Improving Traffic Flow on the West Gate Freeway
Through Innovative Structural Design

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SYNOPSIS
The West Gate Freeway Alliance (Baulderstone, Hyder Consulting, Parsons Brinckerhoff, Thiess and VicRoads) has been formed to design and construct road improvements along the West Gate Freeway, as part of the Victorian Government’s planned Monash-CityLink-West Gate AUD$1.4 billion upgrade to improve traffic flow and safety along Melbourne’s increasingly congested transport spine.

Scheduled for completion in 2010, works cover approximately 6km of freeway and include additional viaducts, structural widenings and road geometry modifications to accommodate new lanes and traffic separation according to destination, reducing the level of merging and providing an enhanced journey for users.

Several structural design innovations have provided significant benefits for design, construction and functionality, including:

- Maximising off-site production to optimise procurement and finish quality.
- Standardisation of lengths and depths for design and construction savings.
- Maximising use of pre-cast piers and existing viaduct/new structure connection details to reduce traffic disruptions.
- Running all 3D models under one platform and providing a fully integrated system, allowing more detailed modelling and resulting in smoother construction.

The design process has benefited significantly from the project alliance environment, allowing a “best for project” approach, with all parties working together to produce the best outcomes. Throughout this project innovation has been developed without the usual restrictions of a traditional contract agreement, and adopting leading edge design practices.
INTRODUCTION
The Monash-CityLink-West Gate upgrade is a AUD$1.4 billion project aimed at improving traffic flow, travel times and safety along the increasingly congested Monash Freeway, CityLink, West Gate Freeway and West Gate Bridge, as part of the Victorian Government’s (in partnership with Transurban) plan to improve the State’s transport system and alleviate increasing traffic congestion.

The Victorian State Government, through its road authority VicRoads, entered into an alliance agreement in March 2007 with Baulderstone, Hyder Consulting, Parsons Brinckerhoff and Thiess, forming the West Gate Freeway Alliance to design and construct planned road improvements along the West Gate Freeway, the most complex of four sections of the project. The West Gate Freeway provides the crucial link between the West Gate Bridge, western suburbs and Geelong to the CityLink Tunnels, Melbourne Central Business District and eastern suburbs.

A prominent element of the West Gate Freeway is the elevated viaduct, which runs along the majority of the Freeway. The elevated section of the West Gate Freeway comprises of two independent carriageways currently carrying three lanes of traffic. The carriageways cross numerous major roads, railways and public car parks, and also pass many adjacent commercial and residential areas/buildings.

After 20 years of use, a major upgrade was required to meet increasing traffic demands along Melbourne’s busiest road corridor. Works include the construction of new viaducts, existing structure widenings, and road geometry modifications to reduce merging at key points on the Freeway by accommodating new lanes and separating traffic according to their origins and destinations, resulting in smoother traffic flow and improved safety. Figure 1 shows a portion of the current freeway and corresponding portion of the proposed improvements.

Figure 1: Existing Montague Street Intersection and Proposed Improvements
PROJECT ALLIANCING
VicRoads determined that the West Gate Freeway section of the Monash-CityLink-West Gate upgrade was embedded with significant risks, such as duration for design and construction (project was due to be opened in mid-2010), interaction with a very high level of traffic (160,000 vpd) during construction and other adjacent works such as the Melbourne Convention Centre Development and West Gate Bridge Strengthening project. Therefore VicRoads decided that the best method of delivering this project would be through an Alliance approach. Project alliancing is a form of cooperative contracting, where the owner, designer and constructor are bound by a single agreement. This arrangement allowed sufficient flexibility to ensure any risks were properly managed, and to facilitate delivery of the project in the shortest possible timeframe [1].

To mitigate the key risks as perceived by VicRoads, the Alliance decided that the project would be delivered in accordance with following Key Result Areas (KRA):

- Safety – no one gets hurt during construction.
- Quality/Functionality – functional design exceeds standards set out in the reference design and quality of work exceeds current best industry practise.
- Financial – Actual Out-turn Cost (AOC) is less than Target Out-turn Cost (TOC).
- Schedule – completion of project by mid-2010.
- Construction Planning / Traffic Operations – no impact on peak period travel on the West Gate Freeway as a result of construction operations and reduction of traffic entering the tunnel.
- Stakeholder Management – Excellent relationships with key stakeholders and community.
- Co-ordination with Adjacent Events and Major Projects – no disruption to adjacent projects such as the Melbourne Exhibition Convention Centre (MECC).
- Sustainability.
- Environmental Management.
- People – improving the work/life balance of the employees of the WGFA.

