Reef runway is first in airport design

Something had to be done to improve conditions at Honolulu International Airport, where aircraft traffic patterns created a lot of noise for people on the ground. The answer was an offshore runway built on a reef. Environmental conditions played a big part in the design and construction of this $81 million project.

BECAUSE OF THE TAKEOFF and landing patterns in existence at Hawaii's biggest airport in Honolulu, aircraft flew directly over heavily populated land areas, creating a lot of unwanted noise. And with the advent of the jumbo-jet age, it became apparent that something had to be done. That something was the design and construction of a new runway, hewn from a coral reef adjacent to the existing air complex. The $81 million project, completed last fall, was the world's first major runway built entirely offshore, and is a contender for the Outstanding Civil Engineering Achievement of 1978. In addition to the massive job of dredging coral fill and constructing the runway itself, the project is a landmark of sorts in the care it took to minimize the environmental impact it would have on the surrounding area. As a result, water quality was improved and provision made for the bird population indigenous to the area.

Begun 11 years ago

Planning began in earnest in 1967 for a new runway parallel to the existing one, but 6,700 ft (2000 m) toward the ocean. This placed the runway offshore on an underwater fringing coral reef. The Reef Runway, as it came to be known, was planned as a preferential takeoff runway for heavy three- and four-engine aircraft; its location insured that it would reduce noise levels around populated areas (as well as increasing safety for downtown and surburban areas of Honolulu). Also, the new runway would bring a long-needed increase in capacity for the airport—insuring adequate landing facilities for the next 20 years.

First of a kind

Because it would be the first major facility of its kind built entirely offshore, the environmental implications were carefully studied early in the game. (Other cities had announced plans for similar offshore facilities—even to Chicago's building an entire airport entirely surrounded by water in Lake Michigan—but nothing concrete has so far been accomplished.) Studies for the project involved the use of three-dimensional hydrodynamic models to determine the runway's overall effect on circulation patterns in the Keehi Lagoon, as well as wave forces on the structure itself. Tests were also made to determine design criteria for the structures that would protect the runway on its seaward side.

Final plans for the runway determined that it would be constructed on coral fill for a length of 14,700 ft (4480 m), with associated taxiways and a protective structure. By the time it was finished more than 19 million yd³ (15×10^6 m³) of dredged material had been used, pumped by three hydraulic suction dredges from four offshore borrow areas, to form the land mass. In addition, some 800,000 tons (730×10^6 kg) of quarried stone and 18,100 four- and six-ton (3600 and 5400 kg) dolosse concrete armor units comprise the protective structure separating the runway from the ocean.

Dredging and filling

Fill material for the runway was the coral dredged from the lagoon. Much of it was placed in formerly dredged seaplane channels that had become partially filled with mud sediments. A small dredge was used to remove mud from areas that would lie below future pavement (it was then pumped to confined areas outside the structural sections of the runway). Dredgers used in the project were the 36-in. (910-mm) dredge Hydro Pacific, the 30-in. (760-mm) dredge San Diego, and the 16-in. (410-mm) dredge Explorer.

The structural fill was placed by equally spacing three 36-in. pipes across the 200-ft (61-m) wide runway. Coarser materials tended to settle out within the limits of the structural-fill paved areas, while finer materials washed laterally into common-fill areas outside paved sections. Similarly, two 36-in. pipes were used to place structural fill in the taxiways. During placement of dredged fill in areas where mud removal was required, the contractor kept the top of the dredge fill at water level—and advanced the fill in as narrow a width as possible to prevent silting up of the dredged mud trenches. Although this method proved highly successful, it was necessary to reenter some areas again to dredge out finer materials, which flowed into the mud trenches from dredging operations. Extensive drilling explorations also took place in order to assure the compliance of dredged fill with requirements of structural-fill materials.

The dredged structural fill was generally placed at an elevation slightly above the finish grade of compacted fill; the material was then removed down to El.

