A fast-track approach
to design and construction

Vancouver's Floating
Concrete Heliport

By Thomas W. R. Taylor and H. Roger Woodhead

Describes the design and construction
of one of the world's newest and most
unique heliports, a floating facility
constructed from styrofoam-filled
concrete. Some of the
interesting aspects of construction are
highlighted and the economic benefits
of this use of reinforced concrete are
discussed.

In June 1986, the Port of Van-
couver, British Columbia, Can-
da, called tenders for a design-
build contract to construct what
is believed to be the world's first
floating concrete heliport. The
Vancouver Floating Heliport, a
concrete structure as large as an
American football field, was in revenue
service before the end of the same
year.

General requirements
In July 1986, Dillingham Construc-
tion Ltd., of North Vancouver, was
awarded a contract to construct the
facility. The consulting engineers,
Taylor Peach and Associates Ltd.,
of Vancouver, who had developed
the conceptual design for the bid,
began immediate work on the de-
tailed design, since a tight schedule
to complete the project before the
end of the year called for a fast-
track approach.

The contractor's plant, located
on the north shore of Burrard Inlet,
the main harbor of Vancouver,
includes a drydock that was of a size
and shape suitable to construct the
heliport facility. The completed
heliport was to be located on the
south shore of the same body of
water, as shown in Fig. 1.

The Port of Vancouver defined
the plan dimensions and preferred
freeboard in the tender documents.
The length and width were dictated
by the requirement that three land-
ning pads had to be operated simul-
taneously. The pads were to be de-
gined for the operation of helicopt-
ers of 5.4, 7.7, and 22.7 Mg (6,
8.5, and 25 tons) gross weights. The
sum of the required pad sizes (each
by regulatory code to be 1.5 times
the size of the appropriate helicopt-
er) and the clearances between each
pad determined the length. The size
of the largest pad determined the
width. The resulting structure was
approximately 86 m long by 33 m
wide (282 x 108 ft).

In addition, the Port specified
that the design was to be capable of
expansion at the largest pad to per-
mit even larger machines to use the
facility in the future. For esthetic
reasons, the owner required that the
freeboard be as low as practical. A
design freeboard of approximately
0.8 m (32 in.) was selected.

The conceptual design of the
heliport was such that it could be
constructed in individual pontoons
in the drydock. The sections would
then be floated out and joined to-
gether. The maximum pontoon size
was tailored to the size of the dry-
dock. The width was such that sec-
tions 16.5 m (54 ft), half the width
of the completed float, could be
constructed.

The length of the drydock was
shorter than the heliport so that a
transverse pontoon had to be built
in addition to the two longitudinal
pontoons. This pontoon also was
designed to be 16.5 m (54 ft) wide.
Pontoon sizes and assembled di-
ensions are shown in Fig. 2.

The freeboard specified by the
owner and the overall aim of mini-
mizing construction costs dictated
that the completed float should be
as shallow as possible. Preliminary
analysis and design indicated that
an average structural depth of 1.83
m (6 ft) would satisfy the freeboard
specification. It was also sufficient
to provide enough overall stiffness
and section modulus to carry
stresses from wave motion without
excessive deflection or cracking.
Further, it meant that the pontoon
did not require prestressing, which
reduced the overall cost.

To insure positive flotation, the
pontoons were filled with blocks of
styrofoam (Fig. 3) so that water
could not accumulate in the cells. It
also eliminated the need to form the interior walls and the soffit of the top slab. Epoxy-coated reinforcing was used to improve the durability of the structure as indicated in Fig. 4, which shows placement of the base slab of one of the pontoons.

**Analysis and design**

Once the general requirements had been set, detailed design proceeded. Although all environmental loading conditions were investigated during analysis, it was apparent that the most severe stresses in the assembled float resulted from wave action. Waves encountered at the heliport were generated primarily by wind and passing marine traffic.

Waves due to wind were typically of a very short length and low amplitude because of the protected location and the relatively short reach to the adjacent shore. The most severe wind-generated waves at the moored location resulted from winds from the north-west to the north-east. The strongest winds in Vancouver were typically from the opposite directions.

Waves generated by marine traffic, however, had a higher amplitude and much longer wave length. The effects of these waves on the structure were investigated in detail, since the facility was to be located adjacent to the south terminal of the Vancouver Sea Bus. The

![Image of Vancouver harbor and facility location.](image1)

![Image of plan of the heliport.](image2)
bow wave generated by the sea bus had an amplitude of about 0.6 m (2 ft), a wave length of about 10.7 m (35 ft), and typically would strike the float at about a 45 deg angle.

The analysis of the response of the structure to loads induced by wave motions was very complex. Preliminary analysis was carried out using the cosine wave formula

\[ M_w = \frac{BHL^2}{2763.5} \left[ \cos \frac{\pi L}{\lambda} + \frac{\pi L}{2\lambda} \left( \sin \frac{\pi L}{\lambda} \right) - 1 \right] \]

where
- \( L \) = float length in ft
- \( B \) = float width
- \( H \) = wave amplitude
- \( \lambda \) = wave length
- \( M_w \) = bending moment in ton-ft

Since the waves could strike the face of the float at any angle from zero to 90 deg, the wetted distance from wave crest to wave crest along the exposed face of the structure might be considerably greater than the actual wave length of the input wave. Hence, a very long, narrow float would be subject to bending moments that would result if the wave length was equal to the length of the structure.

