Shear Wave Velocity Measurements
TR202403

Appendix A

General Guideline for Multichannel Analysis of Surface Waves (MASW) Field Surveying

Provided by
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General Recommendations for MASW Field Surveying

The general recommendations for MASW field surveying and conceptual survey design parameters for six (6) MoDOT example bridge sites are presented below.

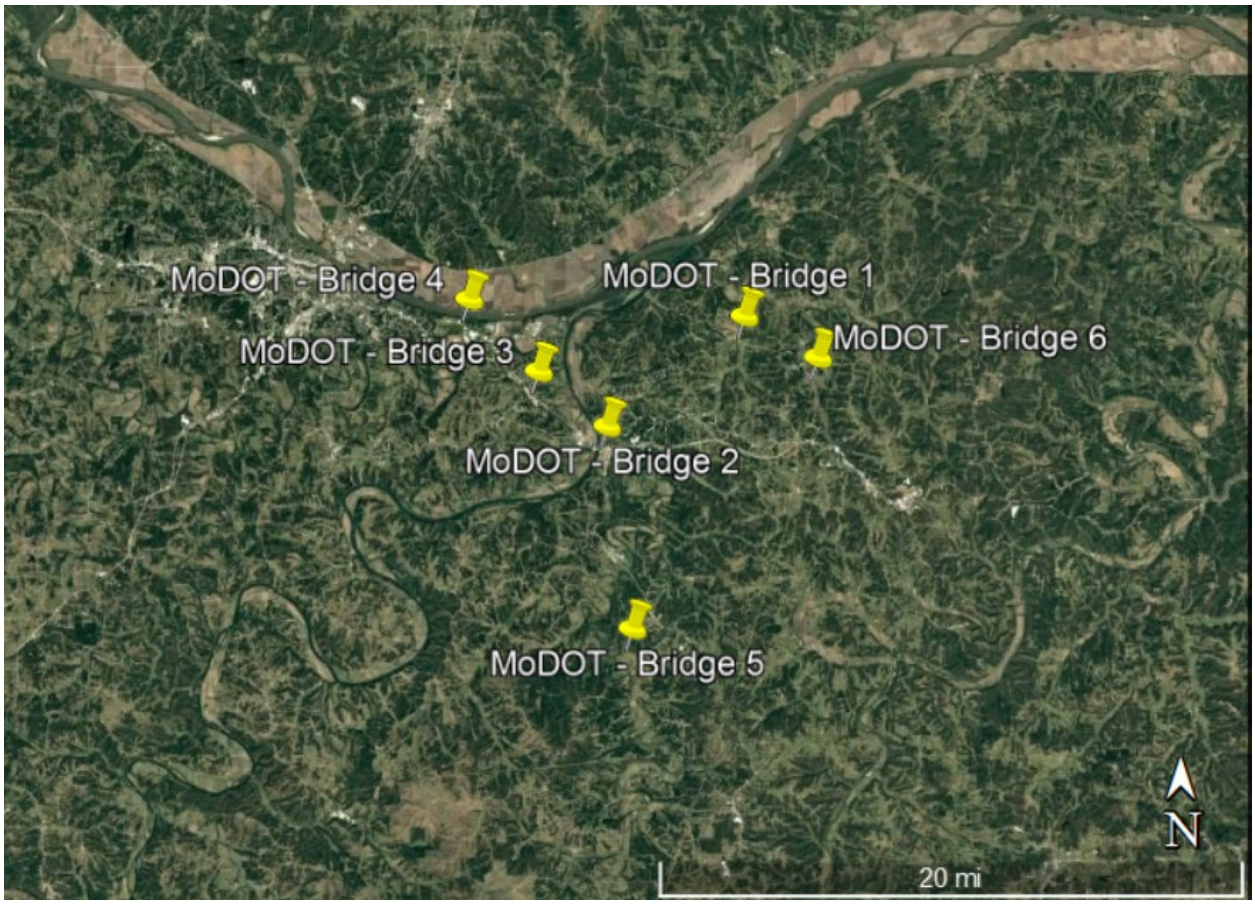
1. Deploy a 24-geophone seismograph equipped with 4.5-Hz vertical geophones with spikes. Geophone base plates can be used on hard surfaces (e.g., gravel and paved roads).
2. Use a default geophone spacing of 5 feet and 10 feet. The spacing can be adjusted (i.e., 2.5-foot) based on the site conditions. The geophone array center (i.e., point between geophones 12 and 13) should be the same for arrays with different geophone spacing.
3. Position the geophones arrays as close as practically possible to the bridge.
4. Acquire both Active and Passive MASW data sets, when possible, using the same geophone array.
5. Acquire MASW data along two perpendicular lines, if site conditions allow, for MASW results consistency confirmation purposes.
6. Active data should be acquired with minimum background acoustic noise energy (i.e., traffic).
7. Passive data should be acquired with ambient acoustic noise energy (i.e., traffic) present, preferably with vehicles moving in one direction. Heavy traffic and/or vehicle moving in both directions close to the geophone array can contribute to data sets contaminated with excessive acoustic energy and make data processing more challenging.
8. Prioritize acquiring Active MASW with 5-foot geophone spacing and Passive MASW with 10-foot geophone spacing. Both Active and Passive data using the standard geophone array configuration (spacing, orientation) should be acquired, when possible:
    - Acquire Active and Passive MASW data in the roadside, parallel to the roadway, as traffic control may not be required and ambient noise from traffic would be beneficial for Passive data.
    - Active and Passive MASW data should be acquired on each side of the bridge when conditions are expected to vary. Note, that if there is a rock bluff present on one side of the structure, the subsurface conditions at that side will likely exhibit significantly higher shear wave velocities compared to the opposite side. As a result, this condition will not govern the design.
9. MASW data can be acquired on a roadway (traveled way or shoulder), if the roadside is not accessible or suitable. Lane closures may be required. Active data should be acquired using geophones base plates and a synthetic strike plate. Ambient acoustic energy may be insufficient for Passive data due to traffic control. Acquire data in one lane on two sides of a bridge to minimize lane closure time.
10. At sites with a divided highway, MASW data can be acquired in the median. However, the geophone array should be positioned as close as possible to a roadway in each direction:
    - Acquire Active MASW data under a bridge structure (i.e., close to existing or future piers) and Passive MASW data (secondary).

