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CHAPTER (1)
INTRODUCTION

1.1 General:

An environmental impact assessment is an assessment of the possible positive or negative impact that a proposed project may have on the environment, together consisting of the natural, social and economic aspects. The purpose of the assessment is to ensure that decision makers consider the ensuing environmental impacts when deciding whether to proceed with a project.

Asphalt Cement also (in Egypt) called Bitumen typically contains about 80% by weight of carbon10% hydrogen; up to6%sulfur; small amounts of oxygen and nitrogen; and trace amounts of metals such as iron, nickel, and vanadium. Asphalt Cement is a very viscous material at room temperature, so it is hard to blend it with aggregate since it will not coat the aggregate particles. Therefore both aggregate and Asphalt Cement should be heated to a temperature between 140-160 degrees Celsius to decrease Asphalt Cement viscosity and help coating aggregate particles, the mixture is called Hot Mix Asphalt (HMA).

The gaseous emissions associated with HMA production are hazardous. As these emissions are hazardous, research for alternative methods of mixing asphalt at less temperature had to be attempted.

1.2 Problem Statement:

There is very little research done on the environmental impact of Hot Mix Asphalt used for paving roads in Egypt. Guidelines for Environmental Impact Assessment (EIA) for road projects using HMA should be established.

Hot Mix Asphalt has been used for decades, Current and impending regulations regarding emissions are making it more attractive to consider greater reductions in HMA production temperature, further reductions in the emission of greenhouse gasses will likely be required in the future. Working conditions in the production and placement of

HMA are also important to the industry as improvements lead to an enhanced work environment, higher-quality work, and better employee and workforce retention. Significant HMA temperature reduction would have two benefits for the workforce: it would further reduce fumes in the vicinity of all paving workers and it would make for a cooler work environment.

1.3 Research Objective:

Establishing the best guidelines for Environmental Impact Assessment for road projects using Hot Mix Asphalt in Egypt is the first objective; this includes finding mitigation alternatives that could reduce this impact. Technology is now available to decrease HMA production temperature. These relatively new processes and products use various mechanical and chemical means to reduce the shear resistance of the mix at construction temperatures while reportedly maintaining or improving pavement performance. The development of these technologies began in Europe with the German Bitumen Forum in 1997. The second objective of this thesis is to evaluate the Warm Mix Asphalt technique as an alternative for Hot Mix Asphalt and weather it could be practically used in Egypt presenting an environmental study and an economical comparison between both techniques.

1.4 Scope of Research:

Temperature reduction in the manufacturing of asphalt mixtures is highly desirable from a number of aspects. Reduced fumes and emissions, and reduced energy consumption, are important environmental reasons to continue pursuing the goal of temperature reduction. There are important construction and performance advantages as well. For instance, improved workability results in better compaction.

This thesis will focus on how to reduce the environmental hazards of the asphalt pavement operation using Warm Mix Asphalt. Also, it will conclude if Warm Mix Asphalt could be practically used in Egypt with further economic study of different methods.

1.5 Methodology:

The methodology followed in this study can be summarized as follows:

- Establish a detailed study of the asphalt paving process.
  - Asphalt Lifecycle.
  - HMA Plant.
  - HMA Pavement Process.
  - Method statement for asphalt paving.
- Studying the environmental impact of Hot Mix Asphalt on:
  - Air Quality.
  - Health Hazards.
  - Global Warming.
  - Fuel Consumption.
- Finding effective guidelines for Environmental Impact Assessment for road construction projects in Egypt.
  - Studying law 4/1994 on the Environment and the EEAA guidelines on Egyptian Environmental Impact Assessment.

  - Classification of road construction projects in the Egyptian law.
  - Method of preparing an EIA report for a road construction project in Egypt.

- Establishing & gathering knowledge base information for Warm Mix Asphalt (as a mitigation procedure).
  - Different Methods Used.
  - Materials Used.
  - Mixing and Placement Temperatures.
  - Previous studies and trials.
  - Plant Upgrades.
- Studying the feasibility of using Warm Mix Asphalt.
  - Material Cost.
  - Plant Upgrade Cost.
  - Per Ton Cost Estimate.
  - Measuring the fuel saving and emission reduction due to using Warm Mix Asphalt.
  - Cost Comparison.

