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Sektion 8 a

Heat distribution – optimisation of existing solutions

Branch optimisation: ductile or rigid - different approaches

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Branch Optimisation: Ductile or rigid – different approaches

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Introduction

Current design strategies of District Heating Systems suggest the placement of cold laid branches only in 'adhesive' regions of a DH network. The consequence of such suggestion is a costly design due to measures such as parallel branches, safety cushions or thermal pre-stressing of a system prior to start-up.

Figure 2 shows a schematic sketch of the assumed and the more realistic System behaviour and the thereof derived design and layout strategy

In order to promote the cost efficient method of cold laying, a safe design with respect to bending *and* axial loading of branching elements has been developed.

The internal forces on a branch component caused either by axial loading and frictional resistance or by bending reactions due to pipe-soil interaction yield stresses on a branch connection.

The following figure 1a indicates that for axial loading the saddle detail gives rise to stress concentrations. Figure 1b shows a photograph of a failure condition at the vertex due to a severe bending load condition.

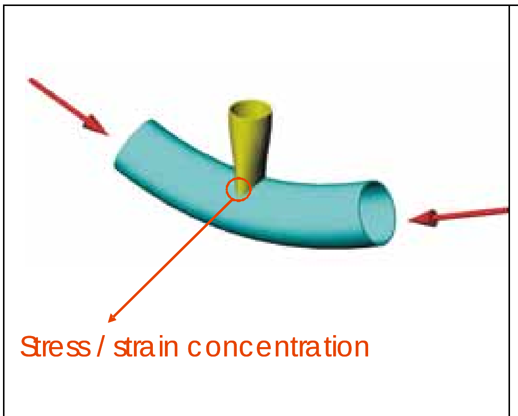


Figure 1a Stress concentration on the saddle point due to axial loading

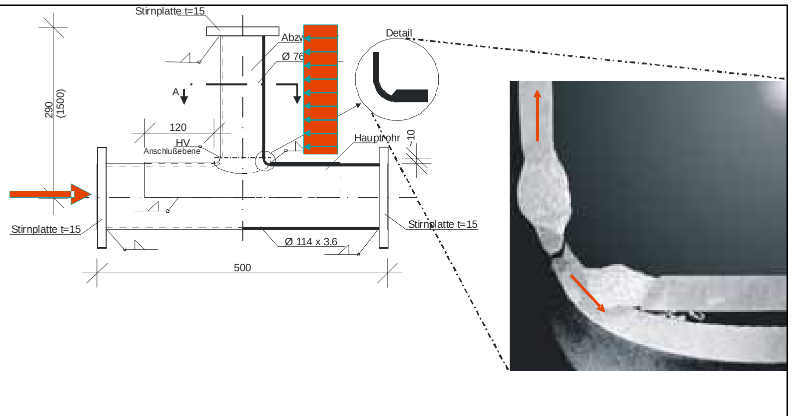


Figure 1b Detail of a failure due to stress/strain concentrations (vertex)

