Soil Steel Composite Bridges

Swedish Development
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Soil Steel Composite Bridges

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Introduction

Heavy concentrated live loads

$h_c$
Introduction, continued
New larger corrugations
Introduction, continued
New culvert profiles

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Introduction, continued
Composite action, quality of the backfill
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Examples of Soil Steel Composite Bridges
Åreskutan ski resort, Jämtland, Sweden
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Examples of Soil Steel Composite Bridges

Railroad bridge close to Ystad, Sweden
11.1 m span single radius arch
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Examples of Soil Steel Composite Bridges

12 m span box culvert over Siktån in Dalarna, Sweden
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Examples of Soil Steel Composite Bridges

17 m span single radius arch in Aitik, Sweden
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- SRA (Swedish Road Administration) saw a need for more accurate design methods since spans of soil steel bridges were growing larger and cover heights were at the same time reduced
- Only standard dimensions with spans up to 5 m were available
- International design methods (Canada, UK, Germany etc) were available but it was unclear how they should be applied to Swedish conditions
- In 1983 a full scale test were performed by the Royal Institute of Technology in Stockholm sponsored by SRA
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Swedish Development, continued

Pipe arch with span 6.1 m and cover height 1.0 m build in 1983
In the research programme that followed the full scale testing, different design models were studied.

The design methods all seemed to have some drawbacks in areas where there really is a need to know how the structure works.

For example, the effect of a low height of cover, the effect of a higher degree of compaction, the effect of the soil grading etc.

How could bending moments be calculated?

How do one determine the ultimate capacity?

Is there a need for further full scale testing?
Swedish Development, continued

Test culvert (pipe arch) with span 6,0 m and cover height 0,75 – 1,50 m built and tested 1987 - 1990
Swedish Development, continued

A design method was developed based on the following important parts:

- Duncan: Soil Culvert Interaction – method
- Vaslestad: arching effects
- Klöppel & Glock: buckling calculations
- Andréasson: soil modulus for frictional materials
Swedish Development, continued

Important features of the design method are:

- Different pipe and arch profiles can be used
- Any live load can be used (one, two or more lanes, concentrated and/or distributed)
- The designer can calculate sectional forces (thrust and bending moments) in the structure for any cover height (high or low)
- Soil material properties can be changed, for example degree of compaction, grading curve etc
- The structure is designed in the ultimate limit state (including fatigue) as well as the serviceability limit state
- The method is code-independent
Swedish Development, continued

- The design method is required by both the Swedish National Road Administration as well as the Swedish National Rail Administration (today Swedish Transport Administration) in their respective codes.
- Structures not only for road traffic load but also for rail road live load have been designed.
Gimån box culvert with span 12,0 m and cover height 1,0 m build and tested 2002
Swedish Development, continued

BoxCulvert – extended design method

- The BoxCulvert could be compared to the horizontal ellipse which is one of the profiles covered by the SDM – method.
- The SDM – method is therefore extended to cover also the BoxCulvert profile
Järpås test culverts (box culverts):
First test: span 8,0 m, cover height 0,45 m - 1, 20 m build and tested 2005
Second test: span 14,2 m, cover height 0,45 m - 1, 20 m build and tested 2006
Swedish Development, continued

Summary full scale tests performed in Sweden 1983 - 2006

- Nyköping 1983. Pipe arch with 6,1 m span.
- Enköping 1987 – 1990. Pipe arch with 6,0 m span.
- Gimån 2002. Box culvert with 12,0 m span.
- Järpås 2005. Box culvert with 8,0 m span.
- Järpås 2006. Box culvert with 14,2 m span.
The principles of the soil steel structure is quite simple. The design methods also have to be simple in order not to complicate the building process. A rational design method has to be used.

The soil steel structure is dependent on the interaction between the corrugated steel wall and the surrounding soil.

In order to build larger structures the quality of the soil has to be taken into account.

Because of the complicated stress distribution through the soil live load (traffic load) has to be described in a uncomplicated way that allows the designer to model both concentrated loads as well as distributed loads.
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Swedish Development, continued

- The soil steel structure is non-linear. Therefore it has to be represented by a tangent stiffness at some defined stress level that will turn the calculations linear elastic.

- Older methods based on the so called ring compression theory often found in international bridge codes are often over-conservative. They describe the way the structure work in an rational way but often result in a conservative design with heavy restrictions on for example minimum cover height.
Swedish Development, continued

• A rational method to calculate section forces in the culvert wall is the so called SCI – method developed by Duncan. This method is based on a large number of FEM-calculations. The result is presented as a number of simple to use section force parameters for both soil and live load.

• Using these parameters maximum normal force and bending moment in the culvert wall can be calculated.

• Comparing the results of the SCI-method with full scale test results it has been possible to develop a method to calculate section forces.
Swedish Development, continued

- Limit state design method
- Design checks are performed in the ultimate limit state as well as the
  serviceability limit state. With heavy live load and low height of cover
  fatigue may also very well come into play. Therefore fatigue design
  checks are performed as well.
- In the serviceability limit state the combined normal and bending stress is
  checked against the yield stress of the corrugated culvert wall. Live load
  deflections has been deemed not governing.
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Swedish Development, continued

- Full scale test in Nyköping 1983
- SNRA starts research project in co-operation with KTH
- Full scale tests in Enköping 1987-1990
- A method for load classification of SSCB is presented 1997
- SDM is presented in 2000
- The Skivarpsån railroad bridge is designed and constructed in 2003 and extensive testing, both static and dynamic follows
- Swedish Bridge Code Bro 2004 requires design according to SDM. SDM is also required by the Rail Administration through the Railroad Bridge Code (BV Bro, ed. 8)
- The BoxCulvert profile is introduced in Sweden in 2002 and full scale tests are performed
- An extension of the SDM to cover BoxCulverts is proposed in 2004
- Full scale tests are performed in 2005 and 2006 to verify the proposed extension of the SDM
- Third revision of SDM is presented in 2006 including the box culvert extended method
- English version of SDM is presented in 2007 including Eurocode adaptation
- Fourth revision of SDM is presented in 2010 with additions to, and refinements of the method
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Summary

In Sweden Soil Steel Composite Bridges are structurally designed according to a handbook developed by the Royal Institute of Technology (KTH) in Stockholm. The bridge codes require the handbook to be used in the design of soil steel composite bridges.