, 1930, p. 293.

† "Il Cemento Armato nelle Costruzioni Civili ed Industriali," by L. Santarella, 2d Ed., Vol. I, Milano, 1927, p. 465.

‡ "Calcul des Plaques Rectangulaires Minces Appuyées a leur Pourtour," by M. Pigeaud, in Annales des Ponts et Chaussées, Paris, March, 1929.

§ "Applied Elasticity," by Timoshenko and Lessells, 1925, p. 289.

|| "Formulas for the Design of Rectangular Floor Slabs," by H. M. Westergaard, in Proceedings of the American Concrete Institute, Vol. XXII, 1926, pp. 26–43.

BENDING MOMENTS IN FREELY SUPPORTED SLABS

In Fig. 4 there is shown a comparison of bending moment coefficients as determined by application of methods in current use and by more precise methods. The precise curves are based on a value for

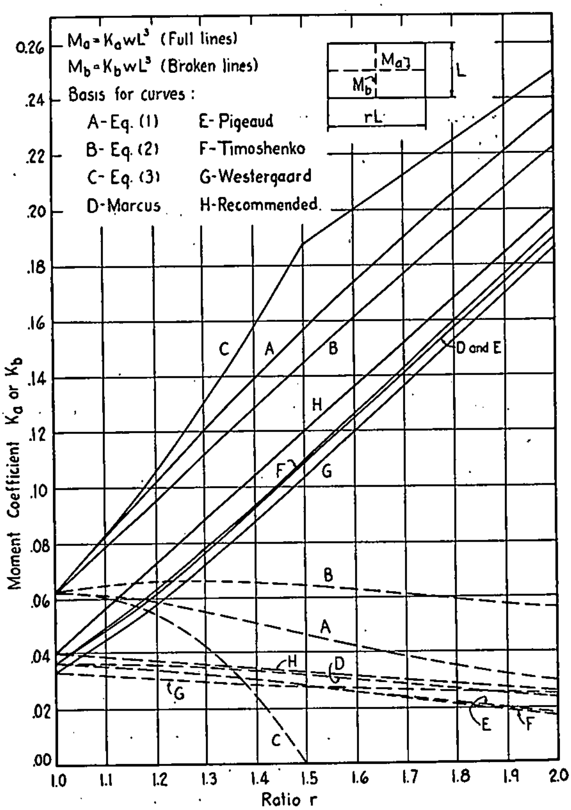

FIG. 4. COMPARISON OF BENDING MOMENT COEFFICIENTS – SLAB FREELY SUPPORTED

Poisson's ratio, $\frac{1}{m} = 0$. In all cases the intensity of moment across the panel is assumed to be uniform and equal to the maximum intensity which occurs near the center. The curves based on methods which include the effect of "plate action" (Curves D, E, F, G) lie close to each other and are distinctly away from the curves which are based on methods used in existing practice (Curves A, B, C). As a basis for a safe and economical method of design, straight lines might be used, such as the ones marked H. These lines provide for a considerable margin of safety over the more precise curves, and allow for uncertainties in theoretical development and for flexibility of supporting beams. The equations for these lines are —

$$K'_a = 0.16\ (r - 0.75) \tag{17}$$

$$K'_b = 0.014\ (3.86 - r) \tag{18}$$

and result in the following recommended equations for bending moments in freely supported panels:

$$M_a = 0.16\ (r - 0.75)\ w\ L^3 \tag{19}$$

$$M_b = 0.014\ (3.86 - r)\ w\ L^3 \tag{20}$$

Bending moments determined by use of Equation (19) average about 25 per cent smaller than the corresponding moments determined by averaging Curves A, B and C, and about 12 per cent larger than corresponding moments determined by averaging Curves D, E, F and G. Bending moments determined by use of Equation (20) average about 20 per cent smaller than the corresponding moments obtained by averaging Curves A, B and C, and about 15 per cent larger than those resulting from averaging Curves D, E, F and G.

Bending Moments in Continuous Slabs

There are a number of cases of continuity or restraint for a slab, as indicated in Fig. 5, depending on the relative position of the panel in the floor. The cross-hatching indicates sides on which the slab is continuous over the supporting beams. These cases provide for a panel in any position (interior, wall or corner), but no distinction is made between the case of continuity for only one panel beyond the support and that of more than one panel. Provision is made for the latter case by a modification which is noted later on.

Current practices in dealing with continuous slabs are in error, partially because they neglect the effect which continuity in one direction exercises on increasing the load carried in that direction, and on decreasing the load transmitted in the perpendicular direction. For example, consider the case of a square panel which is continuous on two opposite sides and freely supported on the other two sides (Case IV or V). Such a panel would ordinarily be designed by assuming one-half the panel load to be carried in each direction, and applying the moment factors of $\frac{1}{12}$ in the continuous direction and $\frac{1}{8}$ in the freely supported direction. Actually, the increased stiffness in the direction of continuity, combined with the effect of "plate action," causes the load transmitted in that direction to be increased to about $\frac{5}{8}$ of the total panel load and causes a corresponding decrease in the fraction of total load carried in the other direction.

Those precise results which are available for restrained slabs are for cases of complete restraint only. For cases of partial restraint, such as occur with continuous slabs, these results must be modified to allow

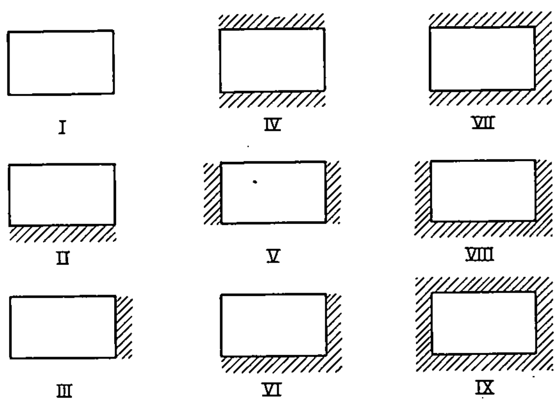

FIG. 5. CONDITIONS OF RESTRAINT

for the possibility of live load occurring in alternate panels only. With panels of equal size such a modification may be made for the positive moments by averaging the results for a freely supported panel with those for a fully restrained panel. Modification of the negative moments requires more juggling because the maximum moments at the supports occur with adjacent panels loaded and some of the other panels unloaded.

For the purpose of studying the effect of restraint on bending moments, tabulations were made of results obtained by application of Westergaard's equations and Marcus' equations,* for positive and negative moment factors, in both long and short directions of slab. The cases shown in Fig. 5 were included, and values were determined for ratios of length to width of panel varying from one to two. Observa-

* "Der Eisenbetonbau," pp. 397–400. See footnote* on page 320.

tion of the general trend in bending moment coefficients led to the following equations which are recommended for all cases of continuity:

$$+M_a = K'_a\ (1-0.05\ br-0.10\ \frac{a}{r})w\ L^3 \tag{21}$$

$$+M_b = K'_b\ (1-0.10\ b-0.05\ a)\ w\ L^3 \tag{22}$$

$$-M_a = K'_a\ (1.60-0.20\ br-0.10\ \frac{a}{r})w\ L^3 \tag{23}$$

$$-M_b = K'_b\ (1.60-0.10\ b-0.20\ a)\ w\ L^3 \tag{24}$$

These equations yield larger bending moments than the Westergaard equations in practically all cases. The positive moments average about 20 per cent larger, and the negative moments average about 12 per cent larger.

When compared with the results of Marcus' equations, Equations (21) and (22) show an average margin of about 12 per cent over the positive moments obtained by Marcus' method. The negative moments cannot be compared because in Marcus' method the effect of "plate action" is neglected for this case.

It is found that the critical moments, that is, those which determine the depth of slab and govern the major portion of steel, are smaller for the majority of cases when determined by Equations (21) to (24), if compared with results based on Equations (1), (2) and (3).

Along a side which is common to two panels, the negative moment may be calculated by averaging the moments for the two panels. This procedure produces results which average about 7 per cent larger than the corresponding values obtained by the Westergaard equations.

Bending Moments in Beams Sustaining a Freely Supported Panel

The bending moments in the supporting beams may be ascertained by starting with the known fact that the sum of moments, in slab and beams, on a section at midspan, parallel to the short side of the panel is —

$$M_b + 2\ M_l = \frac{1}{8}\ r^2\ w\ L^3 \tag{25}$$

and on a section at midspan, parallel to the long side —

$$M_a + 2\ M_s = \frac{1}{8}\ r\ w\ L^3 \tag{26}$$

Subtraction of Equation (20) from Equation (25) yields the bending moment for each long beam —

$$M_l = (0.0625\, r^2 + 0.007\, r - 0.027)\, w\, L^3 \tag{27}$$

and subtraction of Equation (19) from Equation (26) gives for each short beam —

$$M_s = (0.06 - 0.0175\, r)\, w\, L^3. \tag{28}$$

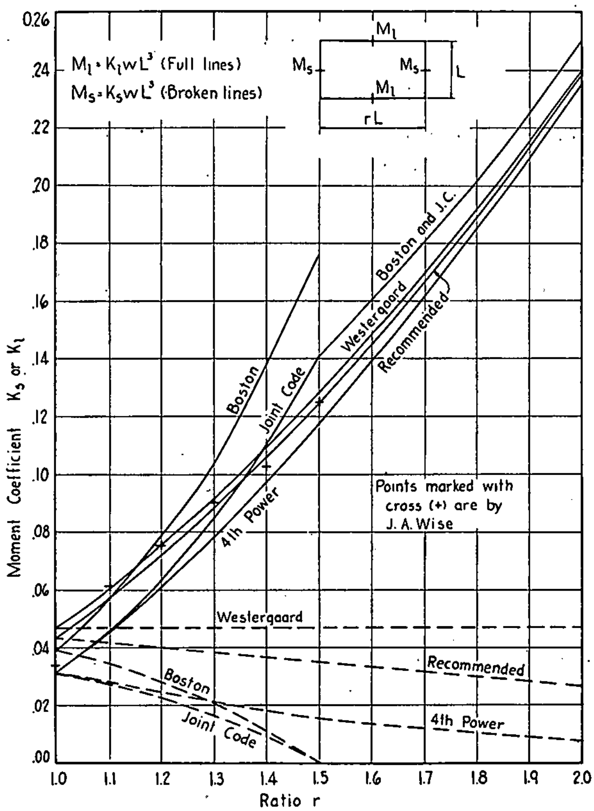

FIG. 6. COMPARISON OF BENDING MOMENT COEFFICIENTS FOR BEAMS SLAB FREELY SUPPORTED

The loading distribution suggested by Fig. 3 leads to the following expression for moment in the long beam:

$$M_l = \frac{1}{48}(3\, r^2 - 1)\, w\, L^3 \tag{29}$$

Now, if the coefficient $\frac{1}{48}$ in this equation is replaced by the coefficient $\frac{1}{46}$, it is found that the results will agree, within 2 per cent, with those by Equation (27). To be consistent, Equation (28) must also be modified. The following recommended equations come from this change:

$$M_l = (0.0652\ r^2 - 0.0217)\ w\ L^3 \qquad (30)$$

$$M_s = (0.0600 - 0.0165\ r)\ w\ L^3 \qquad (31)$$

In Fig. 6, coefficients obtained from Equations (30) and (31) are plotted together with results obtained by other methods. The J. A. Wise* values are calculated from beam loadings which were determined by a precise method, using Poisson's ratio, $\frac{1}{m} = 0.2$. These curves lie closer together than do those of Fig. 4. It is evident from Fig. 6 that current practices give results which in some cases are liberal and in other cases conservative.

Bending Moments in Beams Supporting Continuous Panels

The effect of slab restraint and beam continuity on the beam bending moments may be studied by a method similar to that described for moments in continuous slabs. It is found that if the long beam occurs on a restrained or continuous side of a panel, its bending moment is larger, by approximately $\frac{15}{r^2}$ per cent, than the moment given by Equation (30). If the short beam occurs on a restrained or continuous side, its bending moment is larger, by about 15 per cent, than the moment given by Equation (31). If a beam occurs along a side on which the slab is freely supported, its moment may be determined by Equations (30) and (31), without modification. In any case, if the beam is continuous, its moment is modified, still further, in proportion to the customary moment factors used for continuity: $\frac{1}{8}, \frac{1}{10}, \frac{1}{12}$, etc.

These variations may be expressed by the following recommended equations:

$$+M_l = K'_l\ \left(1 + \frac{0.15}{r^2}\right) w\ L^3 \qquad (32)$$

$$+M_s = K'_s\ 1.15\ w\ L^3 \qquad (33)$$

in which,—

$$K'_l = 0.0652\ r^2 - 0.0217$$

$$K'_s = 0.0600 - 0.0165\ r$$

* "Design of Reinforced Concrete Slabs," by Joseph A. Wise, in Proceedings of the American Concrete Institute, Vol. XXV, 1929, pp. 712–737.

For continuous beams, Equations (32) and (33) may be modified in proportion to the moment factors given in Arts. 708 and 709 of the 1928 Joint Code of the American Concrete Institute.

Equations (32) and (33) are for loads from one panel only. If a beam is common to two panels, the sum of moments obtained from the adjacent panels is used.

This method provides beam moments which average 5 per cent smaller than those provided by the Westergaard equations. The total bending moments on sections across the panels, including slab and beam moments, exceed those required for equilibrium by an average of 10 per cent. The positive moments exceed the required by an average of 6 per cent, and the negative moments exceed the required by an average of 16 per cent.

Shears in Slabs

Pigeaud* gives the following approximate equations for the shears developed at the junction of slab and supporting beams in a freely supported panel. At the middle of the long side of the panel —

$$V_l = \frac{r}{2r+1} \cdot w\,L \tag{34}$$

and at the middle of the short side —

$$V_s = \frac{1}{3}\, w\,L \tag{35}$$

The shears along the panel sides vary roughly as the ordinates to an ellipse. This variation is verified for a number of cases by solutions made by J. A. Wise. The beam loading has a similar variation. It is possible to determine the maximum intensity of beam loading from the known bending moment in the beam. Using Equations (30) and (31) it is found that the maximum slab shears, if assumed equal to the maximum intensity of beam loading, will be —

$$V_l = (0.577 - 0.1920 \frac{1}{r^2})\, w\,L \tag{36}$$

$$V_s = (0.531 - 0.1460\, r)\, w\,L \tag{37}$$

In Fig. 7 coefficients from these equations are plotted, and straight lines are interpolated roughly between the curves. These straight lines

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* See footnote ‡ on page 324.

form the basis for the recommended equations for freely supported panels —

$$V_l = (0.25 + 0.11\ r)\ w\ L \tag{38}$$

$$V_s = (0.44 - 0.08\ r)\ w\ L \tag{39}$$

For a slab which is restrained because of continuity or otherwise, the shears on the restrained sides may be increased, roughly, as follows:

15 per cent if one side is restrained.
10 per cent if two sides are restrained.
5 per cent if three sides are restrained.
0 per cent if four sides are restrained.

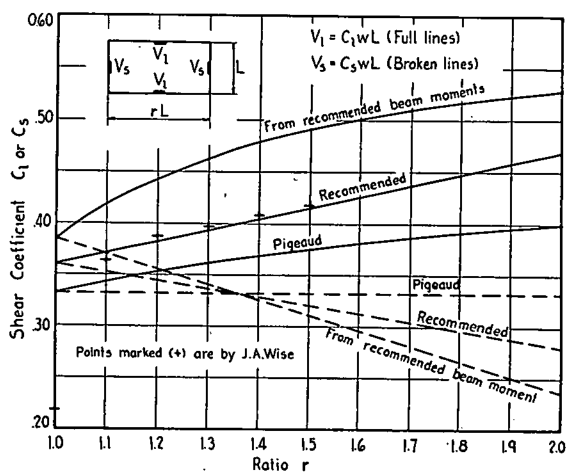


FIG. 7. COMPARISON OF SHEAR COEFFICIENTS FOR FREELY SUPPORTED SLAB

SHEARS IN BEAMS

The end shears in the supporting beams may be determined from the beam loadings consistent with Equations (30) and (31). For a freely supported panel the equations are —

$$S_l = (0.226 - 0.075 \frac{1}{r^2})\ W \tag{40}$$

$$S_s = (0.208 \frac{1}{r} - 0.057)\ W \tag{41}$$

Beams along sides on which slabs are restrained are subject to increases in shear similar to the percentage increases given above for shears in slabs.

Anchorage of Slabs at Corners

The downward forces at the corners, shown in Fig. 2 (*b*), must be sufficient to establish equilibrium of vertical forces. The magnitude of these anchorage forces may be calculated by determining the total beam loads consistent with Equations (30) and (31), and subtracting from these the total applied panel load. Without indicating the intermediate steps, this procedure leads to the expression for the anchorage force at one corner —

$$R_c = (-0.081 + 0.208\frac{1}{r} - 0.075\frac{1}{r^2})\ W \tag{42}$$

Reactions obtained by use of this equation are consistent with the recommended moments to be used for slabs and beams, and allow for

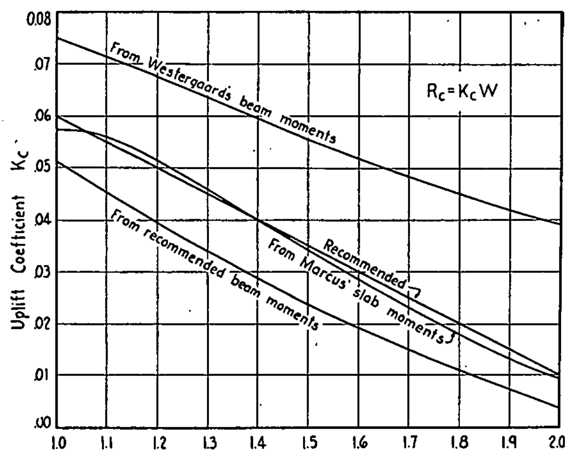


Fig. 8. Comparison of Corner Uplift Coefficients – Freely Supported Slab

some deflection of supporting beams. If supports are rigid, the reactions will be somewhat larger.

Similarly, the following equation may be obtained with the Westergaard equations as a basis —

$$R_c = (\frac{0.65}{3 + \frac{1}{r^3}} + 0.1625\frac{1}{r} - 0.250)\ W \tag{43}$$

and using Marcus' equations —

$$R_c = (0.184 - 1.735\frac{K_a}{r} - 1.735\frac{K_b}{r^2})\ W \tag{44}$$

In Fig. 8 the coefficients from these equations are plotted, and a straight line is interpolated roughly in the region of the curve of Equation (44). This straight line forms the basis for the recommended equation for anchorage forces for freely supported panels, which is —

$$R_c = (0.11 - 0.05\ r)\ W \tag{45}$$

It is necessary to provide negative steel at the corners to resist the bending moment caused by the anchorage. An estimate of the required quantity of steel may be made by computing the bending moment on trial sections taken across the corners and at varying distances from the corner.