- Performing field studies including asphalt mixing plants and asphalt paving sites to observe environmental concerns on the industry.
  - Visit asphalt plants.
  - Observe transportation stage.
  - Visit asphalt placing sites
- Conducting a survey among professionals to gather knowledge about the HMA paving industry and its environmental impacts and determine the practicality of using warm mix asphalt in Egypt.
  - Determining method of survey.
  - Formulating sample size
  - Choosing survey participants
  - Presenting survey results
- Analyze all results (from literature review, field studies and survey)
  - Determining method of analysis
  - Explaining analysis procedure
  - Presenting analysis results
- Derive conclusions and recommendations.

1.6 Thesis format:

This section outlines the various phases of the thesis.

- Chapter 1 presents the introduction, problem statement, objectives, scope and methodology.
- Chapter 2 presents literature review, asphalt lifecycle, asphalt mixing and paving processes.
- Chapter 3 establishes the guidelines for the environmental impact assessment for the road construction projects in Egypt.
- Chapter 4 explains the warm mix asphalt technologies, trials and research.
- Chapter 5 presents the field studies for two asphalt paving projects in Egypt and the survey conducted among professionals in Egypt.
- Chapter 6 explains the results analysis and review.
- Chapter 7 presents the conclusion and recommendations established from the thesis.

Chapter (2)

LITERATURE REVIEW

2.1 Pavement Construction

2.1.1 General

Egypt, one of the most crowded countries in the region. Cities like Cairo and Alexandria have high traffic densities compared to the nearby region. Road construction is one of the authority priorities in Egypt. About 97% of roads in Egypt are constructed using flexible pavement (Asphalt). Asphalt is used on different types of roads such as streets, arterial roads, highways and even on huge airport runways.

2.1.2 Materials Used

2.1.2.1 Asphalt concrete,

(Anderson, Youtcheff and Zupanick, 2000) [(1)]***;*** Normally (and confusingly) known simply as "asphalt" or AC (Asphalt Cement in North America), is a composite material commonly used for construction of pavement, highways and parking lots. It consists of asphalt, which is used as a binder, and mineral aggregate mixed together then laid down in layers and compacted. It does not contain cement which is an ingredient of conventional concrete.

(Anderson, Youtcheff and Zupanick, 2000) [(1)]**;** In the simplest terms, asphalt binder also called Bitumen is simply the residue left over from petroleum refining. Thus, asphalt binders are produced mainly by petroleum refiners and, to a lesser extent, by formulators who purchase blending stock from refiners. The composition of base crude oil from which asphalt is refined can vary widely and thus the asphalt yield from different crude oil sources can also vary widely as shown in figure 2.1. The American Petroleum Institute (API) classifies crude oils by their API gravity (Equation 2.1). API gravity is an arbitrary expression of a material's density at 15.5° C (60° F) and is obtained in the following equation:

$$API\ gravity = \left(\frac{141.5}{specific\ gravity}\right) - 131.5 \qquad \text{Equation 2.1}$$

