CANCUN BARRIER: ALTERNATIVES FOR BEACH RESTORATION

by

J. Diez¹, M.D. Esteban² and R. Paz³

ABSTRACT
Among the effects of hurricane Gilbert, in 1988, on Yucatan Peninsula the erosions in Cancun barrier acquired special meaning, although their first origin had, without doubt, been the inadequate way of tourist development. Paradoxically, but also consequently, their social and economical effects came soon out to the whole estate. Therefore several studies were developed during nineties and later until 2004 to generate alternative projects to recover and maintain the barrier beach. Some of the proposed solutions consisted on a simple nourishment but some other complemented it with small rigid works. The solution finally implemented, along first half of 2006, consisted on just nourishment, whose details are not enough known yet. In this paper the foreseeable efficiency of the proposed and the built projects are discussed together with the more general question about the suitability and environmental behaviour of rigid works in beach regeneration projects.

Additional index words: “rigid” works, natural (bio) reef, nourishment, ecologic and environmental impacts, hurricanes, land planning and management.

INTRODUCTION
An important and hasty tourist development has been taking place in the Cancun coastal barrier (Benito Juarez, Quintana Roo, Mexico) (Figure 1) since 1970, by the alongshore occupation with condominiums, hotels and other facilities of a great part of the barrier; this occupation affected in many stretches most of the barrier wideness including dunes and, some times, even part of the beach itself. This way of development had as consequence the onset of a permanent unsteadiness of the beach, and the subsequent setting of the erosion conditions on, at least, some of its stretches, though they were not well noticed for some not specially storming time (Diez and Esteban, 2006). The erosive situation became suddenly and dramatically evident in 1988 after the Gilbert event. Among the effects of hurricane Gilbert the erosions suffered by the beaches of the Nizuc-Cancun barrier acquired special meaning, although they had to be presumable taking into account the placement of the buildings of the excessive tourist development, doubtless too much close to the shoreline, even built on the active profile of the beach.

The erosion of the beaches early had important effect on tour operators, reducing local incomes and becoming to have a main effect on socio-economic activity of the whole estate. As a result of the Gilbert impact some studies were immediately undertaken (UNAM, 1989-1991) looking for adequate knowledge of the problem and processes to aboard a well founded regeneration project for the whole barrier; it delayed and some local owners, mainly hotels, projected a few small constructions, for local protection in different few short stretches of the barrier beach, with little satisfactory results (Gs I. I., S.A. de C.V., 1999).

Already at the turn of the past century most of the barrier length scarcely had permanent dry beach and the wave attacks on the hotel structures became very frequent. Socioeconomic damages by the affection of tourism were already important at that time and environmental impacts were presumed to be happening, not only on the coastal barrier and its beaches but in the ecosystem of Nichupte lagoon as well if the barrier became broken.

¹ Proffesor, Dept. Urban, Land and Environmental Planning & Management. Universidad Politécnica de Madrid, Spain. jjdiez@upm.es
² Engineer, Dept. Urban, Land and Environmental Planning & Management. Universidad Politécnica de Madrid, Spain. lolaestp@hotmail.com
³ Biologist, Dept. Cell Biology. Universidad Complutense de Madrid, Spain. rosapaz@bio.ucm.es
Therefore local authorities promoted new studies to understand as accurately as possible the behaviour of the whole barrier system and surroundings. Several additional studies were so developed until 2004 (Cfe, 2000-2001, 2001-2003), initially aiming to come forward with a solution for the recovery of the beaches and the permanent protection of the barrier and to generate alternative global projects to regenerate and maintain the barrier beach, looking for the best solution for the increasingly dramatic environmental, economic and social problem. These new studies continued and completed the previous research by UNAM and along them several projects regeneration and protection of beaches of Cancun were proposed.

All solutions consisted from the beginning on a nourishment of the barrier seashore, employing sands of vicinity, but some of them considered necessary to stabilize the poured out sands complementing the nourishment with some small rigid works (two groin constructions, as lateral transversal barriers for the alongshore drift at both points in which barrier ends, and a longitudinal geo-textile disposal to provide backbone steadiness all along the aimed beach platform border) (CFE, 2003).

