Development of a New-Generation Dowel and Screw Combination
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Outline

► Motivation for new dowel/screw combination
► Design of experiments for alternative parameter combinations
► Evaluation process for alternative design proposals
► Features of NG dowel/screw combination
  – Improved stress distribution in system
  – Compatibility with former designs
  – Improved drainage and passage of fines
► Conclusion
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The Vossloh Fastening System W 40 HH (Heavy Haul)

- Rail
- Lag screw with washer \((Ls)\)
- Tension clamp
- Angled guide plate
- Rail pad
- Abrasion plate
- Plastic dowel (insert) \((Sdue)\)
- Concrete tie
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Existing situation

► High forces are applied on crosstie and whole fastening system

► Elevated stresses may exist around any insert within the concrete crosstie

► Performance of crosstie is controlled by concrete quality, production technology, and interaction with other track structure components

► The life cycle of a crosstie is dependent on
  ► Environmental influences
    ► Temperature variations
    ► Moisture
    ► Salt and fines
  ► Installation and operating characteristics
    ► Handling of the tie
    ► Rail installation
    ► Traffic
    ► Train speed
Finite element modeling of components and fastening system, incl. crosstie

Before experimentation, simulation and external consultation were performed to determine effect of many parameters on loading environment:

- crosstie production technologies
- concrete
- materials
- length and design of dowels
- length and design of screws

Objective: Investigation and subsequent measurement to reduce the loads in the track superstructure
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Measurement of crosstie sections by CT scanning
(independent laboratory: SGS Fresenius)

3D tomography images of crosstie part with varying levels of detail
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Objectives of dowel/screw project

Overall aim: reduce the stresses within the crosstie

- Development of new designed dowel/screw: improving the properties while maintaining well-known advantageous features
- Launching a new material for the dowel with further improved characteristics

New features:

- Reduction forces acting in tie during installation and revenue service
- Continuously withstanding pull-out forces at a high level
- Optimization of inner and outer geometry of dowel, i.e. improved interaction of dowel with concrete and screw

In screw: axial (pull-out) forces only
Longitudinal forces
Transverse forces
Plan view crosstie
Side view crosstie
Transverse forces
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NG dowel/screw developmental process

▶ Design of experiments, understanding interaction effects, varying
  – Crosstie producer
  – Existing dowel and screw designs
  – Material
  – Testing procedure
▶ Comparison and weighting of important assessment criteria based on market priorities
▶ Brainstorming and development of design alternatives
▶ Evaluation of alternatives based on weighted assessment criteria
▶ Experimentation and simulation of final designs
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Sdue NG (NEW GENERATION) Characteristics

- Two-part thread
  - Upper region: orthogonal flanks reduce lateral force in the concrete crosstie
  - Lower region: known thread geometry provides the required force transfer in lower areas of the concrete crosstie
- 20% higher wall thickness: peak loads are better tolerated
- Dowel crown for better sealing to bottom of tie mold during casting process

To compare: Sdue 25  Sdue NG

Geometry of dowel crown ensures right angle of dowel in tie mold

Concrete residuals
Ls NG (NEW GENERATION) Characteristics

- Conical geometry of screw core
- External screw diameter remains the same
- New thread geometry causes force primarily in the axial direction
- Less mass leads to easier shipping and handling

To compare: Ls 35  Ls NG
Improved force transmission in dowel and concrete tie

- Deflected radial forces act directly on the deformation of the dowel into the concrete material.
- Direct radial forces cause higher shear forces in the crosstie.

**Sdue 25 and others + Ls 35**

- Upper region: axial forces cause elastic deformation of the dowel material due to the thread geometry exclusively in the axial direction (no radial forces).
- Lower region: axial forces also cause deformation of the dowel material, which leads to relatively low radial forces because of the thread geometry.

