GERMANN INSTRUMENTS A/S, Emdrupvej 102, DK-2400 Copenhagen, Denmark

DOCter Impact-Echo Testing cases

1. Delaminations in anchor block walls

The 600 mm thick walls of two anchor blocks of a sea structure suspension bridge had during construction suffered cracking due to freezing of water left standing in the cooling tubes installed in the walls to avoid thermal cracking during hardening.

In a pilot study radar and impact-echo was evaluated for detection of the delaminations. Only impact-echo proved to be successful and was subsequently used to detect the extent of the delaminations as well as the depth of the defects in four critical areas - each 60 meters by 7 meters - above the sea level on the vertical faces of the anchor block. Testing was done in very rough winter conditions.

Following the testing, 50 cores were extracted. All the impact-echo findings were confirmed in delaminated as well as in solid areas. The cracking detected was subsequently injected.

2. Voids below a sludge basin

Shortly after completion of a sewage plants sludge basin rain fell heavily for three weeks. The rain penetrated the surrounding soil, lifted the basin and partly washed away the sand bed material below the fiber reinforced concrete bottom plate. Before the basin could be taken into operation the voids below the bottom plate needed to be detected and injected.

Radar and impact-echo was initially attempted used for detection of the voids. Only impact-echo proved to be successful.

Testing with impact-echo was performed on the entire plate, 65 meters by 6 meters.

Six major areas were detected as voided. Cores were drilled out for confirmation.

Injection with a pressurized mortar took place through the cored holes until the bottom plate was lifted 1 mm. Finally, the bottom plate was re-tested with impact-echo and no voids were detected. The sludge basin was put into service.

3. Debonding of tile lined concrete vessels

The concrete vessels for pulp production in paper mills are tiled on the outside and the inside on the 300 mm walls. The inside tiles protects the concrete as the pulp mass is slightly acetic. Traditional testing for debonding of the inside tiles is made by hammer tapping the tiles after the vessel is closed down and emptied for pulp mass. Such an inspection procedure is very costly as the pulp production needs to be shot down for 3-4 days.

With the vessel in service impact-echo was used from the outside of the vessel to detect the debonding of the inside tiles.

Detected loose tiles on the inside were confirmed by coring. Similarly, areas found solid by impact-echo were cored and found to be solid.

An impact-echo testing program was set up for regular inspection of vessels in service, involving considerable savings to the owner of the paper mills compared to traditional testing.

4. Delaminations of a highway bridge deck

The bridge deck of a highway bridge had been subjected to de-icing salts during the winter for 15 years. The deck, 30 meter long and 12 meter wide, had a 300 mm concrete slab with an 50-100 mm asphalt overlay and a bituminous membrane in between.

Impact-echo detected the areas where debonding of the membrane had taken place, and, in addition, zones with delaminations in the concrete slab caused by chloride induced corrosion at the top reinforcing steel as well as at the bottom steel. Testing was performed partly from the top surface and partly from the bottom of the slab.

A limited number of cores confirmed the impact-echo test results.

A repair program was undertaken involving installment of a new asphalt/membrane overlay after localized repair of the concrete slab in the corroding zones had taken place.

5. Honeycombing in bridge supporting walls

Two supporting walls, 60 meters long and 5 meters high, of a major highway bridge were cast with a high performance concrete. After removal of the formwork the surfaces revealed a number of honeycombs, which were repaired by the contractor.

The owner of the bridge wanted to test the integrity of the 500 mm thick walls before acceptance. Impact-echo was selected for the testing.

The testing performed revealed two locations with honeycombs, otherwise the walls were evaluated as solid. The integrity of the walls was accepted by the owner.

In addition, impact-echo found an 8 mm bituminous membrane installed on one face of one of the walls against the earth-fill. This membrane was not indicated on the drawings. Installment had been made by the contractor to avoid water intrusion from the earth-fill.

