Recommendation for Reef Ball Submerged Breakwater with Beach, Safety, Aesthetic and Biological Enhancement

For

Property Adjacent to Hotel Occidental Grand Flamenco Xcaret

March 4, 2006

Submitted to

OCCIDENTAL HOTELS & RESORTS

By The

Reef Beach Company, Ltd.

(A division of the Reef Ball Foundation)

With Team Partners Including

REEF BALL FOUNDATION

&

REEF BALL México

restaurando ecosistemas marinos

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Executive Summary

Reef Ball México contacted the Reef Ball Foundation's Reef Beach Company to do an initial assessment at the property adjacent to Hotel Occidental Grand Flamenco Xcaret that is being considered for possible future hotel development by the Occidental Group. It is our understanding that the client desires two stable tourist quality sand beaches on the property where beaches have existed in the past but come and go with erosion and sand building events.

Our initial survey included a photographic aerial over flight, site inspection by Dr. Lee Harris to determine if appropriate bathometric, tidal, bottom type and sand transport exists to all the use of Reef Ball technology, and a biological survey from Todd Barber to determine what impacts the construction would have on the local reef system and how to best construct the breakwater to enhance the snorkeling experience for guests. Additionally, Robert Morant, a dredging and beach renourishment expert, was included in the aerial over flight to search for potential sand banks for initial beach nourishment.

Reef Ball México, under the leadership of Javier Dajer Miguel, followed up on our initial visit with a more detailed bathometric survey, and additional biological documentation for the purpose of obtaining Mexican permits for the project. His divers also searched for sand banks. As suspected from aerial observation, Javier reported finding an observed sand bank 500 meters North of the site. It is 200 meters wide by 1000 meters long. The sand averages .4 meters deep. The bank depth is between 4 - 7 meters. Although the relatively shallow depth of this bank will make sand mining more expensive, there is sufficient sand for initial beach nourishment.

Although most sites initially surveyed cannot use Reef Ball technology due to bathometric, tidal, bottom type, biological or sand transport limitations, this property falls within our guidelines for creation of a submerged Reef Ball breakwater. The southernmost larger pocket beach is highly suitable for Reef Ball technologies however the northern pocket beach has some bathometric limitations and would also require potentially expensive rock removal. The bathometric limitation would still allow the use of the technology but it could be more expensive because larger (non-standard size) units might be needed to fit the deeper slope of the sea bottom. Sacrificing land could reduce or eliminate the need for non-standard sized units as a more landward beach would allow sufficient swimming room for guests while having a shallower depth profile where the submerged breakwater is located. However, the cost of additional removal of rock might be as much or more than the cost of larger Reef Ball modules and remains to be investigated.

Current Conditions

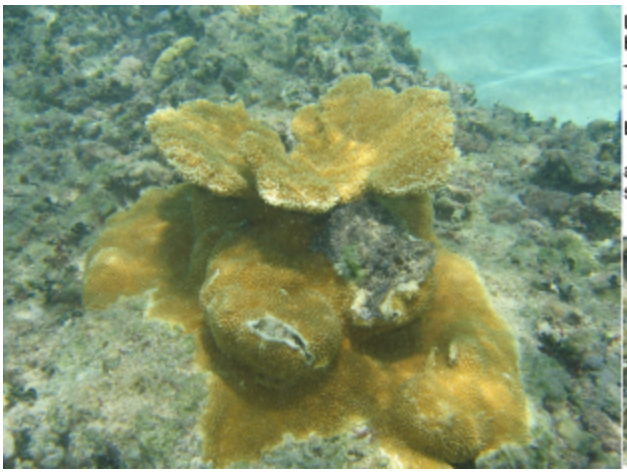
-Physical

The site has a large potential wave climate with two seasonal directions of sand transport. The site is relatively sand starved during the more prevalent southern sand transport due to a natural groin like structure of the land itself as seen in the labeled picture. One can see the sand flowing around the north beach but it spreads out more as you go south so there may be some natural sand growth es pecially on the southern beach. The sand bank is approximately where the arrow below “Sand Flow” in the picture to the right.

A site visit revealed a few smaller rocks on the South beach and, nearly all, large rocks on the North beach. These rocks could be covered with sand but that would decrease the available swimming area if breakwaters are used cost effectively and there would be a risk of exposure during hurricane events. We, therefore recommend the removal the rock. There is additional rock below the ocean surface near shore that should also be removed which can be seen later in this report under the biological findings.