+3.0 ft (+1.0 m) by rubber-tired scrapers (the area under compaction at any one time was generally limited to an average length of about 1,000 ft or 300 m). The fill was proof-rolled with a 60-ton (54 × 10^3 kg) rubber-tired roller; soft areas which developed (under proof-rolling or during excavation by rubber-tired scrapers and other construction equipment) were corrected by removing the soft material, adding structural fill, and proof rolling once more. After that, the fill was placed in 8 in. (200-mm) loose layers and compacted to 95% of maximum density using sheepsfoot and vibratory rollers. (Extensive field testing indicated that lesser compacting was required if the coral materials used were first rolled with two to three passes of a heavy sheepfoot roller; this tended to compact the bottom portion of the layer more effectively). The surface of the layer was then smoothed off with a blade and the compactive effort completed with three to four passes of a vibratory roller (the compactive effort needed was less if sufficient sea water was applied to the highly permeable material to maintain water content on the high side of optimum). The maximum density of the dredged coral varied from 106 lb/ft^3 (1700 kg/m^3)—at an optimum moisture content of 18%—to 116 lb/ft^3 (1860 kg/m^3) at an optimum moisture content of 14%. In-place densities were determined by the combined use of Troxler Nuclear Density Meters and the sand-cone method (extensive comparative research proved the nuclear meter to be most reliable for use in this type of material).

Settlements were negligible, in large measure due to the careful placement of coral fill (described earlier), which virtually eliminated any large pockets of fine compressible material below the paved areas.

The runway pavement itself consists of 9 in. (230 mm) of crushed rock, 7 in. (180 mm) of asphalt treated base, and 5 in. (130 mm) of asphaltic concrete; it was designed to meet existing civil and military load criteria.

