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Bench-scale studies of a permeable reactive barrier system for radiocesium removal

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Purpose

- In this work, we propose to investigate an alternative permeable barrier system for controlling and preventing the migration of radio cesium into the groundwater.
- Natural raw materials; Zeolite (Clinoptilolite) and Sepiolite were used as the proposed reactive media placed in a sand soil environment on a laboratory scale model.
- The mechanical behavior and permeability of these materials are important geotechnical aspects of PRB technology.

Permeable reactive barrier (PRB) technology

- Remediation of the contaminated groundwater is one of the major environmental issue of the contaminated sites (1).
- Permeable reactive barrier (PRB) technology is being introduced as an alternative method for controlling and treating the groundwater, contaminated with heavy metals, chlorinated organics and radionuclides, etc. (2-3).
- To regulate the cost of PRB technology to minimum in line with regulatory decontamination requirements for the contaminants, reactive media should be readily available at a low level of moderate cost (4-5).

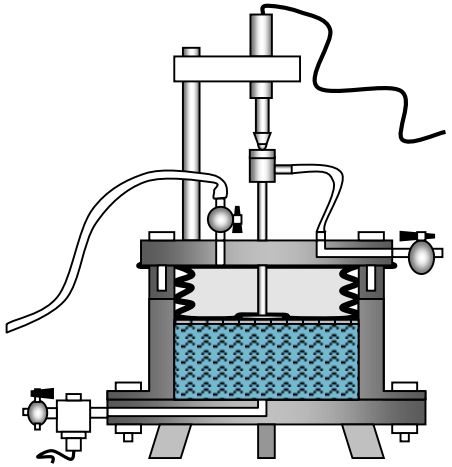
Materials

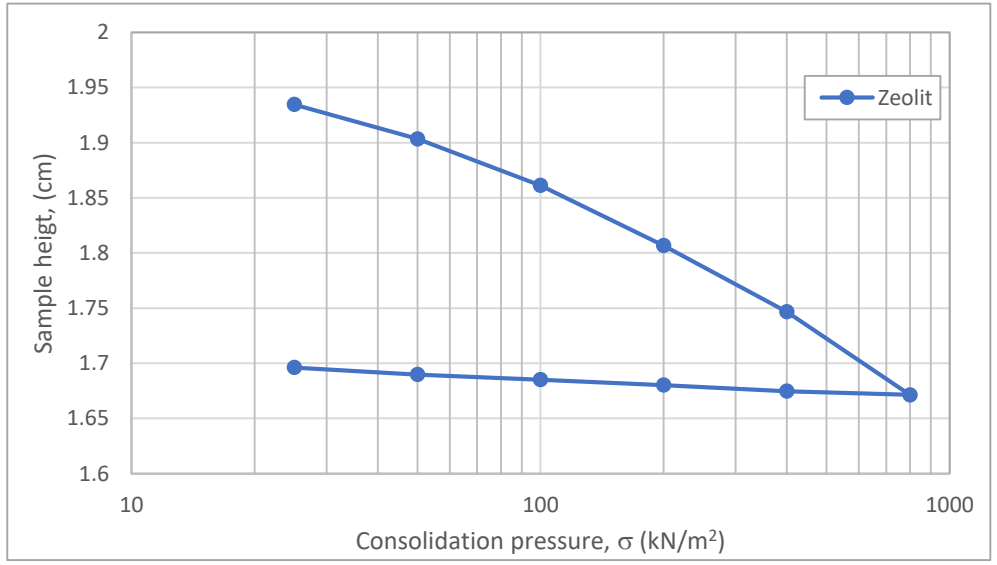
- Index properties of soil based materials; zeolite, sepiolite and sand were determined according to the relevant ASTM standards.
- One of the major radionuclides of the nuclear/radioactive activities was radio cesium (Cs-137 and Cs-134).
- Cs-134 was produced by neutron irradiation of CsCl, using the ITU TRIGA MARK II Research Reactor.
- The radionuclide was added to distilled water to prepare artificially contaminated sample.

