Workshop on popularizing the use of UHPFRC & Factory Manufactured Pre-cast Concrete Elements

SESSION 3 : Navigating NH Pre-cast Concrete Policy

Designer's Perspective including Customization of Design

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सड़क परिवहन
एवं राजमार्ग मंत्रालय
MINISTRY OF
ROAD TRANSPORT
AND HIGHWAYS

सत्यमेव जयते

Ministry of Road Transport and Highways

Government of India

The National Highway Precast Concrete Policy Circular and Policy on use of UHPFRC

SESSION 3 :

File No.RW/NH-33049/01/2020-S&R (B) Pt.
Government of India
Ministry of Road Transport & Highways
(S&R (P&B/New Technology) Zone)
Transport Bhawan, 1, Parliament Street, New Delhi-110001

Dated: 22th February, 2022

CIRCULAR

To,

1. The Chief Secretaries of all the State Governments/ UTs.
2. The Principal Secretaries/ Secretaries of all States/ UTs Public Works Department/ Road Construction Department/ Highways Department (dealing with National Highways and other centrally sponsored schemes).
3. The Chairman, National Highways Authority of India, G-5 & 6, Sector-10, Dwarka, New Delhi-110 075.
4. The Managing Director, NHIDCL, PTI Building, New Delhi-110001.
5. The Director General (Border Roads), Seema Sadak Bhawan, Ring Road, New Delhi- 110 010.
6. All Engineers-in-Chief and Chief Engineers of Public Works Department of States/ UTs/ Road Construction Department/ Highways Departments (dealing with National Highways and other centrally sponsored schemes).
7. All CE-ROs, ROs and ELOs of the Ministry.

Subject: - Use of Ultra High Performance Fiber Reinforced Concrete (UHPFRC) in Design & Construction of Structures/Bridges of National Highways - Regarding

Government of India
Ministry of Road Transport & Highways
(S&R (P&B/New Technology) Zone)
Transport Bhawan, 1, Parliament Street, New Delhi-110001

Dated: 08th April, 2022

CIRCULAR

To

1. The Chief Secretaries of all the State Governments/ UTs.
2. The Principal Secretaries/ Secretaries of all States/ UTs Public Works Department/ Road Construction Department/ Highways Department (dealing with National Highways and other centrally sponsored schemes).
3. The Chairman, National Highways Authority of India, G-5 & 6, Sector-10, Dwarka, New Delhi-110 075.
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7. All CE-ROs, ROs and ELOs of the Ministry.

Subject: - National Highway Pre-cast Concrete Policy - Reg

Broad Content of the Policy Circular dtd 8th April '22

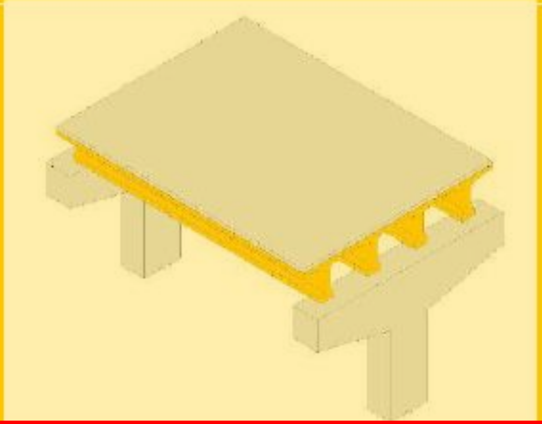
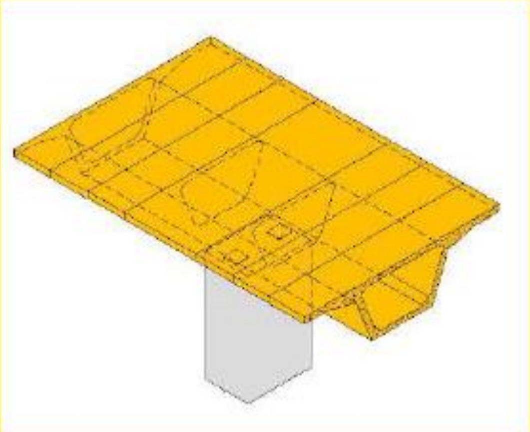
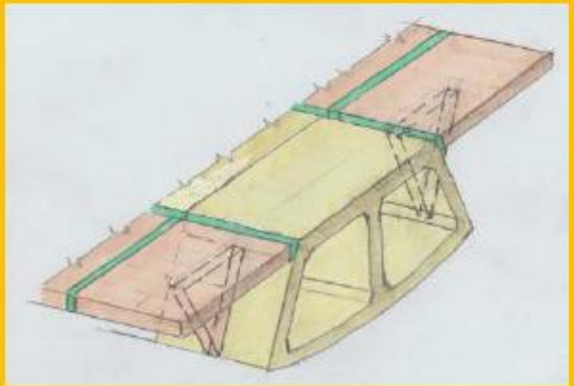
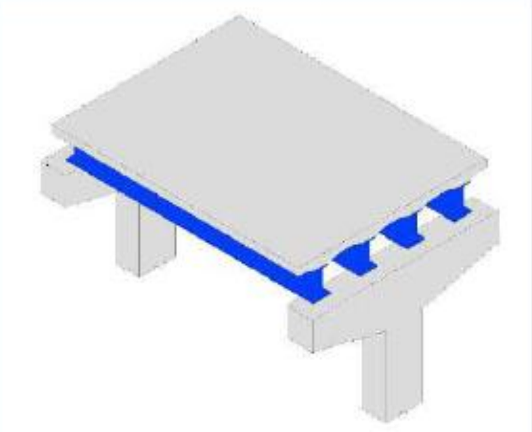
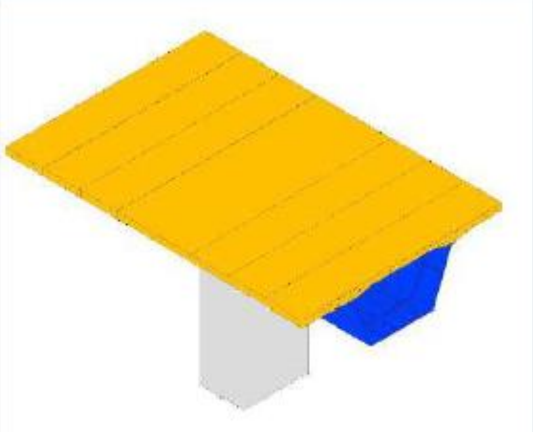
1. Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects

2. Minimum 25% of concrete shall be from a factory within 100 Km radius of the project – A move which will encourage the establishment of factories producing such elements

3. Standardisation of span lengths is promoted to facilitate mass scale pre-casting of elements.

4. Minimum requirements for factory set-up spelt out. QCI is entrusted to certify the factory.

Various possibility of Precast Bridge Deck Segmentation

Longitudinal segmentation into 2 or more self supporting longitudinal elements, which are after installation connected by a concrete slab extending over full width of deck	**Transverse segmentation** into transverse elements extending over the deck's entire cross section	**Hybrid segmentation**: cross section cut longitudinally into three elements, which are all transversely segmented and connected to each other by wet joints after erection of the spine elements
Precast beams	Cast in situ and precast segments	Precast segments
		
Preassembled girders (steel)	Preassembled main girder segments connected after installation by a concrete slab	
		

Designer's Perspective on the Policy Circular

1. **Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects**
2. Minimum 25% of concrete shall be from a factory within 100 Km radius of the project – A move which will encourage the establishment of factories producing such elements
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4. Minimum requirements for factory set-up spelt out. QCI is entrusted to certify the factory.

