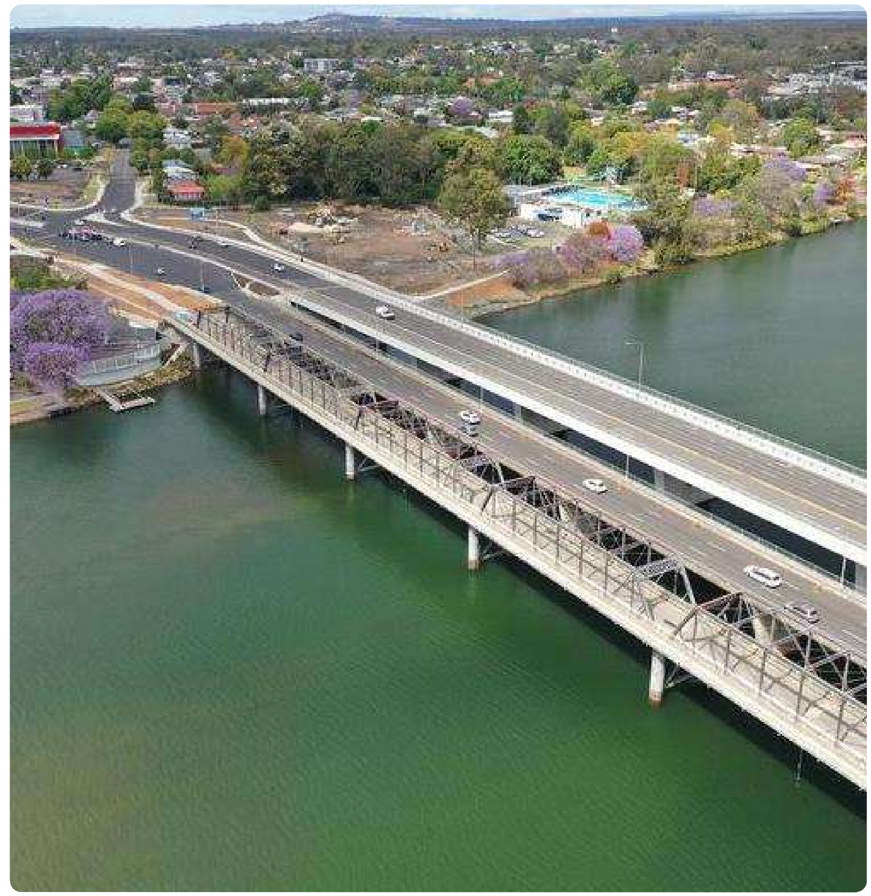
Stantec

Vessel Impact on Bridge Structures in Australia



VESSEL IMPACT ON BRIDGE STRUCTURES IN AUSTRALIA

Agenda

1. Purpose of Vessel Collison Design
2. Tasman Bridge Disaster
3. AS 5100.2 Vessel collision requirements
4. AASHTO Vessel collision requirements
5. Vessel Collision Design Examples:
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    2. New Nelligen Bridge
6. Conclusion

