ANALYSIS #3 HANGAR SLAB SEQUENCE

C-5 Fuel Cell Facility

167th Airlift Wing

Martinsburg, WV

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Construction Management

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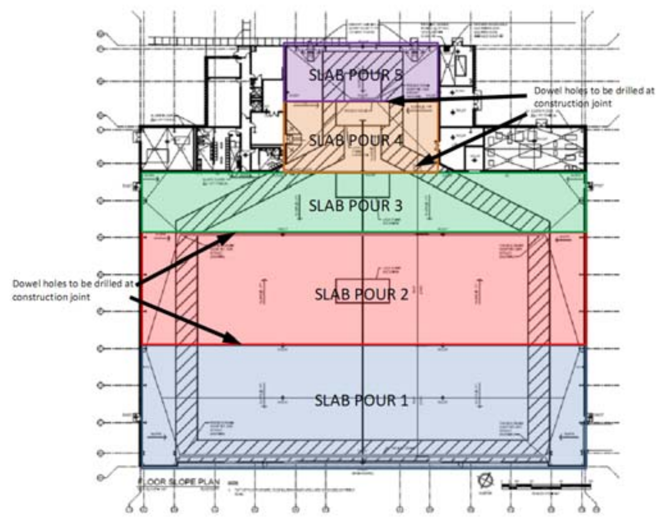
ANALYSIS 3: HANGAR SLAB SEQUENCE

BACKGROUND INFORMATION

The hangar slab of the Fuel Cell Facility, as I have been informed by the project team, must meet specific requirements according to the ANG-ETL documents from the Air National Guard, specifically regarding the placement of dowels in the concrete. The document states that all construction joints require epoxy-coated dowels which shall be placed by means of drilling the previously placed concrete. To complete this process in the correct manner, a minimum of 3 days must pass from the time the concrete is placed until the drilling can begin. In order to reduce the number of days that are spent waiting for drilling, the project team decided to complete the slab in as few sections as possible. The diagram below shows a rough plan of the different sections of the hangar slab, as constructed. The bottom two sections are each approximately 75 feet in width.



While this plan for placing the slabs certainly saves some time by eliminating the number of construction joints with dowels, it created many headaches for the project team when it came to determining effective finishing methods. The 75 feet sections are much wider than most slab pours that Kinsley Construction typically deals with on other projects. To complete the process, some of the intended finishing techniques must be modified and potentially compromised.

GOAL OF ANALYSIS

The goal of this analysis topic is to derive the most efficient sequence for the hangar slab construction for the C-5 Fuel Cell Facility project. The efficiency of the sequence will be primarily measured by cost and schedule impact, as well as productivity and expected quality of the finished product. Since the quality and productivity cannot truly be estimated by simply looking at a sequence diagram, it requires the use of historical data.

INDUSTRY SURVEY

As mentioned above, historical data was needed to perform this analysis. It was decided that the most useful form of historical data would be the experience of industry members who have actually been a part of completing large concrete pours such as the one present on the Fuel Cell Facility project. To gather the knowledge of industry members, a survey was created with a series of questions pertaining to their individual preferences for placing concrete and their observations from completing a variety of widths of concrete pours. The survey questions that were sent to the industry members are as follows:

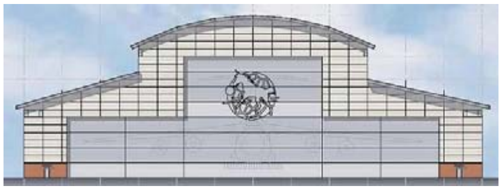
- When placing concrete, do you prefer fewer pours of larger sizes, or a greater number of pours with smaller sizes?
- Which of these options is typically completed with higher productivity?
- Based on experience, what is the largest width of a pour that can be done while maintaining maximum efficiency?
- How does the width of the pour affect the crew size that is necessary?
- How does the width of the pour affect the type of equipment that is necessary?

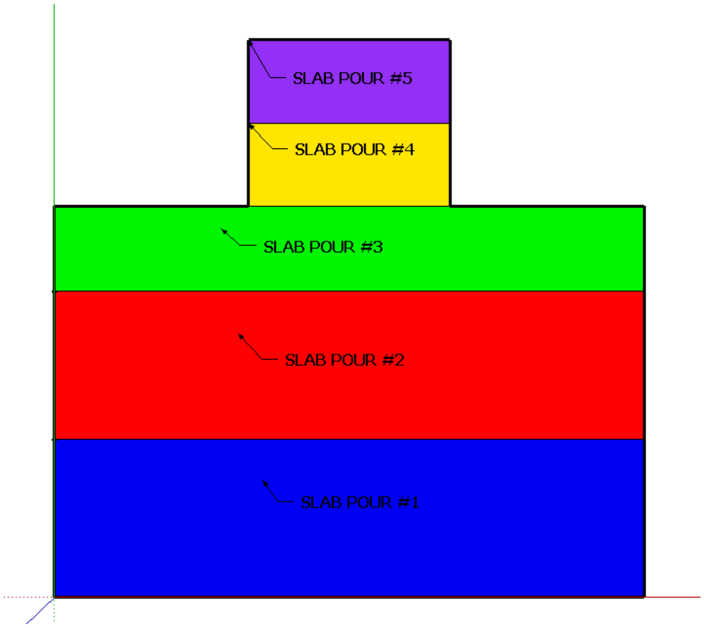
The responses were unanimously in favor of completing the project in fewer pours of a larger size, and each of the industry members surveyed stated that using larger widths of pours yields a higher productivity rate. For the question about the largest width of a pour with respect to maintaining maximum efficiency, a variety of answers was received; the range that was found was anywhere from 60' in width to 120' in width. Most of the surveyed industry members explained in their responses that using larger pour widths creates a need for a few extra workers as well as some extra finishing equipment.

