Fellesprosjektet FP2

Sammenstilling av gruppebesvarelser fra Samhandlingsfasen våren 2012

Innhold

Overordnet mål: FP2 skal bli årets anlegg!

Dette skal oppnås gjennom 6 fokusområder

HMS/YM

Vi skal ha null skader med fravær.

Anleggsarbeidet skal ikke føre til miljøkonsekvenser.

Omdømme

Prosjektet skal ha godt omdømme, og gi god og positiv PR for alle parter.

Samarbeid og kommunikasjon

Vi skal samarbeide, involvere, og ha konstruktiv og åpen dialog, på hvert nivå og mellom nivåer.

Vi skal ha jevnlige samarbeidsmøter hvor vi evaluerer samhandlingen i prosjektet.

Teknikk & teknologi

Vi gjennomfører et pionerprosjekt innen vann og frostsikring av tunnel!

Prosjektet skal være best hittil på bruk av 3D!

Kvalitet og fremdrift

Vi skal levere riktig kvalitet til rett tid!

Økonomi

Alle parters økonomiske mål skal nås.

Kjøreregler prosjektgjennomføringen

Vi opptrer profesjonelt gjennom å

- ha respekt for rammebetingelsene
- 'plan ahead'
- ha et profesjonelt forhold til naboer og publikum

Vi tar vare på hverandre ved å

- sette sikkerhet først
- holde avtaler og
- fokusere på sak, og ikke person
- være tydelige, åpne og ærlige
- vise hverandre gjensidig respekt

Vi har riktig kommunikasjon og informasjonsflyt eksternt og internt gjennom

- åpen dialog gjennom hele anleggsfasen
- korte beslutningsveier
- all skriftlig dokumentasjon på norsk

Vi har kontinuerlig samhandling der vi

- er åpne for nye innspill og løsninger
- fokuser på involvering og opplæring

Vi har smidige og korte beslutningsveier, gjennom

- entydige ansvarsmatriser hos alle parter
- at partene har evne og vilje til å ta avgjørelser på hvert nivå
- klare mandater
- entydige konklusjoner.

Vi skal nå våre HMS-mål gjennom ekstrem ryddighet!

Elin Hermanstad Havik Byggeleder FP	**Magne Storrønning** Ass. Byggeleder FP	**Erik Frogner** Prosjektleder Norconsult	**Jørn Gjennestad,** Anleggsleder JV VH	**Johann Schöndube,** NK Anleggsleder JV VH

FJELLSPRENGNINGSTEKNIKK
BERGMEKANIKK/GEOTEKNIKK 2012

KONTRAKTSTRATEGI FOR STORE JERNBANEPROSJEKTER
- **Hvilke utfordringer står vi ovenfor og hvordan bør disse håndteres gjennom gode kontrakter?**
- **Eksempel fra Follobanen**

Contract-strategy for large railway-projects.

Assisterende Prosjektdirektør Anne Kathrine Kalager, Jernbaneverket Utbygging

SAMMENDRAG
For håndtering av stadig flere store utbyggingsprosjekter ser Jernbaneverket behov for en tilpasning av nye kontrakts- og gjennomføringsmodeller. Det er ønskelig med konkurranse fra både norske og utenlandske entreprenører. Ved evaluering vil det bli fokusert sterkt på sikkerhet, kvalitet og løsninger som er tilpasset en fremtidig driftssituasjon.

For bygging av Follobanen foreslås det en oppdeling i tre store underbygningskontrakter hvor det vil bli benyttet Totalentreprise, med et nærmere avtalt nivå på og omfang av prosjektering, som kontraktsform. Jernbaneverket ønsker å trekke entreprenørene tidlig inn for å utnytte den kompetansen som finnes i markedet til å utforme og bygge gode løsninger.

SUMMARY
In order to effectively manage an increasing number of infrastructure development projects, the Norwegian National Rail Administration is currently adjusting its project execution and contracting strategies. Both national and international competition is an objective. Evaluation criteria will be based on safety, quality and technical solutions accommodating the future railway operations.

The execution of the Follo Line Project is envisaged with 3 EPC-contracts, with agreed scope and terms. The Norwegian National Rail Administration encourages contractors to engage at an early phase in order to exploit the available competence and capabilities on the market.

1. BAKGRUNN

Jernbaneverket har gjennom de siste 20 årene håndtert stadig flere og større utbyggingsprosjekter. I h.h.t. gjeldende NTP for perioden 2010 – 2019 og forslag til NTP for perioden 2014 – 2023 må Jernbaneverket forberede seg på en flerdobling av de årlige investeringsvolumene. Som en del av disse forberedelsene inngår en tilpasning av nye kontraktsmodeller for håndtering av både flere og større kontrakter enn hva Jernbaneverket har håndtert frem til nå.

For underbygningskontrakter har det til nå hovedsakelig vært benyttet Utførelsesentrepriser som kontraktsmodell. Denne har vært basert på Jernbaneverkets tilpasning til NS 8405, prosesskodene og modell for ekvivalent tidsregnskap for tunneler. Det har vært en tradisjon å dele opp underbygningsarbeidene i entrepriser med størrelse opp til 500 mill NOK. For de siste store kontraktene som er inngått er denne grensen strukket opp til ca 1500 mill NOK.

For noen tekniske entrepriser som f eks bygging av et ERTMS-anlegg på prøvestrekningen på Østre linje, bygging av GSM-R og ny rammeavtale for levering av signalanlegg er det benyttet Totalentrepriser basert på NTK07.

2.1 Nye Strategiske føringer fra JBV

I Utbyggingsdivisjonen skal følgende strategiske føringer gjøres gjeldende for kontraktstrategien som velges for det enkelte prosjekt:

- Oppgaver som kan overlates til markedet skal ikke utføres i egen regi.
- Bruk av færre kontrakter som gir færre grensesnitt, mer effektiv kontraktsoppfølging og mer helhetlige anlegg.
- Sikring av god konkurranse både nasjonalt og internasjonalt, gjennom valg av språk, valg av kontraktstørrelser og mer bruk av totalentrepriser.
- Sterkt fokus på kvalitet og fremtidig driftssituasjon.
- Erfaring, kompetanse og politikk innenfor sikkerhet og HMS tillegges vekt ved leverandørvalg.

Nedenfor er det beskrevet hvordan foreslått kontraktstrategi for bygging av Nytt dobbeltspor mellom Oslo og Ski, Follobanen, har tilpasset seg disse overordnede føringene.

2. FOLLOBANEN

Prosjektet omfatter bygging av nytt dobbeltspor på den 23 km lange strekningen mellom Oslo S og Ski stasjon. Med unntak av innføringen til Oslo S og Ski stasjon, dimensjoneres strekningen for en hastighet på 250 km/h. Banen dimensjoneres for både person- og godstrafikk. Det vil bli tilrettelagt for en fremtidig avgrening for godstrafikk til Alnabru.

Den nye banen planlegges bygget ut som en helhet med samtidig utførelse og ferdigstillelse av hele strekningen, men er geografisk delt i følgende delprosjekter:

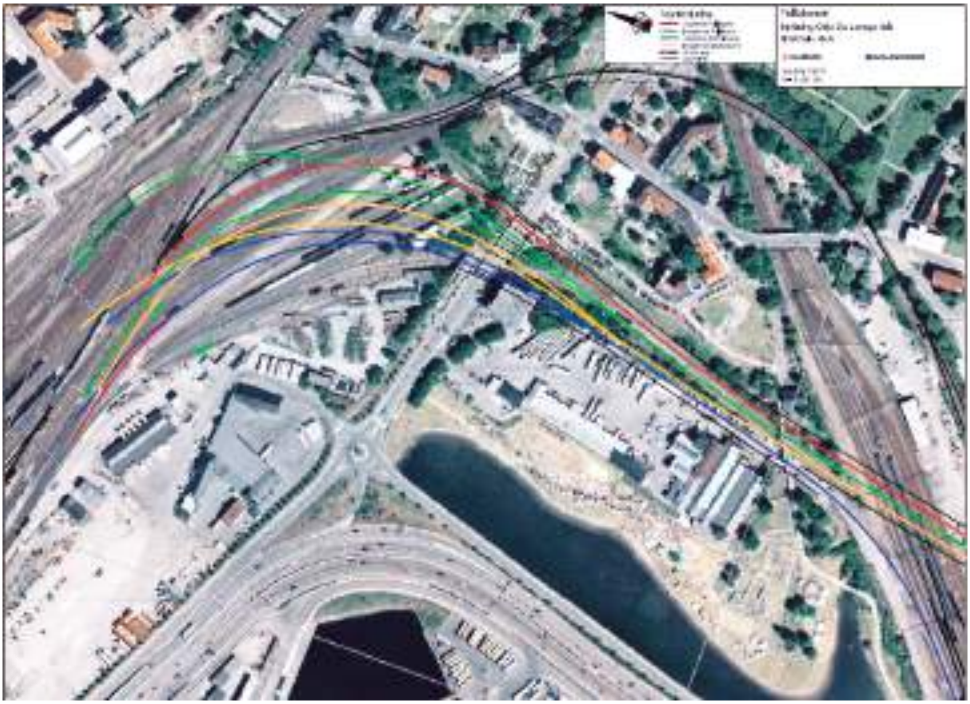
1. Innføring Oslo S
2. Tunnel Gamlebyen – Langhus
3. Ski stasjon inklusive dagstrekning mellom Langhus og Ski stasjon

Figur 1. Trasé for Nytt dobbeltspor mellom Oslo og Ski, Follobanen.

2.1 Innføring Oslo S

Omfatter en innføring av Follobanens to spor med planskilte kryssinger av andre spor til relevante plattformer på Oslo S. En tilsvarende omlegging av eksisterende Østfoldbanens trasé fra Bekkelaget og inn til Oslo S er nødvendig for å oppnå dette, og gjennomføres derfor som en del av prosjektet.

En annen viktig premiss som har vært bestemmende for traséføringen av både Follobanen og omlagt Østfoldbane, er hensynet til kulturminner fra Middelalderen. Foreliggende løsning med både Follobanens to spor og omlagt Østfoldbane i kulvert gjennom Klypen i nordenden av Middelalderparken, tilfredsstiller disse kravene. Videre føres begge Follobanens to spor og inngående Østfoldbanespor i kulvert under sporområdet på Loenga.



Figur 2. Follobanens innføring til Oslo S gjennom Klypen i Middelalderparken og sporområdet på Loenga.

Mellom Ekebergåsen og tilkoblingspunktene mot Oslo S karakteriseres grunnforholdene av bløt og til dels svært sensitiv leire og store dybder til fjell, 20 – 60 meter.

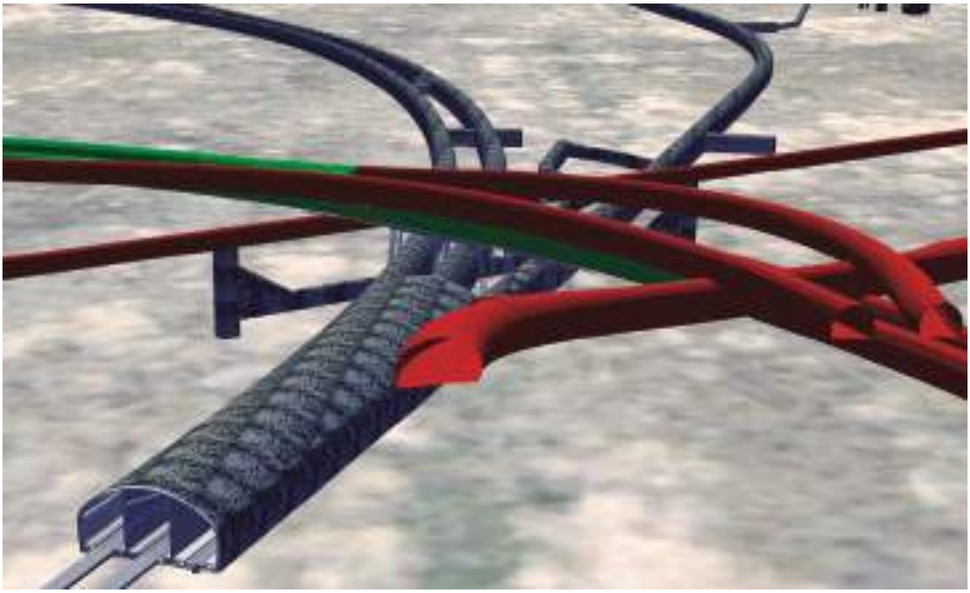
Deler av anlegget må gjennomføres med nærføring til jernbane i drift. Med unntak av begrensede bruddperioder, som er definert og avklart med driftsorganisasjonen på forhånd, skal anleggsarbeidene gjennomføres uten forstyrrelser i togtrafikken inn- og ut av Oslo S.

2.2 Tunnelen

Omfatter bygging av to separate løp for en 19,5 km lang tunnel. Det er besluttet at tunnelløpene skal drives med til sammen fire TBM'er fra ett sentralt hovedriggområde på Åsland, beliggende omtrent midt på tunnelstrekningen.

Figur 3. Angrepspunkter for konvensjonell tunneldriving mot Oslo S og TBM-driving fra Åsland.

To maskiner vil drive sydover til Langhus, mens de andre to maskinene forutsettes å drive nordover til Bekkelaget. De innerste 2,8 km mot Oslo S forutsettes drevet konvensjonelt. På dette partiet inngår bl.a kompliserte kryssinger av både Ekebergtunnelene (E6) og andre installasjoner.



Figur 4. Kompliserte kryssinger av andre installasjoner i Ekebergåsen.

For å sikre en trygg evakuering, vil det bli bygget tverrforbindelser mellom disse to løpene for ca hver 500 meter. Alle disse skal drives ved konvensjonell sprengning.