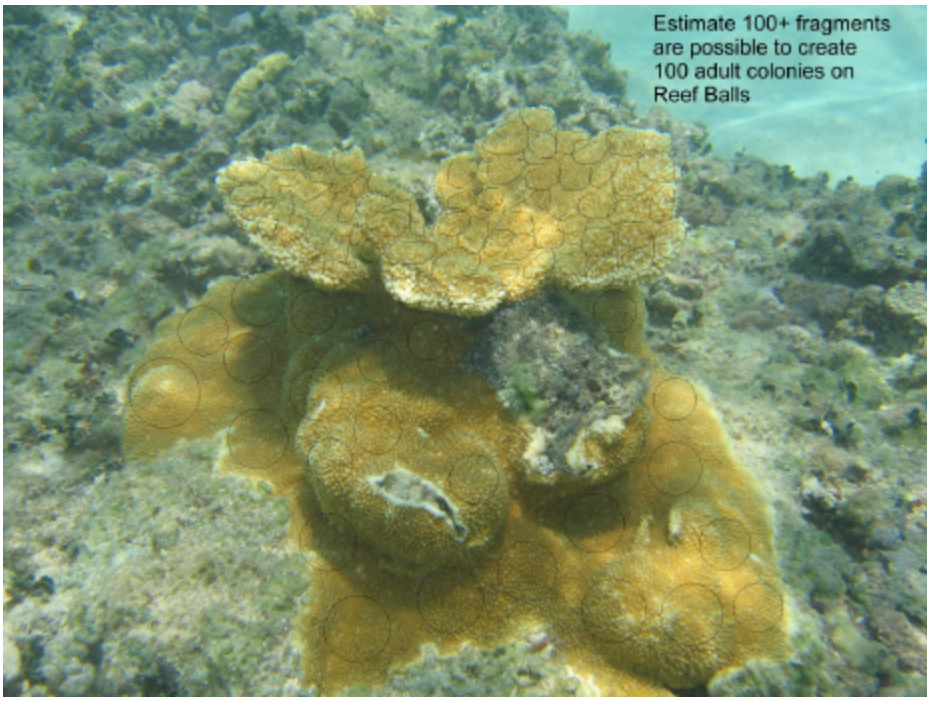
-Biological Survey (Underwater)

Following are pictures of the types of corals that were photographed in the immediate beach area and would be adversely affected if not removed to a nursery for later planting on the submerged breakwater.



Left:
Elkhorn Coral (Acropora palmata)
-classified as endangered by NOAA
-located just off South Beach.

Below right:
One year of growth on
a Reef Ball in Antigua
starting with a fragment
the size of a thumb.



Scattered throughout the site are typical tongue and grove low relief reefs that will need to be removed or converted to snorke ling trail area.
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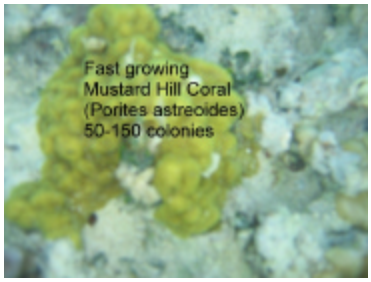
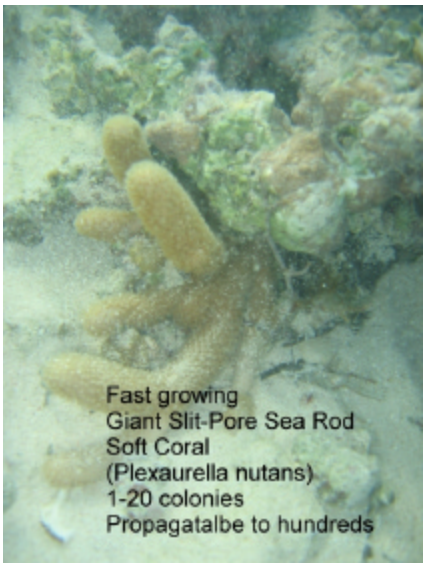
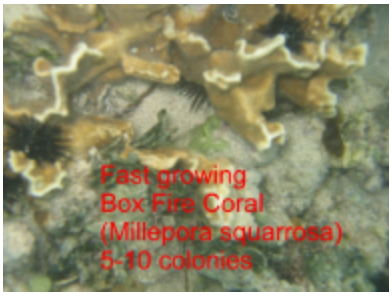
They are covered in a variety of corals that could be transplanted on the Reef Balls in create a rich snorkeling reef.





Over all, the site had plenty of smaller corals that could be used for planting but permitting should not be a big issue as there was not an flourishing coral reef in front of the areas where beaches had been located before as the beach sand probably prevented full development. Only the Elkhorn coral is considered highly valuable ecologically and it can be rescued.



All of the important corals in the area can be saved from the effects of the beach renourishment and construction using proven Reef Ball propagation and transplant strategies.

MINIMUM CORAL TRANSPLANTS REQUIRED BY THE REEF BALL FOUNDATION TO CERTIFY THIS PROJECT

- Maximum propagation and planting of Elkhorn corals affected (likely around 100 fragments)
- 50 Adult colonies of Mustard Coral or 200 fragments
- Fragmentation and planting of all Lavendar Finger coral (likely around 300 fragments)
- 100 Gorgonian (soft) corals of mixed species.
- 50 fragments of Millepora coral (of any subspecies)
- Transplanting of all reasonably movable brain corals.