- It should be noted that areas with significant fill (>20 feet) can reduce MASW signal quality and depth of imaging; however, it will be highly dependent on the fill material properties (e.g., material type, compaction, etc.). These areas should be avoided if possible.
- Use traveled way or shoulder if no other locations with traffic control are available.
- Avoid areas with utilities and other features, such as culverts, if at all possible. Subsurface features can reduce MASW data quality due to acoustic energy attenuation and backscattering. Smaller-diameter utilities (i.e. 6 inches or less), such as electric conduits and services gas lines, do not significantly affect the data quality.

11. Place geophones off pavement where possible. Rigid pavements can attenuate the seismic signal due to embedded reinforcement or possible voids beneath the slabs (especially in karst areas).
12. Reducing the geophone spacing (e.g., from 5-foot to 2.5-foot) can produce better shear wave velocity profiles in areas with variable soil thickness and/or karstic bedrock, due to smearing along shorter distances (geophone array length).
13. Additional MASW data can be acquired in perpendicular directions and used for comparison purposes.
14. Use of a smaller size (e.g., 6x6 inches) metal strike plate is recommended for use for medium-density material (dry soil, fill, etc.), a larger size (e.g., 10x10 inches) metal plate is recommended for softer material (soft and/or wet soil) and a synthetic plate is recommended for hard surfaces (gravel and paved roads, etc.). Alternatively, a rubber mat under a metal strike plate could be used on the hard surfaces to minimize the plate bouncing and improve the low-frequency signal.
15. The MASW traverses should be as straight as possible. Curvature can result in overestimated shear wave velocities. If there is not enough space for a full-length array (i.e., a 230-foot-long array with 24 geophones spaced at 10-foot intervals), the geophone spacing can be reduced or the last several geophones can be left out (disconnected).
16. A railroad with a passing train near MASW traverses can produce appropriate ambient energy for Passive MASW, however due to unpredictability of the train schedule, it is not included in the discussion. Typically, useful Passive data could be generated by an approaching train (e.g., several thousand feet away). However, if a railroad and a passing train are close to the MASW traverse it can produce high-amplitude energy and “overwhelm” the Passive data record rending it unusable.
17. If Passive data are collected, measure the distance from the road that will be used as the Road Offline input in SurfSeis.