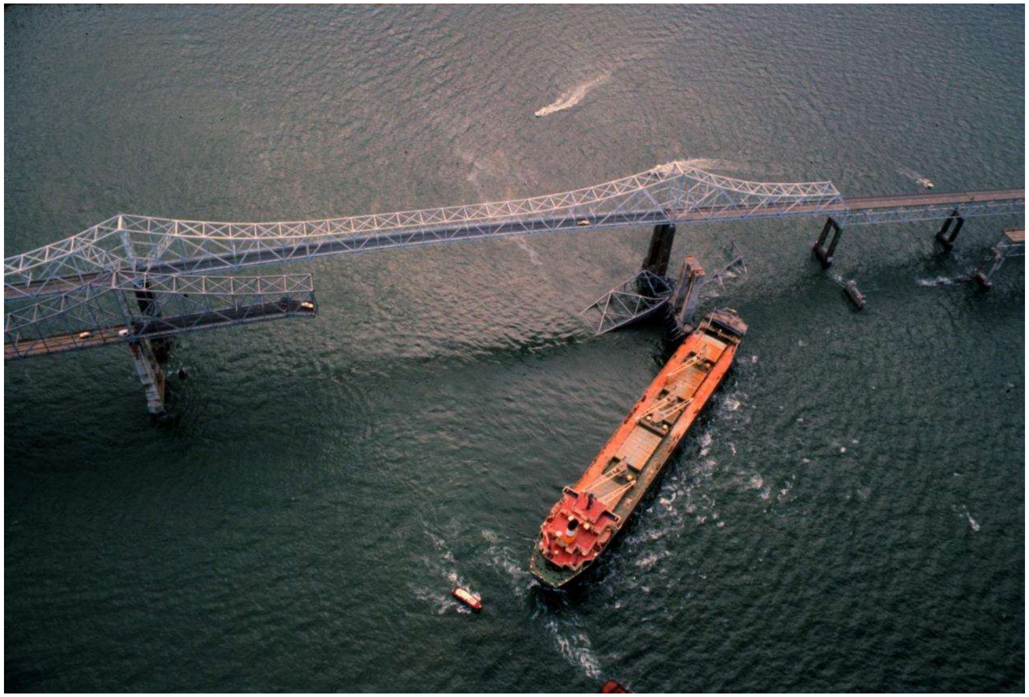
Purpose of Vessel Collison Design

Vessel collisions with bridges have an impact on:

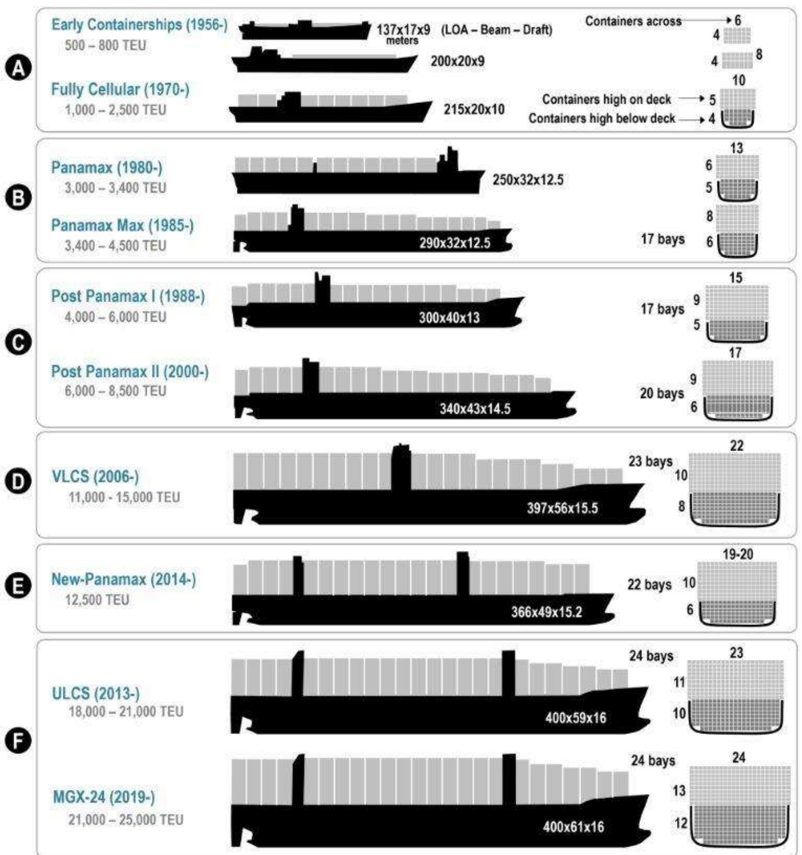
- Public safety,
- Port operations and traffic patterns,
- Environmental pollution/disasters.

Possible reasons for the collision:

- Pilot error
- Mechanical failure of vessels
- Adverse environmental conditions



Evolution of Containerships



Evolution of Containerships

Purpose of Vessel Collison Design

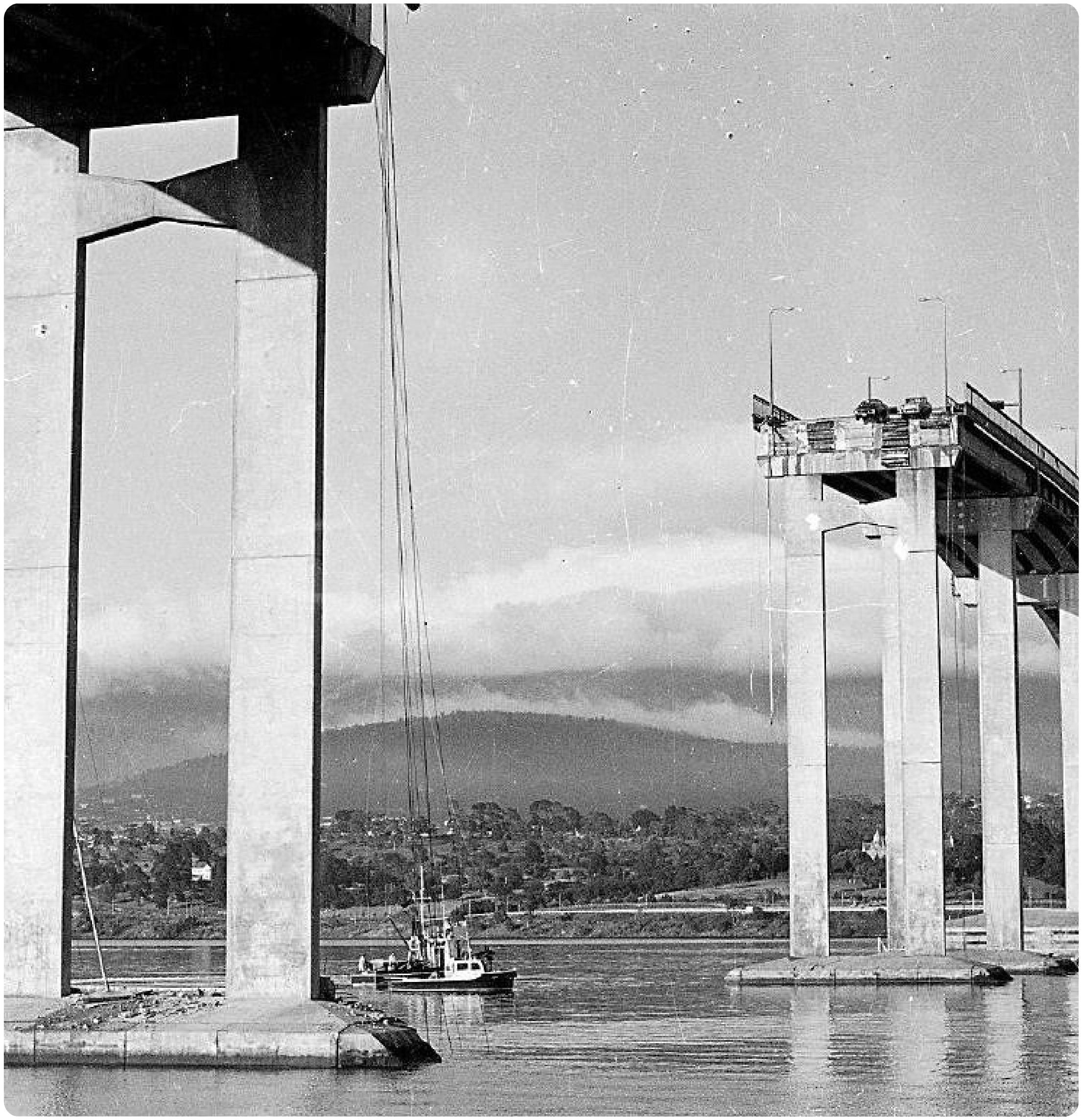
Inherited risk related to old infrastructure:

- Modern vessels became longer and wider,
- Increased frequency of barges and ships in waterways,
- Vicinity of bridges to congested marine terminal facilities,
- Too many bridges over navigable waterways in the same location

Tasman Bridge Disaster

- Hobart, the evening of 5 January 1975
- Bulk carrier Lake Illawarra traveling up the Derwent River
- Collided with two piers

- The disaster resulted in:
  - Changes to the regulations on shipping movements
  - In 1987 a system of sensors was installed near the bridge
  - Vessels above a certain size are required to be piloted
  - Vehicle movements on the bridge are temporarily halted
  - Now mandatory for most large vessels to have a tug in attendance



AS 5100.2 Vessel collision requirements

In our practice:

- Use of more advanced methods of analysis are not common,
- The requirement in cl 11.6 is unclear, considerations could result in very different design scenarios

11.6 Collision from waterway traffic

The harbour master, port authority or other relevant authority shall recommend the type of vessel, weight of vessel and speed of impact on the bridge. This includes the channel and adjacent pier locations. The upper bound loads shall consider all vessels currently operating in the waterway or likely to operate in the waterway for the next 100 years. The minimum velocity of impact shall be the larger of the maximum flood velocity or the maximum speed of the vessel under power. The proposed design vessel and speed shall be reviewed and approved by the relevant authority.

