Purpose

For a long time, users of NDT systems have wished for a rapid, easy to use method for rapid screening of the integrity of structures. The **s´MASH** impulse-response test system fulfills this wish. The idea is to quickly screen a structure for flaws and identify suspect areas for subsequent detailed investigation, e.g. by the impact-echo method (using **DOCter**, or **Mirador**), ultrasonic-echo testing (using **MIRA**), or by invasive inspection with drilled cores (using **CORECASE**).

With the **s´MASH**, rapid evaluation can be conducted for:

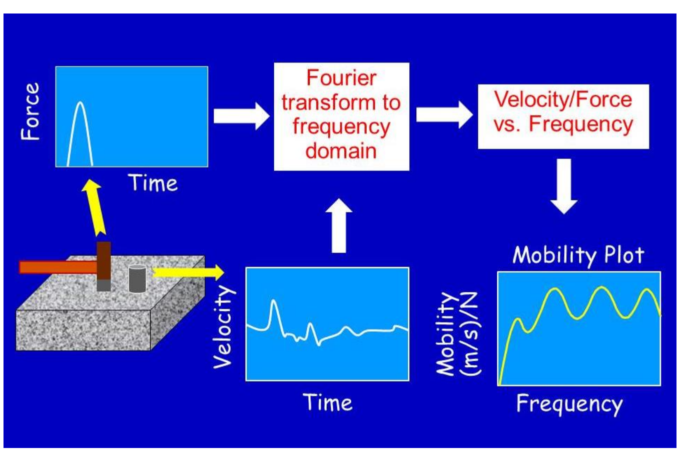
- Detecting voids beneath concrete slabs in highways, spillways, and floors
- Detecting curling of slabs on ground
- Evaluating the integrity of anchoring systems of wall panels
- Locating delaminations and honeycombing in bridge decks, slabs, walls and large structures such as dams, chimney stacks, and silos
- Detecting the presence of damage due to freezing and thawing
- Detecting the presence of alkali-silica reaction (ASR)
- Detecting debonding of asphalt or concrete overlays and repair patches from concrete substrates
- Evaluating the effectiveness of the load transfer system in transmitting forces across joints in concrete structures

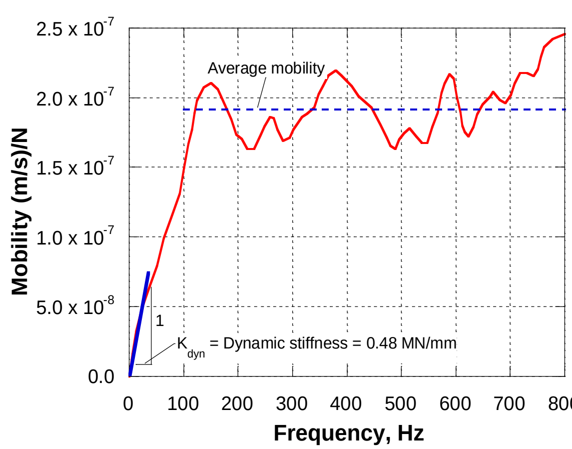
The application of impulse-response to plate-like structures is governed by ASTM C1740, "Standard Practice for Evaluating the Condition of Concrete Plates Using the Impulse-Response Method."

Principle

The **s´MASH** uses a low-strain impact, produced by an instrumented rubber tipped hammer, to send stress waves through the tested element. The impact causes the element to vibrate in a bending mode and a velocity transducer, placed adjacent to the impact point, measures the amplitude of the response. The hammer load cell and the velocity transducer are connected to a portable computer with **s´MASH** software for data acquisition, signal processing, data display, and data storage.

As shown below, the time histories of the hammer force and the measured response velocity are transformed into the frequency domain using the fast Fourier transform (FFT) technique. The resultant velocity spectrum is divided by the force spectrum, to obtain the **mobility** as a function of frequency. An example of a mobility plot for a solid concrete plate-like member is given in the plot on the right.