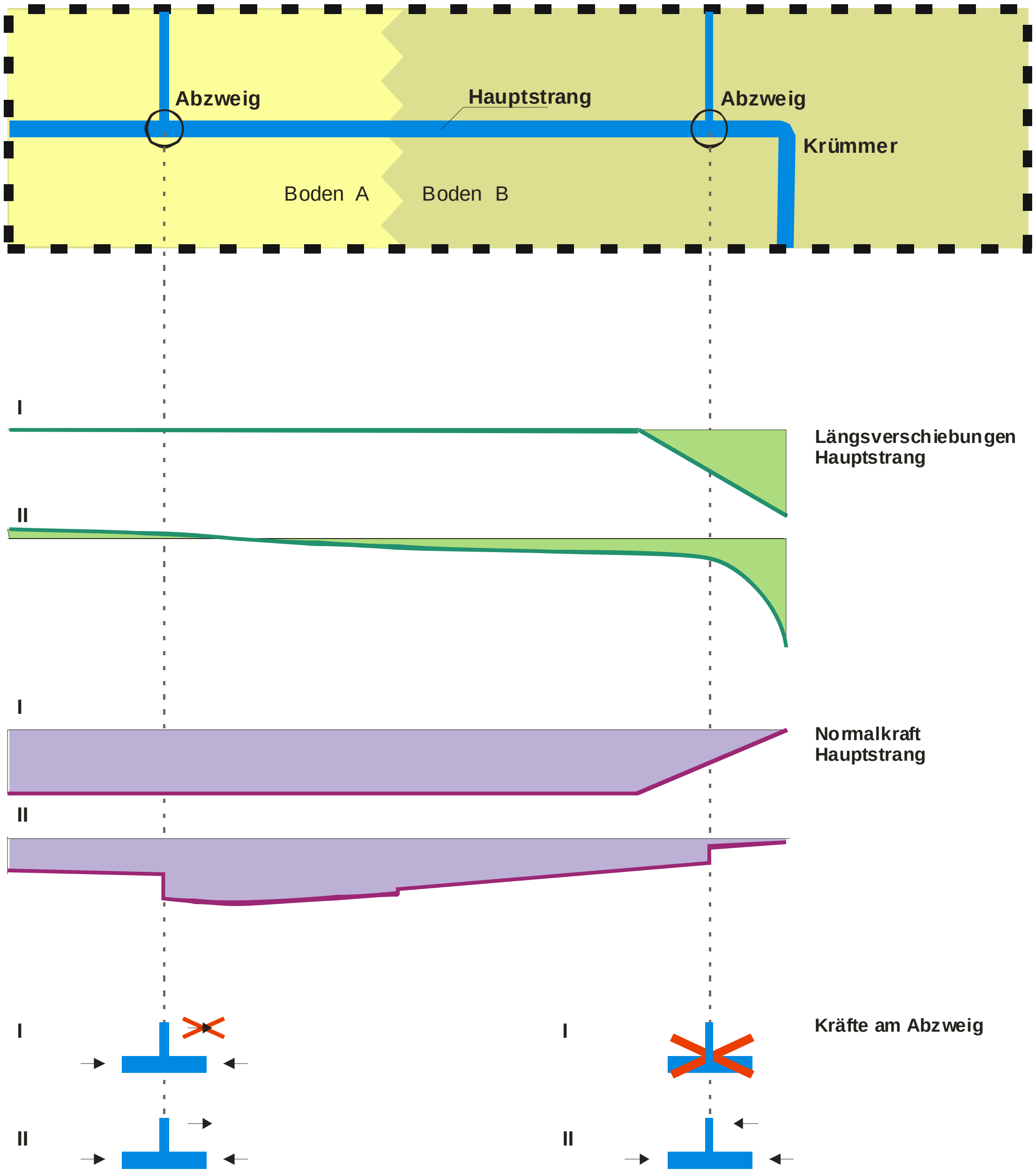
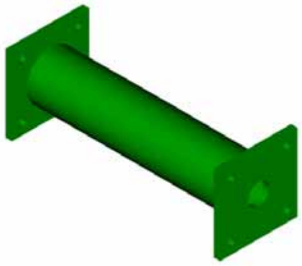
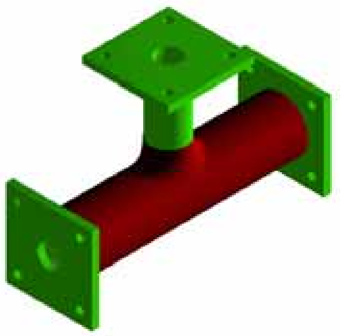
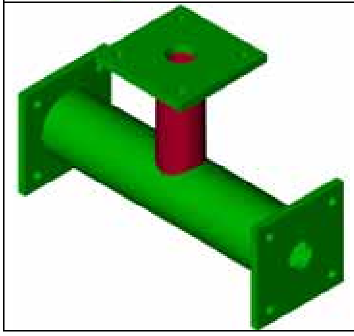


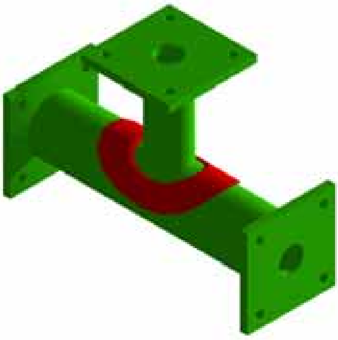
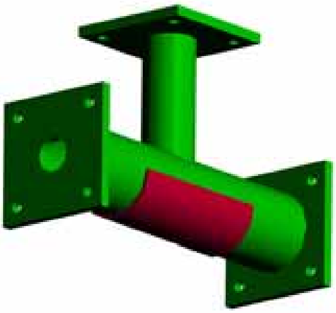
Figure 2: Analysis of the load case 'temperature change' with a simplified (I) and an enhanced model (II)

Discussion of design alternatives

In [1] has been discussed that an optimised reinforcement shall account for the transfer of axial compressive forces in a main pipe **and** appropriate rotational capacity – $\{rot_{ultimate} / rot_{yield}\}$.
It has been pointed out that the state of the art reinforcement can yield a significance increase in stiffness and reduction of rotational capacity at the same time.
The following table 1 shows a series of branch types that have been evolved out of a variety of more alternatives. during the branch optimisation project. The shown alternatives have been evaluated with respect to cost efficiency and structural efficiency. Structural investigations which have been carried out in order to select most suitable alternatives have been discussed in [1].