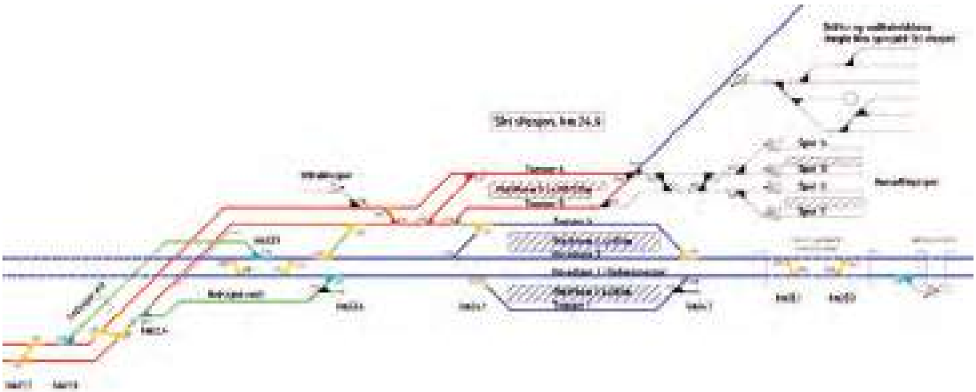
Bergartene i prosjektområdet består hovedsakelig av prekambriske gneiser med noe amfibolitt, gjennombrutt av enkelte permiske intrusiver bestående av diabas og syenitt. Bergmassen er forholdsvis lite oppsprukket og har to hovedsprekkesett med orientering Ø-V og SØ-NV, med steilt fall. Ut mot Ekebergskråningen og parallelt med denne er det påvist flere forkastningssoner fra Perm tid.

Med unntak av området inn mot Oslo S hvor tunneltraséen vil krysse eksisterende installasjoner, samt enkelte svakhetssoner, vil tunnelene gjennomgående få svært god overdekning, i gjennomsnitt ca 80 meter. Anlegget drives i sin helhet uavhengig av eksisterende togtrafikk.

2.3 Langhus - Ski

Omfatter en ca 1,5 km lang strekning syd for tunnelen hvor også Østfoldbanen i sin helhet må legges om, samt en fullstendig ombygging og utvidelse av dagens Ski stasjon.

For å tilrettelegge for en smidig avvikling av trafikken, spesielt godstrafikken, bygges det et vestre og østre forbindelsesspor for kjøring fra h.h.v. Østfoldbanen til Follobanen i sydlig retning og for kjøring fra Follobanen til Østfoldbanen i nordlig retning. For bygging av østre forbindelsesspor inngår driving av en ca 400 meter lang tunnel. Denne skal drives konvensjonelt.



Figur 5. Skjematisk sporplan for Follobanen (blått), omlagt Østfoldbane (rødt), samt Forbindelsesspor Øst og Vest (grønt) fra tunnelpåhugg ved Langhus til og med Ski stasjon.

Mesteparten av anlegget må gjennomføres med nærføring til jernbane i drift. Med unntak av begrensede bruddperioder, som er definert og avklart med driftsorganisasjonen på forhånd, skal anleggsarbeidene gjennomføres uten forstyrrelser i togtrafikken på strekningen.

2.4 Jernbaneteknisk anlegg

Foruten underbygningsarbeider, inngår også alle jernbanetekniske installasjoner i hvert av delprosjektene. For Ski og tunnelen skal det leveres et elektronisk signalanlegg som skal forberedes for en konvertering til ERTMS-funksjonalitet. For innføring av Follobanen og omlagt Østfoldbane til Oslo S skal eksisterende sikringsanlegg bygges om.

2.5 Tidsplan

Det planlegges gjennomføring av en del forberedende arbeider med oppstart tidlig i 2013. Tilbudsforespørsler på Hovedarbeidene forutsettes utsendt tidlig i fjerde kvartal 2013, med kontraktsinngåelse og oppstart i 2014.

Med utgangspunkt i dette forutsettes anlegget ferdigstilt innen utgangen av 2019.

3. VALG AV KONTRAKTSTRATEGI FOR FOLLOBANEN

3.1 Målsettinger

For Follobaneprosjektet er det en målsetting å oppnå følgende gjennom valg av en riktig og markedstilpasset kontraktstrategi:

- Konkurransedyktig pris: Sikre reell, nasjonal og internasjonal konkurranse på like vilkår.
- HMS: Velge kontraktorer med dokumentert førsteklasses HMS kultur og resultater.
- Forutsigbarhet: Velge kontraktorer med dokumentert førsteklasses gjennomføringsevne vedrørende kvalitet og tid.

3.2 Hva har vært vurdert og hva har påvirket valget av strategi?

Som et grunnlag for anbefaling av kontraktstrategi for Follobanen, ble det gjennomført en markedsanalyse. Her inngikk bl.a. en vurdering av ulike kontraktsmodeller. Det ble sett på hvilke modeller som har vært og er i bruk på andre tilsvarende prosjekter. Her kan nevnes ulike former for utførelsesentreprisemodeller, totalentreprisemodell og forskjellige former for samspillentreprisemodeller.

En rekke forhold har vært med på å påvirke valg av strategi. De viktigste faktorene er angitt nedenfor:

<u>Sikkerhet både for gjennomføringsfasen og for det endelige anlegget:</u>

Omfanget av entreprenørens ansvar i forhold til sikkerhet er avhengig av kontraktsformen. For kontraktsformer der entreprenøren skal utføre prosjektering (totalentrepriser), vil ansvaret være mer omfattende enn for entrepriser som ikke omfatter prosjektering (utførelsesentrepriser).

Sikkerhetsarbeidet i forbindelse med prosjekteringen har som formål å utvikle tekniske løsninger som gir mest mulig sikkerhet for togfremføringen, byggemetoder samt legger opp til en fremdrift som ivaretar sikkerhet, helse og arbeidsmiljø i byggefasen. I tillegg skal det legges til grunn tekniske løsninger som ivaretar sikkerhet, helse og arbeidsmiljø i den fremtidige driftsfasen.

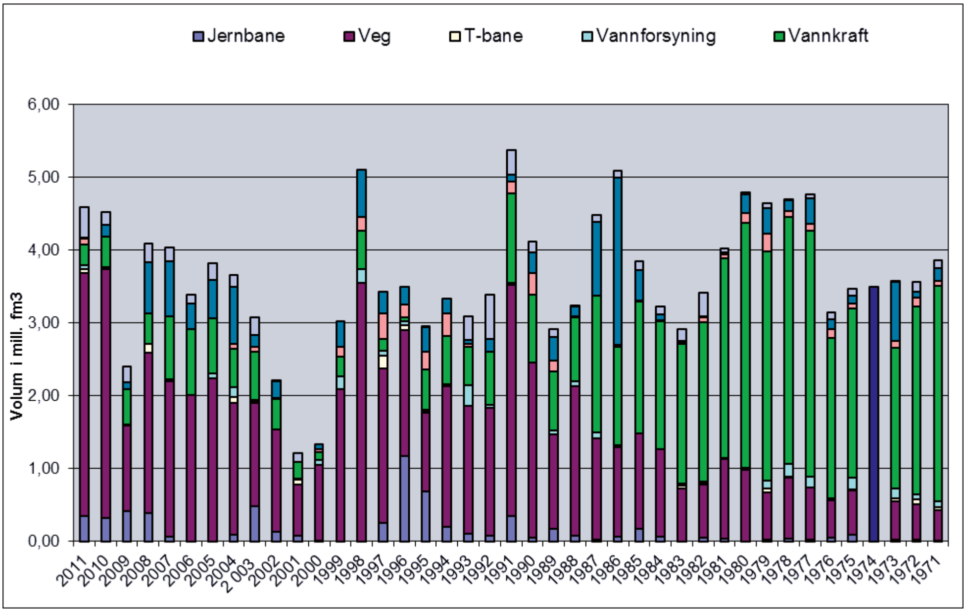
Ved en totalentreprise vil entreprenøren ha ansvar for at det er bygget tilstrekkelig sikkerhet for både utførelsesfasen og fremtidig driftsfase inn i prosjekteringsmaterialet i tillegg til ansvaret for ivaretakelse av sikkerheten ved gjennomføringen.

Ved en utførelsesentreprise vil entreprenøren kun ha ansvar for å følge de sikkerhetskrav som er innarbeidet i tegninger, tekniske beskrivelser, SHA-planer (ref. Byggherreforskriften), eller spesifikke sikkerhetskrav som er gitt i kontrakten. For store og komplekse jobber, risikerer man å miste noe av den nødvendige helhetstenkningen for å ivareta sikkerheten, både for anleggsgjennomføringen og for det endelige produktet.

<u>Størrelsen på prosjektet og hvilken oppdeling som vil være hensiktsmessig</u>:
Med en tradisjonell oppdeling av arbeidene i små og mellomstore entrepriser, vil antall grensesnitt i seg selv medføre en betydelig risiko.
En slik oppdeling vil kreve mye av byggherren hva angår koordinering.

<u>Kompleksiteten ved gjennomføring av deler av anlegget:</u>
Den kompleksiteten som foreligger i hver ende av tunnelen hvor Follobanen og omlegging av Østfoldbanen skal bygges uten forstyrrelser av togtrafikken, må tas spesielt hensyn til ved utforming av kontraktstrategien. Det samme gjelder krevende grunnforhold med bløte og rasfarlig leirmasser på begge sider av tunnelen, samt nærføringen til anlegg i Ekebergåsen.

<u>Leverandørmarkedet:</u>
Det er reist spørsmål ved om det innenfor det norske markedet er tilstrekkelig kapasitet til å gjennomføre Follobanen i tillegg til andre store utbyggingsoppgaver som det er ventet at vil finne sted i samme periode. Ved å ta utgangspunkt i NFFs tunnelstatestikk ser vi bl.a at driving av Follobanen alene vil bidra til en økning på ca 30% av den årlige tunnelproduksjonen i forhold til nivået for 2011.



Figur 6. NFFs tunnelstatestikk for 2011.

Markedsanalysen viser at ved å benytte europeiske aktører som et supplement til norske entreprenører vil det være tilstrekkelig kapasitet og kompetanse i markedet for gjennomføring av Follobanen. Ut i fra den gjennomførte markedsanalysen kan følgende oppsummering gjøres med hensyn til hva de ulike delene av leverandørmarkedet ser ut til å være modent for:

Globale* kontraktorer alene og/eller i allianser:
Kontraktsverdier 5 – 50 milliarder NOK

*) Med globale kontraktorer menes store kontraktorer som opererer globalt (europeiske, asiatiske, amerikanske, etc)

Europeiske kontraktorer:
Typiske kontraktsverdier 1 – 3 milliarder NOK

Norske "riksentreprenører":
Typiske kontraktsverdier 0,5 – 2 milliarder NOK

MEF nivå:
Kontraktsverdier opp til ca 300 millioner NOK

Bør Jernbaneverket innta rollen som leverandør til entreprenøren?
Tradisjonelt ved Utførelsesentrepriser har Jernbaneverket selv stått ansvarlig for leveranse av arbeidstegninger til entreprenøren, samt endringer og opprettinger av disse ved behov underveis.
Ut i fra anleggets størrelse, kompleksitet og fokus på tidsplan, ser Jernbaneverket at det vil være gunstig å overlate ansvaret for denne delen av produksjonen til entreprenøren. Entreprenøren vil være den som er best egnet til å styre og koordinere denne leveransen. Entreprenøren gis derved også mulighet for å bidra med sin kompetanse og legge inn optimale løsninger tilpasset en hensiktsmessig produksjon.

3.3 Foreslått strategi

For underbygningsarbeidene for Follobanen foreslår Jernbaneverket å gå ut med tre store forespørsler. Kontraktsformen vil være Totalentrepriser med et nærmere avtalt nivå på og omfang av prosjektering. NTK07/NF2007 vil bli lagt til grunn som kontraktstandard.

Innføring Oslo S
Det vil allerede fra 2012 og gjennom hele 2013 bli gjennomført en del forberedende arbeider knyttet til dette området. Disse består av i alt 5 mindre entrepriser som omfatter riving, kabelomlegging, forberedende UB, forberedende JBT og tverrslag i berg. Vi foreslår her hovedsakelig tradisjonelle byggherrestyrte enhetsprisentrepriser for hvert av arbeidene, mens det for riving av bygg foreslås fastpris på riveobjektene. Kontraktene inngås separat

Arbeidene i punktene 1 t.o.m. 5 nedenfor vil bli innlemmet som arbeidspakker i én felles totalentreprisekontrakt, der arbeidenes karakter er "Civil Works". Arbeidene har forskjellige egenskaper og kontraktens oppgjørsformer vil være en blanding av fastpriser og enhetspriser avhengig av det enkelte avsnitts karakter og hvor det er riktig at risikoen plasseres.

1. Grunnarbeider i Klypen:
   Gjennom Klypen skal det rammes spunt. Denne skal enten stagforankres eller ha en innvendig avstivning og utgraving må foretas i en trinnvis prosess for å sikre stabiliteten i området. Det er 20 – 40 meter til fjell i dette området og massene består hovedsakelig av bløt leire, som stedvis er kvikk.

Videre er det i dette området muligheter for å støte på kulturminner fra Middelalderen.

2. Bygging av betongkulvert i Klypen:
   Arbeidene består i prosjektering og bygging av betongkulverten gjennom Klypen for både Follobanen og Østfoldbanen. Denne kulverten vil bli ca 600 meter lang og vil strekke seg fra portalen nord for Bispegata til fjellpåhugget i Ekebergåsen. Med unntak av partiet under sporområdet på Loenga, hvor arbeidene må gjennomføres i faser, vil byggingen av kulverten foregå i et "ryddet"område uten direkte grensesnitt mot jernbane i drift.

3. Ombygging og forlengelse av Østfoldbanekulvertene inne på Oslo S:
   Disse arbeidene omfatter ombygging og forlengelse av eksisterende kulverter inne på Oslo S. Grunnforholdene er utfordrende og følgelig også fundamenteringsmetode. Mye av arbeidet må utføres med spor i drift i nærheten av byggeplassen, som vil føre til oppstykket anleggsgjennomføring og mye nattarbeid.

4. Tunnel for inngående Østfoldbane og eventuelt del av Follobanens tunnel:
   Tunnelen går i fjell fra Sydhavna til Ekebergskråningen, hvor den kommer ut parallelt med tunnelen for Follobanen. Det ligger en del utfordringer i arbeidet, for eksempel omlegging av Alnaelven inne i fjellet og kryssing av Ekebergtunnelene. I tillegg har fjellet forkastningssoner og valg av sikring må bestemmes på stuff.

