Design of Footbridges

Dutch solutions for bicycle and pedestrian bridges

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ipv Delft

• infrastructure
• urban furniture
• architecture
• lighting
As one of the Netherlands' main bridge design offices, ipv Delft has focused on designing bicycle and pedestrian bridges for two decades. The company has used their extensive experience in bridge design to write this publication. This design manual focuses on the fundamentals of bridge design, answering practical questions regarding issues such as bridge width and slopes. It also lists the things that should be taken into account before starting on the actual design and it offers insight into the Dutch regulations regarding loads and collision forces. General advice on cost reduction is also included and several of the company's projects are shown to illustrate the theoretical contents. The Brief Dutch Design Manual for Bicycle and Pedestrian Bridges is therefore a vital source of both practical information and bridge design inspiration.

This publication is an English summary of the Dutch Design Manual for Bicycle and Pedestrian Bridges, which was published by CROW in 2014 and written by ipv Delft.

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in cooperation with

CROW publication 342
Dutch, by ipv Delft

Summary CROW publication 342
English, by ipv Delft

Dutch Design Manual

Free Download:
ipvdelft.com / publications
Intended Users: All involved disciplines & stakeholders

- Management
- Urban Planning
- Architects
- Structural engineering
- Traffic engineering
- Maintenance
- Contractors
- Advocates
- Local stakeholders

Dutch Design Manual
Intended Goal: Create Understanding
Between representatives of Technical & Social requirements

Dutch Design Manual
Structure: Follows the Development Process

Analysis of Requirements

Design Development

Traffic Network
Context
Users
Design Checklist
Alignment
Bridge Design
Budget

Dutch Design Manual
Structure: Follows the Development Process

Analysis of Requirements
- Traffic Network
- Context
- Users
- Design Checklist

Design Development
- Alignment
- Bridge Design
- Budget

Why
For Whom
What

Dutch Design Manual
## Involvement of disciplines & stakeholders: *Optimal*

### Analysis of Requirements → Design → Development

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<th>Client</th>
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### Dutch Design Manual
Traffic Network
Finding the best bridge location

Analyse

• Network demand
  - regular users
  - number of users

• Route restrictions

• Adjacent route \((A', B')\)
Network as Design Driver

Cycle Network
- Utilitarian
- Recreational

Alignment 1
- Arterial road
- Road Bridge
- Highway A2

Alignment 2

Dutch Design Manual
Traffic Network Analysis   Bridge Alignment 1
Traffic Network Analysis  Bridge Alignment 2

- structurally / cost efficient
- no piers in highway:
  - no obstruction of sightlines
  - minimal construction hindrance
Context

Location specific requirements & potential benefits

Analyse

- Urban Planning
- Local Wishes
- Ecology
- Land Ownership
- Cables and Pipelines
- Subsurface Conditions
- Potential Benefits
Context: History

Historic railroad truss bridge
Context: History

New bridges refer to history
Context: History

New bridges refer to history
Context: Benefits

- casting deck directly on existing earth dam
- using in soil casted piles
Context: Benefits

- casting deck directly on existing earth dam
- using in soil casted piles
Users

Determine

• Required Space
• Road Planning
• Loads
• Abuse Prevention

Regular
Cyclists, Pedestrians, Mopeds, Disabled vehicles

Special
Disabled, Elderly, Children

Not intended
Not intended vehicle, Hooligans, ...

Occasionally
Maintenance, Emergency Services

Other
Utility companies ...

Dutch Design Manual
Users
Bridge & Intersecting

- regular
- regular
- regular
- regular
- special
- special
- special
- occasional
- not intended
- not intended
- not intended
- other
Dutch Design Manual

Cyclist Measurements

- Width: 75 cm
- Sway: 25 - 80 cm
- Distance: 25 cm
- Vertical Clearance: 2.5 m
Dutch Design Manual  cyclist distance to objects

32.5 cm railing  62.5 cm wall  50 cm extra width in curve
minimum one way

minimum two way in curve

---

Dutch Design Manual

cyclist deckwidth
List of requirements
Gathering all requirements

Design Checklist

- Network
- Context
- Users
- Regulations
- Building Codes

Dutch Design Manual
Alignment

Finding the best contextual fit, alignment with the contextual requirements

Taking into account

- Network
- Context
- Users
  - comfort
  - safety
Alignment: Grade

Ramp Difficulty: \( Z = H^2/L \)

