STORRS

A Handbook

FOR THE USE OF THOSE INTERESTED IN THE CONSTRUCTION OF SHORT SPAN

BRIDGES

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Price in cloth $1.00

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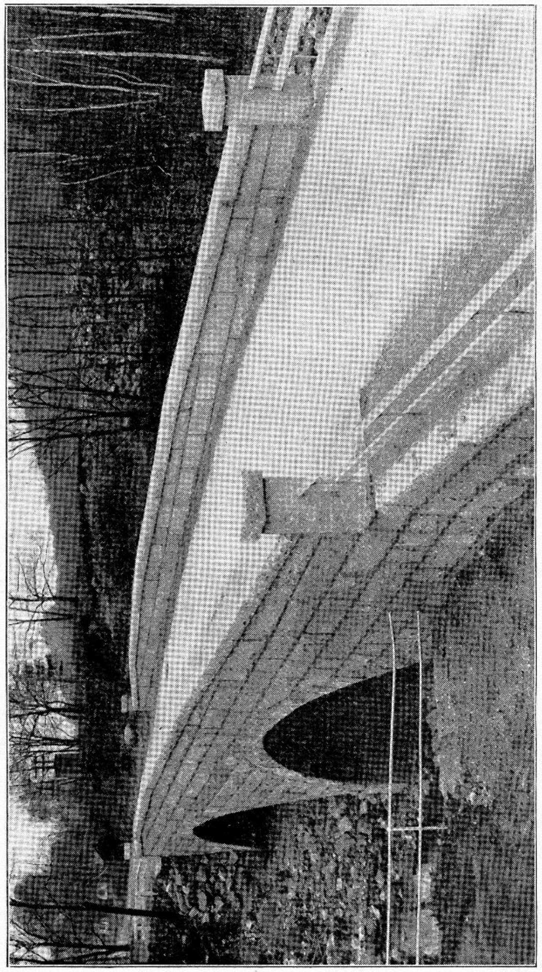


MILFORD STONE ARCH, MILFORD, N. H.

This cut represents an unusual construction for this period of steel and concrete. Milford as a granite town is justly proud of her granite industry. She has demonstrated her pride in her granite by building a granite arch as shown in this illustration. The bridge consists of two arches with 60-foot clear spans, each having a rise of about 15 feet. The roadway is 22 feet in the clear, with a 5-foot sidewalk. This bridge is located over the Souhegan River, near the Pine Valley railroad station, and replaces what was known as the Old County bridge, which was probably built seventy or eighty years ago. This bridge was designed by STORRS, BRIDGE ENGINEERS, of Concord, N. H., and was built by the Lovejoy Granite Company for the town of Milford, in 1917.

INTRODUCTION

This book is intended to be of some assistance to road agents, town clerks, selectmen and others who may be interested in the designing and construction of small bridges, culverts, etc. Most of the designs are intended for what at the present time are considered heavy loads for highway traffic, the bridges having a capacity for twelve-ton and fifteen-ton motor trucks or road rollers. One table, however, gives a design which may be used on back country roads and through hilly sections where the conditions are such that it would be impossible to get extremely heavy loads over the highway.

It has been the intention of the authors to eliminate all technicalities and give on the plates and in the tables such necessary information as would be of practical use to the non-technical man in building the structures called for. It is expected that work of this kind will not be attempted except by parties who have a mechanical turn of mind, or who know something about general construction and the manner in which the different parts of the structure should go together.

The materials used should be exactly as specified and in reinforced concrete work the reinforcement must be placed and held in place as shown by the plans. If some care is taken and the instructions given are followed, there will be no question about the strength of the bridge and its capacity to carry with a sufficient factor of safety the loads called for.

In adopting some design from this book for a bridge the local conditions should be taken into consideration and if conditions are such that there is nothing found in this treatise to meet the requirements, it does not mean that something cannot be designed along similar lines which will prove satisfactory.

If in placing this little book before our friends we have given them any assistance, we are fully repaid for our efforts.

STORRS, *Bridge Engineers.*

FREDERIC E. EVERETT
COMMISSIONER

INDEX

State of New Hampshire

Highway Department

STATE HOUSE, CONCORD

March
Sixteenth,
1 9 1 8.

To Whom It May Concern:

I am pleased to endorse "Storrs" the handbook published by Storrs, Bridge Engineers, Concord, N. H.

It contains a great deal of valuable information and anyone following the tables of this little book will certainly be complying with the standards as laid down by the State Highway Department.

Yours truly,

F. E. Everett
Commissioner.

FEE/P

NEW HAMPSHIRE LAW REGARDING LOAD ON BRIDGES

CHAPTER 173

AN ACT IN AMENDMENT OF CHAPTER 76 OF THE PUBLIC STATUTES, RELATING TO DAMAGES HAPPENING IN THE USE OF HIGHWAYS, AS AMENDED BY CHAPTER 19, LAWS OF 1913.

Be it enacted by the Senate and House of Representatives in General Court convened:

Section 1. Section 3, chapter 76, of the Public Statutes, as amended by chapter 19 of the Laws of 1913, is hereby amended by striking out all of said section and inserting in place thereof the following: Sect. 3. Towns and other municipal corporations shall not be liable for such damages to a person traveling upon a bridge, culvert, or sluiceway when the weight of the load, inclusive of the carriage, or of the carriage alone, exceeds six tons; *provided, however,* that all new bridges upon main trunk lines and cross state highways shall be constructed to bear not less than ten tons, but towns and municipal corporations shall not be liable where the total weight of the load and carriage exceeds six tons.

Sect. 2. All acts and parts of acts inconsistent with this act are hereby repealed, and this act shall take effect upon its passage.

(Approved April 21, 1915.)

REINFORCED CONCRETE

CONCRETE

GENERAL REQUIREMENTS

A combination of steel and concrete, made in such a manner that each material will be required to withstand that character of stress for which it is best adapted—that is, tension for steel and compression for concrete—constitutes a form of construction both economical and durable. The advantages of the two materials are combined and their disadvantages in a large degree eliminated.

The conditions to be met in the construction of reinforced concrete culverts and small bridges make it desirable, from a standpoint of economy, that a relatively high grade of concrete be used. Any decrease in the strength of the concrete necessitates a corresponding increase in some dimension of the members, and thereby adds to the dead load which the structure must sustain. The data contained in this book are based on a 1 : 2 : 4 mixture (by volume) for the reinforced superstructure.

QUANTITIES OF MATERIALS

The quantities of materials required to make 1 cubic yard of concrete vary with the proportions used and also with the character of the stone and sand. The variations due to the latter are comparatively slight, however, and may usually be neglected in making up preliminary estimates for small structures. Table I is based on an average quality of stone and sand.

Table 1

QUANTITIES OF MATERIALS FOR 1 CUBIC YARD OF RAMMED CONCRETE

(Based on a barrel of 3.8 cubic feet)

Proportions by Parts			Proportions by Volume			Quantity per Cubic Yard		
Cement	Sand	Stone	Packed Cement, Barrels	Loose Sand, Cu. Ft.	Loose Stone, Cu. Ft.	Cement, Barrels	Sand, Cu. Yd.	Stone, Cu. Yd.
1	2	4	1	7.6	15.2	1.57	0.44	0.88
1	2½	5	1	9.5	19.0	1.30	.46	.92
1	3	6	1	11.4	22.8	1.11	.47	.94

CEMENT

The cement used should be a high-grade Portland cement and should comply with the standard specifications of the American Society for Testing Materials or those of the United States Bureau of Standards. Damaged bags or barrels should always be rejected.

SAND

A coarse, sharp quartz sand, free from clay or other foreign material, should be used. In places where it is impractical to obtain any other than fine sand the amount of cement should be increased.

BROKEN STONE AND GRAVEL

Any hard, tough stone or gravel may be used. It should be screened to remove dust or sand and also to remove particles larger than the maximum size desired. For reinforced parts no stone should have a dimension greater than 1 inch. For walls and footings the maximum dimension for stone or gravel will depend on the size of the structure. Usually about 2 inches is a fair maximum size.

MIXING

In mixing by hand, observance of the following rules will be found helpful:

(1) A water-tight platform not less than 10 by 12 feet should be provided.

(2) No single batch of concrete should exceed 1 cubic yard.

(3) The size of the batch to be mixed should be based on some integral number of sacks of cement.

(4) Sand in the proper amount should first be spread over the central part of the platform; then the cement should be evenly distributed over the sand and the two thoroughly mixed together while dry. Sufficient water should then be added to make a thin mortar, which should be spread out in a uniform layer. The stone or gravel is spread over this and the whole mass turned with shovels not less than four times until each stone is thoroughly coated with the mortar.

Taylor and Thompson give the following "Data on handling concrete":

Average load of broken stone or gravel for wood wheelbarrow, cubic feet	2.4
Average load of sand for wood wheelbarrow, cubic feet	2.5
Large load of broken stone or gravel for iron wheelbarrow on short haul in concrete work, cubic feet	3.0
Large load of sand for iron wheelbarrow on short haul in concrete work, cubic feet	3.5
Average load of ordinary concrete[2] for iron wheelbarrow, cubic feet	1.9
Large load of ordinary concrete[2] for iron wheelbarrow, cubic feet	2.2
Number of shovelfuls of concrete for barrow in average load	13
Number of shovelfuls per barrow in large load	15
Average net time of one man filling wheelbarrow with concrete, minutes	$1\frac{1}{3}$
Quick net time of one man filling wheelbarrow with concrete, minutes	1
Average quantity of concrete[2] mixed, wheeled 50 feet and rammed, per man per day of 10 hours,[3] cubic yards	2.2
Large quantity of concrete[2] mixed, wheeled 50 feet and rammed, per man per day of 10 hours, cubic yards	3.0

Average quantity of concrete[2] laid as above with a gang of 15 men per day of 10 hours,[3] cubic yards	33
Large quantity of concrete[2] laid as above with a gang of 15 men per day of 10 hours,[3] cubic yards	47
Approximate average quantity of concrete[2] leveled and rammed in 6-inch layers per man per day of 10 hours, cubic yards	11
Approximate large quantity of concrete[2] leveled and rammed in 6-inch layers per man per day of 10 hours, cubic yards	16
Approximate average surface of rough-braced plank form built and removed by one carpenter per day of 10 hours, square yards	25

[2] All measurements of concrete are reduced to terms of quantity in place after ramming.

[3] Note that the leveling and ramming, but not the labor on forms, are included in this item.

WATER

Water used in mixing should be clean, reasonably clear and free from strong alkalis, acids, or other injurious materials.

FREEZING

Concrete bridges should not be built in freezing weather.

DEPOSITING

Concrete should be deposited in place immediately after mixing. It should be deposited in layers not over 6 inches in thickness, and tamped until water flushes to the surface. No concrete should be deposited in running water, and when deposited in still water special appliances should be used and work done by experienced workmen, and the portion next to the forms should be troweled by using a spade or by other means of bringing the concrete into thorough contact with the forms.

FORMS

Forms should be built true to dimensions and be sufficiently well braced to prevent yielding during the process of depositing and tamping the concrete. They should be built of selected lumber of even thickness, free from loose knots or flaws of any nature. The surfaces coming into contact with the concrete should be thoroughly wet immediately before the latter is deposited.

REMOVING FORMS

The length of time that concrete must set before the forms may be safely removed depends upon the weather conditions, the strain that is to be withstood, and upon the manner of mixing the materials. It is usually safe to remove forms from massive abutments and walls in from 24 to 72 hours. Forms for reinforced superstructures and all supporting forms should ordinarily be left undisturbed at least 10 days, and in cold or wet weather the time should be doubled. It is desirable that the forms be removed as soon as possible after the proper period of time has elapsed; otherwise finishing the surface will be more difficult.

FINISHING

Any cavities which appear when the forms are removed should be filled with mortar mixed in the same proportion as that used in the concrete. The exposed surfaces of the structure should then be rubbed down with a wooden float and sand grout, and any fins or ridges due to imperfections in the forms should be removed. Plastering should never be permitted.

REINFORCEMENT

GENERAL REQUIREMENTS FOR STEEL

Reinforcing bars should be made from steel having a safe strength of not less than 16,000 pounds per square inch, and should possess sufficient malleability to be readily bent into the desired shapes while cold. When placed in the concrete they should be free from rust, grease, or foreign materials of any kind; otherwise a perfect bond between the bars and the concrete will not be obtained.

FORMS OF BARS

Many types of patent deformed bars, designed to furnish a "mechanical bond" between concrete and steel, are being manufactured, and can be almost as readily obtained as the plain round or square rods at little additional cost. They undoubtedly possess advantages over the plain rods, and a larger factor of safety will be obtained by using them. They are not specified, however, for designs given in this book. Plain rounds are specified but square rods of equal area may be used. Flat bars, however, should be avoided. Their adhesion to the concrete is much below that of either round or square rods of equivalent area.

NOTE.—The above specifications were taken from the United States Department of Agriculture, Office of Public Roads.

In all beam bridges the placing of concrete must not be interrupted from start to finish. This in some cases will require night work, and should be provided for.

If there is anything not plain and thoroughly understood, be sure and ask someone who knows. It is no discredit to a foreman or workman to be sure he is right before going ahead.

Table 2

CEMENT REQUIREMENTS

Time before Testing	Average Tensile Strength of Three Briquettes	
	Neat Cement	One Part Cement, Three Parts Sand
24 hours	175 lbs. per sq. in.	....
7 days	500 " " " "	200 lbs. per sq. in.
28 days	600 " " " "	275 " " " "

The initial set of neat cement should not take place until at least 30 minutes after mixing and the final set in not less than one hour or in more than ten hours.

In passing through a No. 100 sieve 8 per cent should be retained, and 25 per cent by a No. 200 sieve.

Test briquettes should retain their shape and set firm and hard in air, water or steam.

Table 3

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS

(One cubic foot of steel—weighing 489.6 lbs.)

Thickness or Diameter in Inches	Wt. of Square Bar 1 Ft. Long	Wt. of Round Bar 1 Ft. Long	Area of Square Bar in Sq. Ins.	Area of Round Bar in Sq. Ins.
0 1-8	.053	.042	.0156	.0123
1-4	.212	.167	.0625	.0491
3-8	.478	.375	.1406	.1104
1-2	.850	.667	.2500	.1963
5-8	1.328	1.043	.3906	.3068
3-4	1.913	1.502	.5625	.4418
7-8	2.603	2.044	.7656	.6013
1	3.400	2.670	1.0000	.7854
1-8	4.303	3.379	1.2656	.9940
1-4	5.312	4.173	1.5625	1.2272
3-8	6.428	5.049	1.8906	1.4849
1-2	7.650	6.008	2.2500	1.7671
5-8	8.978	7.051	2.6406	2.0739
3-4	10.41	8.178	3.0625	2.4053
7-8	11.95	9.388	3.5156	2.7612
2	13.60	10.68	4.0000	3.1416
1-8	15.35	12.06	4.5156	3.5466
1-4	17.22	13.52	5.0625	3.9761
3-8	19.18	15.07	5.6406	4.4301
1-2	21.25	16.69	6.2500	4.9087
5-8	23.43	18.40	6.8906	5.4119
3-4	25.71	20.20	7.5625	5.9396
7-8	28.10	22.07	8.2656	6.4918
3	30.60	24.03	9.0000	7.0686
1-8	33.20	26.08	9.7656	7.6699
1-4	35.92	28.20	10.563	8.2958
3-8	38.73	30.42	11.391	8.9462
1-2	41.65	32.71	12.250	9.6211
5-8	44.68	35.09	13.141	10.321
3-4	47.82	37.56	14.063	11.045
7-8	51.05	40.10	15.016	11.793
4	54.40	42.73	16.000	12.566

WELL SEASONED FUEL

The best time to cut, haul and prepare wood for fuel is in the comparative leisure of winter, and where wood is used for fuel it should be thoroughly dried, as in its green and ordinary state it contains 25 per cent of water; the heat to evaporate which is necessarily lost; therefore, the burning of green wood is greatly wasteful.