It is important to note that the responses that were received did not exactly match my personal thoughts and expectations. It was not surprising that the industry members preferred fewer pours of larger widths over the greater number of smaller pours. However, it was my expectation that the widths of pours that could be completed with maximum efficiency would have been significantly lower, based on discussion with the Project Manager for the Fuel Cell Facility project. During one of my site visits, it was explained that there were issues in how to complete the finishing stage of the concrete because of the large widths of 75', as was mentioned previously. From this discussion, and due to my lack of experience, my assumption was that a 75' width was much greater than the typical size for concrete placement. Since the results of the surveys differed from the hypothesis, it was necessary to tweak the method of analysis.

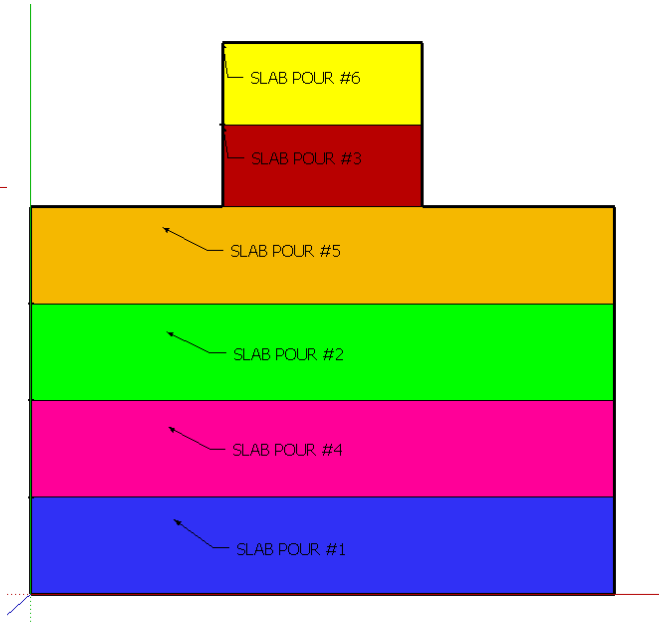
THREE SLAB SEQUENCES

The original plan for this analysis was to use the responses from the third survey question and simply average the widths to determine an approximate maximum size concrete pour that could be expected to maintain peak productivity. This maximum size pour would then be implemented into a construction sequence to determine what would presumably be the most efficient sequence for the Fuel Cell Facility project. However, when the responses simply proved that the 75' width was average, the analysis had to be adjusted. Upon the suggestion of my advisor, Dr. Chris Magent, it was decided to design three potential sequences for the hangar slab construction and then complete a cost and duration comparison to determine the most efficient sequence. Images of the three sequences are shown below.

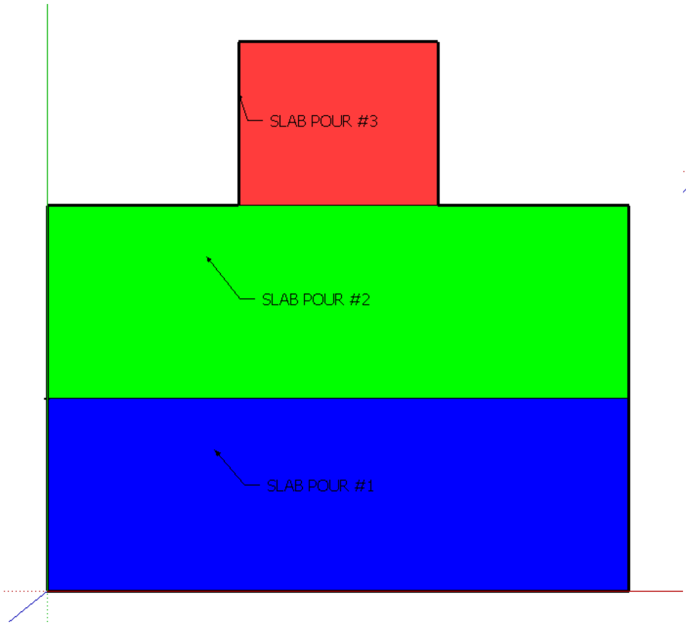




SEQUENCE #1



SEQUENCE #2



SEQUENCE #3

The first of the sequences is meant to be a rough equivalent of the sequence actually used for construction on the project. The actual design calls for an inward sloped piece around the edges of the hangar space, following the walls. However, for comparison purposes, it was decided to simplify the design since the cost of completing this portion of the slab construction would be approximately equal regardless of the sequence chosen. As can be seen in the image of Sequence #1 above, there are five separate pours of varying sizes. The first pour in the sequence has a width of the 80', the second is a 75' width section, the third pour has a 43' width, and the fourth and fifth pours each have a width of 42'. Clearly this sequence involves some pours that fall within the range of maximum width for peak productivity that was determined from the survey responses. It also includes slabs with widths below this maximum range. These slabs with the smaller width, based on the discussion with the Project Manager, were not of nearly as much concern in terms of finishing the concrete.

