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## ABSTRACT

The construction and installation of a Goodyear-type floating tire breakwater at La Salle Marina, Burlington, Ontario is documented. A total breakwater length of about 490 m made from 35,000 tires was installed, making it one of the world's largest Goodyear FTB installations. All work was done by a construction firm using professional labour. Topics discussed include the selection and acquisition of construction materials, the choice of construction site, assembly techniques, mooring the breakwater, problems encountered, and costs.

## RÉSUMÉ

Le document traite de la construction et de l'intallation d'un brise-lames de pneus flottants du genre Goodyear au port de plaisance La Salle de Burlington, en Ontario. À l'aide de 35 000 pneus, on a monté un brise-lames d'une longueur totale d'environ 490 m, ce qui en fait l'une des plus grandes installations de brise-lames à pneus flottants de Goodyear. Tous les travaux ont été exécutés par une entreprise de construction qui s'est servi d'une main-d'oeuvre professionnelle. On a discuté, entre autres, des thèmes suivants: sélection et acquisition de matériaux de construction, choix du lieu de construction, techniques d'assemblage, amarrage du brise-lames, difficultés éprouvées et prix de revient.

## INTRODUCTION

The City of Burlington, Ontario is situated on the shores of Lake Ontario and Hamilton Harbour (Figure 1) and has a population of over 110,000. Surprisingly, prior to 1981, there were no marinas in the city. Most local sailors and boaters used the nearby marina facilities in Hamilton and Oakville or else used offshore mooring cans at La Salle Park (Figure 1).

In 1979, a group of citizens formed a committee to investigate the possibility of constructing a marina to berth approximately 300 boats at La Salle Park. The cost of a conventional bottom-resting breakwater to protect such a marina at La Salle Park in water depths of about 10 m would be prohibitively expensive. Accordingly, the Committee soon turned to floating breakwaters as a possible solution. The floating tire breakwater (FTB), in particular, looked promising and a conceptual design report (Bishop, 1979) confirmed its applicability at the La Salle site.

FTB technology is relatively new and there are very few well-documented case studies. The proximity of the La Salle Marina to the National Water Research Institute (NWRI), which is located at the Canada Centre for Inland Waters (CCIW) shown in Figure 1, offers an excellent opportunity to monitor the performance of an FTB. Therefore, as the first in a series of reports to document the La Salle FTB, this paper describes the construction and installation of the breakwater. A monitoring program which will include the measurement of incident and transmitted waves, and mooring forces for the 60 x 9 module FTB section facing the southwest is scheduled to begin in the fall of 1981.

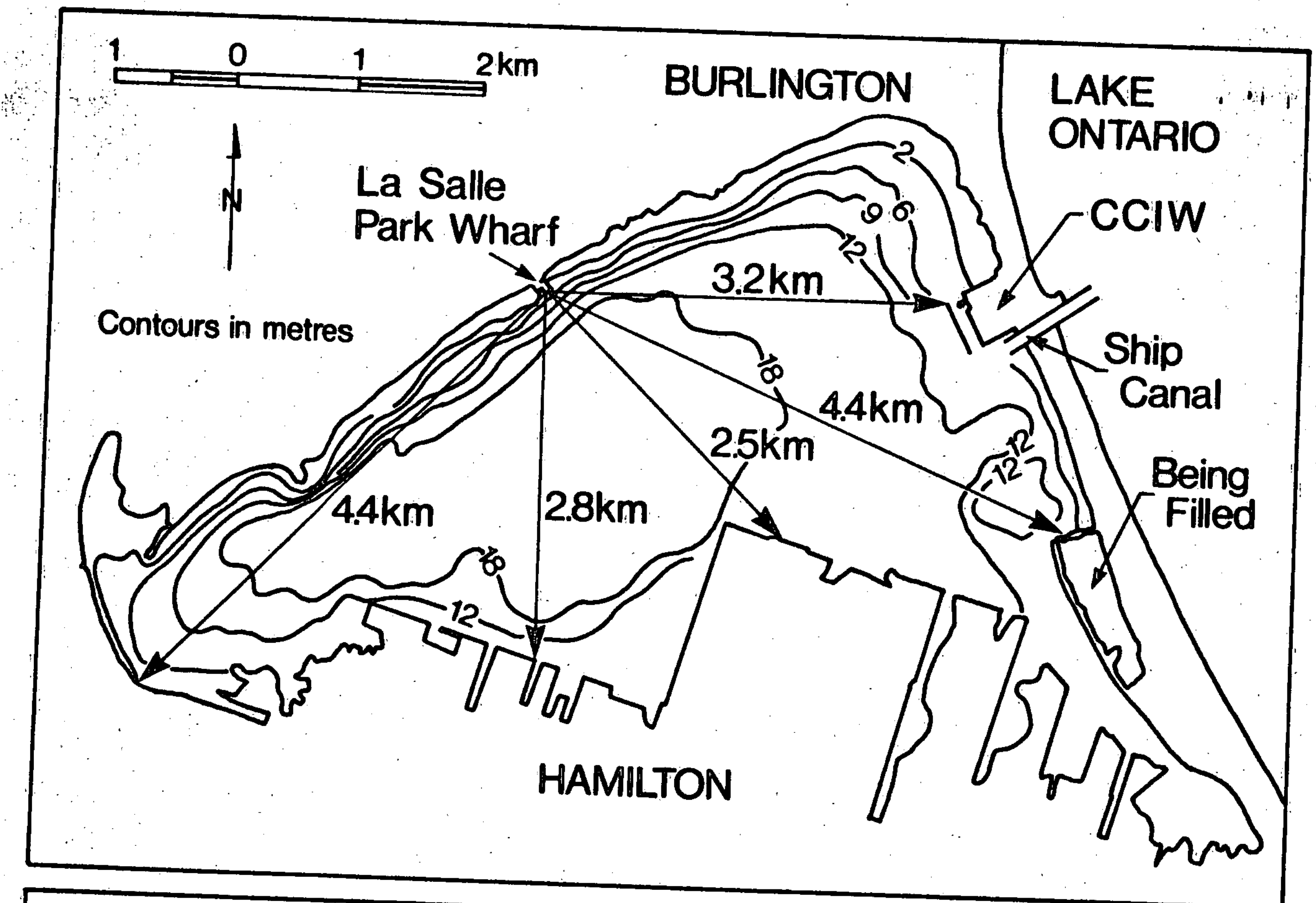
## BREAKWATER DESIGN

Bermingham Construction Limited was awarded the design-build contract for the La Salle FTB. The breakwater design was subcontracted to marine engineering specialists. The resulting design is shown in Figure 2.

