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Expert System Development for Acoustic Analysis in Concrete Harbor NDT

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1. Introduction

Port and Maritime Organization of Iran (PMO), in connection with a research project at Information Technology Mechatronic Offshore research and development cooperative society (ITMO), has added another dimension to its subsea inspection activities by introducing new methods of NDT and expert system for condition monitoring and assessment of concrete structures. ITOM provided a wide range of special and advanced techniques for most aspects of subsea and underwater. The repair of concrete structures under water presents many complex problems.

The harsh environmental conditions and specific problems associated with working underwater or in the splash zone area causes many differences. Proper evaluation of the present condition of the structure is the first essential step for designing long-term repairs. To be most effective, evaluation of the existing structure requires historical information on the structure and its environment, including any changes made to the structure over time, and the records of periodic on-site inspections or repairs.

Reduction of the human experts involvement in the diagnosis process has gradually taken place due to the recent developments in the modern Artificial Intelligence (AI) tools. AI is a research field between psychology, cognitive science and computer science with the overal goal to improve reasoning capabilities of computers. Artificial Neural Networks (ANNs), fuzzy and adaptive fuzzy systems, and expert systems are good candidates for the automation of the diagnostic procedures and e-maintenance application (Filippetti, et al., 1992 & Hedayati 2009). It is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete. The tests available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test.

The present work surveys the principles and a criterion of the diagnosis signal processing and introduces these achievements to an expert system technique. In this paper adoption of a new sensor is discussed and experimental results are presented for an expert system application, based on the concept of spectrum and cepstrum analysis of detected signals and the method of measuring defected parts of subsea concrete without disturbing their structures for a suspected part of the quay wall. A transducer using the principle of vibration sensors has been tried and considered to be suitable for measuring any probable damage due to irregular phenomena such as voids, mix separations and cracks on the suspected superficial portion of the subsea concrete structures. Such transducers are proposed to be the basis for condition monitoring of armored steel structure in the subsea concrete by analyzing the change of vibration sensed by related transducers of the testing probe.

It is a common observation that, when there were voids, mix separation or crack the reflected waves detected by the receiving sensor were different than those from the perfect areas. The results showed that the analysis of surface wave testing has the ability to detect changes in the constructed structures. The vibration signals which appear on the perfect part of structure, give a characteristic vibration signature. This signature provides a base line against which future measurements can be compared.

It is important to note that similar concrete structure in good condition will have similar vibration signature differing only in respect of their constructional and structural conditions tolerances.

2. Development of expert system

Knowledge built in to an expert system may originate from different sources. The prime source of knowledge for developing an expert system should be the domain expert. To design and develop knowledge based expert system, the specific knowledge domain or the subject domain must be acquired. The knowledge domain is to be organized so that the information can be structured in the computer program for effective use. In this respect, a knowledge engineer usually obtains knowledge through direct interaction with the expert. Fig.1 illustrates the process of data procurement for generating the knowledge base.

The domain of reinforced concrete diagnosis serves as a good example in the application area for:

1. Examining the different means currently used to store and transfer information,
2. The knowledge acquisition and knowledge engineering processes required for extracting that information and capturing it in a knowledge based expert system, and
3. Showing how the resulting knowledge based expert system provides an integrated framework for combining specifications, data, and models (Graham-Jones &Mellor 1995).

Fig. 1. Experts appropriate evaluations, assessment, data logging and generating the information for knowledge base in the Shid-Rajaee harbor

The scope of this research work is to integrate inspections and observations, specifications, standards of practice, and data related to quay-wall concrete structure diagnosis (QCD) and to make full use of the available information in the diagnosis process. Expert System (ES) focuses on integrating inspection of commonly encountered problems, specifications, standards of practice and data, both theoretical and empirical, into one cohesive tool. QCDES is a rule-based expert system which has been developed using the expert system shell. The main advantage of incorporating a modular design in QCDES is to have great flexibility in updating or adding modules in the future. The various modules of system development are represented graphically as follows:

