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THE PROTECTION OF THE FORESHORE AT DALLAS ROAD, VICTORIA, B.C.

By G. M. Duncan, Junior Can. Soc. C.E.

TO BE READ BEFORE THE MONTHLY MEETING, NOVEMBER 7TH, 1912.

For several years the sea had been encroaching upon a part of this roadway, which runs along the coast overlooking the Strait of Fuca, with the consequence that the banks were gradually being eroded. In 1903 the City Authorities commenced to build a low concrete wall to form some protection, and they continued building it in sections until it was about 1,500 feet in length in 1906. This wall, which had a height of 6 feet above high water, a section of which is shown in Fig. 1, Plate I did not, however, prove of much service against the heavy seas which are prevalent during certain parts of the year. In 1910 the roadway was getting into a serious condition and the City Authorities saw they would have to take immediate steps to form some permanent protection. A by-law was passed authorizing the expenditure of $75,000 which was augmented by the sum of $20,000 from the Provincial Government for the purpose of erecting more suitable protection works. The City Authorities were in favour, and had the intention of building on top of the old wall, a proposal of which the Public Works Engineer did not approve on account of the unstable condition of the foundations and general state of the wall.

After close investigation into the local conditions and a careful study of the various types of walls elsewhere constructed with similar objects, the conclusion was arrived at that protection could be most effectively and economically attained by a vertical wall carried down into solid ground below low water mark, except at its termination where it was anticipated the depth might be materially reduced. Trial sections of a solid and of a reinforced concrete wall were made and it was found that the cost of the former would considerably exceed that of the latter.

A comparison was then made between walls with counterforts 16 feet and 20 feet apart, respectively, and the balance in favour of economy proved to be for the latter. It was therefore decided that the wall should be vertical, carried up to the level of the roadway, of a reinforced concrete type without a base plate, with counterforts at 20 feet centres, and with a belt of granite in its face where the wash of the sea was greatest.

The calculations for the strains and areas of steel and concrete were then commenced and the following assumptions made:—

That all steel used would have an elastic limit of 32,000 lbs per square inch.

That all rods should have a working stress of 12,000 lbs. per square inch and be capable of being cold bent, 180° flat on themselves.

These assumptions were subsequently required by specification.

Plate No. II gives the results of the calculations. The diagram on the left is for calculating the Earth Pressure or P. for earth horizontal with top of wall and is in accordance with Trantwine's formula, in which

$$P = \frac{\text{weight of a single cubic foot of backing} \times t^2}{2}$$

$$= \frac{100 \times t^2}{2} = 50t^2$$

and the figures thus obtained are those in Col. 1.

COLUMN 2. The figures are found simply by subtracting the loads in the previous column, one from the other.

COLUMN 3. Figures in Col. 2 multiplied by 20. 20 feet is the distance from centre to centre of counterforts.

COLUMN 4. Let W. equal total load uniformly distributed in lbs.
Let S. equal clear span of strip in inches.

Then Moment. in inch lbs. $= \frac{WS}{8}$

COLUMNS 5 AND 6.

Notation:—

h equals Height of Strip.
T " Theoretical thickness of wall to centre of gravity of steel.
p " Ratio of cross-section of steel to cross-section of wall to centre of gravity of steel.
K " Constant for a given steel and a given concrete.
C " Pressure per square inch in outside fibre of concrete in compression.
S " Tension per square inch in steel reinforcement.

r equals $\frac{E.s}{E.c}$ = Ratio of moduli of elasticity of steel to concrete.

M " Bending moment in inch lbs.

F " Factor of safety.

Assumptions

h equals 12 inches.

F " 4

C " 2,500 lbs. per square inch.

S " 56,000 " " " "

r " 10.

Formulae

$$(1)\ K=\frac{C}{2F}\left[\frac{1}{1+\frac{S}{Cr}}\right]\left[1-\frac{1}{3\left(1+\frac{S}{Cr}\right)}\right]$$

$$(2)\ p=\frac{1}{2\left(\frac{S}{C}\right)\left(1+\frac{S}{Cr}\right)}$$

$$(3)\ M=KhT^2$$

Solving equation (1) for K we have

$$K=\frac{2,500}{8}\left[\frac{1}{1+\frac{56,000}{25,000}}\right]\cdot\left[1-\frac{1}{3\left(1+\frac{56,000}{25,000}\right)}\right]$$

