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Three Short-Span Concrete Bridges in Greater Vancouver

Trois ponts en béton, de courtes travées dans le Grand Vancouver

Drei Beton-Brücken mit kurzen Spannweiten in Greater Vancouver

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SUMMARY
Significant constraints upon construction activities can exert a profound influence upon the economics of various bridge design alternatives and their methods of construction. In many instances, unusual or innovative techniques are appropriate. Three examples of current projects where site constraints played a predominant role in the design and execution of short-span concrete bridges are presented. The particular requirements of each site dictated a novel design approach, unusual construction operation, or the adaptation of standard techniques for special purposes.

RESUME
Des contraintes importantes sur des activités de construction peuvent influencer énormément le coût des variantes d'un projet et leur méthode de construction. Dans bien des cas des techniques nouvelles ou exceptionnelles sont appropriées. Trois exemples de réalisations illustrent le rôle prédominant de contraintes locales sur le projet et la réalisation de ponts courts en béton armé. Les conditions particulières de chaque chantier ont conduit à une nouvelle variante de projet, à une phase inhabituelle de construction, ou à une adaptation de techniques conventionnelles à des besoins particuliers. Les conditions nécessaires de chaque endroit a conduit à une approche unique dans le projet, les méthodes spéciales ou l'adaptation de méthodes traditionnelles pour l'utilisation spéciale.

ZUSAMMENFASSUNG
Beträchtliche Einschränkungen in der Bautätigkeit können in der Planung und der Bauausführung entscheidende Einflüsse auf die Kosten von Brückenkonstruktionen ausüben. In vielen Fällen müssen ungewöhnliche und neue Bauweisen in Betracht gezogen werden. Drei Beispiele gegenwärtiger Projekte von Betonbrücken mit kurzen Spannweiten, bei denen Einschränkungen an der Baustelle eine bedeutende Rolle im Entwurf und der Bauausführung spielten, sind hier dargestellt. Die besonderen Anforderungen der verschiedenen Baustellen forderten eine neue und fortschrittliche Entwurfsplanung, ungewöhnliche Bauweisen, oder eine Anpassung der konventionellen Bautechnik für spezielle Fälle.

1. INTRODUCTION

Three examples of short-span bridges, recently completed, or currently under construction in the Greater Vancouver area of British Columbia, Canada, have demonstrated the influence that site contraints have exerted upon the methods adopted for their construction. In each case the particular site constraints limited either the bridge design or the construction techniques to a narrow range of options, although the price tendered for each structure suggests that this did not result in any financial penalty; all three tender prices were at or below normal construction rates for bridges of this size.

Despite the markedly differing nature of the sites, each example demonstrates the close relationship between design and construction in bridgeworks. The unique nature of each bridging requirement demanded novel solutions, yet in no case has this resulted in undue difficulties. It is believed that the bridges described herein illustrate how designs can be developed using standard construction techniques, albeit in an unusual way, without any sacrifice in the economy, durability, and elegance prevalent in successful bridges.

2. LANGLEY BYPASS BRIDGE

2.1 Background

Scheduled for construction in mid-1984, the new bypass bridge will carry the Langley bypass over the Nicomekl River, in Langley, B.C. The bridge, shown in Figure 1, is 35 m long by 24 m wide, and carries the four-lane highway, a left-turn lane, median and sidewalks. The bridge is intended as a replacement for the load-restricted 208th Street bridge.

Unlike the nearby 208th Street Bridge, which is submerged frequently by floodwater, the bypass is located on embankment across the Nicomekl's flood plain. To minimize the restriction on the passage of floodwater at the new bridge site, the deck soffet is located above the estimated 1 in 200-year flood. Only 850 mm above this elevation was available for construction depth, as the new bypass profile has to intersect with the Fraser Highway, close by the north end of the bridge. A two-span structure, supported by abutments and a central pier, was possible but construction would have had a major impact on the river. Additionally, the weak nature of the subsurface deposits caused problems with aseismic design of the substructure; the high lateral loads resulted in an uneconomical number of piles, thus the scheme proved to be more costly than the design selected.

Elimination of the abutments and the introduction of a pier on each side of the river resulted in a central span of 22 m and two 6.5-m long cantilever side-spans. Shorter than a central support, these piers share the seismic loads and experience minimal earth-pressure. The deck extremities abut the road embankments and carry the articulated approach-slabs, which effect the transition from earthfill to structural support. The deck comprises twin post-tensioned concrete slabs which are voided over the central span, linked by a transverse-spanning deck slab and provided with edge cantilevers.