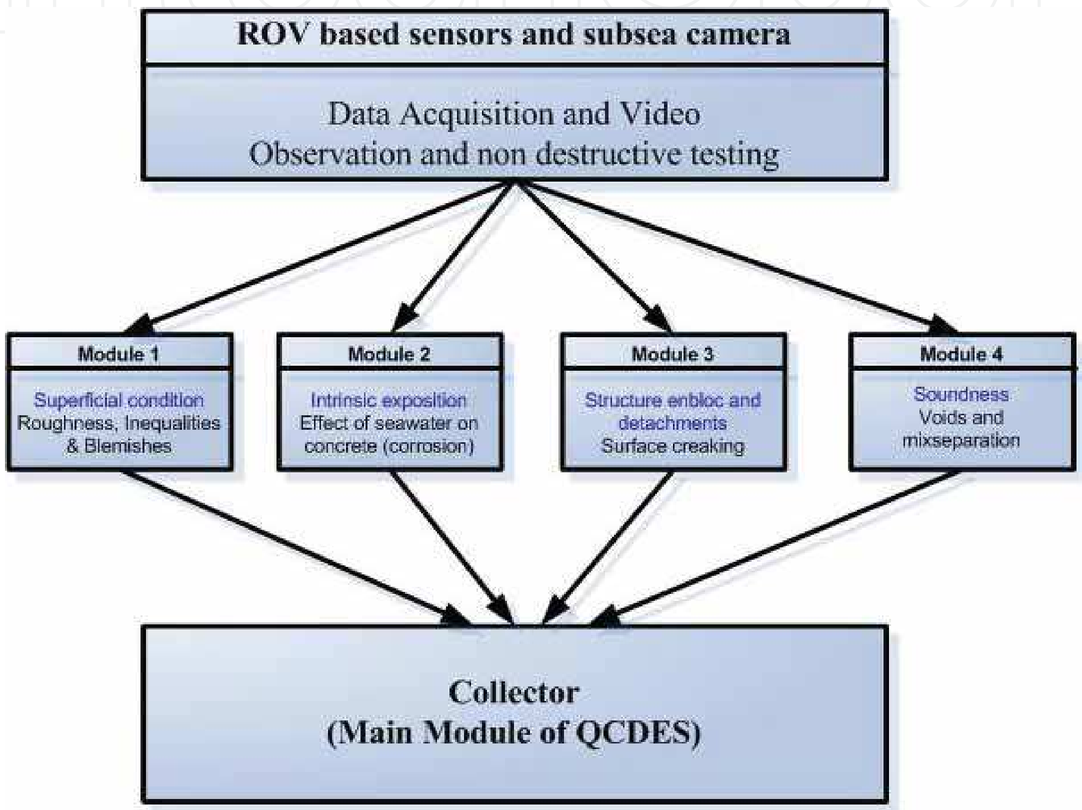

Fig. 2. The QCDES Modules

The development of QCDES has followed the development cycle as follows:

1. Identifying objectives and scope mixseparation
2. Knowledge acquisition (collecting data, reading literature and reports, discussions with domain experts, case studies, etc.)
3. Preliminary planning and choice of system
4. System design and development
5. Testing, validation and trials
6. Reviews and modifications
7. Implementation

3. Study of problem

Inspection of reinforced concrete structures in marine environment is important. The use of NDT techniques in combination with coring may enable one to detect the early onset of corrosion where appropriate steps may be taken to slow down the corrosion process. Such inspection procedures, however, are quite costly as they require experts to conduct the tests and interpret the results. To wait for the appearance of visible signs of corrosion in a structure such as rust stains and/ or cracks before repair will be conducted is not cost effective. The presence of such visible signs is indicative of an advanced stage of corrosion which may require a thorough investigation of the entire structure in order to properly assess the type of repair or rehabilitation needed for the corroded structure.The use of prediction models, specifically, the time to initiate corrosion can provide useful information regarding the early onset of corrosion which allows one to appropriately schedule the required maintenance.

The subject of diagnosis of deterioration and other problems in reinforced concrete structures is indeed huge and enormously wide and of great interest to civil engineers. There are standards for the use of reinforced concrete (British Standards Institution, 1985 &1991). For the purposes of this research work specific domain knowledge relating to common symptoms of cracking, spalling and delamination is needed.

Vibration condition monitoring of harbor concrete structures makes use of vibration analysis for the following purposes:

1. Periodic routine vibration measurement to check their structural condition.
2. Trouble shooting for suspected constructional problems.
3. Check to ascertain that the concrete structure has returned to good operating condition after implementing the reconstruction or repair.
4. Check to enable planning of repair of the harbor concrete structures prior to harbor service shut- down.

Different defects cause the vibration signatures to change in different ways. A changed vibration signature provides a means to determine the source of problem as well as prior warning of the problem itself (Skala & Chobola 2005). This research work is limited to implementing the acoustic signal processing and condition monitoring of concrete structures in the splash zone and underwater portions of structures located in the lakes, rivers, oceans, or ground water.

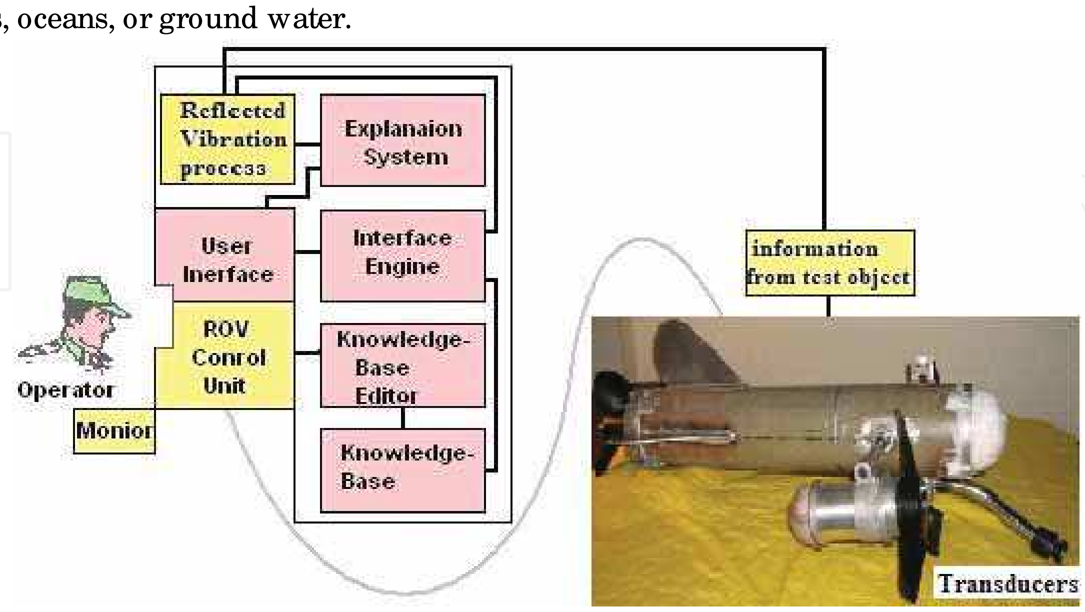

Fig. 3. The most important modules of proposed rule-based vibration signal diagnostic expert system

