COMPARATIVE EVALUATION OF THE ENVIRONMENTAL IMPACT OF FLEXIBLE PAVEMENTS VS. RIGID PAVEMENTS, THROUGH THE ANALYSIS OF TEMPERATURE VARIATION

Carlos Alberto Bravo Aguilar.[1*] – Manuel Aristides Hernández Salazar.[2]
***Correspondence author**

[1]*Civil Engineer. Professor, Department: Ordenamiento Territorial y Construccion, Facultad de Ingeniería Agricola Universidad Nacional Agraria La Molina, Lima Perú.*
[2]*Agricultural Engineer, Independent researcher*

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ABSTRACT

The evaluation of the environmental impact generated by rigid pavements and flexible pavements is proposed by studying the variation of the surface temperature, through an environmental approach, whose climatic impact is generated from the effect of the placement of rigid and flexible pavements. There are economic justifications for deciding to use any of the traditional track materials (made from asphalt and / or concrete), however, there is no sustainable justification, with reference to heat generation for this decision. It is intended to demonstrate that rigid pavements (concrete) generate less environmental impact than flexible pavements (bituminous material), based on the analysis of surface temperature as an environmental variable, through the study of temperature variation, in addition to the relationship and / or influence of green areas on these temperature differentials. Temperature measurements of up to 30ºC have been taken in the asphalt packs, which contribute to an increase in the temperature of the environment in the area involved, which was 17.6ºC on average. In future studies, variables such as traffic, reflectance, construction processes and others can be included that would present us with a more complex panorama for the choice of "friendly" paving alternatives with the environment.

Keywords: Environmental impact, Heat Island, Flexible pavements, Rigid pavements

RESUMEN

Se plantea la evaluación del impacto ambiental que generan los pavimentos rígidos y los pavimentos flexibles mediante el estudio de variación de la temperatura superficial, a través de un enfoque ambiental, cuyo impacto climático se genera a partir del efecto de la colocación de pavimentos rígidos y flexibles. Existen justificaciones económicas para decidirse a emplear cualquiera de los materiales tradicionales en pistas (hechas a partir de asfalto y/o concreto), sin embargo, no existe una justificación sostenible, con referencia a la generación de calor para esta decisión. Se pretende demostrar que los pavimentos rígidos (de concreto) generan menos impacto ambiental que los pavimentos flexibles (material bituminoso), partiendo del análisis de la temperatura superficial como variable ambiental, mediante el estudio de variación de la temperatura, además de la relación y/o influencia de las áreas verdes en estos diferenciales de temperatura. Se han tomado mediciones de temperaturas hasta de 30ºC en las carpetas asfálticas, las cuales aportan elevación de temperatura del medio ambiente en la zona involucrada, que fue de 17.6ºC en promedio. En futuros estudios, se puede incluir variables como tráfico, reflectancia, procesos constructivos y otros que nos presentarían un panorama más complejo para la elección de alternativas de pavimentación "amigables" con el medio ambiente.
Palabras clave: Impacto ambiental, Isla de calor, Pavimentos flexibles, Pavimentos rígidos.

1. INTRODUCTION

In Peru there is a stage of growth in different important areas for development; This growth is reflected in fields such as the productive, industrial, economic and construction sector, which leads to the well-being of its population, we are talking about: canals, reservoirs, buildings, tracks, roads, etc. However, this growth in the construction sector leads us to reflect, how many of these constructions affect the care of the environment in the short, medium and long term?

There is a growing demand for vehicular circulation routes, generally, new lanes are proposed, repairs of others.

Regarding environmental evaluations, generally with few research on the subject, there is a phenomenon of heat transfer to the atmosphere, related to the surface of the pavement and the material used for the road finishes. Currently, both in Lima and in the rest of the country, there is an increase in the percentage of traffic volumes, cars and a large percentage of medium and heavy-duty vehicles. The construction of roads is required to cover this demand. However; how many of these road construction projects will take into account the potential negative effects of the use of certain traditional materials that are "unfriendly" to the environment? In addition, to having a negative economic impact in the medium and long term due to their use?