It is not the purpose of this paper to discuss the design details. Nevertheless, some design-related information is provided as follows:

- The bathymetry of the harbour and the distribution of fetchs to the La Salle Park Wharf are shown in Figure 1.
- The maximum hourly wind speed recorded at Hamilton Airport in 20 years was 25 m/s, once from the south-southwest and once from the west.
- The nine-module wide FTB sections were sized to reduce a 3 s wave with a characteristic height* of 64 cm to a characteristic wave height of no more than 30 cm.
- The windward anchors of the nine-module wide sections were sized to accommodate the forces exerted by a 4 s wave with a characteristic height of 1.2 m.
- The scope of the mooring lines was set at 3 rather than at a more conventional value of 6 or more.

* The characteristic wave height is defined as four times the square root of the area under the wave energy spectral density curve, and can be considered equivalent to the significant wave height.



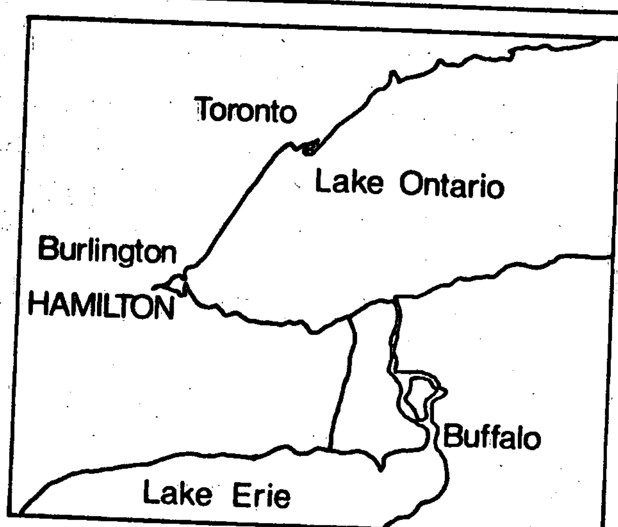




Figure 1 Hamilton Harbour

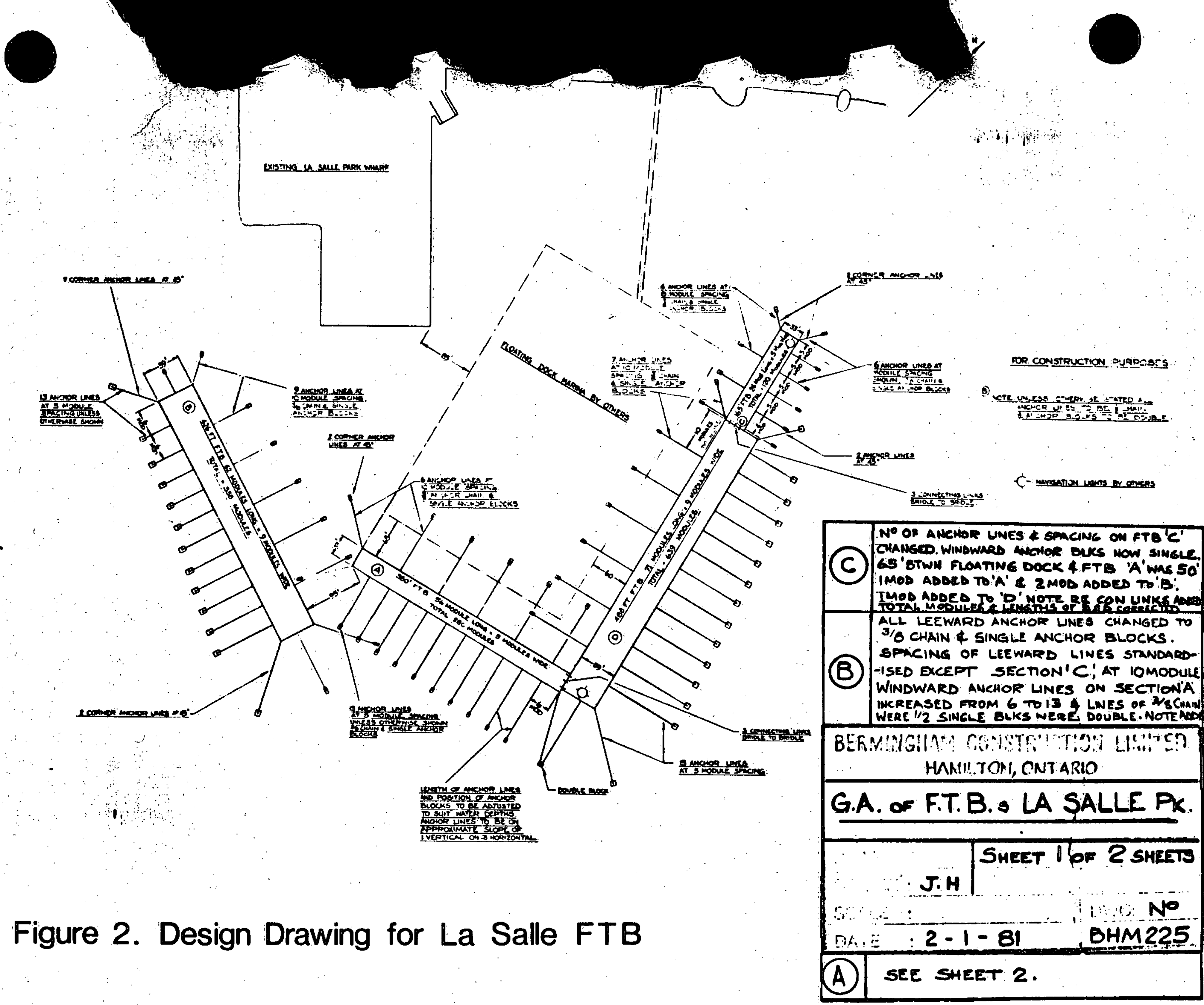



Figure 2. Design Drawing for La Salle FTB

- For winter storage the FTB sections will be towed into slips used for Great Lakes bulk carriers. The floating docks will be taken out of the water for the winter.