Table 4

STANDARD I BEAMS

Depth of Beam, Ins.	Weight per Foot, Lbs.	Area of Section, Sq. Ins.	Flange Width, Ins.	Web Thickness, Ins.
24	105.0	30.98	7.87	.63
24	80.0	23.32	7.00	.50
24	74.0	21.70	9.00	.48
21	60.5	17.68	8.25	.43
20	80.0	23.73	7.00	.60
20	70.0	20.59	6.32	.57
20	65.0	19.08	6.25	.50
18	75.0	22.05	7.00	.56
18	60.0	17.65	6.10	.56
18	55.0	15.93	6.00	.46
18	48.0	14.08	7.50	.38
15	60.0	17.67	6.00	.59
15	42.0	12.48	5.50	.41
15	37.5	10.91	6.75	.33
12	40.0	11.84	5.25	.46
12	31.5	9.26	5.00	.35
10	25.0	7.37	4.66	.31
9	21.0	6.31	4.33	.29
8	18.0	5.33	4.00	.27
7	15.00	4.42	3.66	.25
6	12.25	3.61	3.33	.23
5	9.75	2.87	3.00	.21

THE CARE OF GRINDSTONES

The exposure of a grindstone to the sun has a tendency to harden it. And if one part be left in the water habitually it will grow soft, and wear away faster than the other. If the trough is put upon movable supports in the frame, it can be adjusted to the stone without much loss of time. Or allow the water to drip from a water-pot; an old white-lead keg will answer, fixed above the stone. Always clean off all greasy or rusty tools before sharpening, as grease chokes up the grit; and always keep the stone perfectly round by razeeing it off when necessary.

STANDARD REINFORCED CONCRETE SHORT SPAN BRIDGES

The following concrete bridges while of similar appearance are all four different types as regards reinforcement details. They are designed for heavy highway traffic and are suitable for main thoroughfares. The designs, if properly carried out, will insure permanent construction and extreme rigidity under the heaviest loads. Great care should be taken that the foundations upon which these structures are to be placed are in good condition and of suitable design for these modern structures.

Figure 2 on Plate II shows a side elevation of a bridge of this type with span less than 10 feet. For spans running from 10 feet to 18 feet, Figure I is used. For greater spans up to 30 feet clear, Plate I is used.

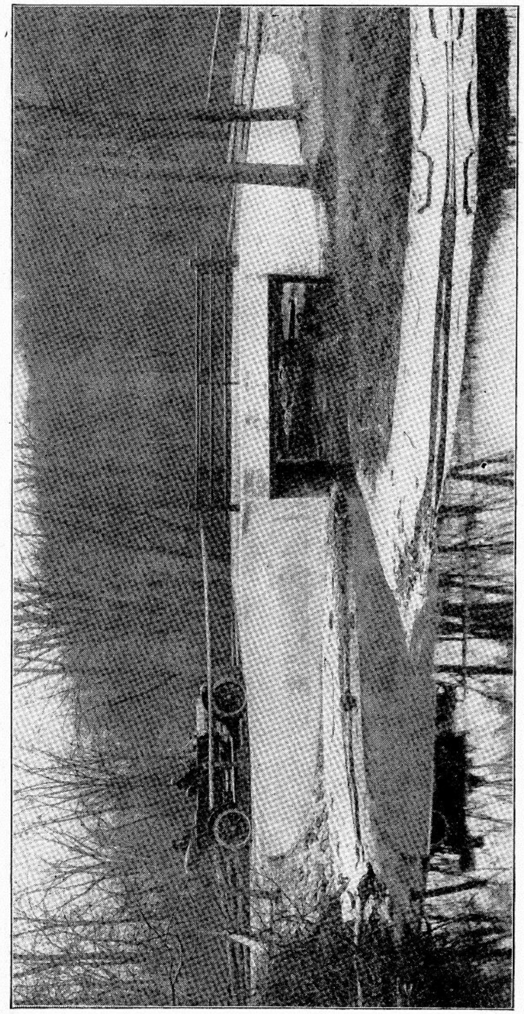
A railing consisting of three lines of 2″ inside diameter pipe with pipe posts set in the concrete curb is used with this type of bridge.

The paneling shown may be omitted, if desired. It does, however, add to the appearance of the structure if sufficient care is taken in finishing.

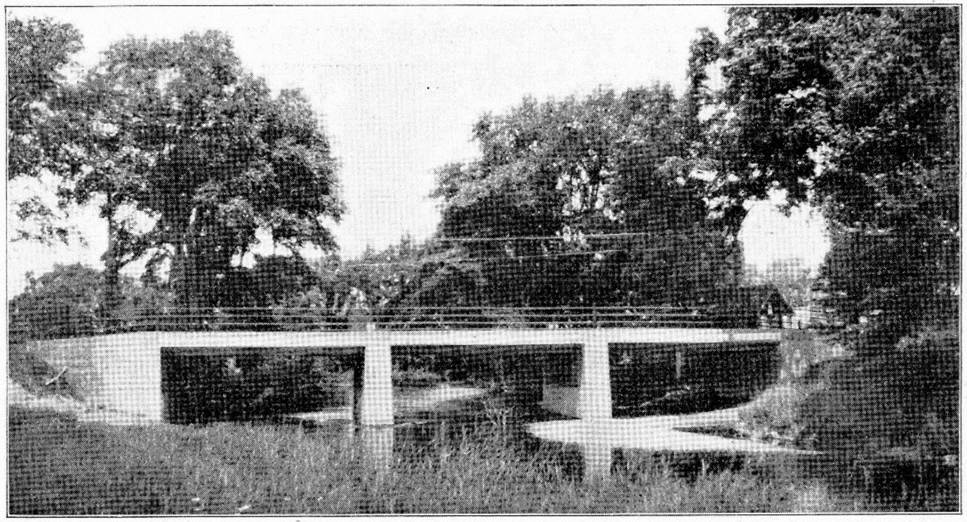
The illustration on the following page is of a bridge of this type built at Bow Mills, New Hampshire, in 1911. This particular bridge has a roadway 26 feet wide, with a capacity to carry electric railway cars.

CHARCOAL

The best quality of charcoal is made from oak, maple, beech and chestnut. Wood will furnish, when properly charred, from 20 to 25 per cent of coal.

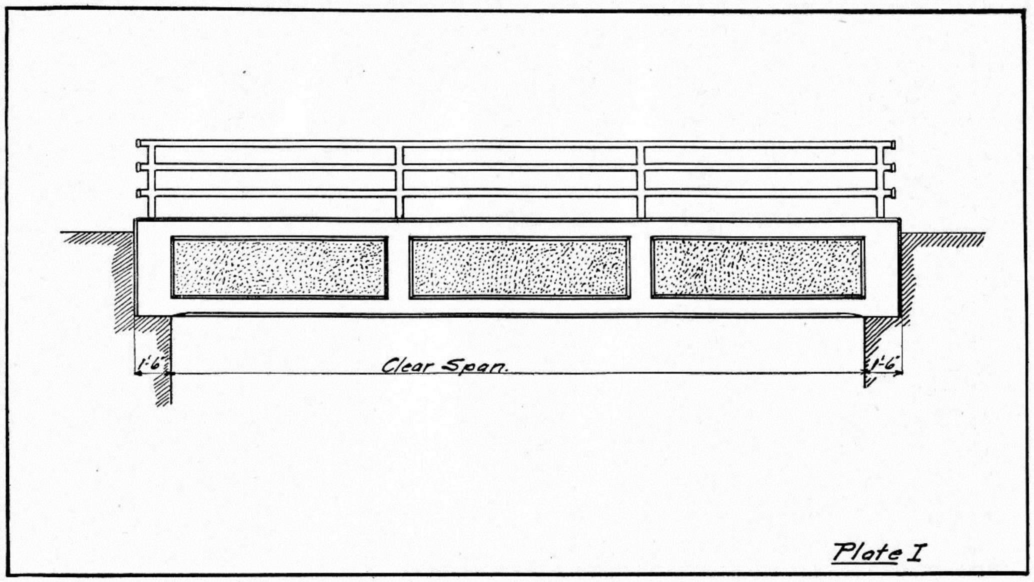


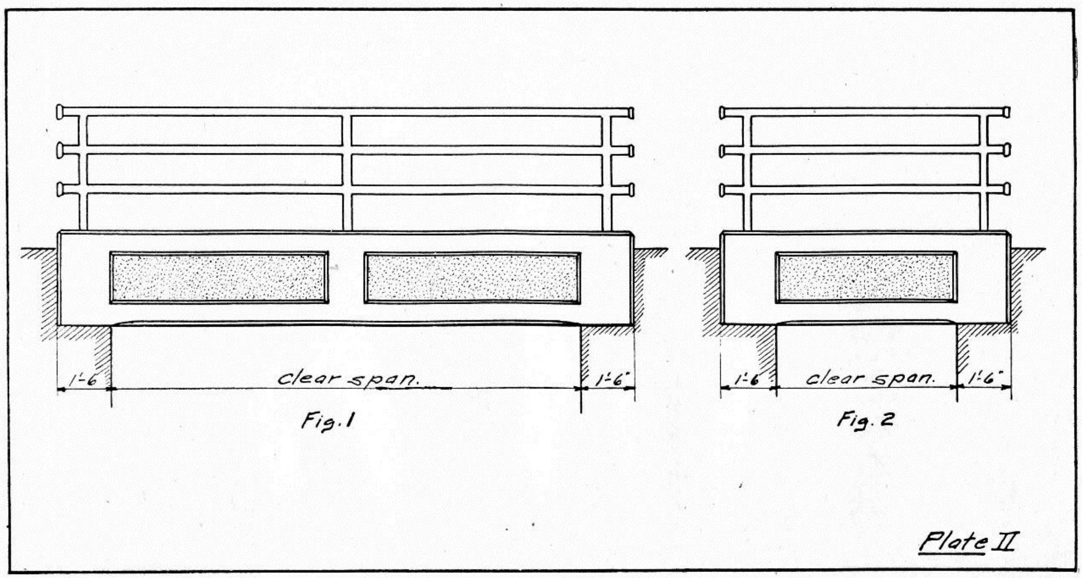
TURKEY RIVER BRIDGE, BOW, N. H.

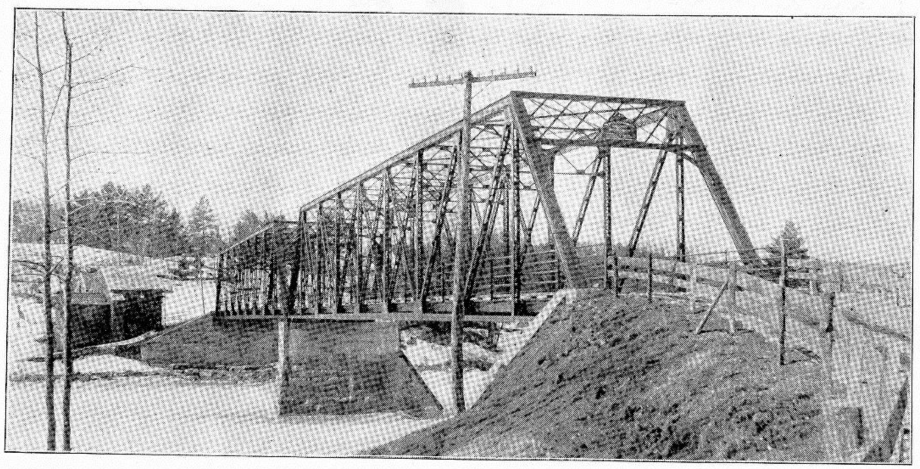


ELM STREET BRIDGE, NEWPORT, N. H.

This cut illustrates a typical I Beam Bridge with the girders encased in concrete. The bridge consists of three spans of about 30 feet each. It carries a 20-foot roadway and a 5-foot reinforced concrete sidewalk. The bridge is located on the main trunk line on Elm Street in the town of Newport, New Hampshire. This bridge was designed with a capacity for 12-ton trucks. It was built in 1916.







HILL AND SANBORNTON BRIDGE

This is a two-span bridge between the towns of Hill and Sanbornton over the Pemigewasset River. This bridge was designed by STORRS, BRIDGE ENGINEERS, and takes the place of a wood bridge carried away by the ice and freshet of 1913.

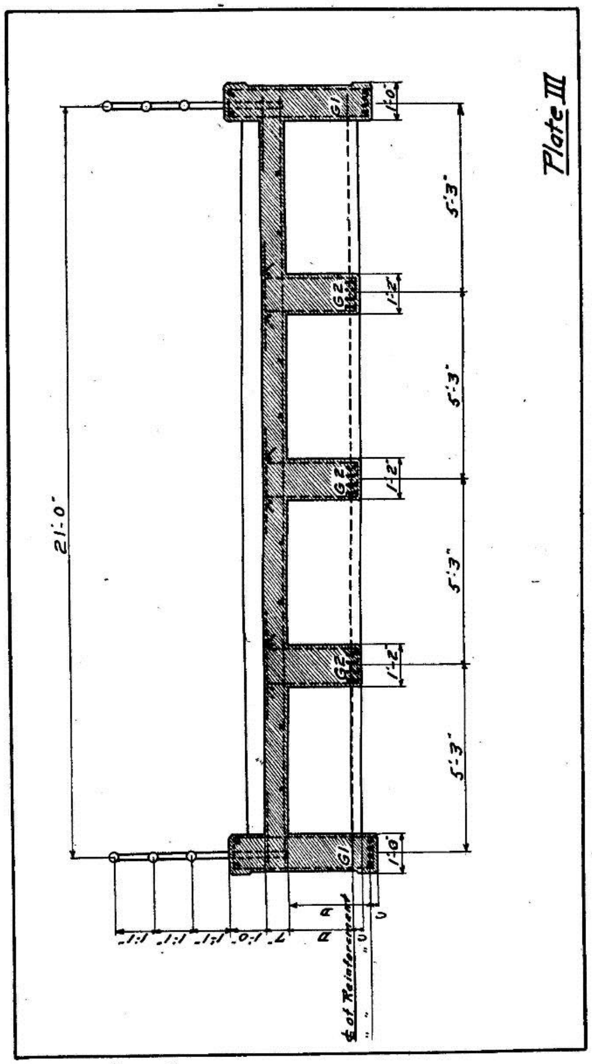


Table 5

CONCRETE GIRDER BRIDGES WITH ROD REINFORCEMENT

(Details shown in Plates III and IV)

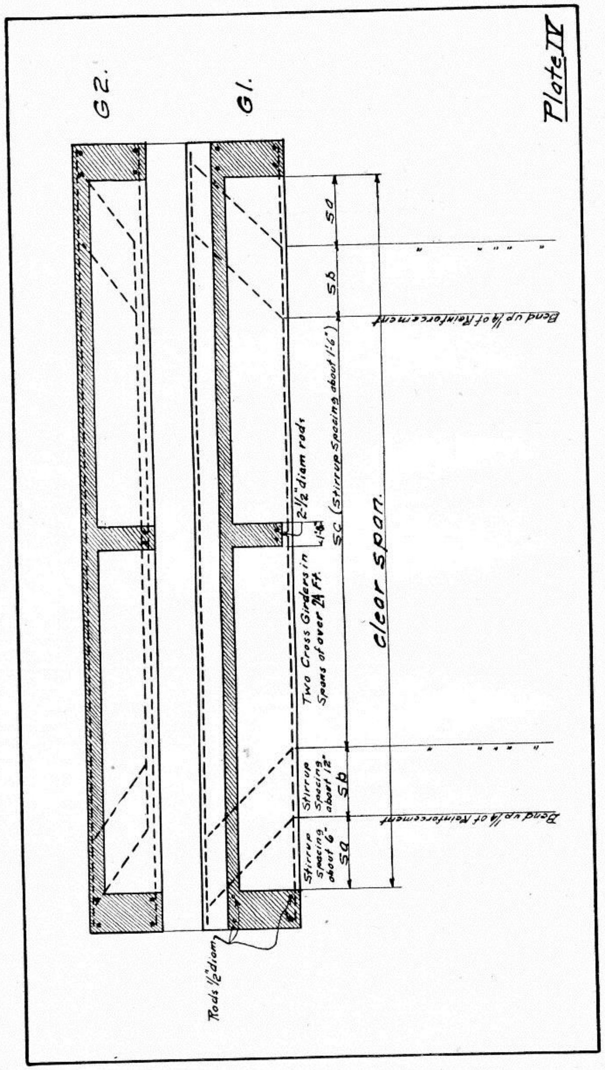
Clear Span	Girder	D	C	Bottom Reinforcement, Round Rods	Stirrup Spacing		
					s-a	s-b	s-c
14'-0" 14'-0"	G-1 G-2	17" 17"	2" 2"	4-7/8" 4-1"	1'-5"	1'-5"	8'-4"
16'-0" 16'-0"	G-1 G-2	18" 18"	2" 2"	4-1" 2-1" and 2-1 1/8"	1'-7"	1'-7"	9'-8"
18'-0" 18'-0"	G-1 G-2	31" 19"	2" 2"	4-7/8" 4-1 1/8"	1'-9"	1'-9"	11'-0"
20'-0" 20'-0"	G-1 G-2	32" 20"	2" 2"	4-1" 4-1 1/4"	2'-0"	2'-0"	12'-0"
22'-0" 22'-0"	G-1 G-2	33" 20"	2" 3"	4-1" 4-1 3/8"	2'-2"	2'-2"	13'-4"
24'-0" 24'-0"	G-1 G-2	33" 21"	2" 3"	4-1 1/8" 8-1"	2'-5"	2'-5"	14'-4"
26'-0" 26'-0"	G-1 G-2	34" 21"	2" 3"	4-1 1/8" 4-1" and 4-1 1/8"	2'-7"	2'-7"	15'-8"
28'-0" 28'-0"	G-1 G-2	35" 22"	2" 3"	4-1 1/4" 8-1 1/8"	2'-9"	2'-9"	17'-0"
30'-0" 30'-0"	G-1 G-2	35" 23"	2" 3"	4-1 1/4" 4-1 1/8" and 4-1 1/4"	3'-0"	3'-0"	18'-0"

