MIT Sea Grant
Fall 1981

Quarterly Report

Researchers Study Tidal Transport in Salt Marshes

Salt marshes are a vital part of the coastal ecosystem, crucial to nutrient cycling. Before this was fully understood, however, thousands of acres of wetlands were filled or destroyed. Today, state and federal agencies take care to protect marshes and look for new, nondestructive uses that benefit coastal communities.

Knowing how nutrients and pollutants circulate within the marsh ecosystem is essential to wetland management. For the past three years Sea Grant has supported research to determine to what extent tides transport substances in salt marshes. Assistant Professor Harold F. Hemond and Associate Professor Keith D. Stolzenbach from MIT's Department of Civil Engineering and John Teal, Senior Scientist at Woods Hole Oceanographic Institution, have studied the physical characteristics of a salt marsh, developed analytical and numerical models of water flow, and dynamically measured that flow. They hope that within the next few years their work will help answer several key environmental questions for those who manage wetlands:

- Do marshes have the ability to remove nutrients from wastewater?
- How much pollution from adjacent industrial or residential development can a marsh absorb without damage?
- Is it possible to enhance artificially the productivity of a marsh?
- What effects might cumulative or individual spills of oil or other pollutants have?

The research team, which has included four undergraduate and three graduate students, has measured how the height, area, density, and shape of marsh vegetation alter the movement of surface water. They also have documented how subsurface flows, which are affected by the permeability and compressibility of peat, effect the exchange of nutrients and substances between surface water and water in the peat.

Detailed information on how physical properties, tides, evaporation, and groundwater movement influence water flow has allowed Professors Stolzenbach and Hemond to develop models that accurately predict surface and subsurface water flow. The models, they note, can account for vegetation of different heights and densities and for varying wind conditions and water levels. Field data collected within the Sippewisset Marsh on Cape Cod have verified the accuracy of the models.

Specially developed instruments and techniques that had not existed previously yielded the first actual data on dynamic variations of seepage of water into peat, subsurface flow of water through peat, and low velocity flow within grass stands. The instruments provide hydrologic information that is necessary not only to the Sea Grant research, but to all studies of wetland ecosystems.

Figure 1. Data for wetland study has been gathered by specially developed instruments installed in Sippewisset Marsh on Cape Cod.

A surface infiltrometer measures seepage of surface water into subsurface peat. The instrument is an open-ended cylinder which is driven into the peat. Water is pumped into or out of the cylinder to maintain a level inside consistent with the level of the rising or falling tide outside. The scientists know how much water would need to be pumped if no seepage occurred. This is compared with the amount pumped when seepage does occur to determine the extent of the water loss.

An acoustical piezometer measures automatically the hydraulic head of water in peat. Part of the instrument, a narrow, open-ended tube, is driven into the marsh surface. A device on top of the tube uses sonar pulses to sense the height of the water in the tube and transmits readings to a remote station at the edge of the marsh. The calculation of the head of water within the peat, considered with the permeability, indicates the speed of subsurface flow. Automatic measurement of subsurface flow has two significant benefits. The peat is not compressed from the weight of an observer during testing, and the observer is free to conduct other measurements.

Since water moves very slowly through marsh grasses, the research group needed a technique to measure low velocity flow. They injected tiny spheres of red dye into the water as the tides were coming in or going out. A camera photographed the spheres from above. As they traveled, a stopwatch located in the camera's scope recorded the time. By moving the tube up and down to inject dye at different depths, it was possible to detect variances in flow velocity at different depths.

The research group now has set its sights on making its results more widely available by incorporating the models into computer programs useable by other investigators.

In this issue

Rope Pathology

Stanley Backer describes himself as a kind of mechanical pathologist. The subject he probes is rope; the disease, deterioration. Professor Backer, of the Fibers and Polymer (F&P) Laboratory in MIT's Department of Mechanical Engineering is leading an interdepartmental research project to discover how and why ropes made of man-made fibers deteriorate. He and his colleagues want to find out why ship ropes, that show only slight outward sign of wear, can snap unexpectedly at a small fraction of their rated strengths. A breaking synthetic fiber rope releases tremendous energy that can seriously injure or kill sailors or dockside workers. The U. S. Navy estimates that a nylon line "snaps back" at a speed of 700 feet per second. (A 45-caliber bullet travels at 850 feet per second.)

