Physical Modelling of an Artificial Surf Reef in S. Pedro do Estoril.

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ABSTRACT:
In one of the tanks with beaters for waves of the LNEC, a reduced scale physical model with 30mx30m, was built for the study of the sea agitation in an artificial surf reef. The model reproduces the bathymetry of the place, the topography of coastal cliffs, and also the reef drawing. The objective is to test the reef drawing in the physical model, in order to optimize it according to the respective drawing parameters. It also intends to secure that the physical model is loyal to the agitation in the place, since the model will be an object of a public consultation in the context of the evaluation process of the environmental impact.

This physical model culminates one year of data and numerical studies gathering on the reef model, including the establishment of the climatology, the waviness in the place, and the test of several reef drawings. The drawing introduced in the model is the one, that according to the numerical simulations, produces better quality waves for the surf practice. For this, it will be necessary to measure the wave quality with 5 parameters: - speed of the wave (peel angle), - form of the tube (Number of Irribarren), - wave height, - wall (ramp for manoeuvres), - wave quality and regularity along the reef. The wave parameters will be valued for each series of per-specified conditions, of the wave height, of the tide height, of the incident angle of the waviness and of the wave period, being enough for the analysis to study monochromatic waves. These 5 parameters will also be compared with the measurements effectuated in the LNEC waves tank.

Key words: Surf Parameters, Peel Angle, Evaluation, Wave Quality Evaluation methodology, Distortion, Perspective geometry, Coordinate transformation, Unit to score conversion, Photogrammetry.

1. Introduction.
This theory main subject is the Physical Modelling of an artificial surf reef, in São Pedro do Estoril, Portugal. This work intends to study the quality of the sea agitation on an artificial reef using the physical existent model in the National Laboratory of Civil Engineering (L.N.E.C.), located in Lisbon, Portugal. This project is financially supported by the Cascais Town Hall.

Figure 1- S. Pedro ASR Perfect Wave in the wave tank during a test on the LNEC, in Lisbon, Portugal
2. Application in the Main Project.
A protocol amongst the CMC, LNEC, IST and FCUL was signed on the 16th of November of 2006, in order to provide S. Pedro do Estoril, a 300m long World Class Wave, using big solid rock blocks as raw Material. This Theory intends to study the results on the best waves to Surf in the S. Pedro ASR, according to the tests made in L.N.E.C.

As an Introduction to the central subject of this theory, a theoretical base is presented, as well as the framing of this dissertation in the extend of the PDE subject. A Study was taken based on the perspective of the ASR seen as a Product, and the Costumer explicit and hidden needs were identified. This study contains the enormous set of entities who directly and indirectly exist and are rising up in the surf Market. If all of these entities are gathered, they actually make part of a important piece in the Economy.

Figure 2- Indirect users on an ASR.

Is S. Pedro a good Spot for the implementation of an ASR?
The answer lies on this PDE study, and is based on the fact that this coast band is very consistent in terms of swell, and has a favourable geographical disposal but the main problem lies on the crowd. The need of a World Class wave in this spot is also an important need. The big amount of medium quality waves is shown in Figure3.

Figure 3- Big amount of Surf Spots in the Estoril Coast region

This Sport is Booming, and this statement taken from the EUROSIMA “after an Inquiry to a set of young persons, aged between 15 and 25 year Old, about the next Sport to try, 90% answered SURF” confirms it. The Relation between the good and bad aspects about the existing waves is shown in the next diagram.

Figure 4- Good versus Bad aspects on the existing waves.

The set of needs is shown in the following diagram:

Figure 5- Explicit and Hidden needs on S. Pedro ASR.

