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PROGRESO PIER

built with nickel-containing stainless steel

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Built to last, built sustainably

Seventy five years ago it was decided to construct a pier into the Gulf of Mexico to allow the import and export of material to and from the Yucatán Peninsula. Nickel-containing stainless steel reinforcing bar was specified.

A recent ISO-consistent peer-reviewed Life Cycle Assessment (LCA) shows that the selection of stainless steel—in place of the usual carbon steel—has been a productive investment for Mexico and the least demanding on the environment.

A comparative LCA

By the 1930s the anticipated advantages of using nickel-containing stainless steel rebar (Type 304, UNS S30400, EN 1.4301) for marine environment applications were known. The LCA of the Progreso Pier shows that the choice at that time of the nickel-containing material for the functional unit (the pier) has been advantageous in both functionality and economic terms.

There is only one Progreso Pier. There is not another existing structure to which its economic and environmental performance can be compared. It was decided, therefore, to compare the actual history of Progreso Pier with a modeled Progreso Pier where a single material substitution was made: standard carbon steel rebar substituted for the nickel-containing stainless steel. All other variables were exactly the same: age, physical location, usage and the climatic environment (temperature, weather events such as hurricanes, salinity and wave action).

> Over the 79 year period covered by the LCA (to 2020), the life-time cost of the lower original capital cost alternative structure is now 44% higher than actual Progreso Pier costs.

Standard engineering design protocols were applied to all the key parameters for the structure. This removed all peripheral considerations and allowed a focused comparison of the performance of the as-built pier (Progreso Pier) with the well-understood and familiar carbon steel alternative (the modeled pier).

The LCA itself conforms to the ISO 14040 series of standards that govern the conduct of LCAs. A copy of the full life cycle assessment report, including engineering design protocols, is available upon request to communications@nickelinstitute.org.

Benefits of appropriate material selection

The LCA of Progreso Pier supports the assumptions made 75 years ago. Significant financial and environmental advantages have flowed from the decision to use nickel-containing stainless steel. The difference comes from the carbon steel rebar alternative model requiring periodic repair, rehabilitation and reconstruction compared to only minor maintenance to the actual Progreso Pier.

As a result, there has been and continues to be less limestone being mined, less stone being crushed, less carbon steel diverted from other uses, fewer chemicals in concrete mixes to defend carbon rebar from the inevitable chloride attack. There is less disruption of the service function of the pier because of the reduced need to repair, refurbish or replace. Capital, labour and materials that would have been required to keep a single piece of infrastructure in operation over the decades have instead been available for other domestic and industrial development.

Progreso Pier remains in service and the full extent of the environmental, economic and social benefits of having selected nickel-containing stainless steel continue to accumulate.

Table 1: Alternative design life cycle costs

Year		Activity	Net present cost (1941$)
0	1941	Initial material cost	$ 467,377
10	1951	Maintenance #1	$1,611
25	1966	Maintenance #2	$2,413
40	1981	Maintenance #3	$3,213
50	1991	Reconstruction	$465,046
60	2001	Maintenance #1	$1,603
75	2016	Maintenance #2	$2,401
79	2020	Residual value	-$194,754
		Total	**$748,912**

Table 2: As-built Progreso Pier life cycle costs

Year		Activity	Net present cost (1941$)
0	1941	Initial material cost	$544,989
44	1985	Maintenance #1	$1,606
59	2000	Maintenance #2	$2,405
74	2015	Maintenance #3	$3,202
79	2020	Residual value	-$32,185
		Total	**$520,018**

△ ***The life-time costs strongly favour stainless steel.***
All dollar amounts are 1941 values and reflect adjustments for the inflation and discount rates that are detailed in the full report.
The timing of repairs (first repair for the alternative design at year 10) and life-time costs reflect the effects of the demanding marine (saline) environment. The inclusion of "Residual value" (and the large reduction of attributed costs for the alternative design) reflects the conservative nature of the assumptions for the "as-built" pier (that its service life will end in 2020) and an additional 23 years of service (to 2041) for the alternative design as a consequence of the modeled total rebuild in 1991. Even with this conservative approach, the as-built Progreso Pier still strongly outperforms the alternative design.