During 2004 and part of 2005 all those studies and new bathymetric data obtained by local authorities were reviewed for validation (Diez, 2004). The advanced process of erosion on the beaches had became very serious, not permitting to go on the discussion about the nature and composition of the best solution, and the mere nourishment was validated to be implemented as soon as possible and strictly monitored to learn from it and discuss de question of the rigid works later.
The erosion (Figure 2: evolution of coastline 1984-2004) was even more serious after passing new different hurricanes throughout the zone, particularly during Ivan (2004) and Wilma (2005). Wilma hurricane, whose trajectory run parallel to the barrier from south to north, had a notable impact on the whole barrier installations, so that it likely had a determinant influence on the beach recovery decision, taken at the beginning of this year of 2006. The regeneration was developed along the first half of the same year, apparently as a simple nourishment of the whole barrier beach, although no professional information could be obtained about it.

**ZONE DATA**

It is necessary to separate in this area the so-called ordinary or common wind waves, corresponding to the regular maritime climate, with its extreme wind regime, corresponding to the storm waves, and the regime due to hurricanes. Although the effect of extreme common storm waves is important respect to the rest of the common waves, it is quite small in relation to the effect of hurricanes when directly affecting the study point. The analysis of the average wind wave distribution seems to clearly show a certain climatic bi-seasonality (winter-summer), much more illustrative and meaningful than the division in the four classic seasons (astronomical), which have not only climatic meaning. The winter spans from September to mid February, with storms coming from the NE, and the summer goes from February to mid September, with storms coming from SE. February and September are transitory periods with the respective roles of spring and autumn. (Diez & Esteban, 2006).

The effect of hurricanes does not depend only on their magnitudes, but also on their trajectories. Hurricane Gilbert had been the most aggressive one, by its force and extension and also by its trajectory, on the beaches of Cancun-Nizuc littoral barrier. Ivan had also a great impact mainly due to its associated storm but it was much less relevant because its trajectory turned aside north just offshore from the barrier, generating so a lesser storm surge on Cancun than Gilbert. Wilma, whose trajectory run however parallel to the barrier, from south to north in front of it, has therefore had an effect even bigger than Gilbert, so seeming to have been so much determinant in the recent decision to regenerate.

According with the continental shelf shape the refraction has to be very meaningful to change the direction of all waves, but maximum for the north-eastern offshore waves (CFE, 2000-2001) (Figure 3).

The referred studies show that the potential sediment transports due to such a tremendous hurricane like Gilbert are not more meaningful than the yearly sediment transport due to common wind waves. The offshore significant wave heights under the Gilbert hurricane reached up to 12 meters in the Cancun area in deep waters and its setup was of 3.6 meters in Cancun (the maximum setup seems to have reached 7.26 meters around).

![Figure 3. Model refraction of northeast waves (CFE)](image)

It is evident a net alongshore littoral transport northwards throughout the barrier, and that a natural feeding of sediments to the barrier system takes place from the south in front of Nizuc point, but also that this feeding is lesser than the northward losses in front of Cancun point, whose rocky support is
not able to hold the littoral transport. It also shows the existence of a transversal swing of the beach cross profile moved by the transversal littoral transport and whose net balance is estimated seawards, mainly due to the difficulty for the recovery of the sand material (difficulty mainly caused to the dyke effect of the natural reefs, outcropped by erosion and still rather unknown, not researched nor sufficiently mapped in the studies, and whose destabilizing role on the beach profile cannot be ignored. These outcrops do not appear reflected in charts and bathymetries before Gilbert event and only begin to be increasingly noticed in bathymetries and cross profiles made since UNAM studies. (Cfe, 2003)

Almost all the cross profiles in the beach are mono-parabolic; only in some zones in the barrier, those placed in its extremes, a little “step” can be distinguished like a reminiscence of the bar. Bathymetric data managed make us think a loss of that “step” since 1985 (CFE, 2000-2001; Diez & Esteban, 2006). The sediment analysis let us to recognize a close relationship between the materials from extraction banks and the materials from the beaches and dunes, and between all of them and the materials of the reefs (Diez, 2004).