5. Kulvert under E18 ved Sydhavna:
   Arbeidet omfatter bygging av betongkulvert under E18 frem til fjellpåhugg for inngående Østfoldbane. Konstruksjonen er i seg selv forholdsvis tradisjonell, men gjennomføringen må pågå med tog i drift og med trafikk på E18, som også nødvendiggjør en provisorisk omlegging av veien.

<u>Tunnelen</u>
Tunnel planlegges med en ferdigstillelse i annen halvdel av 2019. Med utgangspunkt i at TBM er valgt som hoveddrivemetode for bygging av de to parallelle enkeltsporede tunnelene, er det planlagt gjennomføring av forberedende arbeider fra 2013. Formålet med disse er å klargjøre for montering og oppstart av TBM'ene. De forberedende arbeidene vil bestå av følgende entrepriser:

1. Krafttilførsel: Bygging av tunnelen ved bruk av TBM vil kreve betydelig krafttilførsel. En 40 MvA transformatorstasjon på Åsland er nødvendig for dette formål. For fremføring av nødvendig kraft, må det anlegges en ca 5,5 km lang kabeltrasé frem til Åsland.
2. Forberedende tunnelarbeider: Bygging av tre tverrslagstunneler á ca 1 km fra Åsland og inn til hovedtunneltraséen. Det planlegges utsendelse av tilbudsforespørsler på de forberedende tunnelarbeidene i løpet av andre kvartal 2013, med en planlagt kontraktsinngåelse tidlig i fjerde kvartal 2013.

Det legges opp til inngåelse av en kontrakt for driving av hovedtunnelen med fire TBM'er fra Åsland. Verdimessig vil dette bli en av de største enkeltkontrakter for et samferdselsprosjekt som noen gang er satt ut i Norge.

Foruten driving av de to tunnelløpene med TBM, to nordover og to sydover, skal det også bygges tverrforbindelser mellom disse for hver 500. meter. Tverrforbindelsene vil bli drevet konvensjonelt ved systematisk forinjeksjon og sprengning i h.h.t. «Den norske tunnelmetoden».

Det er forutsatt at partiet nærmest Oslo S, ca 2,5 – 3 km lengde skal drives konvensjonelt. Det er ikke besluttet om denne delen skal inngå i den store hovedkontrakten eller om den skal lyses ut som en egen entreprise. Jernbaneverket vil også vurdere om det totalt sett vil ligge nettogevinster i å kjøre TBM'ene helt til utløpet av Ekebergåsen ved Loenga.

Jernbaneverket har vurdert det som viktig å fatte en beslutning om drivemetode i god tid før prekvalifiseringsdokumentene sendes ut. Alternativet hadde vært å overlate valget til markedet, men en slik strategi ble forkastet av følgende årsaker:

1. Utarbeidelse av komplette forespørselspakker for begge drivemetodene vil betinge en vesentlig større ressursinnsats enn utarbeidelse av én presis og gjennomarbeidet forespørsel. Både utarbeidelse av forespørsler og evaluering i ettertid vil ta lenger tid dersom begge drivemetoder skal håndteres enn om konkurransen kun omfatter et alternativ.
2. Jernbaneverket er opptatt av å stå frem som en forutsigbar byggherre. Når det igangsettes en konkurranse om en så stor jobb, skal markedet vite hvilken drivemetode Jernbaneverket vil benytte. På denne måten mener Jernbaneverket at det legges til rette for en rasjonell ressursbruk hos entreprenørene, riktig alliansebygging og gode gjennomarbeidede tilbud, som er spisset mot den jobben som skal gjøres.

Det planlegges utsendelse av prekvalifiseringsdokumenter for den store tunnelentreprisen i løpet av første halvdel av 2013. Videre forutsettes det å sende ut tilbudsforespørslene for denne jobben i siste kvartal i 2013.

Ski stasjon
Underbygningsarbeidene som ligger til Ski stasjon omfatter foruten en fullstendig ombygging og utvidelse av stasjonen også bygging av ny Follobane, nye forbindelsesspor og omlegging av Østfoldbanen nord for Ski stasjon.

Det planlegges inngåelse av en totalentreprise for hovedarbeidene på denne strekningen.

Jernbanetekniske arbeider
For de jernbanetekniske entreprisene, eksklusive signalanlegg, er det vurdert som et alternativ å gå ut med én stor gjennomgående forespørsel som omfatter alle fag. En liknende modell er benyttet for leveranse og montering av de jernbanetekniske installasjonene i St.Gotthard-tunnelen som er under bygging i Sveits.
Alternativt kan arbeidene deles opp fagmessig i flere gjennomgående entrepriser.

For den innerste delen mot Oslo S hvor de ulike sporene kobles mot eksisterende sporgrupper, vurderes det å implementere de jernbanetekniske fagene i underbygningsentreprisen for Innføring Oslo S. Her vil utbyggingen foregå i faser, hvor jernbanetekniske installasjoner veksler med underbyginingsaktiviteter. For å redusere antall grensesnitt som skal følges opp av byggherren, vurderes det som hensiktsmessig at denne koordineringen overlates til entreprenøren.

En tilsvarende vurdering gjøres med hensyn til jernbanetekniske installasjoner for Ski-området.

3.4 Hvordan bør Jernbaneverket legge til rette for gjennomføring av en best mulig konkurranse?

Når Jernbaneverket går ut med tilbudsforespørsler på disse store kontraktspakkene, er det viktig å gi leverandørmarkedet forutsigbarhet med hensyn til gjennomføring. Dette er blant annet gjort ved at Jernbaneverket på forhånd har valgt drivemetode for bygging av tunnelen.

For å legge til rette for både nasjonal og internasjonal konkurranse, vil forespørslene for hovedjobbene bli utarbeidet på engelsk.

Jernbaneverket vil aktivt utøve kommunikasjon mot og med leverandørmarkedet i tiden frem mot utsendelse av tilbudsforespørsler. Viktige kommunikasjonskanaler vil være gjennomføring av en internasjonal leverandørdag, trykket informasjonsmateriell, deltakelse på arenaer hvor anleggsbransjen er samlet og gjennom prosjektets nettsider.

Jernbaneverket vil videre utføre en prekvalifisering av entreprenører i henhold til den foreslåtte kontraktstrategien.

3.5 Hva ønsker JBV å oppnå?

For Jernbaneverket er det en hovedmålsetning å inngå gode kontrakter som er tilpasset den jobben som skal utføres for bygging av Follobanen.
Gjennom kontraktene ønsker Jernbaneverket å utnytte den kompetansen som finnes i markedet til å utforme gode løsninger, både med hensyn på gjennomførbarhet og med hensyn på endelig produkt.

Jernbaneverket ønsker å få levert et kvalitetsmessig godt produkt i h.h.t. den spesifikasjonen som er lagt til grunn for kontrakten. En leveranse til riktig pris og ferdigstillelse til avtalt tid. Ved bruk av foreslått gjennomføringsmodell ved bygging av Follobanen, legges det til rette for en kompetanseutvikling innen bransjen både med hensyn til bruk av ulike kontraktsmodeller, sammensetning av kontraktspakker og bruk av TBM som drivemetode. For Jernbaneverket som byggherre og for den norske anleggsbransjen generelt er det viktig at mye av den kompetanseoppbyggingen som Follobanen nå kan initiere, blir igjen i Norge og blant norske aktører innen bransjen. Dette vil i et større perspektiv gi bedre konkurransekraft i forhold til senere store oppdrag både nasjonalt og internasjonalt. En slik utvikling er både byggherrer og bransjen tjent med.

SUCCESS FACTORS – IN RELATION TO SUCCESS IN A GLOBAL PROJECT

NORWEIGEN TUNNEL TECHNOLOGY

Suksess faktorer i relasjon til suksess vid globale prosjekt – Norsk tunnelteknologi

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SAMMENDRAG

Globalisering har bidratt til sterk innflytelse på ingeniører og anleggsbransjen i løpet av de siste årene. Bedrifter har søkt utenfor sitt eget land for å få prosjekter som kan bidra til en stor del globale prosjektgjennomføring. I globale prosjekter oppstår utfordringer som har påvirket både prosjektdeltagere og selve prosjektmålet. Det er flere faktorer som gjør det viktig med god innflytelse for å oppnå et vellykket prosjekt. Disse faktorer kan identifiseres som suksessfaktorer.

Den norske tunnel entreprenøren Leonard Nilsen & Sønner AS (LNS) implementerer i dag et stort prestisjeprosjekt i Hong Kong, Hong Kong Government's Harbour Area Treatment Scheme, (HATS). På grunn av sin nye globale etablering står LNS overfor ulike problemstillinger og utfordringer. Hensikten med denne forskningen er å utforske og avdekke suksessfaktorer som har en betydelig innvirkning på et globalt prosjekt basert på deres forhold til suksess. Resultatet fra denne forskning skal bidra til å hjelpe LNS og andre bedrifter på vei til å forstå betydningen og viktigheten av suksessfaktorer, samt etablere et verdifullt omdømme i det globale tunnelmiljøet. Ved å innhente kunnskap om globale prosjekter er sannsynligheten større for å oppnå suksess.

Denne forskningen er identifisert som et globalt prosjekt, med suksessfaktorer som inngår i global berg og anleggsprosjekt fra et Norsk Tunnelteknologisk synspunkt. Basert på gjennomgang av eksisterende litteratur, er en kvalitativ forskningsdesign avledet. Data er innsamlet ved semi strukturert intervjuer og diskusjon i fokusgrupper med deltagere fra prosjektet. Fokusgruppene ble brukt til å bestemme løsninger, slik at suksessfaktorer i globale prosjekter ble identifisert. Funnene vurderes og diskuteres med litteraturen.

Forskingen viser at ledelse og kultur er to viktige suksessfaktorer i globale prosjekter. De to suksessfaktorene skyldes flere elementer, bla. god kommunikasjon, språk, virtuelle team, kulturell bevissthet, dokumentasjon, tillit, konflikt, kultur intelligens, emosjonell intelligens, rollebeskrivelse, funksjonsbeskrivelse, teambuilding og påvirkning fra myndigheter.

Resultatet av forskningen viser stor likhet med teori og tidligere forskning, samt at den avslører nye og detaljerte eksempler på elementer og utfordringer, avgrenset til de suksessfaktorene kultur, ledelse og dess relasjon til suksess.

Forskningen er i tillegg ikke komplett før disse ideene har blitt overlevert, og andre har arbeidet ut implikasjoner for sine egne omstendigheter, og bruker ideene til å veilede sine beslutninger og aktiviteter. Selskaper som er selvtilfreds og ikke fokuserer på kvalitet i disse to faktorer, (som er avgjørende for globale prosjekters suksess) har ikke samme evne til å konkurrere på det globale prosjektmarkedet. Sammen med, for å bygge og vedlikeholde et respektabelt rykte eller ikke har samme evne til å heve flere lignende oppdrag i framtiden.

SUMMARY

Globalisation has had a significant influence on the engineering and construction industry during recent years. Businesses have looked further outside their own countries for possible projects, which has contributed to a large amount of global project implementation. In global projects multiple boundaries arise, which present considerable issues for the project's participants as well for achieving the project's objectives. There are several factors that make a significant impact on whether the project will be successful. These factors can be identified as success factors.

The Norwegian tunnel contractor Leonard Nilsen & Sønner AS (LNS) is presently undertaking prestigious tunnelling project in Hong Kong. Due to their new global establishment LNS faces different issues as well as challenges. The purpose of this research is to explore and uncover the success factors that make a significant impact on a global project based on their relation to success. The result of this research will contribute to aiding LNS understand the meaning and importance of success factors, as well as establishing a valuable reputation in the global tunnelling environment. By obtaining this knowledge the HATS project objectives are more likely to be achieved.

Based on a review of existing literature, a qualitative research design is derived has this research identified global project success factors included in global tunnelling and construction project, from a Norwegian Tunnel Technology point of view. Data collected from semi structured interviews and a focus group identify that management and culture are two important success factors in global projects. The focus group was used to determine solutions for these factors in global projects. The findings are evaluated and discussed along with the literature. The two success factors are due to additional elements such as good communication, language, virtual teams, cultural awareness, documentation, trust, conflict, influence by the authority, cultural intelligence, emotional intelligence, role description, functional description and teambuilding.

The results of this research bear a great likeness to earlier research and theory, as well as revealing new and detailed examples of elements and challenges bound to the two success factors of culture and management. In addition, the researcher's job is not complete until these ideas have been passed on to others who have to work out the implications with respect to their own circumstances, and use the ideas to guide their decisions and activities. Companies that are complacent and do not focus on excellence in these two factors, which are crucial to global project success, do not have the same ability to compete in the global project market. As well as to build and maintain the company's reputation, and to acquire assignments in the future.

18. 1 INTRODUCTION

Globalisation is an extremely complex phenomenon (Currie, 2000; Gray, 2000; Held and McGrew, 2003) which has contributed to a remarkable influence in the world during recent years. Businesses have looked outside their own countries for possible projects, with different results. All businesses are facing the development of global competition, and adaptation to a globalising society is one of the most important issues for most organisations (Newell et al., 2001). Globalisation represents a significant shift in the spatial reach of social relations and organisation towards an interregional or international scale (Held and McGrew, 2003). Mahalingham and Levitt (2007) and Turner (2009) consider the most important aspect to succeed in a global project is that you must apply a common success factor together with the other participants/stakeholders to achieve a common understanding of the project goal. Project managers, participants, sponsors, contractors and system analysts all have a specific definition of "project success". Consequently, the definition of success often changes from project to project (Parfitt and Sanvido, 1993). Each project has a set of goals to accomplish, and they serve as a standard with which to measure performance.

