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AN INNOVATIVE NEW DESIGN FOR PRECAST CONCRETE WHARVES

PREFABRICATED / PRECAST STRUCTURES

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An Innovative New Design for Precast Concrete Wharves

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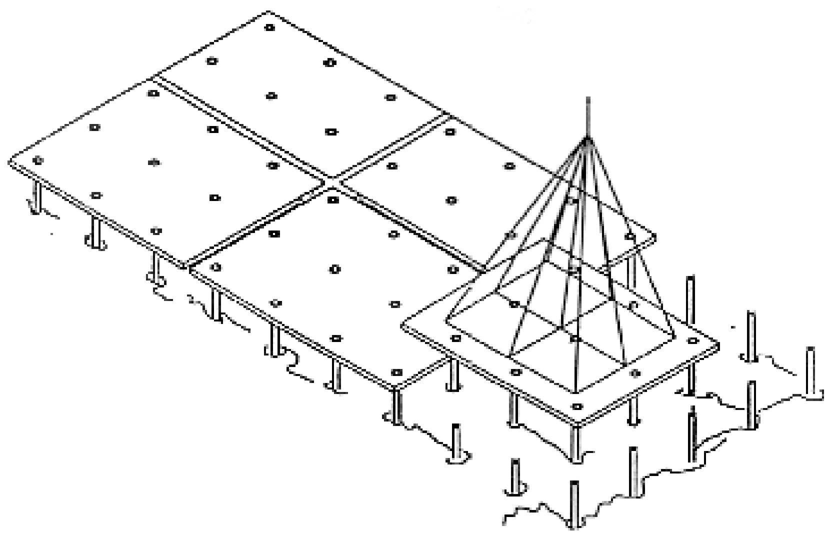
ABSTRACT

The coastal marine environment makes precasting essential to ensure good quality concrete. Conventional precast systems consist of many separate precast beam and slab units and require a substantial amount of site work to handle the numerous pieces and to join them together.

An innovative new system for precast marine wharves has been successfully designed and implemented in Singapore. This system consists of large flat slab panels, with a minimum number of joints and very little in-situ concreting. The system requires only the simplest of formwork and minimal precasting yard facilities. The slabs can even be cast directly on floating pontoons for easy transportation. The design of the precast slabs allows immediate use of the deck after placement, and saves considerable construction time.



The Large Precast Flat Slab System

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1.0 INTRODUCTION

Concrete is still one of the most economical, strong and durable materials used in common construction. Precasting is absolutely essential in the construction of concrete wharf structures. The reasons are as follows:-

Firstly, it is difficult and expensive to construct formwork in the marine environment. The weight of concrete to be supported is much more than in a building on land, some 1-2 tons per square metre of area. Precasting reduces or eliminates the need for on-site formwork.

Secondly, it is extremely difficult to ensure proper quality control of concrete cast over water, with waves, sea spray, and tides to contend with. On some projects, transporting large quantities of wet concrete to site can be a problem due to the location of the wharf. Precasting in a controlled environment obviously solves these difficulties.

Apart from the above technical considerations, the prime advantage offered by precasting is the shorter construction period made possible by reduced site work and more parallel activities. (Precasting can be done in parallel with the foundation installation)

2.0 PREVIOUS HISTORY OF PRECASTING

Most conventional precast wharves consist of separate precast beams and precast slab soffit planks, tied together by an in-situ concrete topping layer. (Photograph 1)

There are several major problems which plague designers of precast concrete wharves:- the difficulty in attaching the deck to the foundation piles, the congestion of reinforcement at the ends of the beams and joints, and the difficulty in allowing for site tolerances in the precast units. A common solution to the problem of attaching the deck to the piles is to use a large in-situ pilecap or a wide in-situ beam to accommodate piling tolerances. The problem of rebar congestion at the joints has been reduced by using 1-way, simply supported beams.