- **This is a welcome step. The willingness of the precast industry to invest in the manufacture of standardized components relies on the push and enforcement of the relevant authorities.**
- **Manufacturers will hesitate to invest in new moulds and facilities for any new projects unless there is a clear indication that the concept will be promoted by the Authorities**
- **In order to promote this concept, there is need for a holistic approach. Development of assembly methods, erection methods, launching methods, and transportation of heavy girder segments are all to be taken up parallely.**

Designer's Perspective on the Policy Circular

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- **Advantages of mass precasting in factory environment, when compared to other construction procedures, are multiple and well known:**

- **Better product quality:**
  - Industrial manufacturing, with intense quality control in Material
  - Control in manufacturing of high initial and final concrete strength
  - Industrial control of manufacturing processes
  - Higher surface quality

- **Lower structure construction costs & Fast Tracking of Construction:**
  - Optimum design, Value engineered design, and construction of bridge decks
  - Utilization of High-Performance Concrete and Prestressing techniques that allow for an optimum design as well as minimizing material wastage.
  - Minimization of lead time for all structural components
  - Elimination of other in situ worksite process interferences
  - Possibility of working on several structures simultaneously and working in adverse climatic conditions
  - No dependence on climatic conditions

- **Higher safety conditions for workers during construction**
  - Utilization of large telescopic cranes, which allows for the elimination of scaffolding and working under the highest safety conditions
  - Better surveillance & monitoring possible

- **Environmental concerns:**
  - Reduction of energy and material consumption, as well as reduction of pollutants
  - Higher structural durability. More sustainable
  - Minimum environmental impact on surroundings

Worldwide Trend in Factory Produced Bridge Beams

1. **Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects**
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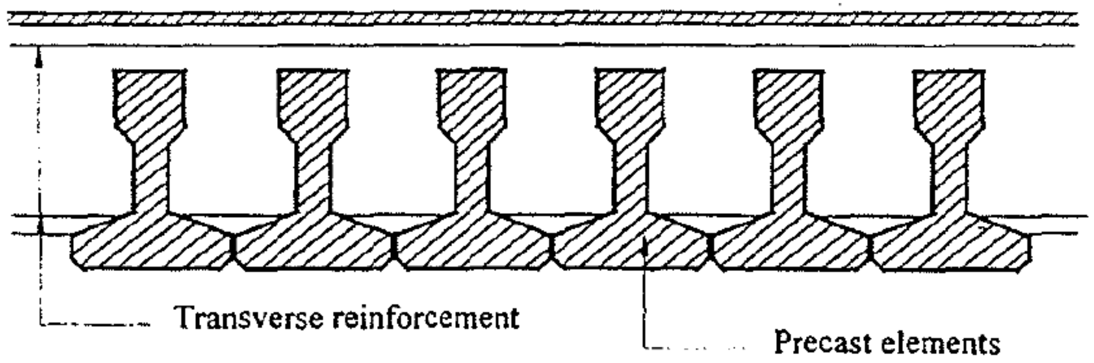
- **Factory-produced precast beams are routinely used in many countries like :**
  - **Belgium,**
  - **Canada,**
  - **UK,**
  - **Italy,**
  - **Spain,**
  - **Netherlands,**
  - **USA**
- **Precast beams are also used in some other countries (like China), but the information is missing in public domain.**

Worldwide Trend in Factory Produced Bridge Beams



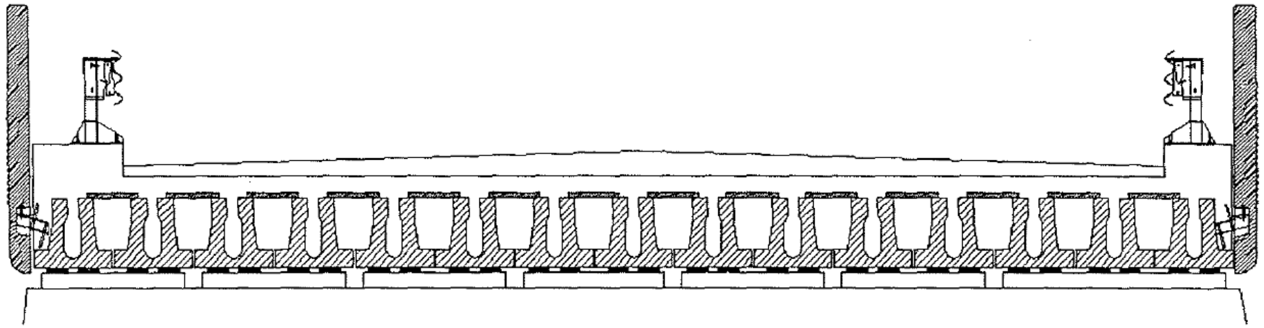
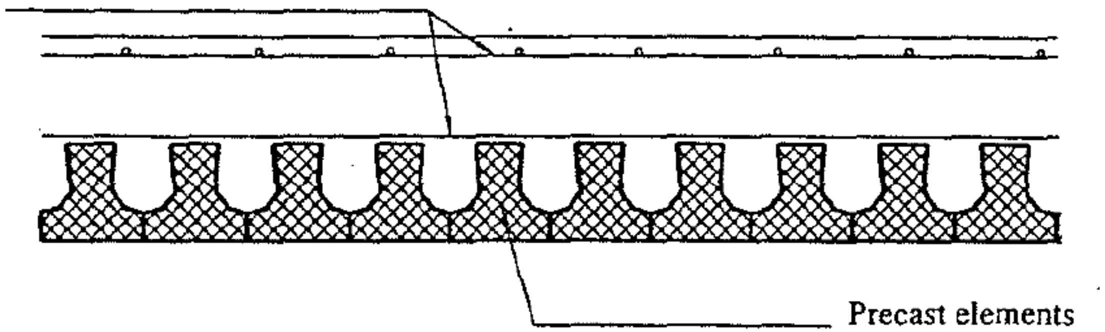


Fig. 4.3: Cross-section of bridge with inverted double-T girders



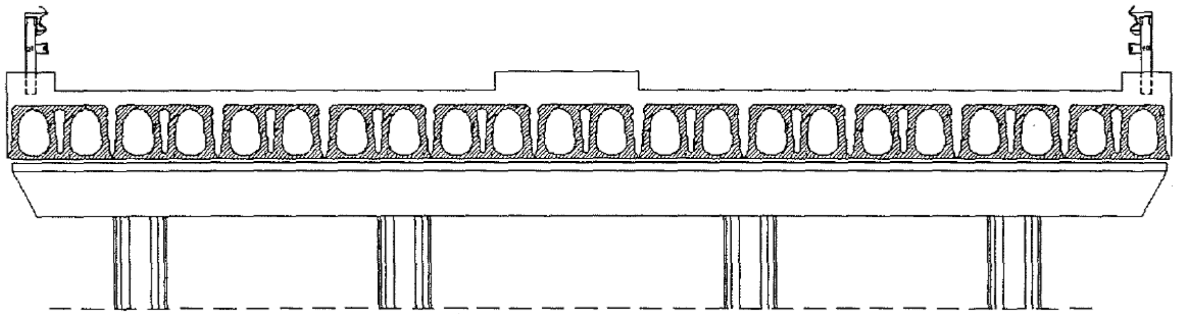
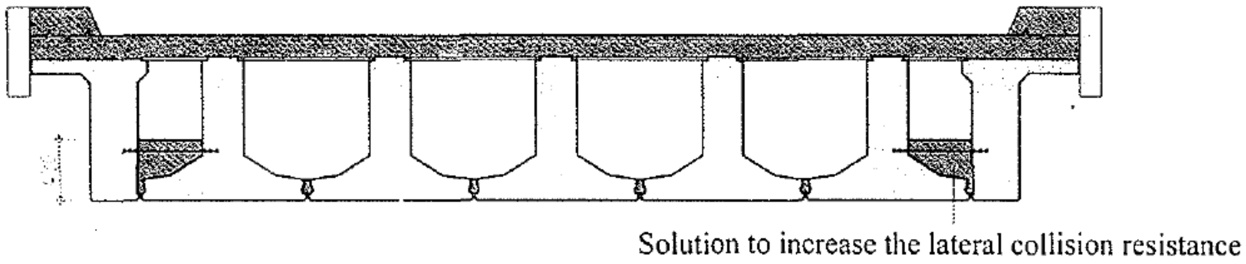


Fig. 4.4: Cross-section of bridge with hollow core beams

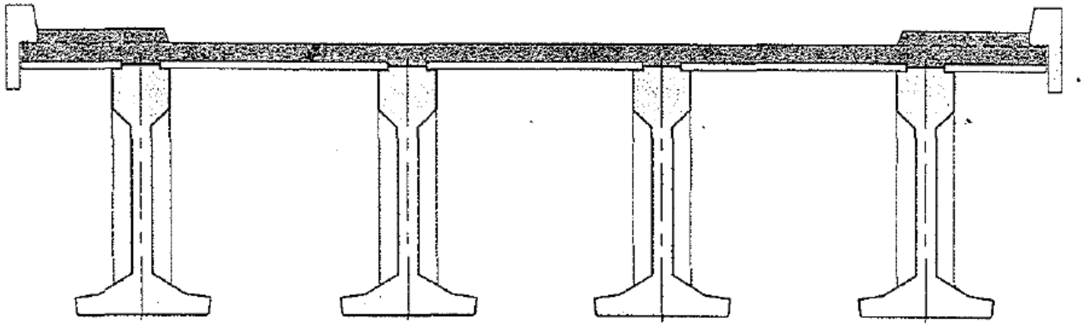
Solid Slab Bridges with precast Elements