K=86.57

Substituting these values in formula 3($M=KhT^2$) we have

$$T=\sqrt{\frac{M}{K\times 12}}\ .$$

Solving formula 2, we have

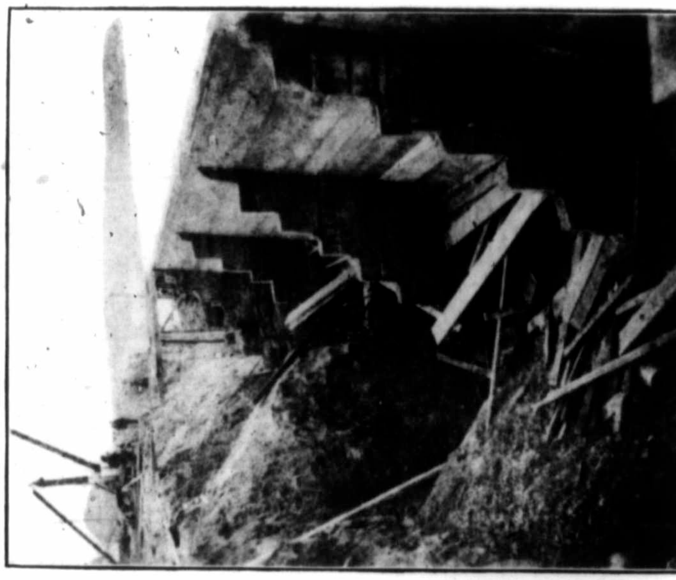
p=.007

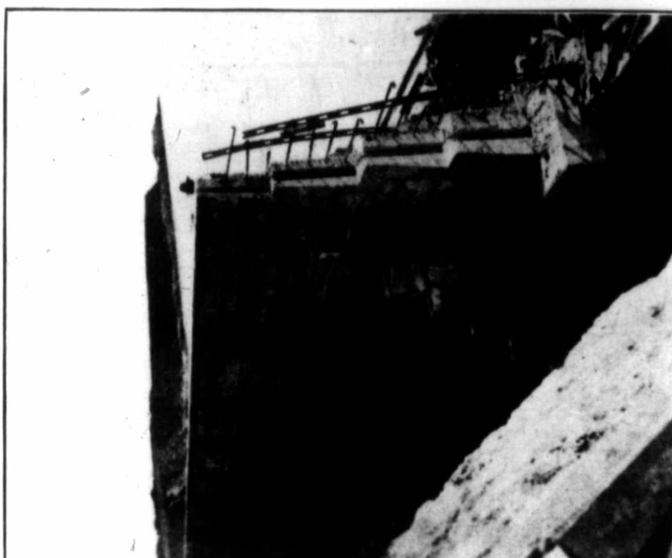
According to formula 1, the theoretical batter for the back of the wall is 1 in 19, but a batter of 1 in 12 was adopted.

Column 7. Diameter of rods to correspond with areas in Col. 6.

Column 8. Similar to Col. 3.

Column 9. Area of steel=Tensile Strain in lbs. divided by working stress of steel per square inch (12,000).



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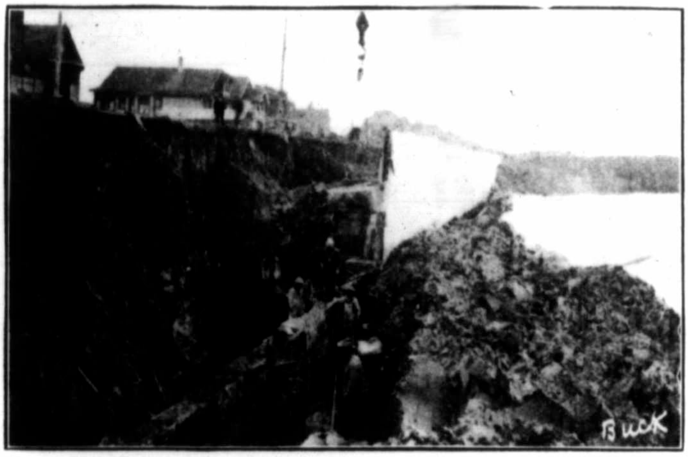
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COLUMN 10. Diamater of rods to correspond with areas in Col. 9.

COLUMN 11. Depends on the slope given to counterforts.
In this case the slope is .6 of the height.

COLUMN 12. Calculated from Col. 3 thus:—
Overturning Pressure for a depth of 2 feet from top of wall equals 286.40 + 858.60 = 1,145 lbs.