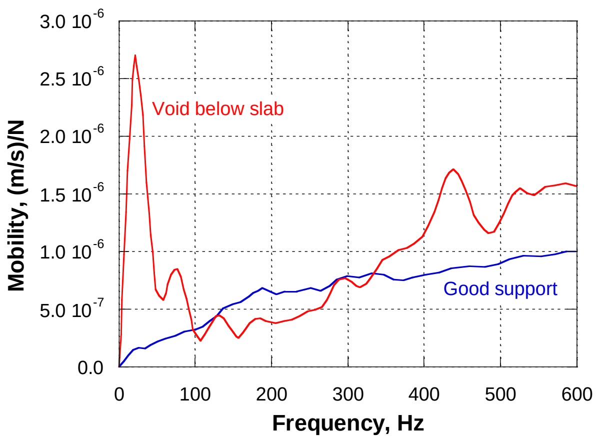


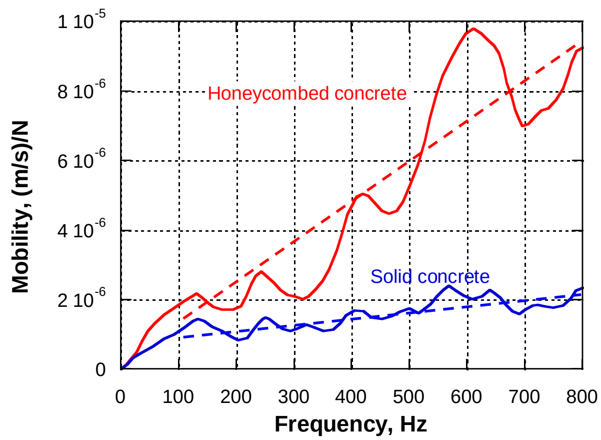


Mobility is expressed in units of velocity per unit force, such as (m/s)/N, and is an indicator of the relative flexibility of the tested element, which is a function of its thickness, elastic modulus, support conditions, and presence of internal defects.

The parameters from the mobility plot that are used for integrity evaluation are:

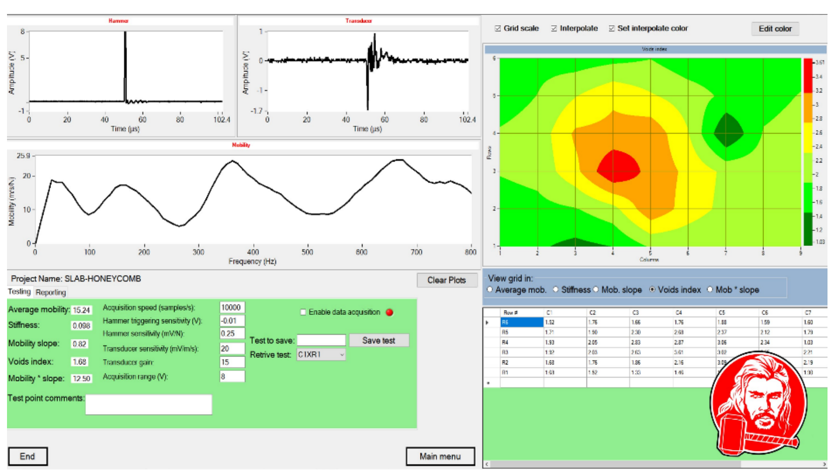
- **Average mobility.** The average value between 100 to 800 Hz on the mobility spectrum (dotted blue line in previous figure).
- **Dynamic stiffness.** The inverse of the initial slope of the mobility plot from 0 to 40 Hz (the blue line in previous figure). This value is also an indicator of the relative quality of the concrete, the relative thickness of the member, the relative quality of the subgrade support for slabs-on-ground, and of the support conditions for suspended structural slabs and walls.
- **Mobility slope.** The slope of the fitted straight line between 100 to 800 Hz. A high mobility slope has been found to correlate with locations of poorly consolidated or honeycombed concrete in plate-like structures (right image below).
- **Voids ratio.** The ratio of the amplitude of the low frequency peak to the average mobility. A high ratio has been found to correlate with poor support conditions or voids that may exist beneath concrete slabs bearing on ground (left image below).