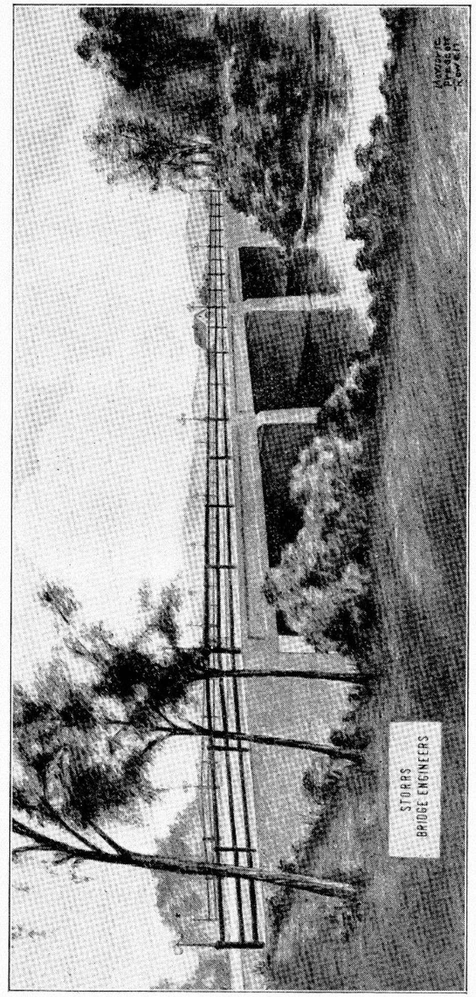
Two ½" diameter rods in top of G-1 and G-2.
Slab reinforcement in bottom, ⅝" diameter rods, 6" centers crosswise.
Slab reinforcement in bottom, two ½" diameter rods in each panel lengthwise.
Slab reinforcement in top, ½" diameter rods, 3'-0" long, 1'-0" centers crosswise over G-2.
Slab reinforcement in top, ½" diameter rods, 2'-0" long, 1'-0" centers crosswise into G-1.

These concrete girders are designed with a capacity for a fifteen-ton truck with a wearing surface of two inches of tar, concrete or asphalt, or six inches of gravel.

HOW TO MEASURE WOOD PILE

To ascertain the number of cords of wood in a pile, multiply together the length, breadth and height, and divide by 128.





Design for a Typical Three-Span Reinforced Concrete Girder Bridge

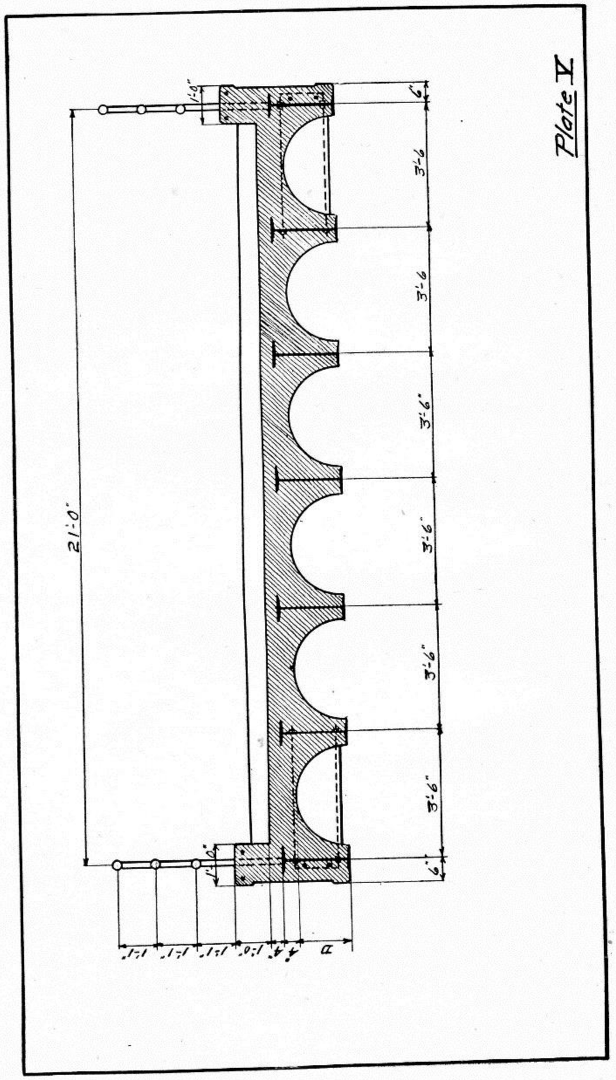


Table 6

STEEL I BEAMS WITH CONCRETE ARCH FLOOR

(Details shown in Plate V)

Clear Span	Beams		D
	Size	Weight per foot	
12'-0"	12"	31½ lbs.	8"
14'-0"	15"	37½ lbs.	8"
16'-0"	15"	37½ lbs.	11"
18'-0"	15"	42 lbs.	11"
20'-0"	18"	48 lbs.	14"
22'-0"	18"	55 lbs.	14"
24'-0"	20"	65 lbs.	16"
26'-0"	20"	70 lbs.	16"
28'-0"	24"	74 lbs.	20"
30'-0"	24"	74 lbs.	20"

These bridges are designed with a capacity for carrying twelve-ton trucks. The wearing surface may be two inches of tar, concrete, or asphalt, or six inches of gravel.

The two outside I beams on each side of the bridge are held in position by two ½" diameter yoke rods passing through the webs of the beams. The bottom rod should be encased in concrete, making a small cross beam. These should be spaced not over 10 feet apart. The yokes should also be placed at the abutments and the cross beams should be run to full width of the bridge at these points. Two ½" diameter rods are required in the top of each curb; also two rods of the same size further down on the outside of the bridge. The latter should be held in place by the yoke rods mentioned above.

RESPONSIBILITY

That's the biggest word in our language! You have come to realize what it might mean to *you* should a disaster occur through your negligence. You understand that *it is up to you* to safeguard the lives and property of your constituents, and that they hold *you* responsible!

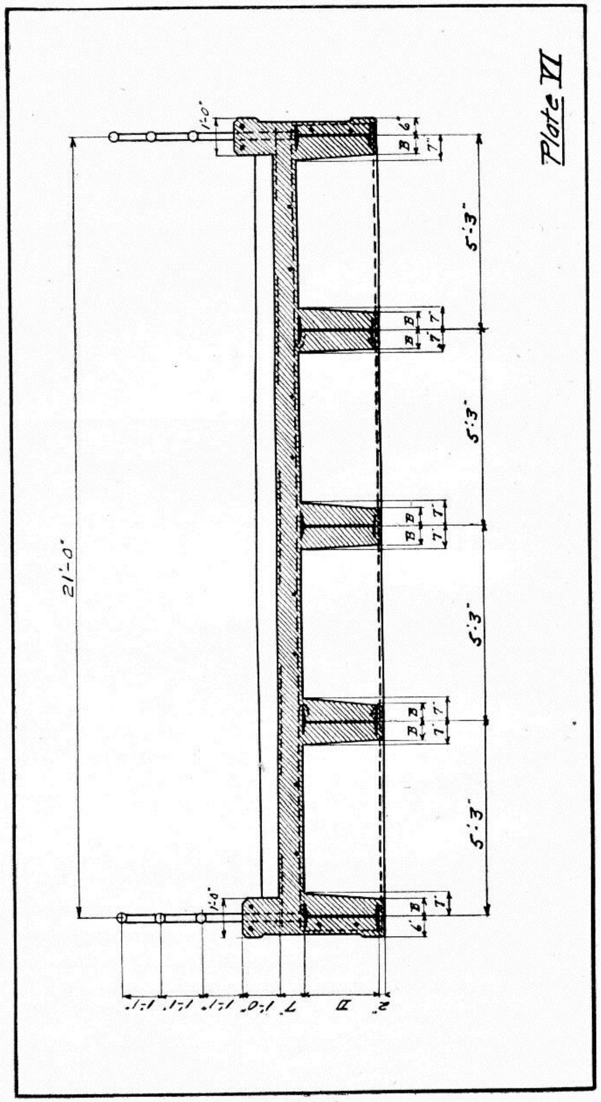


Table 7

I BEAMS ENCASED IN CONCRETE WITH SLAB FLOOR

(Details shown in Plate VI)

Clear Span	Beams		D	B
	Size	Weight per foot		
12'-0"	15"	$37\frac{1}{2}$ lbs.	15"	5"
14'-0"	15"	$37\frac{1}{2}$ lbs.	15"	5"
16'-0"	15"	42 lbs.	16"	5"
18'-0"	18"	48 lbs.	18"	5"
20'-0"	18"	48 lbs.	18"	5"
22'-0"	18"	60 lbs.	18"	5"
24'-0"	21"	$60\frac{1}{2}$ lbs.	20"	6"
26'-0"	24"	74 lbs.	24"	6"
28'-0"	24"	74 lbs.	24"	6"
30'-0"	24"	80 lbs.	24"	6"

Slab reinforcement in bottom, $\frac{3}{8}$" diameter rods 6" centers, crosswise.
Slab reinforcement in bottom, two $\frac{1}{2}$" diameter rods in each panel lengthwise.
Slab reinforcement in top, $\frac{1}{2}$" diameter rods 3'-0" long, 1'-0" centers crosswise over three middle beams.
Slab reinforcement in top, $\frac{1}{2}$" diameter rods, 2'-0" long, 1'-0" centers, crosswise through outside beams and extending into curb.

These bridges are designed with a capacity for carrying twelve-ton trucks. The wearing surface may be two inches of tar, concrete or asphalt, or six inches of gravel.

The I beams are held in position by cross beams about 1'-0" in thickness and reinforced by two $\frac{1}{2}$" diameter yoke rods passing under the beams and hooked up over the top flange of the outside beam. These cross beams should be spaced not over 10 feet apart, and should be used over each abutment. Two $\frac{1}{2}$" diameter rods are required in the top of each curb; also two rods of the same size further down on the outside of the bridge. The latter should be held in place by rods which reinforce the cross beams.

BLOOD POISONING FROM MACHINE OIL

Take care, says *Power and Transmission,* how you let machine oil or lubricator come in contact with a cut or scratch on your hand or arm, as serious blood poisoning may result. In the manufacture of some of these machine oils fat from diseased and decomposed animals is used. All physicians know how poisonous such matter is. The only safeguard is not to let any spot where the skin is broken be touched by any machine oil or lubricator.

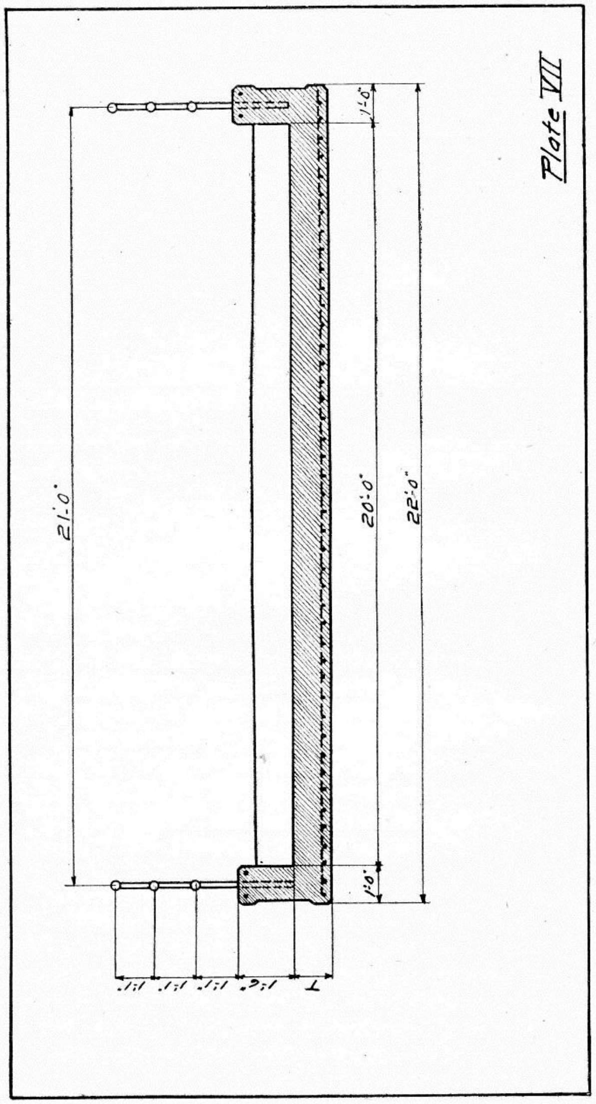


Table 8

CONCRETE SLAB BRIDGES AND CULVERT COVERS WITH ROD REINFORCEMENT

(Details shown in Plate VII)

Clear Spans	Thickness Equals t	Reinforcement	
		Lengthwise	Crosswise
2'-0"	6"	1/2" dia.-6" ctrs.	5/8" dia.-12" ctrs.
4'-0"	8"	5/8" dia.-5" ctrs.	5/8" dia.-12" ctrs.
6'-0"	10"	3/4" dia.-6" ctrs.	5/8" dia.-12" ctrs.
8'-0"	11"	3/4" dia.-5" ctrs.	5/8" dia.-12" ctrs.
10'-0"	13"	7/8" dia.-6" ctrs.	5/8" dia.-12" ctrs.
12'-0"	14"	7/8" dia.-6" ctrs.	5/8" dia.-12" ctrs.
14 -0"	17"	1" dia.-6" ctrs.	5/8" dia.-12" ctrs.

These slab bridges have been designed for a concentrated load of 4,000 lbs. at the center span on a strip 1 foot wide. They have a calculated capacity for a fifteen-ton truck. The wearing surface may be macadam or gravel.

Two ½" diameter rods are required in the top of each curb.

BUSINESS LAW

Ignorance of the law excuses no one.

An agreement without consideration is void.

Signatures made with a lead pencil are good in law.

A receipt for money paid is not legally conclusive.

The acts of one partner bind all the others.

Contracts made on Sunday cannot be enforced.

A contract made with a minor or lunatic is void.

Principals are responsible for the acts of their agents.

Agents are responsible to their principals for errors.

Each individual in a partnership is responsible for the whole of the debt of the firm.

A note given by a minor is void.

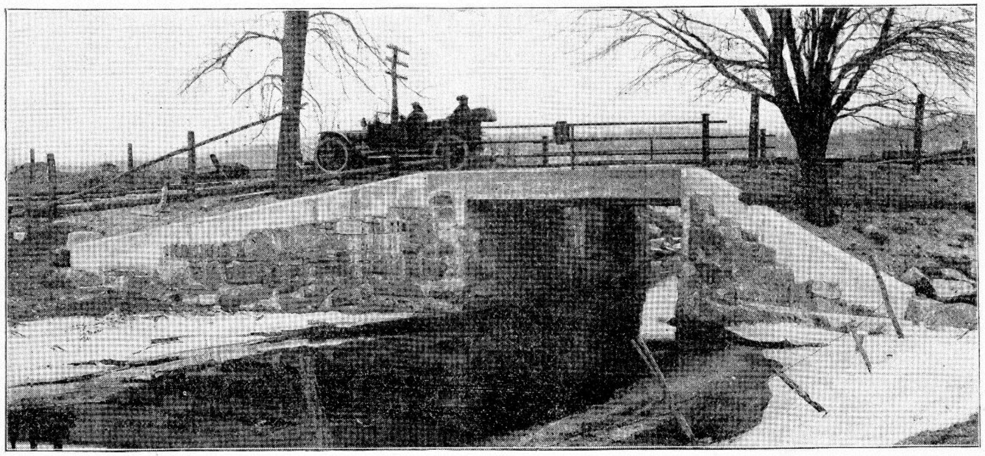
Notes bear interest only when so stated.