Table 1: Branch prototypes for axial load testing

Sketch	Description	Identifier
	Main w/o Branch T = 3,6mm	Typ 0
	Extruded (Design A) Extruded (Design B) t = 4,5	Type 2a Type 2b
	Reinforced Branch t = 10mm	Type 3

	Collar (welded all around) Collar (welded discontinuous) t = 3,6mm	Type 5a Type 5b
	Bottom Plate	Type 9

Type 0 has been selected as a reference element for testing only. Type 9 would have been a minimal cost reinforcement and became therefore subject of testing. The variant 3 has been declared 'best solution' in terms of rotational capacity and axial reinforcement. The types 2 and 5 are close to the state of the art design with minimal variations.

It has been concluded that the optimal reinforcement is achieved if the load carrying capacity is equal to the undisturbed main pipe. Previous publications [1] have shown, that maximum rotational capacity is maintained if the wall thickness adjacent to the branch – i. e. the main pipe – is minimal.

Analytical and experimental investigations

The following figures show results of a Finite Element Calculation. The diagrams show principal stresses vs. a quarter of the circumference of the branching element. The loading has been a unit axial load on the main pipe. It can be observed that the reinforced branch allows an even stress distribution along the intersection of main and branch. The result indicates a minimal deformation of the branch and hence of the hole in the main pipe.

It is also shown, that the principal stresses at the saddle point are maximal for the state of the art solution and that the stress magnitude is in the ratio of 3,5/1,5 = 2,3 times greater compared with the stresses of the type 3 branch.