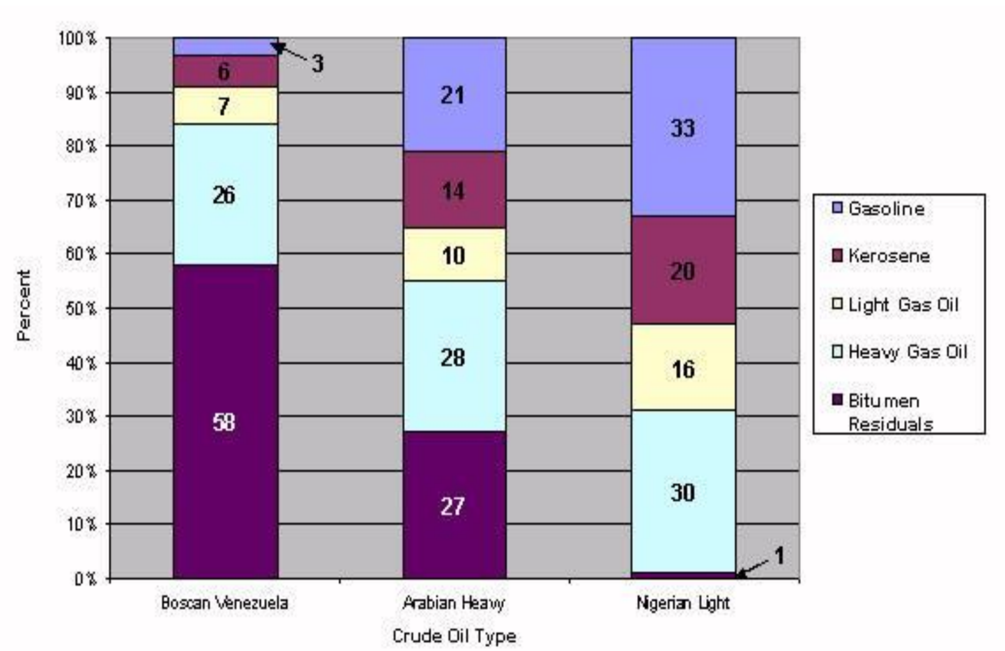

Figure 2.1 The composition of base crude oil from which asphalt is refined

Crude oil is heated in a large furnace to about 340° C (650° F) and partially vaporized. It is then fed into a distillation tower where the lighter components vaporize and are drawn off for further processing. The residue from this process (the asphalt) is usually fed into a vacuum distillation unit where heavier gas oils are drawn off. Asphalt cement grade is controlled by the amount of heavy gas oil remaining. Other techniques can then extract additional oils from the asphalt. Depending upon the exact process and the crude oil source, different asphalt cements of different properties can be produced. Additional desirable properties can be obtained by blending crude oils before distillation or asphalt cements after distillation.

(Abraham, 1929) *[2]***;** Asphalt cement is man's oldest engineering material. Its adhesive and waterproofing properties were known at the dawn of civilization. It was used by a thriving shipbuilding industry in sumeria about 6000 B.C. An ancient civilization in the Indus Valley (northwestern India) used asphalt cement in the construction of large public baths or tanks about 3000 B.C. Egyptians used native asphalts for waterproofing, mummification, and building structures.

2.1.2.2 Hot mix asphalt concrete

(AASHTO, 2000) [4]; (commonly abbreviated as HMAC or HMA) is produced by heating the asphalt binder (Bitumen) to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F (roughly 150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt, and the asphalt cement at 200 °F (95 °C). Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as roads in Egypt.

- **Hot Mix Asphalt Plant**

  The US Environmental Protection Agency EPA [3]; Hot mix asphalt is used primarily as paving material and consists of a mixture of aggregate and liquid asphalt cement, which are heated and mixed in measured quantities. Hot mix asphalt facilities can be broadly classified as either drum mix plants or batch mix plants, according to the process by which the raw materials are mixed. In a batch mix plant, the aggregate is dried first, then transferred to a mixer where it is mixed with the liquid asphalt. In a drum mix plant, a rotary dryer serves to dry the aggregate and mix it with the liquid asphalt cement. After mixing, the HMA generally is transferred to a storage bin or silo, where it is stored temporarily. From the silo, the HMA is emptied into haul trucks, which transport the material to the job site. Figure 2.2 presents a diagram of a typical batch mix HMA plant; a typical drum mix HMA plant is depicted in Figure 2.3.