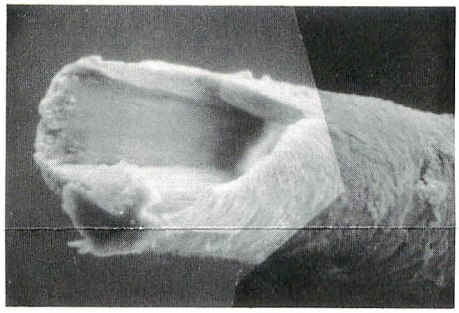
Working with Professor Backer are Professor Frederick J. McGarry of the Polymer Laboratory in the Department of Materials Science and Engineering, Professor James H. Williams, Jr., of the Composite Materials and Non-destructive Evaluation Laboratory, and Professor Giuliana C. Tesoro of the F&P Laboratory, both in the Department of Mechanical Engineering. Each person is concerned with a different aspect of the "pathology"; together, their work seeks to investigate rope materials and structural combinations that will reduce deterioration rates. In addition, they are studying the procedures for testing the condition of ropes in service, and identifying handling procedures to extend the safe life of mooring and towing lines.

The researchers have been examining three basic rope structures: twisted, braided and plaited, as well as three polymer types: nylon 66, nylon 6 and polyester. Other polymer types and new high performance fibers are to be included in future work.

In a current progress report, Professor Backer describes observations from studies of ten worn lines furnished by the U. S. Navy, ranging from two to fifteen years in age. Several of these ropes were made up of more than two and one half million fibers twisted, plied, and cabled together or braided to as many as five superposed geometric configurations (e.g., helix upon helix, etc.). Careful embedding and microtoming techniques have permitted miscroscopic viewing of the three-dimensional paths of fibers and yarns and the tracing of the way rope strands intertwist or interweave; distortions of rope components under different stresses are also noted.

Deterioration of rope-filament properties incurred during marine usage has been studied by different methods. Reduction in strength can come from various types of attrition: cyclic working tensions, external and internal abrasion, bending fatigue, friction, excessive tensions—even fish bites. In addition, exposure to sunlight, sea water, oil and other contaminants, and heated storage areas can contribute to chemical changes and accompanying filament weakening. Finally, deposits of salt, grit or sand and even ice crystals within the rope structure can provide sharp asperity attack on internal fibers.

Usually, physical deterioration is detected by outward signs of chafing, fuzziness, melted ends, or moss and rust



discoloration. The MIT researchers in the F&P Laboratory are looking beyond the obvious, inward to the core of each rope with care and detail appropriate to a pathological study. They have measured losses in fiber strength and elongation and have mapped these changes according to rope geometery. Using optical as well as the scanning electron microscopy, they have correlated the mode of filament fracture with the extent of rope exposure and with the filament location. Molecular weights of corresponding filament samples have been determined, and selected thermal and thermomechanical tests have been conducted.

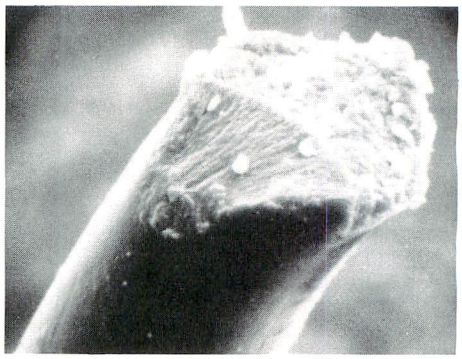
So far, it has been demonstrated that filament weakening occurs at regular intervals along the rope's length. This was expected since rope yarns intertwist or interbraid periodically, hence they rise to the rope surface at regular intervals to be exposed to weather, contaminants and mechanical attrition. But the regular weakening of fibers at other locations such as the very center of twisted rope was observed for the first time; this was demonstrated to occur at the region of maximum lateral pressure where strand rotated against strand during load cycling. Scanning electron micrographs provide clear evidence of the effects of such internal structural abrasion.

Like much information gathered in the early stages of any research project, these results are preliminary—yet to be accurately interpreted. The same cautious approach is being applied to findings concerning reductions in molecular weight of surface fibers. Considering the presence of over two million fibers in a worn rope, each with its own history of mechanical-geometric interactions and environmental exposure, the sampling problems in the pathological study are severe.

Professor McGarry has focused on the role of salt water as an environmental stress-cracking phenomenon. He notes that nylon ropes in marine applications experience a complex history during use, including exposure to salt water and the mechanical action of wind, wave and applied loads. The Polymer Laboratory has been employing a servohydraulic machine to measure fatigue life and residual tensile strength in air, as well as in salt water for component fibers and yarns. Further work is planned for small-scale ropes.

