Alternate Formwork System Evaluation

Executive Summary

The current handset aluminum formwork system used in the Navy League Building’s parking garage is a labor and material (plywood) intensive process. To determine a possible alternate, a variety of pre-manufactured systems were analyzed. The overall goal of this research was to determine if an alternate system could have a positive impact on the budget and sustainability aspects of the concrete formwork.

Criteria such as engineering of the system, material costs, labor, local building codes, and reusability were used to determine an alternate. After selecting the Titan HV system, a budget was compiled to judge both systems. With the handset aluminum system providing cost savings and equal environmental impact as the Titan HV, it was concluded to be the most appropriate system for the Navy League Building’s parking garage.

Although the analysis did not find pre-manufactured formwork to be more beneficial, it reinforced that the standard handset aluminum system is the best choice for Navy League.
Overview:

Determining the best methods of building construction is a challenging aspect on any project. Considering this, the selection of the most appropriate formwork system is necessary for concrete installation. While many different systems may work, a system which is quickly and easily erected can provide benefits to the budget and sustainability aspects of a LEED rated project.

In the case of the Navy League building, the viability of a pre-manufactured system for elevated slab placement will be analyzed. Focusing on the sub-grade garage slabs, the alternate system will be compared to the handset aluminum system actually used on site. The current system is a labor and material (plywood) intensive process. To address these issues, the potential benefits of a pre-manufactured system are compared to benefits of the system as-built.

Analysis Outline:
The basic steps used to analyze the formwork systems are outlined below:

- Gathered detailed erection and production data on the current formwork system (from general contractor and concrete subcontractor)
- Researched pre-manufactured gang form systems
- Determined viability of possible alternates and selected appropriate system based on erection, material availability, and structural stability requirements
- Prepared budget for alternate system
- Compared alternate budget to original and selected system with greater cost / benefit ratio

Goal:

The overall goal of this research is to determine if an alternate system could have a positive impact on the budget and sustainability aspects of the concrete formwork. As cast in place concrete placement is one of the most expensive activities on the project, an alternate formwork system has the potential to reduce costs. A pre-manufactured system featuring reusable components would also reinforce the sustainable theme of the building.
Research & Analysis Introduction (continued)

Images of the current handset aluminum formwork system
Available Formwork Systems

The formwork systems listed below are currently available for rental or purchase through formwork distributors. These systems were examined in terms of their applicability for use in The Navy League Building’s parking garage. A basic overview, list of advantages, and product images are provided for each different system.


The Filigree system uses a combination of factory precast and an on-site cast in place topping to produce elevated slabs. Thin precast panels and trays containing the lower slab reinforcing are set in place on top of standard shoring. After installing further reinforcement and polystyrene foam void blocks, concrete is poured into the precast pieces, thus completing the slab.

As listed on the manufacturer’s website, advantages of the Filigree system include labor and time savings, as well as the claim that it is environmentally friendly. Although not specifically stated by the manufacturer, it is assumed that the time and labor savings are most easily achieved on a high-rise project using crews trained in the Filigree system’s construction.

- **Labor Savings:**
  “The prefabrication technology in Filigree reduces the need for field skilled and unskilled trades. Although all trades are represented, fewer are needed for each task with a reduction in payroll needs and enhanced cash flow. “

- **Time Savings:**
  “Filigree structures go up fast. High production rates of up to 50,000 sq.ft. per 5 day week can be achieved. “

- **Environmentally Friendly:**
  “Many trees are saved by the elimination of wood and plywood framing. “

![Image of a Filigree beam & slab system](image-url)
Available Formwork Systems (continued)

Peri ‘Skydeck’ Formwork System  (http://www.peri.de/ww/en/pub/aktuelles/start.cfm)

This modular system from Peri features aluminum-framed panels with integral faced plywood. Props fitted with special dropheads allow the panels to be removed while the props remain in place to act as reshores.

According to the manufacturer, advantages of the ‘Skydeck’ system include:

- **Lightweight**
  - The slab panels featuring the integral aluminum frame and plywood sheathing do not weigh more than 35 lbs. each

- **Early striking**
  - The dropheads on the props allow the slab panels to be removed and reused while the prop remains to support the curing concrete.

