Bridge Falsework Productivity—Measurement and Influences

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Abstract: One principal element of the construction cost of a cast-in-place prestressed box girder concrete bridge is the erection of falsework. This paper presents the results of the analysis of labor-hours and quantity of work in erecting the falsework for 20 such bridges. Analysis of the bridge data has shown that the best productivity for falsework erection occurs when constructing a low structure on relatively flat ground. Location and design factors such as steep slopes, traffic openings, and tall structures, as well as such construction techniques as the use of cranes or lifts and the type of bent material selected, can reduce falsework erection productivity (measured through installation data for setting of pads, constructing bents, setting stringers, and rolling out the soffit) by over 50%. A belief network diagram was constructed to show graphically the falsework erection productivity influences identified through a study of the 20 bridges. With the collection of additional data, the belief network can be used to calculate a total falsework erection productivity value based on dozens of combinations of influencing factors.

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Introduction

The majority of bridge structures constructed in California since 1982 have used a cast-in-place prestressed box girder design, and over the years highway contractors have refined the construction methods for these specialized structures (Hampson and Fisher 1997). One principal element of the cost of such bridge projects is the construction of falsework. Falsework may be defined in general terms as temporary construction work on which a permanent work is wholly or partly supported until the structure becomes self-supporting. In cast-in-place construction, the falsework provides a stable work platform upon which the concrete forms are set, as well as furnishing support for the concrete superstructure until it has achieved sufficient strength to support itself. With prestressed bridges, the falsework also functions to support any load distribution due to the prestressing of the concrete.

Falsework technologies are identified as a particularly important element in gaining and maintaining a competitive advantage for the construction of these bridges (Hampson and Fisher 1997). The majority of falsework designs are similar, but vary in order to accommodate the different locations and geometrics of the new bridges being constructed. Falsework productivity, however, can range widely, depending upon the particular project, with simple structures achieving significantly higher productivity than complex structures. The purpose of this paper is to identify and quantify the fundamental elements that influence falsework installation productivity. The benefits of the findings of this research are to provide productivity measurement techniques and standards to assist estimators and managers during the bidding and construction of cast-in-place concrete bridges.

Background

On all bridge construction projects, regardless of productivity objectives, the contractor shall be responsible for designing and constructing safe and adequate falsework that provides the necessary rigidity, supports the loads imposed, and produces in the finished structure the lines and grades indicated in the plans (Caltrans 1995). Having satisfied safety requirements, several techniques exist for a manager to use in the study of productivity. Productivity improvement efforts focus on three areas—work-study techniques, planning improvement processes, and crew-level factor analysis.

Falsework, like many construction activities, is unique; hence, the application of industrial engineering work-study techniques as a tool to analyze productivity would likely be inaccurate because of the complexity and nonunique nature of each step in the process (Thomas et al. 1990). Planning improvement techniques have been shown to be effective in a variety of types of construction work, and further study in this area could potentially improve the entire falsework erection process (from procurement of materials to final placement) (Laufer and Cohenca 1990; Thomas and Sanvido 2000). The scope of this study, however, is to focus on influences on field-level operations. A crew-level factor model for labor productivity is therefore better suited to study the productivity of a task such as falsework erection. The factor model methodology identifies the project, site, and management factors that affect productivity (Thomas et al. 1990).

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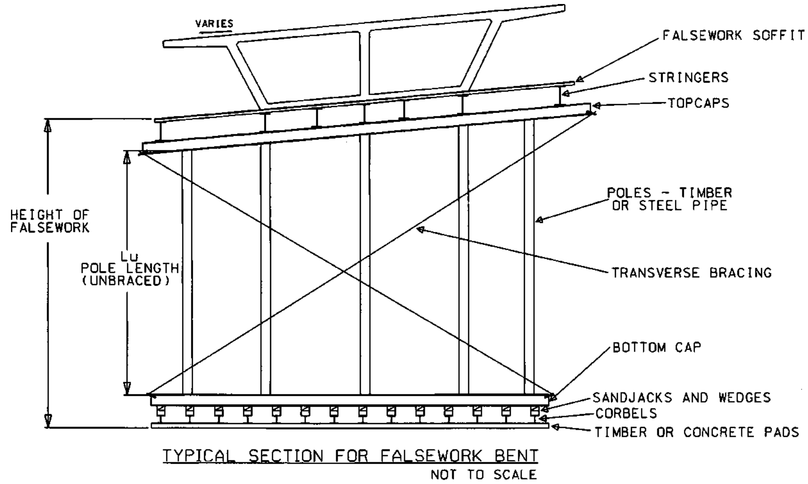

