SAND2010-8741P

NS41A-1506

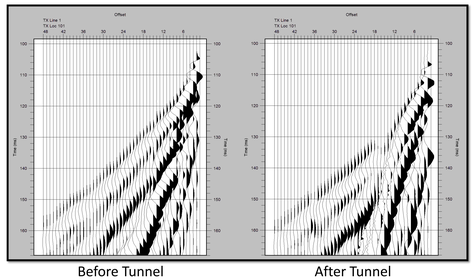
Comparison of the seismic effects of soil disturbance and void space over shallow cut-and-cover tunnels

Nedra D. Bonal, Robert E. Abbott, and Leiph A. Preston
Sandia National Laboratories

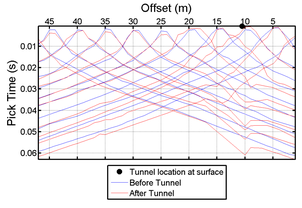
Summary

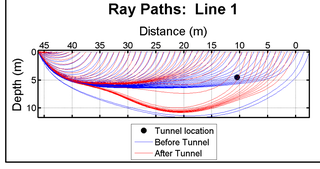
Locating subsurface voids using surface seismic methods has been problematic. This study compares changes in seismic data before and after tunnel emplacement using the cut-and-cover method for three separate cylindrical tunnels. Cut-and-cover construction for tunnels used in this project involved excavating a trench in the soil, emplacing a pre-built metal or plastic tunnel, and packing the excavated soil around the tunnel up to the surface. Data from a "disturbed soil" area (cut-and-cover with no emplacement of a tunnel) are also presented in an attempt to determine if observed changes in seismic waves are due to the void or the disturbance of the soil. 2D surface seismic refraction tomography surveys were collected before and after tunnel emplacement using identical survey parameters and source and receiver locations. Minimal changes in the seismic properties are expected between data collections (10 months apart), therefore all changes in the data are attributed to cut-and-cover construction. First-arriving P-waves are diverted through higher velocity material around the void. This disturbance in ray paths may be a good indicator of subsurface voids.

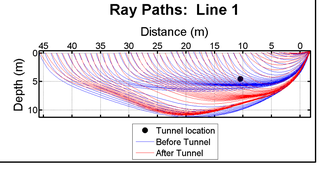
Changes due to tunnel emplacement are clearly evident in the figures below (shot records, first breaks, and ray paths, respectfully) for Line 1, where the tunnel diameter is on the order of the receiver spacing.