It is not legally necessary to say on a note "for value received."

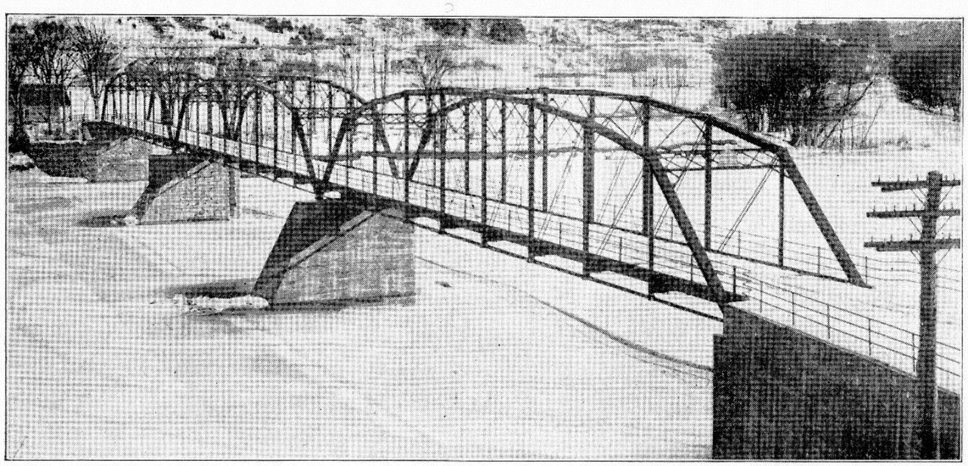
A note drawn on Sunday is void.

A note obtained by fraud, or from a person in a state of intoxication, cannot be collected.

An oral agreement must be proved by evidence.



This Cut Represents a Typical Concrete Girder Bridge Showing the Combination of a New Standard Superstructure in Conjunction with Old Masonry



CLAREMONT AND WEATHERSFIELD BRIDGE

This bridge, which was designed by Storrs, Bridge Engineers, was built to take the place of an old toll bridge which was carried away by freshet. It is built across the Connecticut River.

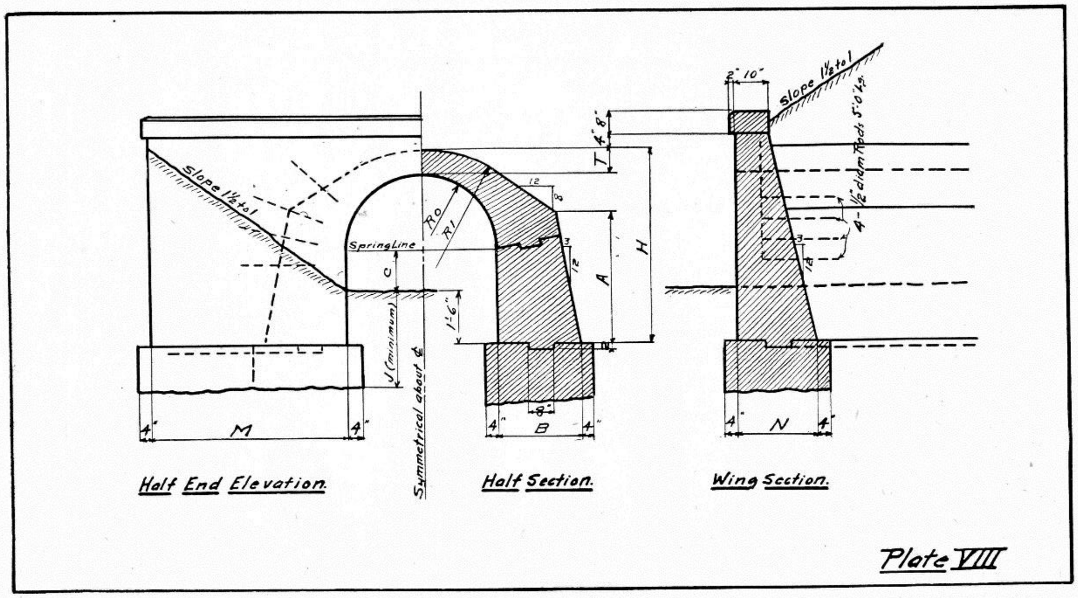


Table 9

ARCH CULVERTS

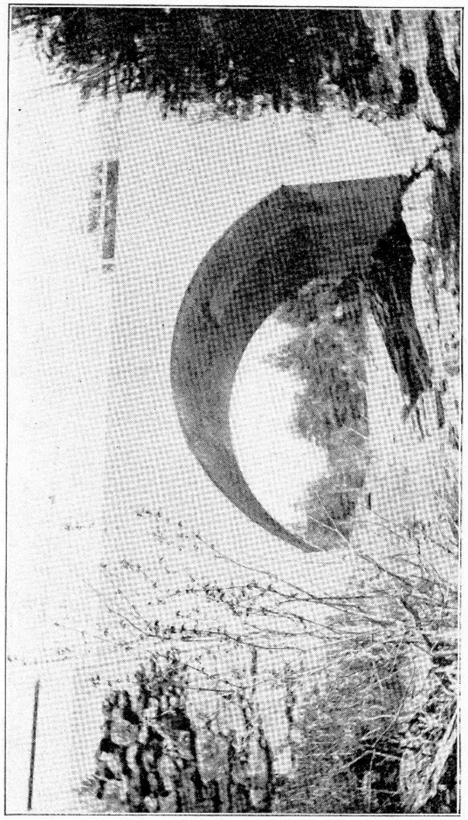
(Details shown in Plate VIII)

Clear Span	Area of Water-way	Dimensions									
		R-0	R-1	C	J	B	T	A	H	M	N
4'-0"	10.3 sq.'	2'-0"	3'-10½"	1'-0"	Minimum 3'-0", or to good foundation.	2'-4"	8"	3'-8"	5'-2"	5'-6"	2'-2½"
5'-0"	16.1 sq.'	2'-6"	4'-9"	1'-3"		2'-8"	8½"	4'-2"	5'-11½"	6'-8"	2'-4⅞"
6'-0"	23.1 sq.'	3'-0"	5'-7¾"	1'-6"		3'-0"	9"	4'-8"	6'-9"	7'-10½"	2'-7¼"
8'-0"	41.1 sq.'	4'-0"	7'-3"	2'-0"		3'-8"	10"	5'-7½"	8'-4"	10'-2"	3'-4"
10'-0"	64.3 sq.'	5'-0"	8'-10½"	2'-6"		4'-4"	11"	6'-7"	9'-11"	12'-6"	4'-0"

Plate No. VIII and table No. 9 are taken from designs of the United States Office of Public Roads, Washington, D. C.

PLAIN CONCRETE ARCHES WITH SHORT SPANS

In places where the fill is of sufficient depth, and ledge or other unyielding foundations may be found, small concrete arches are not only practical but pleasing to the eye as well. They are easily built, and if proper precautions are taken, they form the most permanent class of bridge construction.



WESTMORELAND ARCH, WESTMORELAND, N. H.

The above picture represents a plain concrete arch.

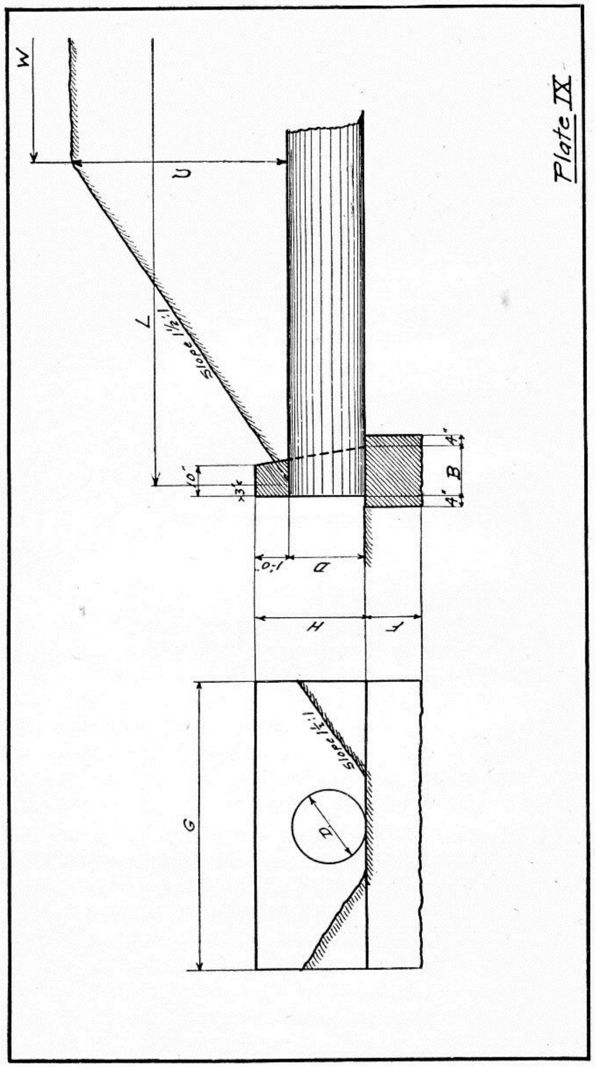
STONE ARCHES

The stone arch bridge is a type extremely appropriate to the "Granite State" and is, if properly designed and built, one of the most satisfactory of all bridges. It is not only a structure which requires almost no attention but it is pleasing to the eye as well. Where stone is plentiful and the location is suitable, a stone arch bridge is easily built at comparatively small expense. Most of the materials are at hand and the work can be done by local labor. This, together with its other advantages, makes a strong appeal in favor of this type of bridge to all who are interested in the common welfare.

There are many examples of these stone arch bridges in New Hampshire, some of these being over the Contoocook River at Peterboro, at Hillsboro, and at Henniker; and over the Souhegan River at Wilton and at Milford. Some of these bridges built many years ago are interesting and artistic, and are doing good service at the present time.

SPIRITS OF TURPENTINE

This is one of the most valuable articles in a family, and when it has once obtained a foothold in the house it is really a necessity and could ill be dispensed with. Its medicinal qualities are very numerous; for burns it is a quick application and gives immediate relief; for blisters on the hands it is of priceless value, searing down the skin and preventing soreness; for corns on the toes it is useful, and good for rheumatism and sore throats, and it is the quickest remedy for convulsions or fits. Then it is a sure preventive against moths; by just dropping a trifle in the bottom of drawers, chests and cupboards, it will render the garments secure from them during the summer. It will keep ants and bugs from closets and storerooms, by putting a few drops in the corners and upon the shelves; it is sure destruction to bedbugs and will effectually drive them away from their haunts, if thoroughly applied to the joints of the bedstead in the spring cleaning time, and injures neither furniture nor clothing. Its pungency is retained for a long time, and no family ought to be entirely out of a supply at any time of the year.—*Practical Farmer.*



STANDARD PIPE CULVERTS

Pipe culverts may be made by using sheet metal, akron, cast iron or any other kind of pipe in conjunction with stone or concrete endwalls. Plate IX shows standard straight endwall construction for all kinds of pipe.

Table 10

TABLE OF DIMENSIONS FOR STRAIGHT ENDWALLS FOR PIPE CULVERTS

Dimensions				
Opening	Wall			
D	G	H	B	F
12″	4′-0″	2′-0″	1′-2″	To a good foundation that will not be disturbed by frost.
15″	5′-0″	2′-3″	1′-3″	
18″	6′-0″	2′-6″	1′-4″	
24″	8′-0″	3′-0″	1′-5″	
30″	10′-0″	3′-6″	1′-8″	
36″	12′-0″	4′-0″	1′-10″	
42″	14′-0″	4′-6″	2′-0″	
48″	16′-0″	5′-0″	2′-3″	

The length of the pipe required may be determined by taking three times the average height of the roadway above the top of the pipe, plus the width of the roadway.

Example.—Assume the height at C to be 6 feet, and the corresponding height on the opposite side of the roadway to be 4 feet, and the width of the roadway 20 feet. Then 6 feet+4 feet =10 feet; average=5 feet; 3 x 5 feet=15 feet+20 feet=35 feet, which is L on Plate IX. To this length 6 inches should be added to give the total length of the pipe.

Table 11

STANDARD THICKNESS AND WEIGHTS OF CAST IRON PIPE

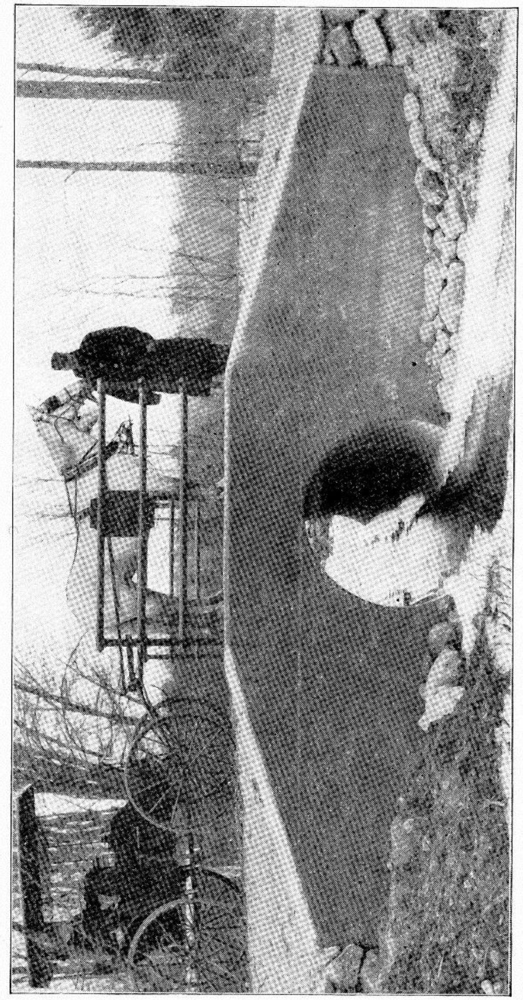
Nominal Inside Diam., Inches	Class A 100 Ft. Head 43 Lbs. Pressure			Class B 200 Ft. Head 86 Lbs. Pressure			Ap'r'x-imate pounds lead per J'nt. 2 in. Thick	Ap'r'x-imate pounds Hemp per Joint
	Thickness, Inches	Weight per Foot	Weight per L'gth.	Thickness, Inches	Weight per Foot	Weight per L'gth.		
3	.39	14.5	175	.42	16.2	194	6.00	.18
4	.42	20.0	240	.45	21.7	260	7.50	.21
6	.44	30.8	370	.48	33.3	400	10.25	.31
8	.46	42.9	515	.51	47.5	570	13.25	.44
10	.50	57.1	685	.57	63.8	765	16.00	.53
12	.54	72.5	870	.62	82.1	985	19.00	.61
14	.57	89.6	1075	.66	102.5	1230	22.00	.81
16	.60	108.3	1300	.70	125.0	1500	30.00	.94
18	.64	129.2	1550	.75	150.0	1800	33.80	1.00
20	.67	150.0	1800	.80	175.0	2100	37.00	1.25
24	.76	204.2	2450	.89	233.3	2800	44.00	1.50
30	.88	291.7	3500	1.03	333.3	4000	54.25	2.06
36	.99	391.7	4700	1.15	454.2	5450	64.75	3.00
42	1.10	512.5	6150	1.28	591.7	7100	75.25	3.62
48	1.26	666.7	8000	1.42	750.0	9000	85.50	4.37
54	1.35	800.0	9600	1.55	933.3	11200	97.60	6.25
60	1.39	916.7	11000	1.67	1104.2	13250	108.30	8.25
72	1.62	1283.4	15400	1.95	1545.8	18550	128.00	12.50
84	1.72	1633.4	19600	2.22	2104.2	25250	147.00	15.00

The above weights are per length to lay 12 feet, including standard sockets proportionate allowance to be made for any variation.