Fig. 1. Typical falsework structure and components

Assessment of Productivity

The first step in the assessment of productivity when using a factor model is task definition and identification of factors. Falsework construction for a cast-in-place prestressed concrete box girder bridge typically consists of four elements:

1. Setting of pads,
2. Constructing bents,
3. Setting stringers, and
4. Rolling out soffit.

Each of these four elements is shown in the drawing of a typical falsework structure in Fig. 1. Through observation of the work and contractor past experience, the factors identified as potential productivity impacts were native ground conditions (level or sloped), falsework design (timber or steel member, use of crane or lift), and the final bridge design (span and height, which dictate material and equipment used).

Databases for the four activities and multiple factors identified above were used to develop productivity measures. The falsework erection databases consist of

- Techniques used to complete task,
- Quantity of work completed for task,
- Work hours to complete task, and
- Site conditions at time of work.

Data for each of the four falsework construction steps is included in a database derived from six separate projects consisting of a total of 20 bridges. The contract value of these six projects ranged from $18 million to $63 million each. Table 1 summarizes the contracts where the contract values listed are approximate values at the time the contract was bid and awarded, excluding extra work. Each bridge was similar in scope, being designed following California Department of Transportation (Caltrans) standards for cast-in-place prestressed concrete box girder bridges. The database contains a total of 38,188 labor-hours. For each of the 20 bridges, labor-hour data were summarized using the contractors' accounting software, input directly from the workers' time cards.

Table 1. Description of Contracts

Project number	Number of bridges	Contract value
1	3	$21,000,000
2	5	$46,000,000
3	6	$63,000,000
4	2	$19,000,000
5	3	$18,000,000
6	1	$52,000,000

Setting of Pads

The first step in erecting falsework is setting the timber or concrete pads upon ground that has already been graded and compacted as required and on which pad locations or bent lines have been laid out. The pads serve as a means of transferring the dead and live loads of the structure under construction to the ground prior to posttensioning. Pads are typically placed along a falsework bent line using either a forklift or a crane, depending on access and pad dimensions. As the pads are being placed along a bent line, corbels, wedges, and sandjacks are placed on top of the pads in preparation for the bottom cap, which is typically a W-shape steel beam that runs the length of the bent line or is divided into maneuverable lengths. The bottom cap distributes the bridge's concrete and live loads along the length of the bent line to ensure even settlement of the pads and is placed with either a forklift or a crane. Once the bottom caps have been set and leveled, it is the responsibility of the field engineer to check the elevation at the ends of the caps to determine the length of the poles to be used at the bent. Fig. 2 shows timber pads and steel bottom caps on sloped ground.

Total labor-hours for the setting of pads include the pads (either timber or reinforced concrete), corbels, sandjacks, wedging, and bottom caps. The bridges in the data set comprise three separate sets of site conditions (productivity factors):

1. Native ground is relatively flat, with easy access using forklifts;
2. Native ground is sloped, pads to be placed near existing roadways, small vertical and horizontal distances between bent lines, access slightly limited using forklifts and cranes; and
3. Native ground is steeply sloped, pads to be placed near existing roadways, large vertical and horizontal distances between bent lines, limited access using forklifts and cranes.