Potential Solutions

It is important to note that we tried to take into consideration the widest possible design considerations as follows: a) to balance architectural beauty; b) enhancement of the uniqueness of the property; c) long term stability of the beach; d) safety for water entry/use; e) protection and enhancement of the environment; physical protection of property during storm events f) regulatory, governmental and resident considerations; g) long term property value; h) engineering requirements; i) integration with the current planned designs and functionality; j) and desired outcomes (i.e. the creation and retention of a natural beach look, feel, width and slope).

Although the team has a great deal of combined experience, we do lack a first-hand knowledge of Occidental's plans and preferences which we believe should be an important consideration in our final recommended solutions but for now we will use our knowledge of other Occidental developments as a stake for guidance. Noting this, we wrote this report using the assumption "What I would do if it were MY property?" (Noting, that being a non-profit environmental organization we will error toward the side of environmental protection).

-Many guests will be scuba divers and/or snorkelers both which activities attract guests and provide the hotel with some minor revenue streams.

-Many guests will be families and would enjoy an area of calmer ocean beachfront that is safe for children.

-The maximum amount of beach/water interface it desired given the physical constrains of the property. Total square footage of beach will be designed by Occidental hotel architects to match expected hotel capacity. This square footage requirement will dictate how far the sand must be filled inland.

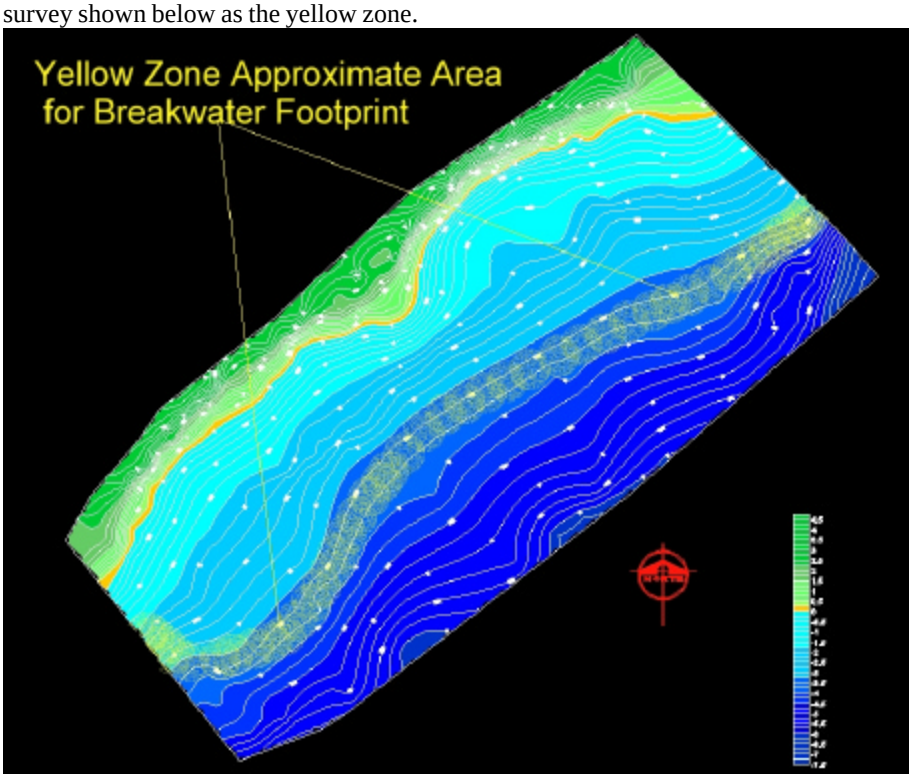
-The budget for proposed beach protection solutions should be less than or equal to the expected net present value of standard beach renourishment techniques for beach creation. (unless there are very strong and clear additional advantages that might warrant budget additions such as property value increases, enhanced guest services or experiences, etc).

-The primary goal is creating stable beaches on the property. Whereas creation of a coral reef to increases property value, reduction of maintenance, additional "bells and whistles", more environmentally friendly methods, community acceptance and more aesthetically pleasing solutions are all considered secondary goals.

