News & Views

Excavation of Tunnel in Rock Containing High Pressure Gas

The 9.1 km long Nabetachi-yama tunnel singletrack railway is located in the central part of Honshu Island, Japan. The tunnel has attracted considerable attention since the ground surrounding the tunnel contains high pressured gas which is presumed to be the main cause of large deformations developed during excavation.

The tunnel is excavated about 150m below the surface. Geological conditions through the tunnel are very complex involving thick fault zones of highly expansive mudstone formed in the Pliocene Epoch of the Tertiary Period. The location of the tunnel is close to the major fault Fossa Magna. This fault, resulting from the contact of the Continental Plate and the Pacific Plate, strikes approximately perpendicular to the axis of Honshu Island.

The mudstone consists of alternating layers of thin tuff and tuffaceous sandstone. The composition of an individual layer of the mudstone varies widely from rock fragments scattered in weathered clay to flakey brittle rock. The undrained shear strength is reported to be 1 to 2 kgf/cm^2. The most peculiar property of the ground of Nabetachi-yama tunnel is a huge amount of convergence caused by high pressured gas trapped in the ground.

Through this note the authors briefly describe the construction process of Nabetachi-yama tunnel and offer a simple model to explain the mechanics of the huge expansion of the ground. The main conclusions are :

* The simple model proposed here is effective for simulating a rock mass containing gas under high pressure.

* The influence of the high pressure gas becomes especially dominant when the cohesion of the ground is small.

* Grouting is considered to be an effective countermeasure to reduce the deformation caused by the high pressure gas.

- *Excerpts from an article by Prof. Toshihisa Adachi, Takeshi Tamura & Norio Doi, School of Transportation Engineering, Kyoto University, Japan; ISRM News Journal, Vol 3 No.1, 1995.*

Shotcrete Repair of Infrastructure in North America : *Dams and Hydraulic Structures*

Numerous dams and hydraulic Structures have been repaired with shotcrete in North America. The earliest repairs were effected in 1954 using a conventional dry-mix shotcrete. More recent repairs have used steel-fibre reinforced dry-mix silica fume shotcrete. Recommendations are provided in Heere's report for the construction of durable shotcete repairs to dams.

In 1994, a major seismic retrofit was carried out on the Litterock Dam in southern California. This 58 m high and 220 m long multiple arch dam was seismically strengthened by application of a dowelled and anchored, steel-fibre reinforced, wet-mix, silica fume shotcrete. A total of 460 m^2 of shotcrete'a nominal 100 mm thick, was applied to the upstream face of this 70 year old multiple arch dam. The work was successfully completed on time and in budget, and in full conformance with a rigorous set of project specifications. At the completion of the project the steel fibre reinforced shotcrete was observed to be essentially crack-free, in spite of the work being completed in an exacting desert climate, where the ambient temperatures rose as high as 40° C during the day, and by the end of the project were falling below freezing at night. Rigorous control of moist curing both during shotcrete application and for seven days thereafter were an important part of crack control on this project.

Fibre-reinforced shotcrete has been used by the British Columbia Ministry of Transportation and Highways to stabilize creek beds and protect bridge piers and abutments which have been eroded by scour from flooding and debris flows in steep mountainous terrain. Large riprap boulders have been stacked and fibre-reinforced shotcrete applied (in lieu of slush grouting), to provide a "toughened" system to reduce the potential for damage from boulder impact, hydraulic uplift forces, and general scour and erosion. Both steel and polyolefin fibre reinforeced shotcretes have been successfully used in such work.

- Extract from an article by D.R. Morgan, Beton- Instandsetzung, 1997, pp21-37.

Time - the Forgotten Dimension

Time is obviously a very important factor in the deformation behavior of rock. Practitioners have taken time into account for many years, as for example, when measuring displacement rates in a slope and prescribing critical values. Such observations have been, and will continue to be, of major significance both in practice and in theory.