During preliminary one-directional analysis, the effects of waves having wave lengths varying from 3 m (10 ft) to the length of the structure were investigated. It was quite apparent that the most severe loading would result if a wave having the same wave length as the structure length struck the float so that the angle of incidence to the long side was zero. Also quite obviously, such a situation would never occur. Therefore, a considerable degree of engineering judgment was required to determine what represented realistic wave loadings.

The structural design developed essentially from the analysis of a space structure supported on elastic foundations of varying stiffness representing the uplift from the water.

The numbers and placement of internal longitudinal walls was governed by the stresses due to landing loads on the deck and hydrostatic pressures on the bottom slab. A series of continuous longitudinal walls spaced transversely at about 3 m (10 ft) was determined to be the optimum. Thicknesses of 150 mm (6 in.) for both the top and bottom slabs were consistent with the stresses from one-way bending action. In determining hydrostatic pressures, it was assumed that the float was immersed to deck level.

Analysis for shears and moments in the top slab was carried out using influence surface techniques. This was considered to be the most rapid method in determining the governing positions of the various specified live loads.

The owner had called for the facility to be initially moored close to the downtown shoreline. Future development plans for the site, however, required that the heliport be capable of being moved to an alternative, currently undefined, site within the harbor.

**Particular care must be exercised to insure that joining procedures are well thought out. Time spent in design is cheap in comparison to the cost of possible delays if such details cause construction difficulties.**

The initial mooring was attained by securing the float to two onshore pile-supported piers using two gangways. In addition to providing access, the gangways acted as articulated stifflegs to keep the float positioned parallel to the shore. Movement of the float parallel to the shore was restrained by a pair of wire rope spring lines connected between the two gangways.

To provide future moorage capability, hawsepipes were cast into the float to accommodate a chain anchorage system. Particular care was paid to the design and detailing of the gangway connections, not only to permit adequate movement, but also to accommodate the high-cycle fatigue and impact loads that were generated by the structure's response to waves.

**Joining the pontoons**

As stated previously, the heliport was assembled from three pontoon sections. The two longitudinal pontoons were essentially mirror images of one another. The only differences were the inclusion of embedded hot-dipped galvanized fittings to connect the gangways to one pontoon and embedded sleeves for future expansion in the other. A transverse drainage slope of 75 mm (3 in.) was built into each pontoon.

The assembly of large floating concrete sections without the benefit of match casting can be a financial nightmare. As a result, particular attention was paid in the design to joining details that would permit simple and accurate assembly. A series of five "joining wells" were provided adjacent to the common edge of the longitudinal pontoons. The wells were designed so that all work associated with assembling the pontoons into a single float could be accomplished "in the dry" by the contractor.

The joining wells were designed with locally thickened walls to carry the wave-generated moments and shears from one pontoon to the other. To reduce the weight of the thickened walls, styrofoam slab inserts were cast within the concrete where stress levels permitted.

The initial mating of the pontoons was assisted by pintles and sleeves cast into both ends of each pontoon. It was determined that a 100 mm (4 in.) maximum diameter tapered solid pintle would be adequate to prevent relative movement between the pontoons and carry all shears in the protected lagoon during curing of the concrete closure placements. Fig. 5 shows details of the joining wells.

During the joining process, a compressible seal was placed along the contact surfaces of the joining wells. After the pontoons were brought together, a series of posttensioning bars were inserted into the top row of post-tensioning sleeves and partially tightened (Fig. 6). Portable ballast blocks were then placed along the outer edges of the pontoons to close the seal at the
Fig. 3—(top, left) Styrofoam blocks being placed.
Fig. 4—(top, right) Base slab of pontoon being placed.
Fig. 5—(bottom, left) Pontoon joining wells.
Fig. 6—(bottom, right) Detail of joining well.
Heliport
continued

Fig. 7—Installation of heliport.

Fig. 8—Completed heliport from incoming helicopter.

bottom of the joining wells. The compartment between the pontoons at each joining well was thus made temporarily watertight.

After dewatering these compartments, the waterproof covers, which had been placed over the outer ends of the bottom row of post-tensioning ducts in the drydock, could be removed and the bottom row of post-tensioning bars inserted and partially tightened.

Before the closure concrete could be placed, shear reinforcing stirrups had to be placed in the joining compartment. Then, after the concrete was cast and cured, post-tensioning rods were stressed to complete the assembly of the first two pontoons. The flotation of the assembly was then checked against the design. Since the third (transverse) pontoon was being constructed in the drydock while the longitudinal pontoons were being connected, time was of the essence if depth modifications were to be made to the third pontoon to assure level flotation of the finally completed structure. The two joined longitudinal pontoons had essentially the same freeboards along transverse cross sections.