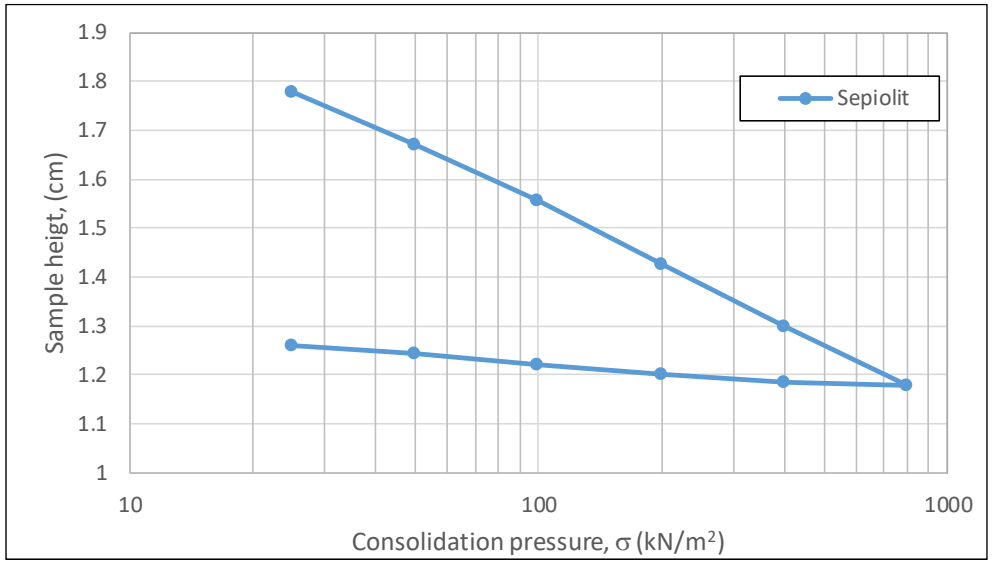
Properties	Zeolite	Sepiolite	Sand
Gravel (%)	0	0	0
Sand (%)	67	23	100
Silt (%)	29	58	0
Clay (%)	4	19	0
Liquid Limit, wL (%)	58	133	Non plastic
Plastic limit, wP (%)	39	73	
Plasticity Index, IP (%)	19	60	
USCS Soil Type	SM	MH	SP

Permeability of the reactive barrier media

- The sludge form of zeolite and sepiolite, prepared at a water content equals to 1.5 times their liquid limits were reconstituted in a small Rowe cell under 20 kPa vertical pressure.
- One dimensional consolidation tests were performed by using front loading conventional consolidation loading frame.