There have been numerous attempts in rock mechanics to account for time. Most of these invoke visco-elastic or visco-plastic models. It is true that, for years, this dimension has been handled both insufficiently and inadequately. Today the reasons for this are clear. Just as elasticity is insufficient and ideal plasticity inadequate to describe the instantaneous equilibrium and stability of rock masses, visco-elasticity is insufficient and visco-plasticity indadequate to follow the changes of equilibrium in time. We must take into account post-failure rock deformation if we wish to obtain a more complete and adequate description of rock blocks and the interfaces, (joints, bedding planes...) between them.

Such a description i.e., incorporating softening , was made possible when Dr. Neville Cook published his classical studies of the complete load-deformation behavior of rock in 1965. This breakthough has stimulated detailed study of equilibrium and stability for the past three decades. These have included the combined effects of elasticity and softening, both of the solid rock mass (blocks) and the surfaces of contact between them-but they have not taken account of the time factor.

I do not think that this was intellectual cowardice. It was reasonable to start from the simplest-although far from simple-case. It was necessary first to understand the "instantaneous" non-linear behavior of the rock and contact surfaces before moving into the even more difficult region where time is added to the interplay between elasticity and softening.

It should be noted also that these studies of dynamic instability without the time factor were necessary not only as a preliminary stage for the subsequent inclusion of time; they are absolutely neceessary to deal with the final stage of whatever deformation process it is that develops over time. Indeed, in following the deformation process in a rock mass by time steps we need to assess, at every stage, whether the current state is stable or whether it will lead to a dynamic jump, i.e., instability.

This control, as well as the determination of the development of such a jump, is obtained by consideration of an extension of the "instantaneous" (without the time factor) theroy.

Similarly, "instantaneous" computational methods are necessary to analyze the deformation of both the rock block and the discontinuities (contact surfaces) in the rock mass at each time step.

I do agree that the "instantaneous" stage of analysis has gone on too long. If we are to progress more rapidly we will need better concentration of efforts within countries, better international cooperation and better individual stimulus.

There is no problem in using constitutive equations which include creep or other time dependent factors (both in the rock volumes (blocks) and contact surfaces (interfaces between blocks)). For instance, one can combine softening with visco-elasticity or consider softening as a function of creep.

Even the first steps that have been taken in this direction during the last decade have revealed interesting new insights. These include (i) fracture acceleration in time; (ii) short time intervals; and (iii) critical velocities. These effects can be observed, for example, in the simple case of a single softening pillar in the center of an excavation within a visco-elastic rock mass. But the phenomena are of a general nature and can appear on very different scales-from micro-cracks to mine openings and even to the Earth's crust itself.

A variety of other conclusions of theoretical and practical significance can now be drawn when considering the interplay between elasticity, softening and creep. But one, which seems to be an important principle, deserves special attention. This concerns the time intervals between instabilites, i.e., between seismic events (of various magnitudes, down to micro-seismicity).

In solving a problem by time steps and fixing the instabilites, we are able to obtain information not only on a single dynamic (seismic) event, but we can determine the intervals between them and acquire information on multiple events. This introduces a new stage in rock mechanics i.e., combining seismicity with the mechanics of rock deformation. We are at a stage which seems to be extermely promising due to the ever growing potentials of geophysics and numerical simulation.

Obviously, when studying time intervals involved in instabilies, we are approaching the ultimate "sacramental" question "WHEN?" When will a micro-event, or rockburst, or earth-quake occur?

For deterministic situations we are close to being able to predict "When". But unfortunately, the geometry and physical properties of rock masses are not deterministic. They are stochastic or statistical in nature and also quite uncertain. This means that we must continue to seek better understanding, examine various scenarios and treat them probabilistically. Let us note, however, that our knowlege of the geometry and properties of rock masses is increasingly dependent on progress in geology and geophysics. So it is appropriate to repeat the question from another very valuable paper by Dr. van der Merwe: "Have the urgency and importance of locating faults and their properties been conveyed to our colleagues in the geological and geophyical worlds?"