Conceptual MASW Survey Design Parameters For Selected MoDOT Example Bridge Sites

Conceptual MASW survey design parameters for MASW surveying at 6 selected bridge sites (depicted as MoDOT – Bridge 1 through 6 on the map) located in the Jefferson City, Missouri area, are presented below. The survey design parameters are based on the assessment of site conditions from available aerial and street view images by Google Maps. Where available, the county, roadway name, structure number, and Average Annual Daily Traffic (AADT, as of May 2025) information is included.

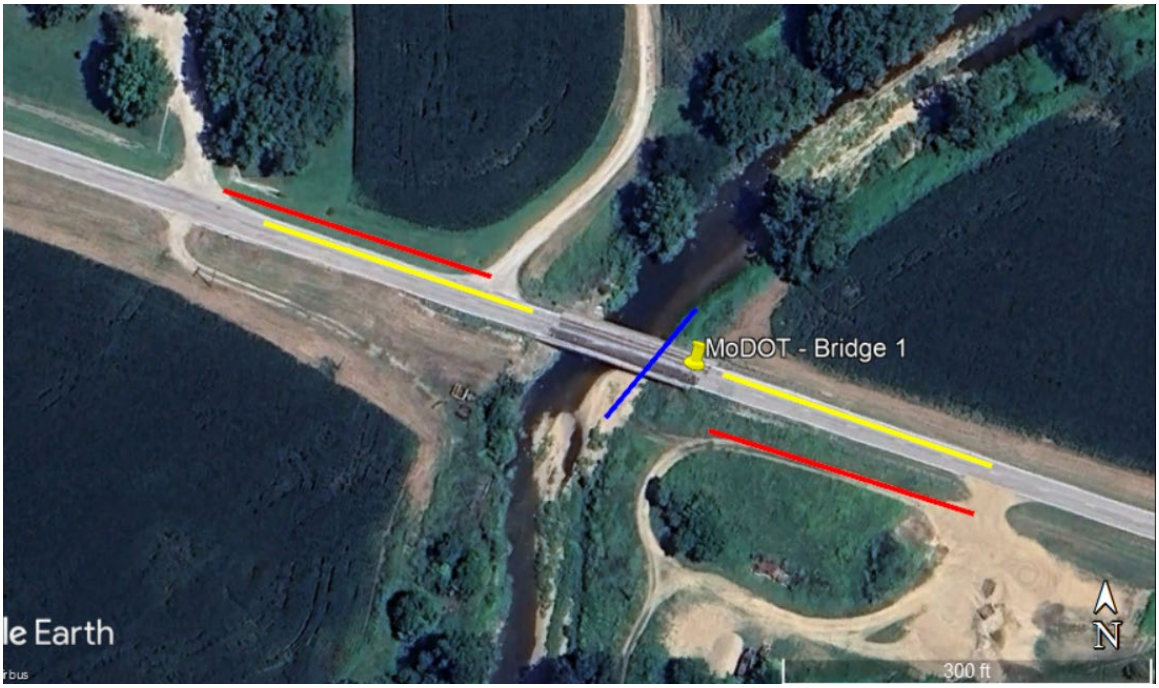


Locations of six example bridge sites. Jefferson City, Missouri area.

MoDOT - Bridge 1

County: Osage.
Roadway: Route W over Loose Creek.
MoDOT Structure Number: A2340.
AADT: less than 400.
Coordinates: Latitude 38.546439°, Longitude -91.920449°.
Site description: Two-lane road; narrow shoulders or no shoulders; asphalt surface.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the roadside or along a nearby private road.
- Option 2 (yellow lines): if Option 1 is not feasible, acquire Active and Passive data in the traveled way or shoulder. The use of geophone base plates will be required. Lane closure may be required. Data at both west and east traverses can be acquired in one lane (e.g., westbound) to minimize lane closure time.
- If the site conditions allow, acquire Active and Passive (secondary) data along a traverse (blue line) under the bridge structure using a 5-foot spacing.