The nature of the continental part linked to the Cancun-Nizuc area is the same than the rest of the Yucatan karstic formation. The sea platform in front of it had soft slope and it is constituted of calcareous materials. According to CFE information and data (Diez and Esteban, 2006), the present landscape began to shape in the late Pleistocene; and its genesis must be understood taking into account several kinds of littoral processes besides the littoral transport, eolian, sedimentary biogenic etc, leading to the formation of the barrier. During Holocene the lagoon opened north-westwards next to Mujeres Island and became a deep narrow bay. The residual barrier at both sides of Cancun point (island) permitted later the formation of a tómbolo and the same happened behind Nizuc point. The Cancun and Nizuc island system became a barrier and generated as a consequence the current Nichupté lagoon. That barrier, of about 17 km. of length and 100 – 400 m. of width in its origin, has evolved to nowadays loosing the northern sandy spit to reduce its length to the current 12 km. Parts of the ancient barrier still remain as multiple sandbanks and, possibly, as current islands like, perhaps, Mujeres and Cantoy islands among other of that bay.

The barrier accumulated eolian (wind drafted) materials since Pleistocene up to recent times reaching some important height in dunes, but most of them were removed by developers. The beach had fine sands but after the referred erosions the sediments show a triple origin: the notably gross sands and coarser materials from the reefs, the carbonated finest sands settled by saturation, and the biogenic sands and shell rests; the three identifiable in most of the size grain distribution curves of these studies.

PROPOSED PROJECTS

Due to the important and not naturally recovered erosion in the barrier beach, a few of short local beach protections were executed in different hotel stretches of the barrier since 1996 and 1999. These protections consisted on small groins and/or exempt but too close geo-textile low breakwaters, and they had little satisfactory results (Gs Ingeniería Integral, S.A. de C.V., 1999, cited by CFE). The fail of these works were likely due to, above all, that the projects had not had into account the whole barrier but only the short zones of the coast to be protected. It is known that the beach works like a system with it environment, and it is necessary to analyze it so to get a good solution. Besides, other of the isolated projects could fail because of a bad localization of the protection element; therefore, it is necessary design them correctly.

All the proposed projects after of them have been based on the sand nourishment. While some of them are based on a mere regeneration, others consist on the nourishment complemented with “rigid” works. The complementary “rigid” works are short transversal supports accreting the extremes of the barrier and a longitudinal stiffener element throughout the edge of the platform of the dry beach. Other common points in these projects are the sand banks to use and the mono-parabolic beach cross profile of reference, such as the Dean profile (Dean, 1990). The sediments of those banks are compatible with the sand of the beach, about all due to that the sand of the beach and the material of the extraction banks are of the same nature. So, this affection is reduced.

The project finally chosen consist on a mere nourishment, without complementary “rigid” works, which volume seems inferior than the volume recommended in the different proposed projects. The dredging and nourishing processes and the behaviour of both parts of the sedimentary system, the beach as
the sand banks, would have to be monitored very strictly during the construction and later during all
the operational time, so that their analysis would allow as soon as possible to diagnose the opportunity
and convenience of reinforcing some or both of the end barriers or introducing elements of shelter
and/or support along the beaches, for an early decision about it.

DISCUSSION

The preference of the mere nourishment in the regeneration of the beaches (Hamm et al., 2002)
among the two basic kind of before mentioned proposed projects is, about all, due to:

• The thinking about the negative effects of the “rigid” works. We think the environmental effect is a
criterion question: in fact, these works can be madden with natural rocks and all the cliff coast are
composed of natural rocks; therefore, if cliffs have not negative effect, neither the mound “rigid”
works, about all, if the design is property. Another negative effect is the undermining due to this kind
of works, with a first step of erosion that can finish with the demolition of these works. Some of the
positive effects are that these transversal and longitudinal works would reduce the sand losses in
the beach and, therefore less dredged would be necessary and the sea bed would suffer less
damages by fatigue.

• Submerged and emerged breakwaters and support works have not been considered like
complementary works. To make stand out that these constructions work suitably if the design
(distance to the coast and draught) is good.

Detached submerged reefs can play simultaneously the sheltering and sill rolls. The shelter is obvious
but their behaviour as support, maintaining sands upland from them, depends on the suitable design,
and this is related with height, depth and waves. This design has to take into account the seasonal
changes (summer profile and winter profile) and the changes due to hurricanes of the cross profile of
the beach. With important slopes or advanced erosion, it is property to combine silled and sheltered
works.