However, precast wharves still take a considerable length of time to build due to the numerous components and separate steps in the construction. (Fig.1)

3.0 NEW METHODS

To reduce the construction time on site, it is beneficial to have larger, more complete precast units. However, the larger size means more complicated units, which are more complicated to build, difficult to transport, and even more difficult to install. Compared to structural steel, concrete is relatively heavy, and does not lend itself well to site adjustment of pieces which do not fit.

There have been attempts at composite steel / concrete decks, which have the advantages as well as disadvantages of both materials.

There has even been a concrete deck installed by the jack-up method, but this method is better suited to steel pontoon-type structures.

4.0 SEARCH FOR THE OPTIMUM SOLUTION

One advantage to building in the marine environment is that large units can be transported and handled much more easily over water than on land.

To make the most efficient use of construction time, the concrete deck therefore should ideally be made in large completed modules, which can be easily built, transported, and installed. However, making bigger units means extra weight, complication, and of course more difficult transportation and handling.

In order to be viable, therefore, the disadvantages of weight, complication, handling and installation must be minimised, while making use of the ability to handle bigger weights over water.

5.0 THE SOLUTION

The simplest concrete deck is a flat slab, with no beams or drop panels. Such structures have been built in the past, but have been rather thick and heavy, in order to carry adequate fendering. Therefore, precasting these would be impractical.

However, the situation is very much changed if the flat slab can somehow be made very thin (and thus light) and yet some means could be devised to handle it without over-stressing the thin structure.

The key to achieving a simple, lightweight deck structure lies in the design of the fendering system. Berthing forces are carried directly from the fenders to the raker piles. (Fig. 2) To enable this, the fendering system had to be designed so that the fenders could be located just below the deck level, and yet still cover a wide range of tidal variation.

The deck is designed to carry purely vertical dead and live loadings and horizontal loads from the moorings to the support piles. Little or no bending moments are carried to the foundations. Thus, large deck beams and fendering structures can be eliminated. The resultant flat slab can then be made 30-50% thinner and lighter. (Photograph 2)

Longer spans between piles would have allowed more room between piles to float in the deck from below with the tide, but would also incur the penalty of heavier piling as well as a heftier deck structure. Therefore, pile spacings are kept small to allow a lighter deck, and the deck slab is designed to be installed by lifting into place.

The use of a thin, light flat slab structure allows large sized panels to be handled by floating crane. The flat slab is easy to precast, and precasting can even be done on a floating pontoon, eliminating one handling step. (Photograph 3) Even the need for a precasting yard is minimised. The pontoon can be moored next to a concrete batching plant for precasting, and then towed directly to site for installation after the concrete is cured.

However, since the deck is relatively thin, lifting must be engineered with great care and precision. (Photograph 4) The lifting should not impose extra stresses on the deck so that no extra strengthening is required. Therefore, numerous lifting points are required to spread out the load. There should be no cracking of the deck during lifting, which means that loads as well as deflections must be well controlled at all points during the lift.

In addition, piling in the marine environment requires generous tolerances to be allowed for in the design. The problem is compounded since each deck unit rests on numerous piles. Piling tolerances are taken care of in the design of the pilecaps.

These problems have all been successfully solved and 3 samples of this type of construction are currently in operation in Singapore. The design can be easily adapted for different sizes and shapes of deck plan. Smaller wharf decks can be installed in one single piece, while for larger decks, the joints between adjacent slab units are simple and easily constructed.

6.0 CONSTRUCTION EXPERIENCE

The large flat slab system of wharf construction has been successfully used on 3 projects by two different contractors in Singapore. Generally, the method of construction was the same. Both contractors preferred to do the precasting directly on floating pontoons, to eliminate double handling and to save on precasting facilities.

The solution to the lifting arrangement was different, with one case of controlling deflections during the lift with a rigid frame and two cases of controlling the forces transmitted by the lifting rig through a load balancing system. Both systems were successful. (Photos 3 & 4)

Precasting is a very simple operation, with only the simplest of formwork required. There were no problems with fit and tolerances in the installation of the deck panels.

There are considerable savings in construction time. Usually the entire deck can be installed within a day, and immediately can support construction loads. This is particularly advantageous when coordinated with a modular system of construction for the above-deck facilities. One project showed a savings in construction time of 43%.

