Innovative composite dowel for steel concrete composite bridges

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Introduction

— New to Australia although it is being used successfully in Europe.
— A viable alternative to standard composite beams and T-Roff/Super-T girders that offers slimmer superstructure.
— Evolution of prefabricated composite beams for bridge superstructures.
— MRWA agreed to construct a pilot project in the South West region of WA. The design of that pilot project is completed and it is currently under construction.
— Preliminary designs for multiple tenders have been completed.
— Cost estimates indicate saving opportunities when compared with T-Roff/Super-T girders.
— The concept is based on the “Perfobond” shear connector developed for a bridge over the Caroni River in Venezuela in the late 80’s.
— Constructability was an issue and needed refinement.
— The innovation is to replace shear studs with composite dowels to improve cost effectiveness and sustainability of bridge structures.
— This allowed to combine the advantages of filler beams with pre-fabrication processes.
At a glance
Reduction of manufacturing processes

Concept and Background

— Ideally, rolled sections are cut into two halves in the rolling mill
— Welded sections cut in half
— Open/Closed welded boxes as an effective alternative to reduce depth

EUR 25321 Final Report (PRECO-Beam)
Advantages

- Compared to pre-stressed cross sections an increase of the structural depth is realised
- More efficient cross section
- Increased stiffness
Advantages

— Span/depth ratio up to 40 can be realised with haunched frame structures.
— Soffit can be profiled.
— Can be implemented for single spans of up to 60m.
— High fatigue resistance due to composite dowels strips.
— Can be precast or with a mould on site before lifting in position.
— Eliminate the need for bracing the steel girders.
— Efficient use of steel and concrete in beam cross section.
— Steel work could be constructed in weathering steel

Bridge in Kuchl, Austria (PRECO Design Guide)
Structural Cross Section

At a glance
Multiple forms

Conventional Prefabricated Composite Girder
Prefabricated Duo Composite Dowel Girder
Prefabricated Composite Dowel Slab
Prefabricated Composite Dowel Rail Girder
Prefabricated Composite Dowel Girder
Prefabricated Mono Composite Dowel Girder
Structural components of Prefabricated Mono Composite Dowel Girder

1. Steel flange
2. Steel web
3. Composite dowel
4. Precast concrete web
5. Prefabricated concrete plate
6. In-situ concrete deck
7. In-situ longitudinal reinforcement
8. Precast longitudinal reinforcement
9. Transversal shear reinforcement
10. Confinement reinforcement
Load bearing behaviour

— Push-out tests in accordance with EC4 were used to study the behaviour to establish a load-slip relation

— Findings:
  — One composite dowel equals load capacity of four 19mm shear studs (Verissimo, Valente, Fakury et al)
  — Slip capacity is greater than the limit specified by EC4
  — No destructive influences caused by local stress peaks
  — Improved fatigue behaviour (detailed category 80 vs 125 or 140)
Load bearing behaviour

A. Compression in concrete from stud weld at a flat angle $\beta$;
B. Concrete under multi-axial load causing a pulverisation of the concrete at stud weld, load increase causing plastic deformation of the dowel;
C. The dowel head prevents vertical uplift of the concrete developing tension in the shear stud;
D. Further shear stud deformation, increase of axial force in the stud, friction develops between concrete cone and top of steel flange.

1. Linear elastic behaviour, mobilisation of friction and local compression of dowel surface
2. Plastified material behaviour accompanied by initial cracks in the concrete of ignition of yielding of the steel dowel until consolidation
3. behaviour after failure, apparent crack pattern in the concrete and initial crack in the steel dowel
Composite Dowels

Different shapes tested during the research funded by the Research Fund for Coal and Steel. Results are summarised in the publication EUR - 25321

Two shapes are included in the general building authority approval Z-26.4-56

Stress concentration factor longitudinal shear (local):
\[ k_{f,L,CL} = 7.3 \]
\[ k_{f,L,PZ} = 8.6 \]

Stress concentration factor bending (global):
\[ k_{f,G,CL} = 1.5 \]
\[ k_{f,G,PZ} = 1.9 \]
Material and geometric requirements

Material properties:
Concrete strength: 25 to 75 Mpa
Steel strength: 235 to 460 Mpa

Geometrical limitation:

Longitudinal dowel spacing:
$150 \text{ mm} \leq e_x \leq 500 \text{ mm}$

Plate thickness of dowel:
$6 \text{ mm} \leq t_w \leq 40 \text{ mm}$
$0.8 \leq \frac{t_w}{h_D} \leq 0.5$

Transverse dowel strip spacing:
$e_y \geq 120 \text{ mm};$ maximal two strips allowed

Concrete cover:
$c_0; c_u \geq 20 \text{ mm}$ or min concrete cover based on durability requirements
Material and geometric requirements

Geometrical limitation:

Width of concrete web:
\[ b_c \geq 250 \text{ mm} \]

Minimum edge distance in longitudinal direction:
\[ \geq 2.5 \times \min (c_o + 0.07 \times e_x; c_u + 0.13 \times e_x) \]

Minimum edge distance in transverse direction:
\[ \geq 5.0 \times \min (c_o + 0.07 \times e_x; c_u + 0.13 \times e_x) \]

Detailing requirements:

Confinement reinforcement:
\[ A_{s,conf} = \min \left( 0.3 \times \frac{P_{RD}}{f_{sd}} ; 2\varnothing 10/\text{Dowel} \right) \]
\[ \geq \varnothing 12 \text{ rebar at confinement-stirrup base} \]
Fabrication

Steel dowels:

Cutting process:
The steel dowel may be fabricated with machine gas-cut to achieve a minimum detailed category of 125.

Cut quality 2 in accordance with ISO 9013 is sufficient.

Specified in AS/NZS 5131, Table 6.5: Maximum roughness CLA Method 12 µm.

Tolerances on specified sizes +2mm/-4mm (‘+’ indicates size increase)

Reinforcement:

Standard steel rebar cages

Concrete pouring:

Formwork needs to be pre-cambered

Low shrink concrete should be used
Western Australian Trial Cuts
Western Australian Girders
Bridge 0270A (pilot project)
Bridge 0270A (pilot project)
WSP Bridge Information Modelling (BrIM)

Site records:
Confirmation of materials installed: concrete compressive tests and concrete curing information, Steel mill certificates, Reinforcement information, Pile driving records, etc.

Bridge Health monitoring:
Installation of strain gauges and accelerometers to allow future health monitoring

Asset management:
Asset management planning
Refurbishment and repair records
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