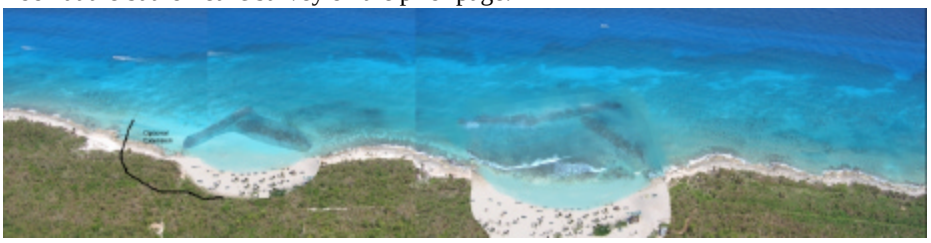
<Javier may wish to add more here>

South Beach (Part I)

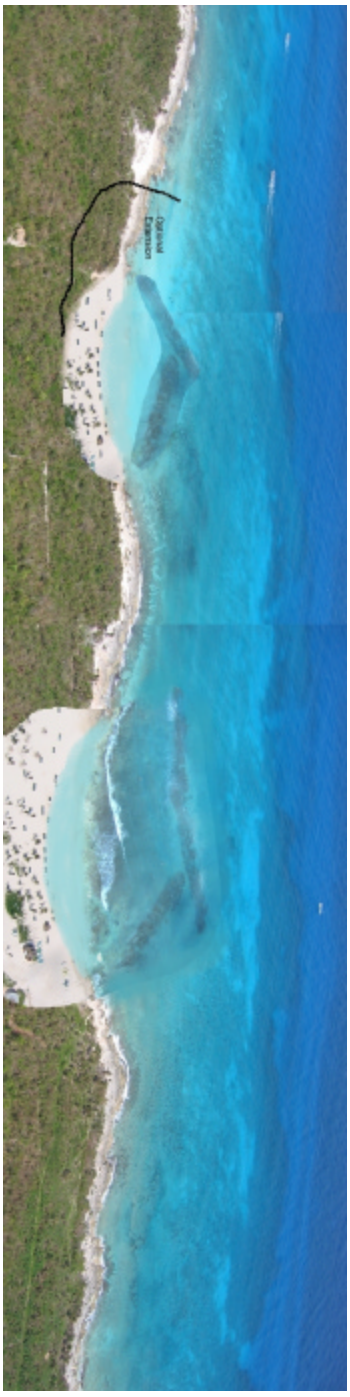
Our proposed solution for South Beach is 5-8 rows of 3-5 feet tall Reef Balls placed along the 3-5 foot biological tide bathometric profile line off South Beach in a natural looking pattern incorporating numerous snorkeling pathways, and optional snorkeling and scuba trails featuring several different Reef Ball molding patterns for uniqu eness. The Reef Balls would be transplanted with a variety of soft and hard corals rescued from the path of beach restoration project and actual footprint of the Reef Balls other imperiled corals rescued from the area might also be used. The actual pattern of the Reef Balls will closely align with the 3-5 foot biological tide line bathometric which has not yet been computed but can be roughly estimated to be at around the 2 meter bathemetric line in the survey shown below as the yellow zone.



This photo renderings represents an initial vision of the project. *Please note the physical shape of the breakwater does not follow the actual bathometry of the property* as it is a cutted and pasted photo of another site with Reef Balls just for visual understanding. Look at the bathometric survey on the prior page.

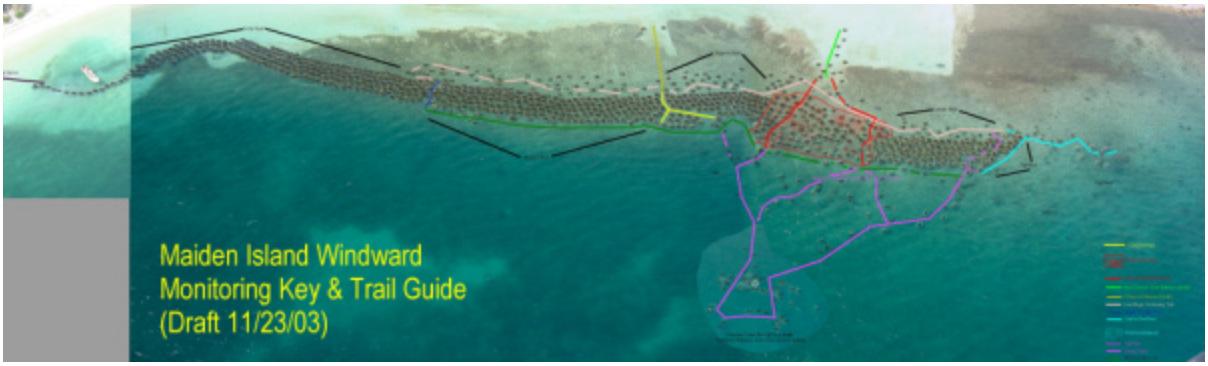


Full page view on the next page:


Proposed
Expansion

In addition to the optional extension of the North Beach which would be Reef Balls outside of the main breakwater structure used for the snorkeling, and scuba tra ils could be of a variety of sizes to represent a natural system (Reef Balls are available in 8 other standard sizes besides the 5 foot tall Reef Ball likely to be used for the actual breakwater). Conceptually, the submerged breakwater is designed to be like an ideal natural barrier reef (that one would look for in high-value oceanfront property. Note also the groinlike tail ending to the south because water currents moving to the south could sweep swimmers into unsafe areas and these reef balls would provide a signal or "fence" to inexperienced guests to make their way to the beach rather than getting caught in currents. The structure wall also act minimally as a submerged groin to help hold sand on the beach.