- **Low maintenance**
  - The props feature self-draining edges and a powder coated finish
Available Formwork Systems (continued)

'Tabla' by Gillespie Practical Technologies, Inc.  
(http://www.gillespietech.com/22.htm)

The 'Tabla' formwork system is comparable to 'Skydeck' in terms of its components and operation. Aluminum-framed panels sheathed with 'plastic plywood' rest on props with an integral drophead. After the slab is poured, the panels can be released and swung down to be removed. The posts remain as reshores.

According to the manufacturer, some advantages of the 'Tabla' system include:

- Fast erection & removal
  - 250 sq.ft. can be erected per man-hour and 400 sq.ft. can be dismantled per man-hour.

- Reusable
  - The deck panels are sheathed with 'plastic plywood' which has a claim of 200 to 250 uses.

- Custom Details
  - The system has components which can accommodate many custom slab details such as beams and cantilever sections.
Available Formwork Systems (continued)


The ‘Titan’ system is similar to both the ‘Tabla’ and ‘Skydeck’ systems in terms of operation and components. The formwork uses main and secondary aluminum beam sections, a reusable drophead, and plywood sheathing. After the slab is poured, the beams sections can be released by hitting a lever. As with the other systems, the posts remain to act as reshores.

Some advantages of the ‘Titan HV’ system include:

- **Safe erection process**
  - The post shores and beam sections can be assembled on the ground, making for a more safe and comfortable work environment.

- **Custom-framed openings**
  - The main beams of the system are designed to allow wood 4x4s in place of the secondary beams. The wood beams can be used to frame unusual slab designs and filler conditions.

- **Quick-release dropheads**
  - The dropheads of the system feature a quick-release mechanism allowing release via a single hammer stroke.
Slab Design Factors

Determining which formwork systems adequately accommodate the structure’s design is an initial step in the selection process. There are a variety of available systems that cater to specific slab designs. Considering this, inappropriate pre-fabricated systems should not be ‘forced’ into use because of their cost or potential schedule and labor savings.

As seen in the plan below, The Navy League Building’s garage is a two-way flat slab with average bay sizes between 20’ x 30’ and 30’ x 30’. The slab thickness varies from 8” – 12” and the average floor to floor height is approximately 9’. The irregular-shaped polygon outline of the building creates a challenge to formwork installation. If a pre-manufactured system is to be used, it must be adaptable to accommodate the angled slab edges. This characteristic, and other factors such as the slab’s multiple elevation changes may limit the possible production efficiencies of the systems described in the previous section.

First Floor Slab Framing Plan
The parallelogram shape and multiple slab elevation changes pose a design challenge to standardized formwork systems
Slab Design Factors (Continued)

Garage Slab Design Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Two-way flat slab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab Design Type</td>
<td></td>
</tr>
<tr>
<td>Design Load</td>
<td>50 psf</td>
</tr>
<tr>
<td>Concrete Strength</td>
<td>5,000 psi</td>
</tr>
<tr>
<td>Slab Thickness</td>
<td>8” – 12”</td>
</tr>
<tr>
<td>Floor to Floor Height</td>
<td>9’- 4”</td>
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<tr>
<td>Average Column Size</td>
<td>2’-0” x 2’-0”</td>
</tr>
<tr>
<td>Number of Levels (of elevated slab)</td>
<td>4</td>
</tr>
<tr>
<td>Area of Garage Elevated Slab</td>
<td>119,685 Sq. Ft.</td>
</tr>
</tbody>
</table>

First Floor Slab Detail

The detail provided above of the garage’s southwest corner show the angled exterior walls and slab elevation changes – two elements which can slow formwork construction.
Formwork System Selection

There are many factors which must be considered to determine the most appropriate formwork system for The Navy League Building. These factors include, but are not limited to, the design characteristics of the system itself, engineering of the system, material costs, labor, local building codes, and reusability.