Even if the researchers are able to reduce deterioration through improved design specifications, the workers who handle the ropes will have to monitor their condition, especially over time and under heavy use. Professor Williams and his associates are investigating acoustic emission, a nondestructive evaluation technique, to reveal hidden flaws or rope

Figure 2. Electron microscopy reveals fractured fibers from rope surfaces. Upper photograph shows end of used marine rope, lower shows end of new nylon rope.



wear and to try to predict the residual strength in a rope.

Professor Williams refers to old movie experiences to explain acoustic emission. The wooden sailing schooner groaning in a storm or the creaking mine shaft about to collapse illustrate structural materials acoustically signalling stress. In the MIT experiments, a sensor, about the size of a fingernail, is placed on a rope. When the rope is stressed, it generates noises not audible to the human ear which are picked up by the sensor and translated into an electrical signal. Signals differ, depending on the amount of stress and condition of the rope. One of the great challenges the researchers face is quantifying a vast number of signals and correlating them with states of deterioration.

Ultimately, the mechanical engineers envision that vessel or dock personnel

Editor: Elizabeth T. Harding
Program Director: Dean A. Horn

Articles by Lynne Newman, Debbie Levey, Elizabeth T. Harding

The MIT Sea Grant *Quarterly Report* reviews the Program's marine-related research, education, and advisory service activities at the Massachusetts Institute of Technology. Funding is provided by the National Oceanic and Atmospheric Administration through the Office of Sea Grant. Free subscriptions of the *Quarterly Report* are available on request from the MIT Sea Grant College Program, Building E38-302, Cambridge, MA 02139. Telephone (617) 253-3461.

might use small sensor monitoring devices which, when placed on a stressed rope and activated, would emit signals that could be interpreted to reveal various states of wear and fatigue.

The researchers meet biweekly to coordinate their research, analyze progress, and discuss problems. Frequent conferences with representatives of the Naval Sea System Command, the research sponsor, and with others, such as the U. S. Coast Guard, cordage manufacturers, and ocean engineers bring much practical experience and a future user's perspective to this project. MIT Sea Grant, which administers the interdepartmental effort, is another participant.

Each facet of rope deterioration research will take several years to complete because the work is ambitious and complex. According to Dean A. Horn, Director of the MIT Sea Grant Program, "The university is a fantastic resource for this kind of a project, one that is long term, requires top people from three research areas, and solves a problem that affects both the public and private sectors."

Sea Grant Education Modules Validated by Massachusetts

On September 24, 1981 an educational program designed to make students in grades four to nine more aware of the importance of water to human life was accredited for statewide use by the Commonwealth of Massachusetts. The program, called *The World of Water,* was developed by E. Ray Pariser, Associate Director of Education Coordination at MIT Sea Grant, with Director Arthur Dutra and the teaching staff at the Sea Lab in the New Bedford, Massachusetts Public School System. The educators created six "modules," one for each grade, that are a progressive series of laboratory experiments with aqueous mixtures and solutions. The experiments demonstrate the ability of water to dissolve many substances—such as salts in seawater and nutrients for circulation in living organisms—a property that makes water vital to life.

Design of *The World of Water* began in early 1978 with money from MIT Sea Grant. In February 1979, New Bedford submitted a proposal to the Massachusetts Department of Education for Title IV C funds to improve the program and make it eligible for state and national validation. Title IV C funds are granted by the federal government through the states for projects promising to promote creativity in education. The proposal for *The World of Water* was accepted and the directors began fine-tuning it for validation.

The Network, an independent agency that develops and evaluates educational curricula, was brought on to try the program in sample schools. The Network tested the program in eleven schools by administering pre- and post-tests to about 550 students, some of whom completed

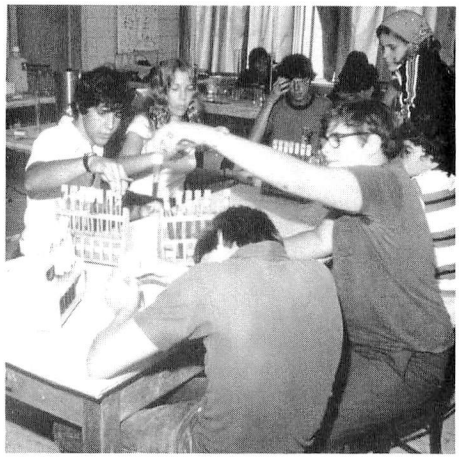


Figure 3. Sea Lab students working on laboratory experiments that help them to understand water's unique qualities and to develop analytical skills.

the modules of *The World of Water* and others who completed the regular science curriculum. The Network analyzed the results and produced a report which showed that students who had completed the modules tested considerably higher on the post-test than did those who had not been exposed to the new learning experience.