Voided Slab Bridges with precast elements

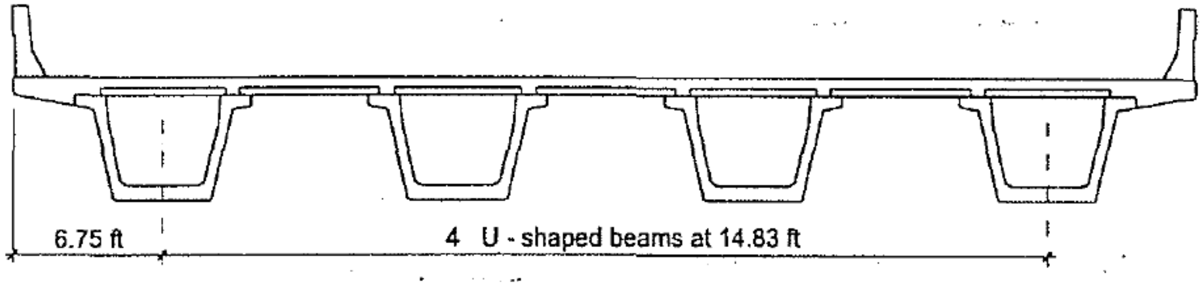
Worldwide Trend in Factory Produced Bridge Beams



