



Strål
säkerhets
myndigheten

Swedish Radiation Safety Authority

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Technical Note

2012:15

A review of the mechanical
integrity of the canister

SSM perspektiv

Bakgrund

Strålsäkerhetsmyndigheten (SSM) granskar Svensk Kärnbränslehantering AB:s (SKB) ansökningar enligt lagen (1984:3) om kärnteknisk verksamhet om uppförande, innehav och drift av ett slutförvar för använt kärnbränsle och av en inkapslingsanläggning. Som en del i granskningen ger SSM konsulter uppdrag för att inhämta information i avgränsade frågor. I SSM:s Technical note-serie rapporteras resultaten från dessa konsultuppdrag.

Projektets syfte

Uppdraget är ett led i SSM:s granskning av SKB:s ansökan om slutförvaring av använt kärnbränsle. Detta uppdrag avser granskning av kapselns strukturella integritet.

Författarens sammanfattning

En inledande granskning av SR-Site med avseende på kapselns mekaniska integritet har genomförts. Fokus har legat på kopparkapseln och gjutjärnsinsatsen. Granskningen visar att ett flertal laster och lastscenarier för kopparkapseln inte analyserats av SKB. Vikten av att kopparmaterialets krypduktilitet är tillräcklig och att insatsmaterialet har tillräcklig duktilitet och brottseghet poängteras i granskningen.

En känslighetsanalys där dessa egenskapers inverkan på kapselns mekaniska integritet föreslås. Ytterligare undersökning av potentiella skademekanismers inverkan på dessa egenskaper föreslås också. SKB:s modellering av förlängning vid krypbrott för de förhållanden som råder i slutförvaret ifrågasätts. En lista ges på kompletterande information från SKB som behövs för den fortsatta granskningen av SR-Site. Förslag på områden som bör ingå i SSM:s kommande granskning föreslås också.

Projektinformation

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Diarienummer SSM 2010/3562
Aktivitetsnummer: 3030007-4100

SSM perspective

Background

The Swedish Radiation Safety Authority (SSM) reviews the Swedish Nuclear Fuel Company's (SKB) applications under the Act on Nuclear Activities (SFS 1984:3) for the construction and operation of a repository for spent nuclear fuel and for an encapsulation facility. As part of the review, SSM commissions consultants to carry out work in order to obtain information on specific issues. The results from the consultants' tasks are reported in SSM's Technical Note series.

Objectives of the project

This project is part of SSM's review of SKB's license application for final disposal of spent nuclear fuel. The assignment concerns a review of the mechanical integrity of the canister.

Summary by the author

An introductory review of SR-Site has been conducted with respect to the mechanical integrity of the canister. The review is focused on the copper canister and the nodular cast iron insert. Review results show that a number of loads and loading scenarios for the copper canister has not been analysed by SKB. The importance of sufficient creep ductility of the copper material and sufficient ductility and fracture toughness of the nodular cast iron material is pointed out in the review. A sensitivity study is suggested where the impact of these properties on the mechanical integrity of the canister is investigated.

It is also suggested that potential damage mechanisms influencing these properties are further investigated. SKB's modelling of creep elongation at rupture under repository conditions is questioned. Needs for complementary information from SKB for the main review of SR-Site is listed. A list of review topics for SSM is also suggested.

Project information

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Technical Note 3

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1. Introduction

The main purpose of the canister used in SKB's repository concept KBS-3 is to ensure a prolonged period of complete containment of radionuclides. This is achieved by the strength of the canister insert and the corrosion resistance and mechanical endurance of the copper canister surrounding it.

This technical note summarises an introductory review of SR-Site with respect to mechanical integrity of the canister. The review is focused on the copper canister and the nodular cast iron insert.

2. Mechanical loads and boundary conditions

In this introductory review of the mechanical integrity of the canister, a number of boundary conditions and loading scenarios are assumed.

- Max density of Ca-bentonite is 2050 kg/m³.
- Thickness of copper canister is 50 mm.
- External pressure of 15 MPa at full bentonite saturation.
- External pressure of 45 MPa at glacial period.
- Asymmetric loads resulting in bending of the canister.
- Asymmetric loads resulting in shear stresses in the copper canister.
- Rock shear displacement of 5 cm at a velocity of 1 m/s and a temperature of 0 °C.
- Rock shear displacement in combination with external pressure of 45 MPa.

Review of these boundary conditions and loading scenarios has not been part of this review.

2.1. Mechanical loads and characterisation of stresses

From a mechanical perspective, the canister can be subjected to pressure loads and friction loads. The bentonite interacts with the copper canister from the outside. This can result in both pressure and friction loads. Inside the canister, interaction between the insert and the copper canister can result in both pressure and friction loads. The copper canister might also be subjected to an internal gas pressure.