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AS 5100.2:2017

Unless a more advanced method of analysis is adopted, or unless otherwise specified by the relevant authority, the ultimate equivalent static vessel impact force shall be determined in accordance with AASHTO LRFD *Bridge Design Specifications*. The resulting minimum equivalent static ship impact force applicable to piers in navigable waterways shall be approved by the relevant authority.

AASHTO Vessel collision requirements

Clause 3.14 of AASHTO

- use semi-probabilistic analysis procedure to determine the probability of bridge collapse for the bridge site-specific waterway traffic.
- includes formulas to determine the vessel impact force for the elements of the bridge structure.
- semi-probabilistic method require detailed information such as vessels type, loading conditions, geometry of the vessels, and frequency of passages.

In our practice

- Vessel Fleet Characteristics is not available (vessel geometry, weight, number of trips, the difference between upbound and downbound traffic).
- Additional effort is required to establish an adequate database.

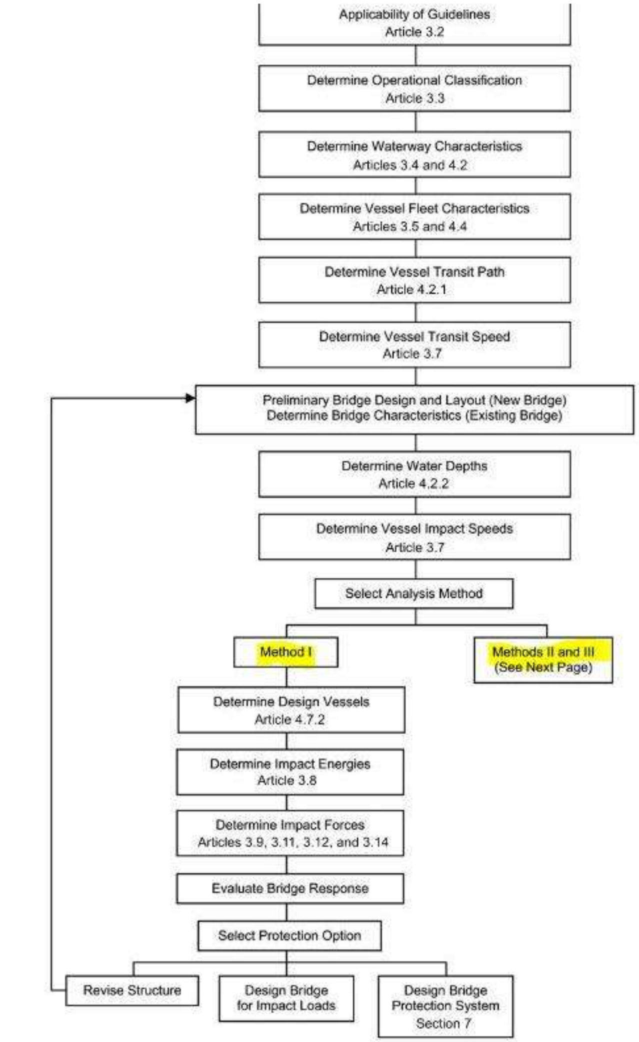


Figure 1.5-1—Design Procedure Flow Chart

AASHTO Vessel collision requirements

US practice:

- Some DOTs have Vessel Collision Risk Analysis Programs.
- Following AASHTO use 3 alt methods for determining the design vessel for each bridge component based on two-tiered risk acceptance criteria.

Australia practice:

- Use a simplified approach which effectively results in an Annual Frequency of Collapse of zero. This is more conservative than the probabilistic approach.
- We consider improvement and amendment of AS5100.2, which require the wide engagement of the industries and establishing an 'accurate' database, can lead to the realization of **SDG 9 and SDG 11.**