Since the origins of Man History, Sports have a very important paper in the Society, and giant support
infrastructures were created in order to improve its quality.
The surf problem is based on its extreme dependency on Natural conditions, such as the Waves, the Wind, and for last, a factor where Human intervention is Possible the, the Bathymetry.
If Human intervention is possible, to improve the bottoms of the sea, the creation of an artificial Surf Reef, is a project that reduces the dependency of the natural conditions for a Sport, and therefore can be compared to the construction of a Football stadium.
In order to understand the ASR, and having theoretical basis of the variables on demand, a short description is done about what is the surf and the ASRs, as well as the several ways to take advantage and enjoying playfully and economically the ASRs.
The main activities taken on an ASR are several such as:
- Bodysurf
- Bodyboard
- Kneeboard
- Kayaksurf
- Windsurf
- Longboard
- Paddlesurf
- Shortboard
- Tow in
- Spearfishing
- Snorkeling.
- Fishing
There is also given a little of the surf and ASRs historical framing, which points to the fishing ASR in the Algarve, on the south region of Portugal, as well as the first ASRs in the world, used in the Punic war by the Romans for costal territorial defence.

4. The Physical Model:
In this chapter, here is let know the physical model, his functioning, as well as aspects that might bring him eventually improvements.
It is set in the LNEC, and was built in a 1:30 Scale. In this model it is possible to control the tides, and the wave beater can produce waves from 1 to 4 meters, and Wave period of 11, 15 and 19 seconds.
The tests equipments are mainly:

The two plates were assembled in order to eliminate major wave diffraction.
The reef is 6,66m long, 1,33m wide, and has a 4,3º slope.

The entire set can reproduce swell from two directions, but the reef is located on a 30º peel angle and is positioned always in this position.
The top view of the entire set is show in Figure 4.
5. Technical Procedure:
The technical data is obtained photographically, and also from the control Tower, connected to the wave height sensors and wave beaters.

The investigators chose a spot over the reef on a ladder, and take sequential pictures over the different test as shown in Figure 5. A video Camera is also recording the whole tests, for subsequent reviews.

The collected data is later analysed and treated according to a theoretical evaluation method for the various tests.

6. The theoretical Evaluation Method

MTMAQO:

According to this evaluation method, there were created evaluation parameters, described, scheduled, and valued in the form to be able to be quantified.

Therefore was created an analysis mechanism for the parameters obtained experimentally. This mechanism, was created by the author, whom it allows through a quality evaluation theoretical model, to obtain a wave quality quantification.

This model is called by "Theoretical Model of wave quality Evaluation Mechanism" and it’s Portuguese minor name is MTMAQO.

In a first phase of the model MTMAQO application, it is possible to obtain an evaluation, based on the conjugation of several evaluated parameters. These level one parameters are in this ASR specific case, 11 surf Parameters. The collected data analysis, sets on converting measured parameter values into parameter SCORES on each test.

So, the first step on the MTMAQO, is to convert the values of the parameters into SCORES. The SCORE has a 0 to 10 Scale of importance.

In a more advanced phase application of the theoretical model, the several SCORE parameters, are valued to a specific Level two evaluation. The importance of each level one parameter is set on a table, and a conjugated SCORE is obtained according to the importance weight of each level one parameter SCORE. in the second phase, a Specific subject evaluation is defined.

On the same basis, and managing, the several level two evaluations, the importance weight of each, is set, and on a conjugation of these level two evaluations, a level three evaluation is obtained, in a way that translates the final quality of the wave.

On this last application of study, there are presented analogies to several levels of evaluation of the model, that all combined in the end, provide a final Evaluation for waves produced on the tests as shown on Figure 6.

7. Level One Surf Parameters:

Several problems show up when intending to SCORE the eleven level one parameters.

- PA: Peel Angle, is the angle between the wave line and the foam line. It sets the speed of the wave.

- TUBO: Tube, It provides an evaluation of the tube type.

- HEIGHT or H: Provides the height of the wave

Figure 9- The MTMAQO evaluation Pyramid. Level one, two and three.

Figure 10- Variable peel Angles in a Natural Surf Reef, in Gland, Indonesia.

Figure 11 - Measuring Wave height
-WALL: Means the available surface for manoeuvres.
-Q&R: It provides a measurement of the wave Quality and Regularity along the ASR.
-BW: Back Wash, is a wave collision phenomenal.
-CF: Collision on the reef. This parameter presents the danger of crashing.
-START: It represents the beginning of the wave, and the difficulty on the drop.
-MOVE: It describes the comfort and mobility inside the surf spot.
-P. Wave Period, is the time gap between two waves.
-TIDE: The tide has effects on the waves.