Conclusion

The recommended equations do not result in a saving of material in all cases when compared with current practices, but they express more closely the actual conditions, and result in a more effective distribution of material. In general, the recommended equations produce lighter slabs and heavier supporting beams. The greatest saving occurs where masonry walls are available to support the slab directly, without use of beams. For the case of a freely supported slab with total thickness of 6 inches, assuming a minimum of 0.200 per cent for temperature steel and allowable stresses of 800 pounds per square inch for concrete and 18,000 pounds per square inch for steel, there is found a saving of from 5 per cent to 16 per cent in volume of concrete and from 5 per cent to 23 per cent in quantity of reinforcing steel.

It is believed that when municipal building codes are revised, and current requirements regarding two-way slabs are replaced by something more nearly in accordance with their actual behavior, the usefulness of such construction will be more apparent and it will be applied more extensively. A number of building codes are now in process of revision, and there are indications that such changes will be proposed.

The recommended equations for the case of a freely supported panel are collected here.

Maximum bending moments in slab —

$$M_a = 0.16\ (r - 0.75)\ w\ L^3 \tag{19}$$

$$M_b = 0.014\ (3.86 - r)\ w\ L^3 \tag{20}$$

Maximum bending moments in beams —

$$M_l = (0.0652\ r^2 - 0.0217)\ w\ L^3 \tag{30}$$

$$M_s = (0.0600 - 0.0165\ r)\ w\ L^3 \tag{31}$$

Maximum shears in slab —

$$V_l = (0.25 + 0.11\ r)\ w\ L \qquad (38)$$

$$V_s = (0.44 - 0.08\ r)\ w\ L \qquad (39)$$

End shears in beams —

$$S_l = (0.226 - 0.075\ \frac{1}{r^2})\ W \qquad (40)$$

$$S_s = (0.208\,\frac{1}{r} - 0.057)\ W \qquad (41)$$

Anchorage forces at corners —

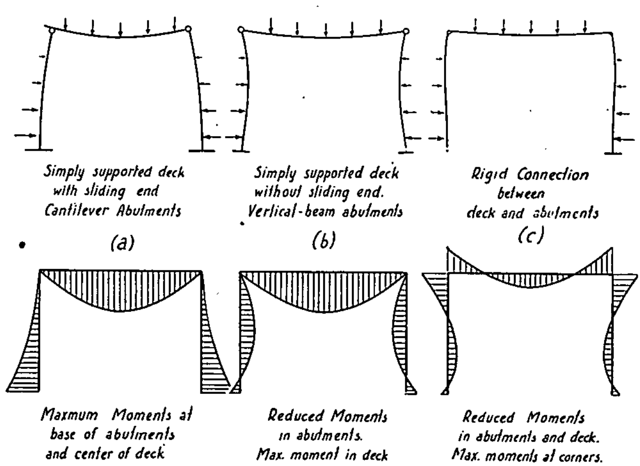
$$R_c = (0.11 - 0.05\ r)\ W \qquad (45)$$

RIGID FRAME CONCRETE BRIDGES AND THEIR APPLICATION TO GRADE ELIMINATION PROJECTS

By R. R. Zipprodt*

(Presented at a meeting of the Boston Society of Civil Engineers held on September 26, 1934)

Progress which has been made in design and construction of bridges during the last ten to twelve years has resulted in the development of a new type, known as the rigid frame bridge. The new type is particularly well suited for use in connection with grade separations.



Effect of Various Corner Conditions.

Fig. 1

A clear conception of what constitutes a single-span rigid frame may be obtained by visualizing a deck supported on two abutments, as in Fig. 1. A deck with one fixed support and one sliding support is shown diagrammatically in Fig. 1 (*a*). The diagram in Fig. 1 (*b*) shows a deck with two fixed supports. The third diagram, 1 (*c*), represents a layout with rigid connections between the deck and abutments. This particular diagram is typical for the single-span rigid frame bridge.

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The three diagrams 1 (*a*), 1 (*b*) and 1 (*c*) represent three fundamental types used in the construction of single-span bridges and of multiple-span bridges equally well. The type shown as 1 (*a*) has been used most extensively during the past fifty years. It is most commonly used in bridges where concrete T-beams or rolled structural steel I-beams are employed in the decks. In this case the abutments are designed as cantilever retaining walls. It will readily be noted that the moments in this type of bridge are greatest at the center of the deck, and also at the base of the abutments.

The moments in the abutments in the type indicated as 1 (*b*) are considerably smaller than those shown in 1 (*a*). The amount of excavation and volume of abutment material can, accordingly, be materially reduced. This type deserves more attention than it has received in the past. It serves a useful purpose under certain field conditions, in addition to being more economical than type 1 (*a*).

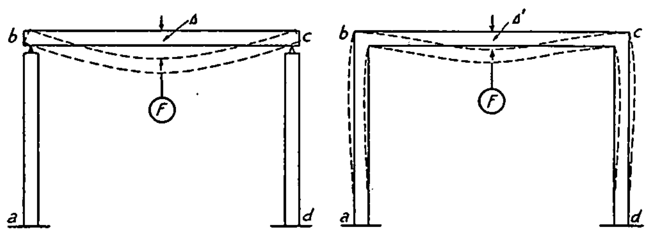
The rigid frame, type 1 (*c*), has an economic moment distribution in the abutments which is similar to that in type 1 (*b*). In addition, the moment distribution in the deck is far more advantageous than in the two preceding types; for example, the moments in the simply supported decks are all positive, the greatest moment existing at the mid-point of the span and governing the depth of the deck. Ordinarily, the depth of the deck is made uniform from abutment to abutment. In the rigid frame, however, the moment curve shown in Fig. 1 has been raised, as it were, thereby effecting a more equal distribution of the moments throughout the deck. On the other hand, the moments at the mid-point of the span have been materially reduced.

In a rigid frame, however, the largest moments, and therefore the deepest sections, occur at the corners. Smaller moments and thinner sections prevail at the base of the abutments and at the mid-point of the deck. The distribution of the moments, and therefore of the construction materials in the rigid frame, is the reverse of the distribution in the more conventional bridge types. This "reversal of form" is one of the fundamental reasons for the advantages evidenced by the rigid frame type.

Fig. 2 represents a deck simply supported on two abutments, and also a deck rigidly connected with the top of the abutments. If a load, F, is applied at the center of both decks, the deflections caused by such application of load are shown as Δ and Δ'. The dotted lines indicate the deflections of the structure under the load F.

The work performed during the gradual application of the loads F is, respectively, $\frac{1}{2}$ F Δ and $\frac{1}{2}$ F Δ'. These expressions for the external work produced by the loads F equal the internal work or resilient energy which is stored in the elastic frames. In the case of the simply supported deck, all of the external work is stored as resilient energy in the deck alone; in the rigid frame, however, the resilient energy is stored in the abutments also. Stated in another way, it may be said that, in the rigid frame, the *entire* structure is put to work. The formulæ expressing this mathematically are shown in Fig. 2.

Putting the entire structure to work acts to considerably reduce the moments. This, in turn, means that the cross sections at various points may be reduced. Therefore the full utilization of the static properties of the entire frame results in a decided saving in the construction materials required.



Simply Supported Deck

$$\tfrac{1}{2}F\Delta = \tfrac{1}{2}\sum_{c}^{b} M^2 \cdot \frac{ds}{EI}$$

All of the external work is stored as resilient energy in the deck alone.

Frame with Rigid Corners

$$\tfrac{1}{2}F\Delta' = \tfrac{1}{2}\sum_{c}^{b} M^2 \cdot \frac{ds}{EI} + \tfrac{1}{2}\sum_{b}^{a} M^2 \cdot \frac{ds}{EI} + \tfrac{1}{2}\sum_{c}^{d} M^2 \cdot \frac{ds}{EI}$$

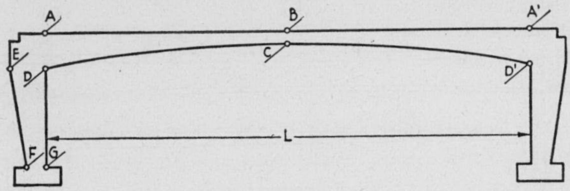
The resilient energy is stored along the entire length of deck and columns.

By introducing rigid corner connections, the entire frame is put to work. Moments and sections are reduced - and a distinct saving in yardage is gained.

FIG. 2

The moments and shears in a simply supported deck are functions of the deck span and loading only. In a rigid frame, however, the moments are also influenced by the proportions of the abutments. If, by way of example, the abutments are relatively high and thin, Δ' may be equal or nearly equal to Δ. The points of inflection in the rigid frame deck are then near the corners of the frame, and the moments in the two decks are nearly equal. When the abutments become gradually shorter and thicker, the value of Δ decreases, with the result that the points of inflection move towards the mid-point of the span, and the moments become smaller at the center and larger at the corners. It is entirely obvious that the design of a rigid frame should be based upon the relative proportions of the entire frame.

Design problems are somewhat complicated by the fact that the relative frame proportions must be known before a moment analysis can be made. Considerable time may be saved in an analysis by making the



(a). Lay out the top of the deck ABA' according to the roadway requirements.

(b) Determine the clear span, L

(c) Lay out BC equal to about $L/35$. This value may be reduced to $L/40$ when the frame is founded on a practically unyielding foundation; it should be increased where the footings rest on highly compressible soils.

(d) Lay out AD and DE equal to about $L/15$.

(e) Draw the soffit curve DCD'

(f) Determine the elevation of F and G from the clearance requirements and foundation conditions.

(g) Lay out FG equal to about 1 ft. 6 in. for 30-foot spans, about 2 ft. 6 in. for 60-foot spans, and about 3 ft. 4 in. for 90-foot spans.

(h) Connect E and F with a straight line.