Table 2 shows the productivity results for the pad placement activity across these three states. As can be seen from the table

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Fig. 2. Timber pads and steel bottom caps on sloped ground

results, the flatter the native ground, the higher the productivity. An average of 1.16 pads per labor-hour can be placed on flat ground, compared to 0.82 pads per labor-hour for moderately sloped ground, and 0.50 pads per labor-hour for steeply sloped ground. The slopes reduce productivity by 25 to 60% because of unfavorable access and the need for cranes (as opposed to forklifts). Crane size and location must be well thought out since larger cranes require longer swing times and take longer to move and set up between locations. When a new bridge is spanning a steeply sloped surface, stair stepping of the native ground is required to provide a level surface for the pads. This may require many moves of the crane to accommodate the various elevations, thereby further reducing productivity.

Constructing Bents

Once the field engineer determines the pole lengths, the poles for the bent are cut to size. The bent itself consists of a top cap (typically a W-shape steel beam the same length as the bottom cap), the designed number of poles (typically a 305×305 mm (12×12 in.) timber pole or a steel pipe), and any required lateral bracing as designed and depicted in the falsework plans. The bent can now be stood in place using a crane. Knowing the weight of the bent, the radius and layout for crane positioning are determined. When using timber poles, the first bent is set and braced to stand alone using a temporary A-frame attached to the top cap and braced to the ground. The remaining bents can now be set and cross braced to previously erected bents. When setting steel poles, a crane is required to hold the bent in position until it can be properly braced. All bents must be plumb prior to being released from the crane. The bent serves as a support for the stringers, transferring the stringer loads to the bottom caps. Fig. 3 shows timber poles as part of a falsework assembly.

Depending on the height of the falsework, 305×305 mm (12×12 in.) timber posts, round timber poles (telephone poles), 457 mm (18 in.) diameter or 508 mm (20 in.) diameter steel pipe assembled into a falsework bents are used. A rough-cut 305×305 mm (12×12 in.) timber post is used with an unsupported height of up to approximately 5.5 m (18 ft). Round timber poles also work well. It is important for the falsework erection crews to keep the poles plumb. Pole heights above ±5.5 m (18 ft.) are usually accomplished by using steel pipe, since the additional bracing of the wood pole becomes expensive. Falsework bents constructed of steel pipe tend to be heavy and will affect the crane size required on a project. Cutting and welding steel pipe is also more labor intensive than working with wood, so use of pipe

Table 2. Setting of Pads Productivity Data

Work condition	Project number	Bridge number	Units of measure	Labor hours used	Quantity installed	Productivity (units/labor hour)	Average productivity (by work condition)
Native ground is relatively flat, with easy access using forklifts	2	2	Each	172	180	1.05	
	2	4	Each	82	99	1.21	
	3	1	Each	132	143	1.08	
	3	2	Each	143	186	1.23	
	4	1	Each	137	170	1.24	1.16
Native ground is sloped; pads to be placed near existing roadways; small vertical and horizontal distances between bent lines; access slightly limited using forklifts and cranes	2	1	Each	195	158	0.81	
	2	3	Each	156	128	0.82	0.82
Native ground is steeply sloped; pads to be placed near existing roadways; large vertical and horizontal distances between bent lines; limited access using forklifts and cranes	1	1	Each	494	208	0.42	
	1	2	Each	451	262	0.58	
	1	3	Each	243	114	0.47	
	2	5	Each	235	135	0.57	
	3	3	Each	101	65	0.64	
	3	4	Each	264	155	0.59	
	3	5	Each	195	64	0.33	
	3	6	Each	912	516	0.57	
	4	2	Each	457	176	0.39	
	5	1	Each	219	104	0.47	
	5	2 and 3	Each	527	306	0.58	
	6	1	Each	272	120	0.44	0.50

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Fig. 3. Timber poles

Fig. 4. Topcaps and stringers

is limited to taller falsework situations. Due to the extensive amount of work required to assemble and erect steel pole bents, productivity is usually much lower compared to the shorter timber bents.