This makes us think about the technical problems of these projects, the lack of technical support for making decisions on the use of asphalt pavements versus concrete ones.

The purpose of this article is to evaluate the environmental impact generated by concrete pavements and asphalt pavements by studying the variation in surface temperature at different times of the day.

Within the study, effects such as the "heat island" are exposed; phenomenon that is very important in environmentally correct and sustainable constructions, however, in most road studies it is not considered.

To understand the heat island effect, a complementary analysis must be made of the influence of buildings and structures adjacent to pavements, and how these elements contribute or not to the absorption and dissipation of heat. Specialists such as Villanueva Solís, Ranfla and Quintanilla-Montoya (2012), point out that the dispersed growth of cities, as well as heat islands, has direct implications for air quality, public health, energy management and the urban planning.

In the world, this problem has become one of the main challenges related to the urbanization process, since the increase in temperature associated with heat islands tends to exacerbate the aforementioned problems (Tan, et. al., 2010). In addition, regarding pavements, the author Yunus (2009) indicates the importance of analyzing and demonstrating that rigid pavements (pavements made of concrete) generate less environmental impact compared to flexible pavements (pavements made of bituminous material) through the study of temperature variation, the influence of green areas on these temperature differentials should also be included.

1.1 <u>Location of area of study.</u>

The study was carried out in Peru, province of Lima, district of Magdalena del Mar; The studies have been carried out in two areas of the district, which include streets with rigid pavements, with flexible pavements and gardens. The data has been taken at different times of the day in the same location, during June.

Fig 1.- Map of south America and Perú

Fig 2.-Map of Peru.

Fig 3.- Lima district map

2. RESEARCH OBJECTIVES

- General objective
    - Evaluate the environmental impact of heat transfer to atmosphere by concrete pavements and asphalt pavements, studying the variation in surface temperature.
- Specific objectives
    - Evaluate possible environmental impact of global warming by concrete and asphalt pavements.
    - Assess the influence of gardens in urban areas, close to pavements, compared to urban heat islands.

3. LITERATURE REVIEW

3.1 PAVEMENTS

A pavement is a structure that allows the transit of vehicles and can be made up of one or several superimposed layers.

Rico and Del Castillo (1999), indicate that the main functions that a pavement must fulfill are to provide a uniform rolling surface, of appropriate color and texture, resistant to the action of traffic, weathering and other harmful agents, as well as adequately transmit to the lower layers the efforts produced by the loads imposed by traffic. In addition, it must be resistant to wear due to the abrasion produced by the tires and have good drainage conditions.

3.2 FLEXIBLE PAVEMENTS (ASPHALT PAVEMENTS)

3.3

According to the Ministry of Transport and Communications (2013), the flexible pavement is a structure composed of granular layers (subbase, base) and, in the surface, a layer made up of bituminous materials such as: binders, aggregates and, if applicable, additive. It is mainly considered as a finishing layer on granular layers: asphalt mortar, two-layer surface treatment, micro pavements, asphalt macadam, cold asphalt mixtures and hot asphalt mixtures. A scheme of the flexible pavement is shown in figure 4

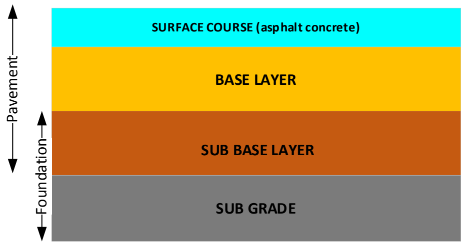

Fig. 4.- flexible pavements scheme

3.4 RIGID PAVEMENTS (CONCRETE PAVEMENT)

The main structural element in this type of pavement consists of a concrete slab that rests directly on the subgrade or on a layer of selected granular material called a subbase.