The scope of this paper generally falls with the two KRA’s of Functionality and Construction Planning / Traffic Operation which together had a 50% total weighting.

VicRoads Reference Design
The reference design as provided to the Alliance by VicRoads, shown in Figure 2, generally involved the following major structural works:

West-bound Carriageway
- New Power Street entry ramp structure.
- New elevated section and structural widening through Kingsway Interchange.
- Structural widening of the existing West Gate Freeway elevated viaduct in the median as well as the edge of the carriageway.
- New elevated section and structural widening at Montague Street Interchange.

East-bound Carriageway
- Realignment of Power Street exit ramp with new structure.
- Structural widening of the West Gate Freeway elevated east bound viaduct.
• Demolition and rebuilding of new eastbound entry ramp from Montague Street.
• Construction of new entry ramp from Bolte Bridge to West Gate Freeway.

![Figure 2: Reference Design General Arrangement (Selected) Plans](image)

**DESIGN INNOVATIONS**

A number of workshops and discussions between design, delivery and stakeholder relations were undertaken during the design process to add innovation and value in design. Several design innovations were considered and implemented, enhancing not only bridge design and delivery, but also in–service, providing significant cost and time savings. The innovations were, in particular, important for works above and around condensed public areas, major roads and busy intersections, where minimal traffic disruptions were required to sustain traffic volumes of 160,000 vehicles per day.

**Changing the Reference Design**

On review of VicRoads’ Reference Design [2], it was evident that it involved a significant amount of widening to the existing viaduct, corresponding to a considerable amount of interaction with traffic to stitch new and existing decks together. It was also evident that the reference design envisaged significant construction works occurring at the very busy Kingsway Interchange carrying passenger, commercial and light rail traffic.

At the start of the Project Development Phase (PDP), several “optioneering” workshops were organised with a view to minimise the aforementioned risks. The workshops involved all participants within the Alliance, so there was input from not only the design and delivery (construction) teams, but also from the safety, traffic operations and stakeholder relations teams.

During the whole process all the options were assessed against the various KRA’s so that a balanced view could be formed of the various options. An option was developed for the west-bound traffic, whereby a new viaduct would take all traffic entering from the Kingsway Interchange destined for the Bolte Bridge and West Gate Bridge, and only a limited amount of widening of the existing viaduct was required. This solution assisted in mitigating the two key risks, by reducing the level of existing viaduct widening that was required to be carried out and moving most of the construction works from Kingsway Interchange to Montague Street Interchange. For
east-bound traffic several options were considered which made slight improvements to the Reference Design but the general concept of the Reference Design was maintained. This new and altered road alignment became the Alliance Base Case Design, which consisted of the following:

- Nearly 30,000m$^2$ of deck area.
- Over 260 no. of 1,500mm deep super-T beams.
- Approximately 70 no. of steel girders.
- Over 120 no. substructure supports.
- Over 2,000 no. pre-cast medium level containment parapets.

General arrangement plans of the Base Case Design are shown in Figure 3.

After the road alignment was provisionally fixed it was decided to carry out a detailed study with respect to the type of structure that could be used for the construction of these new viaducts. The two main options considered were the use of match cast segmental viaducts and a combination of super-T beams & steel trough girders. As the time for compilation of the PDP report, which included the Target Out-turn Cost (TOC), was limited it was decided to develop the two options in parallel by the use of a “Tiger” team. Both these options were assessed in terms of the various KRA’s and cost, and it was found that constructing a viaduct comprising a combination of super-T beams & steel trough girders would provide better value for money as it allowed greater flexibility on span lengths and was a more economical option in terms of cost.

Due to the increased level of involvement of the delivery team and detailed consideration of all options during the Project Development Phase, it resulted in giving the delivery team greater ownership of the design concept, and during the Detailed Design Phase of the project the design team could base their design and plan the works to suit the delivery team requirements. This was important for the delivery team in terms of their pre-planning for traffic management, land acquisitions, procurement of equipment and structural elements, and construction sequencing.
Figure 3: Alliance Base Case Design General Arrangement (Selected) Plans
Maximising Off-Site Production
Due to the significant volumes of local traffic and dense commercial/residential presence within the vicinity of working areas, there was a major emphasis to maximise off-site procurement of structural components. This reduced the level of on-site construction and hence reduced traffic management and disruptions, whilst also providing enhanced aesthetics due to the overall improved finish quality in components. Steel girders, “super-T” beams, pier segmental units and parapets were fabricated/cast off-site, with the transportation and lifting of procured components predominately undertaken at night to avoid peak periods. An example of night transportation and lifting of a steel girder is shown in Figure 4.