Table 12

STANDARD SEWER PIPE

Calibre, Inches	Thickness, Inches	Weight per Ft., Lbs.	Depth of Socket, Inches	Annular Space, Inches
3	1-2	7	1 1-2	1-4
4	1-2	9	1 5-8	3-8
5	5-8	12	1 3-4	3-8
6	5-8	15	1 7-8	3-8
8	3-4	23	2	3-8
9	13-16	28	2	3-8
10	7-8	35	2 1-8	3-8
12	1	45	2 1-4	1-2
15	1 1-8	60	2 1-2	1-2
18	1 1-4	85	2 3-4	1-2
20	1 3-8	100	3	1-2
22	1 5-8	130	3	1-2
24	1 5-8	150	3 1-4	1-2
27	2	224	4	3-4
30	2 1-8	252	4	3-4
33	2 1-4	310	5	1 1-4
36	2 1-2	350	5	1 1-4



This Picture Shows the General Appearance of a Typical Pipe Culvert

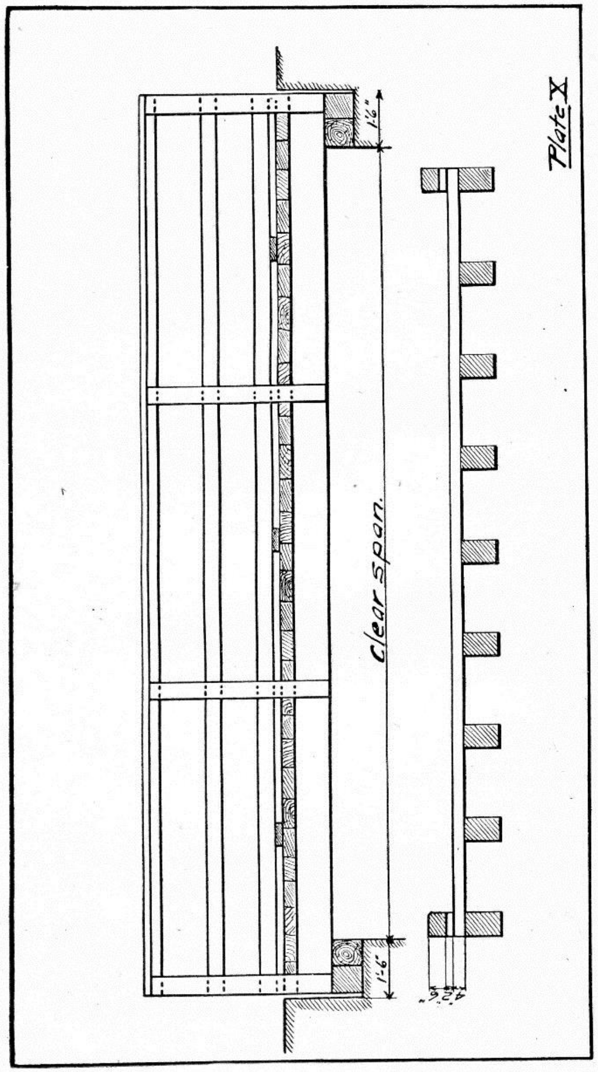


Table 13

WOOD STRINGER BRIDGES

(Details shown in Plate X)

Clear Span	Beams	Spacing c–c	Plank
8′–0″	8″ x 10″	2′–6″	4″
10′–0″	8″ x 10″	2′–6″	4″
12′–0″	10″ x 10″	2′–6″	4″
14′–0″	10″ x 12″	2′–6″	4″
16′–0″	10″ x 12″	2′–6″	4″
18′–0″	10″ x 14″	2′–6″	4″
20′–0″	10″ x 14″	2′–6″	4″
22′–0″	10″ x 16″	2′–6″	4″
24′–0″	10″ x 16″	2′–6″	4″

These bridges are designed to be built with long leaf yellow southern hard pine, both stringers and plank. They have a capacity for a twelve-ton truck. All plank should be thoroughly spiked with 8″ spikes.

Table 14

WOOD STRINGER BRIDGES

For Back Country Roads

(Details shown in Plate X)

Clear Span	Beams	Spacing c to c
8′–0″	6″ x 8″	2′–6″
10′–0″	6″ x 8″	2′–6″
12′–0″	6″ x 10″	2′–6″
14′–0″	8″ x 10″	2′–6″
16′–0″	8″ x 10″	2′–6″
18′–0″	10″ x 10″	2′–6″
20′–0″	8″ x 12″	2′–6″
22′–0″	10″ x 12″	2′–6″
24′–0″	12″ x 12″	2′–6″

These bridges are designed for slow moving loads of six tons, including the wagon, equally distributed on four wheels, wheels 5 feet apart and axles 10 feet apart. The beams may be of native lumber, spruce, pine, or hemlock, but must be sound and free from bad knots. The plank must be 3″, thoroughly spiked with 6″ spikes.

The railing shown is the New Hampshire Standard Wooden Guard Rail as illustrated in Plate XI, with the exception that the posts are 6″ square instead of round. The posts must be firmly bolted to the outside stringer. Two $\frac{3}{4}$″ bolts should be used for each post.

Table 15

SAFE TOTAL LOADS UNIFORMLY DISTRIBUTED FOR RECTANGULAR SPRUCE OR WHITE PINE BEAMS ONE INCH THICK

(For concentrated or wheel loads use one-half the value given in this table)

Span in Feet	Depth of Beam										
	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	16″
5	600	820	1070	1350	1670	2020	2400	2820	3270	3750	4270
6	500	680	890	1120	1390	1680	2000	2350	2730	3120	3560
7	430	580	760	960	1190	1440	1710	2010	2330	2680	3050
8	380	510	670	840	1040	1260	1500	1760	2040	2340	2670
9	330	460	590	750	930	1120	1330	1560	1810	2080	2370
10	300	410	530	670	830	1010	1200	1410	1630	1880	2130
11	270	370	490	610	760	920	1090	1280	1490	1710	1940
12	250	340	440	560	690	840	1000	1180	1360	1560	1780
13	230	310	410	520	640	780	930	1080	1260	1440	1640
14	210	290	380	480	590	720	860	1010	1170	1340	1530
15	200	270	360	450	560	670	800	940	1090	1250	1420
16	190	260	330	420	520	630	750	880	1020	1180	1330
17	180	240	310	400	490	590	710	830	960	1100	1260
18	170	230	290	370	460	560	670	780	910	1040	1190
19	160	210	280	360	440	530	630	740	860	990	1130
20	150	200	270	340	420	510	600	710	820	940	1070
21	140	190	260	320	390	480	570	670	780	890	1020
22	140	190	240	310	380	460	540	640	740	850	970
23	130	180	230	290	360	440	520	610	710	810	920
24	130	170	220	280	350	420	500	590	680	780	890
25	120	160	210	270	330	410	480	560	660	750	860
26	110	160	210	260	320	390	460	540	630	720	820
27	110	150	200	250	310	370	440	520	610	690	790
28	110	140	190	240	300	360	430	500	580	670	760
29	110	140	180	230	290	350	410	490	560	640	740

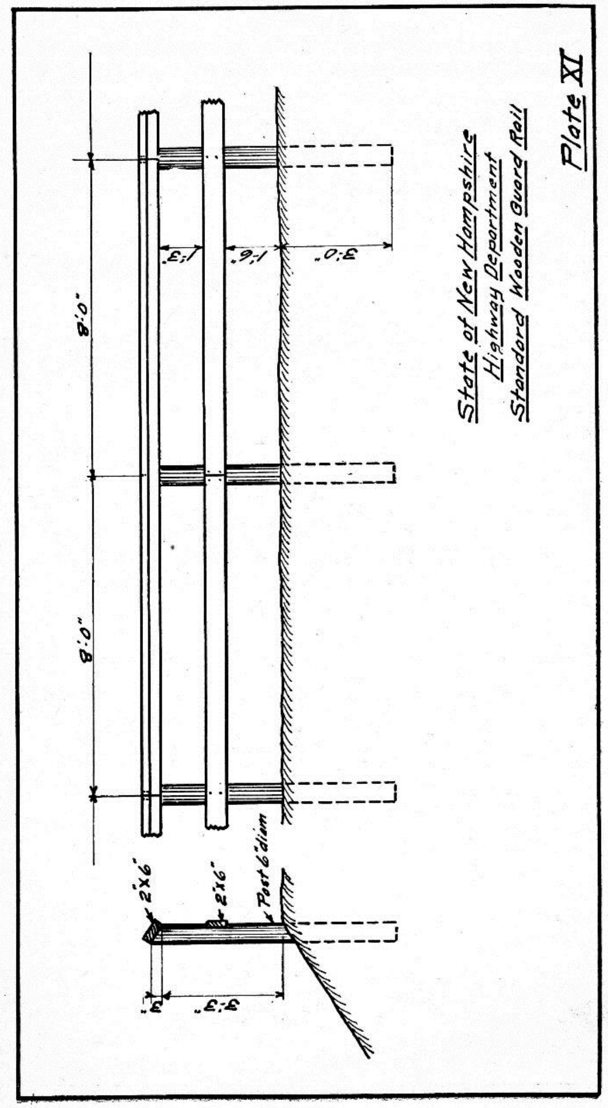
To obtain the safe load for any thickness: Multiply values for 1 inch by thickness of beam.

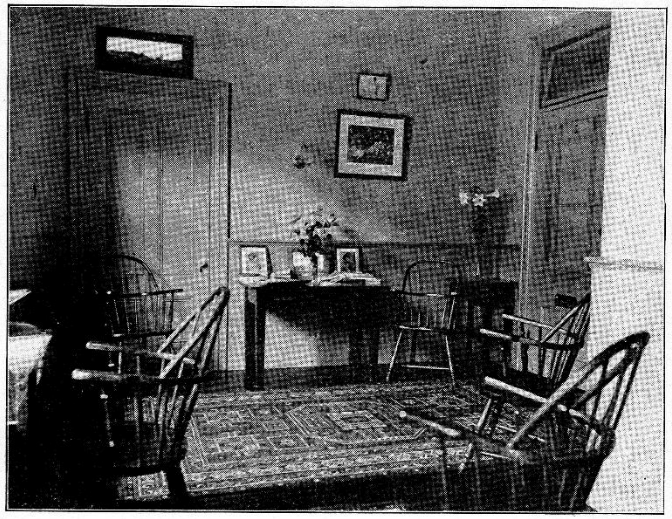
For oak increase values in table by $^1/_3$.

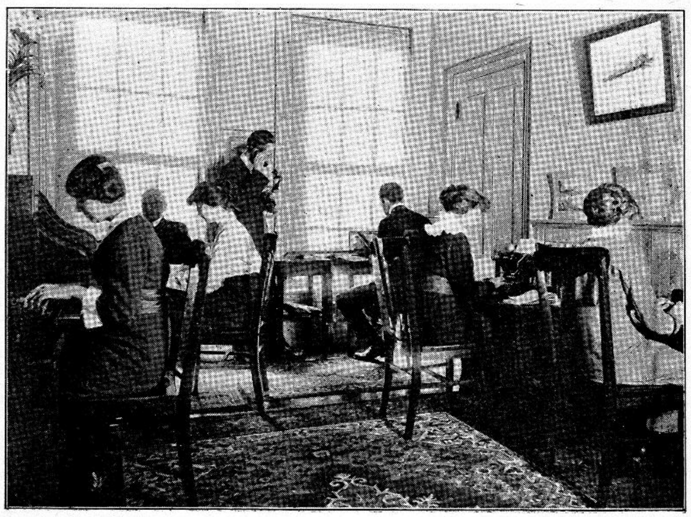
For yellow pine increase values in table by $^2/_3$.

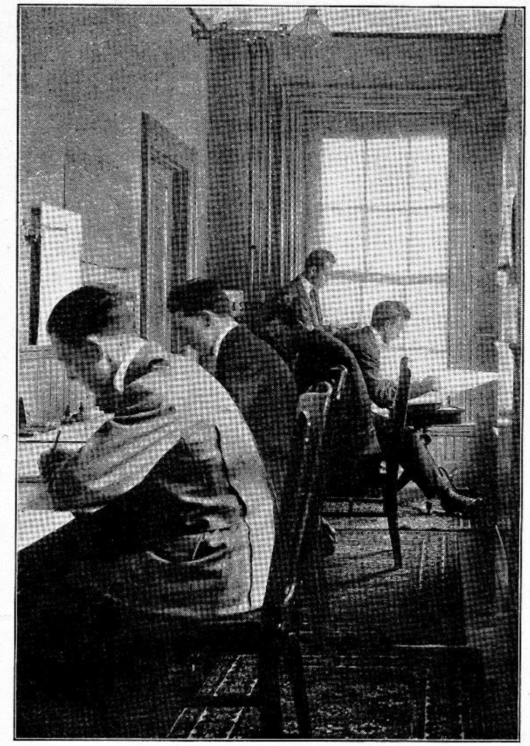
SAFETY ALWAYS !

Most Bridges are safe when they are first built. It's the Bridge which has seen hard service—that has been shaken and pounded and fatigued—that becomes unsafe! Yet "it was built to last!" It has lasted—the question is—how much longer is it to last safely?









ABOUT OURSELVES

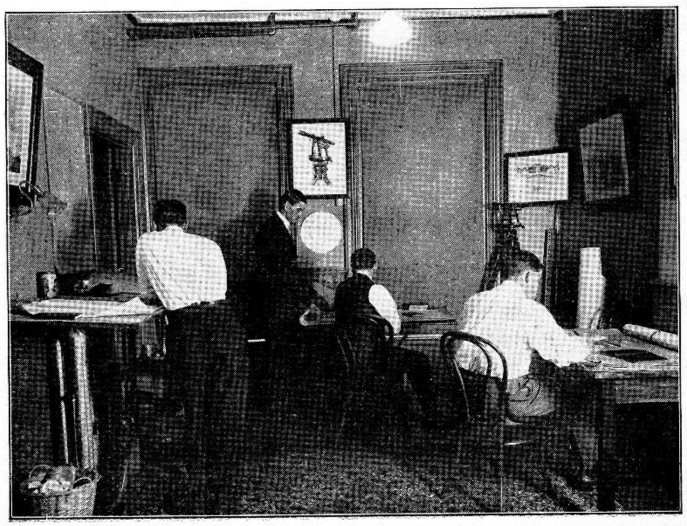
The firm of "STORRS" has been engaged in the practice of bridge engineering since 1906, first in a small office at 112 Pleasant street; later, in 1909, new quarters were opened at 165 North Main street. In the spring of 1914, owing to the increase in business, larger quarters became imperative and a change was made to a three-room suite in the down-town section at 59 North Main street. During the latter part of the year 1914 it became apparent that still more room was needed and two adjoining rooms were secured.

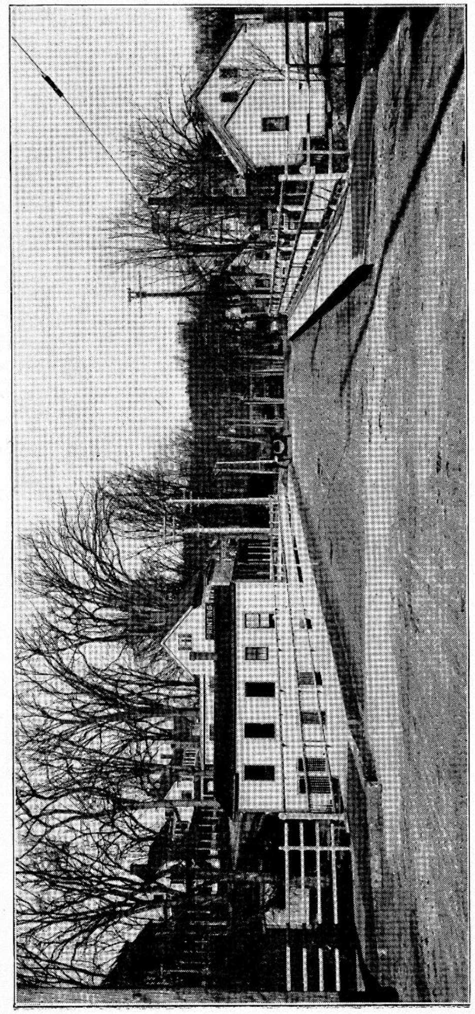
The illustrations were taken soon after this change was made and while the work of designing the five new bridges for the City of Concord was in progress.

Picture 1 shows the reception room of our office, while picture 2 shows a view of our office when everybody is busy. Picture 3 shows the drafting room in which general engineering work is done including buildings, dams, etc., while picture 4 shows the bridge design department.

The firm is equipped for the rapid handling of all kinds of engineering propositions, though specializing in bridge engineering.