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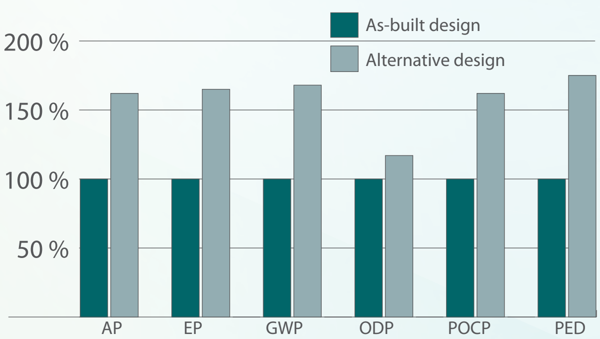
△ *Top: In 1969 a much smaller pier (left) was built using carbon steel rebar alongside the 1941 Progreso Pier (right). The 1969 pier did not stand the test of time.*

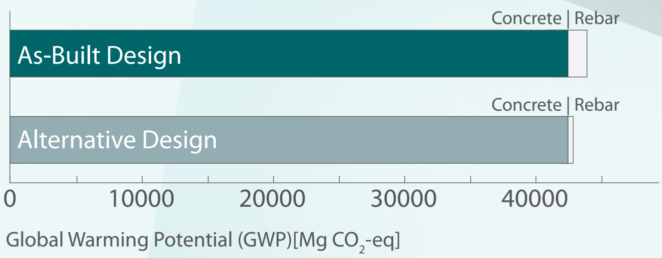
△ *Bottom: Even though they were conveniently located beside each other and shared the same aggressive environment of saline waters, high humidity and extremes of temperature (and occasional hurricane-force winds and waves), differences in design and function made this smaller unnamed pier an inappropriate basis for comparison with Progreso Pier. The "alternative design" approach allowed total control of form and function with only a single variable: the presence or absence of nickel-containing stainless steel.*

Chart 1: Impact relative to as-built design



AP Acidification Potential
EP Eutrophication Potential
GWP Global Warming Potential
ODP Ozone Depletion Potential
POCP Photochemical Ozone Creation Potential
PED Primary Energy Demand

Chart 2: Global Warming Potential



△ ***Charts 1 and 2:***

The environmental impacts of the as-built 1941 Progreso Pier showing the consequences of different material selections: carbon steel (alternative design) or stainless steel rebar (Progreso Pier). The overwhelming importance of concrete is clear and puts the impacts of choice of rebar material into perspective.

The GWP gap between the two structures disappears with the first 10 year maintenance of the alternative structure. The benefits of the "as built" Progreso Pier then turn positive and continue to grow to this day.