However, due to the added weight of the joining wells located along the face that was to be connected to the transverse pontoon, the assembly was deeper in the water at that end. An in-house computer program had previously been developed to predict the flotation characteristics of each pontoon individually and the assembly as a whole. A slight modification to this program permitted the flotation to be updated with actual measured values at each corner of each pontoon. Thus it was possible to accurately predict final flotation characteristics and make the anticipated depth changes to the third pontoon.

An interesting aspect of the flotation was that all pontoons floated deeper in the water than the actual material quantities and measured density of the water would indicate. Actual quantities of concrete placed agreed with design calculations, as did steel and styrofoam quantities. Based on observed conditions of freeboard, the unit weight of concrete including reinforcing was determined to be close to 2725 kg/m³ (170 lb/ft³) as opposed to the 2400 kg/m³ (150 lb/ft³) assumed in the design.

The top slabs of all pontoons were precut and blocked out for the installation of landing lights and grounding terminals at each of the three pads. In addition to the landing lights that were pilot activated, the completed facility had firefighting and fueling facilities and a beacon approach system. The access gangways were fully articulated at each end to allow restricted movement due to tide and currents. Fig. 7 shows the heliport being installed on the waterfront.

At this writing, the facility has been so successfully received and used that the owner is already assessing the need for expansion. A helicopter's eye view of the completed heliport is shown in Fig. 8.

Conclusions

In designing such a facility, particular care must be exercised to ensure that joining procedures and details for connecting pontoons are well thought out and as simple as possible. Time spent in design is cheap in comparison to the cost of

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possible delays if such details cause construction difficulties.

If the facility is moored to the shore by rigid stiffleg struts, the designer must thoroughly investigate the fatigue loads and impact loads that result. The use of reinforced concrete in connection with styrofoam blocks for positive flotation for the Vancouver Floating Heliport has proven to be an economical and durable solution for such an application. The overall completed facility cost of just over $1.6 million (Canadian), or about $570/m² ($53/ft²), (including shore facilities) compares very favorably with the undeveloped cost of the adjacent land. By specifying construction of a floating concrete facility, the Port of Vancouver realized these advantages:

- low initial cost;
- a short construction schedule to minimize interim costs;
- a facility that left existing valuable downtown land available for development;
- a portable facility that allows future movement if site priorities change;
- a low maintenance structure;
- high deck friction to reduce the risk of falls by users;
- good resistance to fuel spills and excellent resistance to heat damage in the event of fire;
- an esthetically attractive structure that fits in well with the shoreline facilities.

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FROM PUBLIC EYESORE TO SEASHORE BEAUTY

Before—and after (model). Credit for this dramatic transformation goes to the State Coastal Conservancy, the Montecito Community Foundation, the Santa Barbara County Art Program, local citizens—and the architect and engineer.

View of completed heliport from an incoming helicopter. Moored near downtown Vancouver, the heliport can be moved to another location if site priorities change.

World’s 1st floating concrete heliport

Fast-track schedule turns design into operating Heliport in just 6 months

Imagine a floating concrete structure as large as a football field ready to land three helicopters—constructed from start to finish in less than half a year!

That’s the record of this new facility built for the Port of Vancouver, British Columbia, Canada. The heliport is made up of three landing pads sized so they could be constructed as individual pontoons in a nearby drydock and floated out to be joined together. The resulting structure is approximately 282-feet by 108-feet with a depth of 6-feet.

The design was developed by Taylor Peach and Associates, Ltd., Vancouver. Plans called for filling the pontoons with blocks of styrofoam to insure positive flotation so that water could not accumulate in the cells. Epoxy-coated Grade 60 reinforcing steel was specified to improve the durability of the structure in this corrosive marine environment. Two hundred and ninety-five tons of epoxy-coated rebar were used. Nearly 1,500 cubic feet of 6,000 psi concrete were required.

The builder, Dillingham Construction Ltd., North Vancouver, reports that the use of reinforced concrete in connection with styrofoam blocks for positive flotation has proven to be an economical and durable solution for such an application.

With epoxy-coated reinforcing steel in place in the sides and internal longitudinal walls, one-half of the pontoon is ready for concrete to be pumped for the base slab. (Photos courtesy Dillingham Construction Ltd.)

Beach pathway transformed by R/C concrete stairway

You can see the problem the community of Montecito, California had with this access to a public beach. The rough, steep grade made walking difficult and dangerous—and invited graffitti.

The solution was the design and construction of a functional set of steps into a 100-foot long stairway that, in addition to accommodating a sewage pumping station and other unsightly existing utilities, fanned out as it descended making places for sitting, resting, tanning and sunset watching.

The stairway design was conceived by the architectural firm of Appleton Associates, Inc., Venice, California as a place where the man-made meets and gives way to the natural. As one approaches the beach, the clean lines and regular geometry of the steps incorporate rough sandstone boulders which are part of the native beach environment.

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