Structural Design and Construction of Falsework: A Guide to Best Practices

An Online Continuing Education Course for Engineers

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1. Introduction

Falsework consists of temporary structures used in construction to support a permanent structure until its construction is sufficiently advanced to support itself.

The British Standards of Practice for Falsework, BS 5975:2008, defines falsework as "Any temporary structure used to support a permanent structure while it is not self-supporting."

Proprietary falsework systems are used on almost every construction site worldwide. Workers erecting these systems may have little or no formal training and engineers are often reliant on technical advice from suppliers for their design and safe use. The failure of any falsework system will have serious consequences and it is therefore essential we have confidence in the technical advice given by suppliers and the falsework systems we use on our projects. Within the U.S., there are more than 10 falsework systems in common use.

The safe working loads and capacities for falsework systems are normally specified by the supplier – but it is not uncommon to have different load capacities for similar systems from different suppliers!

This course note is written to provide recommended loading capacities for the common types of falsework systems available worldwide, as well as good practice notes for their design, erection, and dismantling.

2. Falsework Risks

Falsework supports elevated horizontal concrete elements such as building slabs, bridges, and beams. For years, owners and engineers have recognized falsework as being a temporary process of construction that needs to be engineered by a licensed, professional engineer. For years, vertical construction was not in this category, but in recent years, even vertical formwork has fallen under the scrutiny of the owner and his engineer. No owner wants any sort of incident associated with the project, no matter how large or small. Figure 1, for example, shows falsework over a river using pipe post falsework. The risks of this type of work are illustrated by fall risks, equipment risks, and environmental risks at a minimum.

Figure 1 - *Pipe Post Falsework*

The intent of this course is not to prepare the structural engineer for designing and building formwork and falsework to construct the new San Francisco/Oakland Bay Bridge, the Tappan Zee Bridge in New York, or a 100-story downtown office building. The intent here is to educate the engineer about designing and building safe systems that are economically efficient and within the project's budget. The larger projects will be experienced eventually when the student builds confidence and is surrounded by a team of experts in their field.

2.1 Falsework Accidents

It seems that a year never goes by in the United States without a report of a falsework accident. These accidents are not just the result of design problems but are often caused by human error or bad decisions made by field supervisors from superintendents to foremen and below. Even though methods and procedures are just as important, if not more important than design factors in temporary structures, the focus of this course will remain on design. In any case, whatever their cause, accidents are always unfortunate, and the only good that comes from them is the inherent lesson to be learned.

Who is responsible for the design, construction, and maintenance of falsework?

Mostly, the contractor is responsible for the design, construction, and maintenance of falsework according to contract requirements. The contractor determines the type of falsework to be used and the erection and removal methods to be employed, subject to compliance with the design criteria, safety, and conditions of use found in the specifications.

Case Study of A Falsework Accident

Project Overview

Soon after the turn of the 21st century, a highway project was constructed in northern California by a

joint venture company for the State of California (owner agency). The project involved road widening, overhead bridge ramps, and accompanying drainage on Highway 149 in Butte County. Figure 2 shows typical frames (bents) and stringers (beams) in place on this project for the typical pipe falsework system.

Figure 2- *Typical falsework for this project*

The completed project would eliminate the need for surface intersections with stop signs or signals. On July 31, 2007, an overpass that was under construction collapsed.

Fortunately, no one was killed as a direct result of the collapse. However, one fatality resulted from traffic buildup, and one construction worker and one person driving underneath the collapse were injured. This relatively fortunate outcome was not the result of good decision-making or good planning but was pure luck. The contractor and the State of California dodged a deadly and costly bullet.

Forensic studies were performed, as one would expect, by Cal OSHA. However, the cause of the accident was not ultimately decided by a judge. No one served any time in prison. The injured persons settled with the contractor and insurance companies, and by 2011, one would have thought nothing had ever happened. So what actually caused the collapse of the falsework?