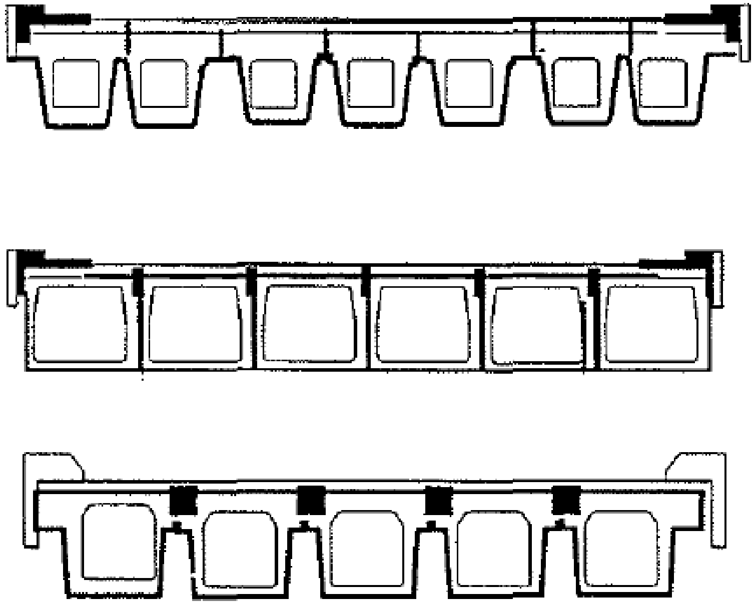
Bridges with Inverted T-Beams



Bridges with I-shaped Girders

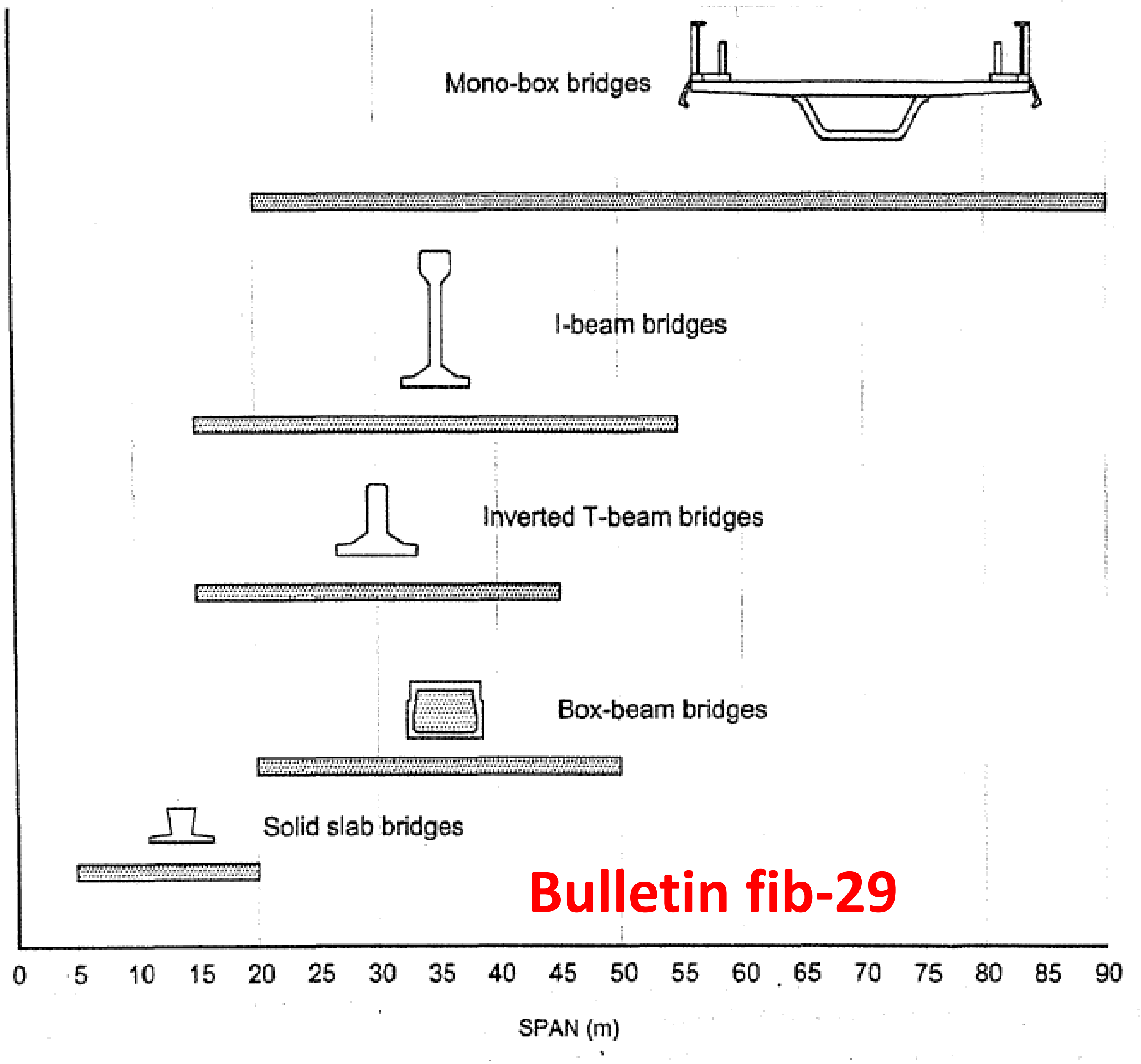


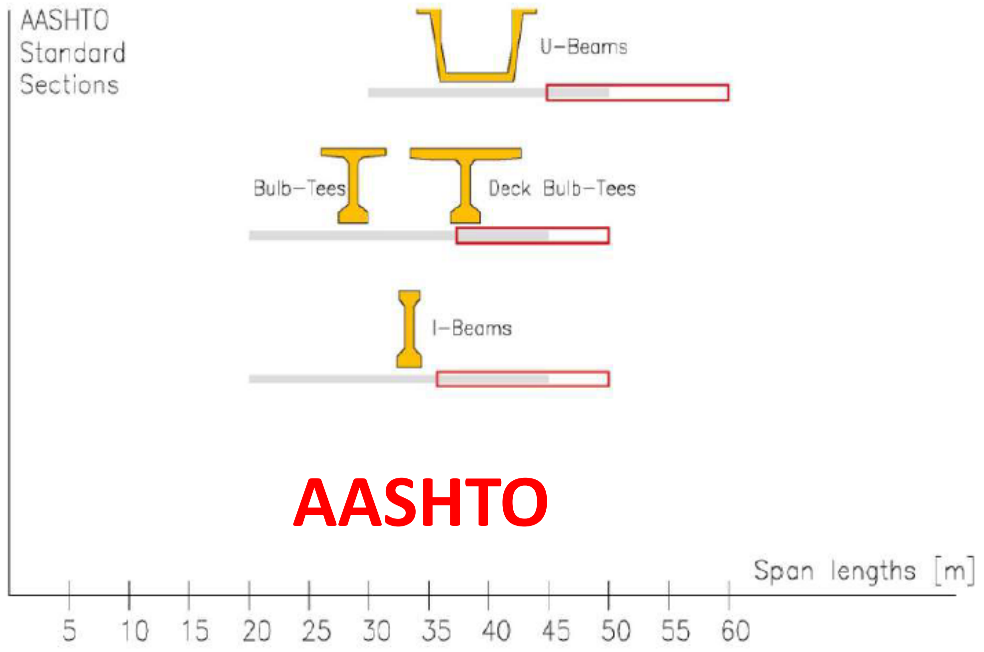
Bridges with U-Shaped Beams



Precast Box Beam Bridges

Worldwide Trend in Factory Produced Bridge Beams



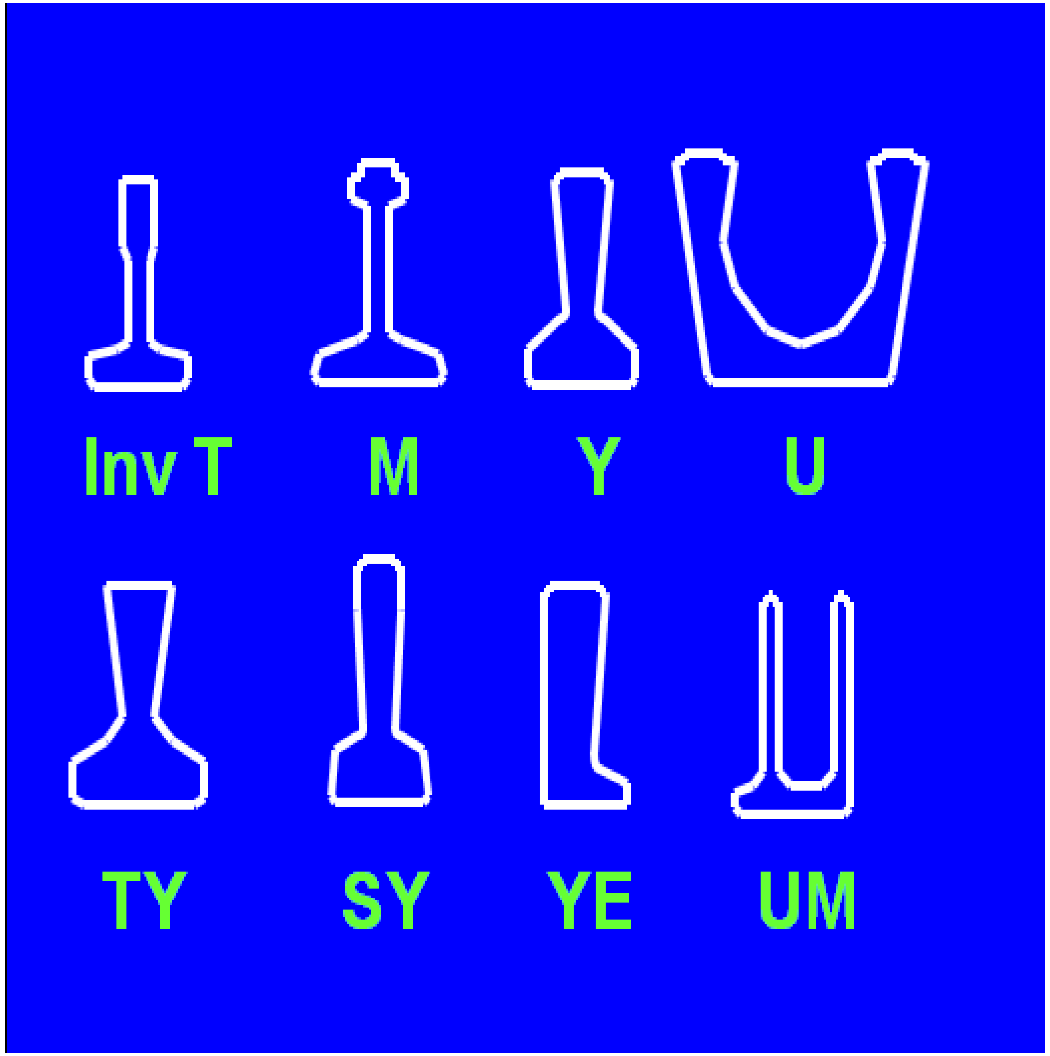


Span range as function of precast girder type according to AASHTO with grey bar for pretensioned girders and red box for post tensioned girders

Overview of Span Ranges for Precast Bridges

Worldwide Trend in Factory Produced Bridge Beams

FACTORY PRODUCED STANDARD PRE-CAST BEAMS FOR SHORT TO MEDIUM SPANS IN UK

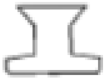
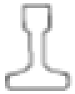
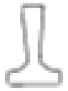
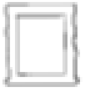
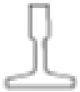
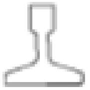
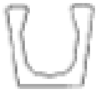


Beam and deck types

Beam	Section	Form of deck	Economical span range (m)	Depth range (mm)
TY-beam		Solid slab	4–17.5	400–850
Inverted T-beam		Solid slab	5–17	380–815
TY-beam		Beam & slab	7.5–17.5	550–850
Y-beam		Beam & slab	14–31	700–1400
SY-beam		Beam & slab	27–45	1500–2000
M-beam		Beam & slab / voided	16–30	720–1360
U-beam		Voided	14–34	800–1600

Worldwide Trend in Factory Produced Bridge Beams

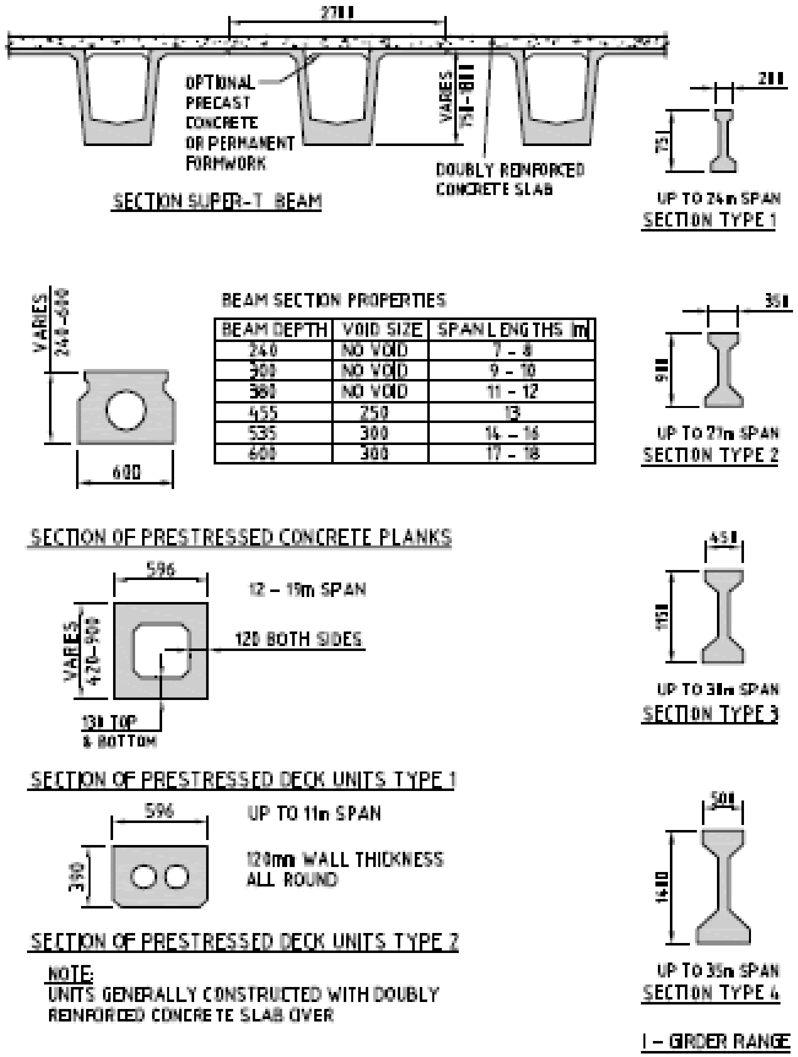
TABLE 1 – Bridge beam sections

Beam	Sections	Depth	Width	Notes
WR		1in – 22in	17¾in	1948 developed by Francis Walley for Costain Concrete Ltd for infill & voided decks
SBB		225mm – 600mm	600mm	Circa 1948 developed by Dow Mac Concrete Ltd. Still in production. Original design had lower flange depths of 2½in, 3½in & 4½in
Inverted T		380mm – 815mm (originally to 695mm)	495mm	1951 PCDG section still in production
Eagle		to 30in	19½in	1965–1970 developed by Dow Mac Concrete Ltd for infill decks
I		710mm – 1980mm	410mm – 660mm	Early 1960s PCDG design to long span beam & slab bridges, usually constructed within span diaphragms
Box		510mm – 1510mm	970mm	Early 1960s PCDG design. Many variants, 1200 wide box by Dow Mac. Shear connector beam by Maunsell etc
Cheshire		762mm – 1371mm	850mm	Late 1960s use on a variety of bridge jobs in the county
Lancashire		750mm – 1300mm	600mm	Late 1960s. Used on M62
M		720mm – 1360mm	970mm	Late 1960s. Accepted as a standard bridge beam. Originally designed to accept an *in situ* long flange
U		800mm – 1600mm	970mm	1973. Standard bridge beam. Voided construction

