Steel application in construction
Prof. Dr.-Ing. Dieter Ungermann
Steel application in construction

1. Examples
2. Steel market in construction
3. Research topics
4. Summary
1. Examples

Steel enables ambitious infrastructure
Viaduc de Millau (France)

- Multi Cable-Stayed Bridge
- Length: 2460 m
- Steel superstructure: orthotropic box deck of 27.75 m width and maximum height of 4.20 m
- Total height: 343 m
Steel enables ambitious infrastructure
Viaduc de Millau (France)

- Pylons and decks are welded constructions
1. Examples

Steel enables ambitious infrastructure
Viaduc de Millau (France)

Thermo-mechanical treatment in rolling process of steel S460 ensures uncomplicated weld procedures

- Deck: S355 23,500 t
  S460 12,500 t
- Pylon: S355 3,200 t
  S460 1,400 t
- Stay cable: 1,500 t
1. Examples

Steel designs urban environment
Railway Station Liege (Belgium)

- Roof made of Steel and glass
- Length: 200 m
- Height: 35 m
- 39 Steel arches (span 157 m)
- Weight 11,000 t
1. Examples

Steel assures modern building concepts
Commerzbank Tower Frankfurt

- Height: 258 m
- 18,800 t Stahl
- Total weight: 200,000 t
- Steel grades: S355 J2G3 / S355 M
  S460 N /S460 M
1. Examples

Steel assures modern building concepts
Commerzbank Tower Frankfurt

Steel-concrete-composite solutions with high bearing capacity and high fire resistance
1. Examples

Steel is hidden in many buildings
High bay racking systems

- Storage of goods on pallets
- Usual dimensions: $l/w/h = 150m/60m/40m$
- Storage positions: >25,000 pallets
- Operation by automatic storage and retrieval machines
1. Examples

Steel is hidden in many buildings

High bay racking systems

- Silo design: Building envelope is carried by the high bay racking system
- Steel consumption of the manufacturers organised in the German national association of storage and plant equipment: 400,000 t p.a.

Source: SSI Schäfer
1. Examples

High bay racking systems
Steel consumption of a high bay racking system

Example:
- Dimensions: l/w/h = 155m/120m/40m
- Column profiles: ca. 190 km length (ca. 70,000 m² plate)
- Pallet beams: ca. 650 km length (ca. 95,000 m² plate)
- Diagonal: ca. 800 km length (ca. 108,000 m² plate)
- Screws: ca. 1,900,000 pieces
- Cladding roof/wall: 18.600m²/22.000m²
1. Examples

Steel is the governing material for industrial buildings

market share
~ 80 %
1. Examples

Steel is a long life product and allows for modification

Müngstener railway bridge

- Construction time 1893 - 1897
- Main dimensions:
  - L = 465 m
  - H = 110 m above valley floor
  - W = 9 m (superstructure)
  - W = 25.7 m (arch base)
- Cast Steel (bearing etc.): ~240 t
- Mield steel (plates & sections): ~4.700 t
- Rivets: ~950.000 pieces
1. Examples

Steel is a long life product and allows for modification

Müngstener railway bridge
Steel is a long life product and allows for modification
Müngstener railway bridge
1. Examples

Steel is durable and documents civil engineering construction history
Rhine railway bridge Waldshut Koblenz (Germany – Switzerland)

- Construction time: 1858 - 1859
- Span: $L = 38.13 / 54.87 / 38.13$ m (total length: 130 m)
Steel application in construction

1. Examples

2. Steel market in construction
   - Construction requirements
   - Steel consumption
   - Steel grades
   - Production steel construction

3. Research topics

4. Summary
2. Steel market in construction

Construction requirements

● **Strengths**
  - Rapid construction
  - High level of Prefabrication
  - Great choice of steel products, profiles, cladding types and attachments
  - Long spans – flexibility in long-term use
  - Architectural image
  - High quality of material and construction

● **Weaknesses**
  - Fire protection
  - Costs compared to other construction materials

● **Opportunities**
  - Sustainability, recyclability

Results of questionnaire in Europe

Importance of various construction
2. Steel market in construction

Steel consumption

- long products
  - wire
  - suspension elements
  - bolts M12-M36
- profiles
  - warm
  - cold
  - > 0,5mm;
  - < 6,0mm
  - > 6,0mm;
  - < 150mm
- flat products
  - plates
- industrial buildings
- commercial buildings
- facade panels
- secondary struct. Elements
- rack structures
- bridges
- wind towers
## Steel market in construction

### Steel grades

- **EN 10025**
  - S235
  - S355
  - S460
  - S690

- **EN 10346**
  - S350 GD
  - HX460LAD

- **Bolt material**
  - 4.6
  - 5.6
  - 8.8
  - 10.9

#### Mechanical properties

- DIN EN ISO 898
Production steel construction in Germany

2. Steel market in construction

Steel application in construction │ Prof. Dr.-Ing. Dieter Ungermann │ METEC and 2nd ESTAD 2015
## Production steel construction in Germany

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Steel application in construction

1. Examples

2. Steel market in construction

3. Research topics
   - Sustainability, Recyclability
   - Durability
   - Construction
   - Fabrication

4. Summary
3. Research topics - Sustainability

Sustainability

- efficient use of materials
- low wastage of materials
- low life cycle costs
- re-use of components

➢ steel is construction material with highest level of sustainability

→ chance to enhance market share

Results of questionnaire in Europe

perceived level of sustainability of different materials
3. Research topics - Recyclability