There are several reasons to conclude that the nourishment volume calculated in the different studies
are lesser than the necessary, independently of the subsequent impacts undergone by the barrier
beach under the hurricanes Ivan and Wilma. All these volumes were calculated with reference to the
mono-parabolic cross profile type, generally assumed since the Bruun profile, but such mono-
parabolic profiles do not correspond actually to a state of balance of the beach in situation of stability
(sedimentary equilibrium) (Bores, 1978), but, on the contrary, to a state of instability, erosion or deficit
of sediment. In fact, any Dynamically Stable equilibrium cross profile (with sediments enough to
warrant the permanence through a regular climatic cycle) (Figure 4) necessarily presents a biconcave
– approximately bi-parabolic- shape, imposed by the different wave dynamic conditions at each side of
the breaking point (bar inductor): upwards equilibrium at the seaside and downwards at the landside –
strand -.

![Figure 4. Dynamically Stable Equilibrium Cross Profile.](image-url)
The fact that the cross profiles of the majority of the beach sections were mono-parabolic or almost does not mean, therefore, that the beaches were in stable balance. Indeed, the profiles must be considered like the main test to realize that the beach erosion had begun before the Gilbert. In all proposed projects, the nourishing volumes were quantified on the basis of a horizontal translation of pre-existing profiles so reproducing the same seaward; so that it brings as consequence maintaining the mentioned deficit or allowing the evolution to another bar profile at the cost of a smaller beach width. The closure depths were calculated with formulations derived from the profile of Bruun, such as the theoretical profiles by Dean, Hallermeier, Vellinga, etc.), according to a simple concave curve which depends on sand grain size distribution, the form and density of grains and to the characteristics of the waves, and all them are lesser than the neutral depth, or Cornaglia depth, that really defines the movable part of the profile and bottoms, reason why they give also values lesser than the real volumes.

The advanced process of erosion on the beaches had became very serious, not permitting to go on the discussion about the nature and composition of the best solution, and the mere nourishment was validated to be implemented as soon as possible and strictly monitored to learn from it and discuss the question of the rigid works later.

CONCLUSION

The question raised in this paper about whether the beach regeneration in Cancun barrier by just sand nourishment is suitable or not, and if it would be better, or even necessary, to complement the nourishing with some rigid works, can be considered alive, but it had already taken time and could have delayed the decision and its implementation too much more, and the situation could also be considered critic so that the decision that Authorities have finally adopted must be applauded at any way; as a matter of fact it already seemed to be urgent as soon as in December of 2004 (Diez, 2004), and so reported for CONABIO recommending the immediate decision.

That is, the case of Cancun barrier nourishment, that can be considered like an environmental, but too territorial and socioeconomic project, is one of the cases in which the “rigid” works would be efficient and even necessary, but time and efforts necessary to show it could permit much more damages and do all works finally useless. So that the decision adopted at the beginning of 2.006 of a mere regeneration following the proposed project by CFE in 2.003 can be considered right.

Nevertheless the question remains and the discussions of this paper permit to conclude:

1. Rigid works, unfortunately too named hard works, can not be considered especially aggressive, if built with natural or degradable materials; as a matter of fact dredging and pouring operations for beach nourishing are much more aggressive. Particularly artificial reefs (longitudinal or transversal) can be done with the same materials -stones- than naturals.
2. Detached submerged reefs can play simultaneously the sheltering and sill rolls. The shelter is obvious but their behaviour as support, maintaining sands upland from them, depends on the suitable design, and this is related with height, depth and waves.
3. Any Dynamically Stable equilibrium cross profile necessarily presents a biconcave shape, so that the necessity of sands are always greater than calculated with conventional profiles. The referred profile can not be established in many actual beaches just for the lack of sediments, maybe since their origin (unfinished) or after any erosive process (incomplete), and this later seems to have been the case of Cancun, already since before Gilbert.
4. The conditions affecting the equilibrium remain so that any reasonably moderate nourishment maintaining them will be early eroded again; not being likely possible to move hotels and other buildings, the works (in this case two small transversal barriers in the extreme points and/or a longitudinal submerged high border for sand contention) to reduce the wave dynamics and the sand movements have to be taken into account without bias.

This can be a good occasion however to verify the behaviour of a beach regeneration by just nourishing. Therefore dredging and nourishing processes and the evolution of both parts of the sedimentary system, the beach as the sand banks, would have to be monitored very strictly during the construction and later during all the operational time, so that their analysis would allow as soon as possible to diagnose the opportunity and convenience of reinforcing some or both of the end barriers or introducing elements of shelter and/or support along the beaches, for an early decision about it.
REFERENCES