Factory produced beams are in use since 1948 in UK

Worldwide Trend in Factory Produced Bridge Beams

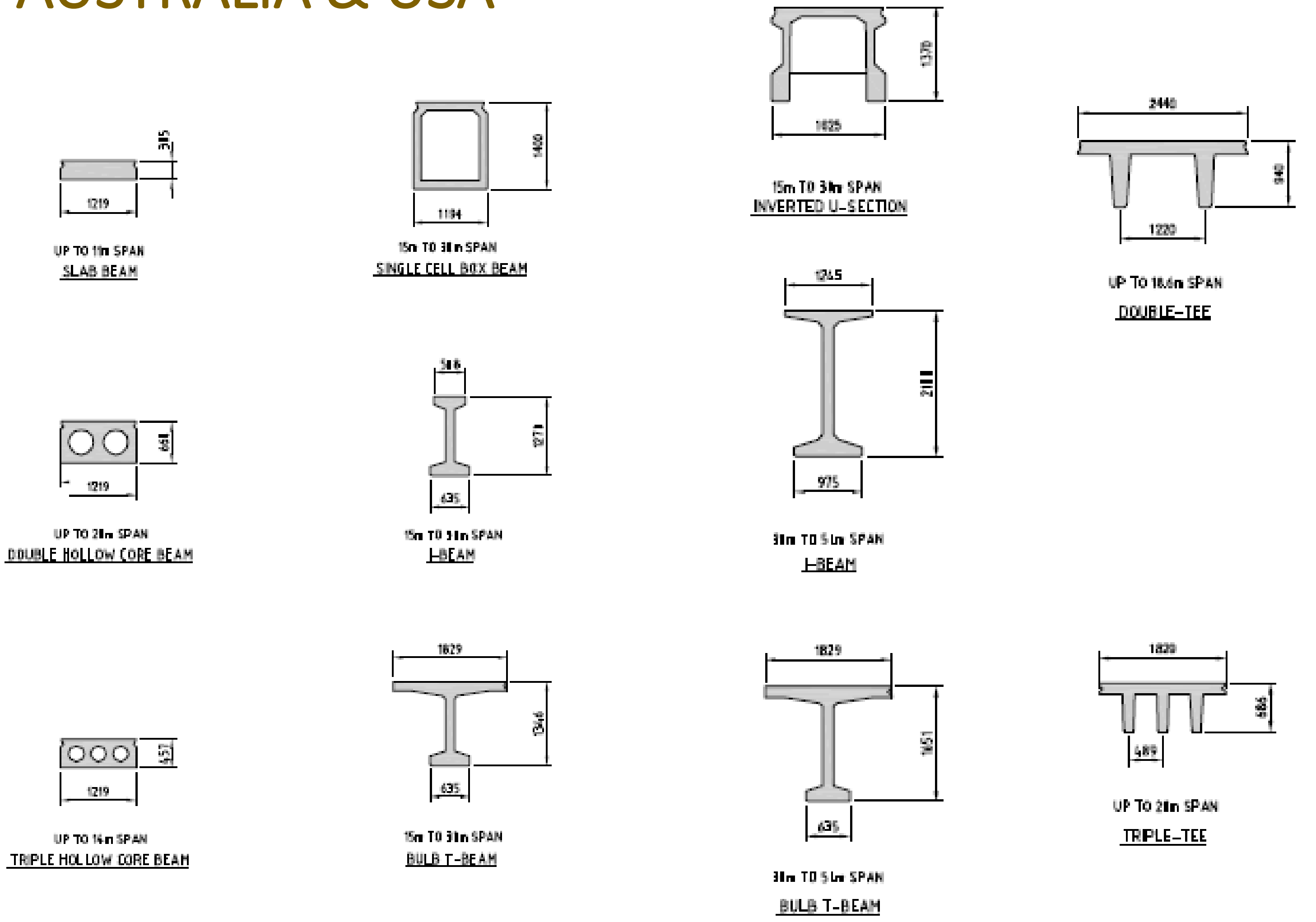
FACTORY PRODUCED STANDARD PRE-CAST BEAMS FOR SHORT TO MEDIUM SPANS IN AUSTRALIA & USA



BEAM SECTION PROPERTIES

BEAM DEPTH	VOID SIZE	SPAN LENGTHS (m)
240	NO VOID	7 – 8
300	NO VOID	9 – 10
380	NO VOID	11 – 12
455	250	13
535	300	14 – 16
600	300	17 – 18

BEAM SHAPES USED IN AUSTRALIA.

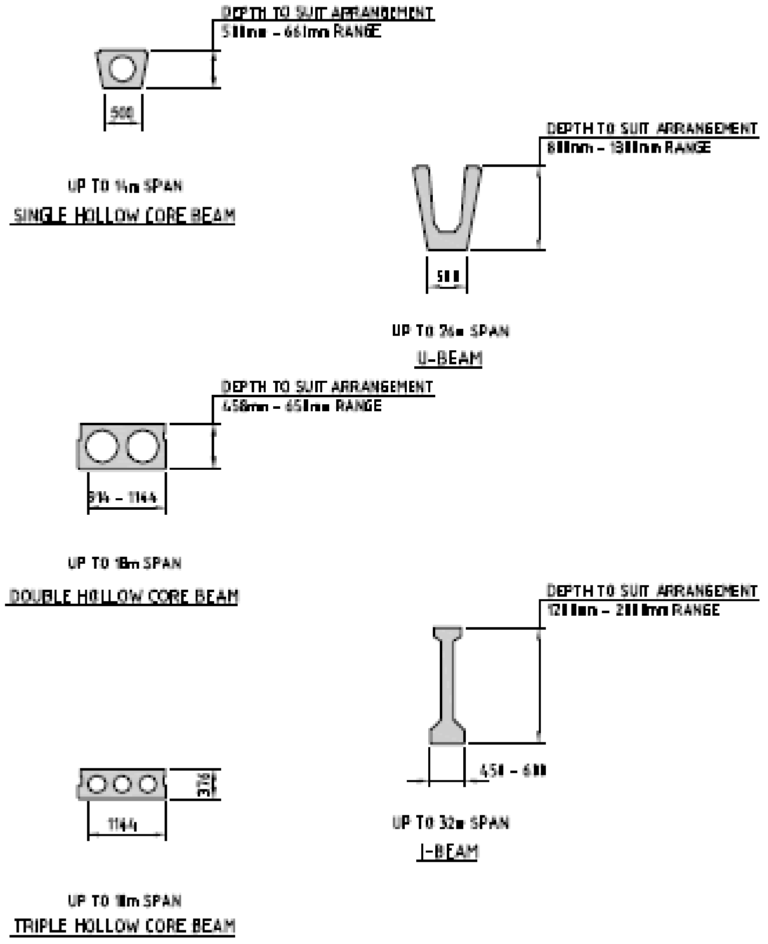


BEAM SHAPES USED IN NORTH AMERICA.

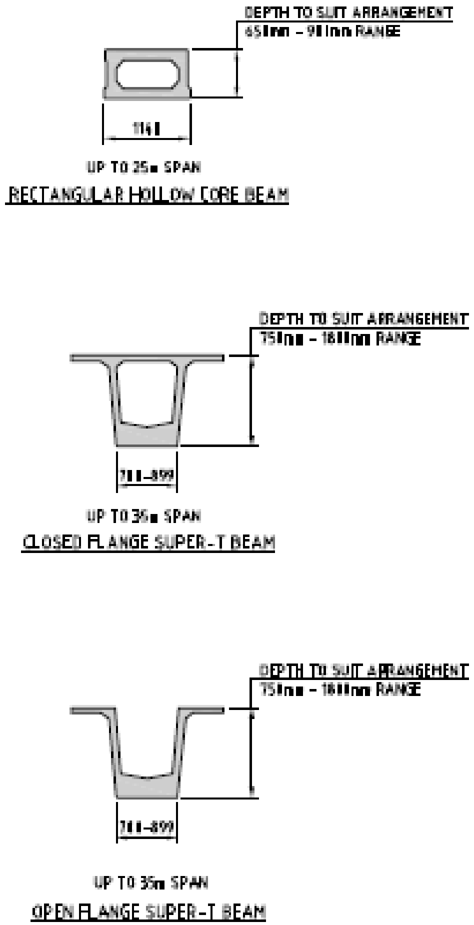
BEAM SHAPES IN NORTH AMERICA.

