QUALITY CONTROL IN TUNNELING

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Motivation
Motivation

No thanks!

We are too busy
Production

Storage

TBM
Production- and Logistics-Management System SDS
Challenges in Segmental Lining
Challenges in Segmental Lining
General Challenge in Segmental Lining

<table>
<thead>
<tr>
<th>Segment</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>No just-in-time production (curing, maturing/resting period)</td>
<td>Just-in-time delivery to TBM with short lead time but up to 100 year service life</td>
</tr>
<tr>
<td>Unique due to type of reinforcement, concrete, design</td>
<td>Precise specification for ring design</td>
</tr>
<tr>
<td>Expensive</td>
<td>Economic efficiency</td>
</tr>
<tr>
<td>Bulky</td>
<td>Limited storage space</td>
</tr>
<tr>
<td>Flawlessness</td>
<td>Strict quality requirements</td>
</tr>
</tbody>
</table>
Product
Solution for quality assurance and logistics in segment manufacture

- Developed on the basis of global customer requirements and tunnel projects
- Designed for production, storage and logistics of segments
- Flexible for customer-specific adaptations
- An all-in-one solution for segment production and tunnel sites
Movie
Modules

Control of entire segment life-cycle

- Production
- Storage
- TBM
Production

Supports production planning and ensures compliance with defined quality and documentation standards.
Production | Processes

Control of entire production process – from reinforcement to the finished segment, its quality control and ring part formation.
Production | Range of Application

Stationary production

Carousel production
Benefits | Error Avoidance

Situation
- Production errors (e.g. wrong reinforcement)

Significance for job sites
- Reworking
- Rejects
- Controls necessary
- Tunnel statistics compromised

Solution
- Monitored process steps
- Monitored components and tools
  - No rejects, certainty to planning, time-saving
Storage

Manages and organises storage, including storage and removal from storage.
Storage | Processes

From storage through to handing over of the delivery note.

Stacking

Store-out

Shipping documents

Store-in

Loading
Benefits | Storage Space Optimisation & Transparency

Situation
- Limited storage space
- Thousands of segments and many segment types

Significance
- Expensive manual warehouse management
- Unable to get a clear overview
- Necessary re-warehousing (damage and loss of time)
  - Delivery delays at the TBM

Solution
- All information is available in real time (storage space, stock)
- Through storage rules, the availability of ring types is guaranteed
- Efficient processes for storage and removal from storage (time-saving)
Benefits | Storage Space Optimisation & Transparency
Reference Boßler Tunnel, Germany

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**Expenditure for one re-warehousing operation**

<table>
<thead>
<tr>
<th>Without Management System</th>
<th>With Management System</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ 1 crane operator</td>
<td>▪ Re-warehousing is avoided</td>
</tr>
<tr>
<td>▪ 1 assistant to crane operator</td>
<td>▪ If necessary:</td>
</tr>
<tr>
<td>▪ 0.5 hr organisation by shift manager</td>
<td>• 1 crane operator</td>
</tr>
<tr>
<td>▪ Search in the warehouse</td>
<td>(~10 min. expenditure)</td>
</tr>
</tbody>
</table>
**Benefits | Storage According to Requirements**
Reference North West Rail Link, Australia

### Danger of wrong storage

<table>
<thead>
<tr>
<th>Without SDS</th>
<th>With SDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong stock</td>
<td>No cost-intensive production restart</td>
</tr>
<tr>
<td>Unclear storage</td>
<td>(USD 120,000)</td>
</tr>
<tr>
<td>Too little inventory</td>
<td>No excessive quantities</td>
</tr>
<tr>
<td>► Production restart</td>
<td>(USD 1,500 per segment)</td>
</tr>
<tr>
<td>Too much inventory</td>
<td></td>
</tr>
<tr>
<td>► Removal</td>
<td></td>
</tr>
</tbody>
</table>
Benefits | Storage According to Requirements

Situation
- Wrong stocks due to error-prone manual recording

Significance for construction sites
- Number of segments in the warehouse insufficient for planned driving
- Production must be restarted

Solution with System
- Warehouse management records the latest stock continually and precisely
- Avoidance of wrong stock
- Through storage rules, the availability of ring types is guaranteed at all times
- No inventory costs
TBM

Capturing of position and installation data during ring construction in real time. Orders in the storage can be triggered from the TBM.
Benefits | Just-in-time Ordering of the Right Rings

Situation
- Rings are ordered by phone from the TBM
- Error-prone – components people
  - Wrong selection of rings
  - Wrong forwarding of ring order

Significance for job sites
- Wrong delivery means returned delivery ➤ Loss of time

Solution
- Ring sequence calculation determines the best matching rings
- Software-controlled ring ordering of available rings from the storage
Benefits | Just-in-time Ordering of the Right Rings
Reference KAT 2 Austria

Risk of wrong deliveries to TBM

<table>
<thead>
<tr>
<th>Without SDS</th>
<th>With SDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of each wrong delivery: USD 15,000</td>
<td>Not one wrong delivery in 1.5 years (50,000 segments)</td>
</tr>
<tr>
<td>Empirical figure: 1 wrong delivery per 1,500 rings</td>
<td></td>
</tr>
</tbody>
</table>

Total savings through avoiding wrong deliveries on KAT 2: **USD 150,000**
Data Flow

RAW MATERIAL
- Charge
- Production date

SDS data server

PRODUCTION
- Formwork
- Reinforcement
- Casting
- Curing
- Production date

USAGE
- Location in the tunnel
- Position in the ring
- Assembly date

STORAGE
- Date of stocking & destocking
- Ring type
- Storage location
- Rest & gestation time

DOCUMENTATION / REPORTING
Documentation and Analysis

Delivery Note

Segment Protocols

Evaluations and Statistics
Benefits

- Compliance with defined quality standards and documentation requirements for production and storage
- Traceability and transparency
- Optimal planning and efficient use of storage capacities
- Reduction of error potential
Thank You!