A stress can be characterised as primary (load controlled) or secondary (displacement controlled). This classification of stresses is useful when analysing structures made of ductile materials. A primary stress is developed by imposed external forces and moments and is necessary in satisfying the laws of equilibrium. Primary stresses are not self-limiting and can thus result in failure or gross distortion if accumulation of inelastic strain becomes large. A secondary stress is developed by the constraint of adjacent material or by self-constraint of the structure. Secondary stresses are self-limiting and they decrease as inelastic deformation takes place. If the material of the structure is sufficiently ductile, secondary stresses cannot cause failure.

2.2. Mechanical modelling of bentonite

When calculating the mechanical loads acting on the canister at rock shear, it is crucial that the mechanical properties of the bentonite are modelled in a correct way. In SKB TR-10-33, results from simulation of a rock shear experiment in the scale 1:10 is presented. See experimental setup in figure 2-2. Numerical simulation results, using the same numerical analysis approach and the same mathematical description of the constituents as in the full scale rock shear simulations (SKB TR-10-34), indicate good agreement with experimental results. SKB's validation of the mechanical model used for the bentonite is of importance for the reliability in simulating the full scale rock shear under repository conditions. This validation should be an essential topic in the main review of SR-Site.

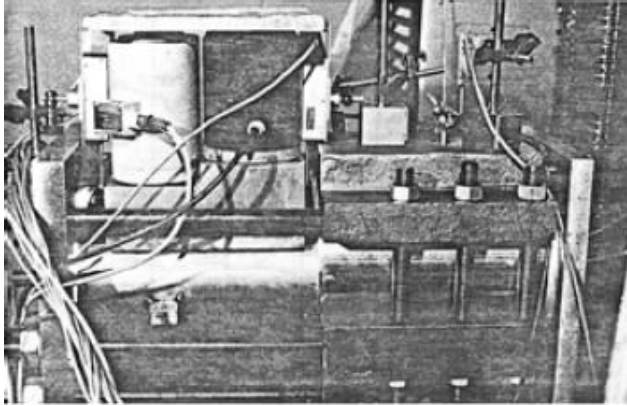


Figure 2-2: Experimental setup of the rock shear test in the scale 1:10 (SKB TR-10-33).

3. Mechanical integrity of copper canister

3.1. Mechanical response of copper canister

External mechanical loads on the copper canister are caused by mechanical interaction between the copper canister and the bentonite. As initial contact between the copper canister and the bentonite has been established and as long as the gap between the copper canister and the insert is not closed, a load controlled situation for the copper canister has to be assumed. If the external load on the copper canister is sufficiently high, inelastic deformation (plastic and creep) of the copper canister will take place and finally, if the load sustains, the gap between the copper canister and the insert will close. As soon as the copper canister and the insert start to interact, the load situation starts to change from load controlled to displacement controlled where the shape of the insert controls the shape of the copper canister. Depending on type of load and position on the copper canister, the change from load controlled to displacement controlled will go more or less slow.

With respect to mechanical integrity of the copper canister, it would be beneficial if the gap between the copper canister and the insert was closed by plastic deformation rather than creep deformation at a low stress level. The reason for this is that creep ductility of the copper might be reduced at lower stress levels. Swelling of the bentonite in the repository is however expected to be slow enough meaning that the gap between the copper canister and the insert will be closed essentially by creep

deformation. Only for the rock shear load scenario will the copper canister deform by both plastic and creep deformation.

For most of the loading scenarios, the shape of the insert will control the shape of the copper canister. As the gap between the insert and the copper canister has been closed, the amount of inelastic strain (plastic + creep) developed in the copper canister is given by the shape of the insert. The time it takes to close the gap essentially depends on the creep strain rate and the loads from the bentonite. Except for giving the time it will take to close the gap, the creep constitutive model (stress-creep strain rate relation) is of minor importance for loading scenarios that are displacement controlled. A creep rate sensitivity analysis in SKB TR-10-34 also indicates this.

For situations that are load controlled, stresses will not relax as inelastic deformation takes place. For these loads, the creep constitutive model gives the accumulated creep strain in the copper canister as a function of time. With respect to the mechanical integrity of the copper canister, load controlled scenarios that sustain are most detrimental. Thus, it has to be demonstrated that these scenarios will not occur.

In summary, this means that the most important mechanical property of the copper material is the copper ductility considering plastic and particularly creep deformation.