- *Excerpts from the Letter to editor by Dr. Alexander M.Linkov, St. Petersburg, Russia (In response to Dr. van der Merwe's letter titled "Time is the conveniently ignored dimension") ISRM News Journal, Vol.2, No. 3&4, 1995, pp 58-59*

Lecture by Professor S. Sakurai - President of International Society for Rock Mechanics

Professor S. Sakurai delivered a lecture on *"Observational Methods in Tunnelling Practices"* on January 21, 1999 at the Department of Civil Engineering, University of Roorkee. He has over 20 years of experience in the area of *application of back analysis in tunnel construction and monitoring in Japan.*

Back analysis is an excellent tool to apply theory in practice. The basic concept of design of structures cannot be used in the tunnels because allowable stresses and strains are not known in rock masses. Thus, there is a lot of difference in prediction and actual observations in the tunnels. He emphasized that the presence of joints in the Rockmass needs special attention.

The allowable strain is easier to evaluate than allowable stresses in the rock masses. The allowable (shear / deviator) strain around tunnels may be taken equal to the critical strain. The critical strain is simply the ratio of uniaxial compressive strength (UCS) and modulus of elasticity of a rock material (the critical strain is inverse of modulus ratio).

Extensive experiments have confirmed that the critical strain in not much affected by the size of the samples of the rock mass. Whereas, both uniaxial compressive strength and modulus of deformation are affected drastically by the size of the sample of rock mass. It appears that the effect of joints cancel out. Infact anisotropy and orientation of joints are not found to influence the critical strain significantly. Temperature effects also cancel out within $\pm$ 30°C.

Therefore, practicing engineers should pay attention to laboratory tests on rocks and specifically in measurement of critical strain from UCS tests conducted at the room temperature. There is no cause for worry for practicing engineers if the observed (in-situ tangential) strain in the tunnels (= ratio of observed radial deflection in the crown and radius of the tunnel) is less than the critical strain. The critical strain gives the first hazard warning level. It is proved by problem-free construction of 50 tunnels in Japan. His famous chart betweeen log (Critical Strain) and log (UCS) may be used to predict hazard warning level II and level III also. Additional supports (rock bolts or shotcrete) is needed in case of hazard warning level II (as squeezing may take place).

Infact, more accurate estimates of strains, stresses and support pressuress may be made from "Back Analysis and forward Analysis" (BAFA). In conventional back analysis, the input is - observed in-situ displacements, pressures, stresses and strains. A model of rock mass is assumed (isotropic or anisotropic) and back analysis is done. The output is mechanical properties of rock mass (modulus of deformation, Poisson's ratio, cohesion, angle of internal friction and external forces). Thus, uniqueness is guaranteed.He suggested that model and its parameters

should be deduced from the observations. The new (non-linear) back analysis is simply based on observed values of plastic observed strains alround a tunnel. Thus, there is no need to assume validity of Drucker and Prager's model or Mohr's model etc. There are many fancy computer programs for forward analysis. However, the result will not be unique.

A case study of a shallow tunnel was presented. The non-linear back analysis and forward analysis predicted amazingly same vertical and horizontal displacements as observed values all over the roof.

Elastic and isotropic model is not working and is dangerous in Rock System Engineering. Collaboration (among academicians, field scientists and project authorities) is very important. Information should be exchanged among all. Critical strain is very important in construction of tunnels and can be obtained in the laboratory. Students should not make-up (imagine) rock mass themselves. They should go to the field and actually see the rock masses.

Our goal is not numerical analysis but construction of structures.

His lecture was highly applaued by over 80 scientists and engineers.

-ISRMTT Local chapter, Roorkee

Indian Society for Engineering Geology : *Presidential Address by Mr. Ramesh Chandra (Chairman, Central Water Commission, Government of India)*

There appears to be some indifference or lack of seriousness to undertake monitoring of the behaviours of important rock structures and to me it appears that we are missing golden opportunities to enhance our frontiers of knowledge. The cost of collecting information is very low, but the information that can be known is very large. We need not forget the powerful words of Mark Twain *"There is something wonderful about science, one can draw so many conclusions from such a few facts"*.... The mathematical tools of analysis such as Finite Element Theory etc. are becoming very powerful, it is a matter of great dis-satisfaction that the properties of the rock material and rock mass structure that are fed into the calculations are not determined to the same precision. The success of any analysis depends upon the tools as well as on the inputs in the form of properties and responses of the material and structures.