## SELECTION AND ACQUISITION OF CONSTRUCTION MATERIALS

### Tires

Tires are the primary construction material. Most Goodyear FTB's have been built using scrap car tires but a few have used truck tires (e.g. Irish Boat Shop, Lake Charlevoix, Michigan; Port Edgar, Scotland). Car tires were considered suitable for use at the La Salle Marina.

Local tire salvage businesses agreed to provide the needed tires at $0.10/tire F.O.B. the Bermingham yard. This cost estimate was based on direct shipment from their suppliers (garages, tire retail outlets, etc.). However, the required number of tires exceeded the local supply over the time allotted for tire acquisition. Consequently, the contractor had to hire a tractor-trailer and labourers to go to the tire salvage yard, sort and pick up tires, and deliver them to the Bermingham yard. The cost of acquiring tires in this manner was about $0.35/tire.

Tires with ripped casings or holes in the tread should be rejected. New reject tires from a local tire manufacturer could not be used because the company slits the casings of all the rejects. Our experience indicates that roughly 10 percent of an unsorted scrap tire shipment will be unsuitable for constructing an FTB.

### Binding Material

Conveyor belting is now recognized as the most suitable binding material for FTB's (Davis, 1977; Bishop, 1980; Penny, 1981). A local conveyor belt manufacturer agreed to cut reject belting into strips, put it on rolls (Figure 3), and deliver it to the Bermingham yard at a cost of $0.55 to $1.10/kg. The belting varied in width from 6.4 to 10 cm, in thickness from 0.95 to 1.3 cm, and in quality from 2 to 5 layers of nylon ply. Conveyor belt <u>edging</u> is not recommended for use as a binding material because the nylon plies do not extend completely across the material.

Our experience indicates that a liberal waste factor of about 25 percent should be allowed when ordering reject belting.

### Supplemental Flotation

The need for supplemental flotation in a Goodyear FTB is well documented (Bishop, 1980; Penny, 1981). Sprayed in place urethane foam appears to be one of the most cost effective means of providing supplemental flotation (Penny, 1981). A subcontractor agreed to spray 225 g of 32 kg/m$^3$ density urethane foam in the crown of each tire at a cost of $1.00/tire.

### Mooring Lines

Steel chain is the most common type of mooring line used to attach FTB's to their anchors. Conveyor belting has been recommended (Bishop, 1980) for use in mooring lines and has been used at several FTB sites (Baird and Ross, 1981). Ungalvanized steel chain was selected for use at the La Salle Marina. It was obtained for $4.62/m - 1/2 inch (13 mm) chain, and $2.79/m - 3/8 inch (9.5 mm) chain F.O.B. the Bermingham yard.

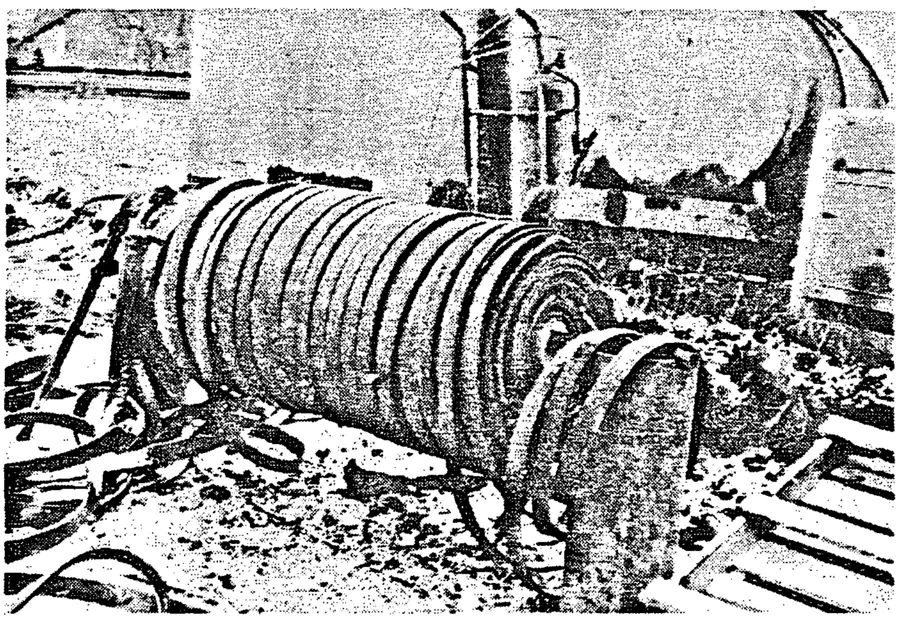


Figure 3. Strips of reject conveyor belting as shipped by supplier.

## Connectors

Steel connectors are commonly used in freshwater FTB installations, while nylon connectors have been recommended (Davis, 1977) for use in salt water. At La Salle, each bolted connection consists of a galvanized steel bolt (50 mm long x 12.5 mm diameter), two flat washers, one lock washer, and a nut. The cost was approximately $0.25/connector.