FIG. 3

preliminary frame layout conform to empirical rules derived through an analysis of a large number of such structures already built. Fig. 3 gives such a set of empirical rules for rigid frames designed for heavy highway

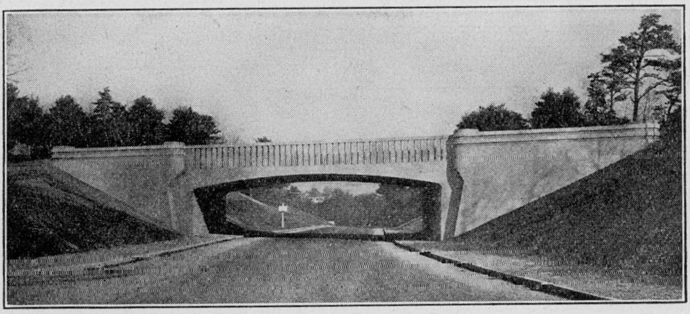


FIG. 4

loading (H 20). The procedure given in Fig. 3 should be followed closely in making the preliminary frame layout.

Fig. 4 shows the first rigid frame bridge designed for the Massachusetts Bridge Department by Fay, Spofford & Thorndike, consulting engineers of Boston. This is the grade separation structure on the Circumferential Highway at Dedham, Mass. The slots in the handrail have been extended downward to a line which is flush with the top of the structural deck slab, in order to show the actual thickness of the rigid frame. The wing walls have been so shaped as to reveal the actual proportions of

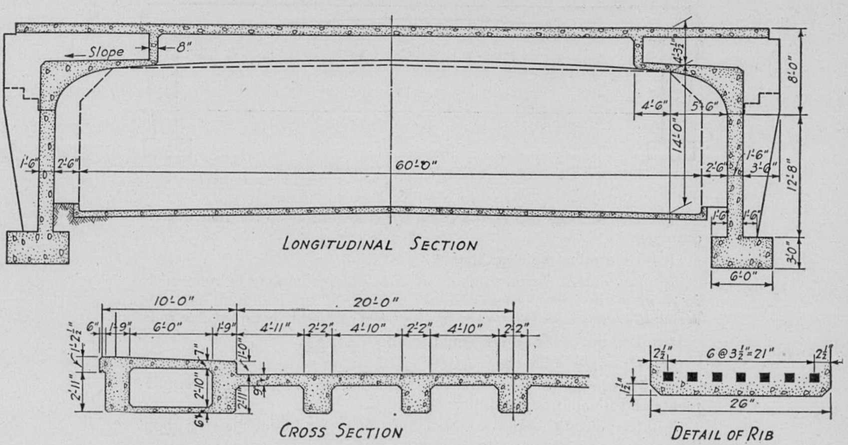


FIG. 5

the abutments. The exterior thus presents a true picture of the structural frame. The general aspect is one of pleasing modern architectural design.

Cross sections through rigid frames may be either rectangular or T-shaped. For longer spans and heavier loadings, it often proves eco-

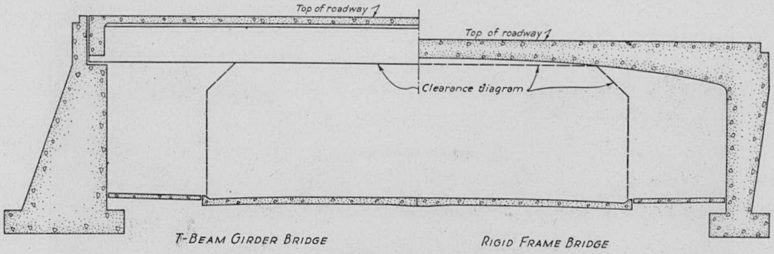


FIG. 6

nomical to use a ribbed deck and also ribbed abutments. Fig. 5 shows a cross section through such a frame, indicating the provision which is made for carrying the necessary public utilities.

It should be noted in passing that the rigid frame principle is readily applicable to bridge layouts requiring any arbitrary number of spans; for example, a rigid frame bridge with three spans and open end bents is

Safety requirements often make it highly desirable that intermediate piers be omitted in grade separation structures; and yet it is essential that the depth of the deck be kept as shallow as possible. The rigid frame bridge fulfills both requirements. It can straddle longer spans with less construction depth than any other deck type of bridge.

Many valuable modifications of the rigid frame principle have been used in recent years in order to increase the span of the deck and yet maintain a minimum depth of construction. One of the most promising types involves the extension of the deck structure in the form of cantilevers beyond the end piers. Suitable counterweights may be added at the extreme ends of the cantilevers in order to reduce the positive moments at the mid-span of the deck. This is the engineering principle according to which the Herval bridge in Brazil was designed and constructed. It made it possible to build the longest concrete girder span known, 224 feet long, with a depth at mid-span of only 5 feet 7 inches, or approximately one-fortieth of the span length. By application of the rigid frame principle it is thus possible to extend the span length of concrete girder bridges far beyond the spans generally used today.

The rigid frame is a deck structure; that is, it is a type of bridge in which the entire supporting structure lies below the top of the deck. The features of a deck structure involve two safety elements: first, there are no projecting structural parts, and therefore the least possibility of collision with and damage to passing vehicles; and second, the concealment of the structure is also of vital importance to its own safety, since bridges have been known to collapse after collision had weakened some structural part.

Deck structures — including the rigid frame — are easily widened. This is a point of major importance in modern bridge building. If it is difficult or economically impossible to widen a bridge, it too often remains in place long after its inadequate roadway width has become a serious menace to the congested traffic which must pass over it.

The question may be raised as to the relative economy of a rigid frame bridge when compared to other types. It is usually the rule that low first costs of grade separations are obtained with the structure that has the shallowest deck. The result is that the use of the rigid frame for grade separations is responsible for producing a lower first cost than does any other type, under similar conditions.

The rigid frame has no bearings or expansion joints between the deck and the seats on the abutments. It is also a fact that by employing rigid construction in bridges that are continuous over two or more spans, the expansion joints over the intermediate piers are eliminated. The rigid frame type of bridge therefore requires less maintenance when compared with the more conventional bridge types.

Despite the very best attention which may be given to maintenance and upkeep, any bridge will approach the time when it must be replaced. The rigid frame has but few vulnerable spots to maintain. Consequently, it may be expected to have an unusually long period of serviceable life. Furthermore, there will be no need for scrapping a rigid frame bridge because of inadequate roadway width, since the structure is easily and economically widened.

In further considering the economics of the selection of any particular type of bridge for a given location, the changes in abutting property values, occasioned by the building of a bridge, must be given more consideration than in the past. In grade separations, a good appearance is

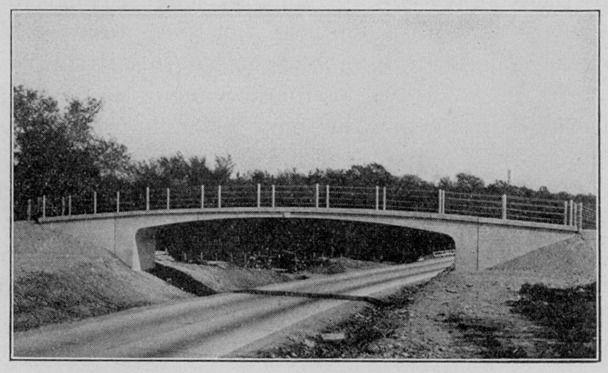


FIG. 9

considered a particularly valuable asset. These structures are frequently built in densely populated regions; but regardless of the type of the surroundings, they are always conspicuous from the underpassing roadway.

The beam type of structure has been widely used in the last fifty years because it is so adaptable to ordinary service requirements. Its profile does not, however, satisfy the esthetic or architectural requirements, which demand a clearance height that is greater at the middle of the span than at the supports.

The rigid frame fulfills both requirements. It provides a horizontal deck for the traffic as well as an arched ceiling or intrados. It presents a new and extended field for architectural expression to go hand in hand with engineering requirements for both service and economy.

Fig. 9 shows a rigid frame bridge built in 1932 by the New Hampshire Highway Department for a cattle pass in Rockingham County in New often both economical and suitable for grade separations, particularly where built in rural regions.

Fig. 6 is a line drawing representing two grade separation structures spanning over a four-lane roadway and two sidewalks. The clearance required over the roadway is indicated by a dotted line. In this case a conventional T-beam girder bridge is compared with a rigid frame bridge. The differences between the two types appear obvious. The troublesome details at the top of the abutment to the left are eliminated in the rigid frame to the right. The rigid frame requires no sliding plates, rollers or rockers; only one expansion joint at each approach slab is required, and this joint is of simple design. No movement of the top of the abutment is possible in the rigid frame; nor is there any possibility that the deck will creep laterally on the bridge seat. The rigid frame is simple to construct, and, later, easy to maintain.

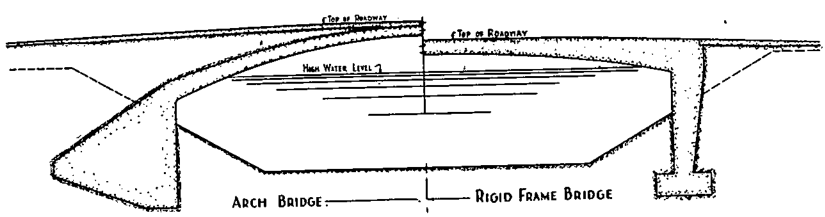


Fig. 7

The outstanding feature about a rigid frame, however, is the shallow depth required for the deck construction. This is clearly illustrated in Fig. 6, where the difference in elevation of the roadway slabs is 1 foot 6 inches. The average thickness of rigid frame decks can often be made as little as one twenty-fifth of the span for ordinary highway loading. Ordinary simply supported deck construction requires a depth of deck that is anywhere from 50 to 100 per cent greater.