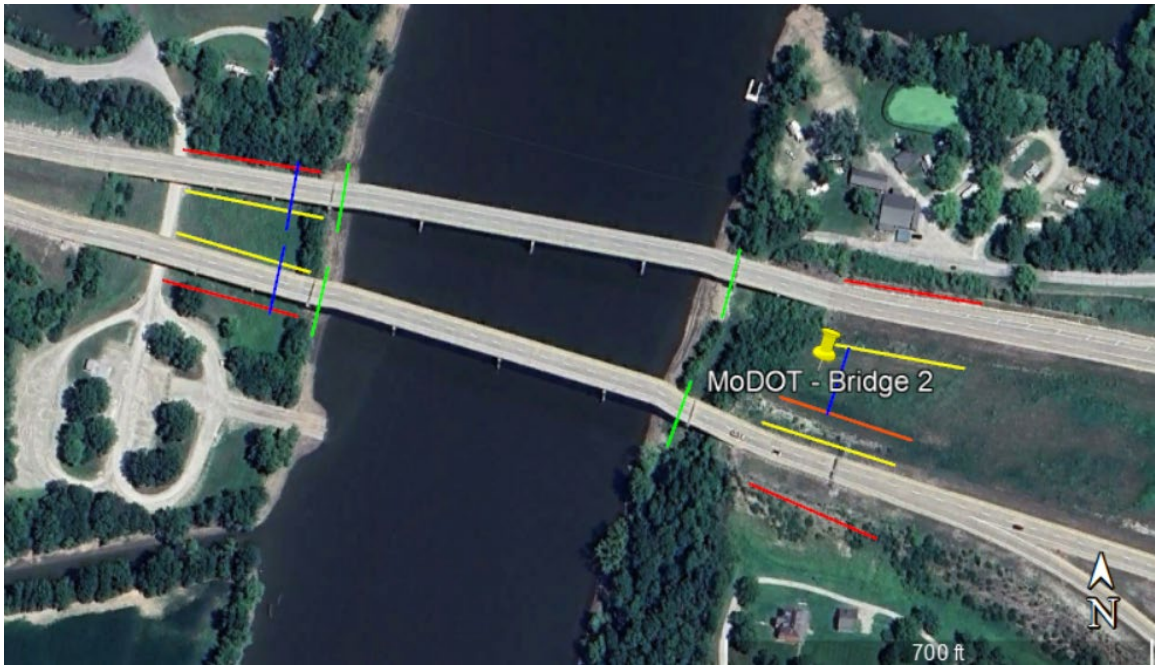


MoDOT - Bridge 1 site. Recommended placement of MASW traverses. Option 1 (red lines) – Active and Passive MASW data acquired using a 5-foot and 10-foot spacing, in the roadside or along a nearby private road. Option 2 (yellow lines) - acquire Active and Passive data in the traveled way or shoulder. If the site conditions allow, acquire Active and Passive data along a traverse (blue line) under the bridge structure using a 5-foot spacing.

MoDOT - Bridge 2

County: Osage/Cole.
Roadway: Route US50/63 over Osage River.
MoDOT Structure Number: A0506 and A5552.
AADT: 9,500.
Coordinates: Latitude 38.492370°, Longitude -92.006997°.
Site description: Divided highway, two westbound and two eastbound lanes; wide shoulders; concrete pavement. Exposed bedrock on the east of the river.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the roadside. Avoid placing traverses on fill material, if possible.
- Option 2 (yellow lines): if Option 1 is not feasible, acquire Active and Passive data in the median, close to the traveled way in each direction, on both sides of the river. If acquiring MASW data along the yellow traverse located on the east side of the river and along the eastbound roadway is problematic due to the rock outcrop, it should be moved to the base of the slope (orange line).
- If the site conditions allow, acquire Active and Passive data along traverses (green lines) beneath the bridge structures using a 5-foot spacing. If these locations are inaccessible, acquire data along traverses (blue lines) shifted away from the river.



MoDOT - Bridge 2 site. Recommended placement of MASW traverses. Option 1 (red lines) – Active and Passive data acquired in the median, close to the traveled way in each direction, on both sides of the river. Option 2 (yellow lines) - Active and Passive data acquired in the median, close to the traveled way in each direction, on both sides of the river. If acquiring MASW data along the yellow traverse on the east side and along the eastbound roadway is problematic, the traverse should be moved to the base of the slope (orange line). If site conditions allow, Active and Passive data can be acquired along traverses beneath the bridge structures (green lines).

MoDOT - Bridge 3

County: Cole.
Roadway: Route M/J over US50/63.
MoDOT Structure Number: A8509.
AADT: 9,500.
Coordinates: Latitude 38.519484°, Longitude -92.050083°.
Site description: Two-lane overpass across a divided highway; wide shoulders on the westbound and two eastbound lanes; asphalt over concrete pavement. Exposed bedrock below the overpass.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the roadside.
- Option 2 (yellow lines): if Option 1 is not feasible, acquire Active and Passive data in the median.
- Optionally, acquire Active and Passive data along traverses (blue lines) on the shoulder or in the traveled way of the overpass, using a 5-foot spacing. Data acquired at these locations can be also used to evaluate the fill material rigidity.