COLUMN 13. Overturning pressure per panel in lbs. (Col. 12) multiplied by ⅓ height.

COLUMN 14. These stock sizes were adopted as being of ample strength and suitable for the purpose, as shown by the formula as follows:—

$$\text{Area of steel} = \frac{Mo}{L} \div 15{,}000$$

where Mo equals overturning moment in ft. lbs. (Col. 13)
L " length of tie rod.
15,000 " working stress in steel per square inch.

Figures 2 and 3, Plate I, are typical sections of the wall and counterforts. The reinforcement is shown in Plate No. III and in the wall consists of horizontal rods 1 foot apart commencing with ¾-inch diameter at 2 feet from top of wall and increasing in diameter with the depth of wall. These rods are link jointed and are kept in place between each counterfort by two face plates each ⅜ in. × 4 in. at 6 feet 8 inch centres. To the horizontal rods is wired expanded metal and No. 16, 1-inch mesh was at first used for this purpose but No. 10, 3-inch mesh was afterwards substituted on account of the former being found to be too light and the mesh too small.

The counterforts are reinforced in the same manner as the wall with horizontal tie rods hooked into face and back plates. It should be pointed out here that these tie rods and also the horizontal rods in the wall are subject to shearing stress at their connections with the face and back plates of the former and at the link joints of the latter, a point which is very easily overlooked. The back plates consist of 6-inch plates, ¼-inch and ½-inch riveted together.

At each counterfort the horizontal rods in the wall were at first placed between the face plate and the hooks of tie rods, but it was afterwards found that a more secure method was to place them at back of face plate and resting on tie rods of counterfort to which they were securely wired, and this method was adopted throughout the rest of the work. The bottom of all face plates are split and spread, and at the counterforts the face and back plates are held together by ⅝-inch bolts. The footings of the counterforts are reinforced with ¾-inch diameter rods at 4½-inch centres which are carried about 2 feet into wall and rods of same diameter at 7-inch centres and 7 feet long are placed between the bottom tie rods so as to thoroughly anchor the counterfort to footing.

To protect the wall from the wash of the sea and battering by drift logs, a belt of granite has been placed in the face of the wall as shown. Holes were drilled through the granite and ¾-inch diameter rods placed therein set with neat cement, thereby double clamping each stone. In the event of the cement mortar between the courses showing signs of disintegration the joints are to be raked out and caulked with lead wool. The lower part of the wall up to the shoulder, excluding the granite, is in the proportion of 1 : 3 : 6 concrete and all other concrete is in the proportion of 1 : 2 : 4. All concrete was of a "wet" mixture and the cement used was Portland. The exposed face of the concrete is of cement mortar in the proportion of 1 part Portland cement to 3 parts sand deposited at the same time as the concrete, and lifting plates were at first used to ensure the bond, but spading was afterwards adopted as being found more satisfactory.