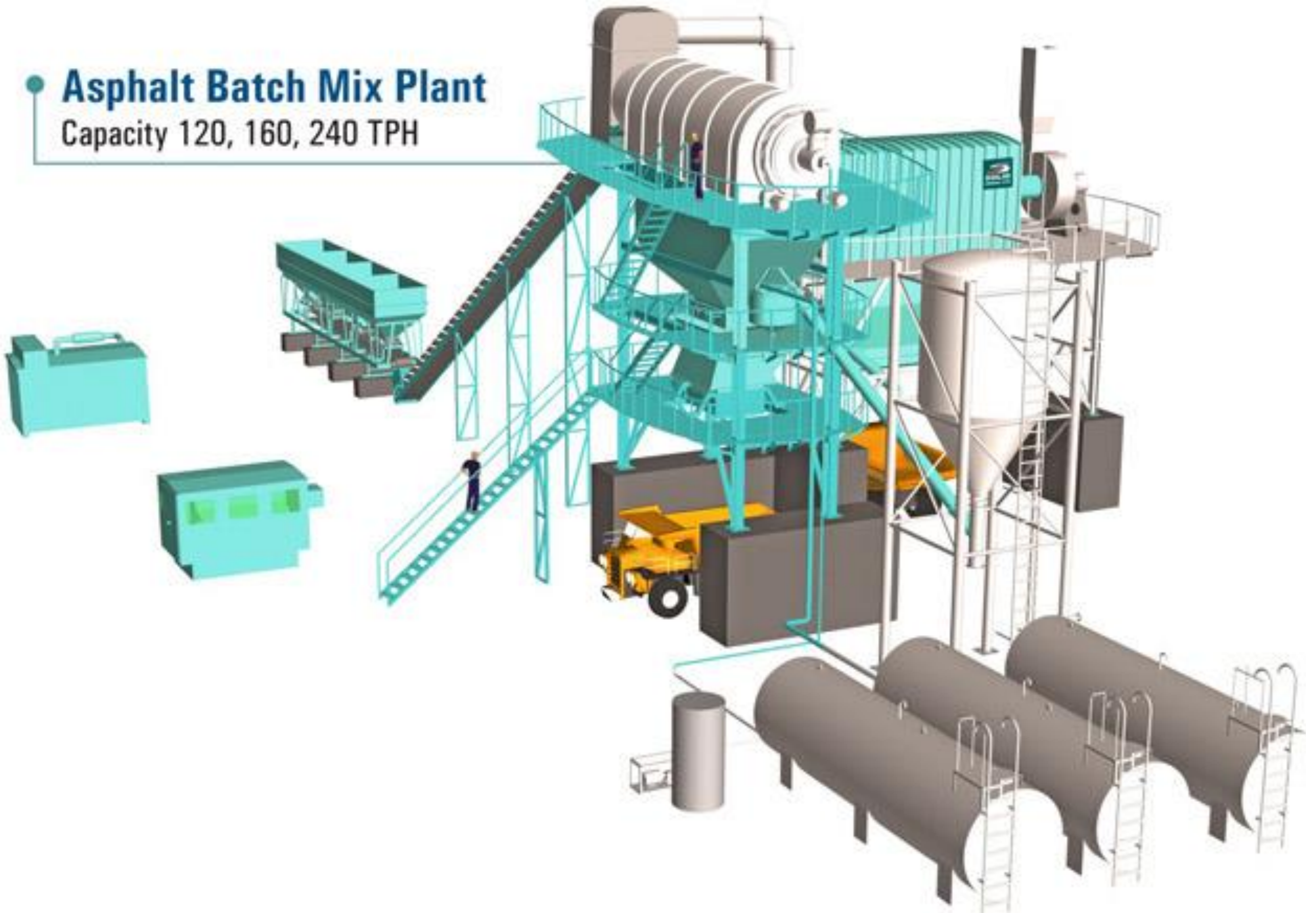

Figure 2.2 Batch Mix Plant

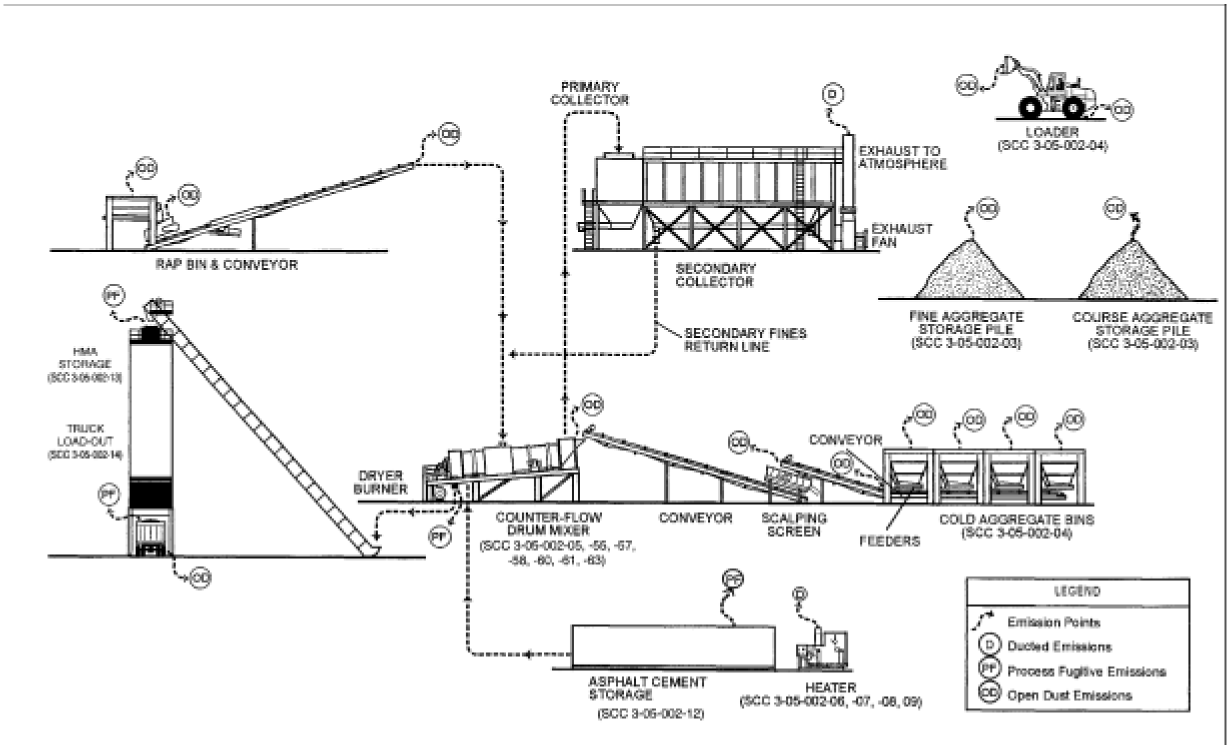

Figure 2.3 Drum Mix Plant

2.1.2.3 Construction Aggregates (Mineral Aggregates)

(**Nelson T.I. & W.P. Bolen, June 2008)** [5]**;** “Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel ,crushed stone, slag, recycled concrete and geosynthetic aggregates. The aggregate serves as reinforcement to add strength to the overall composite material. By weight, aggregate generally accounts for 92 – 96% of the mix and about 30% of the cost”. Sources of mineral aggregates in Egypt vary; one of the most famous quarries in Egypt is Attaka quarry near suez city to the east of Cairo.

2.1.3 Equipment Used

- **Asphalt Paver,** A paver (paver finisher, asphalt finisher) is an engineering vehicle used to lay asphalt on roadways. It is normally fed by a dump truck as shown in figure 2.4. The paver is automatically controlled to meet the specified thickness and smoothness of surface.

Figure 2.4 Asphalt paver fed by a dump truck

- **Roller Compactors,** is a compactor type engineering vehicle used to compact asphalt in the construction of roads. There are different types of roller compactors as shown in figures (2.5, 2.6), every type has its function.

Figure 2.5 Vibratory Roller Compactor

Figure 2.6 Pneumatic Roller Compactor

- **Prime Coat & Tack Coat Spraying Vehicle** is a vehicle used to spray prime coat or tack coat uniformly on the base course or asphalt surface, the vehicle is shown in figure 2.7.

Figure 2.7 Prime Coat & Tack Coat Spraying Vehicle

- **Other equipment**, equipment like dump trucks, surface cleaners, disk cutters and air compressors are also used in the asphalt pavement construction.

2.1.4 Method of Construction

(AJ McCormack Jnr, 1997) [6]; Asphalt pavement consists of layers as shown in figures (2.8, 2.9); in the following section each layer will be explained according to its material and function.