The New Bedford Public School System applied to the Commonwealth of Massachusetts for validation. The State appointed a board of examiners who studied the program materials and the test results from The Network and examined orally the directors of the program. The examiners probed for several hours for answers to questions about commitments from schools to use the modules, how teachers are trained to administer them, how and why they focus on water, and other important criteria. On the basis of this thorough investigation the board recommended that *The World of Water* be validated by the State.

The program directors now are preparing for national validation so that schools from coast to coast will be able to use this unique course on water.

Acoustical Profiling in Geotechnical Engineering

To predict the foundation behavior of offshore platforms under severe loads, the bottom soils must be characterized in detail. Data for this characterization are generally gathered from three sources: samples taken in borings and tested in the laboratory; devices inserted *in situ,* like a cone penetrometer; and various geophysical techniques.

All these methods have some inherent drawbacks. Boring disturbs the soil, so that laboratory samples may differ substantially from the original subsea conditions. *In situ* measurements cause less disruption but are difficult to calibrate. And obviously, both borings and most *in situ* measurements supply information only at individual points within the subbottom. Geophysical techniques, of which the most common is high frequency (acoustic) reflection profiling, provide data over large areas, but are usually difficult to relate to engineering properties.

Combining information from these sources, though, can take advantage of each method's strong points. "Engineering properties can be measured by sampling and penetration, and interpolated using acoustic profiling," says Associate Professor Gregory Baecher of the MIT Department of Civil Engineering. High frequency acoustics has the advantage that the short wavelength results in precise resolution of details within the profile. A disadvantage is that high frequency signals attenuate rapidly and therefore cannot penetrate deeply into the bottom sediments. However, for many engineering applications this limitation is not serious.

Baecher's current Sea Grant project aims to improve acoustical exploration for foundation conditions at offshore sites. Such acoustic data is difficult to interpret objectively, says Baecher. There have been few attempts to incorporate acoustical data within the formal analysis and planning of exploration strategies, despite the rapid advance during recent years in using statistics and operations research for analyzing networks and sequences of direct observations. The approach adopted by the current research uses "rather straightforward statistical techniques to analyze a problem which previously has been analyzed intuitively. By doing so, we hope to squeeze more information out of the same data and improve the efficiency with which such exploration programs are designed," he says.

"We're trying to develop ways of characterizing the accuracy of the information gained from acoustics, and to combine it with direct observations," says Baecher. Two problems in particular are being studied: developing statistical procedures to map the bottom or subbottom at any elevation using combined information, and forming strategies to locate anomalous conditions in the subbottom (such as a clay lens in a sandy profile) that may adversely affect engineering performance.

A major object is to identify the sources of uncertainty about subbottom conditions, and to quantify their influences. "We're trying to get an idea of the level of uncertainty as it manifests in engineering predictions. To do so we must establish means, variances, correlations, spatial distributions and trends for engineering parameters. We have models for inferring these things from direct data, but offshore, half the information comes from indirect data. When you analyze only the direct data to which most present models are limited, large uncertainties remain because you leave out half the information," he says.

A statistical model has been developed to analyze the use of acoustic profiling in making quantitative estimates of foundation conditions. Similar to those used in other types of geological exploration such as mineral resource evaluation, the model is intended to provide a consistent procedure for analyzing data and a vehicle for

optimizing the allocation of exploration effort. It is subdivided into: a geological model which describes the spatial distribution of materials and their physical properties in the subbottom, and an observational model which characterizes the exploration tools. The geological models are based on a stochastic representation of material properties using random field theory, while the observation models are based on geometric probability and detection theory. Although these models, or at least very similar ones, have been around for a long time, their application to geotechnical exploration is quite new.

So far Baecher and co-workers have analyzed extensive empirical data comparing acoustical profiles with direct information, and confirmed that acoustical profiles can be precise when they are calibrated to borings or penetrations. They now have procedures for combining acoustic and direct information to map the distribution of sediments. Confirming what was widely thought, they found that acoustic properties alone can't be used to infer material properties. As Baecher notes, "The primary use of acoustics is to infer the geometry of the subbottom, what the stratigraphy is like, and whether important smaller features exist."