Worldwide Trend in Factory Produced Bridge Beams

FACTORY PRODUCED STANDARD PRE-CAST BEAMS FOR SHORT TO MEDIUM SPANS IN NEW ZEALAND



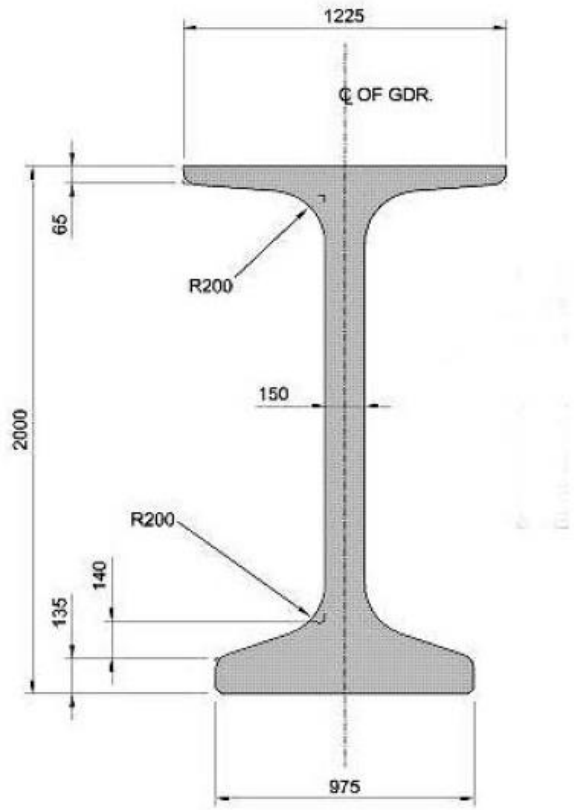
EXISTING STANDARD BEAM SHAPES IN NZ



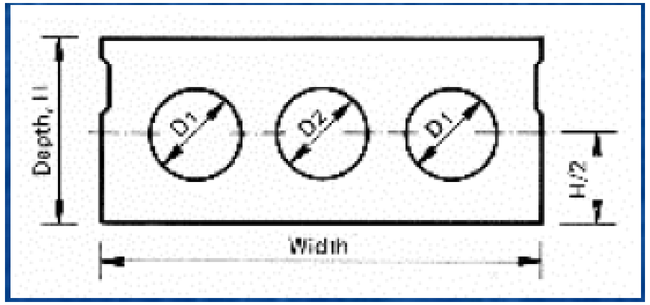
OTHER SHAPES USED IN NZ.

Worldwide Trend in Factory Produced Bridge Beams

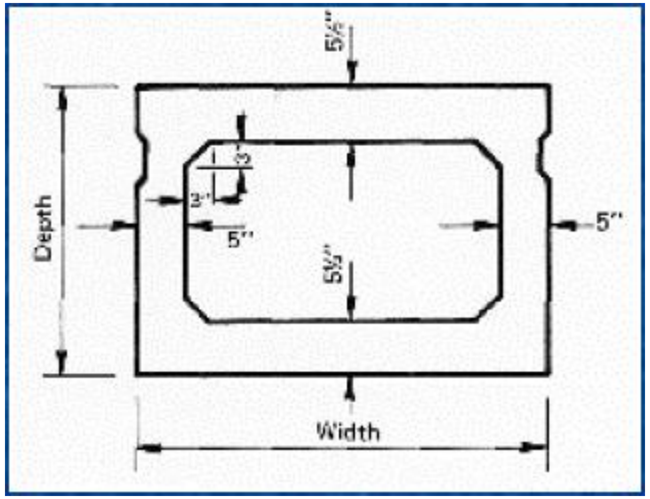
FACTORY PRODUCED STANDARD PRE-CAST BEAMS FOR SHORT TO MEDIUM SPANS IN CANADA



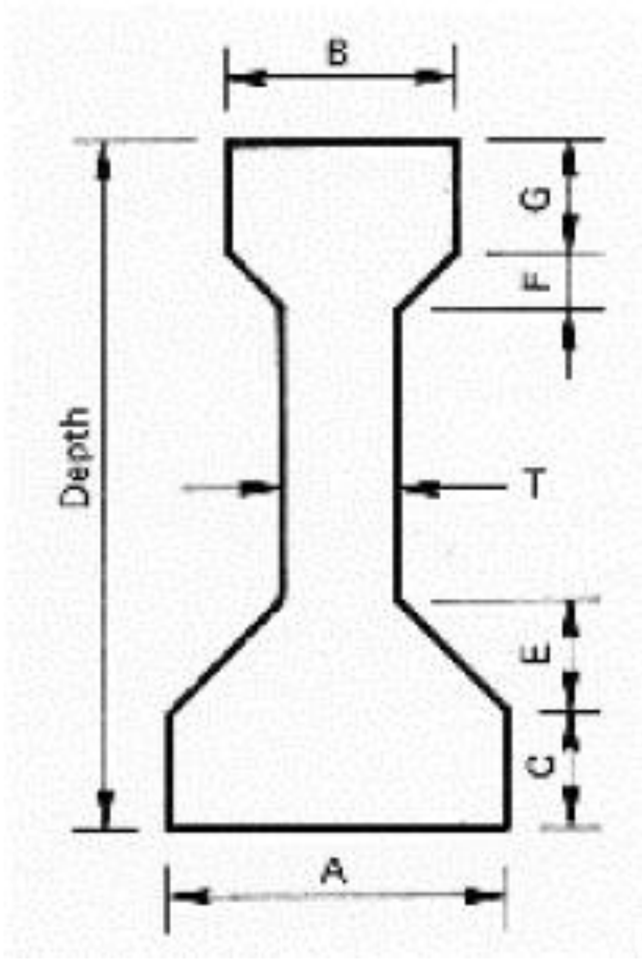
NEW BULB-TEE GIRDER



VOIDED SLAB DECK



HOLLOW BOX DECK



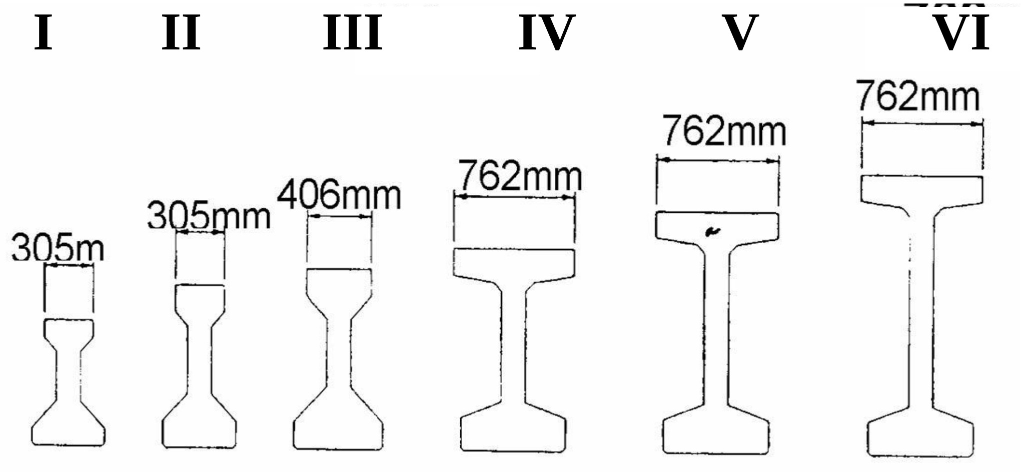
I - GIRDER

Worldwide Trend in Factory Produced Bridge Beams

AASHTO / PCI Standard Beam Sections Used Extensively in USA

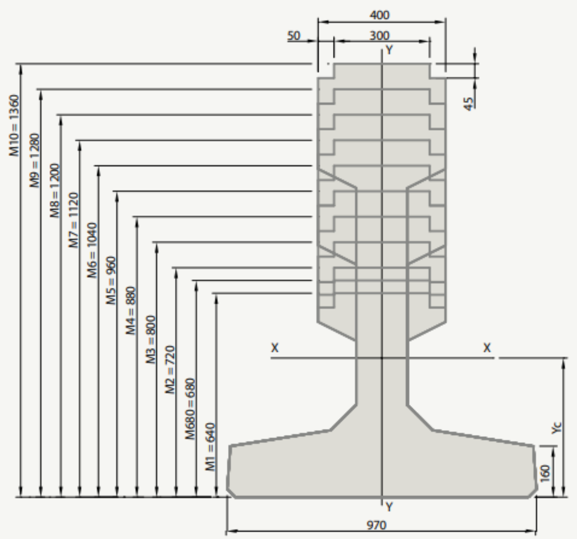
❑Cost effective solution, eliminates tedious, time consuming designs for individual projects

❑Pre-tensioning used for spans upto 40 m
Pre-tensioned, spliced beams for larger spans

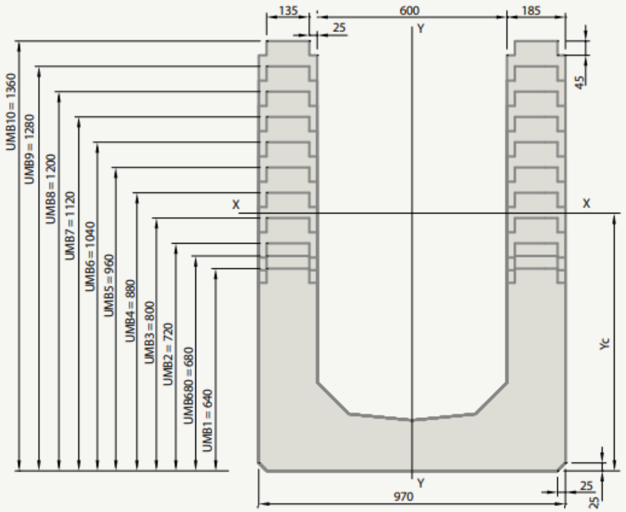


Depth (rounded)	700	900	1000	1500	1600	1800
Web	150	150	175	200	200	200
Span		10- 16^{m}		18-27^{m}	27-40^{m}	