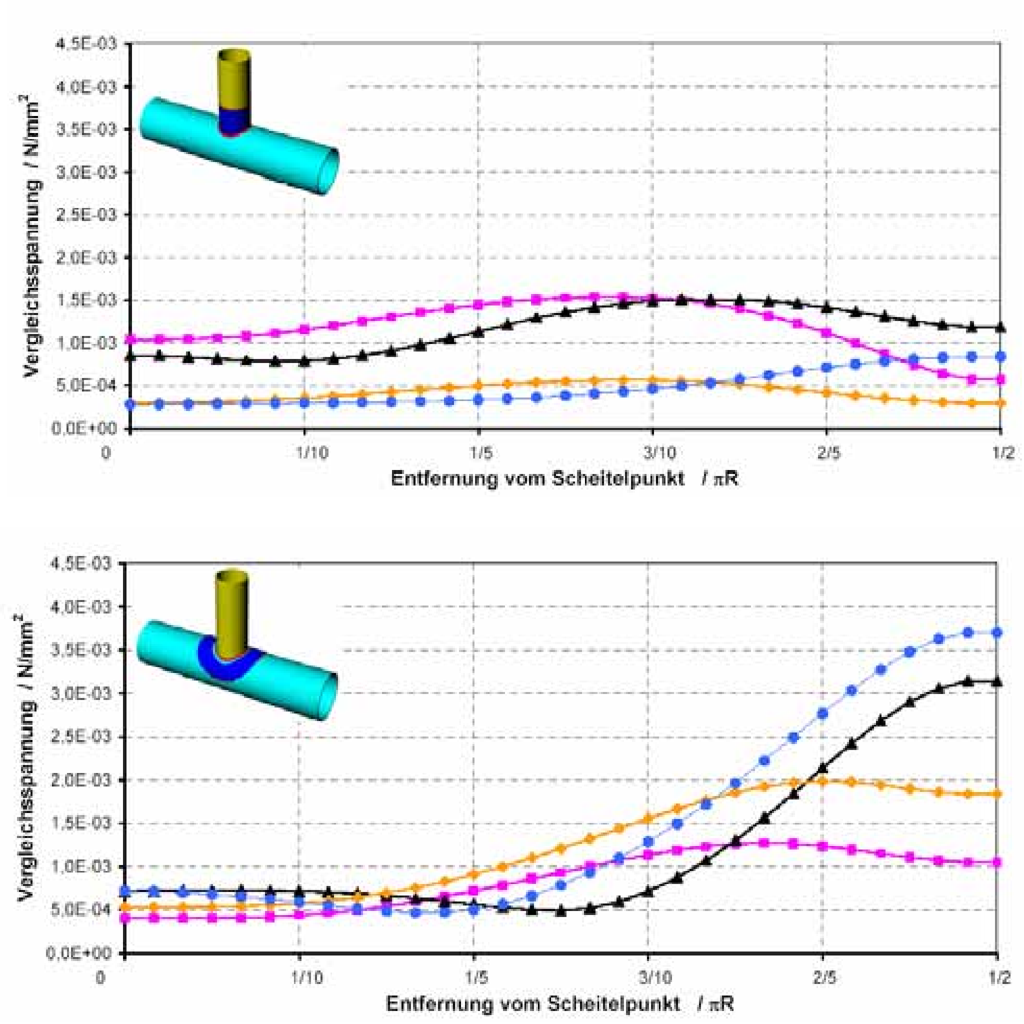


Figure 3: analytical investigations concerning the load carrying behaviour of selected branches under static loading conditions

The experimental results confirm the theoretical findings. It can be observed in figure 4, that only the type 3 branch solution achieves the full ultimate load carrying capacity of the undisturbed pipe. Hence only Type 3 reinforcement compensates the hole in the main pipe fully. The variation Type 9 achieves only 74% of the undisturbed pipe and is therefore the most inefficient reinforcement measure tested. The figures 5 to 7 show load/displacement graphs of selected tested variants. Shown are the reference model Type 0 and the branch alternatives type 3 and type 9. It can be observed that the load carrying capacity of the types 0 and 3 is limited by a buckling type of failure whereas the ultimate limit of the more eccentrically loaded specimen is governed by bending action. Figure 8 shows a photograph of a failed type 3 specimen. The buckling can be observed just outside the branch connection above the branch.