From a realistic shape perspective with the snorkeling trails, etc, we would expect the overhead view to look more like our project in Antigua.



This picture is available in high resolution at
http://www.reefball.com/map/antiguascience/windwardmonitoringkeyandtrailguide.jpg
You can see the snorkeling trails, diving sites and various other intricate design features by viewing this file. As this is the highest quality submerged biological breakwater ever built, and a great deal of resources were used to create it we recommend nearly an identical "copy" of its design features at this property with the obvious changes for site bathometry.

Our biological assessment found very high water quality on the both beaches.

Therefore, this site is ideal for coral transplants that will turn the breakwater into a nearly natural coral reef over time. Based on an observed tropical fish on the few small coral heads in the area, we are 100% confident that the breakwater will be populated with a large amount and variety of tropical fish. However, the area surveyed is currently heavily spearfished so many of the larger fish may be initially lacking until this activity is not longer occurring on the property. We expect this particular location will yield a very good snorkeling reef as long as enough rows and enough proximity to the tide line is allowed to make for a calm swim area.

Dr. Lee Harris, can form an expert opinion on the number of rows of Reef Balls recommended to best balance sand accretion with sand loss from the long shore currents taking into account your goals to insure that the equilibrium balance of the beach will not be too wide or too narrow, on average. (Note that storms, such as hurricanes, will change the beach from time to time and that recovery to the equilibrium depends on a variety of natural factors including time , sand budget and wave climates. Also note that all submerged breakwaters are still considered experimental in nature and results can never be guaranteed in terms of predicting the exact effects on a beach.

Since Dr. Lee Harris, has only had an initial site visit we suggest a preliminary working hypothesis that 5-7 rows will be required for purposes of budget estimates based on our "best guess" from prior projects. (Prior projects have used between 3-9 rows of Reef Balls)

One other important variable to note is that the number of rows must be increased as the depth from the top of the Reef Balls to the waterline increases or conversely if the Reef Balls are placed where the top of the units are closer to the surface of the water less rows can be used. Although typically, clients do not like Reef Balls to be exposed at low tides for visual reasons we have found that Reef Balls are much more effective when close to the surface as pictured here. Therefore, our standard initial recommendation place Reef Balls at the biological tide line (we you see growth ending on docks and other objects in the sea) . At this depth, the Reef Balls will be occasionally exposed during certain very low water events usually seasonally combined with very low tide days.

The trade off between visual aesthetics, snorkeling access, required swimming area size and project budget are factors best decided by an educated client so the design team can make the best choices for final breakwater design.

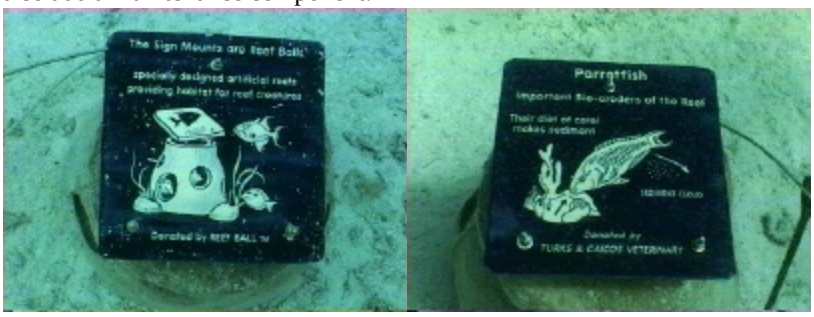
Optional Enhancement Features

There are various other special features one could design into the Reef Balls:

- It would be possible (although it would add a maintenance component) to add underwater lighting to the Reef Balls that could be controlled from the residence house for a spectacular night view of the breaking waves, night snorkeling, or color effects. However, lights could only be used periodically without harming the reef and should not be used continuously every night. They must also be designed to brighten up gradually and be turned off gradually to avoid negative consequences to the reef life.

- Reef Balls designed to create a “blow hole” effect when waves break could also be engineered and included at various points if desired there are several natural blowholes on the property that could be enhanced with some minor concrete work if they are preserved from rock removal.

- Underwater plaques or signs could be added to create snorkeling trails but these also add a maintenance component.



- Layer Cake Reef Balls can be used for some of the modules. They add complexity, species diversity and uniqueness. These units are heavier than standard Reef Balls and require extra anchoring due to the lack of a top hole.