The bridges in the data set comprise three separate sets of site conditions (productivity factors):

1. Native ground is relatively flat, with easy access using forklifts, timber poles, structure height ± 6 m (20 ft);
2. Native ground is sloped, bents to be placed near existing roadways, access slightly limited using forklifts and cranes, timber and shorter steel poles, structure height between 6 and 15 m (20 and 50 ft); and
3. Native ground is steeply sloped, bents to be placed near existing roadways, access using cranes exclusively, steel poles, structure height above 15 m (50 ft.).

Table 3 shows the productivity results for constructing bents across these three states. As can be seen from the tabulated results, as was the case for setting pads, the flatter the native ground, the higher the productivity. The timber bents result in the highest productivity, as expected. The influence of slopes does reduce productivity by about 45% due to issues involving using a crane for placement, as previously mentioned. The steel pole bents utilize many labor-hours to construct (with a larger crew), and a crane is needed for every stage of work; hence their productivity is significantly lower (75%).

Setting Stringers

When a sufficient number of bents have been stood up, the stringers may be placed. Once the layout for the stringers has been

Table 3. Constructing Bents Productivity Data

Work condition	Project number	Bridge number	Units of measure	Labor hours used	Quantity installed	Productivity (units/labor hour)	Average productivity (by work condition)
Native gound is relatively flat, with easy access using forklifts; timber poles, structure height +/−20′	2	4	Each	222	99	0.45	
	3	1	Each	268	143	0.53	
	3	2	Each	339	176	0.52	
	3	3	Each	130	65	0.50	
	3	4	Each	351	155	0.44	
	4	1	Each	162	70	0.43	0.48
Native ground is sloped; bents to be placed near existing roadways; access slightly limited using forklifts and cranes; timber and shorter steel poles, structure height between 20 and 50′	1	1	Each	527	208	0.39	
	1	2	Each	758	262	0.35	
	1	3	Each	117	46	0.39	
	2	1	Each	768	158	0.21	
	2	2	Each	412	122	0.30	
	2	5	Each	475	135	0.28	
	3	5	Each	174	64	0.37	
	3	6	Each	1415	516	0.36	
	6	1	Each	377	120	0.32	0.33
Native ground is steeply sloped; bents to be placed near existing roadways; acess using cranes exclusively; steel poles, structure height above 50′	2	3	Each	280	33	0.12	
	4	2	Each	1173	176	0.15	
	5	1	Each	462	22	0.05	
	5	2	Each	1102	42	0.04	
	5	3	Each	884	40	0.05	0.08

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Table 4. Setting Stringers Productivity Data

Work condition	Project number	Bridge number	Units of measure	Labor hours used	Quantity installed	Productivity (units/labor hour)	Average productivity (by work condition)
Native ground is relatively flat; timber stringers	2	4	Each	90	104	1.16	
	3	1	Each	67	260	3.88	
	3	2	Each	121	260	2.15	
	3	3	Each	191	162	0.85	
	3	4	Eahc	261	430	1.65	
	4	1	Each	171	216	1.26	1.82
Native ground is relatively flat; steel or traffic opening stringers	2	4	Each	112	32	0.29	
	3	1	Each	243	87	0.36	
	3	2	Each	190	32	0.17	
	4	1	Each	1.4	51	0.49	0.33
Native ground is sloped; timber stringers	1	1	Each	125	204	1.63	
	1	2	Each	218	160	0.73	
	1	3	Each	48	40	0.83	
	2	1	Each	173	260	1.50	
	2	2	Each	76	86	1.13	
	2	5	Each	169	60	0.36	
	3	5	Each	34	108	3.18	
	3	6	Each	145	804	5.54	
	4	2	Each	152	212	1.39	
	6	1	Each	116	127	1.09	1.74
Native ground is sloped; steel or traffic opening stringers	1	1	Each	344	207	0.60	
	1	2	Each	562	329	0.59	
	1	3	Each	217	102	0.47	
	2	1	Each	380	186	0.49	
	2	2	Each	140	153	1.09	
	2	5	Each	130	104	0.80	
	3	5	Each	74	54	0.73	
	3	6	Each	851	511	0.60	
	4	2	Each	518	118	0.23	
	6	1	Each	137	86	0.63	0.62
Native ground is steeply sloped; timber stringers	2	3	Each	231	55	0.24	
	5	1	Each	33	38	1.15	
	5	2	Each	173	42	0.24	
	5	3	Each	50	48	0.96	0.65
Native ground is steeply sloped; steel or traffic opening stringers	2	3	Each	258	110	0.43	
	5	1	Each	206	132	0.64	
	5	2	Each	661	360	0.54	
	5	3	Each	586	259	0.44	0.51