Traditionally, a project is considered successful if the project is delivered at the right time, cost and quality (Baker et al., 1998; Ballantine et al., 1996; Chan et al., 2002; deWit, 1988; McCoy, 1987; Morris and Hough, 1987; Pinto and Slevin, 1988; Binder, 2007; Saarinen and Hoble, 1990; Turner, 1999; Wateridge, 1998), but not exclusively. It is not difficult to understand the meaning of meeting these goals. However in practice it is difficult to meet these goals. Furthermore, many of the major issues and problems concerning project management in practice can detract from the main objectives of the project (Clarke, 1995). While success is measured in terms of goal attainment, there is ambiguity in determining whether a project is a success or failure (Chan et al., 2002). Indeed, criteria are needed to compare the goal level against the performance level, and success in attaining project goals and participants' satisfaction (Aaltonen et al., 2008). Success has always been the unlimited goal of every activity. Due to the ambiguous definition of project success and the different perceptions of participants towards this concept, it may be difficult to tell whether a project is successful as there is a lack of consensus (Chan et al., 2002).

But why is it so important to understand the meaning of a successful project? According to Jugdev and Müller (2005), "a diversified understanding of success is necessary for both project manager and executive". Project managers must answer the question "How is your project doing?" To do that, they are constantly trying to define and manage project success in both a subjective and objective way. A basic understanding of the concepts and issues related to success is therefore essential for project managers. According to Rolstadås (2008), the best way to determine whether or not a project is successful is to utilise the parameter success criteria. In contrast, the parameter success factor is utilised to measure the project during the project's implementation, as well as to put in place those relations necessary for obtaining a successful project. However, this definition is utilised and there is no motive to not study and define the factors that lead a project to success. We can probably learn the most from projects that end up being unsuccessful (Rolstadås, 2008).

This research identifies global project success factors included in a global tunnelling and construction project, from the point of view of Norwegian Tunnel Technology. The aim is to explore and uncover those factors that make a significant impact on the global project in relation to success. What difficulties does a global project face? And why do these problems occur? This master thesis represents the first attempt to conduct a structured semi open interview investigation into which success factors have an effect on a global tunnelling and construction project's success when considered jointly. The semi open interview is carried out in relation to the global project HATS in Hong Kong, a joint venture (JV) project between LNS and Leighton Asia.

The results are developed to contribute to support LNS and other global projects in understanding the factors that affect global projects. By managing that knowledge, the HATS project's objectives are more likely to be achieved. Conducting projects in different countries, with their unique legal and political environments, security issues, economic factors, and infrastructure limitations and requirements, increases the complexity far beyond that of projects executed in domestic settings (Freeman and Katz, 2007).

18.2 SHORT DESCRIPTION OF THE CASE

During the last few years and after the financial crisis of 2009, there has been a significant reduction in tunnelling project accomplished in Norway. For this very reason the Norwegian Tunnelling Network (NTN) was established in 2009 by the Norwegian Tunnelling Society, (NFF). The members of NTN are companies and individual workers of the Norwegian tunnel contractors and tunnelling systems. The purpose of the network is to accomplish global opportunities for Norwegian tunnelling contractors. Since the network started, there has been a lot of hard work to place "Norwegian tunnelling technology" on the world map.

In recent years, LNS is the only Norwegian tunnel contractor that has developed a global reputation. The company is presently carrying out a global project in Hong Kong, named the Hong Kong Government's Harbour Area Treatment Scheme (HATS). HATS is an environmental and sewer treatment project in world-class and the client is the Hong Kong Service Department. The project is a JV project with Leighton Asia. Due to its global establishment, LNS is now completing a global project that sets them new issues and challenges.

18.3 GLOBALISATION AND GLOBAL PROJECTS

Globalisation has contributed to a significant influence on the engineering and construction industry during recent years. The opening up of markets and the injection of a certain amount of transparency into the functioning of the political machinery of developing nation-states has led to an increase in overseas investment (Freidman, 2000). Businesses have searched further outside their own countries for possible projects, with different results. Conducting global, international, and cross-cultural business is a mundane reality for most contemporary large organisations (Alon and Higgins, 2005). Orr et al. (2011) defines a global project as a temporary endeavour where multiple actors seek to optimise outcomes by combining the resources of multiple sites, organisations, cultures, and geographies through a combination of contractual, hierarchical, and network-based modes of organisation. Researchers over the last few decades have predominantly focused on increasing the understanding of the impact involved when implementing global projects. Ainamo et al. (2010) call a project "global" when it involves key participants that represent national systems separated by great geographical distance and potentially significant cultural and institutional distances. Global projects involve the collaboration of multiple countries that seems to result in unique tasks that are not confronted on intra-national projects. Kerzner (1995) states that companies and organisations that have succeed in implementing global projects place more attention on the fact that global project are more complex and have different and more demanding challenges. Blair (1998) asserts that globalisation is a fact, and how to stop it should not be an issue or discussion. Moreover, he claims that "the issues are how we use the power of community to combine it with justice" and "the alternative to globalization is isolation". Researchers like Orr and Scott (2008), Mahalingham and Levitt (2007), Horii et al. (2005), and Jarvenpaa and Leidner (1999) have established with their research that it was participants from different national background with dissimilar kinds of critical differences that caused conflicts and misunderstanding that resulted in a tremendous impact on the schedule, cost and quality of a project. Large-scale infrastructure projects involving participants and stakeholders from multiple countries are being undertaken in many parts of the developing world (Mahalingham et al., 2005).

…" Managing international business means handling both national and organizational cultural differences at the same time. Organizational culture is somewhat manageable while national cultures are given facts for management; common organizational cultures across borders are what keep multinationals together" (Hofstedeand Hofstede, 2005).

……… a global project is defined as a transnational project, a temporary endeavour with a project team made up of individuals from different countries; working in different cultures, business units, and functions; and possessing specialized knowledge for solving a common strategic task (Adenfelt and Lagerström, 2006).

According to Mahalingham and Levitt (2007) there are seven different dimensions that make projects in global environment more interesting than intra-national projects. They first divide the dimensions into two groups, physical distance and mental distance. The physical distance challenges are identified as aspects of the geographic and time zones. The mental distance challenges are the aspects of language, emotions, culture, norms and rules. Furthermore, they describes that other challenges that can be faced in global projects are interaction and coordination – the complexity, competence and difference in experience. In addition there is a larger amount of conflict handling arising due to the different backgroundsof the participants collaborating in the project, with respect to their different cultural norms, different working methods and different values.

18.4 SUCCESS FACTORS AND SUCCESS CRITERIA

There is a great deal of interest connected to factors leading to project success and how success can be evaluated or measured (Rolstadås, 2008). Success is an interesting word and has a wide range of definitions. Unfortunately there is no universal recipe for project success (Rolstadås, 2008). The word success suggests different things to different people and is very contextdependent (Jugdev and Müller, 2005). The definition of success often changes from project to project (Parfitt and Sanvido, 1993). An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, and a human resources manager in terms of employee satisfaction. Chief executive officers rate their success on the stock market (Freeman and Beale, 1992). Each projects' participants will have his or her own view of success (Chan et al., 2002). Therefore, the project is only a success when the criteria have been achieved for all parties involved in the project. If none of the criteria has been met, we have an unsuccessful project (Rolstadås, 2008).

But why is it so important to understand the meaning of project success? According to Jugdev and Müller (2005), “a diversified understanding of success is necessary for both project manager and executive”. Project managers must answer the question, “How is your project doing?” To do that, they are constantly trying to define and manage project success in both a subjective and an objective way. A basic understanding of the concept and issues related to success is therefore essential for project managers”.

To determine whether or not a project is successful the parameter success criteria are often utilised. In contrast, the parameter success factor is utilised to measure the project during the project implementation, as well as to put in place those relations to obtain a successful project. The list of factors leading to success is thus dynamic and tends to change during the project life time and varies between different projects (Rolstadås, 2008)..

Traditionally, a project is considered successful if the project is delivered at the right time, cost and quality (Baker et al., 1998; Ballantine et al., 1996; Chan et al., 2002; de Wit, 1988; McCoy, 1987; Morris and Hough, 1987; Pinto and Slevin,1988; Rolstadås,2008; Saarinen, 1990; Turner, 1999; Wateridge, 1998), but not exclusively. It is not difficult to understand the meaning to meet these goals. However it is difficult in practice to meet these goals. Furthermore, many of the major issues and problems concerning project management in practice can detract from the main objectives of the project (Clarke, 1995). While success is measured in terms of goal attainment, there is ambiguity in determining whether a project is a success or failure (Chan et al., 2002).

Successful project should be viewed from the different perspectives of the individuals and goals related to a variety of elements, including technical, financial, education, social and professional issues (Parfitt and Sanvido, 1993; Lim and Mohamed, 1999; Shenhar et al., 1997). They take the concept even further, by stating that the project shall be viewed in a broader sense, more holistically, than just cost, time and performance goals. The result in a project shall be clearly articulated prior to the project’s launch, because the project has a defined result to obtain. Obviously, project outcomes must please the customer, but they should also bring value to the organisation (Shenhar et al.,1997). However, it is very hard to achieve organisational success if the personnel are not motivated and qualified. Hubbard (1990) highlighted that social issues have the greatest impact on project failure. This means that it very important to select the right kind of people in the project group as well as having a well-trained project leader that can create effective teams. According to Belassi and Tukel (1996), Belout (1998), Belout and Gauvreau (2004), Clarke (1995), Pinto and Prescott (1988), Slevin and Pinto (1986), and Tsui (1987) project management the most important success factor for obtaining a successful project.

A global virtual team is defined by three dimensions: (1) no common past or future, (2) culturally diverse and geographically dispersed, and (3) communicating electronically (Jarvenpaa and Leidner, 1999). Advantages of employing virtual teams are flexibility, responsiveness, lower costs, and better utilisation of resources that are necessary to meet everchanging requirements in highly turbulent and dynamic global business environments (Mowshowitz, 1997; Snow et al., 1996). Perhaps the growing importance of virtual teams can best be summarised by Hargrove (1998), who states that “in the future, the source of human achievement will not be extraordinary individuals, but extraordinary combinations of people”.

Conducting projects in different countries, with their unique legal and political environment, security issues, economic factors, and infrastructure limitations and requirements, increases complexity far beyond that of projects executed in domestic settings (Freeman and Katz, 2007). The challenges a project leader at any level faces when leading across cultures are significant. In addition to altering behaviours to accommodate the different expectations of leaders, he or she must recognise and adapt to differences in decision-making and work styles, adjust to differences in influence and negotiation rules/tactics, and deal with the communication challenges that accompany language differences and separation by distance and time zones (Freeman and Katz, 2007). Moreover, they also describe that project success on international projects can mainly be determined from three factors: a) selecting the right projects, b) selecting the right partners, and c) providing effective project leadership. The leadership challenges in a global project and additional risks are the geographic distance, language barriers and cross-cultural gaps.

Hofstede and Hofstede (2005) explains that knowledge of the cultural factor in global projects is the most fundamental factor to manage in order to obtain success. According to Ward (1990), "there will normally be a mixture of tactical and strategic critical success factors. If they are all strategic, the business might founder in the short term while everybody concentrates on the blue skies ahead. Equally, if all critical success factors are tactical, the business might burn out like a super-nova".

Jugdev and Müller (2005) will be used to summarise this chapter, " A project is about managing expectations, and expectations have to do with perceptions on success". Moreover, they describe that," a project manager may find that they are more effective at managing a project when they avoid using single-point indicators of project success and ensure that their project indicators include both efficiency and effectiveness measures over the span of the project/product life cycle… Remain mindful that success measures change over the project and product life cycle and that some of the indictors used at the initial project phases may not be the ones assessed at the closeout phase".

18.5 FINDINGS FROM THE INTERVIEWS

This research has identified two major success factors in global tunnelling and construction projects from a Norwegian Tunnelling Technology point of view. Data collected from semi structured interviews and from focus groups identified that management and culture are two important success factors which have shown importance in relation to success in global projects.

The research has also identified several elements that further describe the two specific success factors, a) language, b) trust, c) conflict, d) documentation, e) communication, f) virtual team, g) cultural awareness, h) influences from the authority, i) culture intelligence, j) emotional intelligence, k) role description, l) function description, m) teambuilding and n) communication.

Virtual team

The result from the interviews describe the following challenges in virtual teams; a) continues communication, b) learn their roles, c) culture, d) team building activates, e) set clear team goals, f) risks, g) build team cohesiveness h) trust and f) different management skills

Team building

Teambuilding is describe from the interviews as: a) increasing the sense of ownership satisfaction and increasing motivation, b) good teambuilding contributes to a more efficient project, c) improving communication in the project organisation, d) understanding the different levels of knowledge in the project organisation, e) reducing the level of conflict, f) reducing the cultural barrier and increasing cultural awareness between the project participants, g) increasing the trust between project participants, and h) holding key people in key positions.

Trust

The aspects that trust affect in a global project is identified from the interviews as: a) increasing the effectiveness of the task in the project, b) a fundamental need when working together, c) providing better communication, d) is crucial for daring to establish and implement the project or work abroad, e) takes a lot of time and much energy, and f) is difficult to develop with different cultural backgrounds

Global project managers skills

The interviews reveal the following leadership skills or personality qualities: a) humble, b) pragmatic, c) patient, d) adaptation talented, e) emotionally intelligent, f) culturally intelligent, g) good listener, f) great technical knowledge, g) good at teambuilding, h) shows great respect, i) not arrogant, j) good at communication, and f) motivational.

Determining success in a global project

The results from the focus group reveal that a global project can mainly be determined as successful with four factors: a) selecting the right project with the right technical solution, b) having the opportunity to select and have right people at right place during the project implementation with the right partners, c) selection of the right project leader, and d) delivering the project at the right time and right cost with no injuries.

Culture differences – behavioural policy

Following the recommendation to implement a behavioural policy regarding cultural differences was it best: a) in an early stage of the project to gather the team and discuss important factors, b) compile an action plan, and c) work with the action plan in the project and regularly evaluate the action plan.

Conflict

Those situations that were identified from the interviews and were described to have an impact on conflict were: a) cultural differences, b) being afraid of losing face, c) ignorance of tunnelling, d) that day-to-day problems were resolved higher up in the system, and e) salary differences. The solutions addressed to reduce the level of conflict identified in this study were to: a) establish detailed role descriptions and functions, a description for each and every project participant, b) demonstrate good respect to other project participants, and c) build and establish trust.

Cultural Intelligence

The results from the interviews identified cultural intelligence as hidden parts that are not obvious in a culture. The hidden parts are described in the interview as: a) beliefs, b) assumptions, c) attitudes, d) values, and e) expectations.