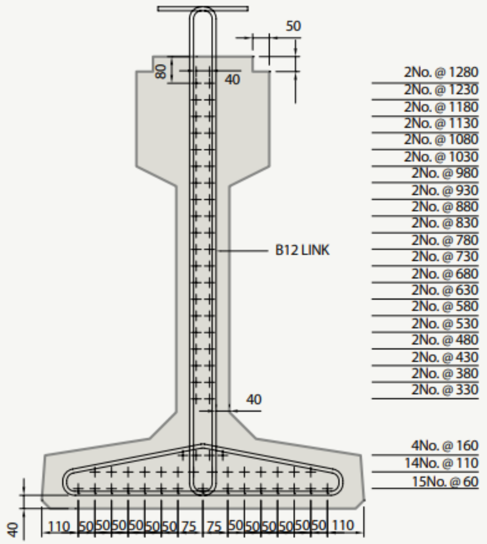
Customisation for Factory Produced Bridge Beams



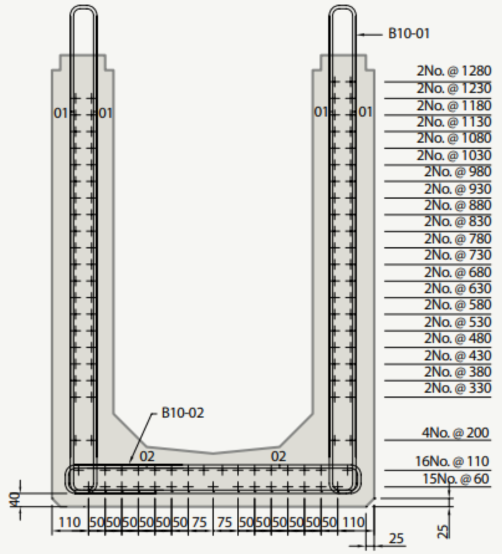
Full M Beam Range



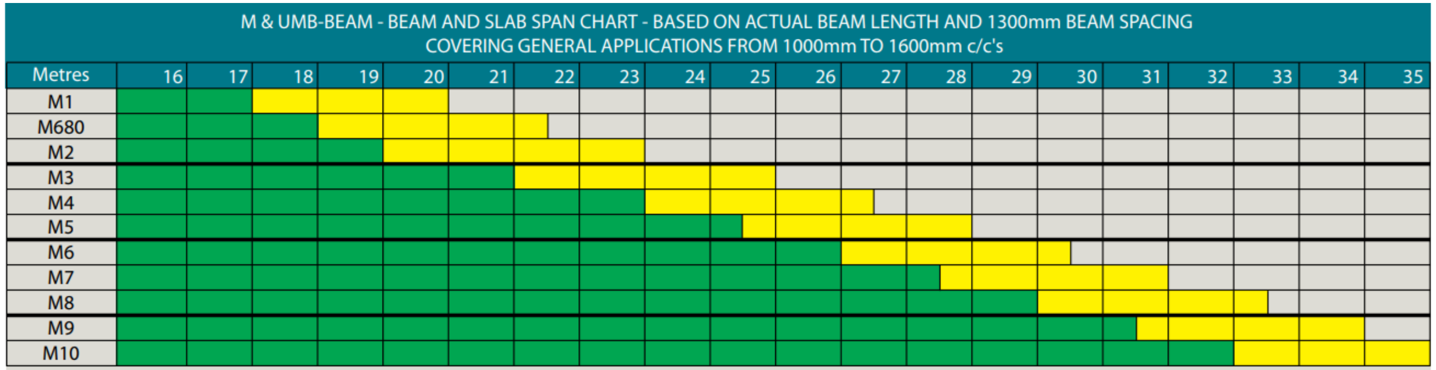
Full UMB Beam Range



M Beam Showing All Possible Strand Locations



UMB Beam Showing All Possible Strand Locations



The above span table is for guideline purposes only and is based on the below criteria, please contact Banagher Precast Concrete with job specific information for a more accurate evaluation.

- Traffic loading as per Eurocode 1
- Design to Eurocode 2
- Simply supported bridge beam structure
- Beams spaced at 1.3m centres
- C40/50 Insitu deck slab 200mm over beam

- C50/60 precast concrete grade @ 28 days with up to C32/40 @ transfer - see (green)
- C57/70 precast concrete grade @ 28 days with up to C45/55 @ transfer - see (yellow)

Note:

- The above figures are for actual beam length
- The clear span will be 1m less than the figues given above
- The centre to centre of bearing in a simply supported structure will be 500mm less than the above figures
- The pier to abutment centres will be perhaps 500mm greater than the above figures
- M-Beams can be poured to any beam depth from 640mm to 1400mm deep if it is found necessary to match the depths to those of other beams like Y-Beams, W-Beams etc..
- This table also covers UMB-Beams

Section	Depth (mm)	Area (mm²)	Ht. centroid over soffit Y_c (mm)	Section modulus - (mm3 x 106) Top fibre Z_t	Bottom fibre Z_b	Second Moment of Area I_{xx} (mm⁴ x 10⁹)	Approximate self-weight (kN/m)	Web Height H (mm)
M1	640	284650	220.1	24.72	47.17	10.381	7.12	200
M680	680	300650	242.9	30.14	54.24	13.173	7.52	200
M2	720	316650	265.4	35.64	61.04	16.202	7.92	200
M3	800	348650	309.8	46.96	74.32	23.020	8.72	200
M4	880	380650	353.4	58.76	87.56	30.944	9.52	200
M5	960	355050	357.0	59.39	100.33	35.813	8.88	440
M6	1040	387050	409.2	75.39	116.23	47.559	9.68	440
M7	1120	419050	459.6	91.52	131.53	60.446	10.48	440
M8	1200	393450	454.1	87.39	143.57	65.187	9.84	680
M9	1280	425450	512.3	108.09	161.96	82.977	10.64	680
M10	1360	457450	568.0	128.65	179.36	101.880	11.44	680
UMB1	640	345675	243.4	29.34	47.79	11.635	8.64	-
UMB680	680	360475	260.1	33.25	53.70	13.964	9.01	-
UMB2	720	375275	276.9	37.41	59.85	16.573	9.38	-
UMB3	800	404875	311.4	46.42	72.86	22.685	10.12	-
UMB4	880	434475	346.5	56.37	86.78	30.071	10.86	-
UMB5	960	464075	382.3	67.22	101.56	38.830	11.60	-
UMB6	1040	493675	418.6	78.95	117.19	49.059	12.34	-
UMB7	1120	523275	455.4	91.56	133.64	60.856	13.08	-
UMB8	1200	552875	492.4	105.03	150.92	74.318	13.82	-
UMB9	1280	582475	529.8	119.36	169.00	89.540	14.56	-
UMB10	1360	612075	567.4	134.52	187.90	106.620	15.30	-

Customisation for Factory Produced Bridge Beams

Alternative Spacings & Spans:

» To determine the beam length "L_{adj}" for a beam spacing "S" other than 1.3m adjust the actual beam length "L" above using the following formula. $L_{adj} = L(1.3/S)^{0.5}$

» To determine the required beam spacing for a given beam length "L_g" and beam size use the following formula where L = beam length for a 1.3m spacing from the above chart. $S=1.3(L/L_g)^2$

» In order to keep control of deck slab moments, beam interface shear links and to use standard 50/20 ribbed FRC shutter BPC recommends a general beam spacing in mm of 1350+0.28D for M-beams where D= beam depth.

Beam spacings greater than this may be used but the permanent shutter will have to be either 75mm deep ribbed FRC or prestressed wide slab with a corresponding increase in deck slab thickness over the beam up to 250mm.

» If using prestressed 75mm wideslab permanent shutter the outside beam face shutter rebates will have to be increased in size from the standard 40mm wide x 50mm deep to 60mm wide x 75mm deep. This also requires the shear links to be narrowed and some adjustment of the top strand locations.

Designer's Perspective on the Policy Circular - 2

1. Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects
2. **Minimum 25% of concrete shall be from a factory within 100 Km radius of the project – A move which will encourage the establishment of factories producing such elements**
3. Standardisation of span lengths is promoted to facilitate mass scale pre-casting of elements.
4. Minimum requirements for factory set-up spelt out. QCI is entrusted to certify the factory.

- **We need a large number of factories to cater to Pan-India needs.**
- **Mandate of 100 Km radius means we need around 430-450 factories to cover the entire country. This is a tall order !!**
- **Standardisation of Precast Girder design is a must to reap full benefits. Standard Designs may be prepared under the aegis of MoRT&H or by the Manufacturer. Design brief for the manufacturer's design must be prepared by Authority.**

Designer’s Perspective on the Policy Circular

1. Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects
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- **IRC 112 is the code which needs to be followed for design of Precast Bridges. Additional design aspects to be considered are :**
  a. Construction Stage Checks: Design during storage, transport, erection and stage-by-stage construction needs to be taken into account.
  b. Interface Design: Design for transfer of forces between p.c elements and in-situ construction.
  c. QA: Setting up a minimum standardised procedure for QA and regulation is a MUST.
  d. Use of HPC, SCC, **UHPFRC** in precast beams.