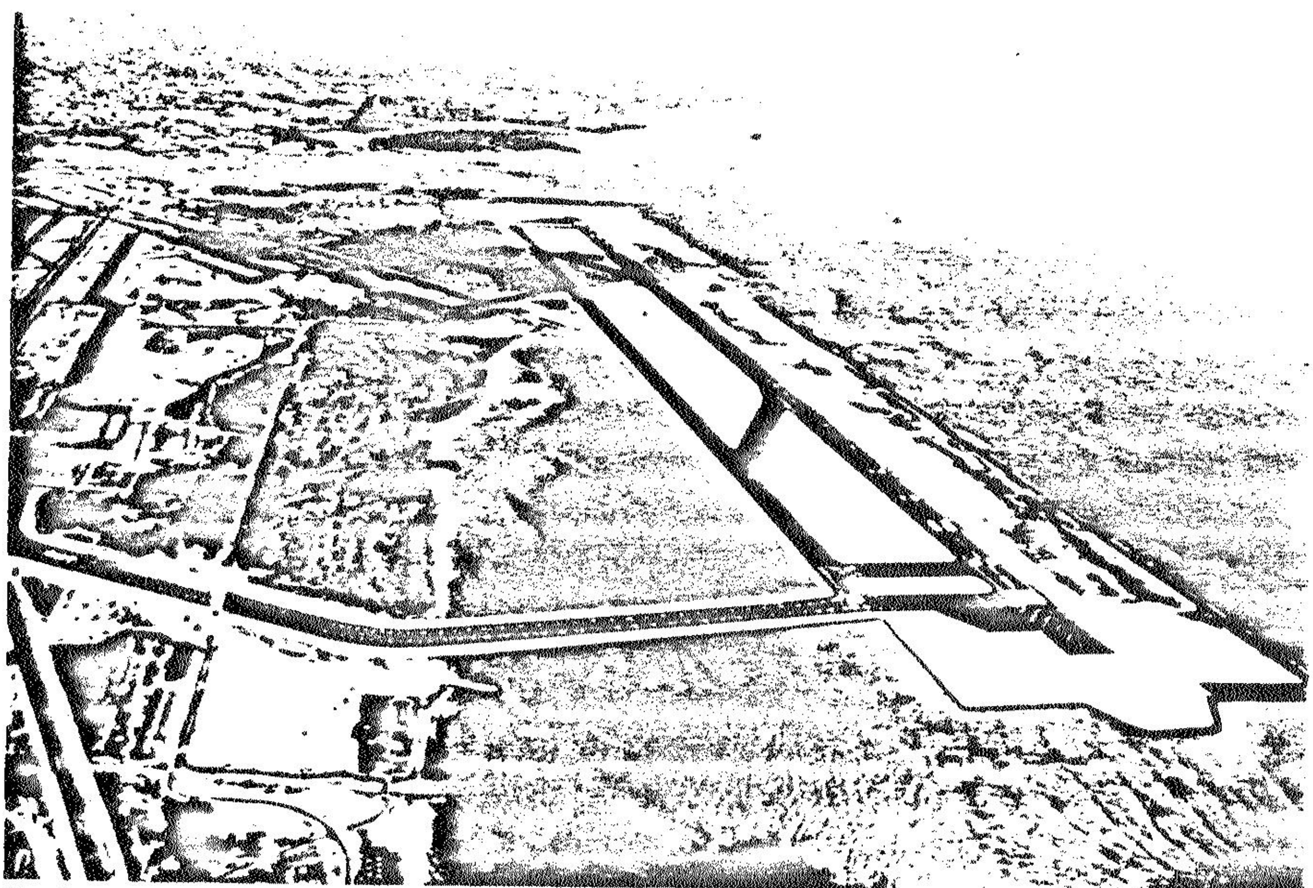
Reducing siltation

During runway construction strict measures were taken to reduce and eliminate siltation outside project limits. The contractor had to enclose the entire work area within dikes in order to protect the surrounding coral reef. Floating siltation curtains (similar to those used to control oil spills) were used to prevent turbidity from flowing outside the project's limits. The monitoring program was initiated before construction began and maintained throughout; when standards were violated outside the runway area, work was stopped and corrective action taken.

Construction of the runway (and connecting taxiways) resulted in a large 240-acre (970,000 m^2) marine pond surrounded on all sides. To maintain water circulation, eleven 72-in. (1800-mm) diameter pipes were installed; one was placed under the runway to the ocean and 10 were placed below the access taxiway. They provide an approximate 20% daily exchange of water with each tide.

Dolosse used for protection

In building the protective structure it was decided to use dolosse (*see photo*), supplied by the Hawaiian Dredging Company—cost being a major factor influencing the decision. (It was the first instance