**Sdue NG + Ls NG**

- only axial forces
- axial forces and minimal radial forces
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Test program – internal experiments

► Tensile tests – recording deflection of dowel and screw
  ► Up to 80 kN (18 kips) in 2-minutes steps of 10 kN (2.3 kips)
  ► Up to 160 kN (29 kips) in 30-second steps of 5 kN (1.1 kips)
Pull-out experiments

Mean value of maximal force [kN]  
Mean value of screw displacement [mm]  
Mean value of dowel displacement [mm]

Conventional dowel material  
New dowel material  
Ls NG
Sdue NG

10 kN ≈ 2.25 kips  
2.5 mm ≈ 0.1 in
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Test program – internal experiments

► Torque tests
  ► Up to 450 N·m (330 ft-lbs) in 10-minute steps of 50 N·m (37 ft-lbs)
  ► Monitoring axial forces and concrete strains after relaxation
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Experimental measuring of transverse strain in crosstie during torque application - Insert of strain gauge device during tie casting

- Strain gauge affixed to metal plate and inserted perpendicular to tie axis
Effect of screw torque on transversal strain in ties

Torque steps: 200 - 250 - 300 - 350 - 400 - 450 Nm

- Sdue 25 (Tie 2)
- Sdue 25 (Tie 1)
- Sdue NG (Tie 4)
- Sdue NG (Tie 3)

Transverse strain [units]

Axial force [kN] 10 kN ≈ 2.25 kips 100 N-m ≈ 75 ft-lbs
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Testing device for analyzing forces of dowel in concrete block

- Comparing different geometries of dowels and screws
- Concrete block without reinforcement
- Measuring screw tensile forces with strain gauges
- Measuring transverse forces with force transducer

Dowel

Force transducer

Transverse forces in concrete

Tensile forces in screw

Two separate blocks
Transverse forces vs. tensile forces: slope of linear correlation

\[ y = 0.0748x - 0.2175 \]

\[ R^2 = 0.9695 \]

- 0.5
- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0

Tensile Force [kN]

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45

Transverse Force [kN]

Experiment 1
Experiment 2
Experiment 3
Average value
Linear approximation

10 kN \approx 2.25 kips
Relaxation tensile experiment on screw-dowel combination

Axial force in screw [kN] vs Relaxation time [h]

- Axial force Sdue NG_new material / Ls NG [kN]
- Axial force Sdue 25_conventional material / Ls 35 [kN]
- Axial force Sdue NG_conventional material / LS NG [kN]
- Axial force of dowel with hight wall thickness_conventional material / Ls 35 [kN]

Initial force 70 kN
Δ = 23 kN
Δ = 19 kN
Δ = 16 kN
Δ = 13 kN

10 kN ≈ 2.25 kips
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Finite element simulation of load applied around dowel (contact pressure between dowel and crosstie)

Sdue 25 (conventional)
Contact pressure: 15 – 17 MPa (2.2 – 2.5 ksi)

Sdue NG with Ls NG
Contact pressure: 13 – 16 MPa (1.9 – 2.3 ksi)

Load parameters
► 10 kN (2.25 kips) axial force applied by screw
► Similar contact pressure
► Transverse force halved for Sdue NG

10 kN
6.4 kN

3.2 kN
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Compatibility to former components

► Sdue NG: compatible to Ls 25 / Ls 35
► Ls 35: compatible to Sdue 9 / Sdue 20 / Sdue 25
► However, optimal effect of the thread geometry is not reached

Sdue 25 + Ls NG  Sdue NG + Ls 25  Sdue NG + Ls 35
Approximately 50% more void volume in the NG screw-dowel combination due to conical shape of screw core, allowing for increased transmission of

- Fines (e.g. sand)
- Water

Improved installation and removal of screw because impurities do not affect the tightening and unscrewing
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Replaceability of Sdue NG by aid of tool

► Easily replace Sdue NG by using conventional tool also used for Sdue 25
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Conclusion

► The NG screw/dowel combination relieves transverse stresses in the concrete, leading to improved crosstie performance and longer life cycles

► A thorough and systematic design process was used in the development of the NG screw/dowel combination
  – Included consideration of market priorities
  – Utilized extensive brainstorming, simulation, consultation, and testing

► The NG screw/dowel allows for improved passage of fines and water through the tie

► The NG screw/dowel is completely compatible with previous combinations of screws and dowels
Questions

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