The depth of the deck in a rigid frame is not only shallow, but the deck material is also distributed to better advantage. The minimum depth of the deck is over that portion of the roadway on the underpass where the greatest clearance is required. The deeper deck sections are near the abutments over the sidewalks, or shoulders. Thus, from a purely utilitarian standpoint, the shape of the deck in a rigid frame is most suitable to the conditions which prevail at grade separations.

Fig. 7 shows a comparison between a flat arch and a rigid frame for use over a stream crossing. It is clearly shown that the roadway level can be lowered considerably by the use of the rigid frame type of structure.

When the crossing at grade of two intersecting roads is to be eliminated, it is necessary either to raise one road by building approach ramps on fill, or to lower the other road by building approach ramps in cuts. It frequently becomes necessary to build a system of concrete retaining walls, especially where the land value is high. Under such circumstances, each additional inch of depth required for the deck construction will result in a considerable additional expense for the building of the approaches.

Fig. 8 represents typical comparative estimates of first cost for four types of structures *designed for the same grade separation*. These estimates were recently prepared by the Westchester County Park Commission, New York. The cost of the approaches in general is about 60 per cent

Comparative Estimates of First Cost for Grade Separations using single-span overhead structures of various types. Prepared by the Westchester County Park Commission, N.Y. (+)

	Overhead Structure	Approaches	Total
Reinf. Conc. Solid Rigid Frame	$ 19,000 (100) (42)	$ 26,500 (100) (58)	$ 45,500 (100) (100)
Steel Girder	$ 21,800 (115) (40)	$ 33,100 (125) (60)	$ 54,900 (121) (100)
Reinf. Conc. Fixed Arch	$ 25,900 (136) (46)	$ 30,500 (115) (54)	$ 56,400 (124) (100)
Reinf. Conc. Ribbed Rigid Frame	$ 17,700 (93) (32)	$ 37,400 (141) (68)	$ 55,100 (121) (100)

Clear width: 40 feet - Clear span: 64 feet - Underclearance for steel girders: 13 feet
Underclearance for rigid frame: 11 feet at curb and 15 feet at center.

(+) Eng. News-Record, Dec. 1, 1927

Conclusions for this grade-separation.

1. *The cost of the approaches comprises about 60 per cent of the total cost.*
2. *The most economical overhead structure is the one with the most economical approaches.*
3. *The grade separation with Solid Rigid Frame Structure is 21 per cent less than the other types.*

FIG. 8

of the total first cost, or about *50 per cent more* than the overhead structure itself. The estimates also show that the cost of the approaches varies considerably with the type of structure chosen, the highest approach cost being 40 per cent higher than the lowest approach cost. It is also apparent that the most economical overhead structure is the one having the most economical approaches. The lowest total cost of structure plus approaches belongs to the solid rigid frame bridge; it is about 21 per cent lower than the next nearest estimated total cost. In converting a grade crossing into a grade separation, it is generally the rule that the most economical structure is the one with the shallowest deck.

The elimination of grade crossings is prompted by a demand for safety. It is essential, then, that the type of structure built should interfere as little as possible with the traffic.

Hampshire. The gracefully arched ceiling is of pleasing effect, as seen from the main traffic artery passing underneath the bridge. The lightness of the structure is impressive, its depth at the center being only 11 inches. An overhead structure of such simple and attractive appearance is an asset to its surroundings in any region, rural as well as urban,

Questions frequently arise regarding the arrangement of the reinforcement in rigid frame bridges. The isometric view in Fig. 10 shows a typical layout for a single span bridge with solid deck and abutments. Dowels extend from the footing into the bottom of the abutment wall, where the usual length of lap is provided with the vertical wall bars.

The first step in laying out the reinforcement is to determine the

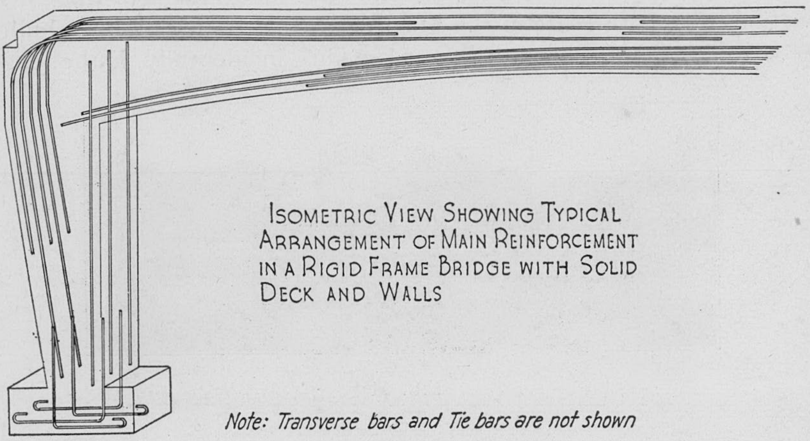


Fig. 10

amount of reinforcement required in the extrados at the corner. The clear distance between these bars should be kept as large as possible, since too close a spacing may interfere with the proper placing of the concrete. A simple, convenient layout is obtained if about one-half of these bars extend from the construction point at the footing to about the quarter point of the deck. The remainder of the bars may extend from the mid-point of the wall to the crown of the deck, where they are to be spliced with similar bars from the other half of the deck.

An ample area of tensile steel at mid span in the intrados should be supplied, since the crown section is highly susceptible to overstressing caused by sliding of the footing on the supporting foundation. One-half of the steel bars in the intrados may conveniently be extended from the wall to about the quarter point on the opposite side of the crown, thus making the length of all of these bars equal to about three-fourths of the span.

A nominal amount of vertical reinforcement is usually supplied near the front face of the wall.

Transverse bars perpendicular to the main reinforcement should be of ample size; for example, three-fourth-inch round bars spaced about eighteen inches apart in both faces. These bars are placed on the inside of the main longitudinal bars. The two systems of bars are finally braced against each other with three-eighths-inch round tie bars spaced about two feet apart in both directions. Diagonal tension or shearing stresses are generally low in rigid frames with solid deck and wall; but additional shear reinforcement must be supplied in case the frame is of ribbed construction, as was the case in the Martinez Street bridge recently built in San Antonio, Texas, shown in Fig. 11. This, incidentally, is the longest

FIG. 11

span rigid frame of reinforced concrete as yet built in the United States. The clear span is 101 feet, 6 inches, while the depth at the center of the span is only 3 feet, 2 inches. In this case, both the deck and the abutments are of ribbed construction.

The statement is sometimes made that rigid frames can be built on solid, firm foundations only. This statement has little or no justification, as will now be briefly discussed. Consider the frame in Fig. 1 (c). Perfect frame action requires that the original horizontal distance between the footings remains unchanged. In this case, the foundation must naturally exert a horizontal thrust upon the footing. Now, let us assume that this distance increases, due to the fact that the footing slides on the foundation; the thrust decreases simultaneously and so does the corner moment, whereas the positive crown moment increases. The increased crown moment can readily be determined and the proper amount of material be supplied to keep the stresses within the allowable limits. Therefore the more the footings move horizontally, the more material must be provided at mid-span. The worst condition that may be encountered is that in which the horizontal thrust as well as the corner moment equal zero, in which case the deck moments then equal the moments in the simply supported deck in type 1 (*b*). It is granted that all of the advantages of rigid frame action are then lost; but it is equally obvious that the supposedly rigid frame reverts to a customary girder layout, and that the saving in the construction materials has been dissipated.

The conclusions from the above discussion are: (1) that a rigid frame can be built on practically any foundation; (2) that the cost of the rigid frame structure increases when the character of the foundation becomes inferior; and (3) that the cost of the rigid frame structure then converges toward the cost of a structure of the customary girder type.

The detail in Fig. 12 is recommended in order to minimize the possi-

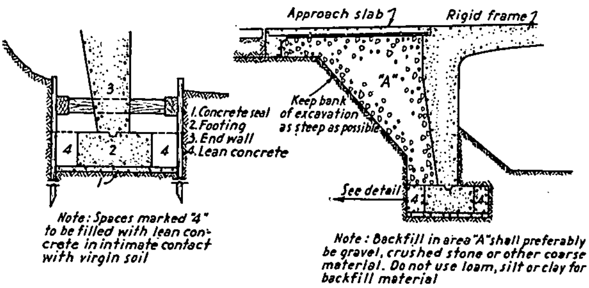


FIG. 12

bility of the horizontal sliding of the footing. Wherever it is feasible, the entire width of the footing excavation should be filled with concrete cast up against undisturbed virgin soil. The figure shows how this may be accomplished in cases where coffer dams are used. The sheet piling may, of course, be withdrawn as the concrete is placed. Incidentally, this is an excellent detail to use for all footings under any type of bridge structure.

Modern analytical methods have made it possible to reduce the time consumed in analyzing a rigid frame to about one-fourth of the time originally required. This has been brought about by the pioneer work done by Mr. A. G. Hayden, designing engineer for the Westchester County (New York) Park Commission, Professor Hardy Cross of the University of Illinois, and others. All of this has resulted in a material reduction of the time consumed in the analysis of any particular project. Further simplifications are under way which promise to make it possible to design any type of rigid frame structure with even less time than has been the case in recent years.

THE CONSTRUCTION OF A SPECTROSCOPY LABORATORY BUILT FOR THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

By Harry E. Sawtell, Member*

(Presented at a meeting of Northeastern University Section of the Boston Society of Civil Engineers, held on April 26, 1934)

In 1932 the Massachusetts Institute of Technology built two laboratories the Eastman Research Laboratory and a laboratory for spectroscopic work. It is this last-mentioned building which will be described in this paper.