"We're extending the mapping model so that it can use geophysical information," he continues. "We have not begun to work on the question of searching for anomalies. The mapping model now quantifies the expected error in two-dimensional mapping, like mapping bottom sediments, and does so fairly accurately. Later this year we will begin extending the search model and hopefully combining mapping and search in optimizing exploration strategy.

"Geotechnical engineering is slowly changing into a discipline in which designs are based on risk analysis, rather than on simple factors of safety or large margins of conservatism. For risk-based design one needs some quantification of the uncertainties affecting the prediction of engineering performance, obviously including soil properties. As risk-based design becomes more and more common offshore, the kind of analysis we're doing will become a more necessary part of the work. Therefore, one can't separate the penetration of this type of technology and the general change of the whole design approach to traditional practice to risk-based design. As that change occurs, all the associated technologies—statistical analysis of exploration data, statistical analysis of wave loading, reliability modeling of structural response and foundation performance—will become increasingly important and more heavily called upon."

Sea Grant to Combine Annual Lecture With Seminar Series

Biotechnology in the Marine Sciences is the subject of the 10th Annual MIT Sea Grant Lecture and First Annual Seminar Series to be held March 18-20, 1982 at MIT. The lecturer on March 18 will be Rita Colwell, Director of the University of Maryland Sea Grant Program and noted marine microbiologist. Dr. Colwell will give an overview of biotechnology and genetic engineering as they are being applied in the marine sciences. A panel discussion will follow. The lecture is free and open to the public.

Four seminars on March 19 and 20 will include presentations and panel discussions by university and industry leaders on current research and development in biotechnology and genetic engineering in aquaculture; marine pharmaceuticals and bioproducts; marine biofouling; and marine pollution control. Registration for the seminars is $300. For information and registration material contact: E. Ray Pariser, MIT Sea Grant, E38-350, 77 Massachusetts Avenue, Cambridge, MA 02139, (617) 253-7041.

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Abstracts

☐ **Development of Joining and Cutting Techniques for Deep-Sea Applications**

Koichi Masubuchi
MITSG 81-2 227 pp. $8.00

This is the final report on four years of research on welding and cutting in deep-sea conditions. During the research program, extensive experiments on arc welding and cutting in deep-sea conditions were performed to study the effects of water pressure on arc welding and on the properties of welds. A prototype of an underwater arc stud welding tool that can attach four studs to the work piece in consecutive order within two seconds was designed. Also, conceptual design of an automatic underwater flux-shielded welding machine for use in deep sea was completed and a simple automatic welding machine operated merely by pushing a button was constructed and tested.

☐ **Measurement and Prediction of Vibration Response of Deepwater Offshore Structures**

MIT/Marine Industry Collegium.
Opportunity Brief #22.
MITSG 81-3 19 pp. $3.50

As offshore structures become ever larger, new methods are needed to predict the response of these giant structures to vibration caused by waves. In this report a new method based on the engineering concept of reciprocity is described for predicting displacement of a structure battered by waves. The new method predicts displacement without explicit calculation of the wave forces. The report also describes new ways to measure dissipation of energy, or damping, and current experiments in predicting damping of structures in the ocean environment.

☐ **Progress in Underwater Telemanipulator Research**

MIT/Marine Industry Collegium.
Opportunity Brief #23.
MITSG 81-4 23 pp. $3.50.

The long-term goal of research at MIT and the Naval Ocean Systems Center (NOSC) in underwater telemanipulators is construction and operation of an underwater, unmanned, untethered telemanipulator. This brief reports progress in underwater telemanipulator research at MIT and NOSC. The brief describes improvements in the NOSC submersible vehicle, EAVE WEST, the NOSC manipulator and its supervisory control system, and experiments and improvements in hardware and software for the supervisory control system of MIT's laboratory manipulators. Also described is an experimental vehicle (EV) being developed as the first step in simulation of an undersea vehicle. The simulation vehicle will test new control concepts and ultimately will train operators of remotely controlled vehicles.

☐ **Progress in Controlled Environment Aquaculture and Algae Husbandry**

MIT/Marine Industry Collegium.
Opportunity Brief #24.
MITSG 81-5 26 pp. $3.50.

Two University of Delaware research projects discussed in this report suggest profitable business opportunities. An experiment with a closed-cycle aquaculture system for growing oysters may have significant value in growing seed oysters up to one centimeter. The system recycles oyster wastes, keeping costs of nutrients down, enhancing the ability of the oysters to use a larger fraction of their food, and reducing the amount of energy needed to heat water in the system. Researchers also are studying the potential for domesticating plants which grow in brackish water (halophytes) for animal or human consumption. The report briefly discusses advances in algae husbandry, including successful experiments in increasing algal yield, sustaining algal growth, and manipulating the physical and chemical characteristics of algae.