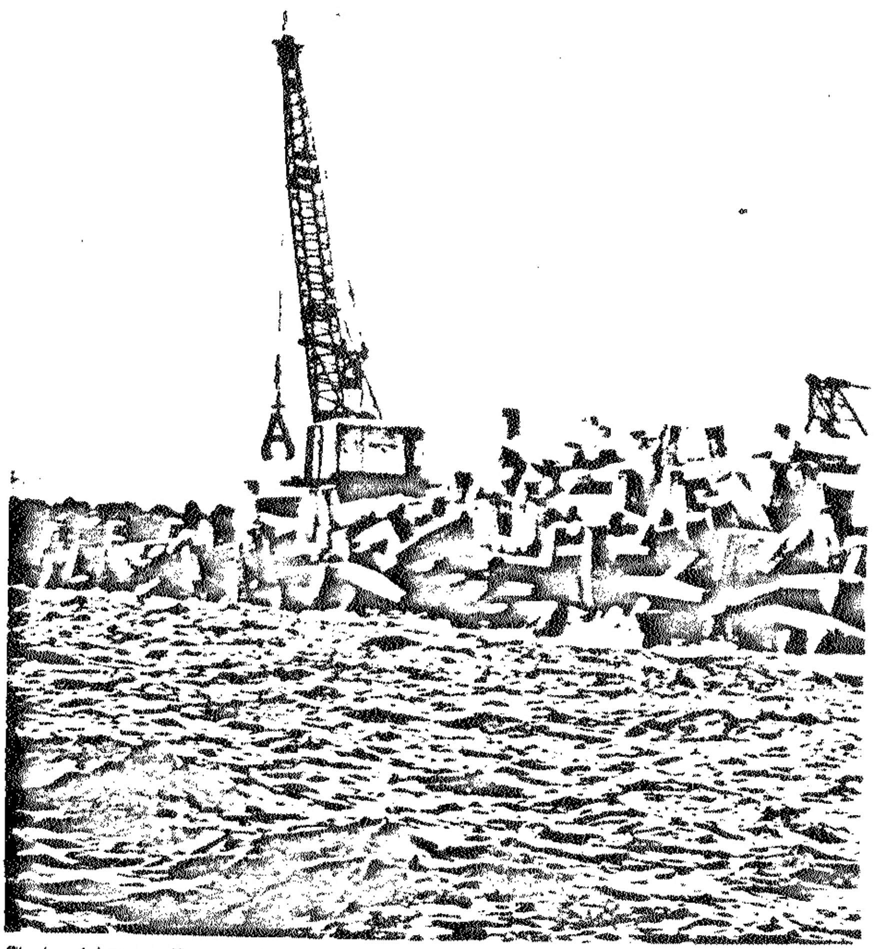
New offshore runway at Honolulu International Airport was hewn from a coral reef; completed project cost approximately $81 million.

of dolosse being used in a U.S. project, other than those designed and built by the Corps of Engineers.) The structure also used filter cloth (Plyfilter X from Cincinnati's Carthage Mills) to reduce the amount of stone required; it was placed directly on the underlayers in sections where an underwater rock berm was constructed. Coral fill then was placed on top of the plastic filter cloth. In other areas, the plastic filter cloth was placed atop a coral berm and shore protection rock placed on top of it.

It was noted early in the planning stage that such a large physical structure would affect the flow of currents along the island's coastline—and in the lagoon adjacent to the airport. Because earlier seaplane runways had been dredged in the coral (with poor connection into the open ocean), sediments had been trapped over the years; thus water quality had been diminished. It was decided that water quality might be enhanced through construction of a channel sloping downward to the sea, around the eastern end of the runway. This, combined with prevailing wind forces, would permit water to flow out, thereby providing a more complete exchange within the lagoon. (More recent studies have shown that the channel is performing as intended. Even during flood-tide conditions, water in the circulation channel ebbs, indicating that the goal of exchanging water within the lagoon is being accomplished. Tests have also shown that water around the runway is now better than it was before.)

Saving the stilt

Another environmental consideration taken into account was the preservation of certain avians, prominent among which was the Hawaiian Stilt, considered a rare and endangered species. In order to minimize the impact of the runway's construction on them, small islands were built in the lagoon so that the birds could rest. In addition, two large bird sanctuaries designed for their nesting were constructed in nearby Pearl Harbor. And, although not specifically planned that way, the shore protection structures themselves have become a major fish habitat. Since the construction, large numbers of fish have been seen in the vicinity of the reef protective structures. One reason the fish congregate there is that they are protected from more predatory fish and other animals.