Emotional intelligence

When it comes to emotional intelligence, the respondents described emotional intelligence as follows: a) shows great empathy towards the other project member, b) has the ability to communicate at all levels of a project organisation, c) motivates the project members and makes each of them feel valuable, d) feels the mood, leans back and allows himself to take the time to really listen, e) even if there is no solution to the problem, you leave feeling optimistic and hopeful, f) has the ability to look at a problem and calmly find a solution, and g) has the ability to describe technical solutions so that everyone can understand.

Selection of a global project manager and suggestions for educating a global project manager

The conclusion from the workshop regarding the selection of a global project leader was the following. If you show good project management skills in your home country and show a great interest in participating in a global project you should have the opportunity for education. The education should be in the area of success factors and challenges involved, as well as work alongside and be an assistant for a well-establish, well-experienced and knowledgeable global project manager.

18.6 CONCLUSIONS

This research identifies global project success factors included in a global tunnelling and construction project, from a Norwegian Tunnel Technology point of view. In global projects multiple boundaries arise, which present substantial challenges and issues for all participants involved in the project. This master thesis represents the first attempt to conduct a structured semi open interviews investigation as to which success factor have an effect on a global tunnelling and construction project's success when considered jointly. Even the literature has its limitations regarding success factors in global projects. The findings of this empirical and literature based research confirmed that culture and management are two important success factors in relation to success in global projects. Culture as a success factor is due to additional elements like language, trust, documentation, communication, virtual team culture awareness and influence from authority. And management as a success factor is due to additional elements like cultural intelligence, emotional intelligence, role description, function description, teambuilding and communication. The result presumes that the diversified understanding of success is necessary for all project participants, when implementing a project.

The identification of success factors will help to adapt a well structure project implementation, where culture and management play a significant role. A holistic understanding of the concept of success factor and elements related to success is therefore essential for all project participants in a global project. The research highlights that it is important to establish several common success factors and to discuss these, including the relevant elements, together with the project goal, in order to achieve success in a global project. It is not difficult to understand that global project establishment can contributed to new issues and challenges affecting the aim to obtain project success. Note that his research invites companies in the global project market and they need to be very good at understanding the two success factors of management and culture. Companies that are complacent and do not focus on excellence in these two factors that are crucial to global project success do not have the same ability to compete in the global project market. As well as to build and maintain the company’s reputation, and to acquire assignments in the future.

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LARGE TBM PROJECTS IN SWITZERLAND – EXPERIENCE AND STATE OF THE ART

Part 2

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ABSTRACT: TBM tunnelling technique has improved significantly-over the last decades and is gaining continuous market presence. Switzerland has a lot of experience with large TBM projects. The various projects have taught us several lessons which led to a continuous development of TBMs. A risk based geotechnical design is highly recommended for a successful tunnel construction. The construction schedule depends a lot on the achievable penetration rate. The existing penetration prediction models (PPM) do not sufficiently reflect the failure mode, which is highly influenced by the stress condition at the tunnel face in combination with the rock mass structure.

INTRODUCTION

Switzerland has more than 40 years of experience in TBM tunnelling with large diameters, which are necessary for motorway and railway tunnels. Many tunnels have been successfully constructed under varying geological conditions with different types of TBMs. The technique has been constantly improved and is well-established in our days. A wide range of site conditions and clients requirements can be fulfilled using a TBM for tunnel excavation. In the first part, a historical overview of all large TBM projects in Switzerland is given, and the development of TBM tunnelling over the last decades is explained using a few representative examples. The second part goes more into the geotechnical design with some case studies. Since construction time is one of the most important issues, the penetration rates that can be achieved will be discussed.

LESSONS LEARNED FROM RECENT PROJECTS

Vereina Tunnel

The Vereina line (*Figure 1*), linking Klosters and Lavin, consists of the Zugwald tunnel (2.1 km) and the Vereina Tunnel (19.1 km). At both sides of the tunnel, loading points for passenger cars, vans and lorries have been set up. For operational reasons, the tunnel portal zones comprise two- and three-track sections, and a train intersection station is placed in the middle of the tunnel.

The hard-rock formation of lot 4a (Zugwald tunnel) and the 10.4 km long lot 4b (Vereina tunnel) were excavated using an open gripper machine (TBM) with a bored diameter of 7.64 m. The tunnel sections with less competent rock and soft ground were excavated using conventional methods like drill-and-blast (D&B).

The lining consists of shotcrete, reinforcing mesh, steel-ribs and carbon glass fibre injection bolts (single-shell lining concept). In addition, drains were installed in order to channel underground water from the vault to the invert drainage.

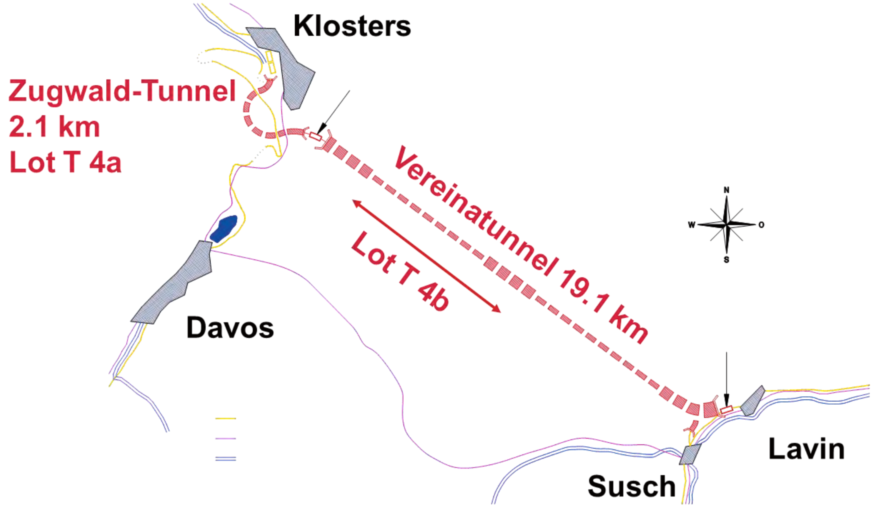


Figure 1 Project overview Veriena line

Geological Conditions

The TBM section of the Vereina tunnel runs through crystalline rock from the Dorfberg and Silvretta crystalline, which mostly comprises biotitic gneisses and plagioclase amphibolites. In long sections, the foliation is flatly bedded and the fissures show a narrow spacing.

Ground Behaviour – Risk Scenarios

Due to the expected geological conditions and an overburden of up to 1500 m, the following main geotechnical hazards were defined in the contract documents:

- Small falling stones
- Crown collapse
- Brittle failure, rock burst
- Plastic deformation
- Instability of the working face
- Water inflow

TBM Design

For both tunnels, the same tunnel boring machine was used. More unfavourable geological conditions were expected in the Vereina tunnel (more overburden and larger deformations) than in the Zugwald tunnel.

The TBM for the Vereina line was designed with the following properties:

- Bore diameter of 7.64 m
- 55 units of 19" disc cutters
- 6 units of 16" disc cutters
- 20'000 kN installed thrust force

For support measures, the following equipment was installed on the TBM:

Working zone L1* (directly behind the shield and between the two grippers)

- Two rock bolt drills (with a covering angle of 270º)
- Erector for the installation of steel ribs
- One drill for exploration drillings

Working zone L2* (backup area, 60 m behind the cutter head)

- Shotcrete robot (covering an angle of 360 º)
- Rock bolt drills

Case Study Vereina Tunnel – Crown Failure

The main geotechnical hazard observed in some sections excavated by TBM was the crown failure. The cave-in made increased supporting measures necessary and, in some cases, led to a jamming of the cutter head or the shield of the TBM.

After an analysis of this geotechnical hazard under the given conditions in the Vereina line, it can be summarised that there were two principal factors causing the crown failure.

The first factor is the given geology. As seen in section 0, the tunnel runs through some sections with a flatly bedded foliation and fissures, which are very narrow spaced. In addition, the anisotropic behaviour of the mineral leads to different tensile strengths of the rock (more strength parallel to the foliation than normal).

The second factor is the required thrust force in order to achieve high advance rates and to prevent a jamming of the shield or the cutter head due to squeezing ground conditions.

Open gripper machines are bracing against the tunnel wall by means of grippers in order to transfer the total thrust force into the rock. The force against the tunnel wall applied by the grippers can lead to an opening of the existing fissures. This phenomenon together with the given geological conditions (flatly bedded foliation and narrow spaced fissures) leads to a crown failure above the cutter head.

To prevent these cave-ins, a reduction of the force applied by the grippers, which means a reduction of the thrust force, penetration and advance rate, or a reduction of the hub may help. It can minimize cave-ins and the related risks like a jamming of the TBM.

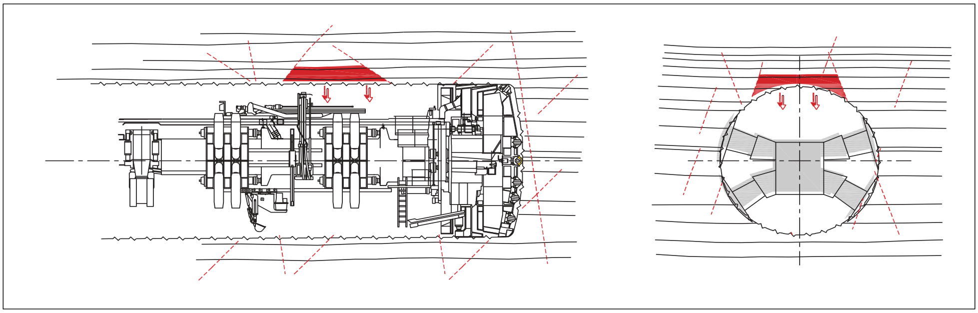


Figure 2 Crown failure at Vereina tunnel

Gotthard Base Tunnel – Faido Section

The Faido section of the Gotthard base tunnel (2 x 11 km single-track tunnel) was excavated using two open gripper tunnel boring machines (TBM) with a bored diameter of 9.4 m, respectively 9.5 m.

Geological Conditions

The Faido section passes through two major tectonic units, the Gotthard massif in the north and the Penninic gneiss zone in the south. Between these two zones lies the Piora Mulde (basin), which mainly consists of dolomite-anhydrite rocks. From the structural point of view, the Gotthard massif can be described as an alternating sequence of orthogneisses (metamorphosed intrusions) and paragneisses (metamorphosed sediments), dipping steeply W-E. According to the forecasts, the bedding properties of the Penninic gneiss zone change in the north in the complex folding of the Chiéra Synform. The steep bedding flattens in a southerly direction, becoming successively flatter southward. The Penninic gneiss zone is divided into the Lucomagno gneisses with high mica content and the Leventina gneisses containing little mica (*Figure 3*).

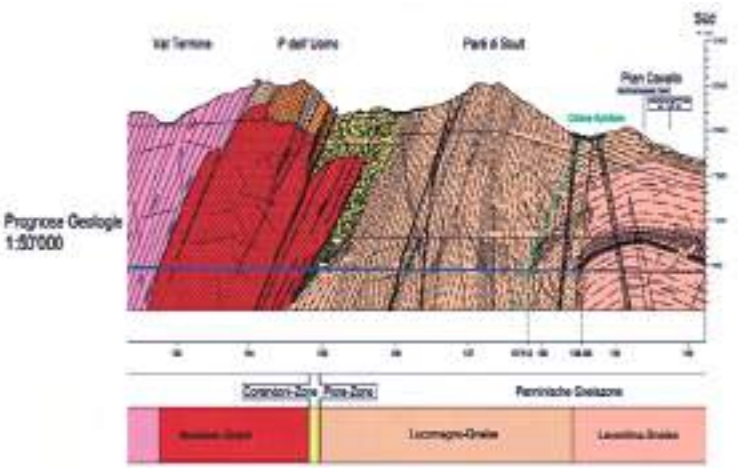


Figure 3 Geology Gotthard base tunnel - Faido section

Ground Behaviour - Risk Scenarios

Due to the expected geological conditions and the high overburden (up to 2500 m), geotechnical hazards like small falling stones, loosening, collapses, brittle failure, spalling, rock burst, plastic displacements, instability of the working face and water ingress were defined in the contract documents.

The following main hazards can be categorised for mechanical tunnelling:

- Jamming or blocking of the TBM including backup
- Failure of the temporary support
- Undersize profile as a result of deformation

TBM Design

In regards to the contract, the Faido section is combined with the Bodio section. After the two open TBMs had completed the Bodio section in 2006, they were refurbished in the assembly cavern at the Faido multifunction railway station (MFS) for further tunnelling towards Sedrun.

As had already been laid down in the construction contract for the Faido tunnel section, the intention was to increase the cutter head diameter from the Bodio section from 8.8 m to 9.3 m. Based on the experience with TBM tunnelling in the Bodio section and the excavation of the MFS Faido, where very squeezing conditions were encountered in places, and the fact that hydraulically extendable overcutters did not work on the Bodio section, it was decided to increase the bore diameter to 9.4 m. The geological conditions encountered at the TBM starting area were flatly bedded and relatively weak Lucomagno gneiss. The overburden at the beginning was 1500 m and increased to a maximum of 2500 m. It was decided to use shifted gauge cutters for an achievable bore diameter of 9.5 m. This was intended to create sufficient room for displacement and for support measures.