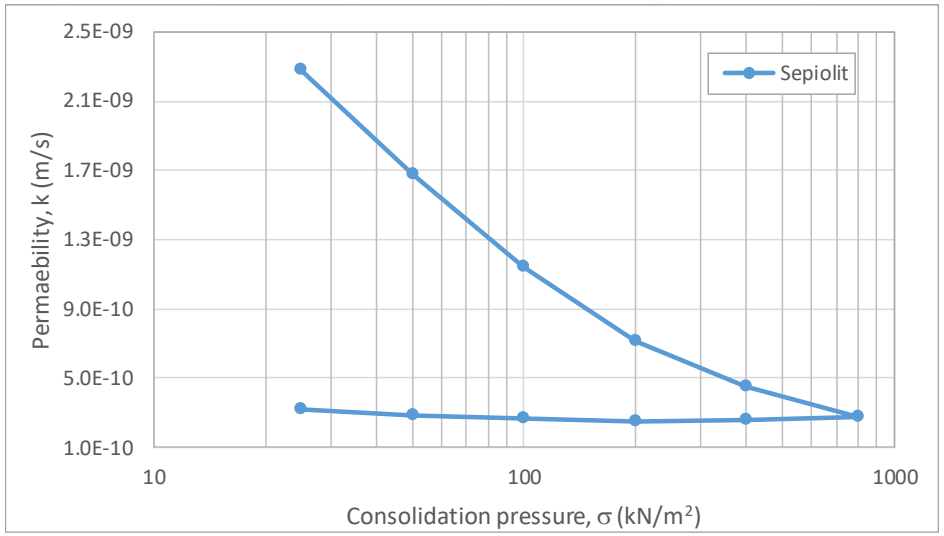


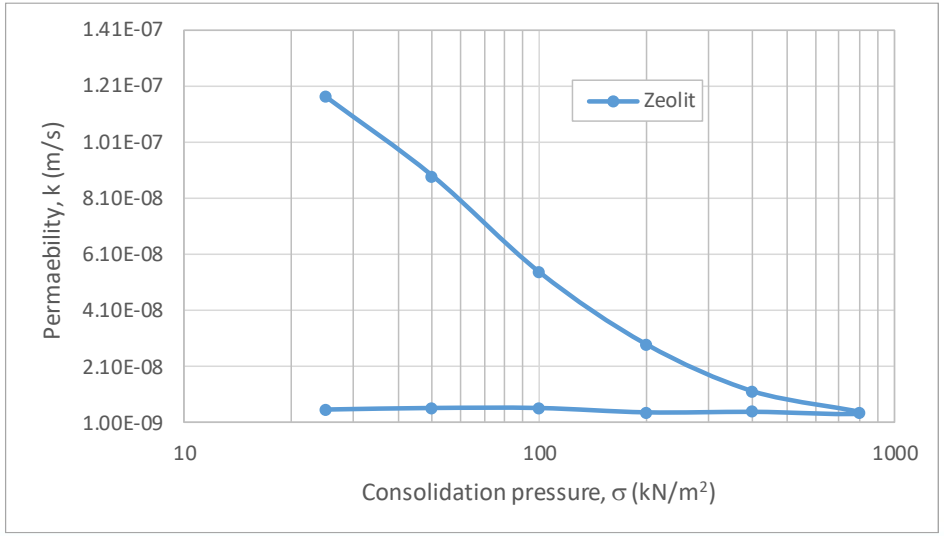




Permeability of the reactive barrier media

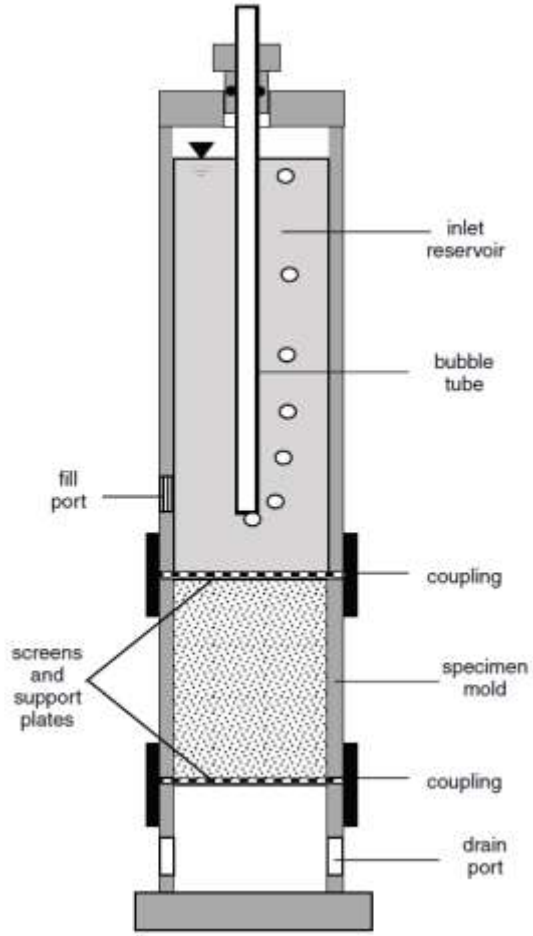
- Vertical permeability of the samples were observed by an odeometer cell that allow falling head type permeability test under a vertical pressure.





Permeability of the soil enviroment

- In the bench-scale model the soil environment is simulated by sand type soil to limit the time of the tests.
- The relative density tests were performed on the dry sand to calculate the unit weight that corresponds to 65% relative density to be used in modelling as an initial state.
- Permeability coefficient of sand was determined as 2160 cm/day by constant head permeability tests.