- Reef Balls can be fashioned into mooring anchors in the deeper optional scuba trails areas.
- Reef Balls can be engineered with attachment points for marker buoys if the reef needs to be marked for navigation purposes.
- A higher than standard number of Reef Ball Coral Adapter Plug Holes can be added to the Reef Balls if a higher density of corals is desired for planting (because the client desires are more complete coral transplanting process for a faster, more complex reef). A Reef Ball Coral Transplant System Poster is in Appendix A for a better understanding of the coral transplanting methods used.
- Scuba Trails and or Snorkeling Trails with a variety of Reef Ball sizes on the offshore side of the breakwater can be added inexpensively at the time of construction of the breakwater.
- Boating or swim through gaps can be added in desired locations throughout the breakwater..
- Note that transplanting (especially hard) corals on the Reef Balls will allow the breakwater to develop even better wave attenuating characteristics over time. Hard corals on the surface of the Reef Balls will create more drag on waves.

With the possible exceptions of underwater lighting and expenses of the coral transplanting teams, most of these options would not significantly affect the overall project costs. Therefore we recommend the client use as many of these options that are a good fit with the overall goals of the project.

Possible Project Concerns

Aesthetics of Project

Due to the uniqueness of the Occidental properties, we believe that aesthetics are an important engineering requirement. The Reef Balls are symmetrical domes that would only be exposed during low tides in the trough of waves similar to the appearance of natural barrier reefs and during certain minimal low tide events where natural corals are often see at the surface too.

Ultra Reef Balls being deployed at Gran Dominicas Hotel in the Dominican Republic, note the appearance of the Reef Ball submerged breakwater as only a dark line in the water. This would be the same look generated at the Maiden Island except your Reef Balls would be spread out a bit more and would not form such an obvious line.

The proposed Reef Ball project would look much more natural than traditional Mexican sand filled container breakwaters.

Longevity

Reef Ball has a long history of using high tech concrete to engineer structures designed to last centuries rather than decades. Our work has required this because longevity is an important design criterion when building coral reefs that potentially last for thousands of years. By using specially designed, high strength concrete and using W.R. Grace admixtures, we will create a high strength, abrasion resistant concrete, (without iron rebar in the modules), that will have an engineering life of hundreds of years. Therefore, the client can consider this solution a final one. Our authorized contractors are trained to meet our concrete standards.

Stability

Physically, the site experiences a significant wave climate and the Yucatan faces threats from hurricanes. Although Reef Balls can be engineered heavier, and/or with modular bases for extra weight, we concluded that directly anchoring the Reef Balls to the seafloor is the best solution and only reliable solution for this area.

Beach Creation

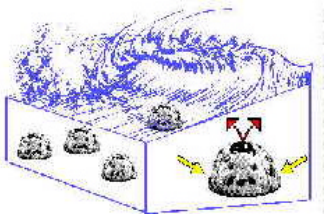
There are three options to obtaining the beach sand; sand nourishment, natural accumulation of sand, or a hybrid approach of seeding some while accumulating the rest.

In most cases, a natural accumulation of sand is desired and Reef Ball submerged breakwaters are normally set up with this system.

Right: Natural accumulation of sand in the Reef Ball Dominican Republic Beach Creation Project after 4 months.[5]

However, due to the beach not having a large active sand transport system we recommend an initial sand nourishment. This is the basis for our recommendation to conduct a hybrid sand renourishment and natural replenishment project rather than relying solely on the natural build up of sand over time. Our system should not only protect the sand filled but will help the system catch more sand over time. Note that some sand will nearly always be lost initially after the fill due to the sand resorting its grain size characteristics. Dr. Lee Harris will be able to take measurements of this to compute the exact amount of sand for the initial fill.

Why Reef Balls Work Better than Solid or Rock Submerged Breakwaters



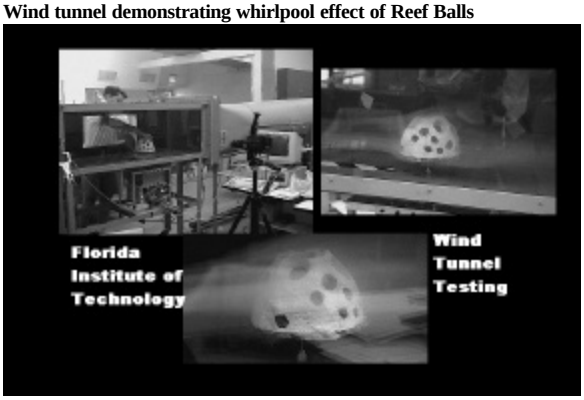
Reef Balls were initially designed to be biologically active and to be stable in hurricanes. Essentially, Reef Balls needed to be the base of a natural reef. To do this, we had to design our holes to create whirlpools so that corals could be fed better by passing currents. Additionally, we created a large hole in the top of the Reef Ball so that waves and currents would be jetted from the top, adding to the stability of Reef Balls. Our goal was to use the least amount of concrete to make a unit that was stable in hurricanes.