8. Data Analysis:
8.1 Unit to SCORE conversion
The results obtained from the tests, hold, the respective physical units, namely HEIGHT in meter and PA in degrees.
In order to be able to attribute these parameters an evaluation (SCORE) on a 0 to 10 scale, it is necessary to convert his physical unit (UNIT) value into the SCORE scale, and this way it is possible to use the MTMQAO.
This conversion method, consists in expressing a function, which defines a value of classification (SCORE), on basis of the value of the physicist (UNIT) unity. Therefore:

\[ \text{SCORE} = f(\text{unit}) \quad [\text{eq. 1}] \]

with the intention of obtaining the conversion function “f”, the method of the polynomial interpolation is used on basis of some reference values. These reference values, are initially defined by the maximum physical unity of note SCORE=10, the minimum value SCORE=0, as well as the limit for acceptable value SCORE=5.
Afterwards, other intermediate values, are defined to translate a more refined behaviour of the function. Depending on the values, so can be possible to define the conversion in one single polynomial function, or a on a set of functions divided by regions defined by as many interpolation polynomial of order “n” as possible, depending on the values. A graphical display is carried out with polynomial functions, and an analogical SCORE function is obtained.

8.1.1 HEIGHT SCORE
For the height score, a single polynomial Function is enough to define the behaviour of this unit conversion.

The reference values are:
- **Maximum** SCORE=10, H=3 m, this value is attributed on basis of the initial objective, in what it takes this ASR objective on the production of a World Class Wave, in which the ideal size for professional surfers is 3 m high waves.
- **Minimum** SCORE=0, H=0m logically, as there are no waves, the classification is null.
- **Acceptable limit** SCORE=5, H=0,5m the least size in order to exist the minimum conditions for the practice of this surf sports is the half meter.
Adding some more values to improve the function behaviour, a values table is obtained, and the interpolation is taken on the basis of this values as show in the following Table 1 and Figure 7.

Table 1 - **HEIGHT reference and function SCORES**

<table>
<thead>
<tr>
<th>H, Altura da onda real (m)</th>
<th>SCORE atribuido</th>
<th>SCORE dado pela função aproximada f(H)</th>
<th>A SCORE &lt; 0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.0487(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.1</td>
<td>0.1692(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>2.5</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>3.5</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1.12(H)^5 + 0.6591(H)^4 + 3.3812(H)^3 - 9.2585(H)^2 + 14.677(H) - 0.9725</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12- Wave HEIGHT Score plot.

According to this results, the order 5 polynomial Function obtained for Wave HEIGHT SCORE is:

\[ F(H)=0.0487H^5 - 0.6591H^4 + 3.3812H^3 - 9.2585H^2 + 14.677H - 0.9725 \quad [\text{eq. 2}] \]

8.1.2 PA SCORE.
The same reasoning is taken upon the peel angle, but this function has a more variable behaviour, what makes it a function divided by 3 polynomial functions.
- **Maximum** SCORE=10, PA=30° this value was attributed on basis of the ASR objective: the construction of a world class Wave, in which the ideal angle for professional surfers is of 30 °, and is also the limit angle. Below this value it is very hard to surf.
In order to provide a level two SCORE, weights are attributed to each parameter, with the intention of gathering the influence of each level one parameter on the level two evaluation. This weights were attributed by the author, but the MTMAQO, has flexibility, for any investigator values attribution.

The Values, and equation for each level two evaluation are shown in Tables 3, 4, 5 and 7.

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The Values, and equation for each level two evaluation are shown in Tables 3, 4, 5 and 7.

Table 2 - PA reference and function SCORES.