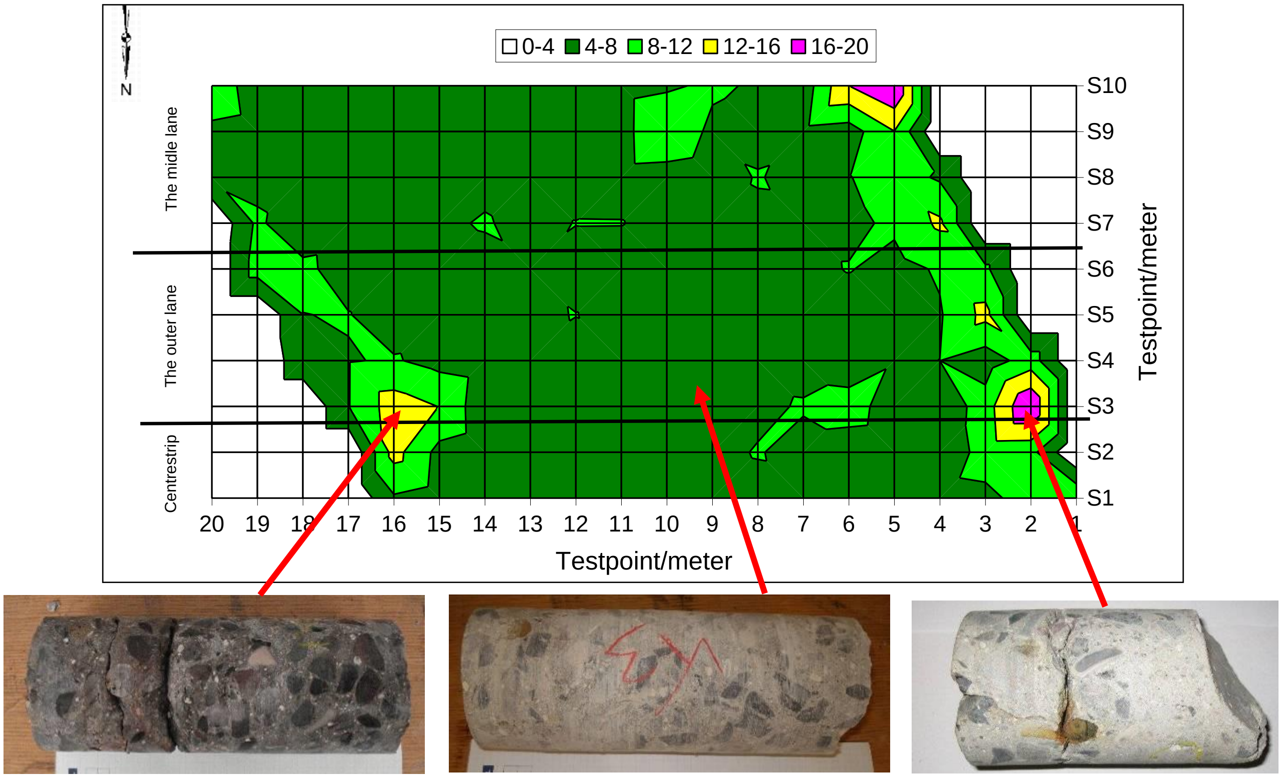
Testing is performed on a grid of points marked on the surface. The **s'MASH** software constructs color contour plots of the various parameters, from which it is easy to identify anomalous regions of the structure that merit further investigation. This is done on-site after the testing has been completed, producing immediate information on the presence of anomalies.

Test Examples



Shown on the right is the result of one test as displayed on the computer with the **s'MASH Thor** software. The top left window is the force-time curve obtained from the impact of the instrumented hammer. The top right window shows the velocity-time curve obtained from the geophone in contact with the concrete surface. The plot in the middle window is the mobility spectrum obtained from the previous two waveforms. The lower left quadrant shows the various parameters calculated from the mobility plot. The top right window shows the contour plot obtained on the defined testing grid and below, the table shows the individual values of the different parameters at each test point.