A study on two similar wharves designed by us and constructed in the same area showed that tendered prices for this type of deck are very similar to the more conventional system of precast beams and slabs, even though the new concept is quite unusual. Generally, the cost of hiring a large marine crane is measured in days, compared with months for smaller cranes working on a more conventional deck structure. The entire construction process is much simplified.

As to construction risks, it can be said that big lifts usually attract the full attention of all parties, and much more effort is expended in ensuring that nothing goes wrong when the all the bosses appear on site to watch the show!

7.0 CONCLUSION

The large flat slab system of concrete deck precasting has been used successfully in Singapore. Very few changes have been required on the original design, and the system has proven to be economically competitive as well as offering considerable savings in construction time. The system has been well proven in operation and has won the Singapore Construction Industry Development Board's (CIDB) Best Buildable Design Award for 1993.

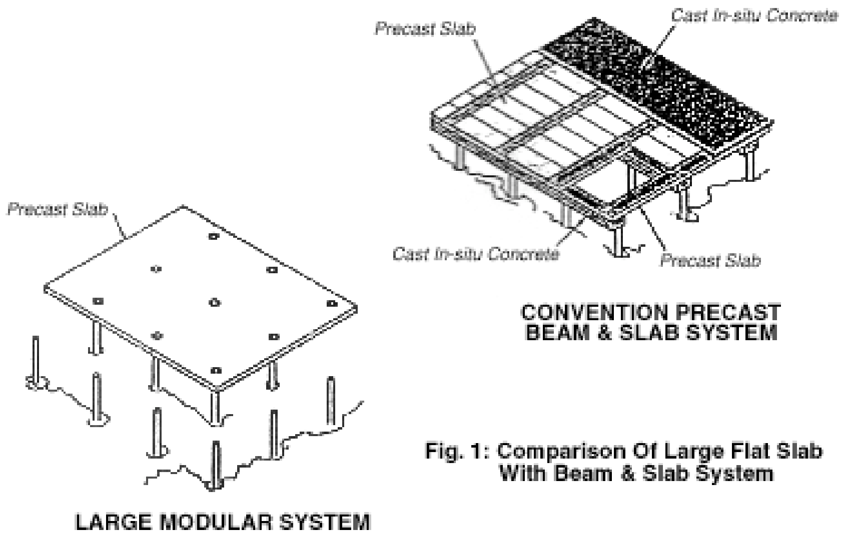

Fig. 1: Comparison Of Large Flat Slab With Beam & Slab System

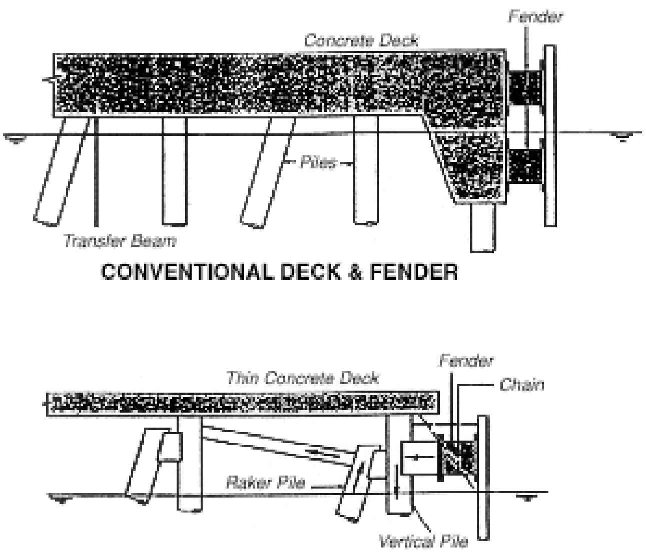

Fig. 2: Isolation of Fendering Forces

Photo 1 : A conventional precast concrete deck consisting of precast beams and slabs, tied together by in-situ concrete top

Photo 2 : Thin, lightweight flat slab system

Photo 3 : Formwork for precasting on a pontoon

Photo 4 : Lifting an entire deck in one piece(1987)