The two TBMs for the Faido section were designed with the following properties:

- Bore diameter of 9.4 m
- Extended bore diameter of 9.5 m (shifted gauge cutters)
- 66 unit of 17” disc cutters
- 27’000 kN total thrust force
- 5 m long cutter head shield

For support measures the following equipment was installed on the TBMs:

Working zone L1* (directly behind the shield)

- Shotcrete robot
- Two rock bolt drills (with a covering an angle of 270º)
- Erector for the installation of steel ribs and wire mesh
- Mobile drilling rig for the installation of rock bolts in the invert

Working zone L2* (backup area, 50 m behind the cutter head)

- Shotcrete robot (covering an angle of 360º)
- Two rock bolt drills

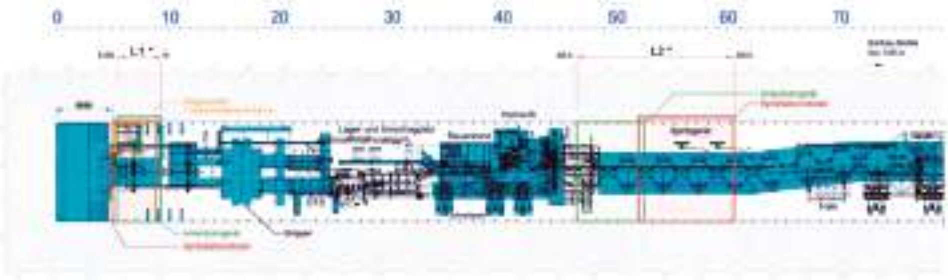


Figure 4 Longitudinal profile of the gripper TBM

Case Studies Faido – Interaction of Tunnel Tubes and Crown Collapse

Interaction between the Two Tubes – Failure of the Temporary Support and Large Deformations

The TBM in the east started on 7 July 2007. The machine in the west started tunnelling in October 2007.

The works in the eastern single-track running tunnel began with a relatively stiff support consisting of 25 cm shotcrete, steel ribs (TH profile), rock bolts and reinforcement mesh in working zone L1*. This temporary support suffered severe damage due to displacement after

only a few metres behind the face. The installed TH profiles deformed and the shotcrete failed in places. In order to reduce the danger of the shield jamming and with the aim of economising the support and achieving better advance rates, the first attempt to optimise the support was the installation of steel TH ribs with friction couplings in the working zone L1*. Depending on how the displacement progressed, the ribs were fixed by welding between zones L1* and L2*.
The application of shotcrete in working zone L1* was abandoned and the shotcrete first applied in L2*.

By applying this temporary support, the displacements increased markedly under more unfavourable geological conditions. The risk of the displacement exceeding limits during a possible machine stoppage increased and would have left insufficient space for intervention between zones L1* and L2*. The maximum settlement of the crown was 150 mm measured at the control cabin.

For the continuation of tunnelling, it was decided to use heavier, but more flexible support. The temporary support in working zone L1* consisted of sliding steel TH ribs (including friction couplings and brakes) and 10 to 15 cm shotcrete including displacement slots. The experience in the Faido section showed that the shotcrete hardened very rapidly under the prevailing conditions of 40 °C and more and humidity of up to 80% and, thus, lost elasticity.

The displacements also occurred very fast and the shotcrete could not absorb them. This often caused cracks and spalling in the shotcrete, which was prevented by the use of styrofoam inserts to form displacement slots. Because a styrofoam insert only provides very limited resistance, it can absorb displacement from all sides. This temporary support system ensured sufficiently high advance rates to avoid a jamming of the TBM shield.

In December 2007, cracks formed for the first time in the shotcrete arch of the tunnel running eastwards behind the backup parallel to the location of the western TBM (about 600 m behind the face of the eastern TBM). The 3D survey of the arch showed additional displacement. With the advance of the following west bore, there were failures of the temporary support over a length of some hundreds of metres in the east as well as the west bores. The maximum settlement of the crown in the east tunnel rose to 222 mm as a result of the concurrent driving of the west bore.

The loading had not only destroyed the arch, but also the in-situ concrete invert blocks, which were completely cracked in places and showed evidence of strong heave. The first aim was to enable the resumption of rail transport to enable the driving of the east bore to be resumed. The invert blocks were anchored back to avoid further heave and damage. The situation in the east bore was still worse, because the backup threatened to jam due to the displacements and the destruction of the temporary support. There was also massive damage in the invert. Various elements of the backup often had to be either removed or relocated to avoid jamming. In particularly critical areas, the shotcrete had to be hammered off and the ribs cut out, working in a very restricted space. Because of the severe damage to the invert, the outer lining of the invert had to be constructed again simultaneous to the continued advance, before the invert filling could be concreted again. A temporary filling to permit rails to be laid was ruled out for technical and economic reasons.

Under these difficult conditions, the advance rate of the west bore sank to a minimum of 1 m/working day, with an average of 3 to 5 m/working day over the section. In comparison to these figures, the best daily advance was 36 m and the average about 11 m.

DETAILED ANALYSIS

Because of the squeezing behaviour, a continuum model (FLAC 2D) was used for back calculations of the rock-mass behaviour and the displacement. The rock mass was assumed to be homogeneous and isotropic and simulated using the Mohr-Coulomb material criteria with and without softening. The softening of the rock mass was taken into consideration by lowering the shear strength parameter to the residual shear strength. The various calculation cases represented the effective construction procedure (leading and following TBM) and produced different ground reaction curves for the adjacent tunnel bores.

The convergence confinement method was then used to determine the rock pressure for each section and derive the required support (*Figure 5*).

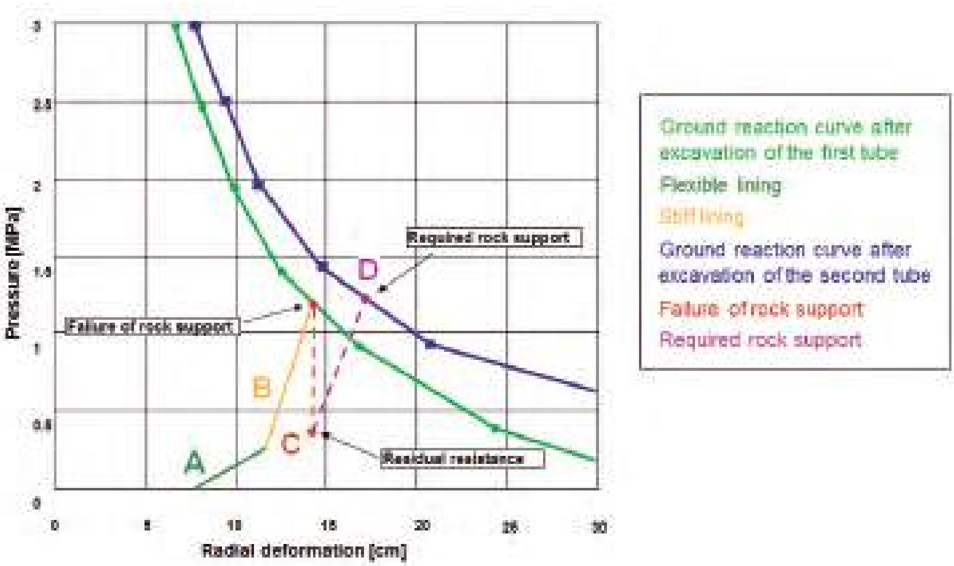


Figure 5 *Ground reaction curve and support characteristic curve*

The support characteristic curve consists of the following parts:

A. Initial displacement: excavation is unsupported; displacement phase: flexible support consisting of TH profile ribs, rock bolts and slotted shotcrete lining
B. Resistance phase: complete and strengthened shotcrete lining
C. Failure of the shotcrete lining, residual resistance from the existing bolting and ribs,
D. Required lining resistance.

As seen in Figure 5, with the excavation of the second tube, the needed support resistance increases (blue line). It was observed that the support resistance of the used system (green line) is lower than the needed resistance, which led to a failure of the primary lining.

INTERPRETATION

According to the forecasts, the Chiera Synform, where the Lucomagno gneiss changes from flat to steeply bedded, should have been encountered 700 m into the TBM drive. This transition was actually encountered 500 m further to the north. The flat bedding of the Lucomagno gneisses, which behave anisotropically, and their high mica content had an unfavourable effect. The extent of the damage to the temporary support was very localised to areas in the crown and also in the invert, but always parallel to the bedding. Figure 7 shows the various failure mechanisms and the resulting loading of the temporary support. The stress transfer in the flatly bedded Lucomagno gneiss can cause a softening and buckling of individual strata. It can also produce a shear loading at joint interfaces, which can lead to brittle failures along the plane of bedding or schistosity.

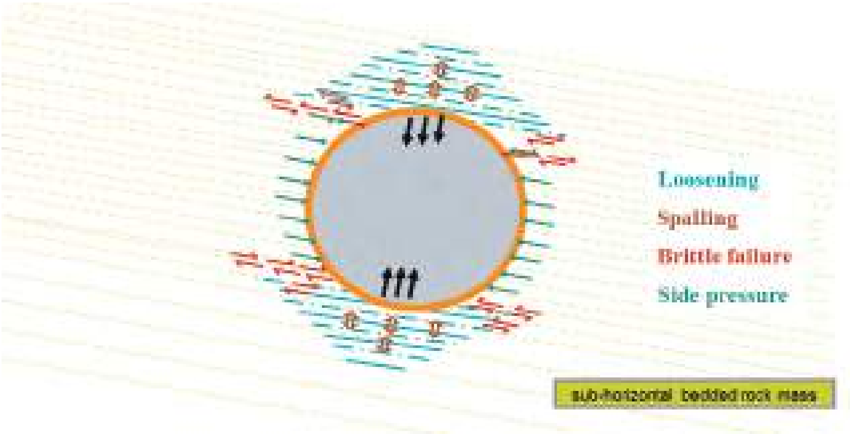


Figure 6 Failure types

The distance of the centrelines of the two tunnel bores is 40 m, which leaves a pillar of 30.5 m with an excavated diameter of 9.5 m. According to the design, the influence of one bore on the other at this spacing could be neglected for long sections, because such unfavourable rock properties were only to be expected over very short stretches.

The observations on site and also the results of the numerical modelling indicated their influence on each other in the section described. According to the calculation, the driving of the east bore causes an increased stress at the west bore of about 40% over the primary stress condition. This increased stress in combination with the low rock strength led to the large displacements and damage in the west bore and large-scale load transfer processes then set off the failure mechanism described above in the east bore. The back-calculation shows a stabilisation after excavation in the east tunnel.

Only after the west bore had been driven was there another increase of displacement in the east tunnel. According to the modelling, the overall displacements in the west tunnel exceeded those in the east, which also corresponded to the observations on site.

Crown collapse TBM West (Tkm 230.311) – Blocking of the TBM

On 4 March 2010, a crown collapse occurred in the west tube. Due to a 6 m long weak zone of kakiritic and cataclastic material the cutter head of the TBM was blocked and the advance works in the tunnel had to be stopped. In order to pursue with the advance works, four pipe umbrellas were installed and the space over the cutter head was filled with a layer of concrete (*Figure 7*).

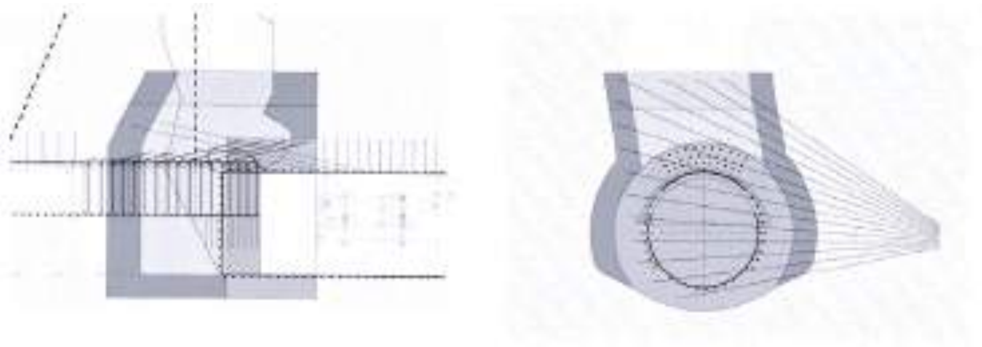


Figure 7 Crown collapse TBM west – first countermeasures

This first countermeasures were unsuccessful, so a new concept was formulated in order to release the TBM (*Figure 8*). The new concept comprised the following phases:

- Identification of the geometry of the collapsed zone with several boreholes
- Excavation of a niche from the east tunnel
- Gel grouting over the TBM in order to protect the cutter head from the cement grouting
- Cement grouting from the niche in order to stabilize the collapsed zone
- Excavation of an adit from the east Tube to the west Tube
- Backwards driving from the adit to the cutter head with conventional methods

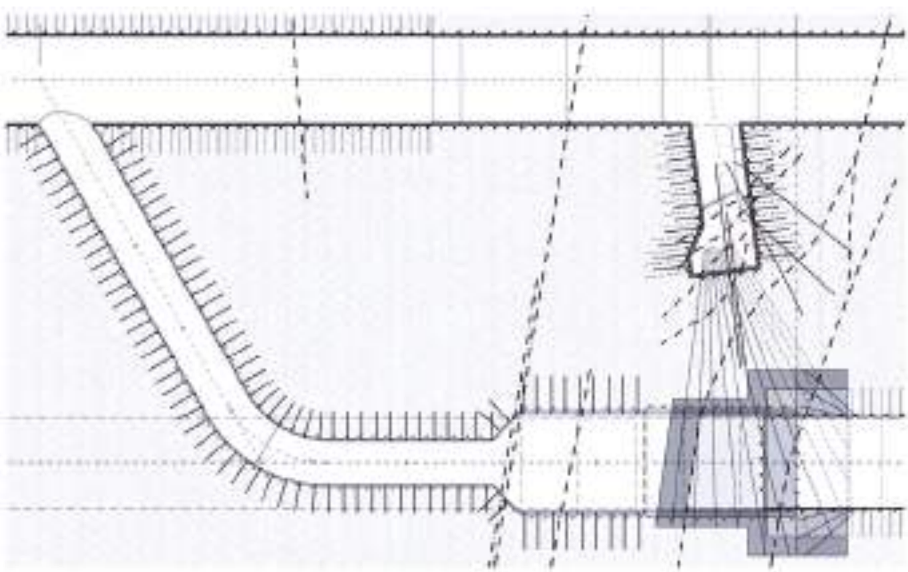


Figure 8 Crown collapse TBM west – grouting

The new countermeasures were successful and the TBM could be freed 20 weeks after the collapse in the crown.

Lessons Learned

The experience with TBMs shows that unexpected behaviour of the rock mass cannot be ruled out in spite of a detailed geological investigation concept and careful planning. A detailed risk analysis, including extensive investigation of the technical and economic risks, is required to determine the most suitable method of tunnelling. If the residual risks are still high, then it is advisable to include additional measures in the contract documents, like re-profiling, repairs or crosscuts (cross-passages) to allow for movement in the tunnel for logistical purposes.