4. Deciding what action to take

Deciding on the appropriate action to take after a defect has been discovered depends on the potential hazard of the defect, the risk of continued structural deterioration, the technology available to repair the defect, the cost associated with the needed repair, and the intended remaining life of the structure. Following are the possible methods of concrete harbor inspection:

1. Visual inspection
2. Tactile inspection (Inspection by touch)
3. Underwater non destructive testing of concrete (signal processing)

5. Diving technology

Underwater work can be generally classified into one of three broad categories for accessing the work site:

1. Manned diving;
2. One-atmosphere armored suit
3. Manned submarine
4. Remotely operated vehicle (ROV).

The industry standards currently allow a diver using compressed air to work at 10 m for an unlimited period of time. If work is being performed at 20 m, however, the diver can only work for approximately 60 minutes over a 24-hour period without special precautions to prevent decompression sickness. The industry standard upper limit is 30 minutes of work time at 30m in seawater. If these limits are exceeded, precautions must be taken to decompress the diver.

Undoubtedly, the most dynamic growth in a particular underwater platform has been exhibited by Remotely Operated Vehicles (ROVs). ROVs look much like an unmanned version of a submarine. Fig.4 displays the application of the proposed model of ROV, especially equipped for NDT of quay wall in Shahid-Rajaee harbor. Thay are compact devices that are controlled by a remote crew. The operating crew and the vehicle communicate through an umbilical cord attached to the ROV. The crew operates the ROV with information provided by transponders attached to the frame of the ROV. Generally the pilot will maneuver the vehicle as closely as prudent to a point adjacent to the platform and over the work site. ROVs may be launched directly from the surface or from a submarine mother ship. Most ROVs are equipped with video and still photography devices. The vehicle is positioned by ballast tanks and thrusters mounted on the frame. Some ROVs are also equipped with robotic arms that are used to perform tasks that do not need a high degree of dexterity. Vehicles owned by industrial users range in depth capability from 200m to 2400 m; the average is 1300m. Structural investigations of underwater facilities are usually conducted as part of a routine preventive maintenance program, an initial construction inspection, a special examination prompted by an accident or catastrophic event, or a method for determining needed repairs. The purpose of the investigation usually influences the inspection procedures and testing equipment used. Underwater inspections are usually hampered by adverse conditions such as poor visibility, strong currents, cold water, marine growth, and debris build-up. Horizontal and vertical control for accurately locating the observation is difficult. A diving inspector must wear cumbersome life-support systems and equipment, which also hampers the inspection mission.

Fig. 4. The proposed ROV and incorporated diagnostic arm for inspection and NDT of a quay wall in Shahid-Rajaee harbor

Underwater inspections usually take much longer to accomplish than inspections of similar structures located above the water surface. This necessitates more planning by the inspecting team to optimize their efforts. Inspection criteria and definitions are usually established before the actual inspection, and the inspection team is briefed. The primary goal is to inspect the structural elements to detect any obvious damage. If a defect is observed, the inspector identifies the type and extent of the defect to determine how serious the problem may be. The inspector also determines the location of the defect so repair crews can return later to make the repair, or another inspection team can reinvestigate if necessary. Many divers who perform structural inspections do not have specific structural engineering training for this task. In this case, another person with the appropriate engineering background is normally employed to interpret the results of the inspection and make the appropriate evaluations. Moreover the diver using air as the breathing medium can expect some loss of judgement at 30m and a severe loss at depths over 45m owing to inert gas narcosis. Reportedly (Hughes 1972), the diver cannot always recognize the exact relationship of objects with the vertical and horizontal, and an error in judgement of up to 30 degrees may be expected.

6. Cleaning the NDT position

Every NDT device now in use requires that the surface of the structure be cleaned to bare concrete or metal in order to obtain accurate measurements. Depending on the environment, preparatory cleaning can be- and often is a more time consuming chore than the actual testing.

Concrete structures present a special cleaning problem where "clean" is, in fact, governed by how much fouling/ corrosion material can be removed and not harm the parent material of structure. The cleaning chore involves removal of sensible organisms (barnacles, mussels,

tube worms, algae anemones, etc.). The quantity of these organisms on a specific structure varies according to the environment, reproduction rates and other factors. Consequently, it is not possible to predict how many of a particular specie will be present. The depth of fouling organism growth also varies according to the specie. Generally, but not always, below 50-60m the population density decreases and the cleaning problem is considerably less.
Several techniques are used to remove marine growth on the quay wall structure. These include hydraulic grinders, brushes, scrapers, needle guns and high pressure water jets. In the present work the ROV based water jetting technique is employed for perfect surface cleaning of concrete and removal of marine growth. For NDT purposes of quay wall, the structure must be cleaned to at least bare concrete, any protrusions left on the surface can introduce an error into the results, and conversely, any abrasion causing removal of parent material of quay wall produces the same affect.