Figure 4: Night Transportation and Lifting of Steel Trough Girder

Project Standardisation
The need to maximise off-site production required a conscious effort to standardise details wherever possible in order to provide consistency in design and construction across the whole project. The use of these standard aspects throughout the project represented significant design and delivery savings in time and cost. Standardisation was particularly crucial in terms of program for design to accommodate requested “fast-tracking” of packages from the delivery team. This in turn assisted with construction timings regarding planned traffic management, temporary land acquisitions and construction sequences, which then brought forward completion dates and reduced the required periods for road works and traffic disruptions. Key project standardisations included but not limited to the following:

- Development of standard drawings to avoid continual replication of similar design details for different bridge “packages”, and to allow duplication of construction components and sequences. There were approximately 200 standard drawings used and referenced for this project.
- Using a single super-T depth of 1,500mm to enable standardised casting moulds and to maximise uniformity and extent of span lengths. Super-T depths of 1,800mm were not used due to poor ground conditions and subsequent lifting issues. Where some spans were shorter and 1,500mm deep super-T beams were not required, 1,500mm deep super-Ts were still used for aesthetic reasons to remove the need for “steps” in pier crossheads.
- Rationalising steel trough girder depths and lengths where possible to match the existing structure. Steel troughs were used in lieu of super-T beams for longer spans over major roads to achieve a single span aesthetic effect.
- Use of pre-cast segmental piers where applicable to minimise on-site construction and traffic lane closures. This was particularly important for construction work in dense commercial and residential areas with large traffic volumes.
- Standardised pilecap sizes where possible to enable consistency in temporary formworks. Typically a 5m x 5m grid was used, with varying depth depending on design requirements.
- Designing all pre-cast parapets to medium level containment. The containment level was decided after discussions with and agreement from VicRoads within the Alliance environment [3].

**Pre-cast Segmental Piers**

The use of pre-cast segmental piers on this project was an important innovation from a design and construction perspective. Over 100 piers were required for the project and were to be constructed with major roads and high volumes of traffic in close proximity. Therefore, pre-cast segmental piers were used in lieu of matching the existing piers and constructing cast-in-place “blade” wall piers, in order to reduce on-site construction tasks and minimise construction times. The overall form and shape of the pre-cast piers was designed to match the form of the existing piers to minimise any aesthetic differences. In total approximately 90% of piers were pre-cast across the project.

Pre-cast piers were constructed using match cast segmental units, with dry joints and shear keys for stability during erection. Post-tensioned stress bars provide the connection between segmental units, pilecap and crosshead. The dead end anchorage of the stress bar is set up during pilecap construction, and the pre-cast crosshead is connected on top by the stress bars inserted into ducts in the crosshead and grouted after placement. Grouting is undertaken from the base of the structure via a grout feed tube to ensure grout has penetrated the whole duct. A typical match cast segmental unit was 4m length x 1.5m width x 2m depth, with sizes chosen for ease of transportation and lifting purposes to reduce on-site time. Figure 5 shows the plan and elevation of a typical match cast segmental unit.

![Figure 5: Typical Elevation and Plan of Pre-cast Pier Match Cast Segmental Unit](image-url)
Use of pre-cast segmental piers provided significant benefits during the design and delivery phases. Having standardised segments allowed for a consistent design throughout the project, removed the repetition of recreating standard pier details for each bridge “package”, and also allowed pre-casting yards to use the same moulds. Pre-casting and procuring pier segments and crossheads off-site reduced the level of disruption to traffic during pier construction. This was particularly beneficial for constructed piers near major roads, as the need for scaffolding to build cast-in-situ piers was eliminated, and lane closures were kept to a minimum, thus increasing worker and community safety whilst still maintaining traffic flow during construction. Photos of typical pre-cast segmental piers during construction are shown in Figure 6.

![Figure 6 Typical Pre-cast Segmental Pier Construction](image)

**Single Dowel Connection for Structural Widening**
Throughout this project, the design of single dowel connections to the existing elevated viaduct were utilised for all structural widenings in lieu of the more conventional dual dowel connections, allowing the use of an E-Z Drill unit [5] and increasing hole drilling productivity on site by 300% compared to original forecasts.

Typically a connection between the existing and new viaduct is done by either breaking out the existing deck to lap new continuity reinforcement or by doweling in connection to the existing deck. The alliance delivery team preferred the dowel option which would limit the amount of traffic management on the existing viaduct that would be required in line with the project KRA’s. However with the depth available to enable a dowel connection to be made there was concern to dowel a hole for top and bottom reinforcement bars. Hence it was decided to design the widening to cater for its load without any assistance from the existing viaduct as the existing viaduct had sufficient capacity to withstand loads to the full extent of the cantilever.