6. Cracking in two tunnels caused by ASR

Two 25 years old tunnels carrying railway tracks suffered from ASR (Alkali Silica Reactions). Prior to upgrading the tracks for high speed trains the extent of the cracking needed to be established, in particular to clarify if delaminations had occurred.

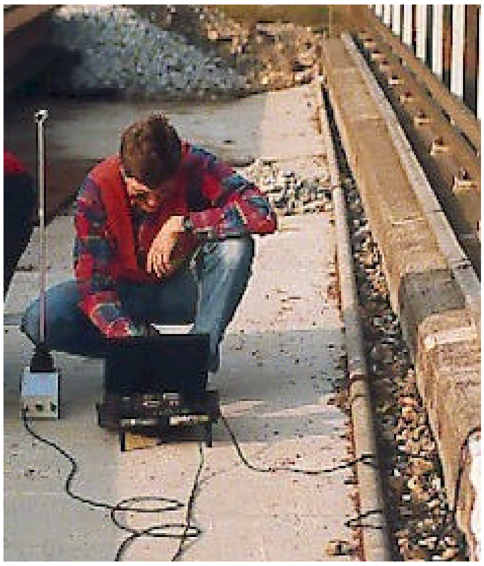
Impact-echo was performed. Three classes of signals were detected, solid concrete, concrete with multiple smaller cracks and one area close to a deck edge exhibiting a major reflection surface at a depth of 180 mm.

Coring revealed the reflection surface to be caused by a cast-in 40 mm in diameter rubber tube. The tube was not indicated on the drawings.

Coring also confirmed the solid concrete found to be solid and the concrete with multiple reflections to contain 5-30 mm long cracks, predominantly parallel to the surface.

An intended strengthening program was decided not to be carried out.

7. ASR delamination of a railroad bridge deck



A 1 meter thick reinforced concrete bridge deck 30 years old, carrying a rail track, suffered from ASR. The span of the deck was 25 meters.

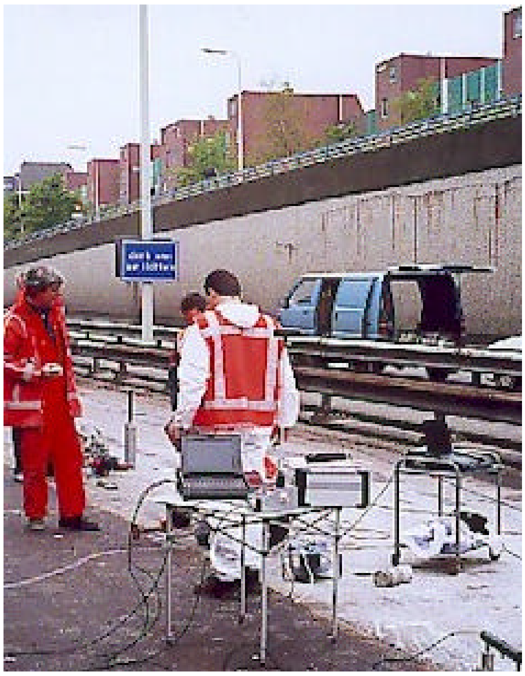
Impact-echo was used to detect the integrity of the slab.

A horizontal crack at mid-depth in the deck was detected across virtually the entire span.

The crack was confirmed by coring.

The bridge was judged unsafe and was demolished. During demolition the lower half part of the slab came down in its entire length.

8. Delaminations near joints of highway slabs



The highway consisted of heavily reinforced 0.8 – 1.2 meter thick concrete slab sections, each 20 meter long and 16 meter wide. The slabs had a 100 mm dense asphalt overlay installed.

The slabs had heavy side walls. The structure was constructed below ground water level with a water stop installed in the joints. A bituminous material had, furthermore, been applied in the 2 mm wide joints between the slabs. The slabs were prevented from floating by connection to a large number of piles driven into the substrate.

The slabs near the joints needed to be tested for delaminations prior to construction of a high rise building on top of the side walls of the highway.

The slabs were tested with impact-echo in an area extending 2 meters on each side of 16 selected joints.