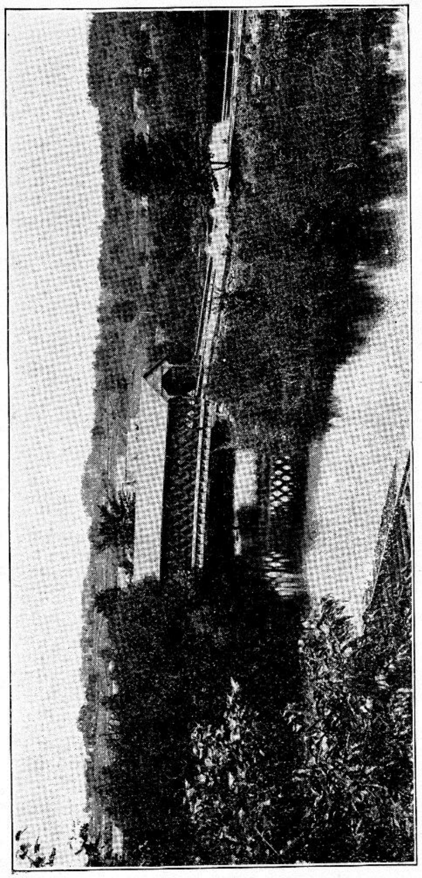
The members of the firm are always glad to talk over, with town or city officials, any matters relating to bridges, and are always glad to receive callers who are interested in this work.





MAIN STREET BRIDGE, PENACOOK, N. H.

This bridge was built in 1915, and was designed by STORRS, BRIDGE ENGINEERS. It has a 26-foot roadway and two 5-foot sidewalks, and arched concrete floor with tar concrete wearing surface. The bridge has a capacity for electric cars.



A Typical Bridge of the Towne Lattice Type

BRIDGE TALKS

Probably the first bridge built by the early settlers of New Hampshire was merely a tree trunk that had fallen over a brook.

Later, as the rude woodland paths became wagon trails, several trees or logs, placed side by side, and perhaps covered with brush and earth, made a structure of greater convenience for the early traffic of the period.

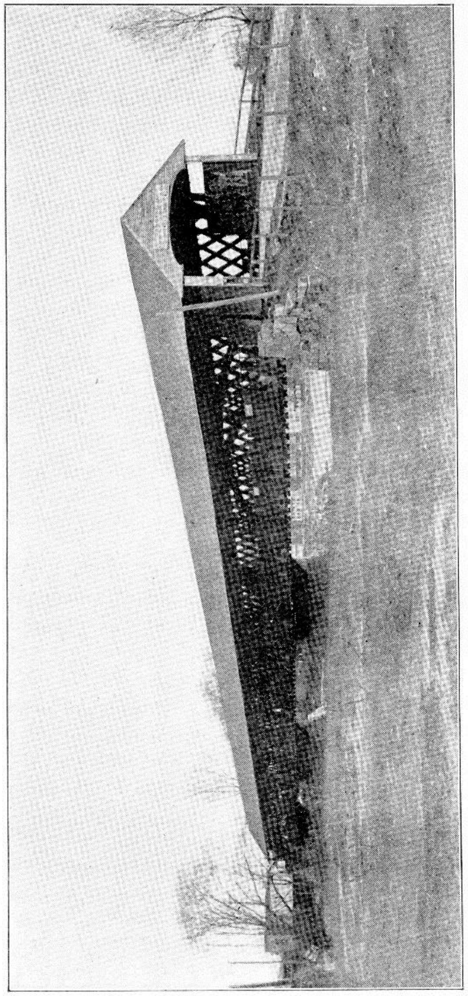
In cases where the stream was too wide for a single span a rude pier of stones or a frame work of timber was built to support the ends of logs extending from it to the adjacent shore. Several piers of this kind were necessary when crossing the wider streams.

In many cases where the depth of water prevented, or where there was danger of spring freshets removing these rude piers, simple trusses were attempted.

Perhaps the most common of this early type of a short span truss was what is known as the "King post." This truss consisted of two inclined timbers forming a letter A, from the apex of which a hanger rod supported a horizontal joist, crosswise of the bridge, upon which the longitudinal floor stringers rested. This enabled the builder to build a span of practically double the length of the earlier simple stringer bridge.

Later the development of this type of bridge was advanced by the use of a horizontal timber at the top with two hangers. This type of truss was later developed by adding additional hangers. From the top of each hanger an inclined brace was carried to the nearest abutment. True truss action, as we now understand it, was scarcely known in these days, the idea of the builder being to carry each load separately to the nearest abutment by the shortest route. This idea, for the longer spans, proved very uneconomical on account of the long braces, whose stresses increased both with their length and with the angle of inclination to the vertical.

This led to the introduction of the panel system, which was introduced into the United States near the close of the eighteenth century by Theodore Burr. The Burr truss may be called the parent of nearly all styles of simple bridge trusses now in use. Although defective from the lack of sufficient bracing so that it generally required an arch for stiffness, yet it contained the sound principle of placing at a constant angle the inclined members of the web system.



HOOKSETT WOODEN BRIDGE, HOOKSETT, N. H.

This picture shows a three-span wood lattice bridge, built about 1850, and replaced by a steel bridge which is shown on page 48 of this book.

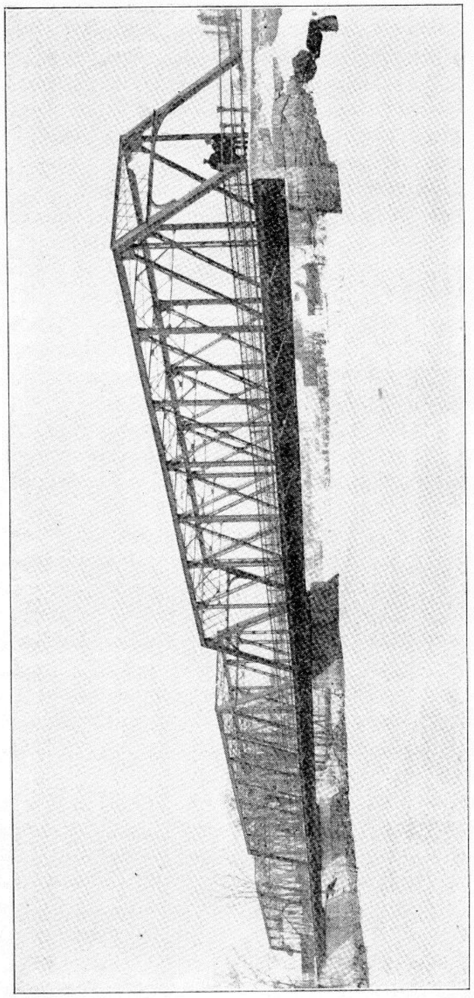
What is known as the "Towne Lattice" truss was introduced in this country about 1820, and consisted of planks pinned together, usually with oak pins. This type of bridge is one of the most common to be found in this section of the country, and while wasteful in the use of timber, it was one of the most easily constructed of any of the long span types of wooden bridges. Many of the longer spans have been reinforced with wooden arches as increased traffic demanded stronger construction.

The original design of this type of bridge called for a high camber or upward curve in the chords and floor, but most of these bridges now in use have been overstrained and now show a perceptible sag.

In addition to this structural weakness there are many cases in which neglect has played a prominent part in the deterioration of the structure. Accumulations of dirt are allowed to collect on the chords. The roofs and side boards not only present a dilapidated appearance, but allow the entrance of rain into the vital parts of the structure. It is a well-known saying that "A chain is as strong as its weakest link," and a bridge with a decayed bottom chord is of very little value as a bridge. Constant care and attention in many cases would have preserved, for years to come, many of these historic landmarks, and even now a proper appreciation of its real strength or weakness may save a bridge of this type for many years.

The oldest wooden bridge with which we are familiar is over the Ammonoosuc River between the towns of Haverhill and Bath, New Hampshire. This bridge was built in 1828 and is still giving fair service. Another bridge over the Ammonoosuc River is at Bath Village, New Hampshire, built in 1832. The bridge across the Pemigewasset River at Franklin is a plank lattice bridge built in 1849.

Later there were a few iron bridges built, mostly under patents, and were a combination of wrought and cast iron. In the 70's and 80's iron bridges were more frequently constructed. The more recent bridges are built of steel. Most of the bridges were designed and built by bridge companies and were built with a capacity for about six-ton loads to conform to what was understood to be the statutory requirement in New Hampshire, which limited the liability of towns to damages. Most of these bridges have given good service but they are of too light construction to safely handle the loads that are now passing over our highways.



HOOKSETT STEEL BRIDGE, HOOKSETT, N. H.

This bridge, which was designed by STORRS, BRIDGE ENGINEERS, has a 20-foot roadway, with 5-foot sidewalk and plank floor.

The more recent bridges that have been designed by STORRS, BRIDGE ENGINEERS, of Concord, N. H., many of which are shown in the illustrations in this book, are designed with a capacity for loads equal to twelve-ton trucks, and steam road rollers. The typical twelve-ton truck is built with axles 12 feet apart with three tons on the forward axle, and nine tons on the rear axle or 9,000 lbs. on each of the rear wheels. This means that there may be a string of twelve-ton trucks covering the whole bridge passing in one direction and another line of twelve-ton trucks covering the whole bridge passing in the opposite direction. Concrete arch and slab floors have replaced the old style plank floors. And new concrete bridges with rod reinforcement are fast becoming popular. On page 46 is an illustration of a typical bridge of the Towne lattice type. This bridge was built over the Merrimack River in the town of Hooksett. It was built about 1850 and was replaced by a steel bridge as is shown on page 48.

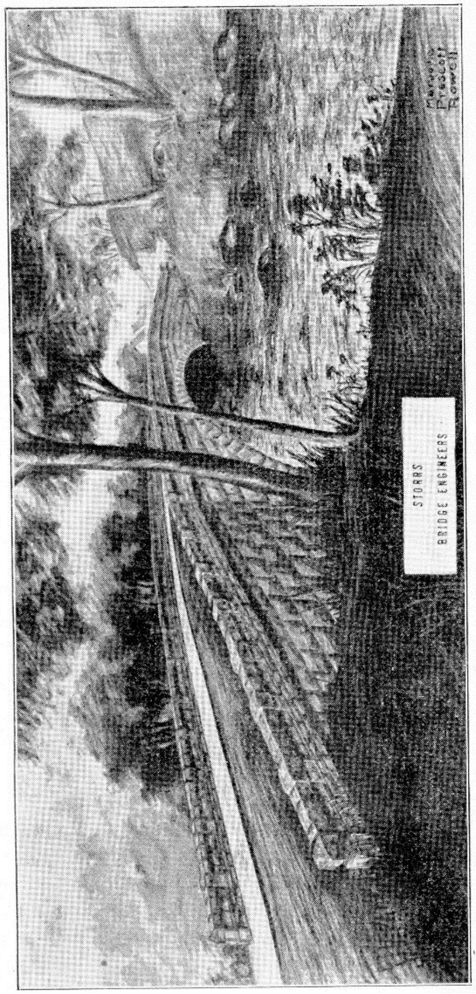
ABUTMENTS AND RETAINING WALLS

In connection with the different bridges shown in this book it will probably be found necessary in many cases to build masonry as well.

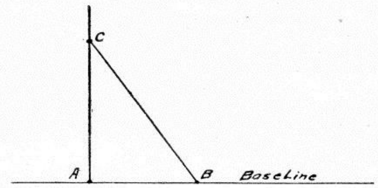
A great deal of the stonework under existing country bridges in many places is not designed for the present severe requirements. Large cracks and bulging walls are indications of structural weakness which should not be allowed to go unheeded.

One of the principal faults in these old walls is a lack of sufficient thickness at the bottom.

There are many theoretical formulas and assumptions for figuring the thickness of retaining walls or bridge abutments. A safe rule, however, for an abutment or retaining wall where the earth is level with the top surface of the wall is to make the thickness of the wall at any point one-half the distance from that point to the top of the wall. For work of any considerable proportions or for surcharged walls it will pay to have the advice of a thoroughly competent engineer.



The Above Illustration Represents a Suggestion for a Stone Arch



TO LAY OUT A LINE A–C AT RIGHT ANGLES TO A BASE LINE, THE RIGHT ANGLE TO COME AT POINT A

Hold 8 feet on the tape at point A; hold 14 feet on the tape at point B, also on the base line. Point C will be located where the end of the tape intersects with the 24 foot mark, and a line drawn from A through C will be at right angles to the base line.

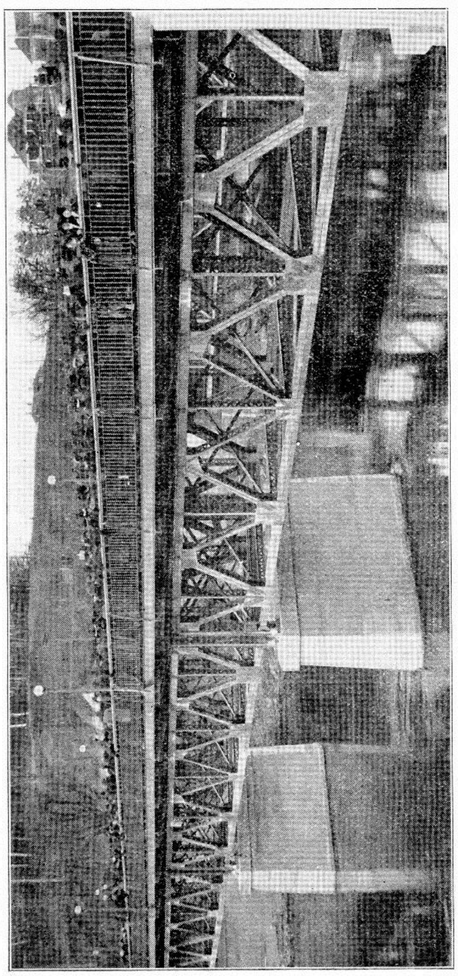
TO FIND THE AREA OF ANY RIGHT ANGLE TRIANGLE

The area of any right angle triangle equals the base A–B multiplied by the perpendicular A–C, divided by two.

TO FIND THE LENGTH OF A SIDE OF A RIGHT ANGLE TRIANGLE WITH TWO SIDES GIVEN

To find B–C take the sum of the squares of A–C and A–B and extract the square root. To find A–C take from the square of C–B the square of A–B and extract the square root of the difference. To find A–B take from the square of B–C the square of A–C and extract the square root of the difference.

Example.—Assume A–C to be 16 feet, and A–B to be 12 feet, what is the length of the side C–B? From the table of squares, shown on page 56, the square of 16 is 256; the square of 12 is 144; 256+144=400. From the table of squares, the number opposite 400 is 20. Therefore, side C–B=20 feet.



RANGERS BRIDGE, WOODSVILLE, N. H.

This bridge is built over the Connecticut River between the towns of Haverhill, New Hampshire, and Newbury, Vermont. It carries a 26-foot roadway and a 6-foot sidewalk, both of concrete. This bridge was designed by STORRS, BRIDGE ENGINEERS, and was built in 1917.

TO FIND THE CIRCUMFERENCE OF A CIRCLE

To find the circumference of a circle multiply the diameter of the circle by 3.1416.

Example.—Assume the diameter of the circle to be 10 inches. 10″ x 3.1416 = 31.416 inches.

TO FIND THE AREA OF A CIRCLE

To find the area of a circle square the diameter of the circle and multiply by .785.

Example.—Assume the diameter of the circle to be 10 inches. 10″ x 10″ = 100″ x .785 = 78.5 square inches.