The following TBM requirements for a successful drive through squeezing conditions can be derived from the experience gained in several projects in Switzerland:

- Largest possible overcut
- Robust shield and cutter head
- Shield with variable diameter
- Shortest possible shield
- Sufficiently large thrust force
- The capability of installing flexible support of the entire tunnel perimeter from directly behind the shield
- The capability of installing support simultaneously with tunnel driving

The requirements may seem self-evident, but will certainly create difficulties in their practical implementation. A design for the „worst case“ is certainly technically desirable, but cannot be implemented with economically justifiable means.

RISK-BASED GEOTECHNICAL DESIGN

Introduction

To conclude the actual lessons learnt, the remaining uncertainties for TBM tunnelling are related to the false prediction of a system behaviour of the TBM within expected or unexpected geological conditions as well as false prediction of penetration rate leading to prolongation of construction time and increased costs.

The geotechnical design is based on relevant geotechnical parameters like the geological model including stress distribution, orientation of the ground structure and ground water appearance. By taking into account the size and shape of the new building in this model, the rock mass behaviour can be determined.

Rock-mass behaviour describes the reaction of the rock mass in the course of the full-face excavation of the TBM considering orientation of fabric, groundwater conditions as well as the initial stress state. Considering the unsupported reaction of the rock mass allows for a categorisation of homogenisation zones distributed over the entire project perimeter. The hierarchical prediction of rock-mass behaviour based on a description of failure types (geotechnical hazards) provides a comprehensive method to quantify the unsupported rock mass behaviour in advance.

By introducing the TBM into the model, the system behaviour between rock mass and TBM can be evaluated. This system behaviour can be divided into the behaviour ahead of the TBM, the tunnel face, the shield and the support area. In all zones, the evaluated system behaviour has to satisfy the criteria defined beforehand.

Support measures and TBM specific features have to be adopted to meet the requirements for the predicted geological conditions. Additional measures for TBM tunnelling may be considered as standard measures for different construction sites and geological conditions depending on the probability of their occurrence. The importance of the detection of adverse conditions ahead as well as the specification of measures to be implemented and prior training of specific measures are essential for successful TBM tunnelling. The specification of active detection measures as probe drilling or measures like georadar and a constant review of TBM parameters in regard to the geological conditions shall be considered as an integrative part of the TBM excavation.

Parallel to the geotechnical design, a risk analysis should be carried out, which has to be improved permanently. After finishing the geotechnical design and the specifications of the TBM, the risk analysis has to be updated and the remaining risks have to be accepted by all parties.

Case Study Lago Bianco

The risk-based geotechnical design of Lago Bianco focuses on the operational aspects of TBM excavation in regard to expected rock-mass behaviour and required measures for continuous excavation. The Lago Bianco hydropower plant is situated in the southern part of the canton of Graubünden, in the Swiss Alps on the border to Italy. The hydropower scheme foresees the construction on an approximately 18 km long pressure tunnel with an external diameter of 6.9 m. The project area is located north of the periadriatic fault zone, within the crystalline Bernina, Sella and Margna Nappe. The alignment runs twice through the geological units due to the anticlinal structure of the geological units. Major fault and thrust zones are characteristic for the contact of the geological units. The mylonit and cataclastic rocks within these fault zones as well as water inflows of up to 250 l/s within fractured crystalline rock types will provide severe tunnelling conditions within local and distinct areas.

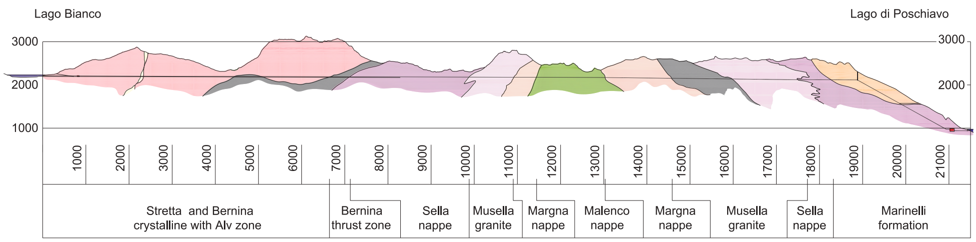


Figure 9 Geological profile of Lago Bianco

Due to logistical and geotechnical constraints for the operation of the pressure tunnel, three distinct zones with different lining and excavation techniques have been distinguished. TBM excavation will start at about chainage 1+000 m depending on logistical aspects and the occurrence of the Alv zone, a fault zone of a decomposed water saturated wacke. The intake gallery will be excavated by drill and blast. The final lining consist of an unreinforced concrete lining with a circular clearance profile. TBM excavation is foreseen with a DS TBM and a segmental lining with a thickness of 25 cm, which is considered as final lining and primary support of the rock mass. The thickness of the proposed trapezoidal segmental lining consists of 4 segments in total, where the roof segment acts as a key block. Stabilization of the ring is achieved by pea gravel, which is inserted shortly after ring completion. The last 5 km of the pressure tunnel are excavated by drill and blast with a counter-heading and lined by a pre-stressed concrete lining to cope with the high internal water pressure and the geological conditions.

Risk-based Rock Mass and System Behaviour of TBM Excavation

Rock mass behaviour in the course of TBM operation defines the support requirements and measures for standard excavation as well as the usage of additional and interventional measures to overcome geological adverse conditions. The main rock mass behaviour types expected for the TBM section of the Lago Bianco pressure tunnel are stable rock mass behaviour with low to high potential of gravitational overbreaks or sliding, shallow and local deep seated overstressing of the ground with deformations within the range of millimetres to centimetres and ravelling ground conditions in presence of disturbed or decomposed rock mass with the potential of high water inflow. Especially at the boundaries of the nappes, higher water ingresses with initial inflow rates of up to 150 l/s are expected as worst case scenario. Standard and additional to interventional measures are introduced subsequently.

In the following, three typical sections of the pressure tunnel Lago Bianco are discussed in regard to rock mass behaviour and the detection of rock mass behaviour. Required measures, detection and system behaviour for the TBM excavation are highlighted.

Homogeneous Zone A; chainage 1+090 to 6+820

The rock mass within the first part of the TBM excavation mainly consists of massive to blocky paragneisses and shists of the Stretta crystalline and orthogneisses of the Bernina crystalline.

Typical block volume distribution is within several dm^3 up to 1 m^3 The gneisses and shists are characterized by a distinct foliation plane with an orientation gentle dipping towards the tunnel axis at an acute angle of 10 to 30°. The overburden reaches up to 850 m. Stable rock mass behaviour is expected with a potential of medium to large gravitational overbreaks or block failure at the face especially due to lack of clamping stress. The influence of block failure at the face is leading to inhomogenous face conditions, with specific higher primary and secondary wear rates of cutters and the cutter head.

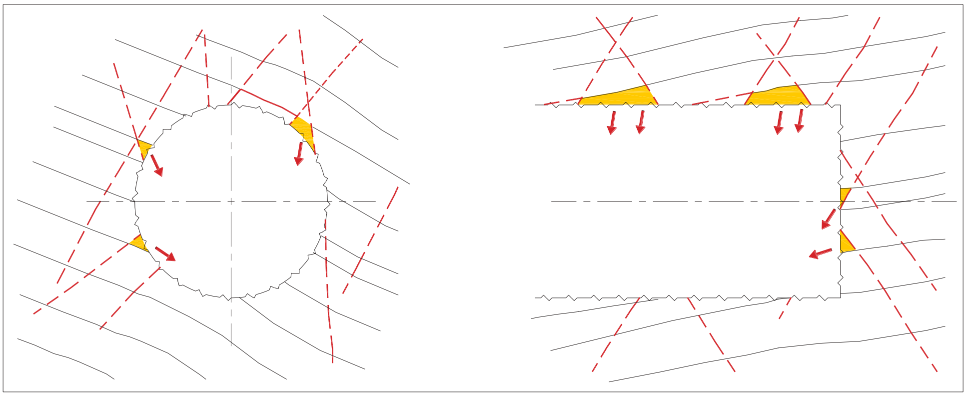


Figure 10 Block failure in competent rock mass

Homogeneous Zone B; chainage 6+820 bis 7+020

A tectonic melange zone with an approximate thickness of 200 m formed during alpine divides the orthogneisses of the Bernina crystalline to paragneisses of the socalled Marinelli formation. The shear zone is characterised by layered structure of weak sheared zone (recrystallised mylonites) embedded in clastic tectonised non-cohesive fault rocks.

The shear zone is dipping towards the excavation direction at an acute strike angle of 20° to 40°. The overburden is in the range of approximately 950 m, with expected stress-induced failure involving large ground volumes and large deformations as well as limited shear failure in the crown. Failure is expected with a self-stabilising effect and limited depth of overbreak.

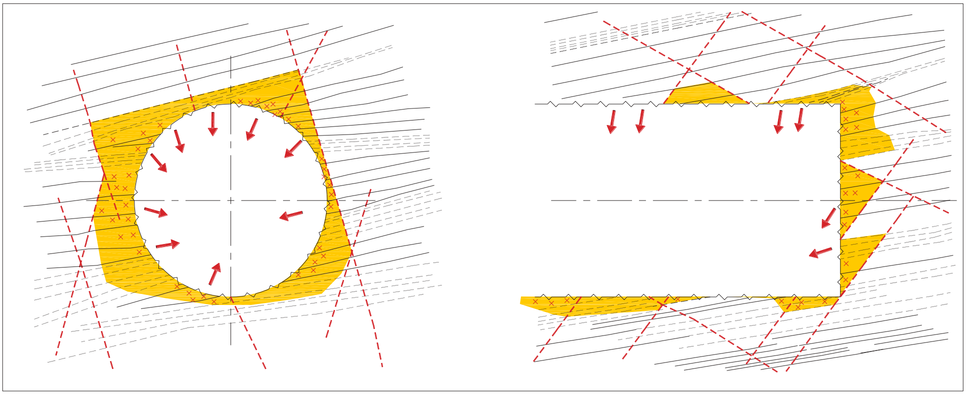


Figure 11 Fault zone at chainage 6'900, Bernina/Sella Nappe

The orientation of the shear zone highly influences the rock mass behaviour, with differential behaviour at the face and especially in the crown. Steeper oriented layers and layers with a defined spacing of the stiff layers provide a bridging effect limiting the depth of overbreak. For shallow orientation in combination with small spacing, a high risk of a jamming of the TBM is expected. Upon local water ingress, the material shows immediate degradation with the potential of limited flowing ground conditions.

The additional measures foreseen within this section will include a heavy-type segmental lining, pipe umbrella and drainage borehole. The investigation of geological conditions will include standard drilling campaigns with destructive drilling in the range of 5 to 10 times of the diameter of the TBM as well as core drilling with preventer in case water ingress is expected.

<u>Homogeneous Zone C ; chainage 14+760 to 16+050</u>

The rock mass of the shear zone is very similar to the thrust zone of the Sella Margna Nappe in the south. The acute orientation of the geological structure towards the tunnel alignment is leading to more unfavourable conditions than expected in the thrust zone of the Sella Margna nappe. The overburden within this range varies between 300 m and 500 m. The more chaotic structure of the non-cohesive fault zone with internal folding and shear planes is expected with deep-seated stress and shear-induced failure. Major water inflows of up to 210 l/s are expected within this zone, which leads to flowing ground conditions. Rock mass failure will induce a high load on the shield and the segmental lining posing a high risk of a jamming of the TBM.

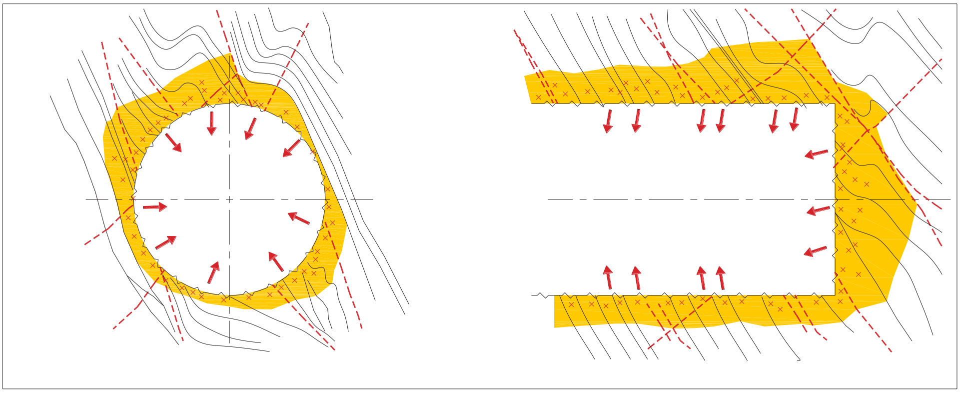


Figure 12 Fault zone at chainage 15'300, Margna/Sella Nappe

The severity of the fault zone especially due to the overall length of the zone and the lack of stabilising stiffer layers is much higher compared to the fault zone of homogeneous zone B. Beside the already described additional measures, continuous shield lubrication and shifting of gauge cutters of up to 10 cm is considered. Interventional measures including consolidation grouting of decomposed rock mass in front of the TBM and excavation of a bypass are considered within this section. Considering the risk of low utilisation of the TBM within this section, combined with the premises of a watertight lining within the subsequent section, a conventional excavation method was considered within this section. Other project requirements might ask for taking this risk and extend the TBM section.

The combined required measures can be divided into standard and additional measures.

Standard Measures:

The standard measures include the usage of normal and heavy-type segments for varying rock mass conditions. The thickness of the proposed trapezoidal segmental lining is 25 cm and consists of 4 segments in total, where the roof segment acts as a key block. Stabilisation of the ring is achieved by pea gravel and subsequent contact grouting measures of the annular gap.

Blocky rock mass conditions at the face demand for a flat cutter head design with sufficient excess length of at least 3-5 cm of the cutters protruding the cutter head. Anti-wear plates and wedges shall protect the cutters to minimise primary wear. The layout of the TBM, which complies with expected rock mass behaviour, includes drill lines at an acute angle of about 7°. Exploration drilling is considered as a part of the standard measures to investigate the geological conditions ahead.