The slabs close to 9 of the joints were evaluated as solid. Delaminations were indicated in the remaining slabs with depth indications between 111 mm to 589 mm.

Coring was performed, one on each side of the joints tested. The impact-echo findings proved to be 95% correct.

The delaminated slabs were repaired by removal of the concrete past the delaminations and casting of a new concrete well bonded to the concrete substrate.

9. Voids in injected cable ducts

Impact-echo was performed on tendon ducts in a post-tensioned concrete tunnel deck after injection of the ducts with a cement grout. The testing was made at the highest top point of the ducts in the middle of the 40 meters long span of the deck. The length of the tested cable ducts was 4 meters.

The 1 mm thick steel ducts had a diameter of 80 mm and were positioned 120-190 mm deep into the reinforced slab.

The impact-echo test signals were classified in three types of signals, fully injected ducts, partially injected ducts and empty ducts.

The test results were confirmed visually at six locations, two in each class, by inserting an endoscope through the holes of the top filling tubes.

Thirty cable ducts were tested with impact-echo of which 21 were evaluated as solid. The remaining ducts, partially injected or empty, were re-injected with grout from the top tubes.

10. Steel liner corrosion in a containment wall

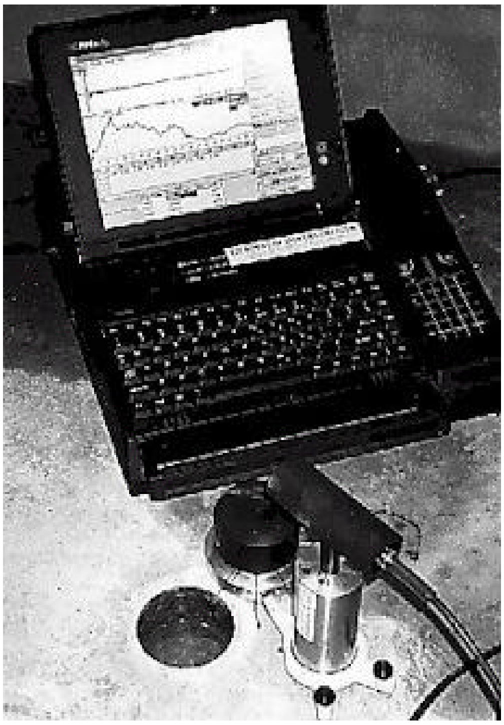
The steel liner in a nuclear plants containment wall was tested with impact-echo for corrosion in the vicinity of the welding joints between the liner and the steel tubes containing the electrical outlets.

The 5 mm thick steel liner was positioned 20 cm deep in the 1 meter thick wall.

Corrosion of the liner cause an air gap and a reflection frequency of approximately 10 kHz for the 20 cm deep air gap. Similarly, if no corrosion has occurred, the impact-echo P-wave will be reflected at a frequency of 5 kHz from the steel liner.

The impact-echo testing mapped quickly the corroding areas of the liner. Coring confirmed the test results. The liner was repaired after removal of the 20 cm cover concrete in the corroded areas.

11. Debonding of composite structures



The 250 mm reinforced concrete slabs and decks of a waste water plant had been overlaid by a 70 mm – 150 mm reinforced concrete layer to ensure proper drainage of any water spillage. A bonding agent had been applied between the layers.

The specifications called for Bond-Testing to be performed to make sure a proper adhesion between the layers had been achieved.

Prior to performing the time consuming and destructive Bond-Testing, impact-echo was used to point out areas not bonded, quickly and non-destructively.

Coring at a couple of locations in non-bonded areas confirmed the impact-echo test results

In the areas found by impact-echo to be bonded, the Bond-Tests were performed subsequently.

12. Integrity of a fire damaged deck

An intensive fire broke out in a high voltage transformer room of an industrial building complex. The 300 mm reinforced concrete deck and walls were heated vigorously for about one hour.

Surface opening cracks showed up, especially on the underside of the deck, after cooling of the structure.