Figure 2.8 Asphalt Pavement Layers (1)

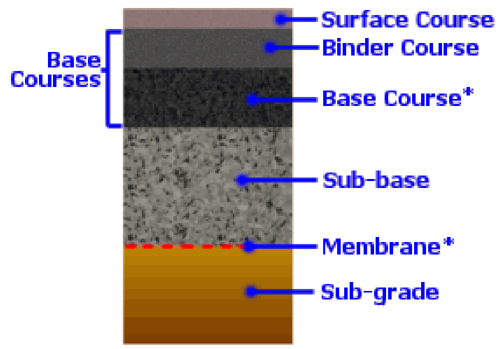

Figure 2.9 Asphalt Pavement Layers (2)

- **Sub-grade:**

  (AJ McCormack Jnr, 1997) [6]; the sub-grade layer of a pavement is, essentially, the underlying ground. It is also known as the "Formation Level", which can be defined as the level at which excavation ceases and construction starts, it's the lowest point of the pavement structure. Usually, a sub-grade will need some basic preparation to make it fit for construction purposes, and this process is known as 'sub-grade formation' or 'reducing to level'. The formation level of the sub-grade is the base of the construction. It will be overlain by the other pavement layers, which may include a capping layer, if the ground is structurally weak, likely to be subjected to exceptional loads or is significantly below an ideal formation level specified by the project engineer. Capping layers are simply layers of a selected fill material, often a crushed rock, laid in layers and thoroughly compacted before placing further layers, up to sub-base layer.

- **Sub-base:**

(AJ McCormack Jnr, 1997) [6]; the sub-base layer is often the main load-bearing layer of a pavement. It is designed to evenly spread the load of the paving, and any traffic thereon, to the sub-grade below. A well-constructed sub-base will prevent settlement and channelization, the phenomenon common on cheap installations of block paving, where two 'ruts' develop in the paving. These 'ruts' are caused when a car travels over the same line of paving to the garage, every morning and every night. Channelization is also apparent on carriageways, particularly at the approach to traffic lights and on upward gradients. The sub-base is intended to prevent channelization and settlement. The materials used to construct a sub-base are chosen for their inherent load-spreading capabilities when correctly laid.