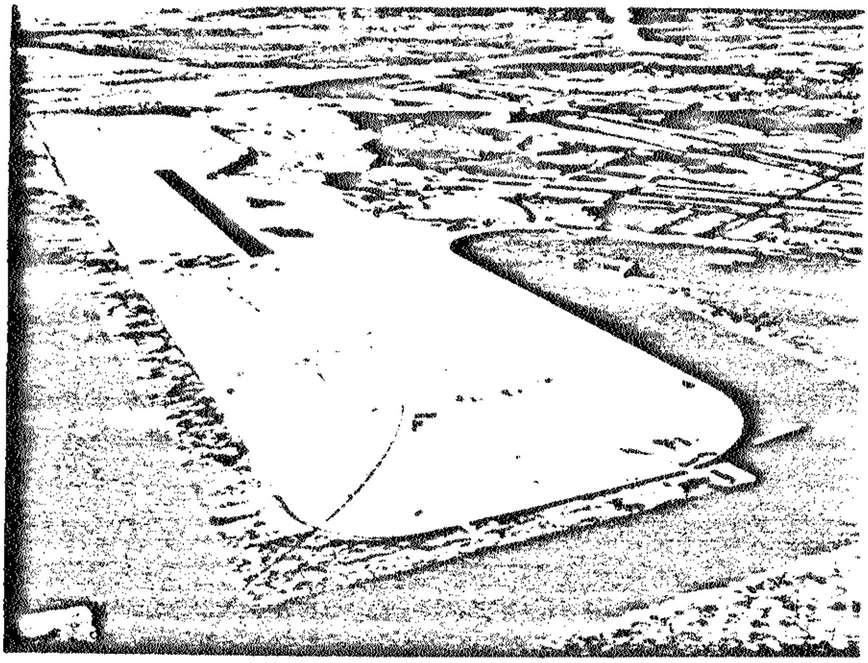
Placing dolosse on the protective structure on seaward side of runway.

Landmark EIS case

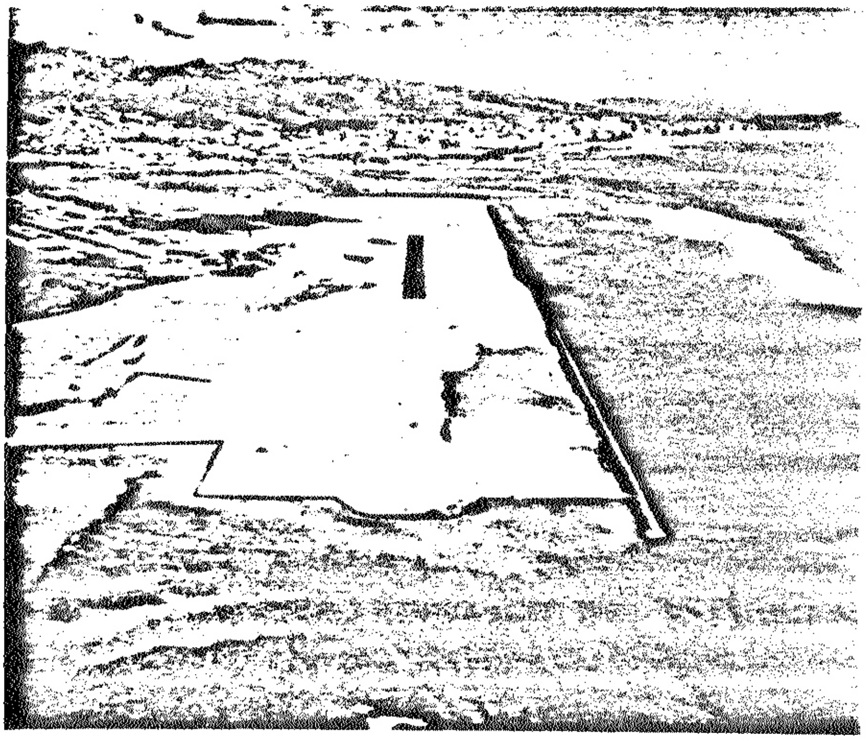
One stumbling block that hadn't been anticipated (and that eventually added to construction time and cost) was the litigation aimed at preventing the runway's construction that went all the way to the Supreme Court of the United States. Although the runway was planned before passage of the National Environmental Policy Act of 1969, the project was caught in the bind of being one of the first airport facilities having to file an Environmental Impact Statement (which was subsequently completed and approved early in 1972). Later that year, a preliminary injunction was requested by various environmental groups and a temporary restraining order was issued by the U.S. District Court. After going through three different courts, and ending up on the doorstep of the Supreme Court, the runway EIS was ruled adequate, affirming the action of a lower court. Interestingly, the court decided that it was not a conflict of interest for a consultant to participate in the development of an EIS which may result in future work, as did the consultant on the runway with the State of Hawaii and the Federal Aviation Administration. Also, as a result of work stoppages caused by the legal action, the state awarded the contractor $850,000 for damages incurred and extended the contract time by 112 days.