7. Underwater non-destructive testing of concrete

Among structures vulnerable to chloride attack include ports, bridges and other marine infrastructures. The economic importance played by these structures demands careful attention in the study of chloride ion penetration phenomena so as to minimize its damaging effects and extend the service life of these important structures. Studies of non-destructive testing (NDT) of concrete have shown that the following techniques and instruments are applicable to underwater work (Kornska et al 2003, Hedayati 2004). Six elementary types of underwater NDT and monitoring techniques are identified as: Visual, Magnetic, Sonic & Ultrasonic vibration and Radiography.
General surveys for condition monitoring of offshore concrete structures consist primarily of visual inspection and testing for:

1. Broken or bent members
2. Cracking and pitting
3. Corrosion
4. Marine fouling
5. Debris accumulation
6. Corrosion system effectiveness
7. Scouring at plateform base & Sedimentation wash

Since repair and rehabilitation of corroded reinforced concrete marine structures draw significant portion of the budget for infrastructures, the capability to accurately predict deterioration levels due to seawater attack, especially the time-to initiate corrosion, in reinforced concrete structures exposed to chloride-induced corrosion can translate to major economic savings and possible extension of service life of a member or a structure.

7.1 Visual inspection

The most obvious limitation to visual inspection is water clarity. For purposes of this discussion it will be assumed that water clarity is sufficient to allow viewing of at least 1m.The diver is capable of carrying out a survey by feel along in zero visibility, but it is difficult, if not impossible, to qualitatively assess the accuracy of this technique, particularly when the diver is wearing gloves and is uncertain of his location on the structure.

Visual inspections are carried out by divers, submersibles and ROV's. The ability of the human eye to detect cracks, bends, or concrete failure in quay wall structural members or any underwater structure varies considerably, depending upon which of these capabilities is used and the extent of marine fouling and corrosion which has taken place. If inspection place has not been cleaned visual observations can reveal the following:

1. Presence and nature of debris
2. Scope, depth and general nature of marine fouling
3. Collision or impact damage
4. Degradation (scouring) or aggradation (silting) at the sediment/ water interface
5. Evidence of cracking (at time there is a color change in organisms immediately over a crack)

On a clean quay wall structure visual observations can reveal, in addition to the above:

1. Corrosion of reinforcements or prestressing tendons in concrete (by surface staining and spalling)
2. Hairline cracks
3. Sulphate attack in concrete (by crumbling)
4. Pitting (by surface relief)
5. Local corrosion (by color and relief)

In all of these instances the observations are surficial and dimensional values are approximations.

7.2 Magnetic reinforcing bar locator

A commercially available magnetic reinforcing bar locator (or pachometer) has been successfully modified for underwater use. The pachometer can be used to determine the location of reinforcing bars or any magnetic material in concrete structures, and either measure the depth of concrete cover or determine the size of the reinforcing bar if one or the other is known. The underwater version is designed for diver application, but it has been modified and used from an ROV.

A magnetic field is generated between two poles at either end of a hand-held probe shaped akin to a telephone receiver. A field is created. The meter measures any disturbance caused by magnetic material passing within the magnetic field generated by the probe. The magnitude of the disturbance is indicated on the instrument meter which may be calibrated to read directly in bar size and distance of the reinforcing bar from the probe. A clean surface is required for highest accuracy from the data acquisition system. The technique can be used as a measure of concrete erosion, or as a measure of reinforcement corrosion.

Techniques are available for approximating each variable if neither is known. Laboratory and field tests of the instrument demonstrated that the modification for underwater use had no effect on the output data.

7.3 Radar

Certain types of radar have been used to evaluate the condition of concrete up to 800 mm thick. Radar can detect delaminations, deteriorations, cracks, and voids. It can also detect and locate changes in material. Radar has been used successfully as an underwater inspection tool, and is being developed for possible future use. Radar with the antenna contained in a custom waterproof housing was used in 1994 in conjunction with pulse velocity testing to investigate the structural integrity in a concrete plug submerged 46 m in a water supply tunnel.

7.4 Ultrasonic testing

Ultra sonic NDT methods are employed underwater to detect and locate discontinuities or flaws and to measure thickness in steel, concrete and wooden structures and is capable of detecting internal material defects. (or any material which will transmit vibrational energy).

In the ultrasonic method an electric pulse is generated in the test instrument and transmitted to a transducer which converts the electronic pulse into mechanical vibrations. The vibrations are transmitted into the object being tested where they are scattered, attenuated, reflected or resonated. A portion of this energy returns to the transducer where it is reconverted to electonical energy and transmitted to the test instrument where it is amplified and displayed digitally. Interpretation of the data for defect presence, sizing, and significance must be conducted by highly skilled ultrasonic NDT technicians. The sound frequency emitted by the transducer for metals testing is high, generally in the range of 3.5 to 5 MHz.

Two different test techniques are used in ultrasonic NDT: Resonance techniques and pulse techniques. Resonance techniques are employed for measurement of test object thickness by measuring from one side only. Ultrasonic pulse techniques are used for flaw detection and may be classified as pulse echo wherein a single (transmit/ receive) transducer is used, or through transmission wherein two transducers (one transmitter; one receiver) are employed. For Underwater testing ultrasonic pulse echo signal transducer and techniques are used exclusively.

As stated above, pulse velocity is determined by measuring the time of transmission of a pulse of energy through a known distance of concrete. In addition the measuring methods are divided in two ways: immersion and contact. In immersion testing the transducer is separated from the object but in contact testing the transducer is placed directly against the test object and mostly used in offshore inspection. Many factors affect the results, including aggregate content and reinforcing steel location. The results obtained are quantitative, but they are only relative in nature.

A special form of this technique is the pulse-echo method. The pulse-echo method has been used for the in-place determination of the length and condition of concrete piles.