BEARING POWER OF SOILS

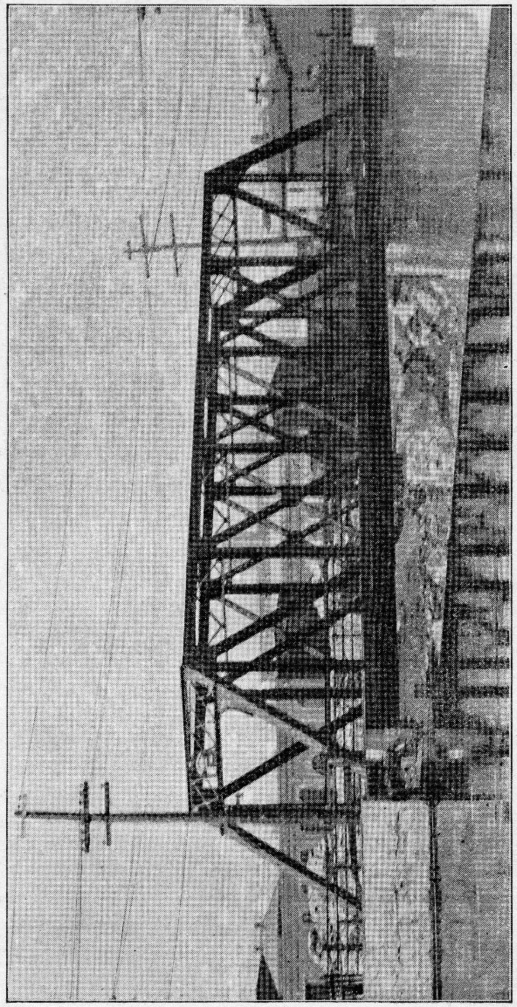
The following tabulations, which are self-explanatory, are useful in connection with the designing of foundations; they show the bearing power of soils in tons per square foot:

(From Baker's Masonry Construction)

Rock, the hardest, thick layers, in native bed	200	tons
Rock, equal to the best ashlar masonry	25	to 30 tons
Rock, equal to the best brick masonry	15	to 20 tons
Rock, equal to poor brick masonry	5	to 10 tons
Clay on thick beds, always dry	4	to 6 tons
Clay on thick beds, moderately dry	2	to 4 tons
Clay, soft	1	to 2 tons
Gravel and coarse sand, well cemented	8	to 10 tons
Sand, compact and well cemented	4	to 6 tons
Sand, clean and dry	2	to 4 tons
Quicksand, alluvial soils, etc.	0.5	to 1 ton

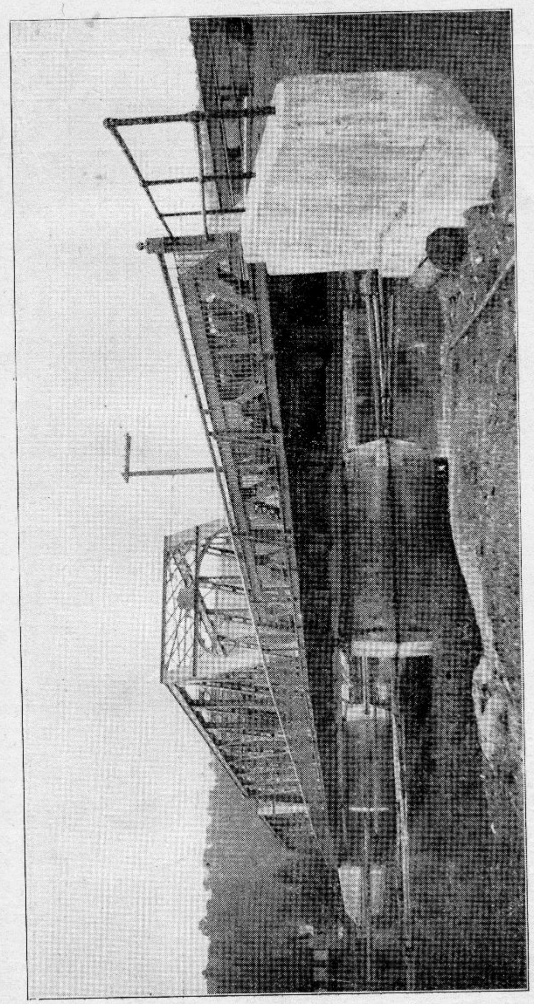
(From Building Code, National Board of Fire Underwriters).

Soft clay	1 ton per sq. ft.
Clay and sand together, wet and springy	2 tons per sq. ft.
Loam, clay, or fine sand, firm and dry	3 tons per sq. ft.
Very firm coarse sand, stiff gravel or hard clay	4 tons per sq. ft.



BERLIN BRIDGE, BERLIN, N. H.

This picture represents one of two bridges built on Mason Street in the City of Berlin in 1912. These bridges have a reinforced concrete roadway 20 feet wide, and 6-foot granolithic sidewalk. They are designed for 20-ton road rollers.



BERLIN BRIDGE, BERLIN, N. H.

This bridge was built by the City of Berlin, near Berlin Mills, New Hampshire, in 1916. Both of these bridges cross the Androscoggin River, and were designed by STORRS, BRIDGE ENGINEERS, Concord, N. H.

Table 16

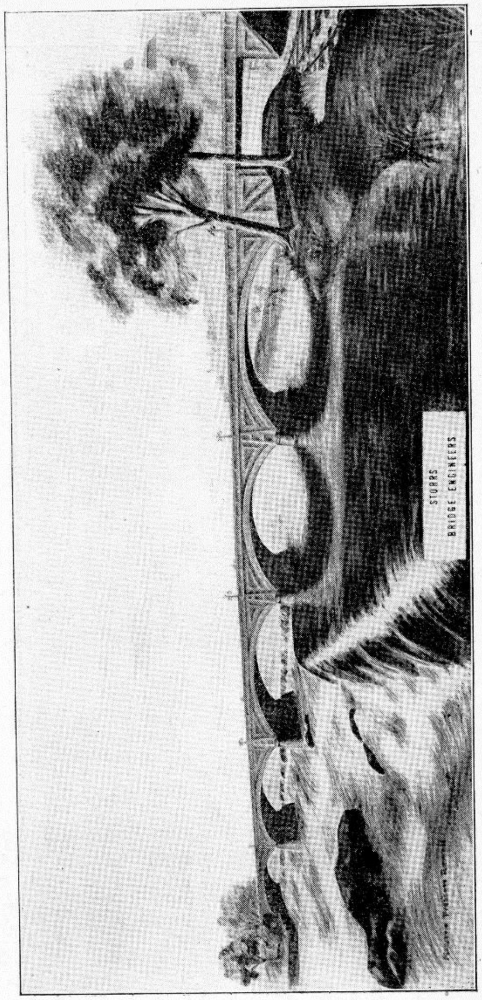
FUNCTIONS OF NUMBERS, 1 TO 49

No.	Square	Cube	Square Root	Cubic Root	No.=Diameter	
					Circum.	Area
1	1	1	1.0000	1.0000	3.142	0.7854
2	4	8	1.4142	1.2599	6.283	3.1416
3	9	27	1.7321	1.4422	9.425	7.0686
4	16	64	2.0000	1.5874	12.566	12.5664
5	25	125	2.2361	1.7100	15.708	19.6350
6	36	216	2.4495	1.8171	18.850	28.2743
7	49	343	2.6458	1.9129	21.991	38.4845
8	64	512	2.8284	2.0000	25.133	50.2655
9	81	729	3.0000	2.0801	28.274	63.6173
10	100	1000	3.1623	2.1544	31.416	78.5398
11	121	1331	3.3166	2.2240	34.558	95.0332
12	144	1728	3.4641	2.2894	37.699	113.097
13	169	2197	3.6056	2.3513	40.841	132.732
14	196	2744	3.7417	2.4101	43.982	153.938
15	225	3375	3.8730	2.4662	47.124	176.715
16	256	4096	4.0000	2.5198	50.265	201.062
17	289	4913	4.1231	2.5713	53.407	226.980
18	324	5832	4.2426	2.6207	56.549	254.469
19	361	6859	4.3589	2.6684	59.690	283.529
20	400	8000	4.4721	2.7144	62.832	314.159
21	441	9261	4.5826	2.7589	65.973	346.361
22	484	10648	4.6904	2.8020	69.115	380.133
23	529	12167	4.7958	2.8439	72.257	415.476
24	576	13824	4.8990	2.8845	75.398	452.389
25	625	15625	5.0000	2.9240	78.540	490.874
26	676	17576	5.0990	2.9625	81.681	530.929
27	729	19683	5.1962	3.0000	84.823	572.555
28	784	21952	5.2915	3.0366	87.965	615.752
29	841	24389	5.3852	3.0723	91.106	660.520
30	900	27000	5.4772	3.1072	94.248	706.858
31	961	29791	5.5678	3.1414	97.389	754.768
32	1024	32768	5.6569	3.1748	100.531	804.248
33	1089	35937	5.7446	3.2075	103.673	855.299
34	1156	39304	5.8310	3.2396	106.814	907.920
35	1225	42875	5.9161	3.2711	109.956	962.113
36	1296	46656	6.0000	3.3019	113.097	1017.88
37	1369	50653	6.0828	3.3322	116.239	1075.21
38	1444	54872	6.1644	3.3620	119.381	1134.11
39	1521	59319	6.2450	3.3912	122.522	1194.59
40	1600	64000	6.3246	3.4200	125.66	1256.64
41	1681	68921	6.4031	3.4482	128.81	1320.25
42	1764	74088	6.4807	3.4760	131.95	1385.44
43	1849	79507	6.5574	3.5034	135.09	1452.20
44	1936	85184	6.6332	3.5303	138.23	1520.53
45	2025	91125	6.7082	3.5569	141.37	1590.43
46	2116	97336	6.7823	3.5830	144.51	1661.90
47	2209	103823	6.8557	3.6088	147.65	1734.94
48	2304	110592	6.9282	3.6342	150.80	1809.56
49	2401	117649	7.0000	3.6593	153.94	1885.74

Table 16 *(concluded)*

FUNCTIONS OF NUMBERS, 50 TO 99

No.	Square	Cube	Square Root	Cubic Root	No.=Diameter	
					Circum.	Area
50	2500	125000	7.0711	3.6840	157.08	1963.50
51	2601	132651	7.1414	3.7084	160.22	2042.82
52	2704	140608	7.2111	3.7325	163.36	2123.72
53	2809	148877	7.2801	3.7563	166.50	2206.18
54	2916	157464	7.3485	3.7798	169.65	2290.22
55	3025	166375	7.4162	3.8030	172.79	2375.83
56	3136	175616	7.4833	3.8259	175.93	2463.01
57	3249	185193	7.5498	3.8485	179.07	2551.76
58	3364	195112	7.6158	3.8709	182.21	2642.08
59	3481	205379	7.6811	3.8930	185.35	2733.97
60	3600	216000	7.7460	3.9149	188.50	2827.43
61	3721	226981	7.8102	3.9365	191.64	2922.47
62	3844	238328	7.8740	3.9579	194.78	3019.07
63	3969	250047	7.9373	3.9791	197.92	3117.25
64	4096	262144	8.0000	4.0000	201.06	3216.99
65	4225	274625	8.0623	4.0207	204.20	3318.31
66	4356	287496	8.1240	4.0412	207.35	3421.19
67	4489	300763	8.1854	4.0615	210.49	3525.65
68	4624	314432	8.2462	4.0817	213.63	3631.68
69	4761	328509	8.3066	4.1016	216.77	3739.28
70	4900	343000	8.3666	4.1213	219.91	3848.45
71	5041	357911	8.4261	4.1408	223.05	3959.19
72	5184	373248	8.4853	4.1602	226.19	4071.50
73	5329	389017	8.5440	4.1793	229.34	4185.39
74	5476	405224	8.6023	4.1983	232.48	4300.84
75	5625	421875	8.6603	4.2172	235.62	4417.86
76	5776	438976	8.7178	4.2358	238.76	4536.46
77	5929	456533	8.7750	4.2543	241.90	4656.63
78	6084	474552	8.8318	4.2727	245.04	4778.36
79	6241	493039	8.8882	4.2908	248.19	4901.67
80	6400	512000	8.9443	4.3089	251.33	5026.55
81	6561	531441	9.0000	4.3267	254.47	5153.00
82	6724	551368	9.0554	4.3445	257.61	5281.02
83	6889	571787	9.1104	4.3621	260.75	5410.61
84	7056	592704	9.1652	4.3795	263.89	5541.77
85	7225	614125	9.2195	4.3968	267.04	5674.50
86	7396	636056	9.2736	4.4140	270.18	5808.80
87	7569	658503	9.3274	4.4310	273.32	5944.68
88	7744	681472	9.3808	4.4480	276.46	6082.12
89	7921	704969	9.4340	4.4647	279.60	6221.14
90	8100	729000	9.4868	4.4814	282.74	6361.73
91	8281	753571	9.5394	4.4979	285.88	6503.88
92	8464	778688	9.5917	4.5144	289.03	6647.61
93	8649	804357	9.6437	4.5307	292.17	6792.91
94	8836	830584	9.6954	4.5468	295.31	6939.78
95	9025	857375	9.7468	4.5629	298.45	7088.22
96	9216	884736	9.7980	4.5789	301.59	7238.23
97	9409	912673	9.8489	4.5947	304.73	7389.81
98	9604	941192	9.8995	4.6104	307.88	7542.96
99	9801	970299	9.9499	4.6261	311.02	7697.69



Design for a Typical Reinforced Concrete Arch of 100 Foot Spans

Table 17

STANDARD STEEL WIRE NAILS

Description	Approximate Size of Wire Nails	Approximate No. to the Pound
3d fine	1⅛ in. No. 16	920
3d common	1¼ " " 14½	615
4d "	1½ " " 13	322
6d "	2 " " 12	200
8d "	2½ " " 10½	106
10d "	3 " " 9½	74
12d "	3¼ " " 9	57
16d "	3½ " " 8	46
20d "	4 " " 6	29
30d "	4½ " " 5	23
6d casing	2 " " 13	260
8d "	2½ " " 13	160
10d "	3 " " 11	108
4d finish	1½ " " 16	767
6d "	2 " " 14	359
8d "	2½ " " 13	214
10d "	3 " " 12	134
3d shingle	1¼ " " 13	429
6d flooring	2 " " 11	151
8d "	2½ " " 10	98
10d "	3 " " 9	66
4d box	1½ " " 15	550
6d "	2 " " 13	250

Table 18

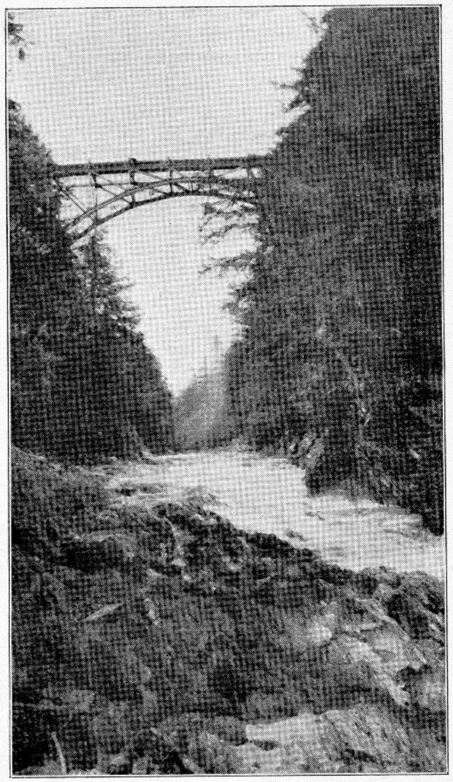
WIRE SPIKES

(Size and number to the pound)

Title	No. of Wire	Length	No. per Pound
10d	7	3 in.	50
16d	6	3½ "	35
20d	5	4 "	26
30d	4	4½ "	20
40d	3	5 "	15
50d	2	5½ "	12
60d	1	6 "	10
6½ in.	1	6½ "	9
7 "	0	7 "	7
8 "	00	8 "	5
9 "	00	9 "	4½

A cubic foot of water contains 7.48 gallons, or 1,728 cubic inches, and weighs 62½ pounds.

A gallon of water contains 231 cubic inches and weighs 8⅓ pounds (U. S. Standard).



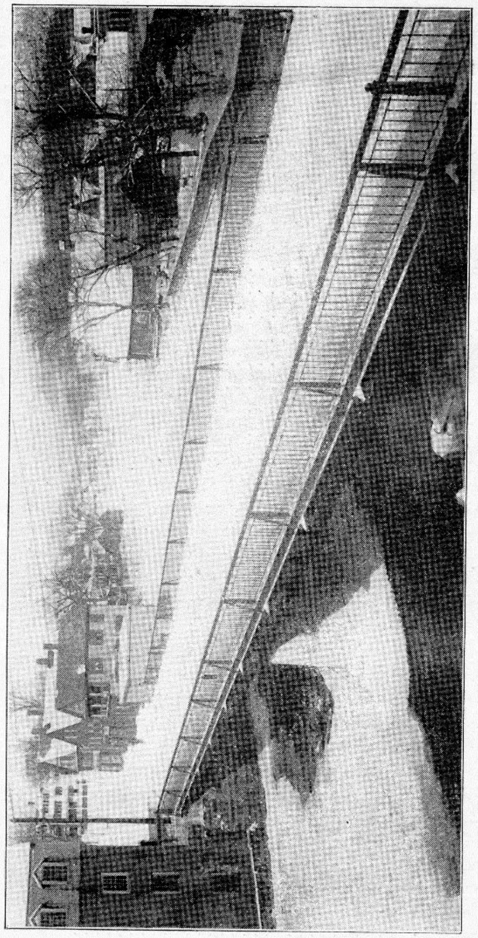
QUECHEE BRIDGE

This bridge is built over Quechee Gulf on the Woodstock railroad in Vermont. It was built under the supervision and direction of STORRS, BRIDGE ENGINEERS, replacing an old wooden Howe truss. The length of the arch is about 200 feet, and it is 165 feet from the base of the rail down to the bed of the brook.