3.2. Copper ductility

3.2.1. Modelling of creep elongation at rupture

In figure 3-2 (left), the red curve shows predicted creep elongation at a creep rupture time of 10.000 hours (about 1 year) as a function of temperature for the former copper alloy used, Cu-OF. The red dots show corresponding experimental results for creep rupture times of 3.000 to 10.000 hours. In the same figure, the blue curve shows predicted creep elongation at a creep rupture time of 10.000 hours as a function of temperature for the present copper alloy used, the phosphorous doped Cu-OFP. The blue dots show corresponding experimental results for creep rupture times of 3.000 to 10.000 hours.

Figure 3-2 (right) shows predicted creep elongation at a creep rupture time of 1.000.000 hours (about 114 years) as a function of temperature for the two copper alloys. If creep rupture time is further increased, the model predicts that the dip in the blue curve vanishes, see SKB TR-09-32.

According SKB, the model indicates that creep elongation at creep rupture for Cu-OFP at repository conditions exceed 40%. Based on experimental results shown in figure 3-2 (left), validation of the model used must be questioned for Cu-OFP.

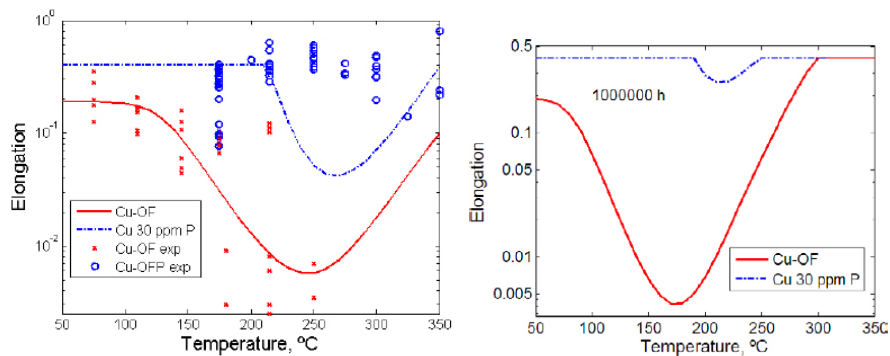


Figure 3-2: Left) Creep elongation at rupture versus temperature for a rupture time of 10,000 h for Cu-OF (0 ppm P) and Cu-OFP (30 ppm P). Measured creep elongation values are shown for comparison. Right) Creep elongation at rupture versus temperature for a rupture time of 1,000,000 h for Cu-OF and Cu-OFP (SKB TR-09-32).

3.2.2. Impact of plastic deformation on creep ductility

Plastic deformation of the copper material reduces creep ductility. This has been pointed out by SKB and further investigations on this issue are planned (SKB TR-10-14).

3.2.3. Impact of damage mechanisms

As sufficient copper ductility is crucial for the mechanical integrity of the copper canister, the understanding of potential damage mechanisms (e.g. radiation, hydrogen embrittlement, etc.) influencing this material property is of importance. Regarding radiation effects on the physical properties of copper, SKB TR-10-46 claims that these are negligible over the one million time period. However, it is suggested that SKB further investigates all potential damage mechanisms that can influence the ductility of the specific copper composition chosen. Both creep ductility and ductility with respect to plastic deformation should be considered.

3.2.4. Sensitivity study

As ductility probably is the most important mechanical property of the copper material with respect to mechanical integrity of the copper canister, it is suggested that SKB performs a sensitivity study where the impact of the copper ductility is investigated. The study should consider potential impact of plastic deformation on creep ductility. How much creep ductility can be reduced without threatening the mechanical integrity of the copper canister should be one result of the sensitivity study.

3.3. Stress corrosion cracking

One requirement for stress corrosion cracking to occur is that tension stresses are sufficiently high and that they sustain under a sufficiently long period of time. For the copper canister, most loading scenarios are essentially displacement controlled. As initial contact between the copper canister and the insert is established, the stresses in the copper canister start to relax caused by creep in the copper. For the

copper lid, however, the canister design makes it possible for stresses to sustain for a longer period of time.

Figure 3-3 shows first principle stress in the copper lid for the isostatic load case with $p=15$ MPa after 10 years of creep (SKB TR-10-28). As seen, tension stresses prevail through the whole lid at a level between 20 and 100 MPa. The time this stress field will prevail depends on the creep constitutive model, i.e. the relation between stress and creep strain rate.

The character of the stresses in the copper lid close to the copper cylinder, caused by external pressure, is probably a mixture of displacement controlled and load controlled. This means that a growing stress corrosion crack in the copper lid from the outside might not relax the stresses in the copper lid as the crack propagates. A numerical simulation of this crack propagation scenario could answer if this is the case.