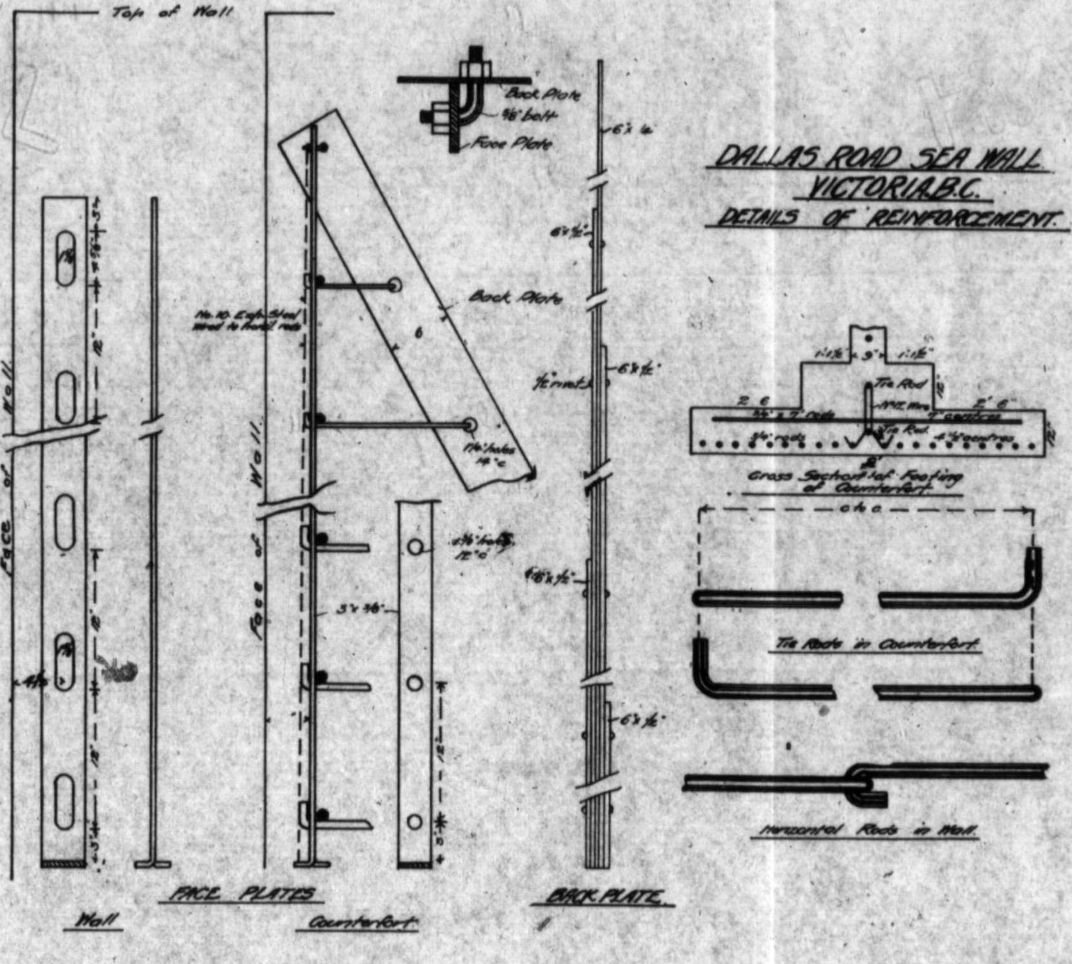
At the back of the wall a layer about 1 foot thick of broken rock is placed for facilitating drainage and a weeping drain of 3-inch drain tile placed in wall between each counterfort. The length of the wall is 1,680 feet, the greater part of which has an average height of 30 feet. It is finished on top with an iron pipe railing supported by reinforced concrete posts at 10 feet centres.

The work was done by contract and the total cost amounted to $119,020, divided up as follows:—Wall, $112,130; Convenience and steps to beach, $3,810; Railing, $3,080.

Work was commenced in January 1911 and completed in February 1912, but a great deal of delay occurred and time was wasted through disputes.

The plans were prepared in the Public Works Department by the author, acting under the instructions of Mr. Edward Mohun, M. Can. Soc. C.E., etc., who designed the work. Mr. A. E. Foreman, A. M. Can. Soc. C.E. was supervising Engineer and the Contractor was the Pacific Coast Construction Co., Ltd., Victoria.

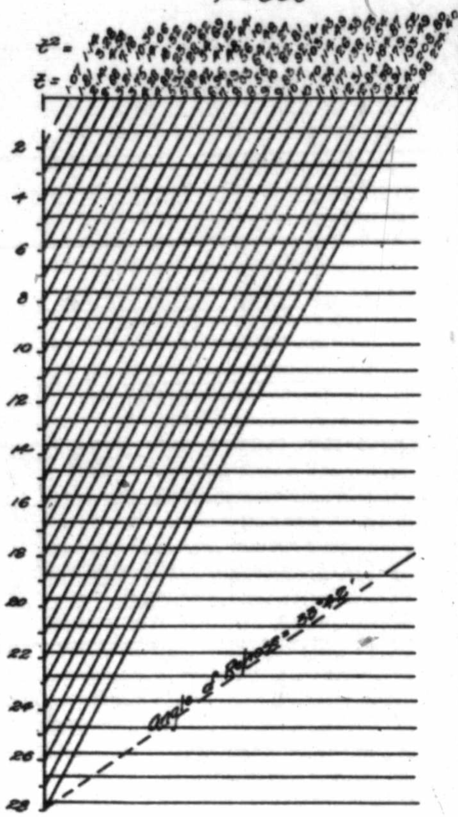
Plate III


DALLAS ROAD SEA WALL
VICTORIA B.C.
DETAILS OF REINFORCEMENT
Top of Wall
Face of Wall
Back Plate
Face Plate
Tie Rod
Cross Section of Footing of Counterfort
Tie Rods in Counterfort
Horizontal Rods in Wall
FACE PLATES
Wall
Counterfort
BACK PLATE