determined and crane location and staging requirements are satisfied, the setting of stringers may begin. Stringers can be made of either timber or steel and are typically 6 to 27 m (20 to 90 ft.) in length. Stringers are set in place one by one, spaced as determined in the falsework design. Typically stringers will be at the edge of the deck and under each girder line of a bridge. The stringers transfer the weight of the bridge between bent lines to the top caps. Bridge contractors use both timber and steel stringers. Timber stringers are used to span short distances, usually 6 m (20 ft.) or less. They are commonly placed at spans that support the structure bent caps and are also used in low falsework spans in which it is desirable to allow the falsework to crash to the ground when it is being stripped. When a new structure is crossing over an existing roadway, traffic stringers are required. These roadway traffic stringers are made of steel and enable the falsework to span the long distances needed to cross existing roadways in lengths as long as 27 m (90 ft.). Fig. 4 shows topcaps and stringers as part of a falsework assembly.

Similar difficulties exist for placing stringers as with bents. Crane access is an influence on productivity. Sometimes, when the bents are short and timber stringers are used, a forklift may be utilized. Proper staging of material is required to ensure an even

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Table 5. Rolling Our Soffit Productivity Data

Work condition	Project number	Bridge number	Units of measure	Labor hours used	Quantity installed (m^2)	Productivity (m^2/labor hour)	Average productivity (by work condition)
Spacing of 100×100mm (4×4″) joists is 89 mm (3.5″) center to center (solid)	2	4	m^2	414	1,651	3.99	
	2	5	m^2	300	1,051	3.50	
	4	2	m^2	1.078	3,525	3.27	3.59
Spacing of 100×100 mm (4×4″) joist is 178 mm (7″) center to center	1	2	m^2	892	5,197	5.83	
	3	1	m^2	375	2,677	7.14	
	3	2	m^2	399	2,900	7.27	
	3	3	m^2	155	740	4.77	
	4	1	m^2	277	1,628	5.88	6.26
Spacing of 100×100 mm (4×4″) joist is 230 mm (9″) center to center	2	1	m^2	411	3,613	8.79	
	2	3	m^2	187	1,637	8.76	
	3	4	m^2	255	1,895	8.42	
	3	5	m^2	160	1,358	8.49	
	5	1	m^2	662	4,100	6.19	
	5	2	m^2	566	5,209	9.20	
	5	3	m^2	758	4,200	5.54	7.91
Spacing of 100×100 mm (4×4″) joists is 305 to 400 mm (12 to 16″) center to center	1	1	m^2	502	5,215	10.39	
	1	3	m^2	191	2,111	11.05	
	2	2	m^2	213	2,473	11.61	
	3	6	m^2	968	11,089	11.46	
	6	1	m^2	298	3,062	10.27	10.96

flow of material for the crane to place onto the bents. The main influence of setting stringers is how high the bent top caps are above the ground. The taller the structure, the lower productivity typically will be. Larger cranes with longer setup and swing times are required, resulting in lower productivity. Most structures comprise both timber and steel stringers.

The bridges in the data set comprise six separate sets according to the site conditions for setting the stringers:

1. Native ground is relatively flat—timber stringers;
2. Native ground is relatively flat—steel or traffic opening stringers;
3. Native ground is sloped—timber stringers;
4. Native ground is sloped—steel or traffic opening stringers;
5. Native ground is steeply sloped—timber stringers; and
6. Native ground is steeply sloped—steel or traffic opening stringers.