The piers each comprise seven 600-mm diameter columns on a common pilecap supported by 54 timber friction-piles, all battered at 3:1. This arrangement permitted ductile-frame aseismic design of the bridge; with a check to ensure adequacy of the piles at maximum ultimate column-strength. The finalized pile arrangement was particularly efficient, with a maximum pile load of 285 kN. Battered piles were necessary because of the very poor subsurface conditions, which were incapable of adequately supporting vertical piles; the upper eight metres of subgrade being subject to liquifaction during earthquakes.

2.2 Construction

Before construction began, the Nicomekl River paralleled the south shoulder of the Fraser Highway. During 1983 the bypass embankment was built, and the river channel relocated some 20 m further south. The river diversion was required to accommodate the new highway intersection and to keep the bypass bridge clear of the associated turning radii. The approach embankments were built in advance of bridge construction to consolidate the soft underlying alluvial-deposits. It is estimated that precompression of the subgrade will minimize differential settlement between the bridge and the embankments, and preserve the riding quality of the finished pavement.

In 1984 the first operation will be to carry out the advance pile-test, followed by installation of the permanent piles, along with construction of pilecaps and columns. The cast-in-place, post-tensioned concrete deck cannot be built until the June-through-September period available for construction activities in the river. Because of the weak subgrade, the use of pile-supported falsework was specified. The post-tensioned decks will be constructed sequentially, permitting reuse of the falsework. The deck-slab linking the post-tensioned superstructures will be built from suspended formwork. Addition of the approach-slabs, parapet railing, waterproof membrane and adphalt will complete the bridge. Unusually for a bridge of this size, the concept does not require the installation of either bearings or deck expansion-joints.

2.3 Discussion

Site constraints led to the construction of an unusual structure. The use of cantilevered end-spans is believed to be an innovative concept, eliminating the problems of high seismic-induced loading on bridge abutments. The avoidance of costly, piled abutments yielded significant savings. Despite the necessity of using temporary piles for falsework support, the construction of a cast-in-place concrete structure in very poor ground-conditions proved to be a practical, economical solution. The result will be an elegant bridge which nicely complements its attractive environment

The use of conventional construction techniques applied to an unconventional structure assisted in minimizing the construction cost. The tender price, very low for a piled bridge, was $540,500, or approximately $643 per square metre. Completion is scheduled for September 1984.

3. KINGSWAY BRIDGE

3.1 Background

Until early 1984, Kingsway Avenue crossed the Coquitlam River via an aging, substandard steel-truss bridge with steeply-ramped approaches. Carrying a major arterial road connecting Port Coquitlam, B.C., with the remainder of the Greater Vancouver area, the single-lane bridge was inadequate for current traffic. A replacement concrete-bridge is scheduled for construction during the summer of 1984 (Fig. 2). 10.8-m wide by 61-m long, it carries two traffic lanes and a sidewalk over the river, and has approach ramps improved to urban-arterial standard.

The site is extremely confined. Immediately north of the bridge site is the Canadian Pacific Railway right-of-way and the CPR river crossing, also a 61-m span steel-truss bridge. About 15 m separates the two structures, this land being used by utility companies for overhead cables. To the south, a block of elderly commercial properties were located immediately adjacent to the existing sidewalk. The road alignment dictated that the new bridge must be at the same the same location. Part of the CPR right-of-way was available for construction working space, and by acquiring the commercial properties, it was possible to arrange a temporary diversion of Kingsway to the south of the bridge site. A preliminary study indicated that the most economical method of providing temporary bridging of the river was to relocate the steel-truss onto temporary abutments during a road closure, a method offered to and the one selected by the contractor.

Inspection revealed that the existing concrete abutments on timber piles were in good condition, and with new cap-beams and wingwalls were capable of supporting the end reactions of the new bridge. To avoid excessive length of approach ramps, the new bridge has a slender profile; a double row of columns in the middle divides the structure into two main spans. For economy, and to simplify falsework, these consist of standard precast, pretensioned concrete girders, continuous with cast-in place concrete beams over the central section. A 200-mm thick concrete deck-slab connects the four girders transversely.