P400000 series TRAUTWEIN constant head permeameter

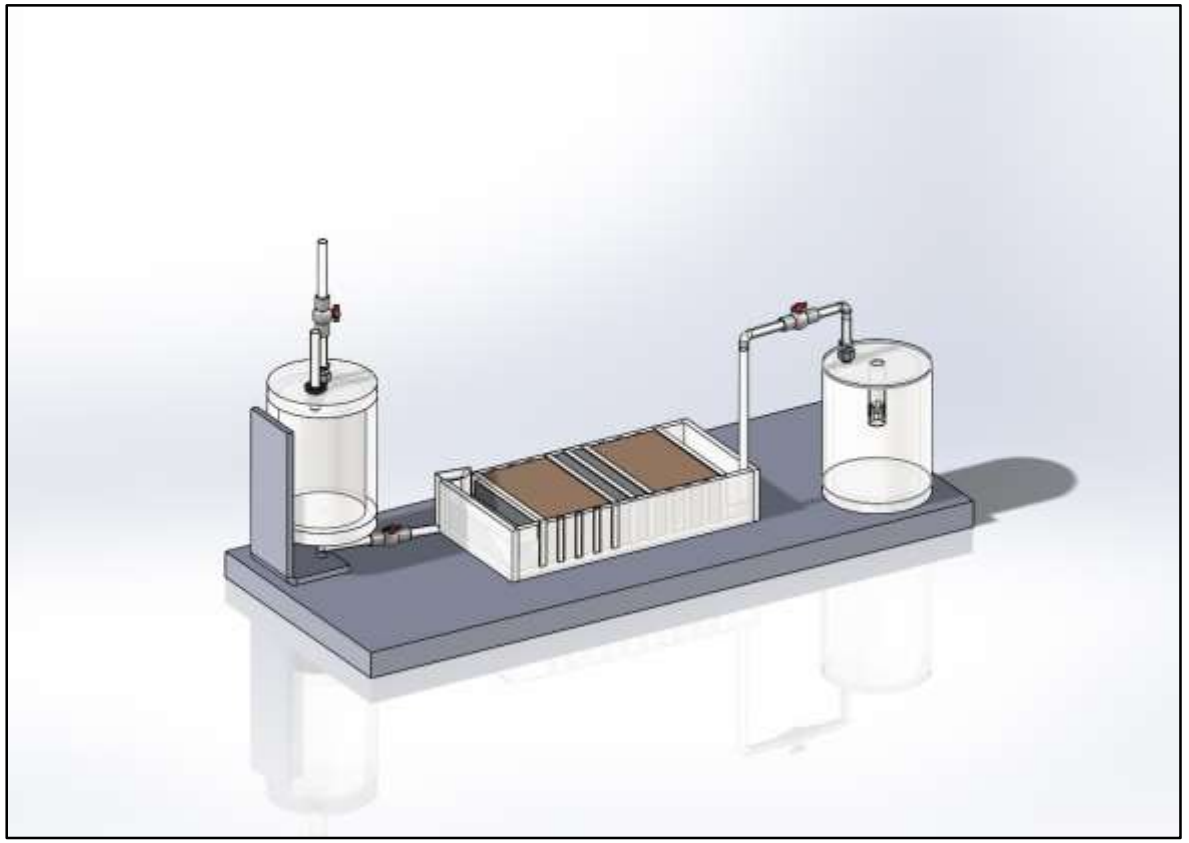
Permeable reactive barrier (PRB) technology

- A Plexiglas box were constructed with the adjustments for the several model set up.
- Pre-wetted non-woven polypropylene geotextile was used as a permeable separator in the media.

Physical and Mechanical properties of Non-wowen Geotextile	Test Method	Unit	Value
Weight	EN ISO 9864	gr/m2	350
Thickness (under 2kPa)	EN ISO 9863-1	mm	2.7
Tensile strength (in both axis)	EN ISO 10319	kN/m	17/22
Elongation at rupture (in both axis)	EN ISO 10319	%	min. 50
Static puncture strength	EN ISO 12236	N	3100
Permittivity, VH50	EN ISO 11058	l/s* m2	65
Apparent Opening Size AOS	EN ISO 12956	mm	0.076