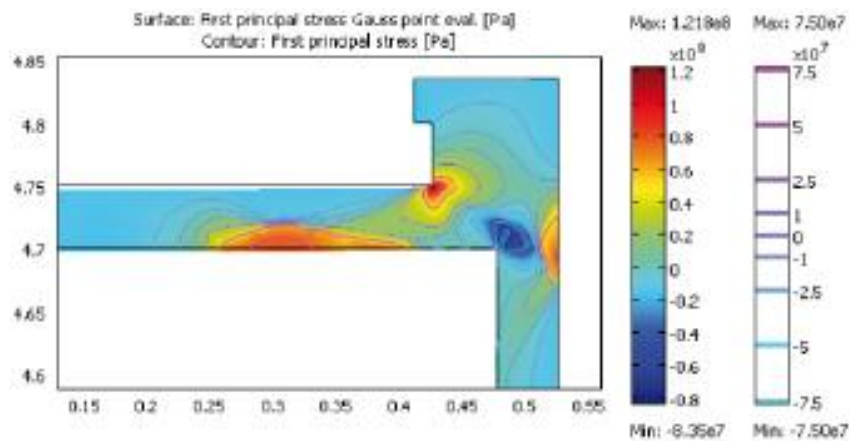


Figure 3-3: First principal stress in Pa at the top of the canister shell (SKB TR-10-28).

3.4. Stress analyses

SKB often reports stress analyses by only reporting equivalent stresses and strains. In reviewing the mechanical integrity of the copper canister it would be of value if also other stress and strain measures were presented such as principle and component measures. For some of the stress analyses, other information might also be needed in order to understand how the analyses have been done. Complementary information will be needed in the main review.

Vertical density gradients in the buffer may result in load controlled stresses in the copper canister (SKBdocid 1206894 ver. 1.0). One of these load cases is analysed in SKB TR-09-32 where it is concluded that no risk for damage of the waste package prevails, see figure 3-4. Based on what is reported in SKB TR-09-32, it is not possible to review the analysis of this loading scenario. It is, for example, unclear how friction between the copper canister and the insert has been taken into account. Additional plots from the analysis describing the evolution of stresses and strains would also be of value for the review.

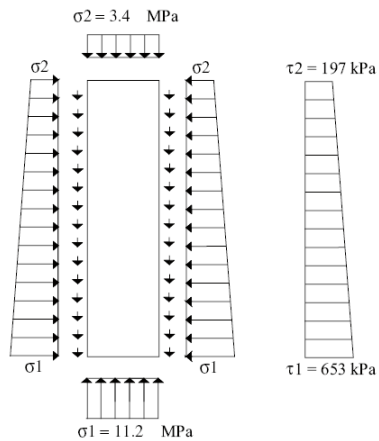


Figure 3-4: Normal stress on the canister surface and resulting shear stresses in the interface between the canister and the bentonite buffer (SKB TR-09-32).

3.5. Alternative loads and loading scenarios

3.5.1. Worst case of uneven bentonite swelling

In SKBdocid 1206894 ver. 1.0 a number of uneven bentonite swelling load cases is presented. With respect to mechanical integrity of the copper canister, it is unclear if worst load case is found.

3.5.2. Location of axial gap between copper canister and insert

In the isostatic load case analysis, the axial gap between the insert and the copper canister is equally divided between top and bottom in SKB's analyses (SKB TR-10-28). This assumption can be a non-conservative. SKB should also analyse a scenario where all axial gap is located at the top.

3.5.3. Alternative bentonite swelling in lid region

In all stress analyses of the copper canister, it is assumed that the volume above the copper lid is filled with bentonite and that the swelling pressure in this region develops as outside the lid, see figure 3-5-1. An alternative loading scenario would be if the swelling pressure is not uniform in the lid region.

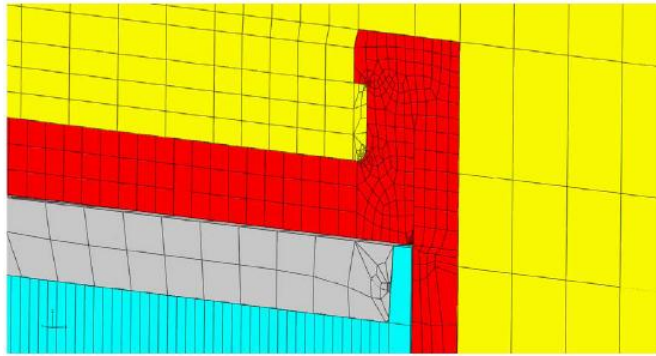


Figure 3-5-1: Detail of upper corner showing bentonite, copper shell, insert lid and insert (SKB TR-10-34).