7.4.1 Echo sounders

Another ultrasonic device, the echo sounders (specialty fathometers), can be useful for underwater rehabilitation work using termite concrete, both to delineate the void to be filled and to confirm the level of the tremie concrete placed. They are also effective in checking scour depth in a stream bed. They consist of a transducer that is suspended in the water, a sending/ receiving device, and a recording chart or screen output that displays the water depth. High-frequency sound waves emitted from the transducer travel through the water until they strike the bottom and are reflected back to the transducer. The echo sounder measures the transit time of these waves and converts it to water depth shown on the display. When an echo sounder is used very close to the structure, however, erroneous returns may occur from the underwater structural elements.

7.4.2 Side-scan sonar

Side scan sonar images have been used to get detailed information about the seafloor (Fig.5). During the last three decades, advanced technologies lead to the increased use of digital collection with side scan instruments. A side-scan sonar system is similar to the standard bottom-looking echo sounder, except that the signal from the transducer is directed laterally, producing two sides looking beams. The system consists of a pair of transducers mounted in an underwater housing, or "fish," and a dual- channel recorder connected to the fish by a conductive cable. In the past several years, the side-scan technique has been used to map surfaces other than the ocean bottom. Successful trials have been conducted on the slopes of ice islands and breakwaters, and on vertical pier structures. Although the side-scan sonar technique permits a broad- scale view of the underwater structure, the broad beam and lack of resolution make it unsuitable for obtaining the kind of data required from local inspections of concrete structures.

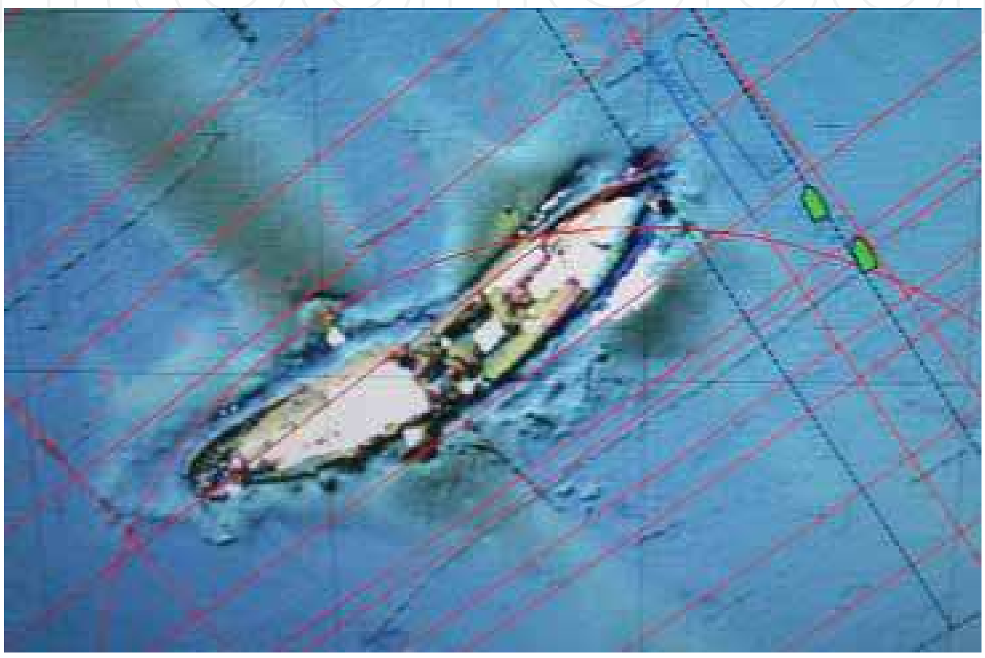

Fig. 5. Application of side-scan sonar in a salvage project and study of bottom protection by authors (Persian Gulf)

7.5 Underwater acoustic profilers

Because of known prior developmental work on an experimental acoustic system, acoustic profiling has been considered for mapping underwater structures. Erosion and down faulting of submerged structures have always been difficult to accurately map using standard acoustic (sonic) surveys because of limitations of the various systems. Sonic surveys, side-scan sonar, and other underwater mapping tools are designed primarily to see targets rising above the plane of the sea floor. Sampling and destructive testing also can be use when other methods are not possible. Produced by impacts on solid material as opposed to disbonded/ delaminated material. Understanding the force-time function aids an inspector's abilities to sonically evaluate a material, as it takes less time for two elastic solids to separate subsequent to a collision. A similar analogy could be made by comparing the effect of walking on a sidewalk to walking in the mud. The sinking phenomenon that one experiences in the mud is similar to the extended time length of impact produced by a delaminated material. The "sinking" of the hammer or coin into the delaminated material results in a plastic deformation of the material, resulting in a duller or hollow sound.

The electronics industry has provided inspectors with equipment that is capable of detecting and recording the sonic wave signals that are produced by an impact. As a result, there are currently several commercially available products available for such signal acquisition. The most common devices for sonic data acquisition are the instrumented hammer and the smart hammer. The instrumented hammer was developed for the airline industry to be used in the detection of anomalies in airplane materials. It measures and records the force-time history and amplitude frequency of an impact via the use of an accelerometer embedded in the head of the hammer. The smart hammer was developed for the shipbuilding industry. This instrument measures and records the sonic response of an impact through a microphone. The microphone uses the sonic data, instead of the force data, to create an acoustic signal. Both impact-force data generators and impact-sound data generators have been proven to generate useful signals for non-destructive sonic testing. The information gained. Fig.6. illustrates the block diagram of proposed non destructive sonic testing system.