## Anchors

Gravity anchors are commonly used to moor FTB's. Scrap concrete was available from local concrete businesses for $10 per 3-1/2 tonne block. Handling and transportation of these blocks added another $20 to the cost of each block.

Each block had a piece of 16 mm (5/8 inch) diameter wire cable embedded in the top for lifting purposes. The mooring lines were attached directly to these cables for single-block anchors, or to other connecting pieces of the same sized cable for double-block anchors. In addition, two 19 mm diameter x 25 cm long anchor bolts were installed in the top of each block as a safety precaution for possible future anchor line attachments.

# CHOICE OF CONSTRUCTION SITE

Local authorities did not want the FTB construction to take place at La Salle Park. The contractor considered building the FTB on the winter ice cover of Hamilton Harbour because this method of construction had been used successfully elsewhere (Irish Boat Shop, Lake Charlevoix, Michigan; Dock and Coal Marina, Lake Champlain, New York). However, the construction contract was not awarded until the end of January, at which point the contractor felt there was insufficient time to build the FTB before the ice became too weak to work on.

The contractor arranged with the Hamilton Harbour Commissioners to build the FTB in a diked landfill site in the southeastern part of the harbour (Figure 1). This site provided protection from waves and had a suitable land construction area which sloped toward the water. The contractor agreed to breach the dike in order to tow the assembled FTB sections across the harbour to the La Salle Marina and to close the dike upon completion.

# ASSEMBLY

## Tire Preparation

Structurally sound tires of the 14 inch (35.6 cm) or 15 inch (38.1 cm) size (inside diameter) were selected from the load of scrap tires. Although the tires of some FTB's have had holes punched in them to help minimize the accumulation of sediment, this was not done at La Salle because the sediment load is expected to be negligible.

The spray foam operation required that the tires be free of ice or water, although the tires could still be wet. Therefore, ice was removed by hand and by shaking the tires, and water was removed using an industrial vacuum cleaner.

An I-beam was used as a track from the tire stockpile area to the module assembly area. Two men sorted, dewatered and stockpiled tires. One man foamed the tires at the head of the track and then rolled the tires toward the module assembly area where two other men stacked them (Figure 4). This five-man crew could foam 2000 tires in an eight-hour day.

## Belting Preparation

The conveyor belting was precut in suitable lengths and bolt holes were prepunched using a pneumatic punch and shear machine. Two pieces of belting 3.0 m long are needed to bind the 18-tire module together. Another two pieces of belting 2.0 m long are needed to bind each module to two adjacent modules.

Four holes were punched in both ends of each piece of belting. Each connection had three bolts. The fourth holes could be used to help pull the ends of the belting together for bolting.

A two-man team could handle the belting preparation to keep up with the module assembly rate of 75 modules per day.

## Module Assembly

Modules were assembled by two-man teams using simple frames (Figure 5). To start, two pieces of belting were hung from the tops of the vertical bars of the frames and the 18 tires were placed in position one at a time. Then the top of the frame was positioned and the module was compressed 10 to 15 cm using load binders (Figure 6). The belting was connected with three bolts which were tightened by an electric socket wrench. The wrench stalled when the appropriate torque had been applied. Three two-man teams could assemble 75 modules per eight-hour day.

## Mat Assembly

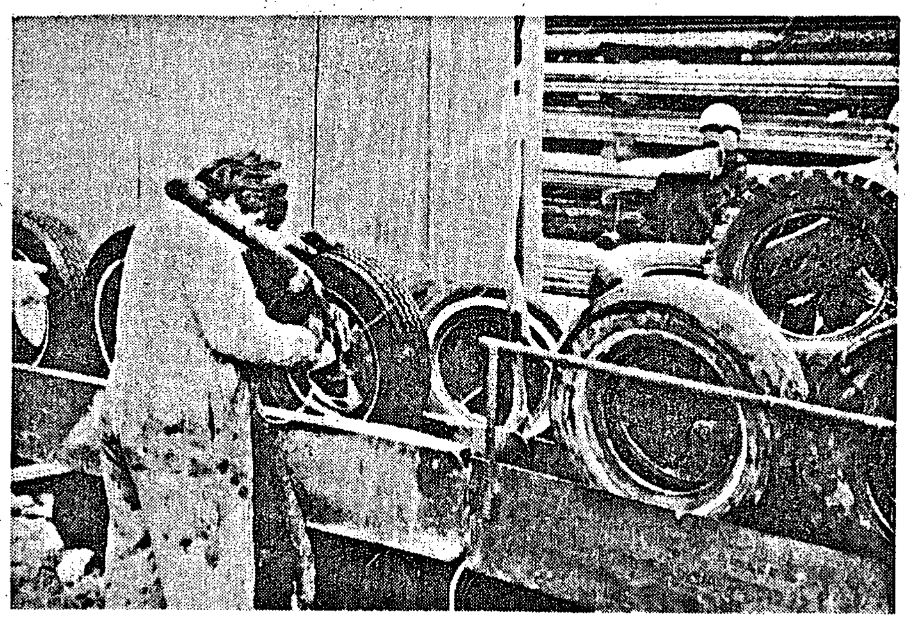
The finished modules were transported by flat bed truck to the breakwater construction site. There, they were lifted from the truck to a module stockpile using a 45-ton crane. The mat assembly took place on land at the water's edge. Modules were lifted from the stockpile to the row being assembled, where they were positioned and bound to the other modules by a five-man crew.