<table>
<thead>
<tr>
<th>Peel Angle (°)</th>
<th>Score attribute (0÷10)</th>
<th>Score after function approximation (IPA)</th>
<th>Δ score = error max/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0,19</td>
<td>0,117</td>
<td>0,013</td>
</tr>
<tr>
<td>20</td>
<td>0,14</td>
<td>0,167</td>
<td>0,089</td>
</tr>
<tr>
<td>30</td>
<td>0,16</td>
<td>0,187</td>
<td>0,019</td>
</tr>
<tr>
<td>40</td>
<td>0,13</td>
<td>0,147</td>
<td>0,05</td>
</tr>
<tr>
<td>50</td>
<td>0,10</td>
<td>0,197</td>
<td>0,12</td>
</tr>
<tr>
<td>60</td>
<td>0,09</td>
<td>0,217</td>
<td>0,03</td>
</tr>
<tr>
<td>70</td>
<td>0,07</td>
<td>0,227</td>
<td>0,05</td>
</tr>
<tr>
<td>80</td>
<td>0,06</td>
<td>0,247</td>
<td>0,11</td>
</tr>
<tr>
<td>90</td>
<td>0,05</td>
<td>0,267</td>
<td>0,17</td>
</tr>
<tr>
<td>100</td>
<td>0,04</td>
<td>0,274</td>
<td>0,22</td>
</tr>
</tbody>
</table>

Figure 13 - PA SCORE plot.

According to this results, the 3 polynomial Functions obtained for Peel Angle PA is:

- \(\text{SCORE}_1(PA)\) if 23>PA>0
- \(\text{SCORE}_2(PA)\) if 30>PA>23
- \(\text{SCORE}_3(PA)\) if 30>PA>90

\(f(PA)=\)

\(f_1(PA)=0,0012*(PA)^2 - 0,0126*(PA) + 0,1053\) if 23>PA>0

\(f_2(PA)=-0,0378*(PA)^3+3,1691*(PA)^2-86,546*(PA)+774,38\) if 30>PA>23

\(f_3(PA)=0,0015*(PA)^2-0,3561*(PA) + 19,675\) if 30>PA>90

8.2 Importance of each parameter on the Level two evaluation.

In this level two evaluation, there was given a specific evaluation for the:

- Security S
- Beginner surfer level NA
- Regular surfer level NM
- Professional surfer level NP
- Visual Impact an Touristic investment potential POT
8.3 RAW analysis

The values on this last 5 tables are used to a Raw evaluation. It is also important to point out the fact that, this last table7, as well as all the other four, have been characterized by parameter weights stipulated by the author, to make the Raw evaluation, where it is reasonable to use this values, but in a more refined evaluation, this values will change, for improvement.

This raw evaluation, was made to both wave directions of 220°, and 235°, and provides good results as shown in Tables 8 and 9.

The results were very similar for both wave direction, and these are shown, in the following plots.

On the 220° RAW analysis, the 3 best wave SCOREs obtained per major order were:

1° 220 MB 19 2
2nd 220 MB 11 2
3rd 220 MB 15 1

On the 235° RAW analysis, the 3 best wave SCOREs obtained per major order were the same as in the 220 analysis.

Table 7 - POT analysis.

<table>
<thead>
<tr>
<th>Quality level</th>
<th>POT %</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PA</td>
<td>0,02</td>
</tr>
<tr>
<td>2</td>
<td>TUBO</td>
<td>0,18</td>
</tr>
<tr>
<td>3</td>
<td>HEIGHT</td>
<td>0,2</td>
</tr>
<tr>
<td>4</td>
<td>WALL</td>
<td>0,12</td>
</tr>
<tr>
<td>5</td>
<td>Q&amp;R</td>
<td>0,3</td>
</tr>
<tr>
<td>6</td>
<td>BW</td>
<td>0,02</td>
</tr>
<tr>
<td>7</td>
<td>CF</td>
<td>0,02</td>
</tr>
<tr>
<td>8</td>
<td>START</td>
<td>0,02</td>
</tr>
<tr>
<td>9</td>
<td>MOVE</td>
<td>0,02</td>
</tr>
<tr>
<td>10</td>
<td>P</td>
<td>0,05</td>
</tr>
<tr>
<td>11</td>
<td>TIDE</td>
<td>0,05</td>
</tr>
</tbody>
</table>

Table 8 - Raw evaluation values for 220°.