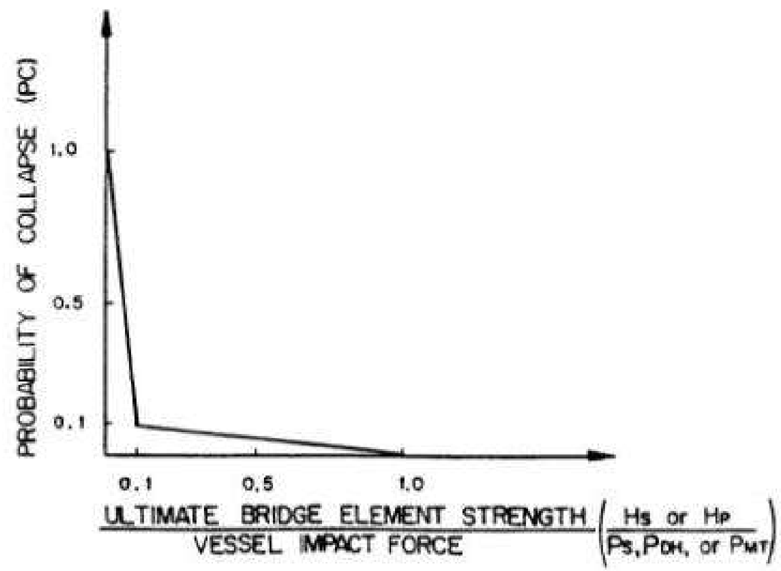
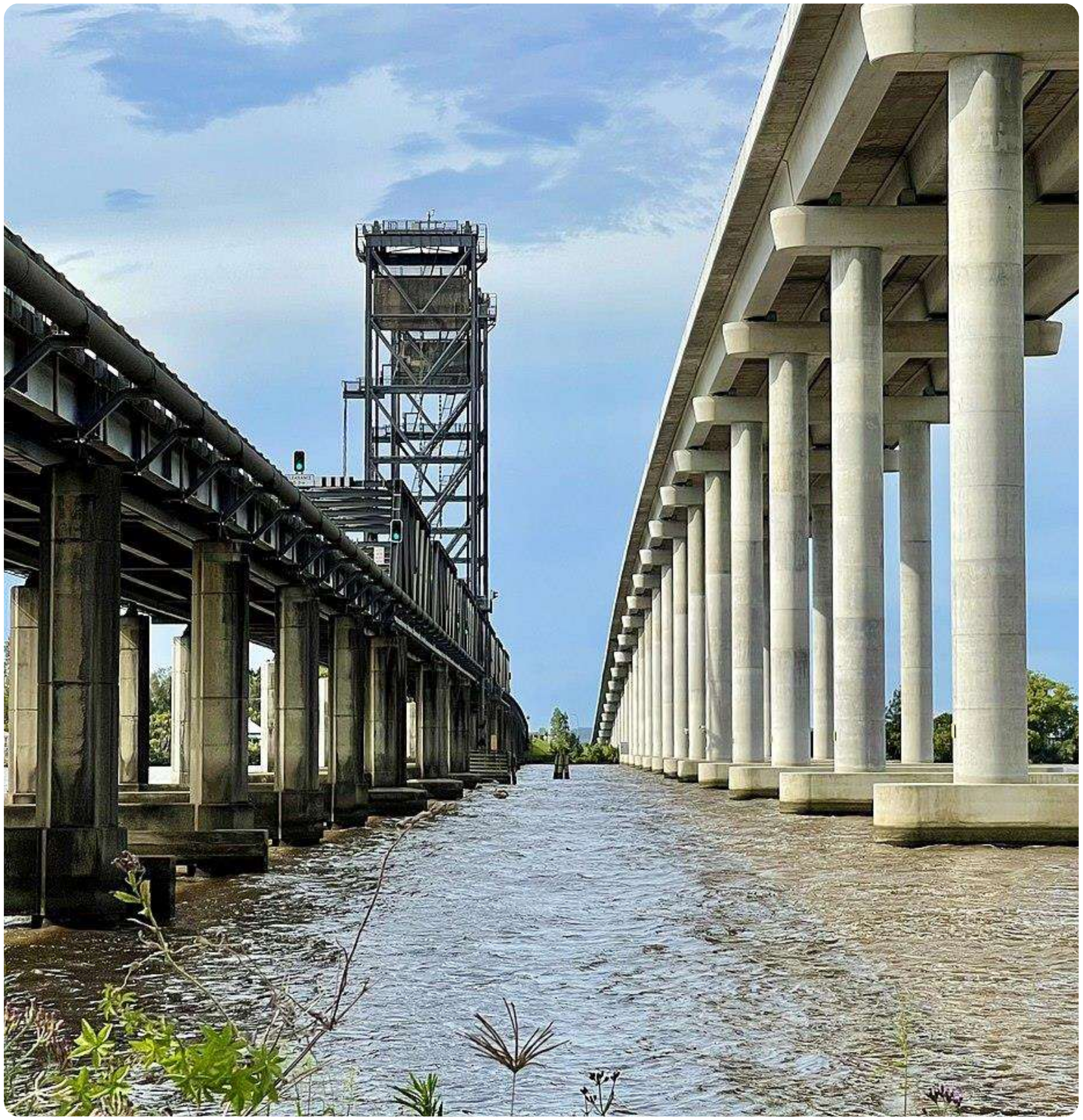