Traditional and barrier submerged breakwaters work by making waves break. As a wave breaks, it loses some of its energy. The problem with these systems is that this is the primary mechanism for wave attenuation. Additionally, as the wave is lifted over the submerged breakwater the acceleration of water as a wave breaks can create washout/scouring.

Reef Balls work to break waves too, but they also add a significant amount of drag or friction on water flow around them by creating water whirlpools *(vortexes)*. Reef Balls are full of holes that are designed to create whirlpools, and offer a variety of angles of reflection from the round shape, so that any wave that traverses a field of Reef Balls has to "fight itself" and therefore looses energy in relation to the number of rows of Reef

Balls that are transversed. For smaller, non-breaking waves, waves may keep their shape; but the drag forces will make them smaller as it passes through the Reef Balls.

Wind tunnel demonstrating whirlpool effect of Reef Balls



With major storm events, the width of the Reef Ball fields must be wide enough to cause a break on the larger waves like a traditional submerged breakwater. This attenuates the wave by the normal breaking process but also reduces the energy of each wave further by fighting (*drag*) the wave by creating whirlpools/wave reflections (*friction*). Note: In major storm events, wash out (*scour*) is possible because the breaking waves can create washout (scour) even with drag (*attenuation/drag*).

Safety & Property Protection

Safety is usually always an issue for our clients. Certainly, children, elderly and other potential waders/swimmers who snorkel or swim on the beaches would be subject to getting caught in the strong currents and waves without breakwater protection. We therefore we have proposed that a line or two of Reef Balls are brought all the way into the shoreline to serve as a visual warning to exit to the beach at that point.

For the entire length of the beach, the submerged breakwater will reduce the energy of the waves to make swimming and wading safer. Reef Balls may also provide a physical barrier to reduce the loss of a swimmer to sea.

Protection from wave run-up and damage to hotel properties might also be another benefit of a submerged breakwater. This cannot be relied upon for submerged breakwaters since a high storm surge can render submerged breakwaters less effective for that period of time. Therefore recommendation of minimal foundation heights should be followed or other erosion control options should be considered for structures.

North Beach (Part II)

North Beach is a very challenging area due both to rocks throughout the area and a deeper bathometric profile. Our recommendations would be essentially the same as the Southern Beach except you might want to exaggerate the curvature of the beach more to maximize water/sand interface and minimize the actual amount of rock to be removed.

Reef Ball Mexico will investigate the physical site preparation costs to determine the financial implications for this beach.

Costs

The Reef Beach Company provides overall project quality control for any erosion control projects. Erosion control projects require a great deal of additional oversight not found in biological projects but they are more technical in nature and we have found this oversight to be the different in project performance. Due to failures of unsupervised projects and the success of supervised ones, we no longer offer unsupervised options. The cost for most of this oversight is already built into your construction estimates from Reef Ball Mexico as they pay a royalty fee of 15% of all projects to The Reef Ball Foundation. However, their will be expenses….billed at cost…throughout the project for necessary oversight travel. Also, your upfront deposit may be slightly higher in a Reef Beach project verses a normal Reef Ball Foundation (biological) project because estimated Royalty Fees must be made in advance of the project…not upon project completion.

Reef Ball Mexico will provide you their estimates for site preparation, permitting, construction of Reef Balls, site survey work, deployment, and required monitoring.

The Reef Beach Company will provide Reef Ball Mexico with quality control, engineering approval, and will certify completion of the work so that Occidential can make a final payment and release any required project bonds. This protects Occidential to insure they get the product that they desire and protects the Reef Ball Foundation's interest in proper application of our technology both from a product and from a biological aspect.

The Reef Ball Foundation's Coral Team will also perform the minimum required Coral propagation and planting charging only expenses. There may be additional fees or expenses required which can be quoted by proposal from the Coral Team if more than the immeadiate rescue of corals imperiled by the project is required (i.e. if Occidential wants more coral plantings to create snorkeling/diving trails or other special features desired by the property but not required for biological mitigation. Note that minimum biological mitigation requirements are that of the Reef Ball Foundation and not necessarily the minimum as required by Mexican Law. In the case of this project, the minimum is represented by the planting of about 800 coral fragments as detailed in the biological section of this report

Possible Additional Participating Companies

Some of these companies may be called in for specific issues during the project as they may arise and all have worked with Reef Ball projects before.