<table>
<thead>
<tr>
<th>Direcção 220°</th>
<th>NÍVEL 1</th>
<th>NÍVEL 2</th>
<th>NÍVEL 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANEXO V.1.1</td>
<td>PRINCIPAIS</td>
<td>SECUNDÁRIOS</td>
<td>PRINCIPAIS</td>
</tr>
<tr>
<td></td>
<td>Segurança</td>
<td>Qualidade</td>
<td>Aprendizagem</td>
</tr>
<tr>
<td></td>
<td>1 PA 0,18</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2 TUBO 0,18</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>3 HEIGHT 0,18</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4 WALL 0,18</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>5 Q&amp;R 0,18</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>6 BW 0,18</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7 CF 0,18</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>8 START 0,18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>9 MOVE 0,18</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>10 P 0,18</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>11 TIDE 0,18</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 9 - Raw evaluation values for 235°.

<table>
<thead>
<tr>
<th>Direcção 235°</th>
<th>NÍVEL 1</th>
<th>NÍVEL 2</th>
<th>NÍVEL 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANEXO V.1.1</td>
<td>PRINCIPAIS</td>
<td>SECUNDÁRIOS</td>
<td>PRINCIPAIS</td>
</tr>
<tr>
<td></td>
<td>Segurança</td>
<td>Qualidade</td>
<td>Aprendizagem</td>
</tr>
<tr>
<td></td>
<td>1 PA 0,18</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2 TUBO 0,18</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>3 HEIGHT 0,18</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4 WALL 0,18</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>5 Q&amp;R 0,18</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>6 BW 0,18</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>7 CF 0,18</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>8 START 0,18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>9 MOVE 0,18</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>10 P 0,18</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>11 TIDE 0,18</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>
8.4 Refined Analysis

This analysis intends to improve the results obtained on the RAW analysis, and the difference between both analysis, relays on the scientific and carefully measured data and posterior conversion for the PA and HEIGHT SCOREs as shown in section 8.1.

8.4.1 POT Improvement:
Another improvement lays on inquiries made to all types of potential tourists, and with the gathered information acquired in the inquiry, a new table was set, and the data on Table 7 was upgraded to a more realistic evaluation as shown on Table 10.

<table>
<thead>
<tr>
<th>Quality for POT</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TUBO</td>
<td>21,75793</td>
</tr>
<tr>
<td>2 ALTURA</td>
<td>19,88473</td>
</tr>
<tr>
<td>3 PAREDE</td>
<td>21,61383</td>
</tr>
<tr>
<td>4 Q&amp;R</td>
<td>20,4611</td>
</tr>
<tr>
<td>5 MARÉ</td>
<td>16,28242</td>
</tr>
</tbody>
</table>

This Table was obtained by the average on the 18 realized enquiries.

For this Refined analysis, before making the Parameters SCORE conversion, it has been necessary to gather values from the test data, the values of HEIGHT and PA.

8.4.2 HEIGHT Improvement: This values were specially analyzed separately, and for the wave HEIGHT, the Procedure included the wave height sensors plots on each test, as shown in Figure 15

A line was plotted over the major wave height values, and the average value of the wave along these points was considered the HEIGHT to use in SCORE = F(HEIGHT) in order to obtain the respective SCORE for this test. This procedure was made to all the tests, and this way, the HEIGHT SCOREs were inserted on the Refined analysis table.

8.4.3 PA Improvement and the Distortion Problem:
For the Peel Angle, a big problem occurred when measuring the angle from the sequential top view pictures taken during the tests. This problem is the
pictures Distortion and so a Photogrammetry study was made, and the author overcome this situation. Although the problem has been solved, it is a very complicated and extremely extensive. For each picture, a long term procedure takes action on a picture’s reference geometry viewed on the AUTOCAD Software, and several algorithms in the MATHEMATICA Software are set to run, to obtain in the final Pell Angle. This Study begins by setting the chosen picture on the Autocad, defining a Picture coordinate system, and identify common points in the picture and in the REAL reference coordinate axis plot in Figure 13.