The Cause

A falsework bent consisting of pipes and beams collapsed onto a passing truck, nearly crushing the driver and causing a construction worker to fall when a guying cable was removed. The frames and beams were placed during a previous night shift with the highway closed in both directions with traffic detoured. During this shift, the frames were braced with wire rope guys to temporary deadmen (counterweights). Before the wire rope guys could be transferred to the adjacent bent for a more permanent attachment, the shift had ended, and the highway was reopened to traffic. The following morning shift began, and the crew and owner agency realized the guying was not complete. Instead of

setting up another road closure the following evening and correcting the situation without live traffic, the decision was made by the contractor and owner agency to relocate the guys that morning.

When the guy was released, so much tension had built up that the frame moved enough to generate momentum that toppled the frame and stringers it supported. The falsework bent failure was caused by human error. Had the plan been followed, the accident would probably have been avoided. However, had a better bracing system been designed and installed initially, this could have prevented the accident.

Corrective Measures

The project was delayed for several weeks. Once the investigation allowed the contractor to continue, a new bracing system was put into place. Figure 3 shows the new pipe bracing system in place.

Figure 3- *Push-pull braces added to falsework.*

This bracing was added to the new falsework bents that were erected after the accident. They went to a push–pull system to take the wire rope tension out of the equation and to allow bracing on only one side of the bent since traffic was on the other side.

The parties involved spent several years, after the completion of the project, in settlement negotiations. The settlements were never made public.

The next section will discuss the measures that are taken by falsework contractors and owners/ engineers to ensure that accidents due to either design to human error or incorrect methods are avoided.

3. Falsework Review Process

Two types of falsework review procedures are common in the construction industry. These review procedures are engineering checks and balances, and they are:

(1) in-house reviews and

(2) owner/engineer reviews.

In-House Reviews In-house reviews occur within the company performing the falsework erection and removal. This part of the process can, and frequently does, involve consulting engineers when the contractor does not have an engineer on his payroll or its engineering staff is too busy. Regardless of the engineering component, this group represents the contractor.

Some contractors develop written procedures that are followed during the design process prior to submitting it to the owner/engineer. These written procedures contain some of the following information:

- ✓ Type of falsework risk
- ✓ Eligibility of persons involved
- ✓ Redundancy
- ✓ Risk avoidance

The contractor must categorize the risk somehow. An example would be to rate the falsework type as low, medium, or high risk. Once the levels have been decided, each risk level would represent a specific type of falsework. In other words, the lower risk falsework would be used for the most straightforward, easier systems; higher risk falsework would be used for projects spanning sensitive waters, busy highways, or in very tall systems. Table 1 has been prepared as one of many options for a review policy matrix. The dimensions used are recommendations or estimates. Each company should consult its legal department before preparing a similar policy.

Each company should develop a policy, communicate that policy to the employees, and manage the policy. Obviously, some terms would still have to be carefully defined in the document. For instance, the word “minimal” could mean different things to different people. The policies cannot have vague wording or contradictions.

TABLE 1 Example of Falsework Risk Categories

Risk Category	1. Designer and 2. Check Engineer	Falsework Type
Low	1. In-house engineer, consultant engineer 2. In-house engineer, ng engineer (not th	Elevation less than or equal to 20 ft in height, beam spans less than or equal to 30 f No risk to public; no nt.
Medium		r equal to 30 ft in s less than or equal inimal risk to roadways, ironment.
High		30 ft in height, 40 ft in length, is risk to public, lroads, and probability ment, both stantial s.

Persons who are n no case should these two these two responsibilities b may not want any in-house involvemer subcontracted to a consulting firm. Each company should e and write a specific policy that addresses the most critical management concerns.

Owner/Engineer Reviews On the other side of the owner/engineer, similar concerns are shared for possibly different reasons. No owner/engineer wants any problem of any kind to occur during the construction process. Since falsework comes with additional risks from normal construction activities, it is scrutinized to a higher degree. Falsework approvals are, in fact, so important to CalTrans that the CalTrans Standard Specifications manual contains a separate specification section for falsework. Their specifications cover anything that has or could possibly go wrong on a highway project.