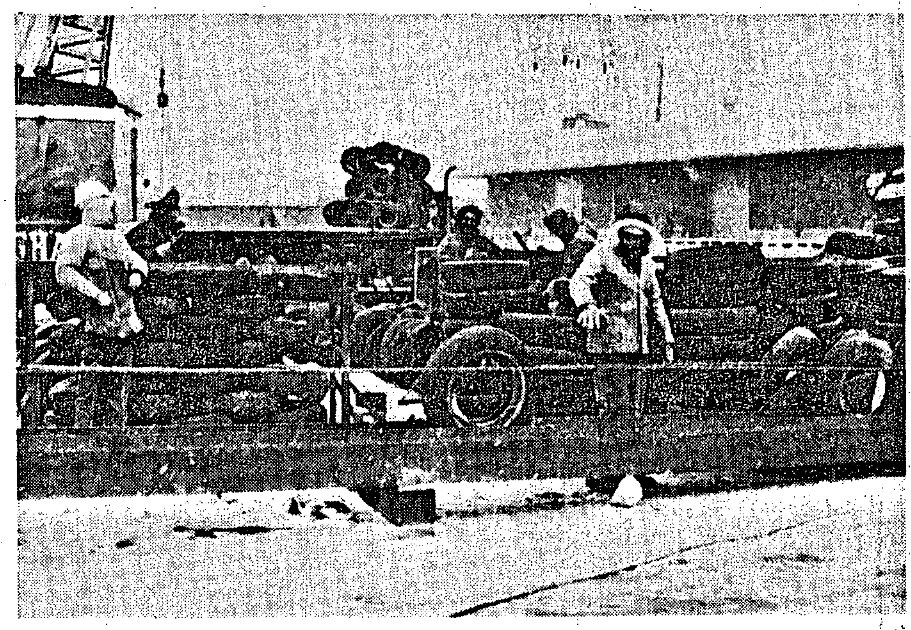
When two rows had been completed a steel I-beam was placed on top of the first row. Each module in the row was attached to the I-beam by steel chain. The crane then lifted the row of modules and moved it a distance equal to one row width toward the water (Figures 7 and 8). In this way, construction of the next row always took place at the water's edge. A small boat was used to help push the mat out into the water when the mat became larger. A bridle line consisting of conveyor belting was threaded through the two outer tires of each perimeter module as the mat assembly proceeded.

A five-man crew could assemble the mat at a rate of 75 modules per eight-hour day.

## Anchor Placement

Anchors with mooring lines attached were placed by a barge-mounted crane with 45-ton capacity. They were positioned by marker buoys which had earlier been located by survey. The breakwater end of each mooring chain was attached to a connecting rope which was later used to retrieve each chain.





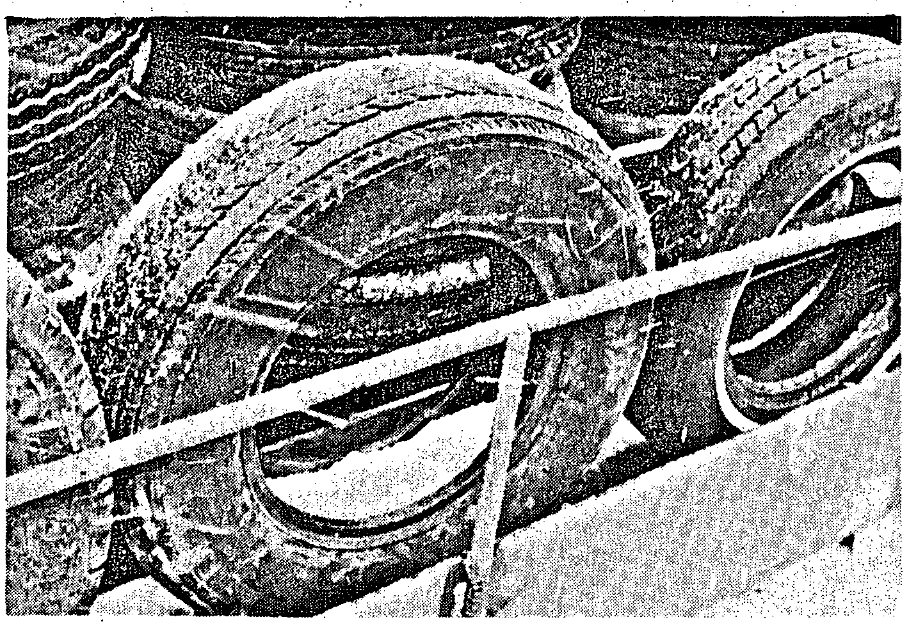


Figure 4   Tire foaming operation

Figure 5. Tire frames used to assemble modules.