Permeable reactive barrier (PRB) technology

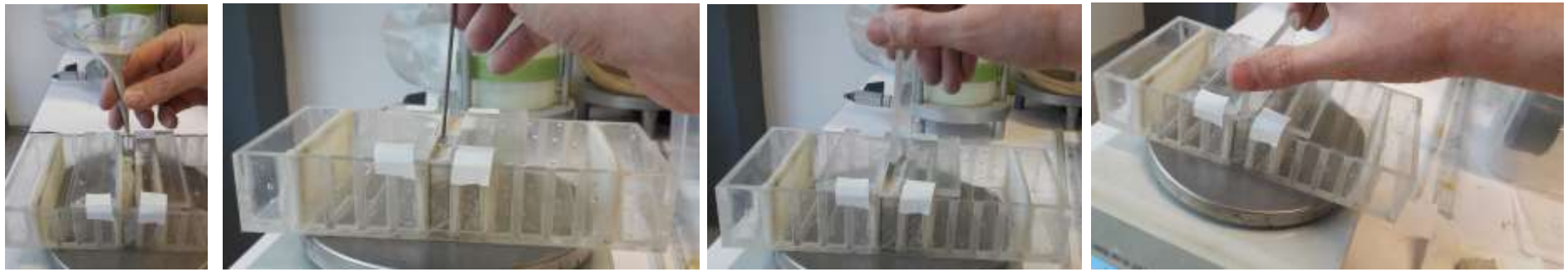
- The bench-scale PRB configuration was designed based on the barrier and sand media experiments.
- The continuous wall configuration of PRB was used which had a vertical cross-sectional area of 3.5 x 9.0 cm^2 .
- In the flow direction PRB barrier was modeled by 1.0 cm thick zeolite (Model 1) or sepiolite (Model 2) individually or 2.0 cm in total with both (Model 3).



A sketch figure for Model 3

Preparation stages: Model-3

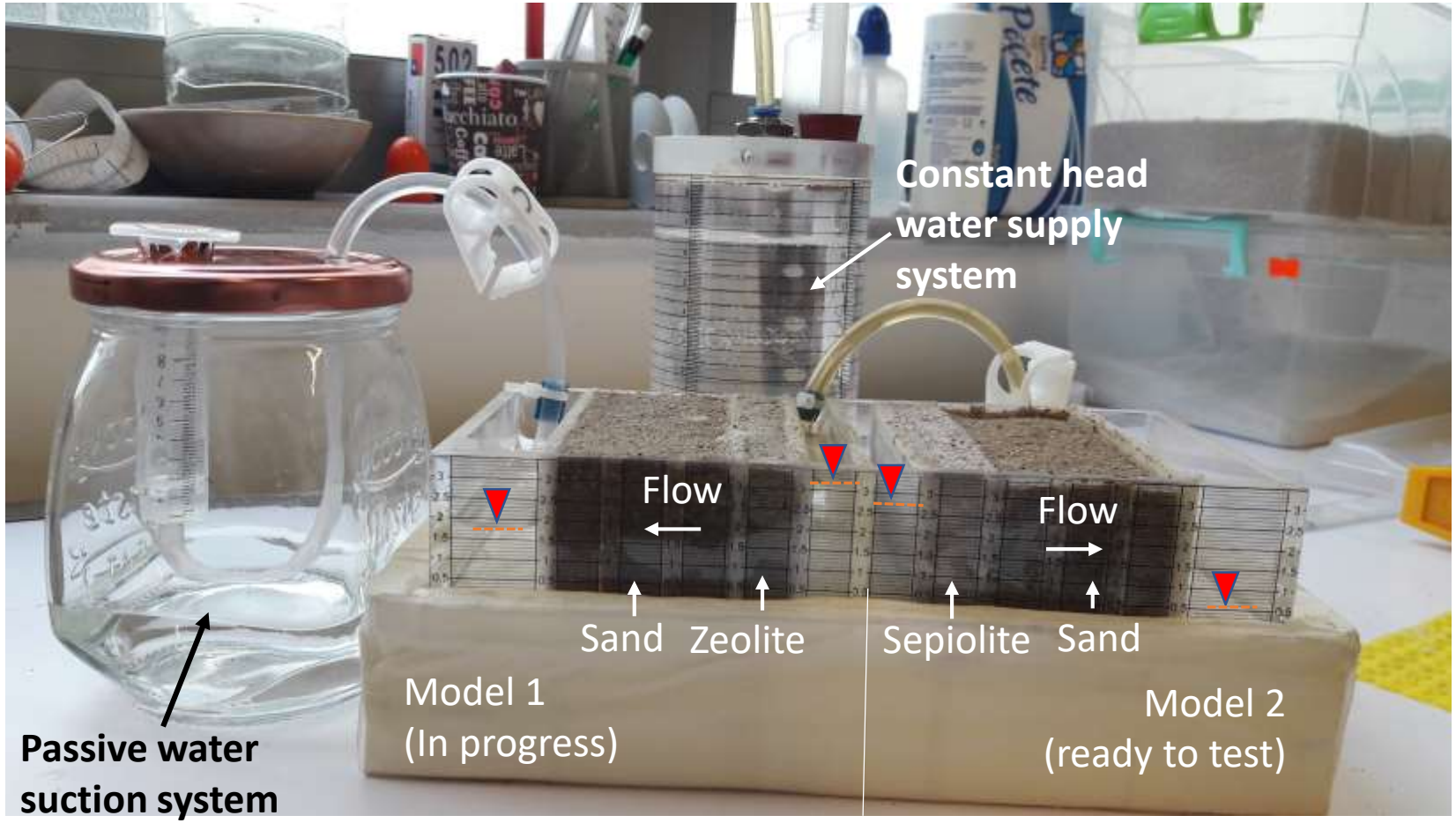
- Each section of the model were filled with the proposed media by pouring from funnel, replaced by steel rod, compacted by tapping.