Two alternative foundation systems were offered to tenderers. The first consisted of sixteen 350-mm diameter steel pipe-piles, raked at 1:3, together with two pile caps and grade beams below the river bed. The second comprised eight 900-mm diameter steel pipe-piles, each vertically below a column and without pile caps or grade beams. All tenders selected the latter system. Both foundation systems utilize the eight 600-mm diameter concrete columns as a ductile frame in resisting seismic loads. Whereas the battered piles were designed as end-bearing axially-loaded members, the vertical piles resisted seismic loads by lateral bearing on the subsurface sand and gravel deposits.

3.2 Construction

The first operation which the contractor has to undertake is to construct the temporary traffic-diversion. This will entail moving the steel-truss bridge some twelve metres downstream, lowering it onto temporary crib-abutments and building road approaches. This will be effected using guide rails and sliding shoes at each end of the bridge, which will be moved laterally and lowered using jacks. This is expected to be accomplished during a weekend road-closure.

The next phase will consist of abutment modifications, and driving of the steel pipe-piles. The manoeuvring space required for the large piling-rig will determine the location of the temporary traffic-diversion. In order to splice the precast girders with the cast-in-place concrete superstructure-beams, temporary support-frames will be required for the interior ends of the girders. Once the beams are cast and the concrete has gained sufficient strength, all falsework can be removed and the remainder of construction work can take place outside the high-water wetted perimeter of the Coquitlam river. Deck construction can proceed using support from the superstructure beams and girders. Installation of expansion joints, parapet railing, waterproof membrane and asphalt will complete the bridge. The final operation will consist of removal of the temporary diversion and disposal of the steel-truss bridge.

3.3 Discussion

Constricted working space characterizes the Kingsway bridge site. The necessity of placing the new bridge at the same location as the old resulted in reuse of the existing abutments, suitably modified for their new role. The problem of maintaining traffic flow during construction was dealt with by sliding the steel truss laterally, an expedient and inexpensive solution, rarely undertaken. Despite the confined nature of the site, efficient structural-design combined with appropriate construction-techniques resulted in an economical bridge. Of a total project tender-price of $797,000, the bridge replacement was priced at $530,000 or $805 per square metre. The bridge is due to be completed in September 1984.