Figure C3.14.5.4-1—Probability of Collapse Distribution

AASHTO Vessel collision requirements - Harwood Bridge

- Pacific Highway Upgrade – W2B
- A probabilistic approach was used (approved in SWTC)
- The bridge in the waterway has been designed with a resistance which results in an acceptable annual frequency of collapse
- The analysis procedure for determining the appropriate Design Vessel is based on AASHTO Method II Risk analysis procedure
- Risk acceptance criteria for Critical Bridge: risk of collapse 1 In 10000 years
- 5 vessels used when calculating the annual frequency of collapse
- Structural assessment utilizes nonlinear plastic behavior and redistribution of the load in the structure, as well as nonlinearity of the ground
- Quasi-static ship impact force 9.45MN used to calculate the resistance of relevant elements (Piles, piers, bearing, superstructure)



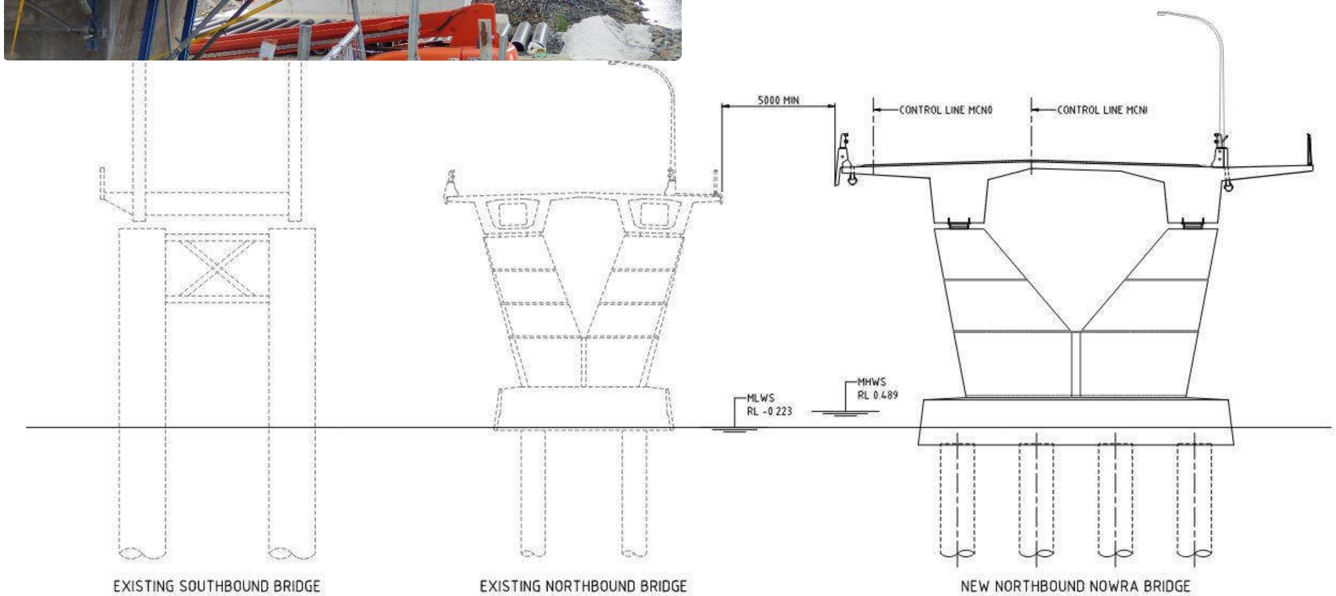
New Nowra Bridge

- Based on maritime authority approvals, the design vessel was a Displacement Tonnage of 60 tonnes vessel traveling at 30 knots (damage control performance level) and 20 knots (for service performance level).