Costs, scope increase

Originally, the Reef Runway had been expected to cost about $20 million. How did that figure grow to the eventual $81 million pricetag? Reasons: at first, just a minimum facility was envisioned, encompassing only civilian requirements. Since then, both civilian and military paving designs, safety requirements and grading criteria changed significantly. The completed project includes a much stronger runway built on a graded area over 2,400 ft (730 m) wide, two bypass taxiways, two high-speed exits, a complete parallel taxiway (only about one-half of the parallel taxiway was originally proposed) and wider shoulders. Also, numerous support facilities were incorporated into the project to insure its success; these include: reconstruction of taxiways at the threshold of one of the existing runways; construction of 3,500 ft (1100 m) of taxiway parallel to another major runway; extended safety areas; a crash fire rescue building; relocation of naval recreational



Final stages of dredging as viewed from air; paving is shown in initial stage of construction.



View shows completed protective structure (at right of runway) with Honolulu in background.

Meet the authors

Three ASCE members closely connected to the Reef Runway Project contributed in large part the information on which this article is based. They are: Wayne L. Rickerd, project manager for the design and construction of the Reef Runway, who wrote one of the manuscripts; Frank V. Hermann, senior airport engineer for The Ralph M. Parsons Company, and Owen Miyamoto, chief of Hawaii DOT's air transportation facilities division, who collaborated on a manuscript accompanying the nomination of the project as OCEA for 1978. Here's a bit about each of them:

After completing his work on the Reef Runway Project, **Wayne L. Rickerd** became field manager for the construction of the Missouri Basin Electric Power Project's Laramie River Station, a 1.5 million-kw coal-fired steam-electric generating plant now being constructed in Wyoming.

Rickerd is a graduate of Oklahoma A&M (now Oklahoma State U.) with a BSCE, and the University of Southern California, where he was awarded his MSCE.

A Ralph M. Parsons employee is **Frank V. Hermann.** He has been involved in planning, engineering design and construction management on the Reef Runway since 1968. He also worked on airports in Taipei, Guam, The Trust Territory of the Pacific Islands and other projects throughout the Pacific Basin. With two degrees (one of them in civil engineering) from Lafayette College, he later earned a master's in city planning at the University of Pennsylvania.

Owen Miyamoto has been with the airports division of Hawaii's Department of Transportation since 1962—and in his current job since 1969. Under his direction the planning, engineering and construction of the Reef Runway was carried out (his responsibility encompasses all airport projects in the state). A civil engineering graduate of the University of Hawaii, he also holds a master's degree from the University of Illinois.

facilities; a sewer system; other building relocations; relocation of bird habitats, and others. Thus, although the total cost more than quadrupled, the scope of work also increased significantly. Not everything proceeded smoothly, however. In addition to the brouhaha over the EIS, there were smaller difficulties with some aspects of such things as the circulation channel, the protective structure, and the bird relocation.

The project has won local praise for the lessening of aircraft noise in the everyday lives of Honolulu citizens (the most noise noticed these days is generated by inter-island aircraft which had gone virtually unnoticed before). Constructing a project such as the Reef Runway points out once again the ability of engineers to construct a facility in a hostile environment, making it rather an environmental enhancement. Although the single cost may appear high, it could be considered small when compared to such alternatives as purchasing nearby land, relocating an entire airport, or restricting flight activities. ▽