- The predetermined unit weight of each media is satisfied by weighing for the known volume of sections.

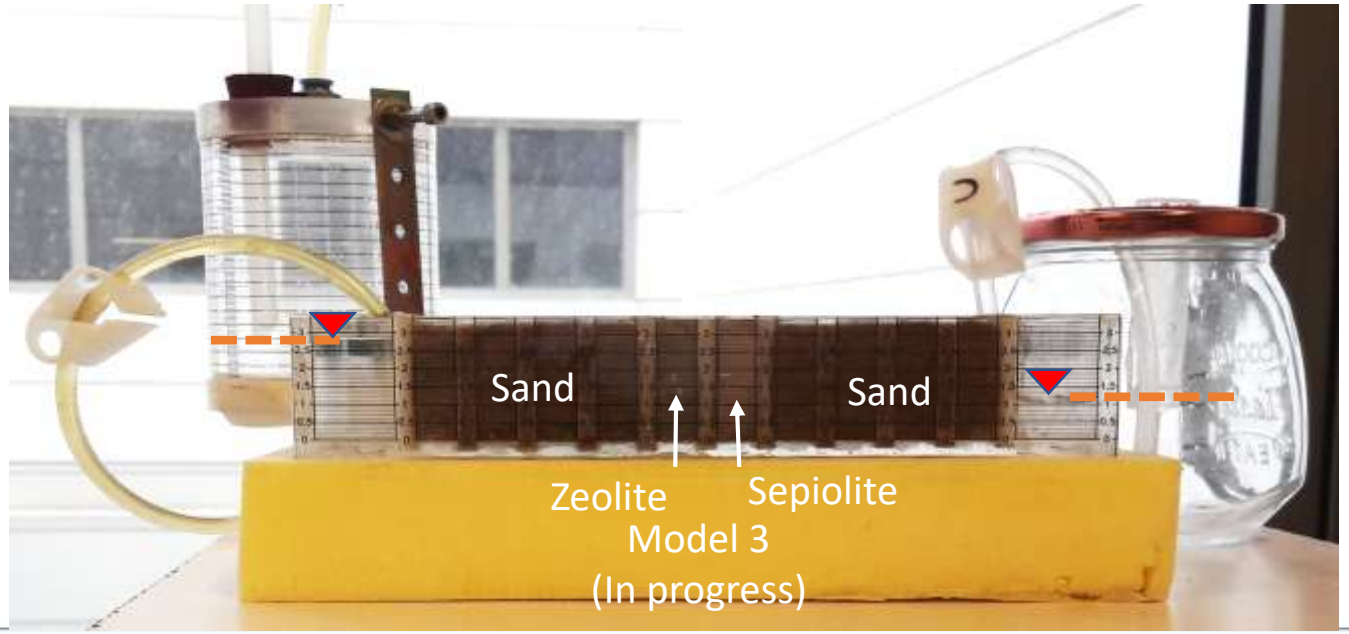
Permeable reactive barrier (PRB) technology

- The bench-scale PRB demonstration system were also designed to investigate the horizontal 2D flow of groundwater at the steady state flow conditions is realized between the proposed head difference.