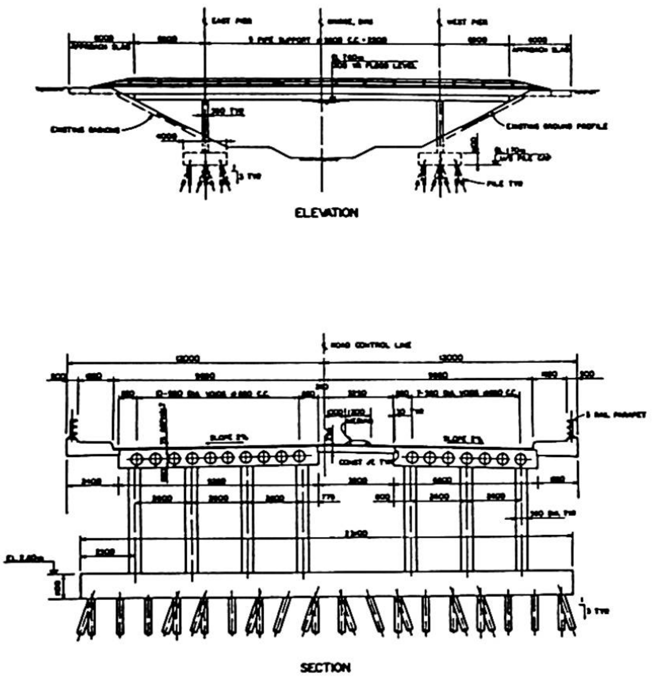

FIGURE 1/LANGLEY BYPASS BRIDGE

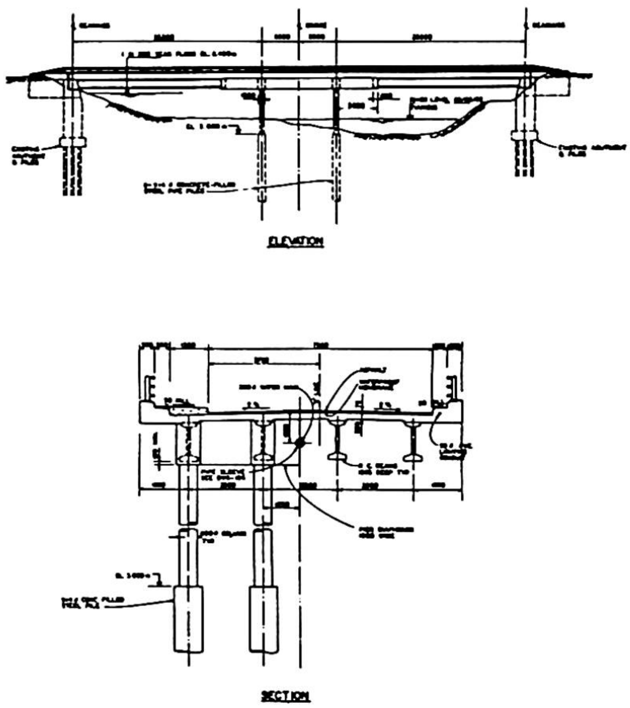

FIGURE 2/KINGSWAY BRIDGE

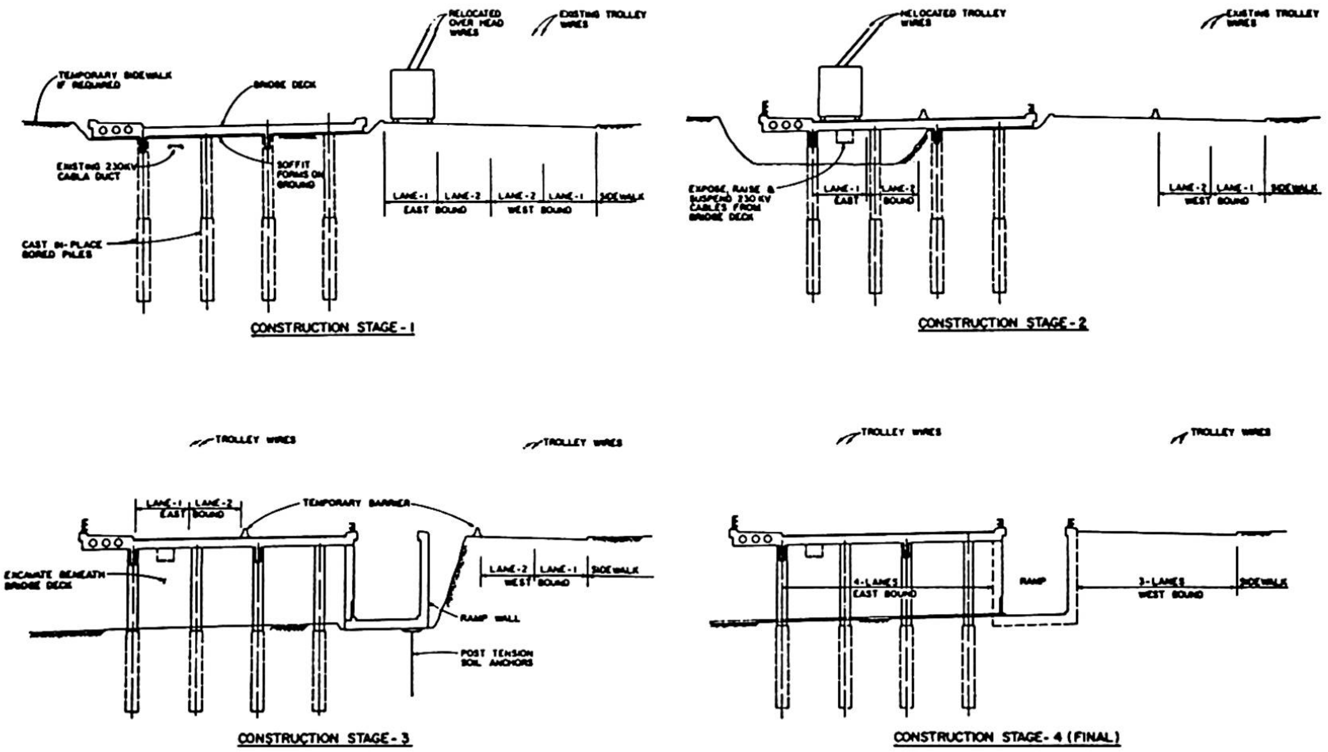

FIGURE 3/OAKRIDGE CENTRE: 41ST AVENUE BRIDGE-CONSTRUCTION STAGES

4. 41st AVENUE BRIDGE

4.1 Background

As part of the Oakridge shopping-mall redevelopment, a grade-separated exit from the car park was required beneath 41st Avenue, a major traffic route in Vancouver, B.C. The city stipulated that four lanes of traffic, including electric-bus service, be maintained throughout construction. The exit route was to pass beneath a new bridge, 17-m wide by 30-m long, carrying four lanes of eastbound traffic and a sidewalk, to emerge in retained cutting in the median. A ramp was to be provided to enable shopping-centre traffic to merge with westbound traffic on 41st Avenue. Because of construction work in the shopping centre, traffic flow had to be maintained within the boulevard limits. A complication was the presence of three sensitive, 230-kV underground electric-power cables. Relocation of these was prohibitively expensive and thus the bridge had to be built around them.