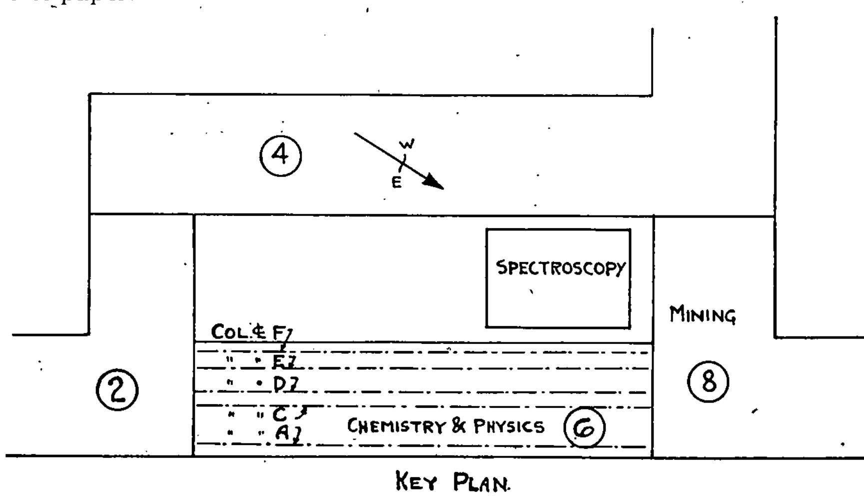


Fig. 1. — Location of Spectroscopy Laboratory

In order that research work in this new laboratory may be conducted with the assurance that the results will be of value, it is necessary to reduce vibration practically to zero. The new laboratory, now completed, was designed and constructed with this end always in view. The building and foundation have been constructed massively and supported by the firmest subsoil available in a location in which the general subsoil

* Member of Chas. T. Main, Inc.

conditions are very poor and unsuited for the support of a building of this character.

This laboratory is located in an areaway surrounded by the Mining Building on the north (about twenty feet away), two teaching laboratories on the west and south, and the Eastman Research Laboratory on the east.

The building is supported upon the same stratum of compact sand which supports the Mining Building, in which is located a massive stamping mill producing very strong vibrations of a nature which causes the Mining Building to shake. It was thought that this mill would have to be moved, because the shocks might be transmitted to the Spectroscopy

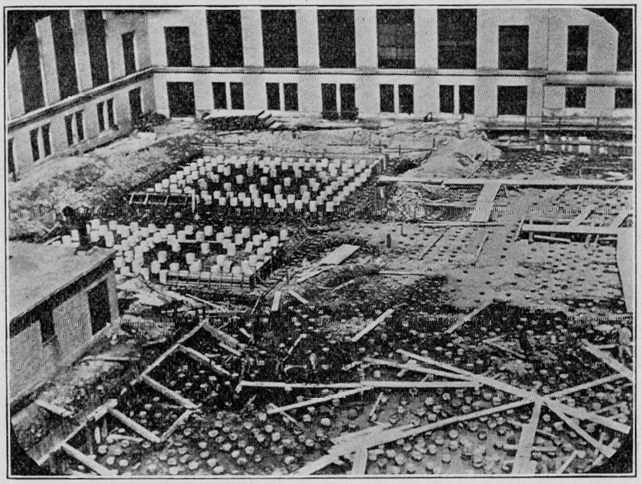


FIG. 2. — SPECTROSCOPY LABORATORY — FOUNDATIONS

Laboratory through the water-bearing fill and the sand stratum, but as yet the vibrations have not caused enough disturbance to require its removal, up to the time of making the test which is described at the end of the paper.

EXPLORATION OF SITE OF THE INSTITUTE BUILDINGS

The site covered by the Institute buildings as a whole was thoroughly explored before the original group of buildings was designed in 1915, and the general conditions at this particular site were quite well known; but to supplement this general knowledge, and to give exact knowledge of conditions under this particular building, numerous new borings have been made.

The character of the soil can be briefly stated as follows: bed rock (slate) is 120 to 135 feet below the general surface; above the bed rock there is an average of 15 feet of boulder clay; then 60 to 80 feet of clay; and above that, in most parts of the site, is found a deposit of sand and gravel varying in thickness from 35 feet to nothing in places. Above this

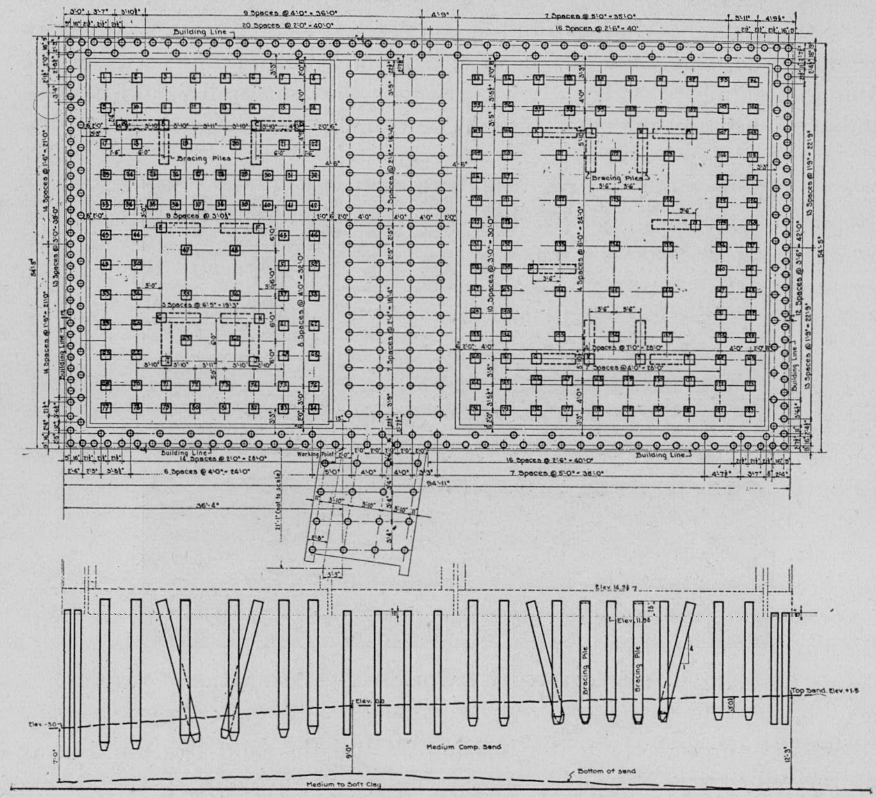


FIG. 3. — PILE PLAN

glacial deposit of sand and gravel is a thick deposit of silt, muck and filling, also varying in thickness from a few feet to 35 feet.

The ground-water level is fixed principally by the level maintained in the Charles River basin, and is found to be on the average at a level of plus 14.5, Cambridge base, which is but a few feet below the general surface.

SUBSOIL UNDER THE SPECTROSCOPE BUILDING

The subsoil at this particular location consists of about 18 to 25 feet of fill and organic silt, saturated with water; a layer of compact gray sand averaging about 9 feet in thickness; about 60 to 65 feet of medium blue clay; and a deep bed of boulder clay, making a total depth of approximately 122 feet to medium hard slate.

Building Dimensions

The outside dimensions of the building are 54 feet, 1 inch wide, 94 feet, 7 inches long, and about 21 feet high above the ground, exclusive of the canopy above the roof.

Superstructure — General

The accompanying illustrations show the design of the building, which is in three distinct parts: (1) the outer shell and corridor, which are both supported upon wooden piles and form the housing for the isolated laboratory floors; (2) and (3) the two separate floor systems supporting the laboratory apparatus, which are completely isolated from the housing structure, having an air space surrounding them.

Substructure — General

The mat foundations and piling also are independent and isolated from the housing structure. All parts of this laboratory are supported, by means of piles, on the thick stratum of compact gray sand.

The outer shell and corridor of the building are supported by means of wooden piles, and those under the exterior walls are placed in such a way as to form another cut-off against vibrations in earth surface and fill reaching the inner or apparatus floors.

Precast concrete piles 15 inches square are used to support the floors, which in turn support the experimental apparatus. These piles were given an embedment of from 4 to 5 feet in the compact sand, and their tops were embedded in the concrete mats about 1½ feet.

Ten batter or brace piles were driven under each of the two mats supporting the special isolated floors. These serve to prevent lateral swaying of the isolated floor structures.

Reinforced concrete mats approximately 3 feet thick were built on the 183 concrete piles; all of which, by their great inertia, help in resisting the vibrations which reach the site.