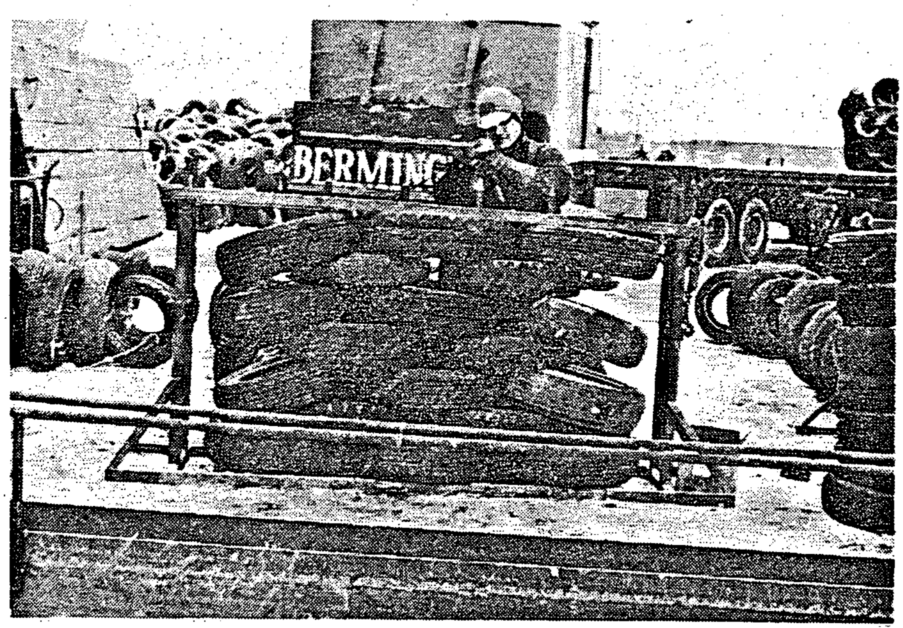


Figure 6. Compressed 18 – tire module

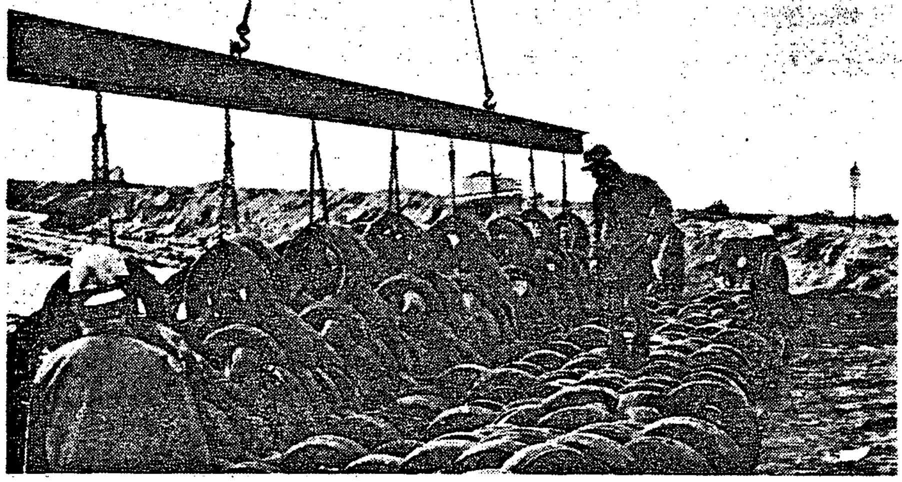


Figure 7. Row of 9-module mat being lifted into the water.

Figure 8. Mat assembly site

It took a six-man crew with a tug, scow, and crane 7 days to position and place the 80 anchors.

Mooring on Site

The breakwater sections were towed one at a time from the construction site to the La Salle Marina. The largest section, 70 x 9 modules, was towed the 4.4 km distance in about three hours. It is estimated that the tug was using about 100 hp (75 kW) to tow the mat.

At the Marina, a breakwater section was positioned vertically above its windward anchors and then the mooring lines from the windward anchors were attached. Subsequently, the breakwater was pushed toward its leeward anchors using two small tugs, and the mooring lines from the leeward anchors were connected.

It took a six-man crew with two tugs 5 days to tow and moor all the breakwater sections.

Adjustments

After completing the installation of the four planned FTB sections, waves of an unacceptably large magnitude were observed entering the Marina between the La Salle Park Wharf and the 60 x 9 module section to the southwest. The contractor was asked to install another section of 24 x 5 modules in this gap. The additional FTB section was assembled on the wharf using a 25-ton crane.

Adjustments in the lengths of some of the mooring lines were made in order to straighten the breakwater. A view of the completed marina is shown as Figure 9, and the as-built drawing is shown as Figure 10.

MATERIAL COSTS in 1981 Canadian dollars (Can $1≃ US $0.83)

Tires

About one quarter of the required number of tires was obtained at $0.10/tire, while the others were obtained at $0.35/tire. The cost of collecting 35,000 tires is:

= 35,000 (.25 x 0.10 + 0.35)
= 10,063 $10,000

Conveyor Belting

The length of belting necessary to bind each module and then to interconnect it with other modules to form the breakwater mat is about 10.0 m per module. To allow for an unsuitable portion of a belting order, the length per module ordered should be increased by 25 percent to 12.5 m. About three quarters of the required amount of belting was obtained at $0.55/kg, while the rest was obtained at $1.10/kg. The belting averaged 0.75 kg/m length. Therefore the cost of the belting for 1700 modules is:

= 1700 x 12.5 x 0.75 (.75 x 0.55 + .25 x 1.10)
= 10,957 $11,000

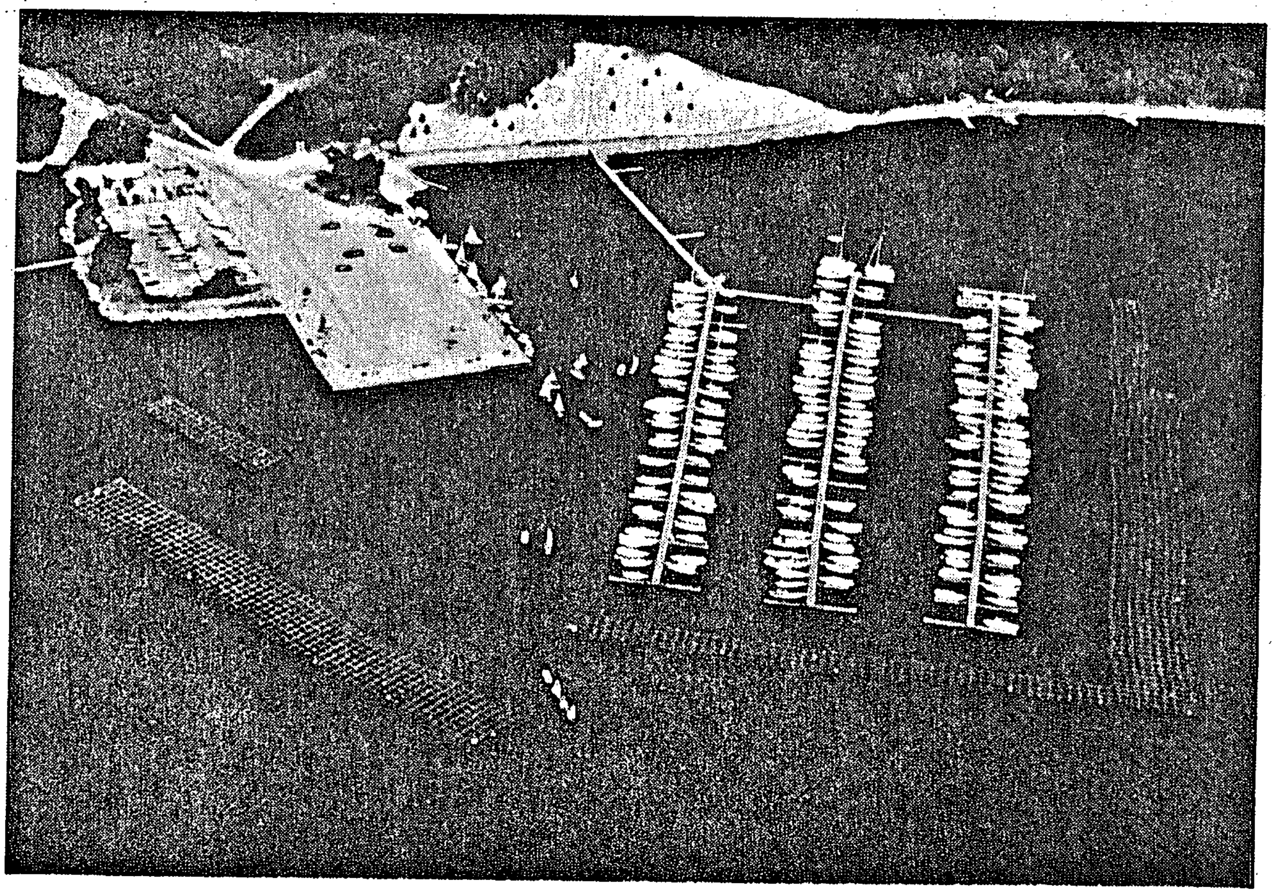


Figure 9 Completed La Salle Marina.

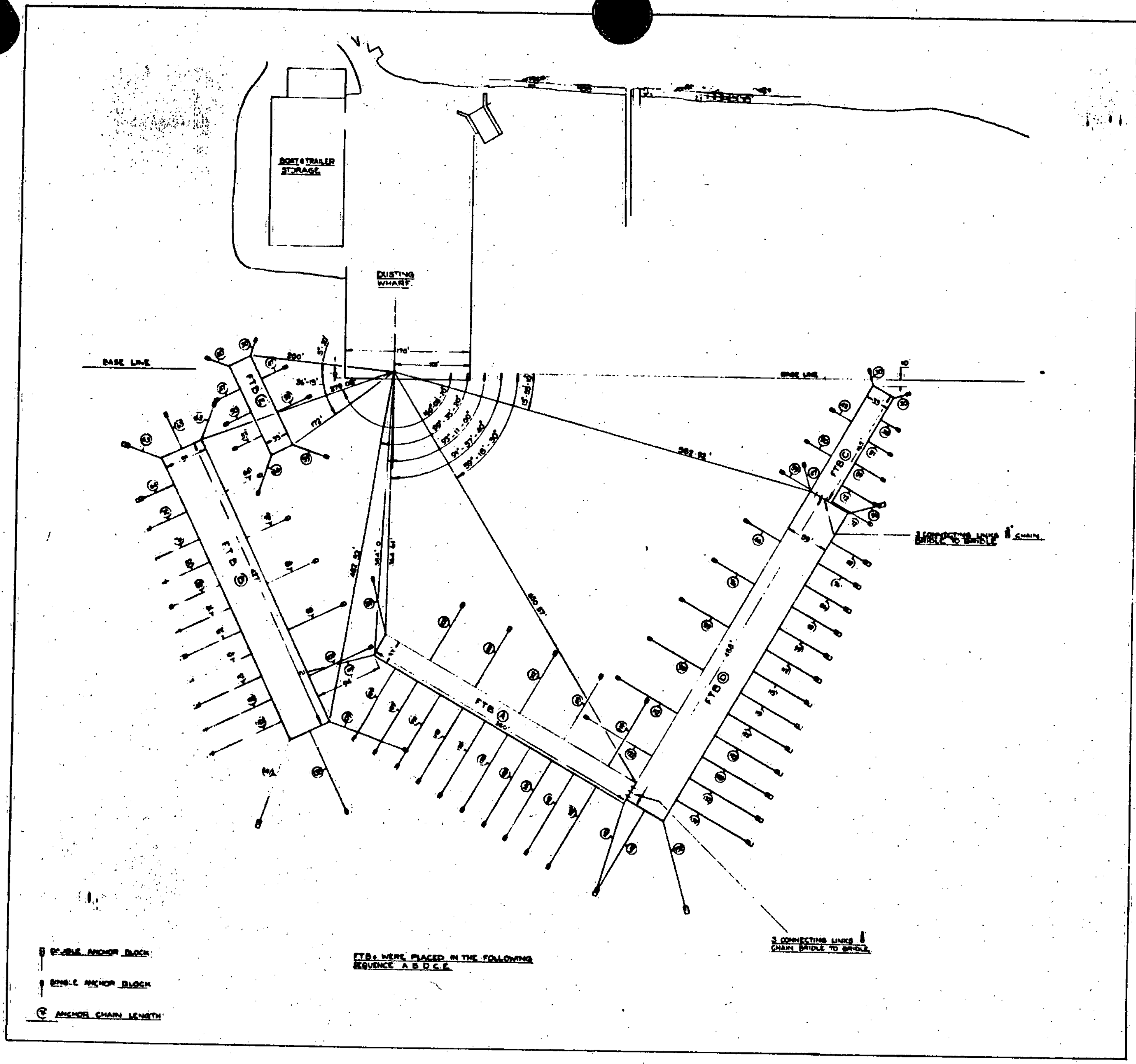



Figure 10. As – Built Drawing of La Salle FTB

### Supplemental Flotation

The subcontracted cost of spraying 225 g of 32 kg/$m^3$ urethane foam in the crown of each tire was:

$$= 35{,}000 \times 1.00$$
$$= 35{,}000$$

$35,000

### Mooring Lines

The leeward and windward mooring lines for the five-module wide sections, and the leeward lines for the nine-module wide sections were 3/8 inch (9.5 mm) steel chain. The windward mooring lines for the nine-module wide sections, and the chains looped around modules at each mooring line - breakwater connection were 1/2 inch (12.5 mm) steel chain. About 1500 m of each type of chain was used. The cost of the chain is:

$$= 1500\,(4.62 + 2.79)$$
$$= 11{,}115$$

$12,000

### Connectors

The number of connectors required per module is 12 (3 connectors/connection). Each connector consists of a bolt, two flat washers, a lock washer and a nut and costs $0.25. Therefore, the cost of connectors for 1700 modules is:

$$= 1700 \times 12 \times 0.25$$
$$= 5{,}100$$

$ 6,000

### Miscellaneous Hardware

The total cost of missing links, master links, shackles, anchor bolts and clevis hooks was about $2,500.