- Quasi-static ship impact force of almost 15 MN (based on ship collision force calculation)

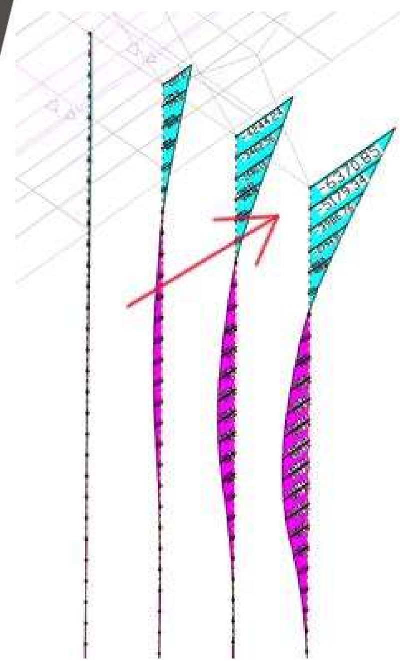
New Nowra Bridge

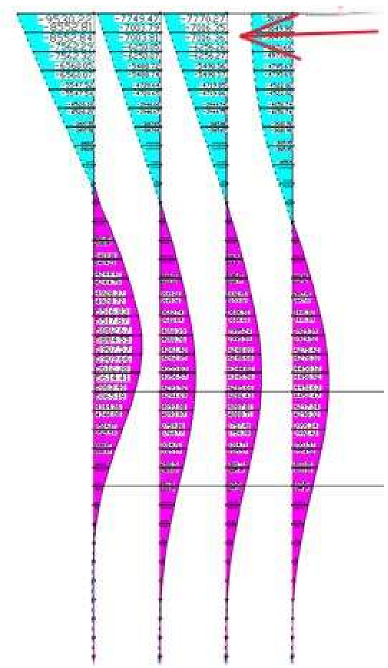
- Fixity and impact between piers 1 to 8



New Nowra Bridge

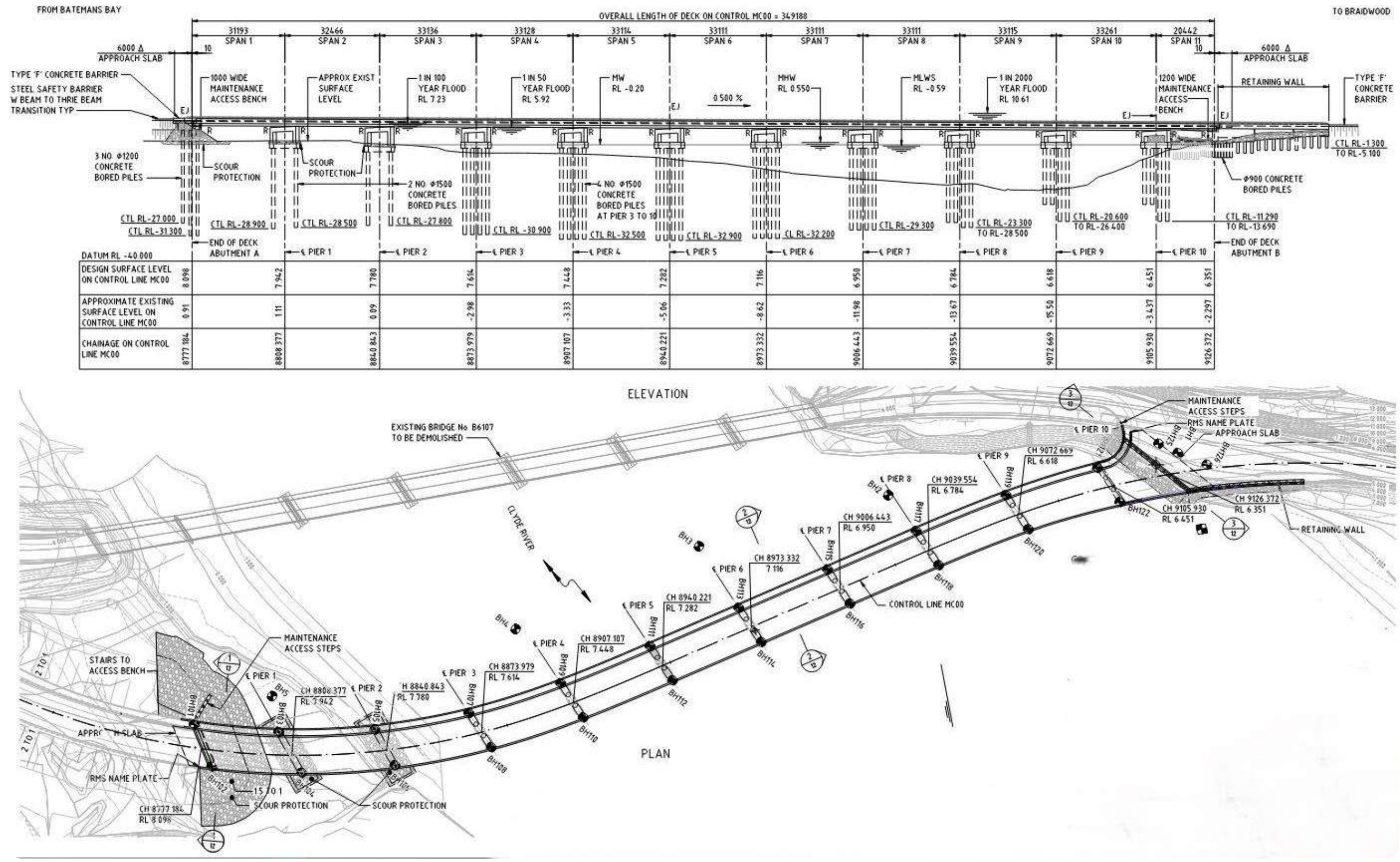
- Perpendicular to channel centre-line.
- Direction of the channel centre-line.
- The innovative idea of using the fixity of the bearing to redistribute the vessel impact loading has contributed to the optimisation of the design of the bridge substructure and foundations.