Face of Wall

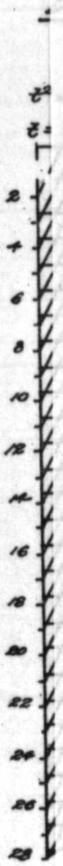
Dallas Road Sea Wall Victoria B.C. Calculations for the Strains and Areas of Steel and Concrete

$P = 50t^2$



Depth from top of wall	Load on Vertical Strip 1 ft wide	Load on 1 sq. ft	Load on horizontal Strip 1 ft high 20 ft wide	Bending Moment	Thickness of wall to c of g of steel	Area of Steel	Dia of Rods in wall	Tie Rods 12000 lbs per sq. in: Tensile Strain	Tie Rods: Area of Steel	Tie Rods: Dia of Rods	Tie Rods: Length c to c	Anchoring Press per panel	Back Plate 12000 lbs per sq in: Moment on Anchorg	Back Plate: Size of Plate
Feet	lbs.	lbs	lbs.	inch lbs	ins.	sq. ins	ins.	lbs.	sq. ins.	ins.	feet	lbs.	ft. lbs.	ins
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	14.32	14.32	286.40									286	95	1 piece 6" x 1/2"
2	57.25	42.93	858.60	25758	4.38	.418	3/4	859	.0716	5/16	.66	1145	760	
3	128.80	71.55	1431.00	42930	6.43	.540	7/8	1431	.1192	7/16	1.27	2576	2576	
4	228.98	100.18	2003.60	60108	7.61	.639	15/16	2004	.1674	1/2	1.88	4580	6106	
5	357.78	128.80	2576.00	77280	8.62	.724	1	2576	.2147	9/16	2.49	7156	11926	
6	515.21	157.43	3148.60	94458	9.54	.801	1 1/16	3149	.2624	5/8	3.10	10304	20608	1 piece 6" x 1/4"
7	701.63	186.42	3728.40	111852	10.38	.872	1 1/16	3729	.3108	11/16	3.70	14033	32379	1 piece 6" x 1/2"
8	915.92	214.29	4285.80	128574	11.13	.934	1 1/8	4286	.3572	11/16	4.30	18318	48849	
9	1161.67	245.75	4915.00	147450	11.92	1.000	1 1/8	4915	.4096	3/4	4.91	23233	69700	
10	1431.18	269.46	5389.20	161675	12.48	1.048	1 3/16	5389	.4481	3/4	5.51	28623	95408	
11	1734.61	303.48	6069.60	182088	13.24	1.112	1 3/16	6070	.5177	13/16	6.12	34692	127205	
12	2060.82	326.21	6524.20	195726	13.73	1.153	1 1/4	6525	.5438	7/8	6.73	41216	164866	1 piece 6" x 1/2"
13	2422.08	361.26	7225.20	216756	14.45	1.213	1 1/4	7227	.6163	7/8	7.33	48442	209914	2 pieces 6" x 1/2"
14	2805.01	382.93	7658.60	229758	14.87	1.249	1 5/16	7659	.6383	15/16	7.93	56100	261801	
15	3224.05	419.04	8380.80	251424	15.56	1.308	1 5/16	8381	.6984	15/16	8.53	64481	322405	1 piece 6" x 1/4"
16	3663.68	439.63	8792.60	263778	15.94	1.339	1 5/16	8793	.7328	1	9.14	73274	390793	3 pieces 6" x 1/2"
17	4140.50	476.82	9336.40	286092	16.60	1.394	1 3/8	9537	.7948	1	9.74	82810	469257	
18	4636.85	496.36	9927.00	297810	16.93	1.422	1 3/8	9927	.8273	1 1/16	10.35	92737	556422	1 piece 6" x 1/2"
19	5171.45	534.60	10692.00	320760	17.57	1.476	1 3/8	10692	.8910	1 1/16	10.95	103429	655056	4 pieces 6" x 1/2"
20	5724.50	553.05	11061.00	331830	17.87	1.501	1 7/16	11061	.9218	1 1/8	11.56	114490	763267	
21	6316.88	592.38	11847.60	355428	18.50	1.554	1 7/16	11848	.9874	1 1/8	12.15	126338	884363	
22	6926.65	609.77	12195.40	365862	18.77	1.577	1 7/16	12196	1.0164	1 3/16	12.76	138533	1015909	
23	7576.81	650.16	13003.20	390096	19.38	1.628	1 7/16	13004	1.0837	1 3/16	13.36	151536	1161776	
24	8243.28	666.47	13329.40	399882	19.62	1.648	1 1/2	13330	1.1109	1 3/16	13.96	164866	1318925	
25	8951.22	707.94	14158.80	424764	20.22	1.699	1 1/2	14159	1.1800	1 1/4	14.57	179024	1491870	
26	9674.41	723.13	14463.80	433914	20.44	1.717	1 1/2	14464	1.2054	1 1/4	15.17	193488	1676898	
27	10410.13	785.72	14714.40	441432	20.62	1.732	1 1/2	14715	1.2268	1 1/4	15.77	208203	1873828	
28	11220.02	809.89	16197.80	485934	21.62	1.817	1 9/16	16198	1.3499	1 5/16	16.37	224400	2039404	