3.5.4. Internal pressure in the canister

An internal pressure might develop inside the canister before any bentonite swelling pressure has been built up. This alternative loading scenario will result in stresses in the copper canister that are load controlled. Highest stresses will occur in the vicinity of the slit, see figure 3-5-2. The slit is also the location from which potential joint line hooking defects from friction stir welding will emanate. Subsequent external pressure caused by bentonite swelling also results in high stresses in the vicinity of the slit. An increased accumulation of inelastic strain in the slit region may be a result of the two consecutive loading scenarios. This increased accumulation can reduce the remaining capacity for plastic and creep deformation.

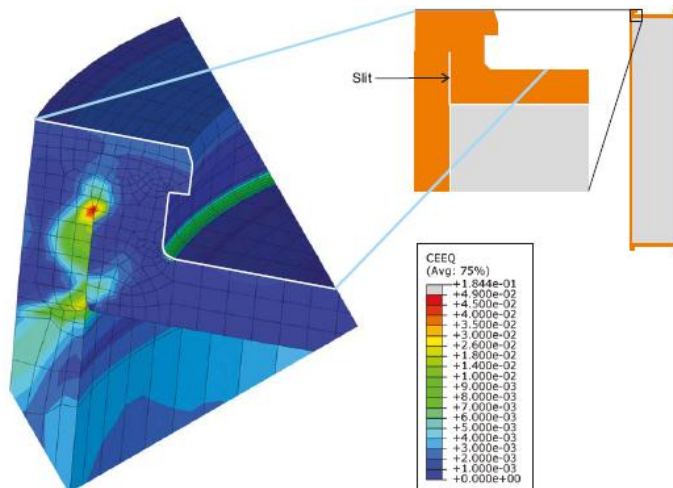


Figure 3-5-2: Creep strain concentration to elements at the slit (SKB TR-10-14).

4. Mechanical integrity of insert

4.1. Mechanical response of insert

The insert gives stability to the canister. This stability is also crucial for the mechanical integrity of the copper canister.

Mechanical loads are transferred from the bentonite via the copper canister to the insert. For most of the loading scenarios the insert response is elastic. For the rock shear load case, however, the insert deforms with plastic straining.

4.2. Mechanical testing of nodular cast iron material

It is important that SKB continuously tests different mechanical properties of the insert material (yield strength, tensile strength, elongation at fracture, ductility, fracture toughness, etc.) as manufacturing of inserts develops. PWR inserts are of particular interest as test results from these are strongly limited.

Figure 4-2 shows a disk of a BWR insert from which specimens for tensile testing and fracture toughness testing have been taken out. SKB is suggested to also perform tensile testing and fracture toughness testing using specimens taken out in the axial direction of the insert.

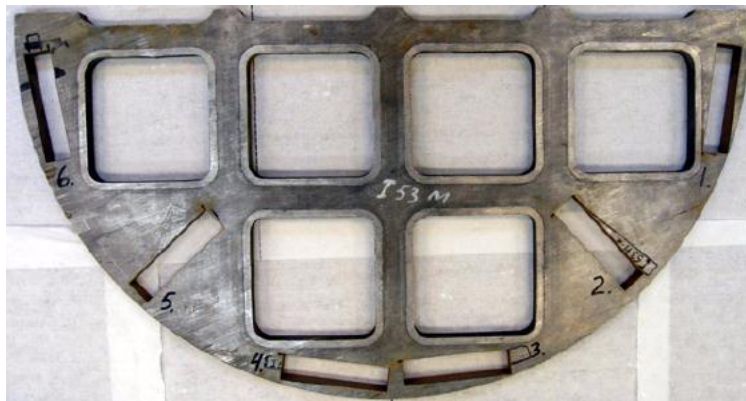


Figure 4-2: Disk of insert showing how specimens for tensile testing and fracture toughness testing have been taken out (SKBdocid 1203550 ver. 1.0).

4.3. Ductility and fracture toughness

4.3.1. Impact of damage mechanisms

As sufficient ductility and fracture toughness of the insert material are of importance for the mechanical integrity of the insert, the understanding of potential damage mechanisms influencing these properties is of importance. Regarding radiation effects on the physical properties of nodular cast iron used for the insert, SKB TR-10-46 claims that these are negligible if the copper content is lower than 0.05%.

However, it is suggested that SKB further investigates all potential damage mechanisms that can influence ductility and fracture toughness for the specific nodular cast iron material chosen.

4.3.2. Sensitivity study

As sufficient ductility and fracture toughness for the insert material are of importance for the mechanical integrity of the insert, it is suggested that SKB performs a sensitivity study where the impact of these two properties on the damage tolerance analysis is investigated. Fracture toughness of the nodular cast iron material is of particular interest to investigate as the fracture mechanics concept is used for a cast material. How temperature sensitive the fracture toughness is should be part of the investigation.