Designer's Perspective on the Policy Circular …contd.

1. Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects

2. Minimum 25% of concrete shall be from a factory within 100 Km radius of the project – A move which will encourage the establishment of factories producing such elements

3. **Standardisation of span lengths is promoted to facilitate mass scale pre-casting of elements.**

4. Minimum requirements for factory set-up spelt out. QCI is entrusted to certify the factory.

- **Additional design aspects to be considered are :**
  e. Aesthetics: There has to be more emphasis on aesthetics for mass-scale precast construction

  f. Connections: Precast Beam-Diaphragm Beam, Precast Beam-Deck Slab, Support Connection..

  g. Detailing: Treatment of Skew Bridges, Curved Bridges, Edge Treatments, and Treatment of longitudinal and transverse gradients are all very important.

  h. Durability & Sustainability: Reduced embodied energy consumption in construction is one of the key elements of design.

REQUIREMENTS FOR MANUFACTURE OF PRECAST BEAMS

1. Ministry encourages the use of factory-produced precast concrete elements in infrastructure projects
2. Minimum 25% of concrete shall be from a factory within 100 Km radius of the project – A move which will encourage the establishment of factories producing such elements
3. Standardisation of span lengths is promoted to facilitate mass scale pre-casting of elements.
4. **Minimum requirements for factory set-up spelt out. QCI is entrusted to certify the factory.**

- **Factory-producing bridge beams should follow a standard quality system (ISO:9001 & ISO 9002).**
- **It shall comprise self-control by the manufacturer and also supervised by an accredited third party.**
- **Factory Production Control shall comprise of Procedures, Instructions, regular inspections, and tests, regular monitoring to control production processes.**

REQUIREMENTS FOR MANUFACTURE OF PRECAST BEAMS

DESIRABLE QUALITY CONTROL PROCESS FOR MANUFACTURE

FACTORY & YARD

1. Time-tested technology, conforming to quality standards shall be used
2. QA/QC processes at various points throughout the entire process shall be such as to mitigate product defects from reaching the field.
3. All materials shall be re-inspected for QA prior to loading into containers for shipment.
4. Provision for 3rd party inspection certificates shall be available for high demanding Clients

ENGINEERING SERVICES

1. Full-Service design & engineering services shall be provided by the manufacturer.
2. Designs shall be carried out by competent professionals and shall be duly proof-checked by an independent agency
3. Along with engineering designs, full installation drawings shall be provided with all engineering packages.
4. All materials shall be regularly inspected

ON-SITE TECHNICAL SUPPORT

1. Dedicated on-site field services shall be a part of the manufacturer’s scope of services.
2. Field Service Representatives (FSR’s) shall oversee the installation, working with the Client’s assembly crew.
3. FSR’s shall be competent engineers with experience in erection and assembly. They shall be present at all times of transport and erection and shall remain on-site until the bridge is fully installed & certifies that the bridge is built as per design intent.

REQUIREMENTS FOR MANUFACTURE OF PRECAST BEAMS

SUBJECT	METHOD	PURPOSE	FREQUENCY
Mixture - composition (except water content)	- Visual on weighing equipment - Checking against production documents	Conformity with intended production	- Daily for each composition used - After each change
Water content of fresh concrete	Appropriate method	To provide data for the water/cement ratio	- Daily for each composition used - After each change - In case of doubt
Chloride content	Calculation	To ensure that the maximum chloride content is not exceeded	In case of increase of the chloride content of the constituents
Water/cement ratio of fresh concrete	Calculation according to specific standard	To assess specified water/cement ratio	Daily, if specified
Air content of fresh concrete	Test according to specific standard	To assess conformity with specified content of entrained air	First batch of each production day until values stabilise
Concrete mix	Visual check	Correct mixing	Daily for each mixer
Potential concrete strength	Testing according to specific standard	To assess conformity with intended value	Daily for each type of concrete
Density of hardened concrete	Testing according to specific standard	To assess specified density	As frequently as potential strength

Typical Factory Production Control in Concrete

REQUIREMENTS FOR MANUFACTURE OF PRECAST BEAMS

DIMENSIONS (Figure 10.9)	PERMITTED DEVIATION (mm)
Length (L)	- (20 + L/2000) + (20 + L/2000)
Height (h)	- h/100 or -10 (whichever is the greater) + (10 + h/100)
Width (a, b, e)	± (10 + b/200)
Flange depth (m)	± 10
Flange depth (s)	- 5 + 10
Vertical skewness (v_1, see fig 1b)	± 0.03 h
Horizontal skewness (v_2, see Fig 1c)	± 0.05 d
Verticality (g, see Fig 1d)	± 0.02 h
Lateral deviation (with reference to theoretical axis)	± L/500
Camber or sag (with reference to declared value evaluated taking into account the age and the load history of the element)	50% of the declared value or L/800 (whichever is the greater)
Position of holes or inserts (with reference to drawings)	± 30
Mutual position holes or inserts within a group	± 5
Concrete cover (The absolute minimum required by the durability should always be fulfilled)	- 5 + 10
Position of ordinary reinforcement (not related to cover), except the longitudinal position of stirrups.	± 10

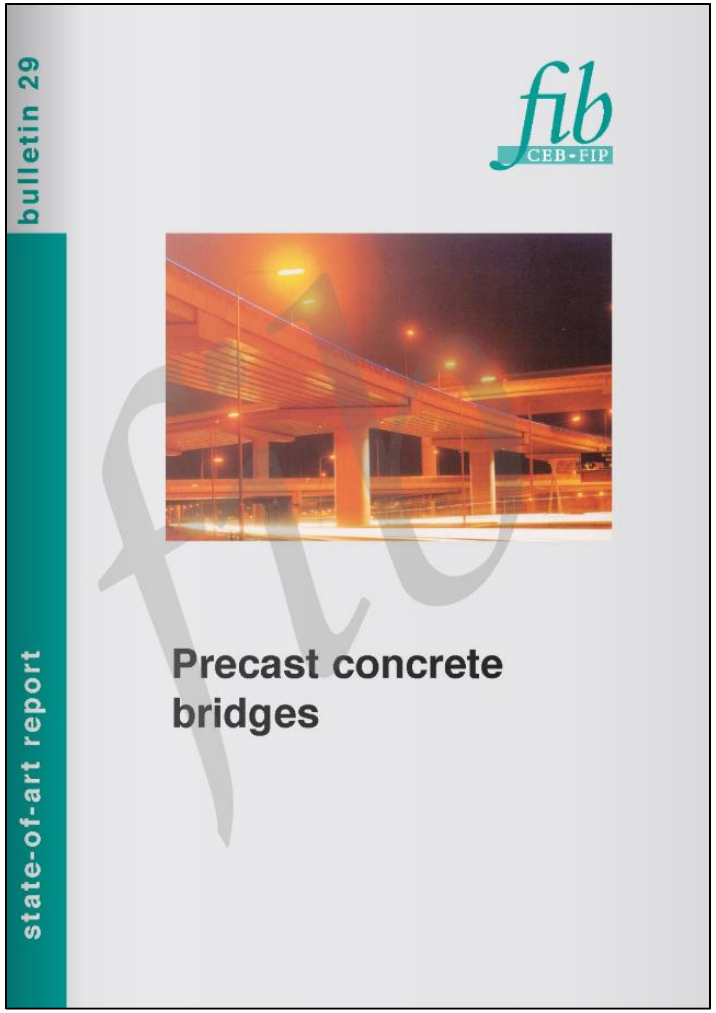
Example of Product Tolerances in Bridge Elements

CONCLUDING REMARKS

- Policy Circular dated 8th April 22 is a welcome step. It is likely to be the catalyst for real change in the industry
- "Short" & "Long" term measures are required to be taken by MoRT&H to realize the benefits.
- As a Long-Term measure, MoRT&H may initiate consultancy contracts for the preparation of Standard Drawings of Simply Supported and Continuous Spans using precast factory-produced beams of various shapes.

CONCLUDING REMARKS

- **Following short-term measures are needed urgently for encouraging manufacturers to invest in precast factories:**
  - To bring out a Special Publication of IRC on **<u>“Factory Produced Precast Concrete Bridges”</u>** (*in line with Bulletin fib 29*) covering the subject and helping stakeholders to get away from existing prejudices.
  - DPR Consultants should always promote the use of precast technology in their design. Contract Agreement of EPC/HAM contracts should mandate the use of precast beams



Workshop on popularizing the use of UHPFRC & Factory Manufactured Pre-cast Concrete Elements