The need to use the subbase arises only if the subgrade does not have the necessary conditions to resist the slab and the loads on it; that is, that it does not act as an adequate support.

Rigid pavement will be considered in any of its forms or modalities (plain concrete slabs with joints, reinforced concrete slabs with joints, soil-cement, roller-compacted concrete, etc.). Figure 5 shows a structural scheme of the concrete pavement.

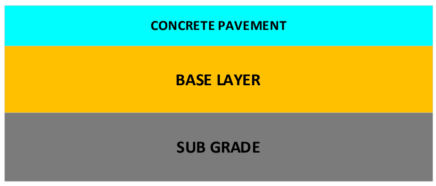

Fig 5.- Rigid Pavement Scheme

3.5 ENVIRONMENTAL CONCEPTS

3.5.1 Greenhouse Gas (GHG)

According to Baird (2001), the most abundant gases on earth are Nitrogen (N) and Oxygen (O). In addition, there are others such as nitrogen dioxide and carbon dioxide, which allow heat to pass into the interior but do not allow it to go out. This produces the warming of not only the earth, but also the atmosphere. This phenomenon is called the greenhouse effect.

The earth is colder than the sun, therefore it cannot return the energy received by it in the form of light and heat, but rather through infrared radiation, which is absorbed by greenhouse gases, thus heating the entire surface. Moreover, if the greenhouse effect did not exist, it is more than certain that there would be no life on earth as we know it since it would be 30 degrees colder than today.

GEG	NOTES
CO2	Carbon dioxide. Its excess would accentuate greenhouse effects
N2O	Nitric dioxide. It is considered a powerful greenhouse effect gas
HFC	Hydrofluorocarbons are refrigerant gases whose molecules contain hydrogen, fluorine and carbon atoms. They are used for air conditioning machines.
CFC	Chloro-Fluoro-Carbons are refrigerant gases whose molecules contain chlorine, fluorine and carbon atoms. They also damage the ozone layer.
PFC	The emission of perfluorocarbons produces a greenhouse effect.
HCFC	They are refrigerant gases whose molecules contain hydrogen, chlorine, fluorine and carbon atoms. They also damage the ozone layer.
SF6	The emission of sulfur hexafluoride produces a greenhouse effect.
Important to know:	
The gases mentioned in the table have a lasting effect on our atmosphere. Several centuries after their emission, about a quarter of these will still be present in the atmosphere. In addition, when these are presented, the radiation that is returned to space will be less, which will cause the increase in heat of the earth and air. This later would cause important climatic changes such as the melting of the poles, droughts, floods, increased rainfall, sea level would rise, etc.	

Source: IPCC1996
Table 1.- Greenhouse gas.

3.5.2 Urban Heat Islands – UHI

Idrobo and Hernández (2009) point out that the urban heat island is an urban phenomenon of heat accumulation. The specialists Villanueva-Solís, Ranfla and Quintanilla-Montoya (2012) complement the definition, which is the difference in temperature between the urban area and its surroundings. Likewise, it is the result of two different but associated processes; the first and most important, the modification in the ground cover as a result of the urbanization process that transforms the surfaces with impermeable materials such as asphalt and concrete. The second refers to activities in the city, mainly transport and industry, due to thermal emissions that contribute to urban heating (Oke, 2009).

According to Peña (2007), the study of the urban heat island, in its beginnings, was approached by sciences such as geography and urban climatology. However, in recent years, interest has been aroused in other branches of science for the study of this phenomenon, such as disciplines linked to the study of climate change, due to the fact that the presence of the urban heat island contributes to the increase of carbon dioxide emissions.

4. MATERIALS AND METHODS

The present investigation was developed by the sectors, avenues and streets, of the district "Magdalena del Mar", province of Lima, Peru.

The scheme of the work used was the following:

· Bibliographic search on the subject.
· Choice of strategic district for the study.
· Location of areas to work, through a mapping of the representative areas of the district.
· Development of the methodology and data collection in the place.
· Information processing.
· Preparation and issuance of Plans
· Analysis of the obtained results.
· Recommendations / Conclusions.
· Drafting of final document.