$ 3,000

### Anchors

The cost of a 3.5 tonne scrap concrete anchor block was $10. The trucking and handling of each block cost an additional $20. Therefore, the cost of 110 anchor blocks is:

$$= 110\,(10 + 20)$$
$$= 3300$$

$ 4,000

### Miscellaneous

| | | |
|---|---|---|
| Portable shelter | $ 6,000 | |
| Hydro, heat | $ 2,000 | |
| Pneumatic punch set up | $ 2,000 | |
| Miscellaneous construction materials | $ 5,000 | |
| | | $15,000 |
| Total | | $96,000 |

## LABOUR COSTS

### Tire Preparation

A five-man crew consisting of two men to prepare tires for foaming (including sorting, de-icing and de-watering), one foamer, and two men to stack foamed tires could foam 2000 tires in an eight-hour day. This gives a labour requirement of 0.02 man-hours per tire or 0.40 man-hours per module (18 tires per module + 2 link tires).

### Belting Preparation

A two-man crew could do the cutting and punching of belting to keep up with the mat assembly rate of 75 modules/day. This gives a labour requirement of 0.21 man-hours per module.

### Module Assembly

A two-man crew could assemble about 25 modules (consisting of 18 tires each) in an eight-hour day. This gives a labour requirement of 0.64 man-hours per module.

### Mat Assembly

A five-man crew could assemble the breakwater mat at the rate of about 75 modules per day. This gives a labour requirement of 0.53 man-hours per module.

#### Summary - mat assembly

| | | |
|---|---|---|
| Tire preparation | = | 0.40 man-hours per module |
| Belting preparation | = | 0.21 man-hours per module |
| Module assembly | = | 0.64 man-hours per module |
| Mat assembly | = | 0.53 man-hours per module |
| Total | = | 1.78 man-hours per module |

Thus the labour requirement to assemble a Goodyear FTB can be estimated at two man-hours per car tire module. This includes the cutting and punching of conveyor belting, the foaming of tire crowns, and the assembly and interconnection of modules.

### Placing Anchors

A six-man crew took 7 days to locate marker buoys by survey and to place 80 anchors (of which 29 were double 3 tonne anchors). This gives a labour requirement of 4.2 man-hours per anchor or 0.20 man-hours per module.

### Mooring the Breakwater

A six-man crew took 5 days to tow, moor and adjust all the breakwater sections. This gives a labour requirement of 3.0 man-hours per anchor or 0.14 man-hours per module.

Summary - mooring the breakwater

| | | | | |
|---|---|---|---|---|
| Placing anchors | = | 4.2 man-hours per anchor or | = | 0.20 man-hours per module |
| Mooring | = | 3.0 man-hours per anchor or | = | 0.14 man-hours per module |
| | | 7.2 man-hours per anchor or | | 0.34 man-hours per module |

Thus the labour requirement to moor this Goodyear FTB using gravity anchors can be estimated at 1 man-day per anchor or 0.5 man-hours per module.
TOTAL COSTS

## TOTAL COSTS

| | | | |
|---|---|---|---|
| Materials | | | $96,000 |
| Labour | 2.5 man-hours per module x 1700 modules x $16 per man-hour = $68,000 | | $68,000 |
| Miscellaneous Equipment (cranes, semi-trailor, pickup trucks, tugs, scow) | | | $50,000 |
| Engineering and Profit | | | $34,000 |
| Total | | Can | $248,000 |

This gives a unit cost of Can $35 per square metre of FTB (US $29 per square metre). This can be compared to the estimated cost of NZ $140,000 (Penny, 1981) for the proposed 165 module x 10 module Goodyear FTB for Lyttelton Harbour in New Zealand (US $25 per square metre of FTB* assuming NZ $1 ≃ US$0.83). The cost estimate for the Lyttelton FTB is based on a government labour rate of NZ $9.00 per man-hour, does not include an allowance for engineering or profit, and assumes that piled anchors will be used.

## PROBLEMS ENCOUNTERED

There was insufficient lead time in ordering the tires and conveyor belting. This resulted in higher material costs, delays in construction, and varying quality of conveyor belting. A minimum lead time of three months is recommended.

It was difficult to monitor the quantity of foam being sprayed into the tires. The man spraying the foam had to estimate by eye when 225 g ( 7 ℓ ) of foam was in each tire. Spot checks were carried out by making volume displacement measurements. An automatic shut-off attachment for the spray gun would be a useful tool.

Adjustments made to the lengths of the mooring lines in order to straighten the breakwater took longer than expected. In some cases three or four adjustments were made.

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* The typical size of a Goodyear module in North America is 2.1 m x 2.0 m, while the dimensions reported from New Zealand are 1.8 m x 1.6 m (Penny, 1981).

## CONCLUSIONS

The Goodyear FTB at La Salle Marina was successfully assembled and installed in a three-month period. The breakwater's performance to date has been satisfactory. A Super 8 mm movie of the construction, installation and performance of the breakwater has been made (Bishop and Nudds, 1981). Copies of this 10-minute movie are available from the Hydraulics Division, NWRI.

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