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Dr. Alfredo Torruell

http://www.reefball.com/map/contractorresumes/alfredotorruell.htm

***Don Ward, Ph.D.,* Consulting Coastal/Ocean/Engineer**
http://www.reefball.com/map/antiguiaaerial/CurriculumVitaedonward.htm

Advanced Coastal Technology
www.advancedcoastaltechnology.com
Jay Sample, President

Dr. Lee Harris, Ph.D., P.E., Consulting Coastal, Ocean and Civil Engineer of the Florida Institute of Technology will be doing the engineering, physical modeling, survey work and scientific monitoring of the project. He has worked with submerged breakwaters since the 1980s and has been involved with hundreds of projects worldwide.

http://www.fit.edu/AcadRes/dmes/faculty/harris.html

John Walch, Ocean Worlds Consulting, Coral Propagation
http://www.reefball.com/map/contractorresumes/johnwalch.htm

http://www.reefball.org

Kathy Kirbo, Executive Director

The Reef Ball Foundation is a 501(c) non-profit charitable organization. Its mission is to help restore our world's ocean ecosystems and to emphasize and protect our natural reef systems through preservation, technology, and innovative public education opportunities, and community involvement. The Foundation works with governments, businesses, schools, research institutes, and community organizations. If you wish to qualify as a Reefs Around the World project, then your expenditures could be a tax write off as a donation to a US bas ed charitable organization. The Foundation's Volunteer Services Division can also be used to assist in your coral transplanting activities reducing or eliminating the cost of doing so. For example, we could use coral transplant experts and paying ecovolunteers to finance the coral planting portions of the project by simply providing this division with rooms, diving support and food for the volunteers

Qualification requires a full a coral transplant program on your breakwater, and 2 follow up monitoring visits per year for 3 years. If a US based tax write off is important to the client, further discussions with the Reef Ball Foundation are warranted.

http://www.reefball.org/coralaroundtheworld/announces.htm

Appendix A: Reef Ball Coral Transplant System Example

For a more recent example, please visit
http://www.reefball.com/map/antiguascience/antiguapressrelease.htm
Which is the project which most closely resembles your project.

Curacao Coral Restoration Project
- *Porto Mari*

Coral transplant technology used to save hurricane damaged corals.

Volunteers gathered dying corals and learned how to spot the ones that would not survive naturally.

The first day the tanks are set up to hold our corals while we stabilized them for transplant onto the Reef Balls, everyone learned a quick lesson in playing in the sand and aquariums.
They also learned that they could not allow the different corals to touch each other so that they did not have the opportunity to sting each other.

Water is supplied directly from the sea so no filtration system is required, just shade to make sure the coral's don't get a sunburn.
Two tanks are set up, one for the unprocessed fragments and the other for the fragments ready for transplant.

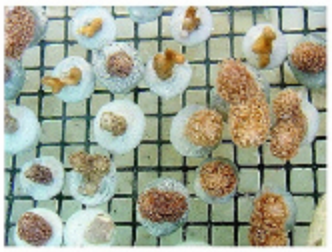
An acropora fragment (elkhorn coral) was a prized find as the area used to be abundant with this species before the storm. The fast growing nature of this coral will bring quick micro habitats to the reef system.

The team springs to action to make several hundred molds.

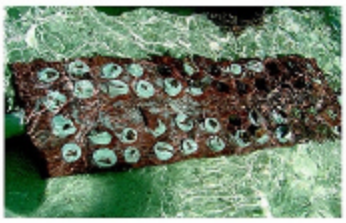
Everyone jumps in to give a hand the first day of construction. Assembling these molds took more time because we had to make bases and fit the Reef Ball adapter plugs in the locations where we wanted corals.

When shaped properly, it fits perfectly into a Reef Ball adapter plug hole and allows the coral to be embedded in quick setting concrete specially designed for the purpose.

your.

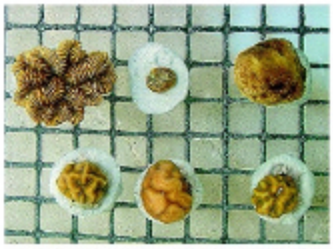


Finger corals, (Porites) are good complexity builders



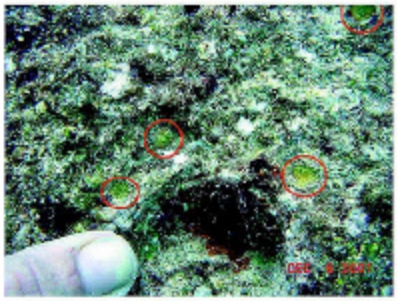
Stabilizing natural fragments in the plugs insures that instead of dying in the sand after the hurricane, they can be saved to grow into healthy adult corals creating a natural reef system.

Arranging the corals roughly by species type makes counting them easier.



Here are several types of brain corals which were cultivated, not propagated.

8.5 Month old Acropora! It started as a plug less than 1 inch long.



There are 4 naturally recruited corals here. Two of which appear to be star corals.

Natural recruit next to plate coral plug.

Reef Balls, Mid-July 2000