4.1 METHODOLOGY

The methodology that was used includes the observation of the work area, followed by data collection (taking of temperature on the surface of pavements and gardens next to the streets) and the complete analysis of the results taken from measurements in different hours of the day: (morning and evening). The methodology is indicated in a methodological design (see figure 6)

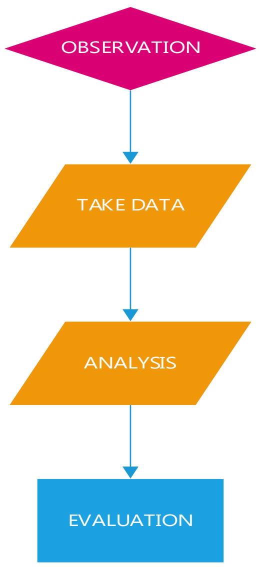

Fig 6.- Research methodology

There are statistical, programming, drafting and evaluation tools (see Table 1), that will lead us to conclusions.

Item	TOOL	Detail
1	Statistical tools	Previous study of the primary data based on analysis of doubtful data through the hydrographers, frequency tables. Adjustment of these data with correlation and regression techniques, flowcharts, Thiessen polygons and isohyets curves.
2	Programing tools	MS. Visual Basic
3	Processing tools	MS. Excel, MS. Word, MS Power Point
4	Validation tools	MS. Excel

Table 2.- Research tools

4.2 Type of research

The research was descriptive (deductive), since it is limited to writing delimited characteristics of the group of elements studied, making comparisons with other groups.
In turn, it was longitudinal since it studies the variables over a period of time that can be continuous or periodic. Which in turn is considered prospective, since they are oriented to the study of events that are about to occur.

4.3 Variable identification

For this study, temperature in pavement Surface and time, were the main variables.

4.4 Data analysis procedures.

The procedure for data analysis was:

- Search of bibliography specializing in the subject.
- District selection and determination of areas to study. The determination of the zones is related not only to the type of material used for its construction (asphalt and/or concrete), but also to the presence of particular elements that it may have around it (tall buildings that generate shadows, presence of nearby vegetation, presence of high pedestrian traffic, presence of light or heavy load vehicles, etc.).
- Measurement of temperatures in asphalt pavement, concrete pavement and gardens, four times a day. The taking of temperature was carried out with laboratory thermometers in approximately 7 minutes per taking.
- Quantitative and qualitative analysis from the data taken in the measurement.
- Generation of charts and graphs that technically show the generated study.
- Interpretation and conclusion, from the analysis of statistical tables and graphs. It is valid to mention that the interpretations and conclusions must be validated by bibliography related to the topic.
- Drawn of isotherm plans that show the temperature phenomenon in the study areas.

5. RESULTS AND DISCUSSIONS

It should be noted that all the graphic charts, plans and photos presented in this document, have been obtained during the development of the research.

In the urban map of the district of Magdalena del Mar; Two strategic areas of the district were taken. One of them in the eastern part of the district and another in the western part.

Each of the zones was sub-divided into various sectors, where each of them has a flexible pavement zone, a rigid pavement zone and gardens.

In each of these sectors, a surface temperature of pavements has been taken, four times throughout the day, taken with a laboratory thermometer, for a period of 7 minutes. The first measurement was made to an Asphalt Road, the second measurement to a Concrete Road, and the third measurement to a garden zone (natural vegetation).

The measurements gave us different temperatures, which in turn were graphed, which reveal the temperature taken vs. the hour of measurement. It is worth mentioning that the name "Asphalt" refers to the area covered by an asphalt road, the name "Green" refers to the area covered by a green area (natural vegetation), and the name "Concrete" refers to refers to the area covered by a concrete road.