4.4. Modelling of insert material

The nodular cast iron material used for the insert shows strain rate dependence, see figure 4-4. Results from tensile testing up to a strain rate of 0.5 1/s are considered in modelling the insert material. The model is used in simulating the rock shear load scenario in SKB TR-10-34. One way to validate the modelling of the insert material in SKB TR-10-34 would be to check that simulated strain rates in the insert do not exceed 0.5 1/s. This check has not been reported in SKB TR-10-34.

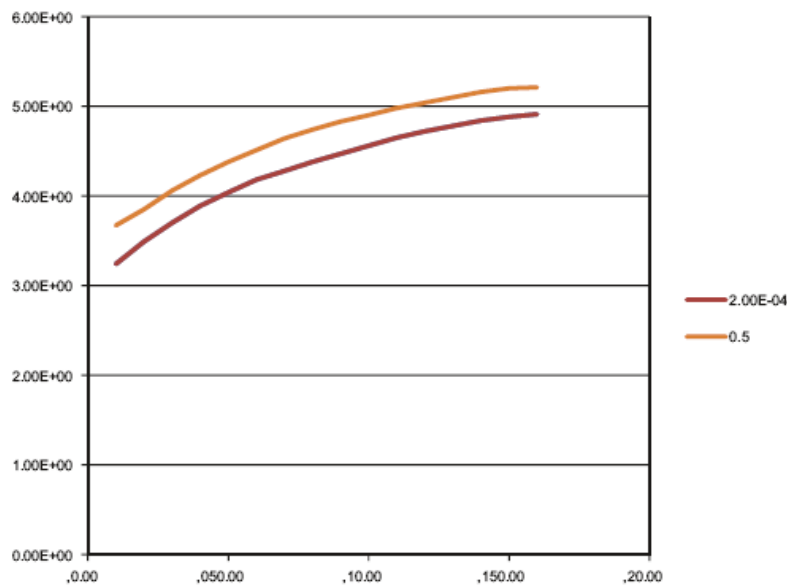


Figure 4-4: Yield surface [MPa] versus plastic strain [%] for different plastic strain rates. Note that the base (plastic) is defined to coincide with strain rate = 2×10^{-4} (SKB TR-10-34).

4.5. Damage tolerance analysis

4.5.1. General

A comprehensive defect tolerance analysis has been performed by SKB where the impact of different types of defects has been investigated for different loading scenarios. The failure mechanisms fracture and plastic collapse are considered. The PWR insert shows a slightly better defect tolerance than the BWR insert. The rock shear load case has, however, not been analysed for the PWR insert. Furthermore fracture toughness data from BWR inserts have been used also for PWR inserts. According to SKB TR-10-28, more production trials and material testing are needed for the PWR type inserts. Validation of fracture toughness data used in the damage tolerance analysis for the PWR should then be done.

4.5.2. Channel tubes

According to SKB TR-10-46, channel tubes are constrained to the insert in the rock shear analyses performed in SKB TR-10-34. In the damage tolerance analysis performed in SKB TR-10-29, boundary conditions and loading for the submodel consist of displacements on the boundary obtained from the global model in SKB TR-10-34. As the channel tubes are constrained to the insert in the global model, loading on the submodel can be underestimated. This effect is not evaluated in SKB TR-10-29.

4.5.3. Safety factors

In the damage tolerance analysis, safety factors for the failure mechanisms fracture and plastic collapse are suggested for different loading scenarios in SKB TR-10-28. A strategy from nuclear industry and the ASME code principles for safety class 1 components have been applied. The probability for a loading scenario to occur directly influences the safety factors. How SKB has chosen the probability for a loading scenario to occur has to be reviewed.

4.5.4. Impact of residual stresses

Residual stresses from casting of the insert have not been considered in the damage tolerance analysis. According to SKB TR-10-28, the effect of these stresses on fracture is low due to the secondary character of the load. Residual stress measurements to a depth of 1 mm show compressive stresses (SKBdocid 1208266). It is suggested that SKB further investigates residual stresses in both BWR and PWR inserts and their impact on the damage tolerance analysis.

4.6. Steel lid

In the rock shear analyses presented in SKB TR-10-34, the steel lid is constrained to the insert in order to improve the numerical convergence rate, see figure 4-6. How this simplification influences the mechanical response locally has not been evaluated in SKB TR-10-34.

Best estimate materials data instead of min materials data should be used for the steel lid in calculating the stresses in the steel lid (SKB TR-10-34).

The steel lid is not evaluated in SKB TR-10-34. It is unclear if SKB finds this evaluation unnecessary.