☐ **Oil Spill Clean-up: An Economic and Regulatory Model**

MIT/Marine Industry Collegium.
Opportunity Brief #25.
MITSG 81-6 24 pp. $3.50.

Sea Grant researchers are developing an integrated set of computer models to help policy makers respond effectively to oil spills. The models will be tools for identifying and evaluating alternatives and trade-offs involved in cleaning up oil spills. Three features characterize the models. Decisions are categorized in three hierarchical levels: strategic, tactical, and operational, since decisions at one level place constraints on decisions at the next level. The components of the models are modular to allow maximum flexibility. And an analysis of parameters is incorporated to determine the importance of each parameter to the overall problem. The report includes a schematic drawing of the models along with a description of each of the components.

☐ You may order one copy of any of these reports free of charge.

Please check off those publications you would like to order, and return this entire page—or a copy of it—to the Sea Grant Program, Massachusetts Institute of Technology, Building E38-302, Cambridge, MA 02139.

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☐ **The Engineering and Economics of Coal-Fired Ship Propulsion**

MIT/Marine Industry Collegium.
Opportunity Brief #26.
MITSG 81-7 28 pp. $3.50

By the turn of the century a substantial portion of the world's merchant ships, now fired by oil, may be powered by coal. Researchers at Sea Grant are studying the thermodynamic and mechanical problems of converting oil-fired ships to run on coal. This brief discusses the problems and benefits of coal as a fuel for ships, including the problems of pollution and the need for facilities for storing coal at port. The report examines how coal is handled and burned aboard ship. A discussion of the economic feasibility of coal conversion concludes that there is economic incentive to convert from oil to coal if the ship meets specified criteria of size and speed of travel.

☐ **The Piezocone Penetrometer**

M. M. Baligh, A. S. Azzouz, A. Z. E. Wissa, R. T. Martin, and M. J. Morrison.
MITSG 81-10 21 pp. $3.50.

A Sea Grant team has developed a piezocone penetrometer capable of measuring simultaneously cone resistance, pore water pressure, and skin friction during soil penetration. The piezocone was tested in a marine clay deposit from which extensive penetration data already are available. Results indicate that the penetrometer is reliable and extremely useful in identifying soils and determining soil stratification. Measurements of pore pressure dissipation when penetration stops can be used to estimate the consolidation and/or permeability of soils.

☐ **Final Report on a Study of Ship Wave Resistance**

Francis Noblesse.
MITSG 81-13 24 pp. $3.50.

Sea Grant researchers have examined a new analytical theory for predicting wave resistance of a ship in rectilinear motion at constant speed in a calm sea. One objective of the project was to test the theory using various idealized geometrical ship forms. Towards that objective, this report proves the convergence of the sequence of slender-ship approximations defined in Noblesse's slender-ship theory of wave resistance.

☐ **Enhancement of the Stability of Common Polymeric Materials Against Undersea Degradation**

R. G. Donnelly and R. E. Cohen.
MITSG 81-14 216 pp. $8.00.

The report summarizes Sea Grant research on strengthening common polymeric materials against undersea degradation. Several common polymeric materials were subjected to small amplitude cyclic flexure in a simulated marine environment, and changes in molecular weight and crystallinity were monitored. A polyethylene resin was treated by a variety of surface modification techniques and subjected to similar conditions to evaluate these treatments. Each technique was effective in retarding degradation; however, effectiveness varied greatly among them.

☐ **Boston Harbor Management Study**

Judith T. Kildow.
MITSG 81-15 268 pp. $8.00.

This final report outlines problems with current management of the Boston Harbor and recommends ways to improve it. Emphasis is on centralizing authority for the development of the harbor and striking a balance between the needs of the public and private sectors. The author compares management of Boston's harbor with that of six other major urban harbors across the nation and analyzes some of the issues, such as public access, marina development, and water quality, with which planners need to deal as Boston Harbor expands.

☐ **Special Summer Programs Preliminary Announcement Massachusetts Institute of Technology**

Brochure. No charge.

A preliminary announcement for MIT's thirty-third Summer Session Program lists all courses to be sponsored in 1982. The brochure provides course titles, faculty, dates, and costs. If you are interested in any of the offerings, you may order more detailed booklets after March 1st from Sea Grant. Information on accommodations and registration is available from MIT's Summer Session Office, E-19-356, Cambridge, MA 02139.