In view of this the strength of the joint was not critical to the performance of the deck and did not require to be fully in accordance with the current Australian Standards for Bridge Design. The joint was then analysed for A14 and T44 loading [4] that was the loading case the existing viaduct had been designed for and it was found that a single dowel (N24) connection at approximately 100 mm below the surface of the top of the deck slab would have enough capacity to withstand the local loads. As the depth to reinforcement was greater than normal it was possible that cracks may form.
at the surface and appear to be larger than usual hence it was a decided that we would provide a galvanised dowel connection with a water proofing membrane on top of the joint to prevent any water ingress and to limit the risk of reinforcement corrosion. Dowel connection details and photo are shown in Figure 7.

![Figure 7: Single Dowel Connection Detail and Photo](image)

The adoption of the single dowel connection design allowed for the use of the E-Z Drill, which could drill holes in a single row at a very high rate. The E-Z Drill uses a dry drilling process, with dust collected using a Macro Dust Collection System, and hence negates any mess or slurry that a conventional diamond core drill with water creates. A photo of construction work using the E-Z Drill is shown in Figure 8. This was particularly important for areas of work above dense commercial and residential areas with heavy traffic volumes, as it avoided using methods that required substantial traffic management and closures below the area of work, and also access via scaffolding.

Prior to the drilling of dowel holes, removal of old parapets and “breaking back” of the existing cantilever deck was required. Similar to dowel hole drilling, it was preferable to avoid using traffic management and scaffolding methods in high traffic and populated areas. This was achieved by using a specifically designed “travelling” gantry connected to the existing viaduct and used to contain demolition and construction works at elevated structure height. A photo of construction work using the travelling gantry is shown in Figure 8.

![Figure 8: Workers using Travelling Gantry and E-Z Drill](image)
Fully Integrated 3D Modelling

Using a fully integrated 3D modelling system on this project was an important innovation that provided significant benefits in design and delivery. Due to previous experiences with non-integrating software and compatibility issues between files, a conscious effort was made to have all modelling programs running on one platform for this project.

All modelling software was based on new and current Bentley XM technologies, with each design team using the following programs:

- Structural 3D modelling – Microstation
- Civil 3D modelling – InRoads
- Drainage 3D modelling – Storm & Sanitary

All files were run through a Bentley based document management system (DMS) called Projectwise, acting as a “control centre” and providing a collaborative and controlled environment. With all files being run via one platform, the 3D models from each design team could be fully integrated with each other and all files easily referenced and up-to-date. As a result of the fully integrated system and enhanced program features, a 3D model could be produced with more accuracy and in more detail than previous projects, and any changes could be seen easily within the models. As such, structural modelling in this project has become best practice in the industry. All components of the bridges were modelled, including parapets and railings. Examples of structural 3D models created are shown in Figure 9.

![Figure 9: Detailed 3D Structural Modelling incorporating Survey and Road Design](image)

The greater level of detailing and accuracy in the 3D models has significantly reduced the time and costs spent on construction works, and hence reducing the need for prolonged traffic management and disruptions. Detailed 3D modelling has led to the reduction of required construction rework on-site, with current figures being only approximately 0.08% of project costs [6], and subsequent reductions in time spent on site for re-construction.

One benefit in particular was the introduction of modelling all shear studs along the steel trough girders and their interface with Transfloor panels. Detailed 3D models of the steel trough girders including shear stud layouts were sent to the fabricator and site surveyor for their information to use as a basis for creation of their own models.
The fabricator and site surveyor then sent their detailed 3D model back to the design team for verification. Procurement of components and construction only took place once agreement had been reached on any discrepancies between models. This process of modelling and verification has reduced on-site time considerably with Transfloor panels fitting seamlessly along the steel trough girders between shear studs. This significantly advanced completion dates and reduced the level of interference with through traffic. Photos of the steel trough girder shear studs layout and placement of Transfloor panels is shown in Figure 10.

![Figure 10: Shear Stud Layout and Easy Placement of Transfloor Panel](image)

**CONCLUSION**

Construction works on the West Gate Freeway section of the Monash-CityLink-West Gate upgrade inevitably required some disruptions to traffic, given the heavy traffic volumes and surrounding dense public area in close proximity to construction sites whilst the project was being carried out. The West Gate Freeway Alliance worked diligently to minimise disruptions wherever possible and accelerate the construction program. The alliance environment has significantly benefited the design process, where innovations were developed without the usual restrictions of traditional contract agreements, which further expedited the design and delivery process, providing significant cost and time savings. Throughout this project the structural design methods use are at the leading edge of design practice.

**REFERENCES**