To facilitate replacement of the atmosphere in the insert, the steel lid has a valve and there are milled notches in the insert top. In addition, the steel lid has a gasket to ensure a gas tight seal. Type of valve and gasket is unknown. It is important that the introduction of these two components does not have a negative impact on the mechanical integrity of the canister.

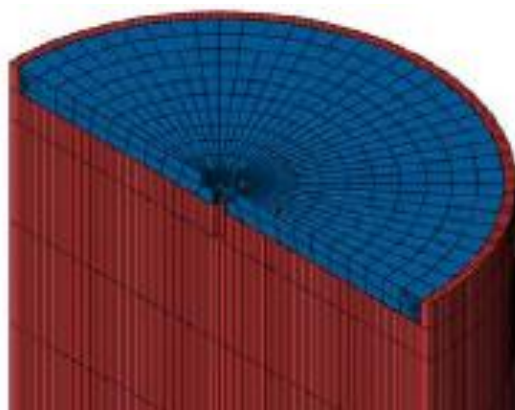


Figure 4-6: Finite element model of steel lid and BWR insert (SKB TR-10-34).

5. Main review findings and recommendations to SSM

A number of alternative loads and loading scenarios for the copper canister has not been analysed by SKB. This shortcoming should be followed up in the main review.

With respect to mechanical integrity of the copper canister, load controlled scenarios that sustain are most detrimental. SKB has to demonstrate that these scenarios will not occur. This topic should be followed up in the main review.

The creep constitutive model (stress-creep strain rate relation) has a minor influence on the mechanical integrity of the copper canister for displacement controlled loading scenarios. Potential stress corrosion cracking at external pressure load might be an exception.

SKB's modelling of creep elongation at creep rupture under repository conditions is questioned. Experimental results do not agree very well with corresponding predictions for the Cu-OFP copper.

With respect to mechanical integrity of the copper canister, ductility considering both plastic and particularly creep deformation is probably the most important mechanical property of the copper material. In the main review, certain attention should be paid to this property and corresponding analyses using this property.

With respect to mechanical integrity of the insert, ductility and fracture toughness are probably the most important mechanical properties of the nodular cast iron material. The use of the fracture mechanics concept has to be done with care as the insert is made of a cast material. In the main review, certain attention should be paid to ductility and fracture toughness and corresponding analyses using these properties.

Impact of constrained channel tubes and residual stresses in the insert has not been taken into account in SKB's damage tolerance analysis of the insert. This issue should be followed up in the main review.

SKB is suggested to further look into potential damage mechanisms (radiation, hydrogen embrittlement, etc.) that may influence the material properties of the copper and the nodular cast iron material in the repository. This topic should be followed up in the main review.

SKB's validation of the mechanical model used for the bentonite is of importance for the reliability in simulating the full scale rock shear under repository conditions. This validation should be an essential topic in the main review of SR-Site.

Coverage of SKB reports

Table 1: Coverage of SKB reports in the introductory review.

Reviewed report	Reviewed sections	Comments
TR-09-32	All	
TR-10-14	2, 3, 4	
TR-10-28	All	
TR-10-29	All	
TR-10-33	All	
TR-10-34	All	
TR-10-46	3.4	
TR-11-01	5.4, 8.1, 8.2, 8.3.1, 10.3.15, 10.3.16, 10.4.5, 12.7, 12.8	
R-10-11	All	
SKBdocid 1177857 ver. 1.0	All	
SKBdocid 1187725 ver. 1.0	All	
SKBdocid 1196484 ver. 2.0	All	
SKBdocid 1203550 ver. 1.0	All	
SKBdocid 1206868 ver. 1.0	All	
SKBdocid 1206894 ver. 1.0	All	
SKBdocid 1207426 ver. 1.0	All	
SKBdocid 1207429 ver. 1.0	All	
SKBdocid 1207576 ver. 2.0	All	
SKBdocid 1208266 ver. 1.0	All	
PM SKB0903c	All	