- Target normal circumstances: \( Z = 0.075 \)
- Max. \( Z = 0.2 \)
- Min. \( Z = 0.033 \)

More wind nuisance → Less wind nuisance
Less comfortable → More comfortable
25 m Flat stretches
• over 3 -5 m height
• in bends in ramp
• at end of ramp

Dutch Design Manual
Bridge Design

Designing for the requirements

Requirements
Network, context & Users

Determine
Best Alignment &
Spatial Integration

Starting Point
Detailed Bridge Design
Structure: Follows the Development process

Analyse
- Traffic Network
- Context
- Users
- Design Checklist

Design
- Alignment
- Bridge Design
- Budget

Dutch Design Manual
Hovenring, Eindhoven
The Netherlands
Eindhoven
North Sea
United Kingdom
English Channel
Belgium
France
Germany
Context (national)  Eindhoven - population 220,000
Context (international)  The Netherlands in Europe
The Netherlands compared to Australia
Context (national) The Netherlands compared to Sydney - Canberra Region
Dutch network compared to Sydney - Canberra Region
Network (national)  transport over water and road
Network (international)  The Netherlands, a hub for Europe
Flood Risk Areas

- 26% by sea
- 29% by rivers

Foundation Piles almost always required

Context (national) flooding risk
Travel Time: bike & car
Equal up to 7.5 km

Network (regional) travel time in dense populated areas
8 mln people with all needs within cycling distance

Network (national) travel time in dense populated areas
18 million bikes
• > 14 million trips / day
• 35,000 km bike path
• 2500 km highway
• 8 million cars

Network (national) Cycling Facts
Context (regional)  Eindhoven - Brainport of the Netherlands
Context (regional)  Eindhoven - technology and innovation
Network (regional) Project Location in the region
Context (regional)  Eindhoven - Impression Brainport Avenue (highway A2)
• roundabout congested with car traffic
• traffic lights for cyclists and pedestrians
New developments

- high-tech business areas
- residential areas
- highway connection
Context (local)  Commercial and Safety Requirements
Context (regional)  Existing landmarks

Westcorridor Eindhoven

Hovenring  Evoluon  Light Needle

landmark bridge  future technology museum
Users  Deck Width

4.4 m

cm 32.5 75 25 75 25 75 25 75 32.5
Users  Not intended visitors (Latin American mayor delegation 2017)
• 9 metric tons maintenance vehicle
• height above the road
• collision loads

Users  Intersecting Infrastructure
### Analysis of Requirements

#### Involvement of all Disciplines & Stakeholders

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#### Checklist

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<td><img src="design.png" alt="Design" /></td>
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**Hovenring**

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- Analysis of Requirements
- Involvement of all Disciplines & Stakeholders
Cross

Large roundabout

Ellipse

Small roundabout

Alignment  Route and Bridgeform Study
Design Concept Evaluation

- too much weight
- not efficient
- reasonably efficient
- efficient
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<td>Not distinctive</td>
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**Design**  Evaluation Final Concepts
Earth Dam

Bridge

Alignment  Ramp Type
Collision Loads
Collision Loads Signage Portals as Anti-Collison Portals
Collision Loads
Commonly used Signage Portals
Collision Loads  Custom designed Anti-Collision Portals
Collision Loads  Anti-Collision Portals proven usefull
Think Filter!

Collision Loads  Anti-Collision Portals - Cost-saving Filters
Collision Loads  Concrete Barrier Pylon Foot
Collision Loads  Concrete Barriers protect supports
Structural Design  Bridge Deck and Counterweight
aluminium lamellas with translucent sheeting

one fluorescent tube

Lighting Design Architectural Lighting
aluminium lamellas with translucent sheeting
structural beam

Lighting Design  Architectural Lighting
Technical Space

Bridge Design  Integrated Technical Space
Lighting Design  Deck & Facial Lighting
LED facial lighting
LED deck lighting
wiring
extruded al. handrail
fixation point

Lighting Design  Custom Handrail with Integrated Lighting
Lighting Design

Custom Handrail with Integrated Lighting

- LED deck lighting
- Custom aluminium extrusion profile
- LED facial lighting
- fixation point
Lighting Design  Intersection Lighting
Lighting Design  Intersection Lighting
Lighting Design  Intersection Lighting
Lighting Design  Intersection Lighting
Integral Design  Integration of traffic lights, lighting and signage
Design details  Pylon Cable Anchorage

2 layers of 12 cables
All sockets can be inspected from inside the pylon.