5.1 STUDY AREA 1

In this first area, we took 7 sampling points from which 3 data were collected (one on the surface of the flexible pavement, one on the rigid pavement and one on the green area), at 4 moments of the day. These measurements were made in June, during the day. The average atmospheric temperature was 17.9°C.

Fig. 7.- Magdalena del mar district map.

Data obtained

Point	Location	Tipe	TIME & TEMPERATURE							
			10:35 a. m.		12:30 p. m.		2:55 p. m.		4:00 p. m.	
			Cº	Fº	Cº	Fº	Cº	Fº	Cº	Fº
1	Juan de Aliaga Av.	Asphalt	22.0	71.6	25.0	77.0	24.0	75.2	23.5	74.3
		Garden	20.5	68.9	22.5	72.5	22.0	71.6	20.5	68.9
		Concrete	21.0	69.8	23.5	74.3	23.0	73.4	22.5	72.5
2	Manuel Gonzales St	Asphalt	21.5	70.7	23.5	74.3	23.5	74.3	22.0	71.6
		Garden	20.0	68.0	22.5	72.5	21.0	69.8	20.0	68.0
		Concrete	21.0	69.8	23.0	73.4	23.0	73.4	22.0	71.6
3	De la Roca Av.	Asphalt	22.5	72.5	25.0	77.0	23.5	74.3	22.0	71.6
		Garden	20.0	68.0	22.0	71.6	21.0	69.8	20.0	68.0
		Concrete	21.5	70.7	24.0	75.2	23.0	73.4	22.0	71.6
4	Bernardo Monteagudo St	Asphalt	20.5	68.9	23.5	74.3	22.5	72.5	21.0	69.8
		Garden	19.0	66.2	22.0	71.6	21.0	69.8	20.0	68.0
		Concrete	22.0	71.6	23.0	73.4	22.0	71.6	21.0	69.8
5	Alberto del Campo St	Asphalt	24.0	75.2	24.0	75.2	23.0	73.4	21.5	70.7
		Garden	22.0	71.6	22.5	72.5	21.5	70.7	19.0	66.2
		Concrete	23.5	74.3	23.5	74.3	23.0	73.4	22.5	72.5
6	Mar del plata St.	Asphalt	23.5	74.3	26.5	79.7	23.0	73.4	22.0	71.6
		Garden	22.0	71.6	22.5	72.5	21.5	70.7	20.5	68.9
		Concrete	23.0	73.4	23.5	74.3	22.0	71.6	21.0	69.8
7	Juan de Aliaga St.	Asphalt	24.5	76.1	27.0	80.6	24.5	76.1	21.0	69.8
		Garden	23.5	74.3	22.0	71.6	20.5	68.9	19.0	66.2
		Concrete	24.0	75.2	25.0	77.0	24.0	75.2	21.0	69.8

Table 3.- Data of study area 1

In general, asphalt pavement temperatures are higher than concrete pavement temperatures, and both are lower than landscape temperatures. However, we have some anomalous data on asphalt pavements that, at some times, are lower than concrete pavements, due to the fact that vehicles have been parked in the data collection area, or the shadow of some buildings is projected.

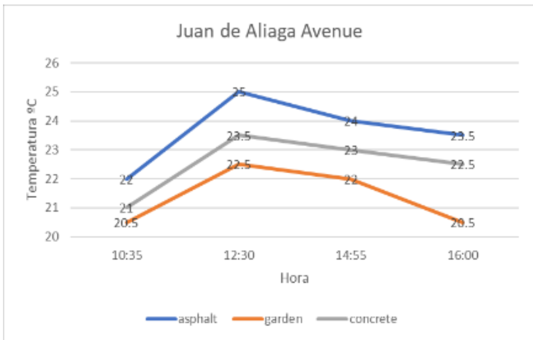

Fig 8.- Measurement Juan de Aliaga Av.