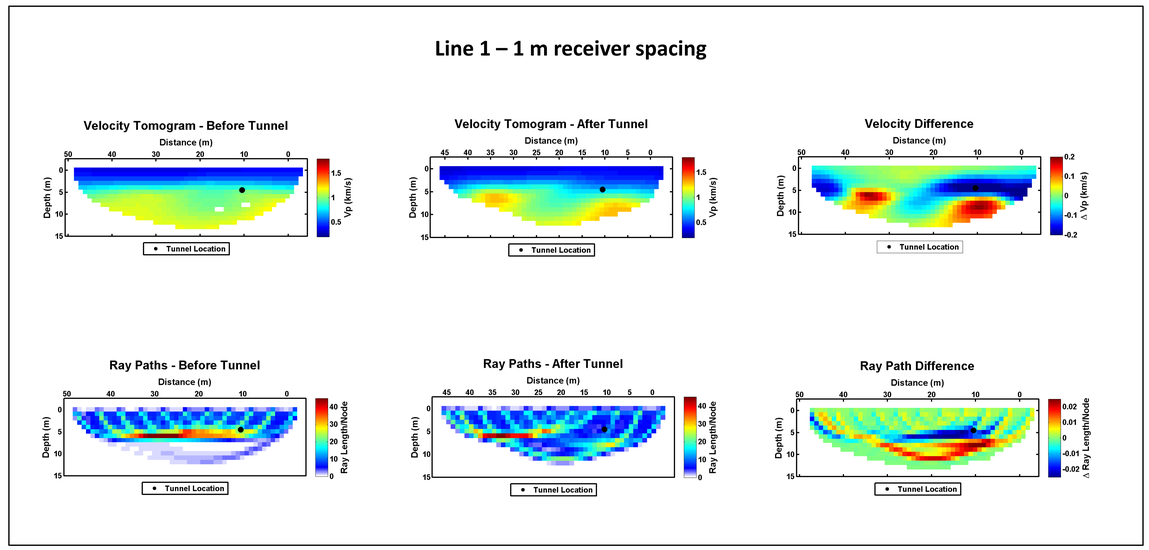


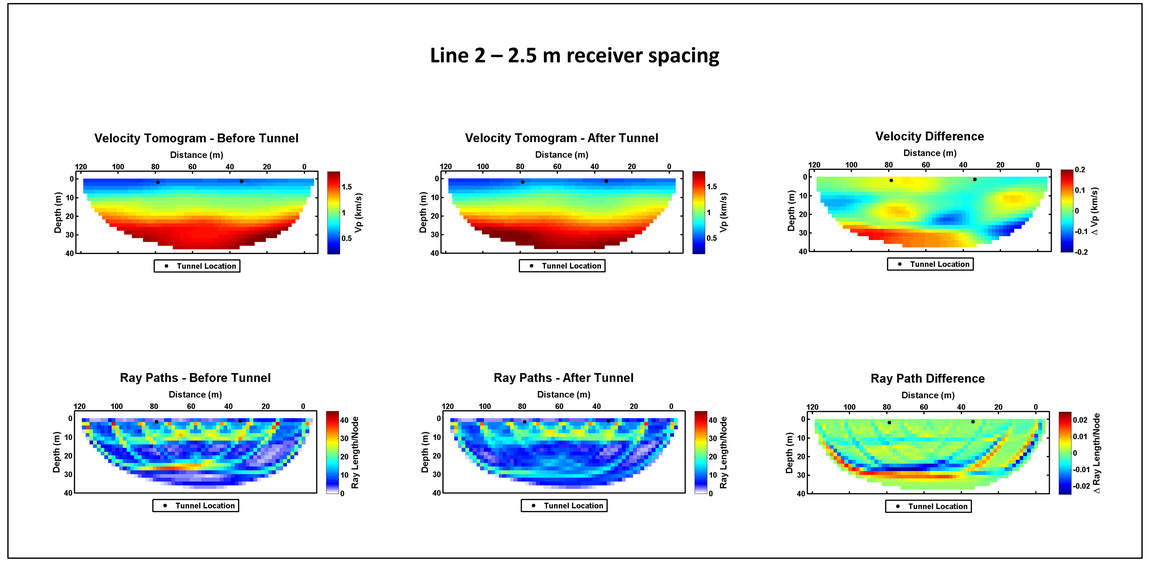
Before Tunnel After Tunnel





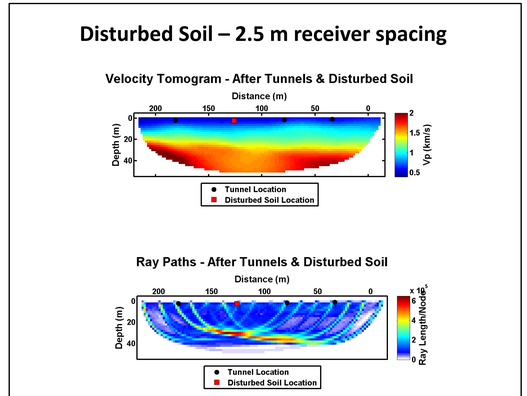






Tunnel & Disturbed Soil Parameters

	X-axis Location (m)	Receiver Spacing (m)	Target Type	Target Diameter (m)	Depth to bottom of Target (m)	Angle w.r.t. survey line (degrees)
Line 1	10.5	1	Void space from pvc pipe	0.9	4.9	90
Line 2	33.75	2.5	Void space from pvc pipe	0.6	1.6	90
Line 2	78.75	2.5	Void space from metal pipe	0.6	2.1	60
Line 2	126.25	2.5	Disturbed soil with no void space	~1.0	2.9	90
Line 2	181.25	2.5	Void space from metal pipe	0.6	2.6	75



In the area where cut-and-cover construction was used but a tunnel was not emplaced, there is no evidence of disturbed soil. Unfortunately, the tunnel was constructed in the wrong location where data prior to construction does not exist. Therefore, images before construction, velocity difference, and ray path difference cannot be shown. Additionally, the receiver spacing may need to be on the order of the length of the disturbed zone to be detected with this method.

Conclusions

- The tunnel is detected for receiver spacing on the order of the tunnel diameter (Line 1 at 1 m spacing and 0.9 m diameter). Tunnels are not detected for receiver spacing on the order of four times the tunnel diameter (Line 2 at 2.5 m spacing and 0.6 m diameter).
- Tunnels have greater detection using ray analysis rather than tomography due to the smoothing effects of tomography.
- Ray path deviations due to tunnels extend well beyond the tunnel boundaries. Rays begin to diverge at extended distances (up to 30 m in Line 1) from the tunnel location.
- Three-dimensional data are needed to increase ray coverage for a better tomographic image.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.