Design Characteristics

To begin, the critical factor in selecting an alternate formwork system for the Navy League Building is its adaptability to the current structure’s design. The parking garage is what is known as a ‘cut-up’ design – the basic outline of the structure is an irregular polygon while the slab itself features a variety of beam sizes and drop panels. The concrete subcontractor chose a standard system due to these irregularities.

Use of standard metal formwork is also supported by the ’Interactive Horizontal Formwork Selection System’ by Hanna and Sanvido. This document confirms that a standard metal system is the most appropriate under the given conditions. However, it must be noted that many of the formwork systems described above were not yet available after the document was published.

Considering that a pre-manufactured formwork system must be selected to suit the Navy League’s structure, and not vice versa, the Filigree system can be eliminated as it does not correspond to the slab design. The garage was engineered as a cast in place two-way flat slab. The Filigree’s combination of precast and cast in place components in addition to the foam void blocks would require a redesign of the slab and corresponding reinforcement.

Despite the Filigree system’s incompatibility, the remaining three systems, which are very similar in components and operation, can be adapted to the garage. All feature removable aluminum beams and post shores with integral drop heads. The ‘Skydeck’ and ‘Tabla’ systems both contain a possible difficulty in their sheathing. The ‘Skydeck’ system uses faced plywood while ‘Tabla’ uses plastic plywood – both of which can be expensive to repair or replace if modified. Considering the risk of potential damages for these rented formwork systems, the Titan HV system, using standard plywood sheathing, stands out as a potential alternate.

Engineering

Given that the Titan HV formwork system may be used for the garage, it must be professionally engineered to accommodate the slab’s design. Manufacturers, such as Titan, typically have in-house engineering staff to design layouts and provide logistical support. The cost of these support services provided by Titan are included in the rental
cost of the formwork. Additional costs may be incurred to have the formwork design approved and stamped by a professional engineer in the state. As the Navy League’s garage is of a complex design, the use of any formwork system would have to be certified by a P.E.

Material Costs

While engineering may be one cost of formwork systems, the majority of formwork erection costs are from labor and the system materials. Contractors can elect to rent either of these formwork systems, or make the investment to purchase the system’s components. For the Navy League, the concrete subcontractor would most likely opt to rent the Titan system and use it on a trial basis.

As listed under Cost & Production Factors, average costs for material rental of the Titan HV system versus a standard system indicate the standard system is less expensive. Despite including labor savings of 25% for the Titan HV system, its material costs of $0.80 / Sq. Ft. / Month are a large source of the $56,224.00 cost difference. However, $56,224.00 is only a small fraction of the building’s total cost of $28 million. The cost difference is not substantial enough to eliminate the Titan HV.

Labor

Before the concrete subcontractor selects a system like Titan HV, labor costs and productivity must be taken into account. The Titan system was designed so that two men could erect 3,000 – 5,000 sq.ft. per day of a typical slab. With faster erection times, along with the drophead posts eliminating reshores, systems like Titans’ can produce as much as 30% labor savings. However, labor savings claims may not account for the type of labor. The labor force used on the Navy League is familiar with the standard metal system. Furthermore, seasoned superintendents may be hesitant to use an new type of formwork. Given these conditions, making the switch to a new system would initially cause inefficiencies and reduce potential labor savings.

Local Codes

Despite all the factors associated with formwork selection, one that overrides the others are the local building codes. Many manufacturers advertise low costs under the assumption that the decking and beam sections can be removed the day after pouring a slab. On the other hand, one must consider that many building codes are designed around the use of standard formwork and construction.

Typically, code inspectors require a formal stripping letter (usually three days after a pour) before the formwork system can be removed and reshores added. In the
Formwork System Selection (Continued)

case of the Navy League Building, Arlington county relies on the engineer of record to approve alternate stripping and reshoring procedures for the formwork system. If approved by the structural engineer, the Titan HV system can be used as advertised, and thus reduce material costs.

Reusability

To reinforce the sustainability theme of the building, formwork reusability should be addressed. Both the Titan HV and the handset aluminum system are designed to use plywood sheathing. The system as-built used ¾” thick, 4’x8’ sheets of FSC Certified plywood. On average, the contractor was able to reuse each sheet (or smaller pieces) up to three to four times before it became unusable. If selected for the project, the Titan HV would use the same type of plywood. Considering the sheathing material, the environmental impact due to wood consumption is assumed to be equal for both types of formwork.