Table 4 shows the productivity results for setting stringers across these six states. As can be seen from the table results, productivity depends on ground conditions and stringer material. The table shows that timber stringers yielded the highest productivity, ranging from 0.65 stringer per labor-hour on very steep ground to 1.85 stringers per labor-hour on flat ground. Due to access limitations, the best results are on flat ground. Very poor productivity was achieved on flat ground with steel stringers because the cranes were required to move and set up often; on sloped ground the crane can be set higher and access many locations, resulting in fewer moves.

Rolling Out Soffit

The final stage in the falsework is the "rolling out" of the soffit. The soffit typically consists of 100×100 mm (4×4 in.) timber joists up to 6 m (20 ft.) long, set perpendicular to the stringers spaced anywhere from solid to 400 mm (16 in.) center to center, depending on stringer layout and loading requirements. On top of the joists, 16 mm (5/8 in.) plywood sheeting is placed, which will serve as the form for the bottom slab, or soffit, of the bridge concrete. This system effectively supports the concrete bridge prior to concrete curing and stressing. The concrete load and construction live loads transfer through the plywood to the joists and finally to the ground.

The conventional soffit typically employs 1,219×2,438 ×16 mm (4 ft.×8 ft.×5/8 in.) thick sheets of plywood and 100×100 mm (4×4 in.) joists. The plywood is nailed at the corners to the 100×100 mm (4×4 in.) joists. Laminated joists that are much stronger have been used in the past, but typically Douglas fir is the economical choice. Joist spacing is determined by the loading and designed spacing of the stringers below. When the falsework is stripped, nearly all of the joists can be reused. The sheeting will see three to five uses; however, at least 10 to 20% is lost due to the customized fitting required around columns. A handrail is installed along the edge of the soffit. Timber or steel posts are connected to joists as 2,438 mm (8 ft.) intervals with a 91 kg (200 lb) lateral capacity, and 50×100 mm (2 × 4 in.) members are secured 1,067 mm (42 in.) above the soffit and also at midheight.

The design of the soffit attempts to maximize the joist spacing. Typical spacing for a medium depth structure would be 305 to 400 mm (12 to 16 in.). Under the heavy loads at the bent caps the joists would be placed solid. Cost analysis shows that it is more effective to space the joists wide than to increase joist spans. In other words, it is more cost effective to set an extra stringer for support than to add extra joists. The bridges in the data set com-

