WHITEPAPER

IMPROVING CORAL GROWTH ON ARTIFICIAL SUBSTRATES

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OVERVIEW:

One of the most perplexing problems with artificial substrates, whether for fish production or coral habitat rehabilitation, is the reluctance of many marine species to settle and grow on these chemically aggressive surfaces. We began working on this problem in the Whitsunday Islands, central Great Barrier Reef, in 2001. We decided to focus the work on modifying Ordinary Portland Cement since it is by far the most common underwater construction material. Since then, we have established a coral nursery and tsunami rehabilitation project in Langkawi, Malaysia and a much larger coral nursery program for Perhentian Marine Park, Malaysia where we have continued to refine our marine life enhancing surface treatments. To date, the Perhentian results are very promising although we can expect growth and mortality rates to differ between species, years, depths, and latitude.

It is possible to state the following:

- Successful coral planula settlement occurred a few weeks after tile manufacture (Perhentian) and as much as 2-3 years earlier on the newly treated surfaces than on Ordinary Portland Cement.
- A second settlement occurred 12 months later (Perhentian) taking coral density on the treated surfaces to 62.5 colonies per square metre.
- No corals have settled on the Ordinary Portland Cement control.
- Early coral survival is greater on treated surfaces for at least 4-5 years (Australia).
- Surface contact (lateral) growth rates of several massive coral species are greater on treated surfaces (Langkawi).
- Surface contact and “fusion” by branching corals is rapid and aggressive providing significant strength of attachment for the colony (Perhentian).
- Long term exposure to treated surfaces in closed aquaria showed no toxicity to a number of coral species nor to crustaceans and several fish species (Langkawi).

The surface treatment appears to beneficially modify Ordinary Portland Cement enhancing its use as a substrate for coral growth. The treatment’s value in coral nursery applications has been proven and it will now be used for
a trial large scale reef top transplanting in the Perhentian Coral Reef Rescue Project. The concept behind its design is to use Ordinary Portland Cement as the inexpensive structural material for artificial reef development and coat it with FTV’s latest surface treatment.

BACKGROUND:

Aragonite Production in Corals

Coral skeletons are principally aragonite and are made of bonded Ca$^{2+}$ and CO$_3^{2-}$. Aragonite is the crystalline form of calcium carbonate and is the form responsible for the mechanical strength of the skeleton. It now appears that the chemistry of the substrate surface has a large impact on aragonite production at the base of the coral. Modifying the “micro-environment” beneath the coral leads to more favorable conditions for coral growth. It’s worth mentioning that isn’t just about pH. The use of other non-toxic substances appears to further promote coral growth as well as modify the surface micro-environment. Trials to further optimize concentrations of these special additives are underway.
SUMMARY OF RESULTS:

Coral settlement rates (as measured a few months after spawning when corals are easier to locate) are dependent on “abundance” of planulae, predation, competition, and surface chemistry. Coral growth rates are largely dependent on a number of variables including temperature, light, depth, water movement, latitude, and calcium carbonate in solution.

In a simple experiment looking at settlement success, corals on treated and untreated Portland Cement surfaces were counted every 12 months from about 12 months after spawning. The experiments were carried out in Whitsunday Islands, Australia from 1999 to 2005. Results were, at the time, problematic to assess since the settlement of corals on the treated surface began and continued annually 2-3 years earlier than settlement on untreated surfaces. Figure 1 shows average % coral cover on all settlement plates.

Figure 1

![Graph showing percent coral cover with time](image-url)
It can be seen that lateral growth of new colonies (% cover) started earlier on the treated surfaces. There is also an indication that, with more time, there could be enough data to suggest significantly different lateral growth rates. A faster lateral growth rate would result from more rapid aragonite production at the fine margin of coral growth where soft coral tissue is “reaching out” across the substrate. Note that these experiments were carried out with a predecessor of “Compound 7”.

In this trial, small coral fragments were simply placed on top of a treated surface. After 6 months, we can see the coral spreading rapidly across the treated surface (Compound 7) as a heavy growing base from only a few initial points of contact. Note also that the abundant macro algae are being “out-competed” by the coral’s rapid and aggressive calcification.

Figure 2
This photo illustrates the aggressive growth of an Acropora branch onto the treated surface (Compound 7). Rapidly developing tissue is seen as a translucent mass under the branch and to the right of the heavily calcified attachment.

Figure 3
An experiment in Whitsunday Islands, Australia looked at extension rates of branch length in *Acropora aspera* on treated and untreated surfaces of settlement plates placed in a shallow reef slope environment already supporting extensive *Acropora* thickets. Extension within the colonies was complicated beyond 36 months when branches became numerous, fused, and ill-defined. Figure 4 shows these results.

**Figure 4**

![Graph showing linear extension of Acropora](image)

It can be seen that settlement of *Acropora aspera* occurred earlier on the treated surfaces. Growth rates are similar to those published in the literature. The important difference is in the cumulative growth rate (Figure 5). Clearly, getting “started earlier” can make a significant difference in the rehabilitation of *Acropora* dominated degraded coral environments.
Early in 2018, trial settlement tiles were placed on the reefs at Perhentian. These included treated and untreated Portland Cement surfaces. The program is part of the Fizzy’s Coral Reef Rescue Project and aims to look at the reaction of local coral planulae to the two chemically different surfaces. Perhentian corals are reported to spawn during the period from December through February. During last year’s coral spawning, the experimental tiles were exposed to natural larval settlement from more than 60 nearby potential spawning species in the Marine Park. Larvae that attached and grew on the treated surface accounted for 37 individuals per square metre. None settled on the Ordinary Portland Cement. This year (March, 2019), more larvae settled on the experimental tiles (Figure 6). The population density on “Compound 7” has now climbed to 62.5 colonies per square metre including those larvae that survived from 2018.
The Ordinary Portland Cement had experienced no settlement during 2018. That result was repeated again this year and the Ordinary Portland Cement still has no coral attached and growing. The conspicuous lack of sedentary organisms and low biodiversity on most concrete artificial reefs is explained by surface chemistry and texture.

It seems clear that the use of Ordinary Portland Cement will continue for underwater construction. It is also abundantly clear that these surfaces can be modified through the application of “Compound 7” so that they encourage the rapid settlement of marine life and lead to significantly higher biodiversity.

Figure 6

Young colonies are highlighted to improve resolution. Tile is 400mm wide. See macro photo insert.
CONCLUSION:

“Compound 7” is able to alter the micro-environment within the thin film between living coral tissue and the substrate. This apparently results in higher settlement success for planulae and much more aggressive attachment and growth for coral fragments on treated surfaces when compared with Ordinary Portland Cement surfaces. When corals are able to start colonizing a surface earlier, their growth will greatly exceed that of “later starting” colonies and environmental rehabilitation can be advanced several years over other methods. While longer term extension rates may be no faster, “earlier starting” provides a significant advantage in our coral reef rehabilitation strategies.

Corals growing on Compound 7 in our Perhentian experimental fragment nursery