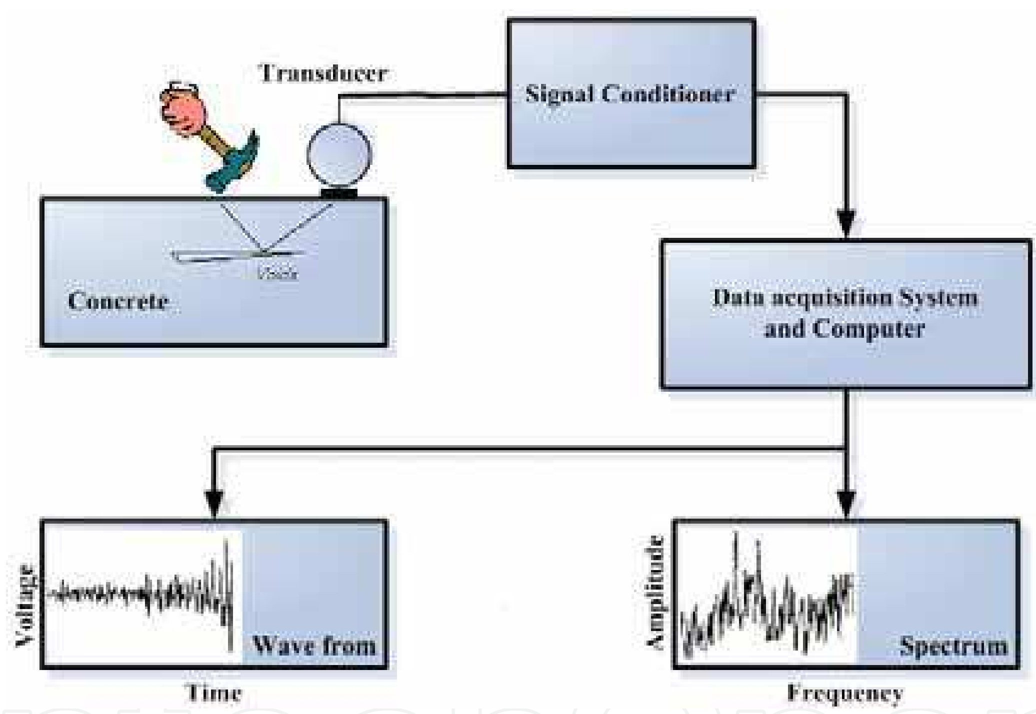

Fig. 6. Schematic diagram showing how impact-echo of proposed system works

7.5.1 Acoustic sounding

Acoustic sounding is used for surveying concrete structures to ascertain the presence of delaminations. Delaminations can be a result of poor concrete quality, debonding of overlays or applied composites, corrosion of reinforcement, freezing and thawing or global softening. The test procedures used for delineating delaminations through sounding include: coin tap, chain drag, hammer drag, and an electro-mechanical sounding device. The purpose of each test is to sonically detect deficiencies in the concrete. The American Society for Testing and Materials (ASTM) has created a standard, ASTM D 4580 – 86, which covers the evaluation of delaminations. The standard describes procedures for both automated and manual surveys of concrete. A major advantage to sonic testing is that it produces immediate results on near surface anomalies. The

effectiveness of sonic testing relies heavily on the user's expertise in signal interpretation and consistency.
Soundings are taken by striking the concrete surface to locate areas of internal voids or delamination of the concrete cover. Although the results are only qualitative in nature, the method is rapid and economical and enables an expeditious determination of the overall condition. The inspector's ability to hear sound in water is reduced by waves, currents, and background noise. Soundings are the most elementary of NDT methods (Wu T et al 2000).

7.5.1.1 Impact hammer

A standard impact hammer (ASTM C 805), modified for underwater use, can be used for rapid surveys of concrete surface hardness. The underwater readings, however, are generally higher than comparable data obtained in dry conditions. These higher readings could be eliminated by further redesigning of the Schmidt hammer for underwater use. Data also can be normalized to eliminate the effect of higher underwater readings.

7.5.1.2 Coin-tap test

This important method of testing the concrete is one of the deepseated and most widely researched ways of sonic testing. The test procedure requires the inspector or operator to tap on the concrete sample with a small hammer, coin, or some other rigid object (impactor) while listening or recording the sound resulting from the impact. Areas of nondelaminated concrete will create a clear ringing sound upon impact while regions of delaminated, disbonded, or softened concrete will create a dull or hollow sound (Fig.7). This change in sonic characteristics is a direct result of a change in effective stiffness of the material. As a result, the force-time function of an impact and its resulting frequencies of an impact differ between areas of good and poor quality concrete (Cawley & Adams 1988)