We are also shy of putting or drilling a pilot tunnel before taking up work of main tunnels, i.e., probing ahead of tunnels by smaller dia. tunnels, trying to know in advance the surprises that are likly to come in the course of our main construction works. These are considered very necessary and informative. ...

- *Excerpts, Proc. ISEG Symp. Modern Practices in Geotechniques, Lucknow, India, 1996*

Earthquake Resistant Building With Bamboo

Hitting at a punishing 7.5 on the Richter scale, the 1991 earthquake near Limon, Costa Rica, crumpled bridges, office buildings, hotels, and homes like pieces of paper. At the epicenter of the earthquake were 30 experimental homes built under a United Nations program funded by the Neherlands. The homes were the vanguard of an effort to build sturdy, low-cost houses out of bamboo in the Central American country.

Amid hundreds of collapsed structures, 30 bamboo homes were found still standing unaffected by the natural disaster. *None of the bamboo houses had any damage, not a single crack.*

The three-bedroom, 47 m^2 experimental homes were constructed from thick bamboo pole frames covered with a woven mesh of split bamboo coated with mortar. The bamboo provides support and flexibility, while the mortar provides strength. Besides flexibility, there are many other reasons to build houses out of bamboo. *The houses made from bamboo are approximately 20 percent cheaper than houses made of concrete blocks.* In addition, bamboo homes are simple to build, and they're ecologically desirable because they don't require the destruction of forests for lumber.

To compare materials, one can look into their strength and stifneess, says Dr. Janssen. "It is even more interesting to also look into their mass per volume, and ask, `How much strrength and stiffness can I buy with 1 kilogram? Out of all materials, bamboo ranks very high.

Dr. Janssen offers a free consultancy service to individuals working to benefit developing countries. For more information, write to the Eindhoven University of Technology, Bamboo Lab, P.O. Box 513, 5600 MB, Eindhoven, Netherlands; telephone: 011 31 40 247 29 48; e-mail: j.j.a.janssen@bwk.tue.nl

- *Excerpts, Earthquake Hazard Centre Newsletter, Vol.2 No3, January 1999, pp6-7*

Heat from volcanic rock could power the planet

Molten volcanic rock could be used to produce electricity in future. A team from Sandia National Laboratory in - Albuquerque, New Mexico, has begun exploratory drilling at Mammoth Lakes in California. It plans to find out how deep the molten rock, known as magma, lies and how it could be used to provide energy.

According to John Finger, co-manager of the project at Sandia's geothermal research department, "the energy contained in magma deposits around the world could easily power the planet many times over. In America there have been several studies of the amount of magma and a US gelogical study has worked out that there are more than 50,000 sites. Each site contains the equivalent energy of 172 million barrels of oil and the magma is easily accessible".

- Excerpts from the News,
The Times of India Oct.3, 1998

ISO Quality Management Principles

* *Customer-Focused Organization* : Organizations depend on their customers and therefore should understand current and future customer needs, meet customer requirements and strive to exceed customer expectations.

* *Leadership* : Leaders establish unity of purpose, direction, and the internal environment of the organization. They create the environement in which people can become fully involved in achieving the organization's objectives.

* *Involvement of People* : People at all levels are the essence of an organization and their full involvement enables their abilities to be used for the organization's benefit.

* *Process Approach* : A desired result is achieved more efficiently when related resources and activities are managed as a process.

* *System Approach of Management* : Identifying, understanding and managing a system of interrelated processes for a given objective contributes to the effectiveness and efficiency of the organization.

* *Continual Improvement* : Continual improvement is a permanent objective of the organization.

* *Factual Approach to Decision Making* : Effective decisions are based on the logical and intuitive analysis of data and information.

* *Multually Beneficial Supplier Relationships* : Mutually beneficial relationships between the organization and its supplier enhance the bility of both organizations to creat value.

- Source : Standards India
Vol. 12, August 1998, pp 113.
(Bureau of Indian Standards)

Scientific Basis of Vastu Shastra

* One should face north-east in the office to benefit from infrared solar radiations in the forenoon and to develop intellectual might. Conversely facing south west in the dark office leads to ill-health and slow death. Dark office in the basements leads to loss of solar energy and fresh air, and erodes one's efficiency. (Strong lighting will help).