Finding Progreso

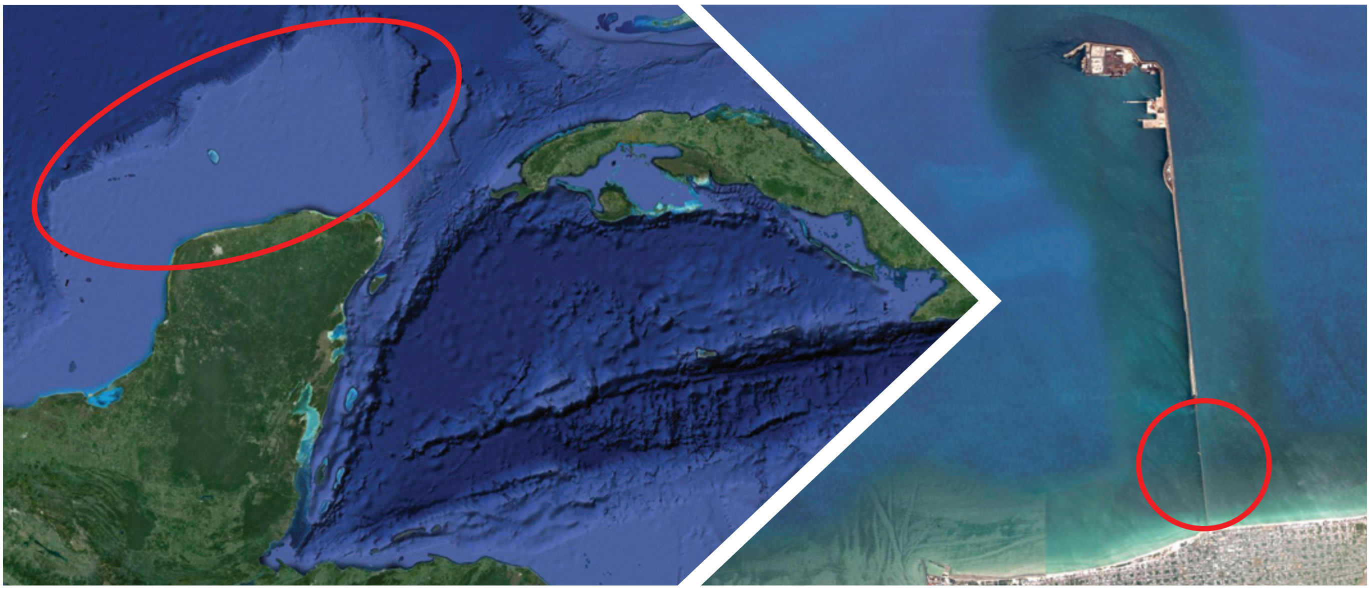
Progreso is the port city of the Mexican state of Yucatán and its pier, visible from orbit, is the longest in the world. The need for length is determined by the geology. The limestone shelf that forms the Yucatán Peninsula transitions from land to sea at such a slight angle of decline that it is literally kilometres before the water is deep enough to accommodate cargo vessels.

In 1941 the original structure was completed with a length of 2.1km. It is that structure that was the subject of the life cycle assessment.

With the rise of commercial activity (including large cruise ships) and the increasing draft of cargo and container vessels, the pier was extended in the 1980s to its current length of 6.5km.

▽ *Left: The Campeche Bank (with the prominent Alacranes Reef feature) that makes the Progreso Pier necessary.*

▽ *Right: The pier today with the original 1941 pier circled.*



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Gross Domestic Product (GDP) and Sustainability

The Influence of Appropriate Material Selection

There would be little difference, over time, to the size or growth of Mexican GDP if Progreso Pier had been built using carbon steel rebar.

The reconstruction and periodic repairs required by the alternative design would have resulted in GDP measures of economic activity. There would have been additional mining and quarrying, cement and rebar manufacture, transportation and landfilling of rubble, transportation of replacement materials, and all the employment and wages that go with such activities.

In this way, GDP methodology measures the consequences of corrosion damage as an economic positive.

This does not mean that the financial and environmental choice of stainless steel rebar in 1941 for the as-built Progreso Pier has had, over its decades of service, a dampening effect on Mexico's GDP. Rather it means that the resources of all kinds that would have been needed to sustain a pier built using carbon steel rebar have been available for other projects such as the 1980s 4.4km extension of the pier.

The choice of appropriate materials is an investment in sustainability and frees up physical and human resources for other projects.

About the Nickel Institute

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Nickel Institute is the global association of the world's primary nickel producers who together account for approximately 85% of worldwide annual nickel production outside China. Our mission is to promote and support the use of nickel in appropriate applications. NI grows and supports markets for new and existing nickel applications including stainless steel and promotes sound science, risk management, and socio-economic benefit as the basis for public policy and regulation. Through its science division NiPERA (www.nipera.org), NI also undertakes leading edge scientific research relevant to human health and the environment. NI is the centre of excellence for information on nickel and nickelcontaining materials and has offices in Asia, Europe and North America.