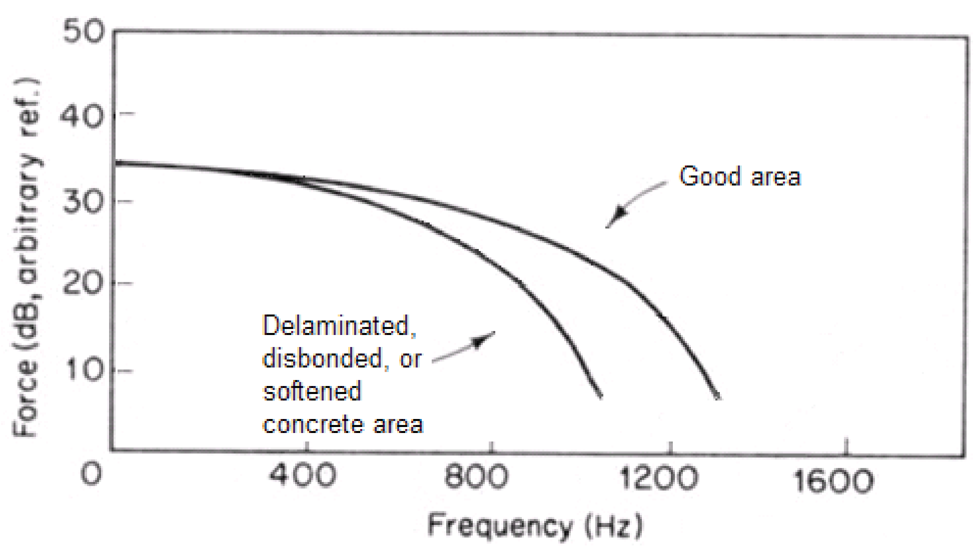

Fig. 7. Spectra of time histories for a typical tap test results

8. Spectru & cepstrum analysis

The vibration spectrum can be expressed on a linear frequency scale with constant bandwidth. This type of spectrum provides fine resolution at higher frequencies but a poor resolution at lower frequencies. Whereas a constant percentage bandwidth analyzer uses logarithmic frequency scale and cover three decades with equal resolution. It is for this reason that the best analysis method for the comparison of spectra and fault detection is the use of constant percentage bandwidth with a logarithmic frequency scale (Farid Uddin 2003).

Cepstrum analysis is carried out to identify a series of harmonics or sidebands in the spectrum. Cepstrum may be considered to be the frequency analysis of frequency analysis. The power cepstrum is defined as:

$$C_p(\tau) = F^{-1}\{log\, F_{xx}(f)\} \tag{1}$$

Where $f_x(t)$ is the time signal and its Fourier transform is

$$F_{xx}(f).$$

Fig. 8. shows a spectrum from a concrete structure in its deteriorated condition. It contains several harmonics. It is not possible to detect from this spectrum that there are two series of harmonics indicating two different phenomena.

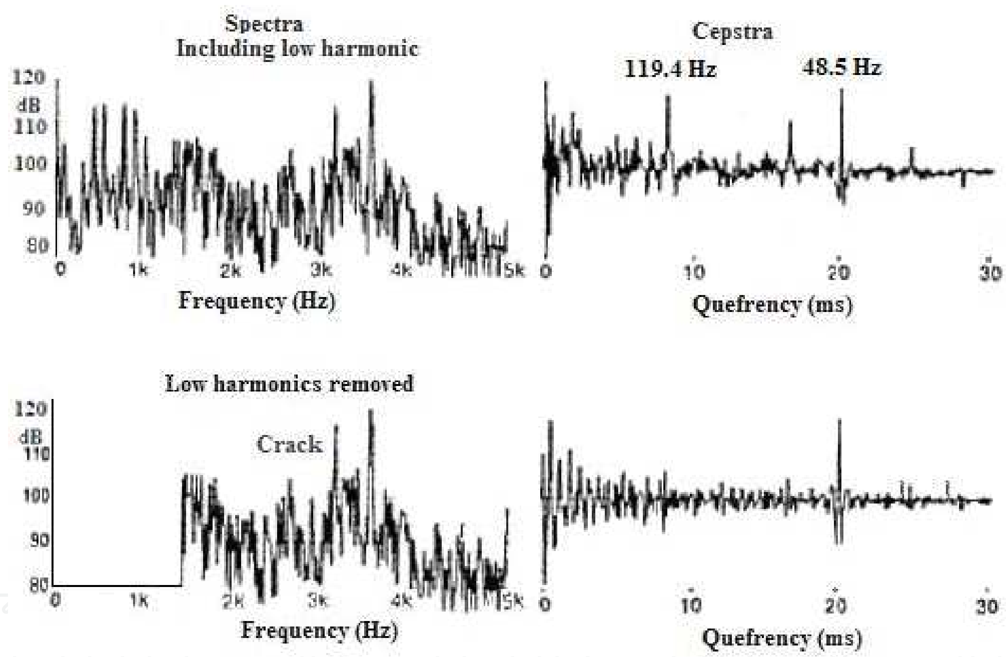

Fig. 8. The spectrum from a concrete structure in its deteriorated condition

Cepstrum of this spectrum is also give in the side. It may be seen that the cepstrum identifies these two families of harmonics (with a spacing of 48.5 Hz and 119.4 Hz respectively). Fig. 9 shows the edited spectrum such that frequencies below that of half of the impactor frequency are removed. The cepstrum of this spectrum is then calculated. The cepstrum does not show the 119.4 Hz component at all. It indicates that this component originates from the lower frequency range. The cepstrum does retain the 48.5 Hz component indicating its origin in the medium frequency range. It may thus be concluded that the impactor effect on the tested structure at 49.8 Hz may have an incipient fault while the recorded components at 119.4 Hz indicates delamination, voids or other fault.