- **Base Course:**

(AJ McCormack Jnr, 1997) [6] this is a load-bearing, strengthening layer of the pavement. The material used as a base course is 'chunkier' than a wearing course, usually comprising 20mm or 28mm aggregate in a bitumen binder, known as Dense Bitumen Macadam (DBM). On public highways and other heavier-use projects this layer is very important.

- **Binder Course:**

(AJ McCormack Jnr, 1997) [6]; the binder course material should be laid and leveled out reasonably level and thoroughly rolled and compacted before proceeding with the wearing course.

- **Wearing (Surface) Course:**

(AJ McCormack Jnr, 1997) [6]; this is the top layer of the pavement, the layer that is seen and trafficked. It needs to be fairly regular to provide a smooth ride for wheeled vehicles, although this is much more important on higher speed pavements than on residential driveways. Surface courses that use limestone or other light colored aggregates will wear over time to give a grayish appearance to the surface, as the tar binder is gradually eroded by traffic and exposure to the elements, to reveal the grey-white aggregate.

- **Prime Coat:**

  (AJ McCormack Jnr, 1997) [6]; Bituminous Prime Coat shall consist of supplying and applying liquid asphalt to a previously prepared and approved sub-base. The material for Prime Coat shall be medium curing cut back asphalt.

- **Tack Coat:**

  (AJ McCormack Jnr, 1997) [6]; Bituminous tack coat shall consist of supplying and applying emulsified asphalt diluted with an equal quantity of water (1:1) to a previously prepared bituminous courses or binder course or to an existing bituminous surface. The material for bituminous tack coat shall be rapid curing cutback.

2.1.4 Method Statement:

(Specifications of the new runway project Cairo Airport, 2006-2010)[7];

The sub-base (or base course) surface shall be cleaned of all foreign material and broomed free of dust. Prior to the placing of the mix, a prime coat or tack coat shall be applied to the base or surface. All bituminous mixes shall be introduced to the paver at a temperature not less than 135 deg.C and not more than 163 deg.C. The bituminous mix shall be spread and finished to crown and grade by automatically controlled bituminous paver. Bituminous mix may be spread and finished by hand methods only where machine methods are impractical. After spreading and strike off, and as soon as the mix conditions permit the rolling to be performed without excessive shoving or tearing, the mixture shall be thoroughly and uniformly compacted. Rolling will not be prolonged to an extent that cracks appear. Rollers shall be of the steel-wheel and pneumatic tyre type and shall be in good condition.

2.2 Emissions

Environmental Protection Agency (EPA) [3]; The primary emission sources associated with HMA production are the dryers, hot bins, and mixers, which emit particulate matter (PM) and a variety of gaseous pollutants. Other emission sources found at HMA plants include storage silos, which temporarily hold the HMA; truck load-out operations, in which the HMA is loaded into trucks for hauling to the job site; liquid asphalt storage tanks; hot oil heaters, which are used to heat the asphalt storage tanks; and yard emissions, which consist of fugitive emissions from the HMA in truck beds. Emissions also result from vehicular traffic on paved and unpaved roads, aggregate storage and handling operations, and vehicle exhaust, Emissions during placing stage are shown in figure 2.10.

The PM emissions associated with HMA production include the criteria pollutants PM-10 (PM less than 10 micrometers in aerodynamic diameter) and PM-2.5, hazardous air pollutant (HAP) metals, and HAP organic compounds. The gaseous emissions associated with HMA production include the criteria pollutants sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC), as well as volatile HAP organic compounds.

Figure 2.10 Showing
Asphalt Emissions during
Placing

2.2.1 Asphalt Fumes

(National Institute of occupational safety and health, NIOSH, 2003) [8]; Asphalt fumes are defined as the cloud of small particles created by condensation from the gaseous state after volatilization of asphalt.

- **How are people exposed to asphalt fumes?**

Fumes created from heating asphalt can be inhaled into the lungs or can condense onto exposed areas of the skin.

2.2.2 Human Health Effects

(National Toxicology Program, NTP, 1997) [9]; Asphalt fumes are irritants to the mucous membranes of the eyes and respiratory tract; hot asphalt can also cause burns of the skin. It has been reported that irritant effects on the respiratory tract can possibly progress to such nonmalignant lung diseases as bronchitis, emphysema. Workers engaged in road repair and construction reported symptoms of abnormal fatigue, reduced appetite, eye irritation, and laryngeal/pharyngeal irritation.