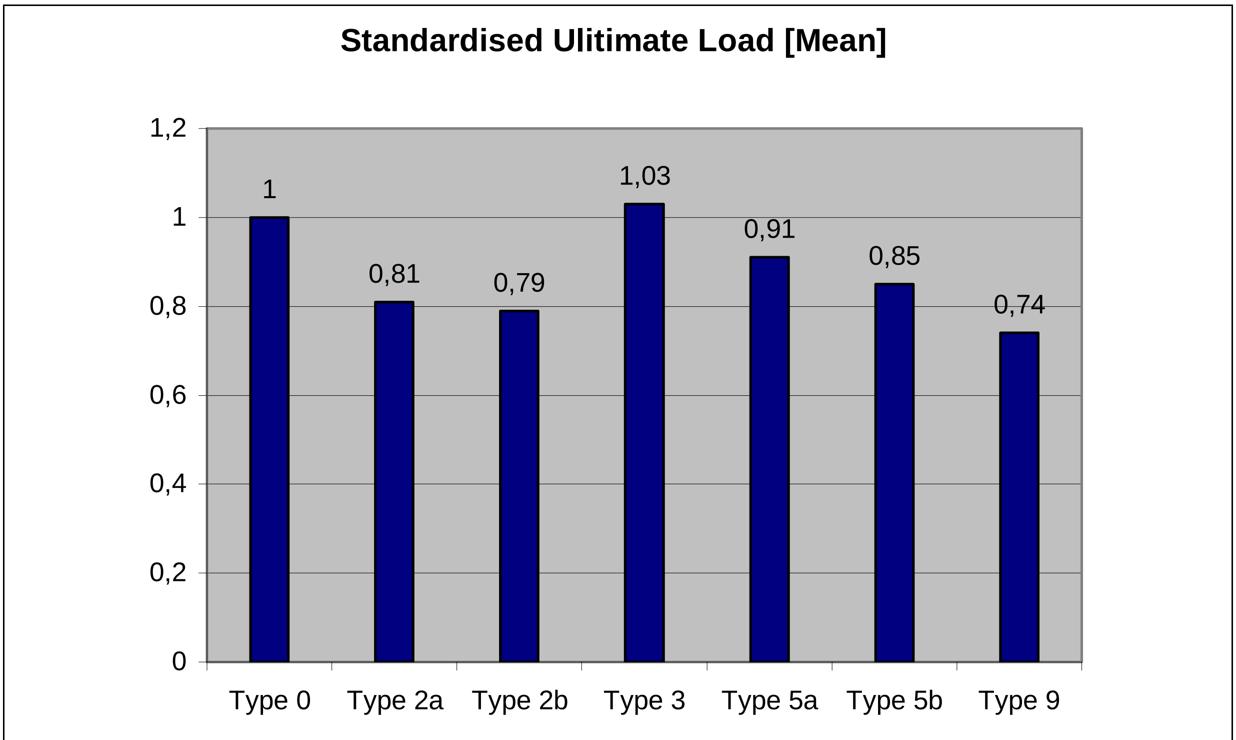


Figure 4: Standardised ultimate loads of the tested specimen – mean values

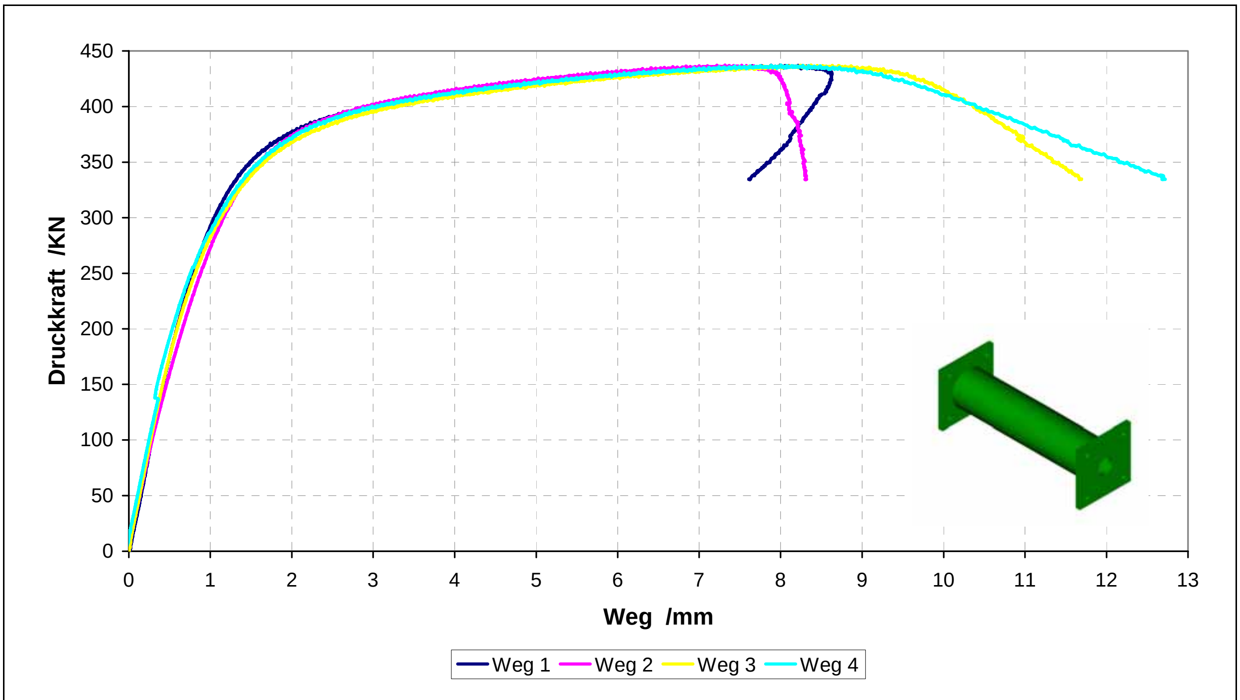


Figure 5: Ultimate Load vs axial deformation - Type 0

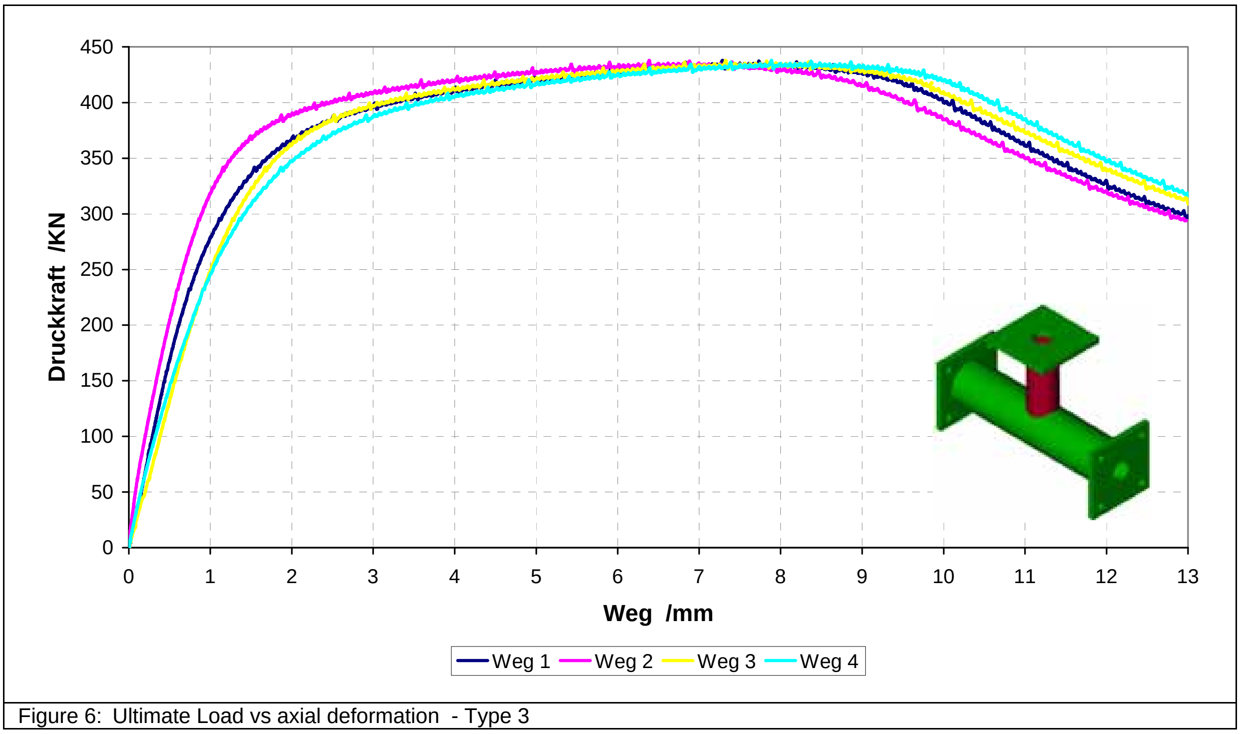


Figure 6: Ultimate Load vs axial deformation - Type 3

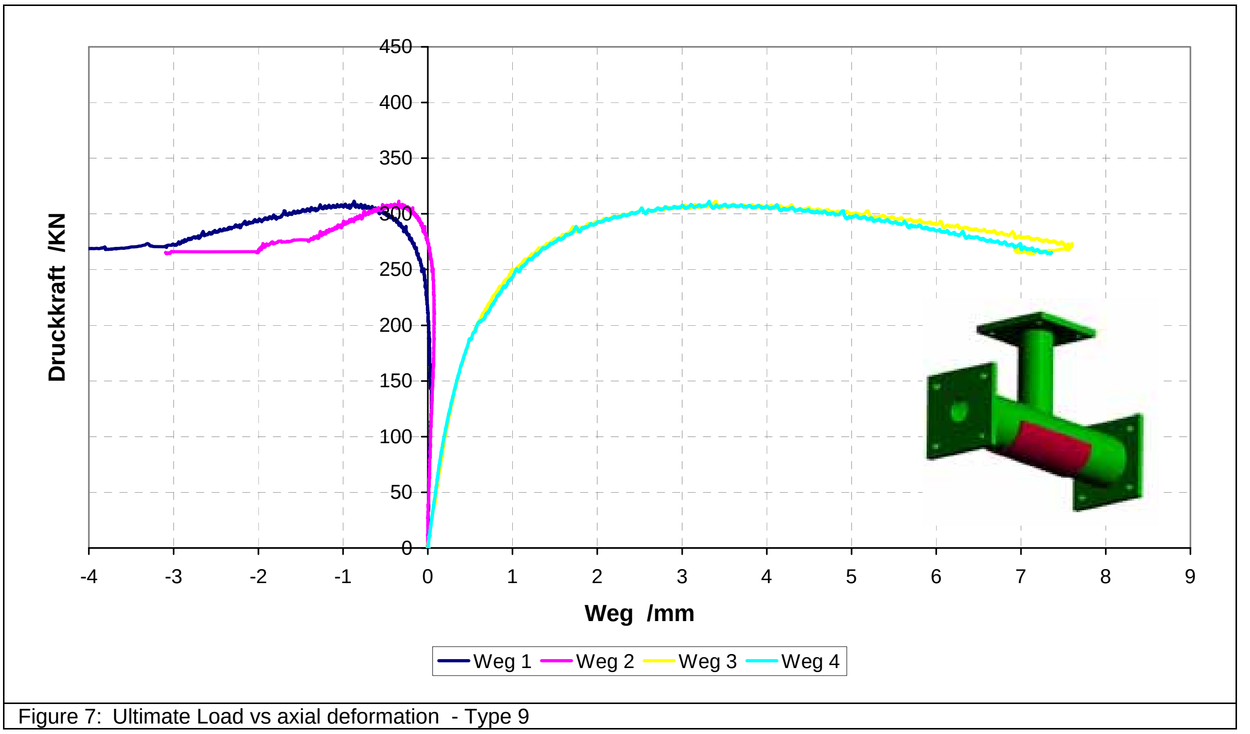


Figure 7: Ultimate Load vs axial deformation - Type 9

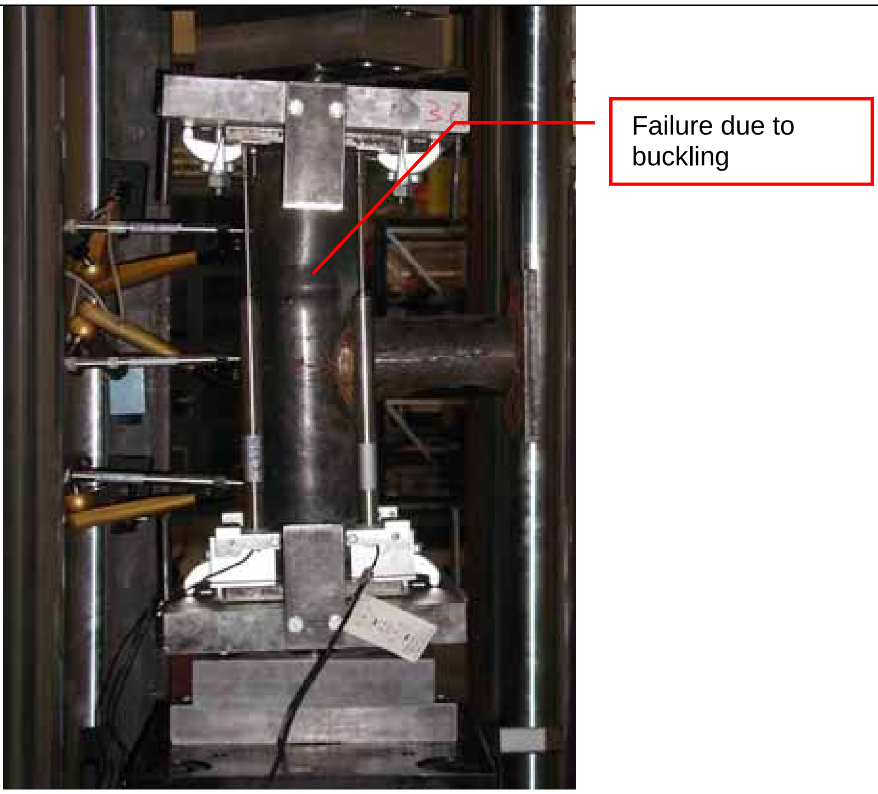


Figure 8 Specimen Type 3 during testing

Summary / Abstract

The paper presents results from the EU sponsored and AGFW co-ordinated RD project Branch Optimisation.

With regard to increased stressing of cold laid DH systems a design approach utilising plastic deformation capabilities in branches is discussed. The behaviour of state of the art designed branches is compared with optimised components in different stress/strain conditions i.e. bending and/or axial loading. The results presented are based on calculations and experiments.

The discussion encompasses the principle design systems - extrusion and welding.

References

[1] F. Thiele, R. Vollmar
Branch Optimisation – the potential of detailing
The 8th Symposium on District Heating and Cooling
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[2] T. Bauch,
Rechnerische Untersuchungen an verschweißten, nicht ruhend beanspruchten Rohrabzweigen von Fernwärmeleitungen
Diploma of the University of Kassel (not published)

[3] M. Bräutigam
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Diploma of the University of Kassel (not published)

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