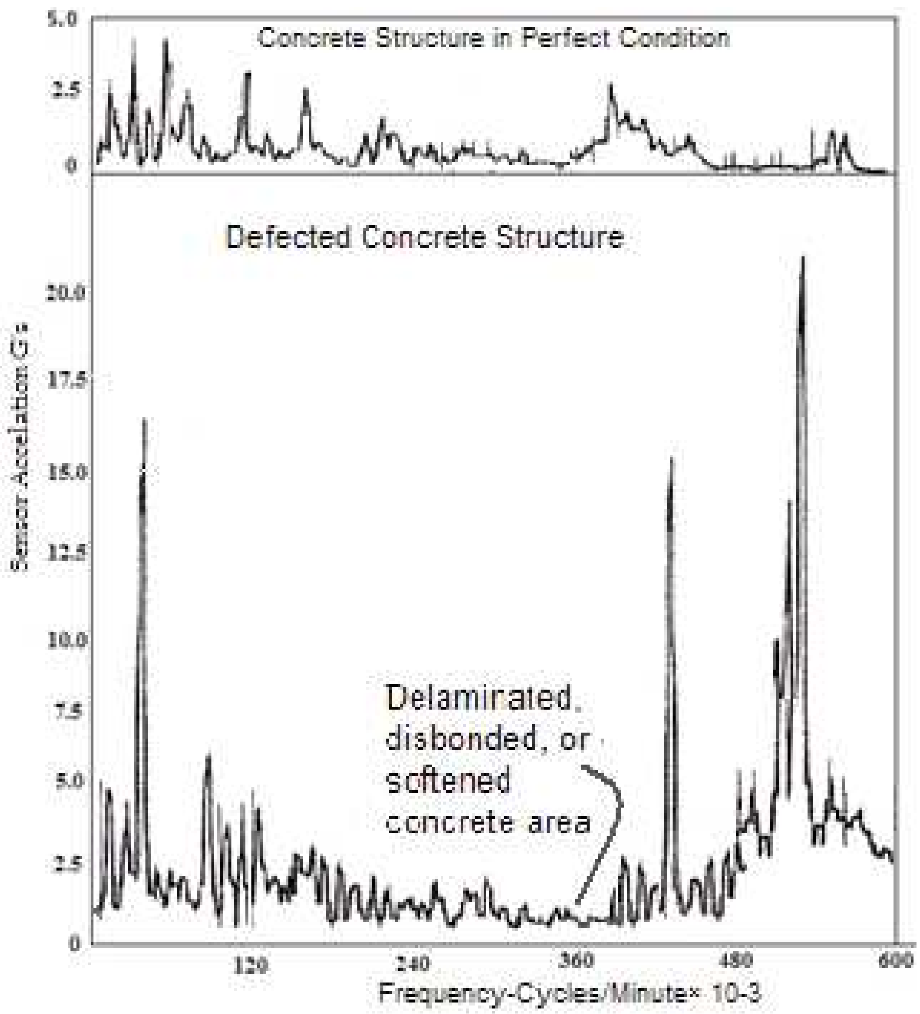

Fig. 9. Frequencies below that of half of the impactor frequency are removed.

In this research the Acousto – Vibration (AV) technology utilized to detect defects, such as voids and mix separations in the constructed pats.

9. Conclusion

The Reinforced Concrete Structure Diagnosis Expert System is implemented through this research work as a prototype rule based system using the Professional expert system shell. It is apparent that in the proposed method, the perfect undersea concrete structure should not produce vibration signals more than the normal value. This is never the case, for it is impossible to eliminate all asymmetries in the materials and geometry of the concrete and steel armor in the structure. It results from the measurements having been carried out that several predominant frequencies arise in the specimens under test.
To extract knowledge from the expert the knowledge engineer must become familiar with problem of vibration and acoustic analysis. The rule base system is goal driven using backward chaining strategy to test the collected structure vibration and acoustic properties information is true. The case specific data plus the above information with the help of explanation subsystem, allows the program to explain its reasoning to the user and will provide the expert system shell requirements. Significant difference can exist between the

signals created by subsea concrete defects. The respective amplitudes of the mentioned signals may exceed each other in a different way in repeated measurements of the same specimen. This device serves as a base for development of expert system monitoring module. The change of reference signal with proposed expert system implies that something within the subsea concrete structure has altered and diagnosis is made.
By integrating the different modules, the proposed system has the power to provide diagnosis of problems in reinforced concrete harbor structures. This can assist civil engineering trainees, inspectorate staff, professional engineers as well as their top harbor management personnel regarding the likely problems so that early action can be taken.
The present work will be particularly of great assistance to new comers who are not familiar with the field and will facilitate them in gaining a better understanding of the causes of the problems and in making decisions about any necessary actions

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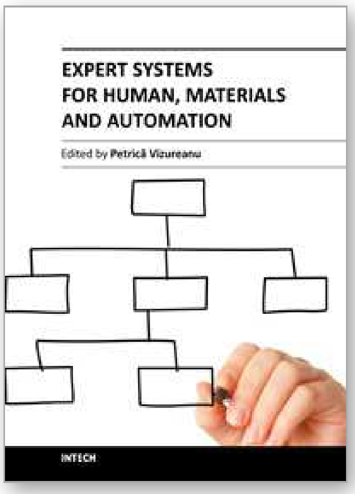

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The ability to create intelligent machines has intrigued humans since ancient times, and today with the advent of the computer and 50 years of research into AI programming techniques, the dream of smart machines is becoming a reality. The concept of human-computer interfaces has been undergoing changes over the years. In carrying out the most important tasks is the lack of formalized application methods, mathematical models and advanced computer support. The evolution of biological systems to adapt to their environment has fascinated and challenged scientists to increase their level of understanding of the functional characteristics of such systems. This book has 19 chapters and explain that the expert systems are products of the artificial intelligence, branch of computer science that seeks to develop intelligent programs for human, materials and automation.

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