2.3 Environmental Issues (Pollution)

(R. M. Harrison, 2006) [10]; Pollution is the addition of something which has a detrimental effect on to the ecosystem. One of the most important causes of pollution is the high rate of energy usage by modern, growing populations. Pollution, contamination of Earth’s environment with materials that interfere with human health, the quality of life, or the natural functioning of ecosystems (living organisms and their physical surroundings).Although some environmental pollution is a result of natural causes such as volcanic eruptions, most is caused by human activities.

2.3.1 Impacts of Pollution

(R. M. Harrison, 2006) [10]; Pollution also has a dramatic effect on natural resources. Ecosystems such as forests, wetlands, coral reefs, and rivers perform many important services for Earth's environment. They enhance water and air quality, provide habitat for plants and animals, and provide food and medicines. Any or all of these ecosystem functions may be impaired or destroyed by pollution.

Moreover, because of the complex relationships among the many types of organisms and ecosystems, environmental contamination may have far-reaching consequences that are not immediately obvious or that are difficult to predict. For instance, scientists can only speculate on some of the potential impacts of the depletion of the ozone layer, the protective layer in the atmosphere that shields Earth from the Sun's harmful ultraviolet rays.

Another major effect of pollution is the tremendous cost of pollution cleanup and prevention. The global effort to control emissions of carbon dioxide, a gas produced from the combustion of fossil fuels such as coal or oil, or of other organic materials like wood, is one such example. The cost of maintaining annual national carbon dioxide emissions at 1990 levels is estimated to be 2 percent of the gross domestic product for developed countries. In addition to its effects on the economy, health, and natural resources, pollution has social implications. Research has shown that low-income populations and minorities do not receive the same protection from environmental contamination as do higher-income communities. Toxic waste incinerators, chemical plants, and solid waste dumps are often located in low-income communities because of a lack of organized, informed community involvement in municipal decision-making processes.

2.3.2 Air Pollution

(Dupasquier S. & Parriaux, 2002)[11]; Air pollution is the accumulation in the atmosphere of substances that, in sufficient concentrations, endanger human health or produce other measured effects on living matter and other materials. Among the major sources of pollution are power and heat generation, the burning of solid wastes, industrial processes, and, especially, transportation. The six major types of pollutants are carbon monoxide, hydrocarbons, nitrogen oxides, particulates, sulfur dioxide, and photochemical oxidants.

In both developed and rapidly industrializing countries, the major historic air pollution problem has typically been high levels of smoke and sulphur dioxide arising from the combustion of sulphur-containing fossil fuels such as coal for domestic and industrial purpose. The major threat to clean air is now posed by traffic emissions. Petrol and diesel-engine motor vehicles emit a wide variety of pollutants, principally carbon monoxide (CO), oxides of nitrogen (NO_X), volatile organic compounds (VOCs) and particulates (PM_{10}), which have an increasing impact on urban air quality.

In addition, photochemical reactions resulting from the action of sunlight on nitrogen dioxide (NO_2) and VOCs from vehicles leads to the formation of ozone, a secondary long-range pollutant, which impacts in rural areas often far from the original emission site.

Acid rain is another long-range pollutant influenced by vehicle NO_X emissions. In all except worst-case situations, industrial and domestic pollutant sources, together with their impact on air quality, tend to be steady-state or improving over time. However, traffic pollution problems are worsening world-wide.

2.3.3 Major Air Pollutants

(The Environment Agency 2008) [12];

- ***Sulphur dioxide (SO_2):*** It is a major contributor to smog and acid rain. Sulfur dioxide can lead to lung diseases.
- ***Nitrogen oxides (NO_x)*:** Nitrogen oxides (NO_x) Cause smog and acid rain it is produced from burning fuels including petrol, diesel, and coal. Nitrogen oxides can make children susceptible to respiratory diseases in winters.
- ***Particulate matter (PM):*** Particulate matter (PM) measured as smoke and dust. PM_{10} is the fraction of suspended particles 10 micrometers in diameter and

smaller that will enter the nasal cavity. $PM_{2.5}$has a maximum particle size of 2.5 μm and will enter the bronchi's and lungs.