* The entrance of a building is preferred towards north or east for more inputs of energies.

* A garden is an energy source for each office and residence. In modern flats indoor plant pots should be used to cheer up residents properly.

* The centre of residence should be sunny and airy - If rich, plan a central courtyard in the residence as in the past or in the villages, for good health and happy moods.

* The master bedroom should be towards the south west. The ultraviolet raditions after sunset tranquilizes one's memory leading to sleepy mood easily.

* Sleeping with the head pointing north wards means ill health and insomnia. Because north pole of one's body repels the north pole of the earth. Thus body's magnetic and electrical fields are disturbed.

- *Source : Hindustan Times,*
Feb. 7, 1999

Value of Time

To realise the value of *one year*, ask a student who failed a grade.

To realise the value of *one month*, ask a mother who gave birth to a pre-mature baby.

To realise the value of *one week*, ask the editor of a weekly newspaper.

To realise the value of *one hour*, ask the lovers who are waiting to meet.

To realise the value of *one minute*, ask a person who has missed the train.

To realise the value of *one second*, ask the person who just avoided an accident.

To realise the value of *one millisecond*, ask the person who won a Silver Medal in the Olympics.

And remember Time waits for no one.
Yesterday is History. Tomorrow is mystery.
Today is a gift. That's why it's called the present !!

- Source : GC Alma Mater, December 1998
(IIT Madras Alumi Association)

Joy of Teaching

I don't believe I can really do without teaching. The reason is, I have to have something so that when I don't have any iedas and I'm not getting anywhere I can say to myself, "At least I'm living; at least I'm doing something; I am making some contribution" - It's just psychological.

It you're teaching a class, you can think about the elementary things that you know very well. These things are kind of fun and delightful. It doesn't do any harm to think them over again. Is there a better way to present them? The elementary things are easy to think about; if you can't think of a new thought, no harm done; what you thought about it before is good enough for the class. If you do think of something new, you're rather pleased that you have a new way of looking at it.

The questions of the students are often the source of new research. They often ask profound questions that I've thought about at times and then given up on, so to speak, for a while. It wouldn't do me any harm to think about them again and see

if I can go any further now. The students maynot be able to see the thing I want to answer, or the subtleties I want to think about, but they remind me of a problem by asking questions in the neighborhood of that problem. It's not so easy to remind yourself of these things.

So I find that teaching and the students keep life going, and I would never accept any position in which somebody has invented a happy situation for me where I don't have to teach. Never.

-Professor Richard Feynman, Nobel Laureate (Physics)

Mother Nature

Nature is vast, deep, high, intelligent, infinite and eternal. The heaven appearing before us is only this bright, shining mass; but in its immeasurable extent, the Sun, the Moon; Stars and constellations are suspended in it, and all things are embraced under it. The earth, appearing before us, is but a handful of soil (or rock, or rockmass); but in all its breadth as depth, it sustains mightly mountains (with dams, and reservoirs) without feeling their weight; rivers and seas dash against it without causing it to leak. The mountain appearing before us only a mass of rock (classification ?); but in all the vastness of its block size, (with all its degree of jointing and number of joint sets) grass and vegetation grow upon it, birds and beasts dwell on it, and treasures of precious minerals are formd in it('s) (inter block shear strength through their joint roughness and joint alteration or filling); and treasures of precious minerals are found in it. The water appearing before us in but a ladleful of liquid (producing water pressure; but in all its unfathomable depths (to produce rock stress conditions), the largest crustaceans, dragons, fishes, and turtles are produced in them, and all useful products abound in them (through active stress).

- Confucius [551 - 478 B.C.]

Welfare Economics for Developing Nations

A nation should have clear objectives which should direct its economic reforms (It should rarely be vice versa). Indian constitution should be changed to make (basic) primary education as a fundamental right of children.

Only educated people can make a nation (self reliant in selected areas and consequently make it) rich. India can afford the cost as the cost of educating all

children at the primary level would be an additional half-percent of GDP (It is worth even if overhead expenses are ten times). The salaries of Public sector undertaking's (PSU) are alone 3 percent of Indian GDP. Bad performers in PSU should be scrapped immediately. Good performers should be encouraged. Defence expenditure should be cut. Dialogue should be initiated with neighbouring countries on all outstanding issues.