Sustainability, Recyclability

- Steel is recyclable on different levels

- **Material**
  - scrap metal
  - mill: 88% new steel products
  - storage: 11%
  - re-use

- **Profiles**
  - disassembly of construction
  - new building

- **Buildings**
  - change in use and / or enlargement

Growing Sustainability
### 3. Research topics - Sustainability


**Sustainability of steel in the construction sector (NASTA)**

<table>
<thead>
<tr>
<th>Research Topic</th>
<th>Description</th>
<th>Cost</th>
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<td>Integrated and sustainable <strong>slab systems</strong> in steel and composite construction</td>
<td>€ 937,300.00</td>
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<td>Multidimensional energy enhanced <strong>claddings</strong> in steel-lightweight construction for industrial buildings</td>
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<td><strong>Building in existing contexts</strong> and structures – potentials of lightweight buildings in steel</td>
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<td>Holistic assessment of <strong>steel and composite bridges</strong> according to criteria of sustainability</td>
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<td>Development of assessment criteria for the sustainability of steel structures of renewable power plants with exemplary appliance</td>
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3. Research topics
   - Sustainability, Recyclability
   - Durability
   - Construction
   - Fabrication

4. Summary
3. Research topics - Durability

Bridges in Germany – some facts about the condition

- Bridges of Germany’s local authorities: Grading of condition (1,0 … 4,0)
- 15% of bridges should be replaced in short-term

Enhancement of market share through reduction of lifetime costs

Choice of materials

Federal and state authorities

- Prestressed concrete 70%
- Other 1%
- Composite structure 6%
- Steel 6%
- Other concrete 17%

Local authorities

- Prestressed concrete 16%
- Other 2%
- Timber 3%
- Stone 8%
- Composite structure 8%
- Steel 8%
- Other concrete 55%

Source: Difu study 2013

Maintenance / repair of damages

Causes for damages

- by design
- cracks
- corrosion
- moisture penetration
- other

Source: Difu study 2013
3. Research topics - Durability

Hot-dip galvanizing in bridge construction

Periods of corrosion protection:

- Organic coating (repair needed during lifetime)
  - 25…33
  - 50…66
  - 75…100

- Hot-dip galvanization (lifelong protection)
  - > 80 years

Service life of bridges
- = 100 years

Service life of bridges
- = 100 years
3. Research topics - Durability

Fatigue resistance of hot-dip galvanized steel (S355JR+AR, S355J2+N, S460M, S700MC)

- Cyclic loads lead to fatigue failure
- Zinc layer reduces fatigue resistance
- Influence was examined and is manageable
- Steel bridges get more economical and sustainable

- Incipient crack, which did not lead to failure of the specimen
- Second incipient crack, which also has grown into the base material

Cyclic loads lead to fatigue failure
- Zinc layer reduces fatigue resistance
- Influence was examined and is manageable
- Steel bridges get more economical and sustainable

Initial state

Cracks "jump over", under cyclic loads

Fe

shrinkage cracks in zinc layer

increased stress in base material

- Micro cracks in δ₁ phase (already existent in initial state, immediately after galvanizing process)
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   - Construction
   - Fabrication

4. Summary
3. Research topics - Construction

Integral composite bridges

- avoidance of maintenance intensive bearings and dilatation joint
- efficient shear connection between steel and concrete with steel anchor grip
3. Research topics - Construction

Steel-concrete composite structures

- connection of advantages of both materials “steel and concrete”
  - high bearing capacity
  - minimum material use
  - economic fabrication

selection of VFT-WiB-types

thermal cut of anchor grip

anchor grip with reinforcement
Steel application in construction

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2. Steel market in construction

3. Research topics
   - Sustainability, Recyclability
   - Durability
   - Construction
   - Fabrication

4. Summary
Laserwelded Steel Hollow Plates

- light weight – efficient fabricated structure
- investigated applications:
  - deck plates in steel bridge constructions:
    - bridge construction analogue to orthotropic steel deck:
    - wheel loads are transferred from deck plate to secondary girders and from secondary girders to main girders
    - hollow plate functions as top flange of the main girders
  - decks in RORO ships or ferry boats:

main deck with common HP cross sections
3. Research topics - Fabrication

Laserwelded Steel Hollow Plates

- construction:
  - upper deck plate
  - lower deck plate
  - web plates

- closed low-weight steel construction
- composed of two deck plates and intermediate webs
- webs can be steel plates or sections
- two-dimensional load transfer of single loads (e.g. wheel loads)

→ optimal design principle
3. Research topics - Fabrication

Laserwelded Steel Hollow Plates

- fabrication:

  I-Core Panel at Meyerwerft:
  stake weld at upper and lower deck plate:

  Fabrication of a hollow plate at Meyerwerft Papenburg

- connection of deck plates and web with laser stake welds:
  - deck and web plate are welded through the deck plate
  - deck plate of up to 10 mm thickness can be processed
  - automatized process with high accuracy
  - high speed welding with minimal heat impact
  - less straightening

  → economically efficient fabrication
Steel application in construction

1. Examples
2. Steel market in construction
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4. Summary
Steel is in strong competition with alternative construction materials, i.e. concrete

- Enhancement of market share is possible through
  - Efficient use of materials
  - Innovative design concepts
  - Mechanizing of fabrication
  - Development of more durable constructions
  - Working out the advantage in sustainability and life cycle costs