Achieving constructability in structural design for building structures

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Summary

Constructability in structural design is investigated by using a case study of a 21m concrete roof structure as basis for the evaluation. The case study shows that even in a case where the designer paid special attention to constructability during the conceptual phase, the contractor may still have special preferences which differ from the concept design. Therefore, by just relying on lessons learned programmes and previous knowledge, a design may not be suitably constructible for a given contractor. It demonstrates that the conceptual design is a function of a number of factors which need to be considered in conjunction with each other, rather than a merely counting on previous experience and knowledge.

Keywords: Concrete construction, constructability, roof construction

1. Introduction

A lack of constructability in a design can cause serious repercussions in the construction of a project, and mainly arises when a designer does not implement sufficient construction knowledge in the preparation of design concepts and details. Although interaction often takes place between bridge designers and contractors, the design-bid-build procurement methods which are prevalent in building construction projects, often prevent the embodiment of constructability in design concepts.

A case study of a 21m clear span concrete roof structure is used here as basis to explore the principals involved in achieving a constructible design. Based on this case study, the paper identifies the relevant considerations for constructability. Although it is often argued that experience and lessons learned programmes will assist designers in better designing for constructability, it is demonstrated that constructability is achieved through collaboration and design management processes, in addition to lessons learned programmes.

2. Project description

The facility to be constructed was a modern wine cellar, consisting of four floor levels and a flat concrete roof. The footprint of the structure has dimensions of 21m x 65m and was constructed in the hills surrounding the picturesque university town of Stellenbosch, in the heart of the Cape wine lands in South Africa. The concrete structure of the wine cellar was constructed on the slope of a hill, with a roof span of 21m covering the fermentation tank hall with a clear height of 9m from floor to ceiling.

3. Design process

An item that received particular attention by the professional team prior to tender is the concept for the roof structure. For temperature control purposes it needs a concrete roof slab and both the client and architect expressed a preference for a flat soffit. An issue of particular relevance for the construction of the roof is the height of the roof above floor level (9m). If formwork was to be supported on false work it would potentially result in a costly solution. Apart from the height, the fact that the building is located on the side of a hill would render access from the side of the building particularly difficult.

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Two options were considered. The one consisted of 21m long post tensioned concrete beams at 5m spacing supporting an in-situ concrete roof slab. The other consisted of 21m long steel girders at 5m spacing with precast floor planks. The project quantity surveyor had no preference from a cost point of view, with the main advantage of the steel girder option being the potential time saving during construction. This became the option of choice and was extensively discussed with an experienced contractor to discuss with him the erection procedure and potential risks.

4. Appointment of contractor and construction phase

Following an open tender process, the contract was awarded to a different contractor from the one who had given advice on the roof concept.

As construction started the appointed contractor approached the client and professional team with a request to reconsider the concept for the roof. He offered alternative options within the cost and schedule constraints. Specific problems that he had with the conceptual design included:

- unfamiliarity with erection of large steel plate girders,
- quality management on a concept that he was not familiar with.

The contractor offered an alternative solution of using a floor system consisting of a reinforced concrete slab with spherical polystyrene formers, a system the structural engineer was not familiar with and which had potential deflection and shear capacity issues. However, as a counter suggestion the concept of using an 800mm deep post tensioned concrete slab with 550mm diameter pipe-like void formers was put forward, an option not previously considered. This concept is often used in road over road bridges, and not in building construction. Although the building contractor had no experience with the concept, he was prepared to accept it due to his experience with reinforced and post tensioned concrete slabs.

Although the concept would require high false work to support the formwork, the contractor was able to programme the works in such a way that the original schedule could still be met, thereby obviating the need for the time saving offered through the original concept (steel girders).

The proposed solution also satisfied the client and architect who were both keen on the resulting flat soffit and limited depth in comparison with the steel girders.

5. Lessons and conclusions

Several factors play a role when a constructible design is to be chosen. There could be others (such as maintenance, community preferences, etc.) but factors that may play a role as identified in this case study include: Previous experience of the particular contractor and professional team, time constraints, cost, site access, safety of erection, available skills, and aesthetic considerations.

From this case study it can be deducted that conceptualizing a constructible design is a multi-facetted process. It is not a one way process, but one where several factors need to be considered in relation to each other. These factors do not stand in isolation, and it may not be possible to lay down quantifiable rules to determine the constructability of a design without considering the factors as part of a system. In other words, a structural concept which applies for one project, a specific client and professional team, and a chosen contractor, may not be the solution for a similar project in another environment and with other team players.

It does not mean to say that the conceptual design can only be determined in collaboration with the appointed contractor, but it does mean that the professional team need to take into consideration the known characteristics of the specific environment when the concept is developed in collaboration with the client. The specifics could include the preferences, knowledge, expertise, and risk attitude of potential contractors.