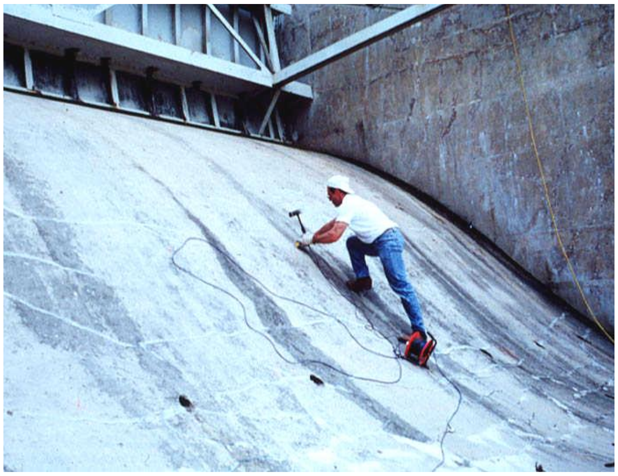
The data can also be exported for a more detailed analysis (e.g., to MS Excel). Below is the contour plot in Excel of the average mobility from **s'MASH** tests performed on the soffit of a bridge slab that was suspected of containing delaminations. Tests were performed on a 1 × 1 m grid. Based on the contour plot, cores were drilled at three locations: (1) a region of low mobility, (2) a region of intermediate mobility, and (3) a region of high mobility. The cores confirmed that low mobility (rigid response) corresponded to a sound slab and higher mobility (flexible response) corresponded to the presence of delaminations.



Application examples

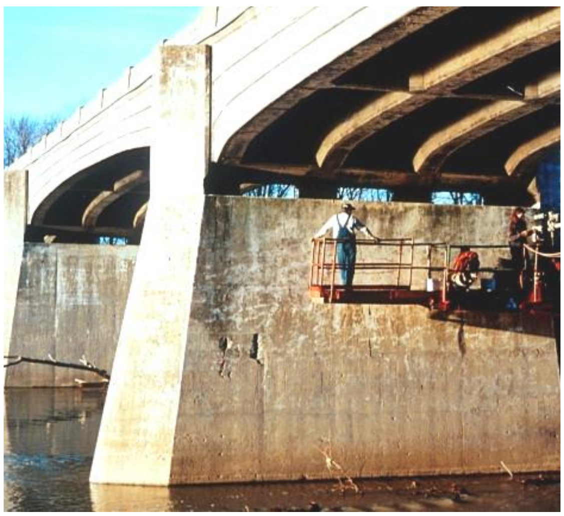
Testing for voids behind tunnel lining

Testing for delaminations in bridge deck



Testing for delaminations in dam spillway

Testing for tightness of joints of concrete tank



Testing for honeycombing and delaminations in bridge piers

Testing for voids below industrial floor

Testing for anchor integrity for granite panels in high-rise building

Testing for delaminations in asphalt covered concrete pavement

s'MASH Specifications

- Data Acquisition System:
  - 2 channels, 4 MB/channel
  - 8 bits resolution, 50 MHz bandwidth
  - -5V to 5V Input Voltage Range
  - USB interface
- Omni-directional (360°) dry contact geophone transducer
- Electronic impact hammer with external force sensor
- Windows OS based **s'MASH Thor** software for real-time waveform displaying and creation of contour plots for visual representation of average mobility, mobility slope, dynamic stiffness and voids ratio
- Operating conditions: Temperature: -10 to 50 °C, RH ≤ 95 %

s'MASH Ordering Numbers

s'MASH-4000 Kit

Item	Order #
Instrumented impact hammer with certificate	SMASH-4000-10
360º transducer with certificate	SMASH-4000-50
Belt box extension with 3 m cable	SMASH-4000-90
User Manual	SMASH-4000-100
Laptop computer with **s´MASH** software installed	s´MASH-4000-200
USB flash drive with **s´MASH** software	s´MASH-4000-210
Data acquisition box	s´MASH-4000-220
110-220V AC adaptor	s´MASH-4000-240
Attaché case	s´MASH-4000-110

The acquisition box can also be used for **DOCter** impact-echo testing as a combined system.

A training course is offered separately, covering the theoretical background of impulse-response testing, testing methodology, testing cases from a variety of structures and hands-on training on testing with the **s´MASH**.