WEIGHTS PER BUSHEL

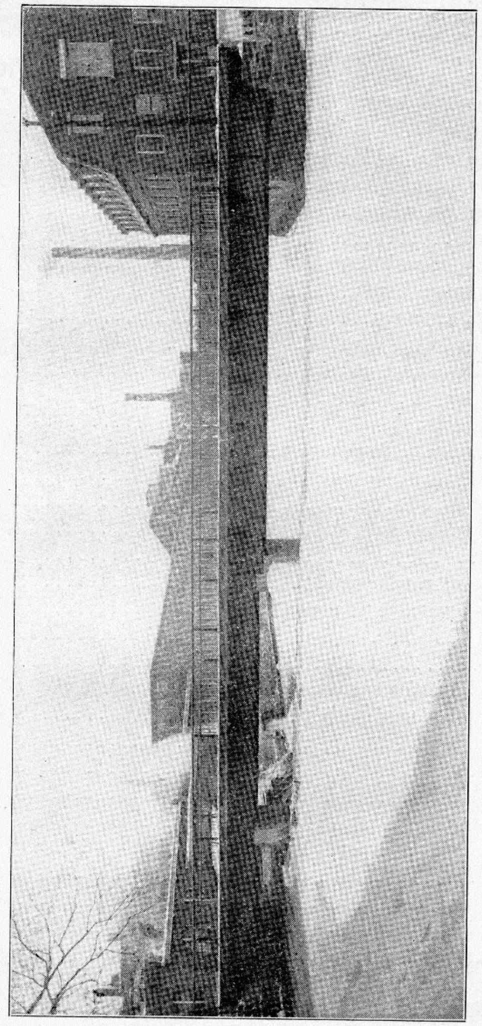
The following table gives the weight per bushel as prescribed by an Act of New Hampshire Legislature, 1917, Chapter 190, Section 11, establishing a standard of weights and measures:

Article	Lbs. per Bushel
Apples	48
Dried apples	25
Beets	60
Small white beans	60
Soy beans	58
Barley	48
Bran	20
Buckwheat	48
Indian corn	56
Corn meal	50
Cracked corn	50
Cranberries	32
Carrots	50
Clover seed	60
Flaxseed	56
Herds grass or timothy seed	45
Japanese barnyard millet	35
Lime	70
Oats	32
Onions	52
Pears	58
Peaches	48
Dried peaches	33
Dried peas	60
Parsnips	45
Irish potatoes	60
Sweet potatoes	54
Roasted peanuts	20
Green peanuts	22
Quinces	48
Rye	56
Rye meal	50
Coarse salt	70
Fine salt	50
Shorts	20
Tomatoes	56
Turnips	55
Wheat	60



BROAD STREET BRIDGE, CLAREMONT, N. H.

This cut illustrates a deck plate girder with a concrete slab floor and two reinforced concrete sidewalks. This bridge was designed by STORRS, BRIDGE ENGINEERS, and was built by the town of Claremont on Broad Street over Sugar River in 1915.



BROAD STREET BRIDGE, CLAREMONT, N. H.

(Showing side view of bridge)

WEIGHT OF A CUBIC FOOT OF SUBSTANCES

Name of Substance	Average Weight Lbs.
Anthracite, solid, of Pennsylvania	93
Anthracite, broken, loose	54
Ash, American, white, dry	38
Asphaltum	87
Brass (Copper and Zinc) cast	504
Brick, common, hard	125
Brickwork, ordinary	112
Cement, hydraulic, ground, loose, American Rosendale	56
Cement, hydraulic, ground, loose, Portland	94
Chestnut, dry	41
Coal, bituminous, solid	84
Coal, bituminous, broken, loose	49
Coke, loose, of good coal	26.3
Copper, cast	542
Earth, common loam, dry, loose	76
Elm, dry	35
Glass, common window	157
Gold, cast, pure, or 24 carat	1204
Grain, at 60 lbs. per bushel	48
Granite	170
Gravel, about the same as sand, which see.	
Gypsum (plaster of paris)	142
Hemlock, dry	25
Ice	58.7
Iron, cast	450
Iron, wrought, purest	485
Iron, wrought, average	480
Lead	711
Lignum vitæ, dry	83
Lime, quick, ground, loose, or in small lumps	53
Maple, dry	49
Oak, live, dry	59
Oak, white, dry	50
Oak, other kinds	32 to 45
Petroleum	55

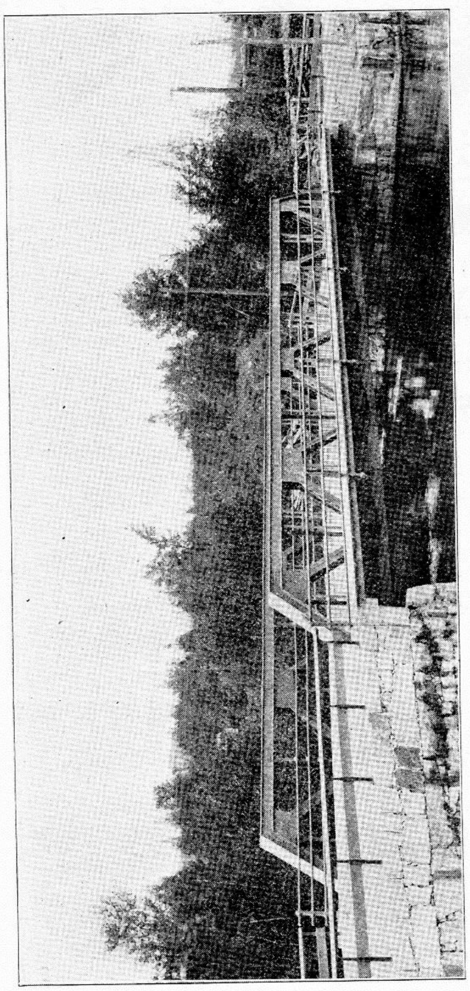
WEIGHT OF A CUBIC FOOT OF SUBSTANCES *(concluded)*

Name of Substance	Average Weight Lbs.
Pine, white, dry	25
Pine, yellow, Northern	34
Pine, yellow, Southern	45
Platinum	1342
Salt, coarse, Syracuse, N. Y.	45
Sand, of pure quartz, dry, loose	90 to 106
Silver	655
Slate	175
Snow, freshly fallen	5 to 12
Snow, moistened and compacted by rain	15 to 50
Spruce, dry	25
Steel	490
Sulphur	125
Tar	62
Tin, cast	459
Walnut, black, dry	38
Water, pure rain or distilled, at 60° Fahrenheit	$62\frac{1}{3}$
Water, sea	64
Wax, bees	60.5
Zinc, or Spelter	437.5

Green timbers usually weigh from one-fifth to one-half more than dry.

DECIMALS OF A FOOT EQUIVALENT IN INCHES

1 inch	.0833
2 inches	.1667
3 inches	.2500
4 inches	.3333
5 inches	.4167
6 inches	.5000
7 inches	.5833
8 inches	.6667
9 inches	.7500
10 inches	.8333
11 inches	.9167
12 inches	1.0000



BOROUGH BRIDGE, CONCORD (PENACOOK), N. H.

This is a pony truss bridge designed by STORRS, BRIDGE ENGINEERS, and built by the City of Concord in 1915, replacing an old covered lattice bridge about 95 feet long. This bridge is located over the canal at Holden's mill near Contoocook River Park. The new bridge was designed with a capacity for 12-ton trucks. It has an 18-foot roadway with concrete slab floor, and a 5-foot sidewalk outside the trusses.

Table 19

MEASURES

LINEAL MEASURE

12 inches = 1 foot.
3 feet = 1 yard.
5½ yards = 1 rod or 1 perch = 16½ feet.
40 rods = 1 furlong = 220 yards = 660 feet.
8 furlongs = 1 mile = 320 rods = 1,760 yards = 5,280 feet.

SQUARE MEASURE

144 square inches = 1 square foot.
9 square feet = 1 square yard.
30¼ square yards = 1 square rod.
40 square rods = 1 rood.
4 roods = 1 acre = 43,560 square feet.
A square acre is 208.71 feet on each side.
A circular acre is 235.504 feet in diameter.
A half acre is = to 147.581 feet on each side.
A quarter acre is = to 104.355 feet on each side.
100 square feet = 1 square.

CUBIC OR SOLID MEASURE

1,728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
A perch of stone = 24.75 cubic feet = 16′6″ x 1′6″ x 1′.
A cord of stone = 99 cubic feet = 4 perches.
A cord of wood = 128 cubic feet = 4′ x 4′ x 8′.
A ton of bituminous coal = 44 to 48 cubic feet.
A ton of anthracite coal = 41 to 43 cubic feet.
1 gallon water = 231 cubic inches.
1 cubic foot = 7.48 gallons.

LIQUID MEASURE

4 gills = 1 pint = 28.875 cubic inches.
2 pints = 1 quart = 57.750 cubic inches.
4 quarts = 1 gallon = 231.0 cubic inches.

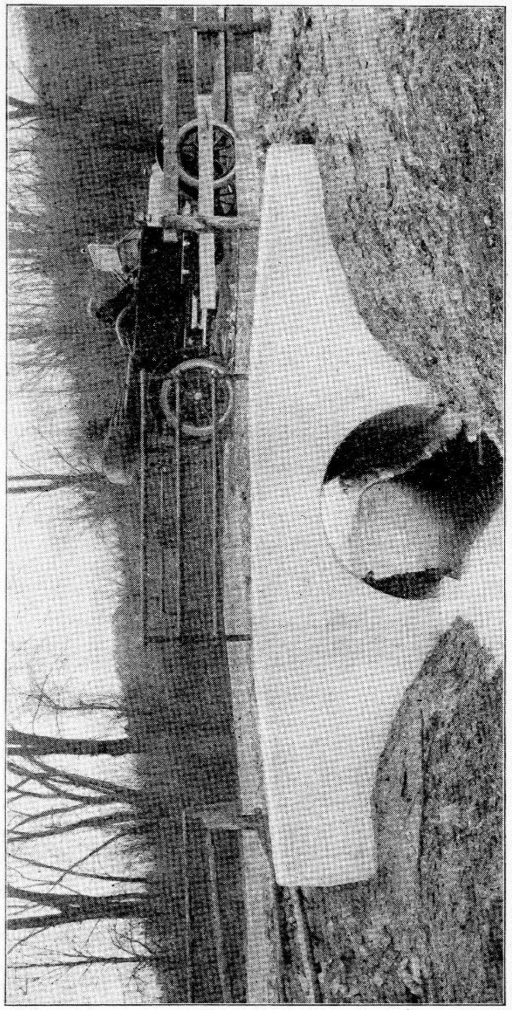
A cylinder 3½ inches in diameter and 6 inches high will hold almost exactly 1 quart, and one 7 inches in diameter and 6 inches high will hold very nearly one gallon.

A gallon of water weighs 8.338 pounds avoirdupois.

DRY MEASURE

2 pints = 1 quart = 1.16365 liquid quarts.
4 quarts = 1 gallon = 268.8025 cubic inches.
2 gallons = 1 peck = 537.6050 cubic inches.
4 pecks = 1 struck bushel = 2150.42 cubic inches.

A struck bushel = 1.24445 cubic feet.
A cubic foot = .80356 of a struck bushel.
A flour barrel contains 3 struck bushels.
A heaped bushel = 1¼ "struck" bushels = 1.555 cubic feet.
When heaped the cone must be at least 6 inches high. The bushel measure is a cylindrical vessel 18½ inches in diameter and 8 inches deep.



BRIDGE "C," BOW BROOK, BOW, N. H.

This is an illustration of a concrete pipe culvert which carries Bow Brook, and is located in the town of Bow, New Hampshire. It was built in 1911, and was designed by STORRS, BRIDGE ENGINEERS.

Table 19 *(concluded)*

MISCELLANEOUS MEASURES

12 units	= 1 dozen.
12 dozen	= 1 gross.
12 gross	= 1 great gross.
20 units	= 1 score.
24 sheets of paper	= 1 quire.
20 quires	= 1 ream.
2 reams	= 1 bundle
5 bundles	= 1 bale.
25 lbs. powder	= 1 keg.
14 lbs.	= 1 stone.
100 lbs.	= 1 quintal.
1 chaldron	= 36 bushels or 57.244 cubic feet.
1 ton displacement in salt water	= 35 cubic feet.
1 fathom	= 6 feet.
1 cable length	= 120 fathoms.

YOUR RECORD

What have you done—or *left undone*—to make public Bridges *safe* during the past year? Have you voted consistently for "Safety Always," or have you been content to let things drift? Are the Bridges under your control, or official charge, *safer* than they were a year ago, or even as *safe?* Do you *know?*

Table 20

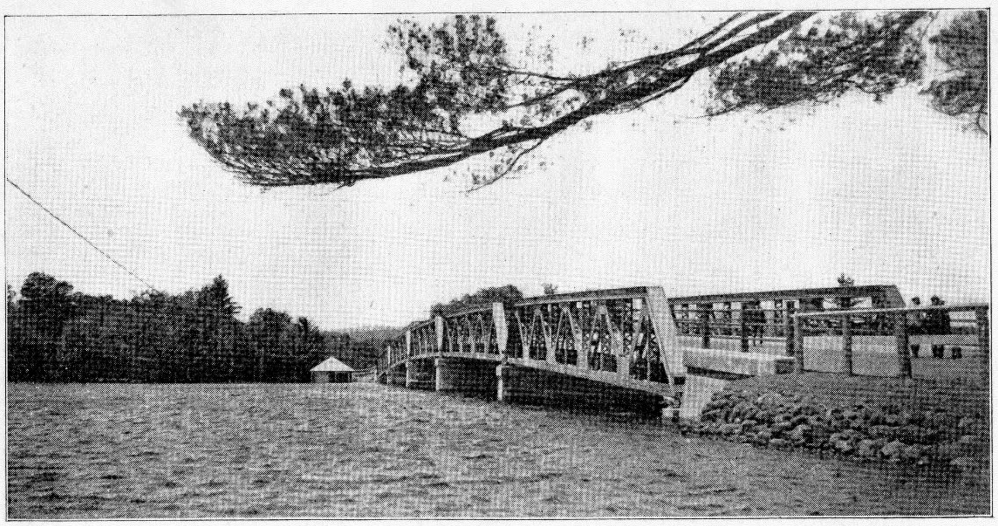
WOOD PIPE WEIGHTS

(Approximate weight per lineal foot of Michigan pipe)

Size Inside Diameter	Pine			
	Pressure per square inch			
	40 Lbs.	80 Lbs.	120 Lbs.	180 Lbs.
6-inch	10.5	11.5	11.75	12.5
8-inch	13.7	14.6	14.9	16.2
10-inch	16.8	18.6	19.3	20.4
12-inch	19.9	20.8	21.9	25.2
14-inch	23.1	25.5	26.7	29.9
16-inch	26.7	28.6	32.1	34.9
18-inch	29.8	31.7	35.5	41.3
20-inch	33.4	36.5	40.6	45.27
24-inch	40.9	45.6	55.	65.
30-inch	75	82	....	....
36-inch	90	100	....	....
48-inch	145	160	....	....

PEMBROKE BRIDGE, CONCORD, N. H.

This cut illustrates a steel bridge designed by Storrs, Bridge Engineers. It was built by the City of Concord, replacing an old wood lattice bridge which was built since 1891, and which took the place of a bridge that was carried away by the freshet during that year. The original bridge was a toll bridge, one of several toll bridges which crossed the Merrimack River in the city of Concord. The picture represents a view taken at the end of the bridge, which consists of four spans, the two central spans being high trusses, and the end spans pony trusses. The bridge carries a concrete roadway of 18 feet in the clear, and a sidewalk. It is built with a capacity for carrying 12-ton trucks.



WINNISQUAM BRIDGE

This bridge is built over Lake Winnisquam, near Winnisquam station, and connects the towns of Tilton and Belmont, New Hampshire. It is located on the Merrimack Valley trunk line and was built jointly by the adjoining towns and the State of New Hampshire. It consists of five spans of about 95 feet each, and carries a reinforced concrete roadway, and has a capacity for 12-ton trucks. The masonry is of concrete, and the piers are built in 26 feet of water on a pile foundation. This structure was designed by Storrs, Bridge Engineers, of Concord, New Hampshire, and was built under the direction of Mr. F. E. Everett, State Highway Commissioner, during the year 1916.

INDEX

MEMORANDUM