Figure 16- REAL Reference, coordinate Axis.

With a minimum of 4 identified common points on the (PX)REAL reference axis and on the (Px)Picture coordinate system, it is possible to determine any other Picture additional point real coordinate.

Figure 17- Perspective Geometry.

The method is based on the Bydimensional Invariance. Taking the values of the 4 point of each coordinate system, as well as the wanted point coordinates in Px, and inserting them into the algorithm based upon 2 matrices like the one on Figure 13, the REAL coordinate of an extra unknown point is obtained.

Figure 18- Equation Matrix to obtain extra point coordinate. Repeating the procedure for 3 points, and applying this 3 point on a vector analysis algorithm, the obtained result is the REAL Peel Angle, as Show on the following example.

Example on test 220º MB 15 1, Picture 264, and MATHEMATICA algorithm code.

Determination in the REAL ref XY, point a , Picture 264
\[
\begin{align*}
\text{Solve}\{ f[mA,mB,mC,mD,mE,mF,mG,mH]=0,g[mI,mJ,mK,mL,mM,mN,mO,mP]=0\},\{Xu,Yu\}\n\end{align*}
\]
\[
\begin{align*}
\{Xu=4.69282,Yu=3.58269\}
\end{align*}
\]

Determination in the REAL ref XY, point b , Picture 264
\[
\begin{align*}
\text{Solve}\{ f[mA,mB,mC,mD,mE,mF,mG,mH]=0,g[mI,mJ,mK,mL,mM,mN,mO,mP]=0\},\{Xu,Yu\}\n\end{align*}
\]
\[
\begin{align*}
\{Xu=6.70197,Yu=3.96482\}
\end{align*}
\]

Determination in the REAL ref XY, point c , Picture 264
\[
\begin{align*}
\text{Solve}\{ f[mA,mB,mC,mD,mE,mF,mG,mH]=0,g[mI,mJ,mK,mL,mM,mN,mO,mP]=0\},\{Xu,Yu\}\n\end{align*}
\]
\[
\begin{align*}
\{Xu=5.40452,Yu=3.08302\}
\end{align*}
\]

Determination in the REAL ref XY, real PELL ANGLE, Picture 264
\[
\begin{align*}
\{u\}=&\{u[XuA,YuA,XuB,YuB]\}\\
\{v\}=&\{v[XuB,YuB,XuC,YuC]\}\\
\{\theta\}=&\{1.29745,0.881796\}
\end{align*}
\]

The angle Between the two lines is:
\[
(180/\pi)\times\text{VectorAngle}\{u,v\}\quad^\circ
\]

The angle Between the two lines is: 23.428°

Clear \{u,v\}

In this case the Picture’s Peel Angle taken from AUTOCAD software is 28°, and after eliminating the distortion, the REAL peel Angle taken from the MATHEMATICA algorithm, is 23.428°. The results on the several long term distortion corrections obtained are disposed on Table 9.
After analysing the error results on these 7 pictures, the conclusion was that inside the “44-45-54-55” Square on Figure 20, the distortion was minimal, and even so, the relative error on the distortion, was not that accentuated. Consequently, the Peel Angle data taken for the REFINED analysis can set values from this Square because it is the less affected by distortion Area. It is natural to understand this fact just by realizing that the investigator had taken pictures mainly positioned over this area.

The Results on this REFINED analysis are posted on Table 11, and Figure 20.

9. Results.

- 1st _220 MB 19 2_SCORE=6,776;
- 2nd _220 MB 15 2_SCORE=6,743;
- 3rd _220 MB 11 2_SCORE=6,661

10. Conclusions

It is very difficult to study a wave behaviour due to its chaotic blowing properties, but yet, it was possible, after defining the surf parameters and applying this theory to the S. Pedro ASR surf Model. The best results were obtained in the lowest tide and smaller waves, due to the minor boundary conditions influence.

The perfect angle for the ASR physical model would be between 35° to 40°.

11. References