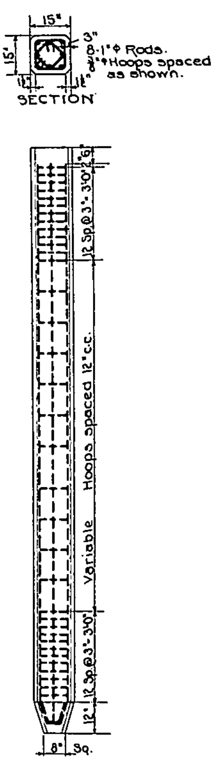


Fig. 4. — Reinforced Concrete Pile

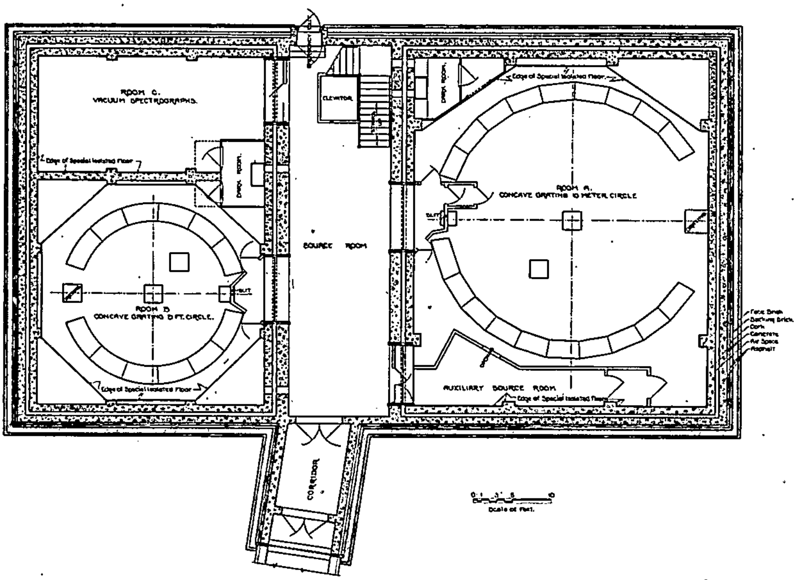


FIG. 5. — SPECTROSCOPY LABORATORY — FIRST FLOOR

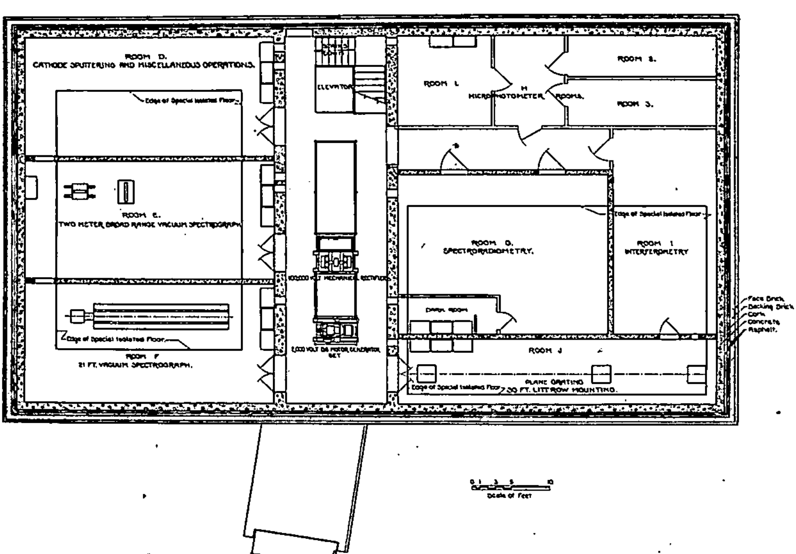


FIG. 6. — SPECTROSCOPY LABORATORY — SECOND FLOOR

Superstructure — Detail Description

The superstructure of all parts of the laboratory is made of reinforced concrete, designed for rigidity and resistance against excessive deflections, vibrations and temperature changes. The inertia of the building is much greater than for ordinary structures, due to the massive parts.

The isolated or floating floor surfaces are still further protected against excessive vibrations reaching them by supporting them on layers of sand for the purpose of reducing lateral vibrations, these layers of sand being separated by felts and cork, which reduce the vertical vibrations.

In order to minimize the effect of changes in outside temperature on the temperature in the rooms, there is embedded a layer of cork 8 inches

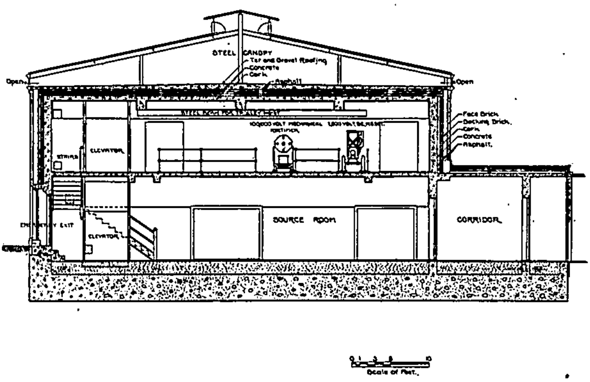


Fig. 7. — Spectroscopy Laboratory — Transverse Section

in thickness between the two masonry side walls, each of which is 12 inches thick, thus making a total thickness of the side walls at the second story of 2 feet, 8 inches.

The more important experiments are to be carried on in the first story, where the exterior walls are given additional insulation, consisting of a 6-inch air space and a 12-inch concrete wall, all of which makes a total wall thickness of 4 feet, 2 inches, including the exterior 12 inches, which is of brick.

The roof insulation consists of 12 inches of cork embedded in thick layers of concrete, and the roof is further insulated against changes of outside temperature by having a steel canopy built above it to prevent the sun's rays from reaching it, and to create a circulation of air over it to diminish the effect of the high temperatures of the summer season.

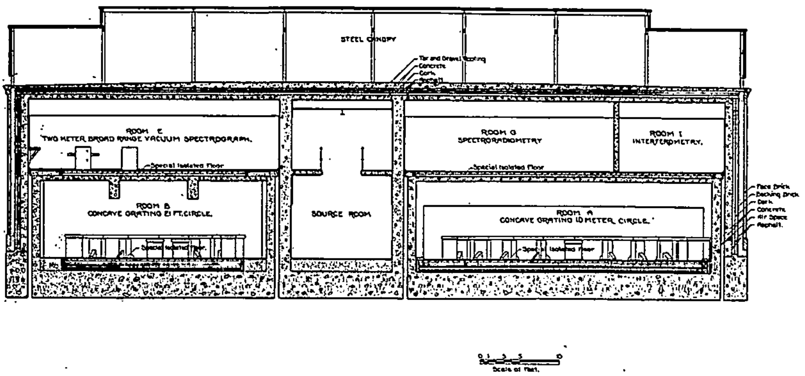


FIG. 8. — SPECTROSCOPY LABORATORY — LONGITUDINAL SECTION

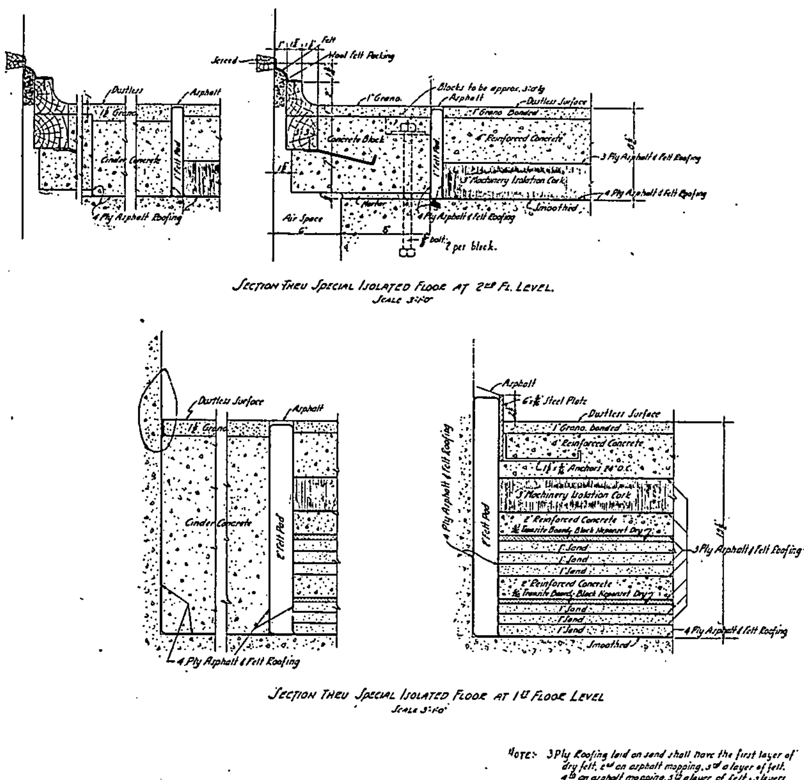


FIG. 9. — DETAIL, ISOLATED FLOOR AND ROOF

The insulation of this building is so complete and effective that in case all heat were suddenly shut off in Boston's coldest weather, it would take about three weeks for the temperature in the experimental rooms of the lower floor to drop one degree F.

This laboratory, having no window openings, reminds one of a camera, being light-tight, windowless, and having no structural columns in the experiment rooms.

Conditioned Air

Fresh conditioned air is supplied to all of the working spaces in the building, the humidity being maintained within a 5 per cent change the year round, and a uniform temperature maintained in the experiment rooms.

Tested Resistance to Vibration

Regarding the resistance of the building to vibration, it is gratifying to find that the design is successful, according to a report of a vibration test printed in "The Tech" of March 25, 1932. The report follows:

Founding of Ore Stamping Mill Fails to Penetrate Massive Walls

A miniature earthquake brought to the very door of the new Spectroscopic Laboratory failed to send even a quiver through the massive walls and foundations of the structure during a vibration test which was run last week. No expense was spared in the construction of the new unit to shut out all tremors which might interfere with the operation of the delicate apparatus housed in the structure.

Dozens of piles were sunk and quantities of insulating material were used to keep out sound, heat and vibration. The test last week showed that the efforts of the designer had been successful. In the Mining Laboratory, adjacent to the new structure, there stands a massive stamping mill used for the grinding of ores. Two iron plungers, weighing 400 pounds each, strike 200 blows per minute, reducing the ore to powder. In the recent test this machine was operated to produce tremors comparable to those of a distant earthquake.