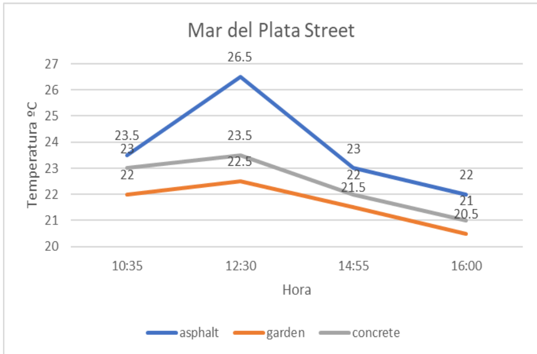

Fig 9.- Measurement Mar del Plata St.

Photo 1.- Data in asphalt surface

Photo 2.- Data in garden surface

Photo 3.- Data in concrete surface.

There are also some data on asphalt pavement temperatures, considerably higher than other areas, because in these places there are no trees that, with their shade, can mitigate the effect of solar radiation.

5.2 STUDY AREA 2

In this zone we took 6 sampling points to which 3 data were taken (one in flexible pavement, one zone of rigid pavement and one in green area), 4 times a day. These measurements were made in the month of June, during the day there was an average atmospheric temperature of 17.6°.

Fig 10.- Magdalena del mar District map.

Data obtained

POINT	LOCATION	TYPE	TIME & TEMPERATURE							
			11:03 a.m.		01:05 p.m.		3:21 p.m.		4.22 pm	
			Cº	Fº	Cº	Fº	Cº	Fº	Cº	Fº
1	Jose Galvez St.	Asphalt	26.0	78.8	29.0	84.2	30.0	86.0	29.5	85.1
		Garden			there are no gardens in the area					
		Concrete	25.5	77.9	26.0	78.8	28.0	82.4	29.0	84.2
2	Ulises del Boy St.	Asphalt	23.5	74.3	24.5	76.1	24.0	75.2	24.5	76.1
		Garden			there are no gardens in the area					
		Concrete	23.0	73.4	24.0	75.2	23.0	73.4	23.5	74.3
3	Miguel Grau Av.	Asphalt	27.0	80.6	28.0	82.4	29.0	84.2	28.5	83.3
		Garden	26.0	78.8	27.0	80.6	26.5	79.7	27.0	80.6
		Concrete	26.5	79.7	27.5	81.5	27.0	80.6	27.5	81.5
4	Ramon Castilla St	Asphalt	30.0	86.0	29.0	84.2	28.5	83.3	28.0	82.4
		Garden	28.0	82.4	27.0	80.6	26.0	78.8	26.0	78.8
		Concrete	28.5	83.3	28.0	82.4	28.0	82.4	26.5	79.7
5	Francisco Pavon St.	Asphalt	30.0	86.0	28.0	82.4	27.5	81.5	27.5	81.5
		Garden	27.0	80.6	27.0	80.6	24.5	76.1	24.0	75.2
		Concrete	28.0	82.4	27.5	81.5	25.5	77.9	25.0	77.0
6	Pascual de Vivero St.	Asphalt	25.5	77.9	25.0	77.0	23.5	74.3	23.0	73.4
		Garden	21.0	69.8	21.5	70.7	20.5	68.9	20.0	68.0
		Concrete	25.0	77.0	24.5	76.1	23.0	73.4	22.0	71.6

Table 4.- Data of study area 2

The data has been taken on a relatively cold day, however, asphalt surface temperatures of up to 30ºC can be observed, mainly in places with little vehicular traffic and little shade from buildings or trees.

In all cases, the surface temperature of asphalt paved roads is higher than concrete pavements and gardens.

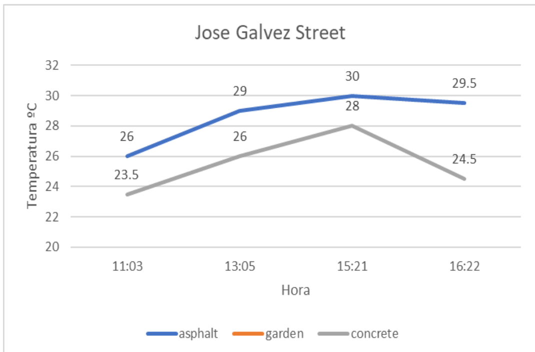

Fig 11.- Data in Jose Galvez St, note the increment of temperature in absence of gardens.