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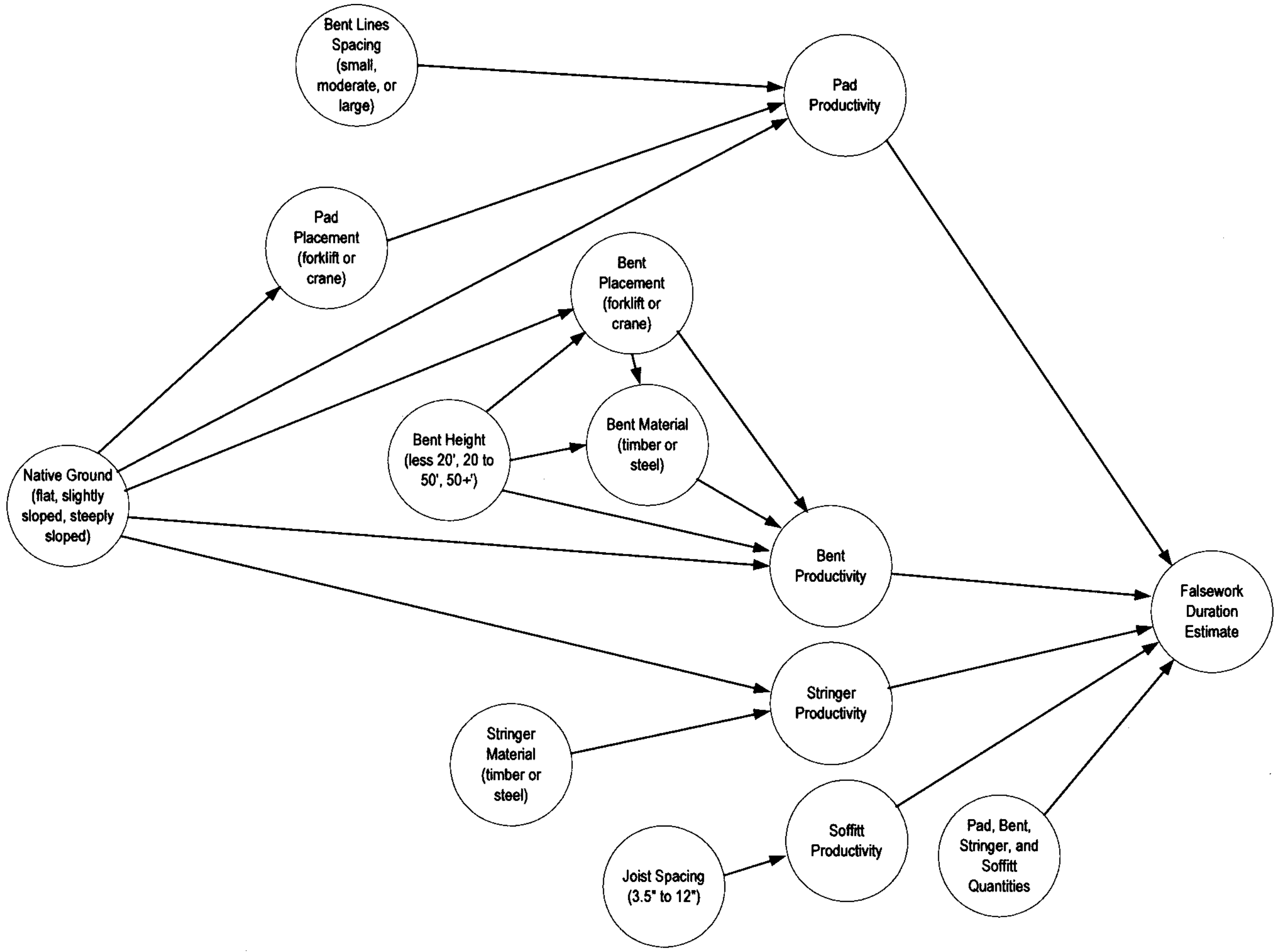

Fig. 5. Belief network of falsework duration estimate

prise four separate sets of site conditions for rolling out of the soffit:

1. Average spacing of 100×100 mm (4×4 in.) joists is 89 mm (3.5 in.) center to center (solid);
2. Average spacing of 100×100 mm (4×4 in.) joists is 178 mm (7 in.) center to center;
3. Average spacing of 100×100 mm (4×4 in.) joists is 230 mm (9 in.) center to center; and
4. Average spacing of 100×100 mm (4×4 in.) joists is 305 to 400 mm (12 in. center to center).

Table 5 shows the productivity results for rolling out the soffit across these four conditions. As shown in the table, the main influence on productivity is the spacing of the joists. The wider the joist spacing, the higher the productivity. Due to the various thicknesses of concrete to be supported and the stringer locations, the spacing can range from as little as 89 mm (3.5 in.) center to center (or solid) to 400 mm (16 in.) center to center. Joist spacing can range within a structure, depending on stringer spacing; as expected, the wider the joist spacing the higher the productivity. It is easy to see why 400 mm (16 in.) joist spacing is desired when a productivity of 10.96 m^2 per labor-hours (117.94 sq ft per labor-hour) is achieved at 305 to 400 mm (12 to 16 in.) spacing compared to 3.75 m^2 per labor-hour (40.31 sq ft per labor-hour) when they are placed solid. Labor-hours are reduced because a much smaller number of joists are handled, also lowering the amount of material required.