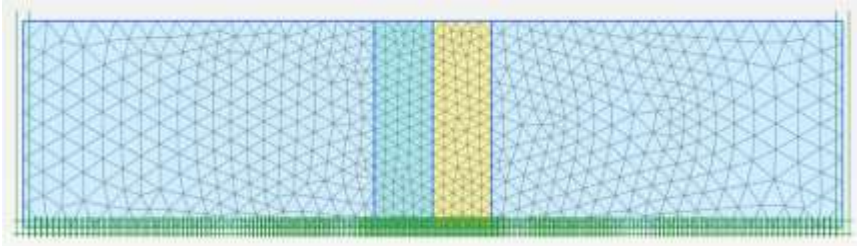
Permeable reactive barrier (PRB) technology

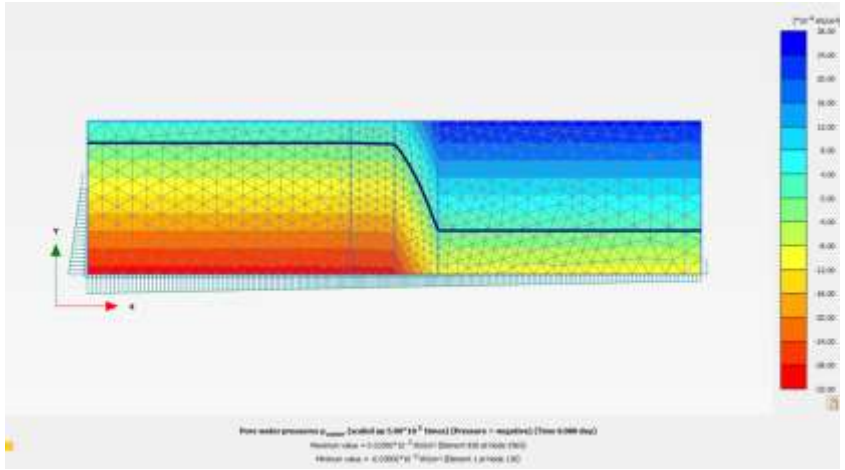
- During the test, water head at the upperstream was supplied by a similar approach used for the bubble tube constant head permeability test device.
- The head at the downstream was fixed simply by drilling a hole at the same elevation on an injector vertically located in a jar for the use of principle of computational fluid.



Permeable reactive barrier (PRB) technology

- The hydraulic conductivity of the saturated media was studied by a flow net analysis.
- The amount of the observed discharged and model prediction was compared.
- An improvement on the model parameters are required for a better simulation on the seepage behavior regarding the observed data in the bench scale PRB system.
- The vertical permeability coefficients determined on the reconstituted raw barrier materials might be inadequate to model the natural horizontal flow.





Permeable reactive barrier (PRB) technology

- The effect of the simulated continuous release of contaminant solution in the upstream was observed in the soil media not only at the downstream both also in the upstream and PRBs.
- The bench-scale PRB system will be used to approximate the operating conditions for the information on the transport behavior of the radio cesium and change in the hydraulic conductivity in PRB system.
- Remediation process over time can lead to changes in the hydraulic conductivity of a PRB.

Conclusions

- This study presents the mechanical behavior and permeability of the zeolite and sepiolite media of PRB.
- A bench-scale continuous wall PRB with configuration was designed based on results of the odeometer and consolidation test results.
- In up-stream and down-stream of porous medium were considered to create a steady-state condition of flow through sand and reactive media with atmospheric pressure.
- The seepage velocity through sand-reactive media was modelled with regulation of water level in the reservoirs.
- This configuration is capable to solve the problems water flow and pore blocking of the PRB.

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