Since the TBM part of the pressure tunnel has to be excavated from the intake area downwards to the pressure shaft, special attention has to be paid to the drainage system. As standard measure, a sink with a permanent pump has to be installed right after the cutter head. Along the tunnel, sinks are foreseen on a frequent basis.

Additional Measures:

The detection of unfavourable conditions ahead allows for an accurate implementation of additional measures for the TBM excavation.

Additional measures can be implemented within a short time upon the usage of preinstalled equipment or equipment on site on the TBM. The detection of adverse ground conditions ahead such as fault or weak zones is, in most cases, problematic and associated with uncertainty in the prognosis, which defines only a short period of time to implement the measures upon detection. The substantial success of the measures relies on the implementation within TBM excavation, short utilisation and handling by the tunnelling crew. The prior specified measures shall provide immediate support and stabilisation of the ground ahead. Measures include consolidation of haunch and roof at least 5 m ahead of the cutter head by pipe umbrella, the lubrication of the shield and active support of the ground by grouted glass fibre reinforced plastic anchors at the face.

Additional measures related to the topic of groundwater handling involve active pumping devices of up to 250l/s and dewatering grids along the muck channel. Successful pre-grouting measures demand for a minimal radial distance of about 1 m of the circumferential situated drill lines to guarantee full penetration in the desired action area of the TBM. Drill lines have to be situated as close as possible to the cutter head, preferably in the front shield. The handling of the drill equipment must allow for non-restricted movements to feed the drill lines.

Additional measures include the possibility of probe drillings, pipe umbrella for immediate stabilisation of the ground ahead of the cutter head, bentonite lubrication to reduce the friction between squeezing ground and the shield, drainage holes to relieve water pressure and segments with higher amount of reinforcement and a higher load capacity. Also special segments with tubes for drainage drillings are considered.

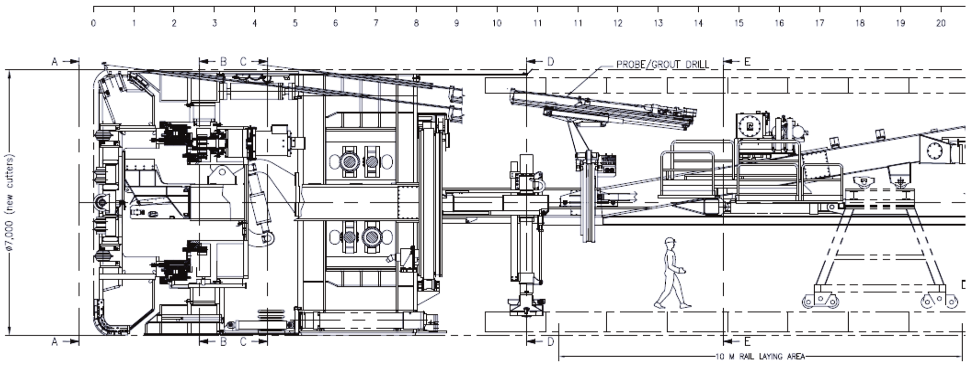


Figure 13 *Longitudinal profile of double-shield TBM with moveable drill rig*

<u>Interventional Measures:</u>

Interventional measures require either a longer utilisation and installation time at the site e.g. bypass operation (Wenner 2008) or specially skilled workmanship as grouting companies for pre-excavation grouting to consolidate, seal or stop water ingress.

The sum of varying rock mass behaviour types that are expected define the TBM specifications for standard, additional and interventional measures.

Uncertainties and Improvements Regarding the Prediction of Penetration Rate

The accurate assessment of penetration for TBM advance rates is a sensitive process towards the estimate of construction time. Leitner (Leitner 2005) describes the current available prediction models in detail and distinguishes three main categories. Despite the models based on a linear cutter test, the influence of rock mass is either considered by coefficients or by weighted factors in rock mass classification systems. Nevertheless, the prediction of penetration (advance) rates or wear of TBM is still associated with uncertainties since the variability of in-situ geological conditions strongly affects the performance of the TBM.

Common penetration prediction models as NTNU (Bruland 1998) and Gehring (Gehring 1995) rely on past empirical experiences gained from various projects. Due to the development and rapid usage of TBM in various ground conditions, current penetration predictions are not suitable to comply with actual demands. Recent results from Abrock research group showed a high influence of rock-failure processes and geological variability on penetration and wear. The geological and geotechnical influencing factors for various penetration predictions models are presented below (Wannenmacher 2012).

		PPM Gehring	PPM NTNU	PPM CSM	PPM Yagiz (based on CSM)	PPM Barton	PPM Alber	PPM Palmström	PPM Thuro	PPM Gong-Zhao (2008)
Intact Uniaxial Compressive strength	[MPa]	●	●	●	●		●	●		●
Destruction Work	[kJ/m³]	●							●	
Intact Tensile Strength	[MPa]			●	●					●
Quartz content (%)	[%]					●				
Porosity	[-]		●							
Uniaxial Compressive strength 1)	[MPa]						●			
RQD oriented along the tunnel axis	[-]					●	●			
Volumetric joint count (*jv*)	[-]									●
Number of joint sets	[-]					●	●			
Joint spacing of the main joint set	[-]	●	●		●					
Joint size (*jL*)	[-]							●		
Joint roughness number (*jR*)	[-]					●	●	●		
Joint alteration number (*jA*)	[-]					●	●	●		
Joint water reduction factor	[-]					●	●			
Joint orientation related to the tunnel axi:	[-]	●	●		●			●		●
Stress reduction factor	[-]					●				
Drilling Rate Index "DRI"	[-]		●					●		
Cutter life index (basis NTNU)	[-]					●				

1) *derived by RMR*

Recent experience from projects in Switzerland (Weh 2007, Weh 2012) showed a major influence of the stress state and anisotropy especially within massive rock mass types. Wannenmacher is studying as part of his dissertation the influence of fabric orientation and the potential of removable blocks on the penetration for jointed rock mass.

Assumptions for rock mass behaviour are basically driven by the assessment of acting stress within a rock mass, where else common PPMs are mainly based on available experience and neglect the very complex stress field acting at the face. Geotechnical conditions are not covered explicitly for the prediction of novel and more severe conditions for tunnels.

Effects of spalling within massive rock mass or effects of gravitational failure of blocks lead to a substantial decrease of a base penetration rate. Secondary effects such as clogging of the mucking buckets in the cutter head (see Figure 14) or cutter failure (see Figure 15) due to dynamic loads decrease the utilisation of a TBM.

Figure 14 Clogging of mucking buckets

Figure 15 Wear of cutter

Effects of block failure on pre-existing joints or spalling cannot be prevented at all. Countermeasures to react to these phenomena include the back-loading cutters compared to front-loading cutter systems. Wear plates and wedges actively reduce the enormous dynamic loads on the cutters due to blocky ground conditions.

Effects of anisotropy and block removability are governing the processes of primary and secondary chipping. High resolution laser scanning (Weh 2012) was performed to investigate the differential depth of cutter indentation within anisotropic massive rock mass types. Grooving of cutters, especially the depth of scarfs depends on the orientation of the fabric of the rock mass towards the rotational direction of the cutter.

The overall penetration is limited by the differences of the depth of penetration which induces a load for the cutters as well as the cutter head. The angle of the fabric towards the tunnel axis defines the maximum penetration, where normally situated orientation defines the maximum feasible penetration and parallel oriented fabric defines the minimum penetration rates (see Figure 17). As a matter of fact, the thrust must be reduced within these section, lowering the overall penetration.

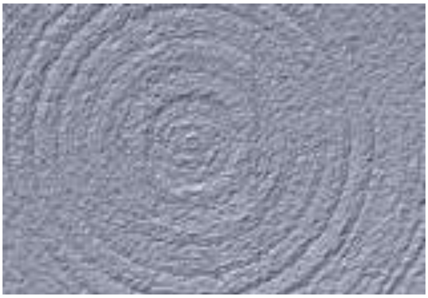


Figure 16 Penetration scan

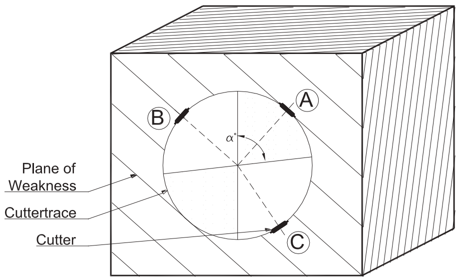


Figure 17 Joint orientation

Gehring (Gehring 1995), as opposed to the Colorado School of Mines (Ozdemir 1977, Frenzel 2011) estimates the cutter load with a linear relationship, which overestimates the cutter load especially for lower and not essentially uneconomical conditions. With a thrust cutter load higher than the 200 kN, the model is within the limits of predictions, considering further uncertainties of rock mass.

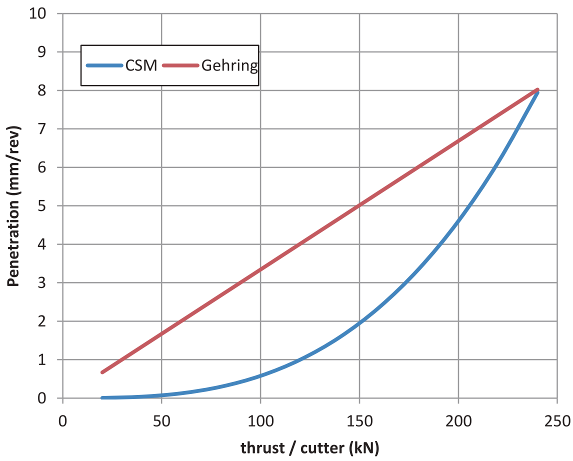


Figure 18 Comparison of CSM and Gehring (Weh 2012)

The majority of penetration prediction models include a scale-dependent correction factor for rock mass properties. Nevertheless, the effect of jointing and joint conditions on the cutting process is acknowledged in various ways.

Penetration prediction models based on rock mass classification systems often teem with input factors regardless of the applicability. These factors are hardly known in advance to full scale and either impede an overall application or form a wide-spread basis of penetration prediction.

Empirical systems, on the other hand, are developed from information collected during excavation and, therefore, highly rely on the quality and quantity of the information collected. The drawbacks of these systems arise from the improper description of rock classes. The spacing of the main discontinuity may be a good choice as input factor in rock mass which is hardly jointed at all but improper for the assessment of rock mass conditions in overall jointed masses with more than one discontinuity set. The effect of orientation within empirical systems as Gehring and NTNU is based on the orientation of the effective joint set. The overall relationship found within these models represent a very similar relationship with the highest influencing factor for jointed rock mass with an orientation of the effective joint set at an angle of about 60 to 90 . The drawback of these models is related to the limitation of only one joint set to be considered.

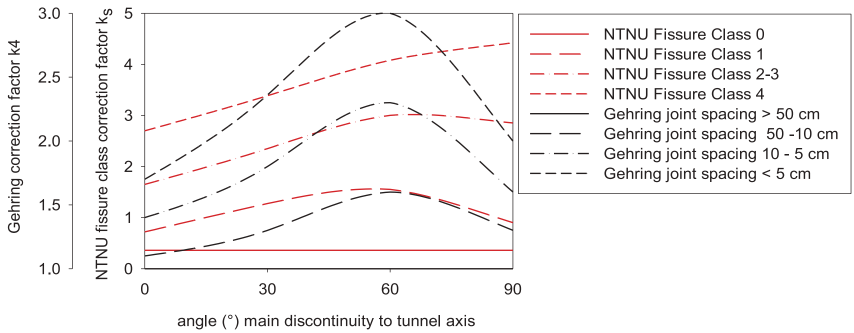
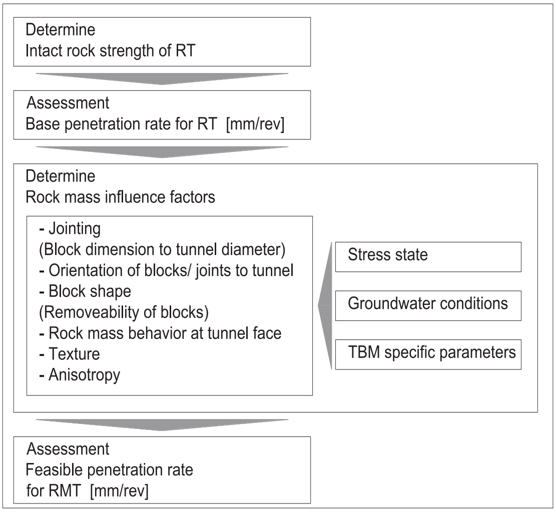


Figure 19 Comparison of joint spacing and joint orientation for the PPM of NTNU and Gehring

The assessment of a feasible penetration rate (Türtscher 2012) depends on various influencing factors as the intact rock strength for the assessment of the base penetration rate. The assessment of the damage of the sample, defined as the non-linearity of the stress-strain relationship within crack closure phase, is essential for the overall prediction of a base penetration rate. Rock mass influence factors either decrease or increase the base penetration rate and are superimposed by the stress state, groundwater conditions and TBM specific parameters. Considering the mentioned effects, the feasible penetration rate can be determined.



REMAINING RISKS OF TBM TUNNELLING

The high grade of mechanised TBM excavation and utilisation of additional measures allows for the usage of TBMs under various and even adverse ground conditions. The design of additional measures and interventional measures prior to excavation gains a high grade of importance, beside the fact of the design of standard measures which dominantly effect the achievable utilisation of the TBM.

The main risks for the TBM excavation are still related to the depth of the geological prognosis and expected rock mass behaviour. The effective design of additional and interventional measures highly depends on “in-time” detection of adverse geological conditions ahead. Sensitivity analyses should focus on impacts if adverse conditions remain undetected and specified measures are not effective.

Project relevant risks are still related to accurate prediction of the achievable penetration rate and the in-time implementation of required additional or interventional measures. The often time-consuming and cost-intensive risks and delays are in most cases associated with insufficient rock mass characterisation or rock mass behavior prediction, and, thus, an inadequate TBM design concept.

The assessment of reliable failure modes of rock mass at the face, the shielded section and support section is essential for the determination of an overall advance rate and subsequently for the project schedule. The description of failure modes based on descriptive analyses proofed to be an essential part for the geotechnical design.

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