Table Analysis/Belief Network

Refined in the early 1980s, the quantitative mathematical tool of Bayesian belief networks was specifically created for modeling and solving uncertainty problems (Olmstead 1983; Ashley and Perng 1987; Jeljeli and Russell 1995; Diekman et al. 1996). Belief networks are a graphical tool constructed from nodes and arcs where each node represents a discrete variable with a set of possible states and each arc represents an influence, thereby indicating a probabilistic dependency between the nodes. By combining many nodes, a model of influences on a construction process can be created and used to analyze a problem and assess uncertainty.

The intuitive nature of the belief network diagramming process makes this a tool well suited to capturing the findings of the bridge falsework data. Based on the data from Tables 2 to 5, a complete picture of influences on falsework productivity can be created. Fig. 5 shows the belief network diagram for the process. The diagram shows the importance of native ground condition (with five successor arcs) and bent height (with three successor arcs) for productivity. These two areas represent the key items for designers, estimators, and construction managers to examine when considering bridge location, design, cost, and productivity. Further analysis of the diagram is possible as additional data are collected. Future research should investigate how best to incorporate jobsite data into the diagram to allow a mathematical solution of the network with which users may predict productivity out-

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comes, given specific site conditions and bridge size and characteristics.

The present data set combines field-measured values for four nodes—pad productivity, bent productivity, stringer productivity, and soffit productivity—based upon combinations of influences on each node. For example, productivity values for bent installation are known only if a forklift is used and the ground is level, not if a crane is used and the ground is level. Additional data collection coupled with the mathematical power of the belief network of Fig. 5 will allow dozens of combinations of influences to be analyzed for a total falsework productivity value assessment.

Assessment of node contents and probabilities can be done by experts based upon past experience. Research has proven the effectiveness of the use of this method to determine node contents (McCabe 1998), but as the number of conditioning influences on a node increases, expert predictions of outcomes and associated probability assessments are less desired. Ideally, as additional filed data are collected across numerous projects, actual field data could be used to determine node contents. Combining the work-related database fields with crew interruption records, labor productivity data for crews that are interrupted during a work task in a specific location can be determined. This building of layers of influence conditions upon a base of expected productivity values is the fundamental tool used to supply outcomes and probabilities for all diagram nodes. Note, however, that a consistent, extensive data collection effort is needed to reach the level where all node outcomes for all conditions can be assessed. Once data are available, researchers have developed graphical or mathematical techniques that can be used to create the node outcomes and their probabilities (Spetzler and Zamora 1984; Kuprenas 1988).

The belief network tool in its current stage is best used as a communication tool. A manager or engineer can look at the figure and gain an understanding of the complexity of the process and the root cause influences on productivity. One can look at the network and see the importance of native ground condition across several productivity influences. When planning or bidding a project, an engineer may use this knowledge to assess the need to factor in costs and methods to improve native ground conditions and then use the quantitative power of the belief network to balance this effort against decreased productivity and a higher framework duration estimate.

Conclusions

Falsework technologies are identified as a particularly important element in gaining and maintaining a competitive advantage for the construction of concrete cast-in-place prestressed box girder bridges. This paper has identified and quantified the fundamental factors that influence falsework installation productivity. A database of labor-hours and quantity of work installed was created from data from six different projects with a total of 20 separate bridges, ranging in construction cost from $18 million to $63 million.

Analysis of the bridge data has shown that the best productivity for falsework erection occurs when constructing a low structure on relatively flat ground. Location and design factors such as steep slopes, traffic openings, and tall structures, as well as construction techniques such as the use of cranes or lifts and the type of bent material selected, were shown to influence falsework construction task productivity. Productivity measurements for setting of pads, constructing bents, setting stringers, and rolling out the soffit vary by over 50% within each of these tasks, based upon combinations of factors influencing the task.

These new standards enable contractors to better understand the complexities of falsework erection and to be more competitive when submitting bids on future bridge projects. A belief network was constructed to graphically show the falsework productivity factors identified through the productivity study and their relationship to one another. With the collection of additional data, the belief network can be used to calculate total falsework erection productivity values based on dozens of combinations of influencing factors and can be expanded to include other bridge construction elements.

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