Photo 4.- Data in Jose Galvez St, no green areas.

5.3 ISOTHERMS

The result, from the generation of isotherms, shows that with the measurement of a group of points taken strategically, it is possible to have an idea of the generation of heat that originates in unreviewed areas.

"Verification points" were taken at certain points in the compromised area, thus verifying that the measurement, indicated by the thermometer, was within the range of temperatures generated by the isotherms.

In appendix 1, are included some isotherm plans, as a results of this investigation.

6. CONCLUSIONS

- There is an environmental impact generated by rigid pavements and flexible pavements in the urban environment. Faced with both alternatives, it is concluded that the concrete pavement has a lower effect of heat generation, compared to the asphalt pavement; which could potentially generate thermal islands or urban heat islands (UHI).

- The environmental impact, described above, has a negative nature by raising the atmosphere temperature; it generates a thermal gradient with respect to the environment. The heat originated by the pavements contributes to the rise in temperature of the area involved.

- In reference to the previous conclusion, it is possible to say that the surface temperature produced by a green area regulates the temperature compared to asphalt and concrete pavements; both possibilities in an area with characteristics of equal time and equal incidence of heat. The fundamental role played by vegetation areas is to attenuate the high temperatures caused by solar incidence.

- The different measurements made in the corresponding areas show us that shadows generated by trees in green areas and buildings, lowers the temperature generated on both asphalt and concrete surfaces.

7. RECOMMENDATIONS

The generation and use of isothermal curves, as a temperature prediction tool, is demonstrated with the generation of accompanying maps. It is convenient to say that the use of this tool would generate other potential research works related to sampling, orientation and interpretation of unmeasured areas from points taken strategically.

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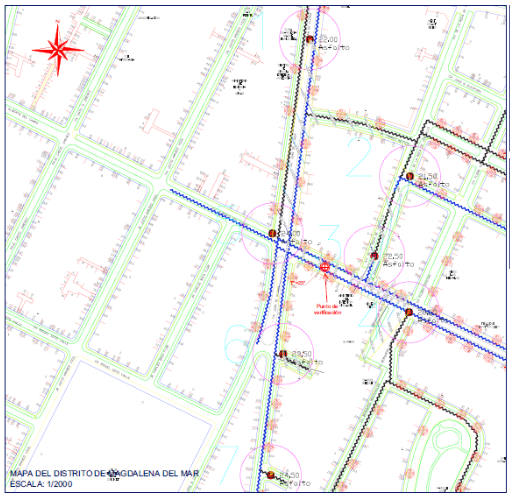
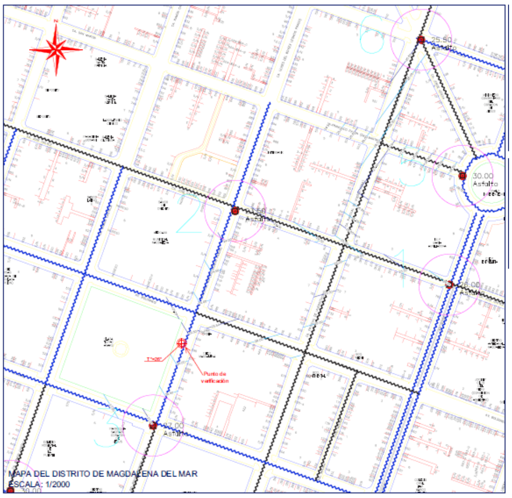
APENDIX 1

<u>Maps</u>

1.- Distribution of asphalt pavements and concrete pavements in study area.



2.- Data collection points in sector 1 and isothermal curves



3.- Data collection points in sector 2 and isothermal curves