Cost & Production Factors

<table>
<thead>
<tr>
<th>Formwork Cost &amp; Production Factors</th>
<th>Standard System</th>
<th>Titan HV System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Framing Material Unit Cost (not including sheathing)¹</td>
<td>$0.50 / Sq. Ft. / Month</td>
<td>$0.80 / Sq. Ft. / Month</td>
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<tr>
<td>Sheathing Unit Cost ²</td>
<td>$1.19 / Sq. Ft.</td>
<td>$1.19 / Sq. Ft.</td>
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<tr>
<td>Average Labor Savings ³</td>
<td>---</td>
<td>Up to 30%</td>
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<td>Formwork Construction Labor Unit Cost ⁴</td>
<td>$2.80 / Sq. Ft.</td>
<td>$2.10 / Sq. Ft.</td>
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<tr>
<td>Stripping &amp; Reshoring Labor Unit Cost ⁴</td>
<td>$0.72 / Sq. Ft.</td>
<td>$0.54 / Sq. Ft.</td>
</tr>
<tr>
<td>Average Framing Total (not including sheathing)⁵</td>
<td>$269,244</td>
<td>$430,791</td>
</tr>
<tr>
<td>Sheathing Total</td>
<td>$54,598</td>
<td>$54,598</td>
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<tr>
<td>Formwork Construction Labor Total ⁴</td>
<td>$335,118</td>
<td>$251,339</td>
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Cost & Production Factors (Continued)

<table>
<thead>
<tr>
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<th>Standard System</th>
<th>Titan HV System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripping &amp; Reshoring Labor Total 4</td>
<td>$86,174.00</td>
<td>$64,630.00</td>
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<tr>
<td>Overall Material &amp; Labor Total 6</td>
<td>$745,134.00</td>
<td>$801,358.00</td>
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<tr>
<td>Overall Cost Difference</td>
<td>$56,224.00 in favor of the Standard System</td>
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</table>

Estimating Notes:

1) Framing material cost data for the Standard System was obtained from a Washington D.C. area concrete contractor. Framing material rental cost data of the Titan HV System was obtained from the supplier.

2) Amount of sheathing required: \[ \frac{119,685 \text{ Sq. Ft. (total area)}}{3 \text{ reuses}} \times 1.15 \text{ (waste factor)} = 45,880 \text{ Sq. Ft.} \]

3) Possible labor savings of up to 30% as advertised by manufacturer. Labor savings of 25% were used as conservative estimate in calculations.

4) Formwork construction and stripping & reshoring labor cost data for Standard System was obtained from a Washington D.C. area concrete contractor. Labor cost data for the Titan HV System was obtained from the Standard System’s labor costs minus 25% in labor savings.

5) Material totals based off of 89,748 Sq. Ft. (approximately two entire levels) of framing needed during a 6 month construction period.

6) Overall material and labor totals based off of total elevated slab area; 119,685 Sq. Ft.

Conclusion

Considering the various factors used when selecting a formwork system, the pros and cons of the Titan HV system and handset aluminum system appear to balance. With the handset aluminum system providing a possible savings of over $56,000, it was concluded to be the most appropriate and most reliable system for the Navy League Building’s parking garage.
While the Titan system may indeed produce labor savings, the lack of crews experienced with its installation indicate that a standard system is a conservative choice. Other than labor issues, another major factor is the garage’s unusual design. The Titan HV may require modifications and custom-framed sections to conform to the irregular polygon shape of the building. The standard handset aluminum formwork system is more adaptable to the building and more compatible with the available labor force.

In addition to labor issues, the environmental impact of each system was considered. Given that both systems accommodate plywood sheathing, both would require equal amounts of wood. Thus, the environmental impact of the standard system is equal to that of Titan HV.

Although the analysis did not find pre-manufactured formwork to be more beneficial, it reinforced that the standard handset aluminum system is the best choice for Navy League.