Suggested needs for complementary information from SKB

1. The axial gap between the insert and the copper canister is equally divided between top and bottom in SKB's analysis of the copper lid and the copper bottom, see section 11.2 in SKB TR-09-32. How can a situation where the whole axial gap is located at the top be excluded?
2. In SKBdocid 1206894 ver. 1.0, a number of uneven bentonite swelling scenarios are described. With respect to the mechanical integrity of the copper canister, how are worst cases of uneven bentonite swelling chosen?
3. Vertical density gradients in the buffer can result in shear stresses acting on the copper canister. One of these load cases is analysed in SKB TR-09-32, section 11.4, where it is concluded that no risk for damage of the waste package prevails. Based on what is reported in SKB TR-09-32, it is not possible to review the analysis of this loading scenario. It is, for example, unclear how friction between the copper canister and the insert has been taken into account. Additional plots from the analysis describing the evolution of stresses and strains would also be of value for the review.
4. In all stress analyses of the upper part of the copper canister, it is assumed that the volume immediately above the copper lid is filled with bentonite and that the swelling pressure in this region develops as outside the lid. What motivates this assumption? Is it, for example, not possible that a swelling pressure is developed at the outside but not at the inside of the copper lid?
5. Has SKB investigated how sensitive the mechanical integrity of the copper canister is with respect to the copper ductility, considering plastic and particularly creep deformation?
6. As sufficient copper ductility is crucial for the mechanical integrity of the copper canister, the understanding of potential damage mechanisms (e.g. radiation, hydrogen embrittlement, etc.) influencing this material property is of importance. Is SKB planning to investigate this topic further?
7. The character of the stresses in the copper lid close to the copper cylinder caused by external pressure is probably a mixture of displacement controlled and load controlled, see figure 6-23 in SKB TR-10-28. This means that a growing stress corrosion crack in the copper lid from the outside might not relax the stresses in the copper lid as the crack propagates. A numerical simulation of this crack propagation scenario could answer if this is the case. Has SKB planned to investigate the effect of such crack propagation?

8. Residual stresses from casting of insert have not been considered in the damage tolerance analyses. According to SKB TR-10-28, section 7.3.2, the effect of these stresses on fracture is low due to the secondary character of the load. Residual stress measurements to a depth of 1 mm in a BWR insert show compressive stresses, see SKBdocid 1208266 ver. 1.0. In other regions of the BWR insert, residual stresses must be tensile. What impact do tensile residual stresses have on the damage tolerance analysis? In this context, what are the differences between BWR and PWR inserts?
9. Regarding the damage tolerance analysis of the PWR insert, fracture toughness data from BWR inserts have been used (SKB R-10-11) and the rock shear load case has not been analysed (SKB TR-10-29). How will SKB take care of these shortcomings?
10. In the rock shear analyses performed in SKB TR-10-34, the steel lid is constrained to the insert in order to improve the numerical convergence rate. How will this simplification influence the mechanical response locally? Furthermore min data are used in characterising the steel lid material instead of best estimate materials data. How does this influence the evaluation of the steel lid for the rock shear loading scenario?
11. Type of valve and gasket used for the steel lid is unknown. Complementary information is needed.
12. SKB has not performed tensile testing and fracture toughness testing using specimens taken out in the axial direction of inserts. How is this shortcoming explained?
13. In modelling the insert material in SKB TR-10-34, results from tensile testing up to a strain rate of 0.5 1/s have been considered. Has SKB checked that simulated strain rates in the insert reported in SKB TR-10-34 do not exceed 0.5 1/s?
14. Channel tubes are constrained to the insert in the rock shear analyses performed in SKB TR-10-34. As a consequence, loads on the submodels used in SKB TR-10-29 can be underestimated. Has this effect been evaluated by SKB?
15. Has SKB investigated how sensitive the mechanical integrity of the BWR and the PWR insert is with respect to ductility and fracture toughness of the nodular cast iron material?
16. As sufficient ductility and fracture toughness of the insert material are of importance for the mechanical integrity of the insert, the understanding of potential damage mechanisms influencing these properties is of importance. Is SKB planning to investigate this topic further for the nodular cast iron material chosen?

Suggested review topics for SSM

1. A number of alternative loads and loading scenarios for the copper canister has not been analysed by SKB. This shortcoming should be followed up in the main review.
2. Load controlled scenarios that sustain are most detrimental for the copper canister. SKB must show that such scenarios do not occur. This topic has to be followed up in the main review.
3. Uneven bentonite swelling might result in load controlled axial stresses or shear stresses in the copper canister. It is unclear if SKB has found the worst load case with respect to the mechanical integrity of the copper canister. SSM is suggested to review this loading scenario in detail.
4. Sufficient ductility of the copper material, considering plastic and particularly creep deformation, is crucial for the mechanical integrity of the copper canister. In the main review, certain attention should be paid to this property and corresponding analyses using this property.
5. Potential damage mechanisms in the repository influencing ductility of the copper material should be one topic of special interest in the review.
6. Sufficient ductility and fracture toughness of the nodular cast iron material are important for the mechanical integrity of the insert. In the main review, certain attention should be paid to these properties and corresponding analyses using these properties.
7. Potential damage mechanisms in the repository influencing ductility and fracture toughness of the nodular cast iron material should be one topic of special interest in the main review.
8. SKB's validation of the mechanical model used for the bentonite is of importance for the reliability in simulating the full scale rock shear. This validation should be an essential topic in the main review.



2012:15

The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 270 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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