Basic education, health care and quality control has enabled Chinese goods produced in rural areas to compete in the international market, as education led workers to improve the quality of products.

Further, the (basic) primary education is labour intensive and does not require machines and high capital. Economic reforms will be meaningful only if social opportunities are thrown up and under-preveleged are able to participate in the development process (in developing nations).

Famines were not caused by lack of food in the country but becaues of hoarding by businessmen. Only welfare (Government) state can get rid of famines.

- Prof. Amartya Sen
Nobel Laureate (Economics) &
Bharat Ratna
Jan. 1999, India

Happiness Index

Rousseau believed that a good bank account was a necessary prerequisite of happiness in life. Most people agreed with him and continue to do so. But he has been proved wrong by a recent World Happiness Survey, led by professors of the London School of Economics. Contrary to the popular notion that the search for happiness should ultimately land one in the USA, the professors have found that the USA ranks only 46th, way behind countries like Ghana, Latvia, Croatia, Estonia and India, which ranks as high as fifth.

But the most exciting revelation is that the happiest people in the world belong to one of the poorest countries - Bangladesh. The survey probed the link between personal spending power and the perceived quality of life which proved that *money does not bring happiness*. The British have larger bank balances and spending power but stand 32nd on the list. Apparently, they were not listening when the Beatles sang, *Money can't by me love*. The conclusion is further reinforced by the finding that countries like Japan, The Netherlands and Canada, believed to be economic 'powerhouses', have also failed to make their people happy.

In fact, the entire findings point to the ancient Indian conviction that poverty is not to be scoffed at, that riches bring misery and that the poor are the blessed ones who represent God (Daridra Narayan). It makes nonsense of all modern theories for pushing up income levels and standards of living, which touches off the rat race that leaves man with little time and energy to taste the happiness he is working for.

The ancient sages preached that contentment with one's own state and the curbing of material desires were the secret of happiness. Great men have spent a lot of words on the theme. "...O yet happiest if ye seek/No happier state, and know to know no more", wrote Milton, apparently in tune with the ancient Indian point of view. Dr Johnson once told Boswell that a man was never happy except when he was drunk. He may have been joking. Pope sighed, "O happiness! Our being's end and aim!/...For which we bear to live, or dare to die". Now it transpires that the key to happiness is one of the easiest things to achieve--a low income. Income is not the only thing, as one tends to think. As Stevenson said "The world is so full of a number of things/I'm sure we should all be as happy as kings".

- *Source : The Times of India, December 22, 1998.*

Your own blood pressure-some facts about it

* Vegetarians have b.p.5 mm lower than that of regular non- vegetarians.

*. 20-30 minutes moderate exercise, 4-5 days in a week lowers b.p. by 7-10 mm.

* Reduction in alcohol intake by 100 ml/week causes lowering in b.p. by 1 mm.

* A cup of coffee raises b.p. by 5 mm for 1-2 hours.

* Cigrette raises b.p. for shorter duration but if taken along with coffee causes higher rise in b.p.and for a longer duration (>2.5 hours).

* Low calcium intake (<300 mg/day) exposes you to 11-14 % greater risk of suffering from high b.p. The risk is 3-6 % if daily calcium intake is approximately 1200 mg.

* Extreme dietary restriction of salt intake (<0.6 gm/day) loweres b.p.but moderate restriction (approx. 4 gm./day) have dubious benefit.

* Increased potassium intake lowers b.p. but benefits are doubtful.

* Excessively nervous/emotional and introvert persons are prone to high b.p. due to suppressed emotions.

* Temp. excitement/fright/fight raises b.p. temporarily. But constant repetition of such stimulli lead to labile and then sustained rise in b.p.

* High aerial lead content raises b.p.

* Expossure to high noise level raises b.p.

* Cold weather causes 3-7 mm rise in b.p.

* Meditation and bio-feed back can lower b.p.

It is a life - style disease; take care of it.

- Source : P.Sleight (1987) Oxford Text-Book of Medicine 2nd Ed., pp. 13, 360-13,382