The deck carried a cooling tower in operation. The owner needed urgently to have the deck investigated non-destructively for depth of the surface opening cracks as well as for delaminations. Impact-echo was chosen.

The wave speeds of the deck ranged from 2200 m/s to 2800 m/s. The depth of the surface opening cracks were measured between 19 mm to 109 mm. Delaminations were detected at depths ranging between 83 mm and 270 mm.

The deck was subsequently supported and strengthened by a steel structure.

13. Voids below two layers of reinforcement

After casting of a 650 mm thick lightweight concrete roof, testing was performed with impact-echo to detect air voids beneath the heavy top reinforcement layers.

The concrete cover was 50-60 mm. At the top of the roof two layers of 32 mm reinforcement were present, closely spaced.

Prior to testing, the P-wave speed of the lightweight concrete was measured on the surface using two transducers spaced 300 mm. The P-wave speed was measured to be 2500 m/s.

Impact-echo detected, using a 5 mm impactor, the voids at a depth of 120 mm from a measured frequency of 10.4 kHz.

The solid parts of the roof were evaluated by means of the solid frequency at 1.92 kHz and the absence of the 10.4 kHz void peak in the frequency spectrum.

14. Thickness of concrete pavement

The thickness of a concrete road pavement was evaluated with impact-echo.

Prior to testing, the acoustic impedance difference between the pavement and the substrate was checked to be sufficient for P-wave reflection to occur from the interface.

The P-wave speed C_p was measured for every 10 meter on the surface using two transducers spaced 300 mm. Based on the P-wave speed the thickness was evaluated from the solid frequency f_s measured, using the equation $T = C_p/2f_s$.

800 measurements were performed. The thickness estimated was at 8 locations compared to the actual thickness. The thickness measured by impact-echo was within ?5 mm from the actual measured ones.

The 200 mm design thickness of the pavement was met by 92% of the test results.

15. Testing for voids in sewage tubes prior to installing the tubes

Fourteen tubes, each with a dimension of 2.25 meter in diameter, 2.25 meter long and 23 cm thick, were tested for flaws prior to putting the tubes into operation.

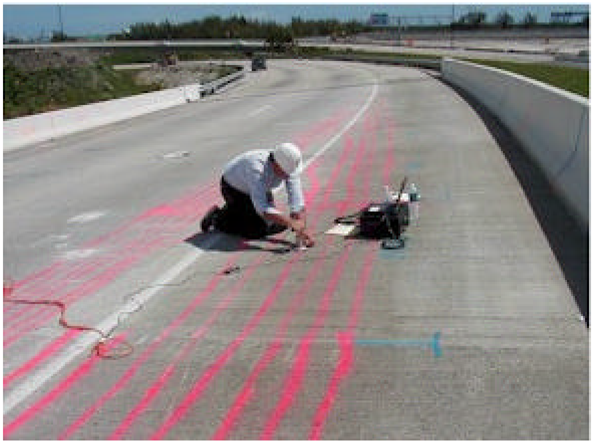
The 23 cm thick tube walls were reinforced in two layers, positioned 50 mm from the outer and inner surface. The tubes had been cast standing vertically in steel forms.

Each tube was tested from the inside in grid containing 20 test points.

Of the fourteen tubes only one was found to be solid, the remaining thirteen tubes all contained varying degrees of delaminations around the top steel of the bottom steel layer. Three cores taken in one of the tubes confirmed the defects found non-destructively by the DOCter Impact-Echo Test System.

The cause of the defects is believed to be premature stripping of the steel shutters. The consulting engineer rejected all thirteen tubes.

Testing for voids in steel cable ducts in a bridge deck



The cable ducts were located accurately by means of radar. Subsequently, impact-echo was used to detect the voids. The wave speed of the concrete was found to be 3,820 m/s using the Longship.

Testing was performed above the cable ducts. A number of voids were detected. At one location the concrete was removed and the depth to the void of 123 mm, estimated by impact-echo, was found to be 122-125 mm deep. Opening of the duct revealed strands not protected by grout. The strands showed signs of corrosion.