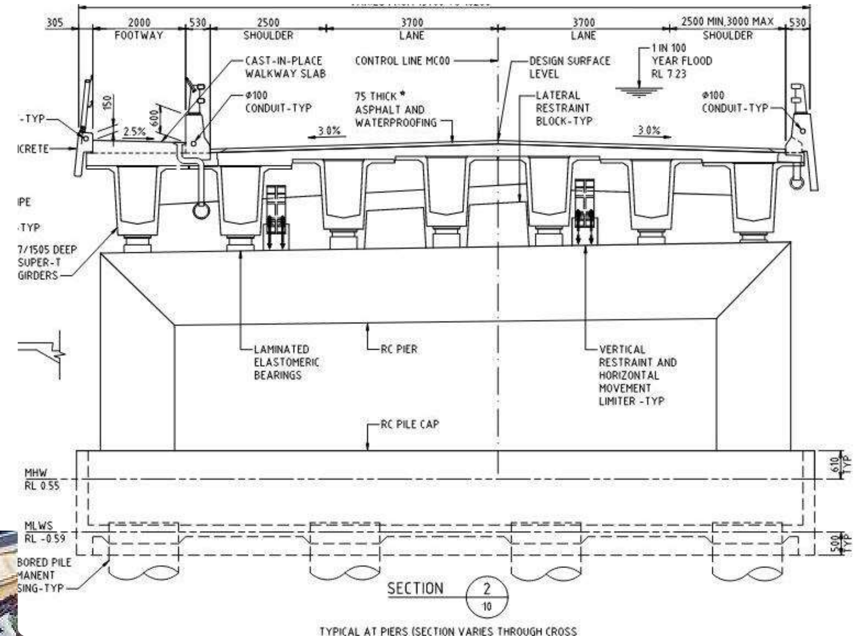
New Nelligen Bridge

- Based on maritime authority approvals, the design vessel was a Displacement Tonnage of 18 tonnes traveling at 20 knots.
- Data developed with TfNSW at the time based on location of bridge up the Clyde River: smaller loads than Nowra, still used ship impact formula.
- Impact between piers 3 to 9.



New Nelligen Bridge

- Limiting devices are added at pier 3 to 9 to control bearing shear deflection under ULS impact load.



Conclusion

- International practice shows that due to vessel impact and bridge protection requirements designs of new bridges have resulted in a significant change in proposed structure types over navigable waterways -
    - longer- span bridges being more economical than traditional shorter span structures.
- Based on literature data -
    - the typical costs for incorporating vessel collision have ranged from 5% to 50% of the basic structure cost without protection,
    - typical costs for adding protection, or for retrofitting an existing bridge for vessel collision, have ranged from 25% to over 100% of the existing bridge costs.
- Due to the increase in bridge costs associated with vessel collision design, it is important to improve knowledge, provide additional research, and have wide industry engagement to improve our understanding of vessel impact and the development of sustainable and cost-effective protection systems.

Thank you