11220.02	224400.40	6732012
20	30	
224400.40	6732012.00	



2
4
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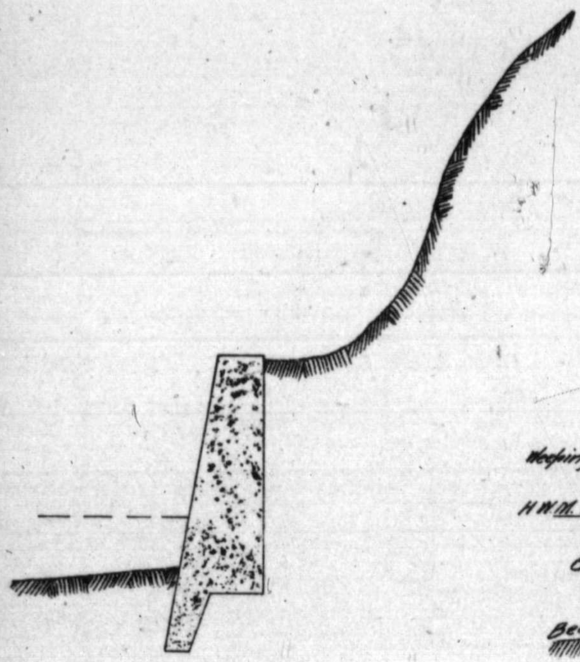
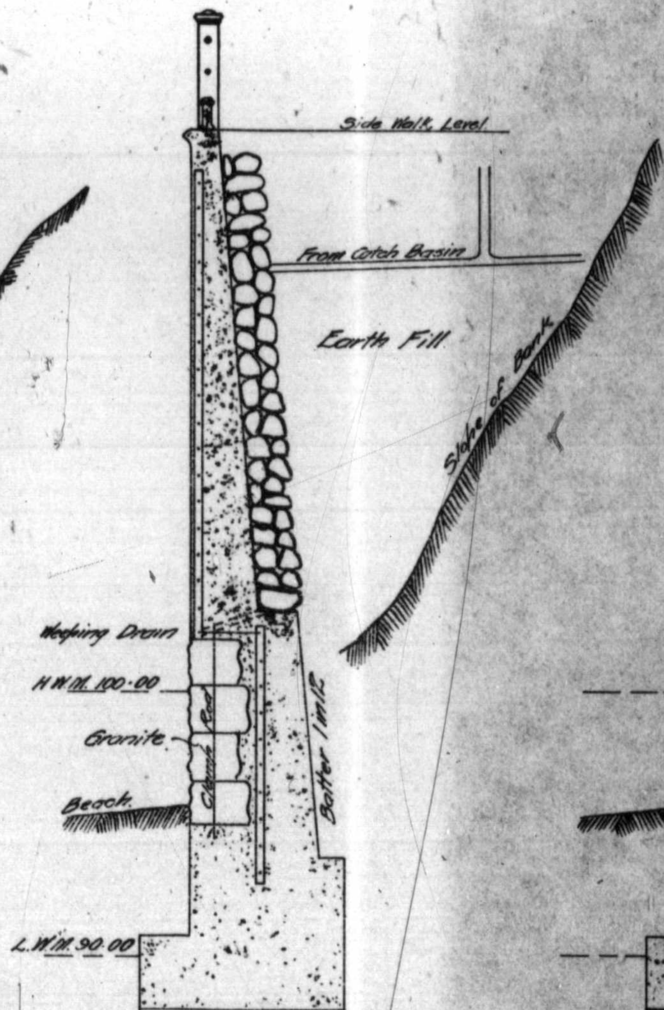
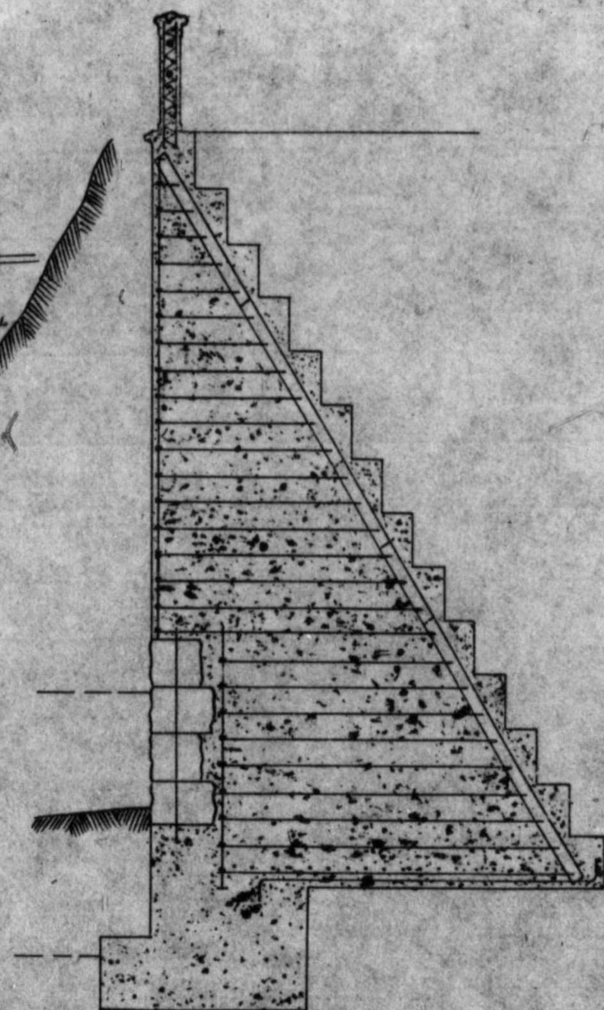
DALLAS ROAD SEA WALL.
VICTORIA. B.C.