Because of the close proximity of traffic, deep excavation for bridge foundations would have proved costly. Accordingly, a system was developed which involved only shallow excavation at the bridge abutments; intermediate foundations were formed using bored piles, socketed into the underlying glacial-till. The bridge selected, a three-span continuous concrete-slab, utilized discrete-column intermediate supports, formed within the pile shafts, which were located to avoid the 230-kV and 22-kV underground cables. The bridge deck was to be built in shallow excavation, and could be used to carry eastbound traffic when complete. The 230-kV cables were to be enclosed and suspended beneath the bridge deck, whereas the 22kV-cables were to be diverted through ducts cast into the concrete superstructure.

4.2 Construction

Commencing in mid-1983, the first stage of construction was to temporarily provide four traffic-lanes to the north of the bridge using the three westbound-lanes along with the median (Fig.3). Electric-bus operations were maintained by deflecting the overhead wires. With the bridge site clear of traffic, piling work started. Eight 750-mm diameter bores were sunk ten metres into the till. A five-metre long, 600-mm diameter column-form was suspended in each bore, aligned and plumbed. With the reinforcing cages in position, the piles were concreted, and the annuli filled with sand.

The bank-seat abutments and deck downstand-walls were built around the electric cables in shallow excavation, then backfilled. Excavation for the deck slab involved working within 1.5 metres of traffic. Deck formwork was bedded on the bottom of the excavation. After fixing inserts for suspended services, reinforcement and ductwork were placed, and the deck was concreted. Waterproofing, deck asphalt, and parapet railing were installed, and the two eastbound traffic-lanes diverted over the bridge. At this point, the overhead wires for electric buses were repositioned in their final location.

The second construction stage involved excavation beneath the bridge deck. This work commenced from the south, working towards the median. As the deck formwork was undermined it was removed. Carefully exposing the 230-kV cables, the utility company suspended them from the bridge deck. Excavation for the exit ramp followed, along with removal of the column forms.

The third stage involved construction of retaining walls for the exit ramp. With only 2.5 metres between the north wall and westbound traffic, the excavation face was supported with rock-bolts and shotcrete. Generally the walls are U-shaped with the ramp traffic running directly on top of the footing. However, to the north of the bridge deck, the ramp wall becomes L-shaped and overturning must be considered. The solution was the installation of a row of ten 90-tonne ground anchors, drilled vertically through openings in the footing, some fifteen metres into the till. Inclined anchors could not be used as no part of the permanent works was permitted beyond the north edge of the median. Construction work was completed by the laying of asphalt, the installation of parapet railing, and the placing of rubble slope-paving beneath the bridge.

4.3 Discussion

The structural system adopted was influenced mainly by the need to avoid traffic disruption along this busy route. Additional factors were the presence of sensitive underground services together with the need to provide an attractive, economical grade-separated exit from the shopping centre. To this end, the 3.6-metre wide ramp was widened to 6.0 metres beneath the bridge, and the bridge supports skewed differentially, at 25° and 40°, to accommodate the curve beneath the bridge without excessive over-spanning. The resulting exit route is provided with a generous turning radius, good visibility and the maximum of natural lighting. Visual amenity is improved by attention to detail: the retaining walls feature a pleasant, vertical-ribbed finish; the rubble slope-paving provides an attractive, rough texture; and the slender parapet railing affords the maximum of natural lighting. Of a total price of $812,000 for the underpass, approximately $500,000 or $980 per square metre related to the bridge, which was completed early in 1984.

5.0 CONCLUSIONS

In today's economic climate, it is imperative to obtain value from investment in in public-works projects. The examples described illustrate how economy was achieved in bridge construction by careful evaluation of site constraints at conceptual-design stage. Of vital importance is to perceive the construction methods implicit in the design. Ingenuity in the application of construction techniques can yield substantial savings in the cost of bridgeworks at constrained sites.

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	Contractor:	MDM Construction
41st Avenue Bridge:	Owner:	Woodward's Stores
	Architect:	Armour Blewett & Partners
	Contractor:	PCL Construction

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