The second sequence of slab pours implements six different pours to be completed in alternating succession as can be seen in the image above. For this sequence, the different pours are much more similar in width; the four pours in the lower portion of the building are each 49.5' in width and the upper two are again 42' in width as in Sequence #1. The purpose of Sequence #2 is to look at completing the construction in more pours of a smaller width, as was the original intent of this analysis. Obviously the 49.5' width does not fall within the range of maximum widths that was found in the surveys, but due to the dimensions of the building, it was the most representative size to use for examining the lower end of the range while maintaining the idea of a greater number of pours. Use of this sequence would presumably allow for a higher quality finished product based on the information provided by the Project Manager.

Sequence #3 is based on the higher end of the range of maximum widths, but again was influenced by the dimensions of the building, as is any sequencing of activities. As seen in the image above, the larger widths allowed this sequence to be done in a fewer number of pours. The first two pours of this sequence each have a width of 90' and the third has a width of 84'. Using this sequence would further reduce the number of construction joints necessary, as well as the number of dowels to be drilled for, which was the reasoning by the project team for using larger width pours from the beginning. However, it also would most likely make the finishing process more difficult and potentially lower the quality of the finished product.

COST AND DURATION COMPARISON

To determine which of these three sequences is the most efficient requires comparison of some hard numbers. The quality impact of the different sequences, which was discussed in the previous paragraphs, is important but is difficult to quantify for measurement. Through the use of RS Means 2009 Construction Cost Data, an estimate for the cost of each of the three sequences was created as well as an approximate number of hours that would be required for completing the work. It is important to note before examining the estimated durations that they should not be associated directly with the construction schedule of the project. They have been derived by implementing the Crews that were included in Means and were not adjusted to meet the schedule since their creation was meant solely for comparison of the sequences against each other. These durations also do not include the 3 day waiting period necessary before drilling for the dowels.

The full estimate sheets can be found in Appendix M. The total cost and duration estimates for the three sequences are as follows:

Sequence #1: Total Cost = $408,290.78, Total Duration = 427.90 hours

Sequence #2: Total Cost = $414,533.98, Total Duration = 458.26 hours

Sequence #3: Total Cost = $401,025.78, Total Duration = 384.53 hours

The derivation of these values, as can be seen in the full estimate sheets, involved adjusting the Daily Output values to reflect the information that was provided in the surveys of industry members. Since the response to all surveys was that productivity increases with the width of the pour, as long as it is not above the maximum range, the Daily Output value provided by Means was adjusted up or down based on the width of the individual pour being analyzed. This adjustment and the quantities determined through a detailed take-off produced the results seen above. As mentioned earlier, the Total Duration values do not reflect the necessary 3 day waiting period necessary for drilling for the dowels at all construction joints in the concrete. In general, the durations of each of the three sequences would be increased when considering this factor, and though the additional time added would not be equal, the differences can be assumed to be negligible.

It is clear from the values of cost and duration listed above that the sequence with fewer pours of a larger size is cheaper and takes less time than the sequence with more pours of a smaller size. Sequence #1, which represents the as-built construction sequence falls almost right in the middle. To compare the cost of the two new sequences against the as-built sequence in terms of percentage, the numbers come out as follows:

Sequence #2: $^{(414{,}534\,-\,408{,}291)}\!/_{408{,}291} = \mathbf{1.5\%\ higher}$

Sequence #3: $^{(401{,}026\,-\,408{,}291)}\!/_{408{,}291} = \mathbf{1.8\%\ lower}$

These cost differences must also be correlated back to the difference in expected quality of the finished product. It is yet again proven that a higher quality product comes at the expense of more money and more time. Another element that may not be quite as obvious is that a higher quality product sometimes causes a reduction in productivity. To be certain that a finished product turns out well, specifically concrete in this case, extra time and care must be taken. This extra time required to be spent for a given quantity of work leads to the downfall of productivity. Maintaining both high quality and high productivity is a challenge that is presented every day in the construction industry.

CONCLUSIONS

The sequence of concrete pour sizes that was selected by the project team for the Fuel Cell Facility hangar slab construction seems to be the best option of the three sequences analyzed based on cost and duration, as well as the quality impact. It is possible that by implementing slightly larger pour widths, the cost and duration may be reduced through higher productivity, while maintaining the same level of quality. However, the dimensions and shape of the hangar area are not very conducive for creating many varieties of sequences. My recommendation, if this project were to be repeated, would be to use the same sequence and method for construction that was chosen by the project team. For other projects which may not have as much concern as far as the quality of the finish, utilizing larger pours may be more beneficial.