Design details  Pylon Cable Anchorage
### Costs
- **Bridge**: € 6.3 million
- **Intersection**: € 4.5 million

### Funding
- **Eindhoven**: 40%
- **3 Grants**: 60%
- **Bridge Budget**: € 8.5 million

### Daily Users
- **Cars**: 25000
- **Cyclists**: 5000

### Dimensions
- **Deck width**: 4.5 m
- **Deck Area**: 1300 m²
- **Steel**: 1015 metric ton
Business Area
City Centre
Visibillity
New Bridge
Old, Characteristic Trees
Enschede Bridge
Context - Alignment Constraints
bridge position

required height 4.6m

line of sight

stopping distance

low traffic light

traffic lights

stopmarker

R 75 m (5x)

R 180 m (5x)

2.5

Enschede Bridge

Final Alignment
Enschede Bridge  Modular Construction
Facts & Figures
• bridge length 280 m
• ramp length 150 m
• width 3.5 m
• lighting element
• budget: €2.0 million
• costs: €1.4 million
Haarlem submerged bridge  

Context
required height 2.5 m

rain water pump
Facts & Figures

- length 110 m
- width 5 m
- slope < 4%
- costs: €1.1 million

Haarlem submerged bridge  Result
Heerhugowaard Station bridge  Alignment Fitting in the Context
Possible main span materials

- steel  
- stainless steel  
- high performance concrete  
- fiber re-inforced composite

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main span contour

Heerhugowaard Station bridge

Main Span Contour - Optimal Materials
Facts & Figures

- bridge length  154 m
- ramp length  120 m
- width  3.5 m mainspan, 4m straight slopes, 6 m corners
- costs: €1.7 million
Tender Type: Client side development

Contract Type

Plan
Concept
Sketch
Preliminary
Final
Detailed
Construction

Client

Contractor

Budget Tender & Contract format

Tender & Contract format

D&C
E&C
Detailed Contract

Budget

Tender Type: Client side development

Contract Type

Plan
Concept
Sketch
Preliminary
Final
Detailed
Construction

Client

Contractor

Budget Tender & Contract format

Tender & Contract format

D&C
E&C
Detailed Contract

Budget
Tender Type: Market orientated development

Client

Tender & Contract format

Contractor

Plan

Concept

Sketch

Preliminary

Final

Detailed

Construction

Budget

D&C

E&C

Detailed Contract
A Thorough Analysis

Analysis of Requirements

Traffic Network
Context
Users

Design Checklist

Design Development

Alignment
Bridge Design
Budget

Why
For Whom
What

Dutch Design Manual
Create Understanding

Between representatives of Technical & Social requirements

Dutch Design Manual
Because Crossings are:

- Hard to Integrate
- Hard to Upgrade
- Advertisers / Kickstarters
- Gapclosers
Contextual Benefits

- Lowering intersection for comfortable ramps
- Ramps as sound barriers

Eindhoven Hovenring benefits from the context
Contextual Benefits

- Signage portals as high traffic filter

Eindhoven Hovenring benefits from the context
Contextual Benefits

- bridge deck casted directly on existing earth dam
- Using in soil casted piles
Think Modular!

Enschede Bridge  Modular Construction
Think Filter!

Collision Loads  Anti-Collision Portals - Cost-saving Filters
Think Filter!

Users  Unauthorized vehicle loads - use a filter
Seek Integration!

Custom aluminium extrusion profile

LED deck lighting

Fixation point

LED facial lighting

Lighting Design

Custom Handrail with Integrated Lighting
Seek Integration!

Users Not intended visitors (Latin American mayor delegation 2017)
Seek Integration!

Integral Design  Integration of traffic lights, lighting and signage
Tender Smart: Develop Client Side what you know best!

Budget Tender & Contract format
Conclusions

To develop bridges that satisfy all involved and their requirements:

- **Analyse** requirements thoroughly
- **Involve** all from the start
- **Create** understanding & openness
- **Start** with the crossings
- **Seek** Modularity
  - Contextual Benefits
  - Filters
  - Integration
- **Outsource** Only what you can’t do yourself

*Be open to practical custom new solutions.*
*Bridges are almost never standard solutions.*
*A custom solution can be best and cheapest.*

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