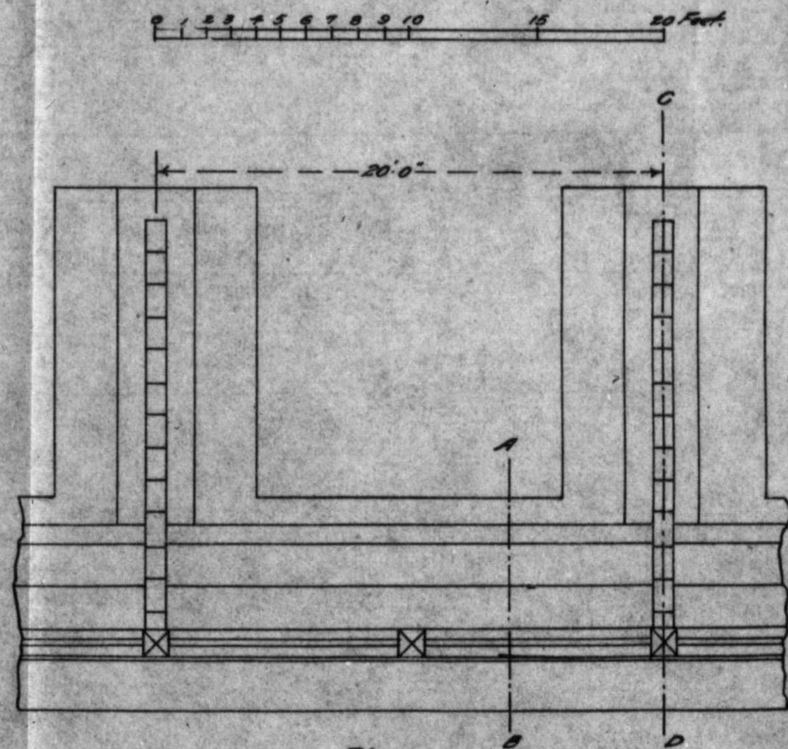
Section of Old Wall.
Fig. 1.



Section AB.
Fig. 2.



Section CD
Fig. 3.



Plan.