MoDOT - Bridge 3 site. Recommended placement of MASW traverses. Option 1 (red lines) – Active and Passive data are acquired in the roadside. Option 2 (yellow lines) - Active and Passive data are acquired in the median. Optionally, Active and Passive data can be acquired along traverses (blue lines) on the shoulder or in the traveled way of the overpass.

MoDOT - Bridge 4

County: Cole.
Roadway: Algoa Rd over Moreau River.
Cole County Structure Number: 2180036.
AADT: 549.
Coordinates: Latitude 38.554907°, Longitude -92.093832°.
Site description: Two-lane bridge; narrow or no shoulders; asphalt surface pavement. Limited ROW. A railroad bridge is present to the north.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the roadside.
- Option 2 (yellow lines): if Option 1 is not feasible, acquire Active and Passive data in the traveled way or shoulder. The use of geophone base plates will be required. Lane closure may be required. Data at both west and east traverses can be acquired in one lane (e.g., eastbound) to minimize lane closure time.
- Optionally, acquire Active and Passive data along traverse (blue line) along the gravel road, using a 5-foot geophone spacing.
- Avoid placing a traverse (white line) at locations where utilities are present. At this location water, gas, communication, storm sewer and overhead electric utility lines are present, that can significantly reduce MASW data quality and interpretability.

MoDOT - Bridge 4 site. Recommended placement of MASW traverses. Option 1 (red lines) – Active and Passive MASW data are acquired using a 5-foot and 10-foot spacing, in the roadside. Option 2 (yellow lines) - acquire Active and Passive data in the traveled way or shoulder. If the site conditions allow, acquire Active and Passive data along the gravel road, using a 5-foot geophone spacing. Placing a traverse (white line) at locations with utilities must be avoided.

MoDOT - Bridge 5

County: Osage.
Roadway: Route T over Maries River.
MoDOT Structure Number: A1840.
AADT: 580
Coordinates: Latitude 38.392743°, Longitude -91.991238°.
Site description: Two-lane bridge; narrow or no shoulders; asphalt surface pavement. Limited and sloped ROW.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the traveled way. The use of geophone base plates will be required. Lane closure will be required. Data at both west and east traverses can be acquired in one lane (e.g., eastbound) to minimize lane closure time. Avoid perpendicular traverses due to the terrain limitations. Due to site limitations no other options for traverse placement are recommended.

MoDOT - Bridge 5 site. Recommended placement of MASW traverses. Option 1 (red lines) – acquire Active and Passive data using a 5-foot and 10-foot spacing, in the traveled way.

MoDOT - Bridge 6

County: Osage.
Roadway: Route W.
MoDOT Structure Number: Existing single cell box culvert, no structure number.
AADT: less than 400.
Coordinates: Latitude 38.526052°, Longitude -91.874121°.
Site description: a future bridge in the rural area. Two-lane road; narrow or no shoulders; asphalt surface pavement. Limited and sloped ROW.
Recommended MASW survey parameters (refer to the image below):

- Option 1 (red lines): acquire Active and Passive data using a 5-foot and 10-foot spacing, in the roadside, on both sides of an existing culvert.
- Option 2 (yellow and green lines): if Option 1 is not feasible, acquire Active and Passive data in the traveled way or shoulder. The use of geophone base plates will be required. Lane closure may be required. Shift the traverses, if necessary, to avoid subsurface features, such as culverts, if possible. The southern traverse in the traveled way (green line) is shortened to use 5-foot spacing only to maintain the traverse straightness.
- If the site conditions allow, acquire Active and Passive data along a traverse (blue line) perpendicular to the roadway, using a 5-foot spacing. Site access authorization may be required.

MoDOT - Bridge 6 site. Recommended placement of MASW traverses. Option 1 (red lines) – Active and Passive MASW data are acquired using a 5-foot and 10-foot spacing, in the roadside. Option 2 (yellow lines) - acquire Active and Passive data in the traveled way or shoulder. If the site conditions allow, Active and Passive data can be acquired along a traverse (blue line) under the bridge structure using a 5-foot spacing. Active and Passive data along a traverse (blue line) perpendicular to the roadway, using a 5-foot spacing.