Of General Interest

BOSTON SOCIETY OF CIVIL ENGINEERS' EXCURSION TO NEW BRIDGES UNDER CONSTRUCTION ACROSS CAPE COD CANAL

An excursion by members of the Boston Society of Civil Engineers was made on Saturday, October 20, 1934. Fifty persons viewed the work under construction. The trip was made in a bus of the Boston Elevated Railway, leaving the Engineers' Club at 9.30 A.M. and returning at 5.30 P.M. The bus trip was very enjoyable, and the autumn foliage presented beautiful scenes. The trip down was made through Milton, Brockton and Wareham; the return trip was via Plymouth, Kingston and Quincy.

The party gathered at the Town Hall at Bourne, a privilege arranged by Mr. Benjamin Bourne, Chairman of the Selectmen and County Commissioner. A light lunch was served there by the Dutchland Farms, following which the President, Mr. Arthur T. Safford, called upon Mr. Carroll A. Farwell, of Fay, Spofford & Thorndike, consulting engineers on the new highway bridges, to describe the objectives of the excursion. He then introduced Mr. H. P. Dunbar, of the United States District Engineers office, who described the undertakings in the canal work, and the new railroad bridge. Mr. Farwell described the work on the highway bridges, and Mr. George H. Delano, maintenance engineer, and Mr. H. C. Holden, district engineer, represented the Massachusetts Department of Public Works in the construction work of the highway approaches to the bridges. Mr. James W. Rollins, of Blakeslee-Rollins Corporation, described the problems of the foundations and pier work on the highway and railroad bridges. Other speakers included Mr. M. T. Staples, resident engineer of the Carlin Construction Company, and Mr. Diehl, of the American Bridge Company.

The committee on arrangements consisted of E. N. Hutchins, C. A. Farwell and E. S. Averell.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

SEPTEMBER 26, 1934. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers' Club, and was called to order by the President, Arthur T. Safford, at 7 P.M. Forty-seven members and guests were present. Thirty-seven attended the buffet supper preceding the meeting.

The President announced the death of the following: George W. Fuller, died on June 18, 1934, a Member since June 12, 1895; Frank P. [illegible]onsberg, died on June 14, 1934, a Member since October 18, 1911; George E. Stuart, died on August 20, 1934, a Member since January 27, 1915.

Announcement was made that the October meeting would be omitted, but an excursion would be held in its place, on October 20, 1934, to the new bridges across the Cape Cod Canal.

The President, stating that this meeting is a joint meeting with the Highway Section, called upon Prof. Albert Haertlein, Chairman of that Section, to introduce the speaker, Mr. R. R. Zipprodt, Regional Structural Engineer, Portland Cement Association, who gave a talk on "The Use of Reinforced Concrete Rigid Frame Bridges in Grade Crossing Eliminations."

The meeting adjourned at 8.45 P.M.

EVERETT N. HUTCHINS, *Secretary.*

Designers Section

OCTOBER 10, 1934. — The Designers Section of the Boston Society of Civil Engineers met in the Society rooms in Tremont Temple on Wednesday evening, October 10, 1934.

The minutes of the meeting held on May 9, 1934, were read and approved.

Mr. W. J. D. Reed-Lewis, an engineer of the Lawrence-Portland Association, presented "A Discussion of Certain Chemical and Physical Characteristics of Cement and their Relation to the Qualities of Concretes." The lecture was illustrated by very ingenious diagrams on colored lantern slides. A lively and interesting discussion followed the presentation of the paper.

There were sixty-three members and guests present.

The meeting adjourned at 8.50 P.M.

ALBERT HAERTLEIN, *Clerk.*

Northeastern University Section

OCTOBER 4, 1934. — The Northeastern University Section of the Boston Society of Civil Engineers held its regular meeting in Room 51–H of the Huntington Building of Northeastern University on October 4, 1934. There was an attendance of twenty-three.

Before the meeting, at 6.30 P.M., nine members and three guests met for supper at Putnam's Café.

The Chairman, J. N. DeSerio, opened the meeting and made announcements of plans for the coming year. The first was to the effect that during each five-week school period during Division A, and probably during Division B, there would be a field trip to some place of engineering interest. The other announcement had to do with the Section Prize to be awarded for a worthy paper written on an original subject by some member of the Section. Details of the prize contest are given in the April, 1934, issue of the "Journal of the Boston Society of Civil Engineers," and also in the "Northeastern News" of October 5, 1934.

Mr. DeSerio then introduced the speaker of the evening, Captain F. H. Peacock of the United States Coast and Geodetic Survey. Captain Peacock has been connected with the Survey for the past twenty-one years, having joined immediately upon his being graduated from college. His subject was "Personal Organization and Life in the United States Coast and Geodetic Survey." He spoke for about half an hour, and then spent the next hour answering general questions from the floor.

The meeting adjourned at 9.30 P.M.

KENNETH F. KNOWLTON, *Clerk.*

OCTOBER 27, 1934. — Fifty-one students of the Junior and Senior engineering classes, along with four faculty members, left the Laboratory Building at noon for the field trip to the new high-level bridge being constructed at Bourne as a Federal P. W. A. project. The trip was made in all kinds of vehicles, from new Fords to an Austin.

This trip was proclaimed the best ever by several. The bridge is built with cantilever arch construction from both shores, and is to be joined at the center, after which the three central spans become a continuous structure. There are two more simple steel spans on each shore beyond this. From the ends of the steel there is reinforced concrete construction which passes over the present roadway. The bridge gives a clearance of about 135 feet above the canal, and it was necessary to use a six per cent grade on the approaches. A special light-weight cinder concrete is being used on the floor. This concrete weighs about one hundred pounds per cubic foot.

This trip gave the students an excellent opportunity to see at first hand the work of modern structural engineering. Let's hope that we have more like it in the future.

KENNETH F. KNOWLTON, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[Oct. 20, 1934]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

HUCKINS, EDGAR WOLCOTT, Quincy, Mass. (Age 43, b. Boston, Mass.) Attended Massachusetts Institute of Technology, 1910 to 1912; instrumentman with Stone & Webster until 1916. Returned to Massachusetts Institute of Technology, graduating in 1918, degree of B.S. Served until 1919 as 2d Lieutenant, Corps of Engineers. Then returned to Stone & Webster until 1931 as engineer appraisals, cost engineer and assistant superintendent. While with Stone & Webster was office engineer on construction of the Edgar Station at Weymouth from 1923 to 1926; resident engineer until 1929; and for a few months assistant superintendent. Then transferred to Boston office as assistant to construction manager, where I remained until October, 1931. From then on miscellaneous positions — surveys; Emergency Planning and Research Bureau; office manager, Engineering Societies of New England. Now computer of Coast and Geodetic Survey. Refers to *I. S. Crosby, F. M. Gunby, E. N. Hutchins, C. W. Robinson, H. E. Sawtell.*

NÚÑEZ, LUIS ALBERTO, Havana, Cuba. (Age 32, b. Havana, Cuba.) Graduate of "Instituto de la Habana," with degree of Bachelor of Letters and Sciences, in 1919. Was graduated from "Universidad de la

Habana," with degree of Civil Engineer, in December, 1924, and obtained degree of Architect in February, 1925. On graduating, obtained distinction (granted every two years to student with best academic record) of "Alumno Eminente;" also a traveling scholarship. From February, 1925, to 1927, was on construction work. From July, 1927, to June, 1934, assistant Professor of hydromechanics and machinery, chief of hydraulics and machinery laboratory at University of Havana. May, 1934, to date (on leave of absence) at M. I. T., pursuing studies relating to professorship. Refers to *K. C. Reynolds, G. E. Russell.*

RAPHAEL, WILLIAM, Cambridge, Mass. (Age 32, b. Meriden, Conn.) Graduate of Drexel Institute, Philadelphia, Pa. Designing engineer, Standard Oil Company of Pennsylvania, 1929–32. Construction engineer, Colonial Beacon Oil Company, Rochester Branch, 1932–33. Engineer in charge of construction and maintenance, New England Branch, Colonial Beacon Oil Company. Refers to *Joseph Driscoll, F. W. Hamilton, H. A. Mohr, A. L. Wannlund.*

TAYLOR, DONALD WOOD, Cambridge, Mass. (Age 33, b. Worcester, Mass.) Education: entered Worcester Polytechnic Institute, in 1918; graduated in 1922, degree B.S. in Civil Engineering; June, 1922, to March, 1922, with United States Coast and Geodetic Survey, final rating junior hydraulic and geodetic engineer; March to July, 1925, topographic draftsman with Bureau of Power and Light, city of Los Angeles, Cal.; September, 1925, to October, 1926, estimator, Edward F. Miner Building Company, Worcester, Mass.; October, 1926, to October, 1931, with New England Power Association, assistant resident engineer on construction one year, structural design and hydraulic design and research two years, assistant resident engineer throughout preliminary work and construction of McIndoes hydro-electric plant two years; October, 1931, to date, at Massachusetts Institute of Technology, as follows: October, 1931, to June, 1932, night and unemployed student; October, 1932, to date, special and graduate student; also, October, 1932, to June, 1934, research assistant in soil mechanics; September, 1934, to date, research associate in soil mechanics. Refers to *J. B. Babcock, C. B. Breed, G. Gilboy, E. G. Lee, H. T. Pierce.*

ADDITIONS

Student Members

EMERSON COBB, 48 Niles Street, Abington, Mass.

FRANCIS J. FLYNN, State Hospital, Taunton, Mass.

WILLIAM A. GRADY, 17 Sheridan Circle, Winchester, Mass.

WILLIAM C. PAUL, 3 Everard Street, Worcester, Mass.

ROBERT W. SMITH, 262 Lynnfield Street, South Peabody, Mass.

DEATHS

HENRY H. CARTER . .	October 4, 1934
GEORGE W. HAMILTON	April 6, 1934

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BOSTON SOCIETY OF CIVIL ENGINEERS

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