- ***Carbon monoxide (CO):*** Carbon monoxide (CO) is a colorless, odorless gas that is produced by the incomplete burning of carbon-based fuels including petrol, diesel, and wood. It is also produced from the combustion of natural and synthetic products such as cigarettes. It lowers the amount of oxygen that enters our blood. It can slow our reflexes and make us confused and sleepy.
- ***Carbon dioxide (CO_2):*** Carbon dioxide (CO_2) is the principle greenhouse gas emitted as a result of human activities such as the burning of coal, oil, and natural gases. Chlorofluorocarbons (CFC) are gases that are released mainly from air-conditioning systems and refrigeration. When released into the air, CFCs rise to the stratosphere, where they come in contact with few other gases, which lead to a reduction of the ozone layer that protects the earth from the harmful ultraviolet rays of the sun.

2.3.4 Global Warming

2.3.4.1 Introduction

(Thomas R. Karl and Kevin E. Trenberth, 2003) [13]; The phrase *global warming* refers to the documented historical warming of the Earth's surface based upon worldwide temperature records that have been maintained by humans since the 1880s. The term *global warming* is often used synonymously with the term climate change, but the two terms have distinct meanings. *Global warming* is the combined result of anthropogenic (human-caused) emissions of greenhouse gases and changes in solar irradiance, while climate change refers to any change in the state of the climate that can be identified by changes in the average and/or the variability of its properties (e.g., temperature, precipitation), and that persists for an extended period, typically decades or longer.

According to the World Meteorological Organization (WMO), the decade of the 2000s (2000–2009) is the warmest on record. The global mean surface temperature for 2009 is currently estimated at 0.44°C/0.79°F above the 1961-1990 annual average of 14.00°C/57.20°F. WMO states that in 2009 above-normal temperatures were recorded in most parts of the continents. Only North America (United States and Canada) experienced conditions that were cooler than average.

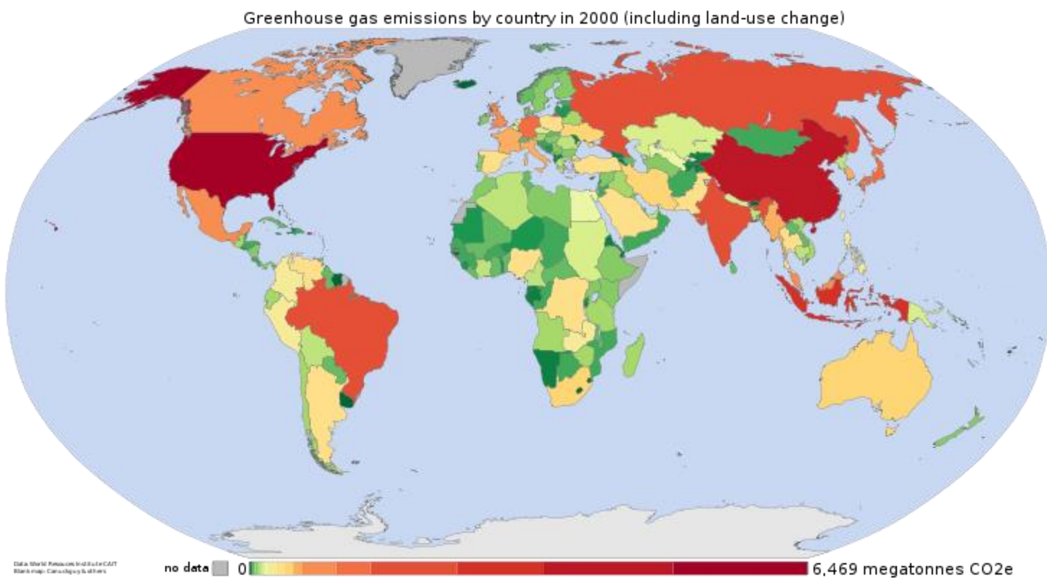

Figure 2.11 Greenhouse Gas Emissions By Country

2.3.4.2 Greenhouse Gases

(Thomas R. Karl and Kevin E. Trenberth, 2003) [13]; The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in the atmosphere warm a planet's lower atmosphere and surface. It was discovered by *Joseph Fourier* in 1824 and was first investigated quantitatively by *Svante Arrhenius* in 1896. Existence of the greenhouse effect as such is not disputed, even by those who do not agree that the recent temperature increase is attributable to human activity. The question is instead how the strength of the greenhouse effect changes when human activity increases the concentrations of greenhouse gases in the atmosphere.

Naturally occurring greenhouse gases have a mean warming effect of about 33 °C (59 °F). The major greenhouse gases are water vapor, which causes about 36–70 percent of the greenhouse effect; carbon dioxide (CO_2), which causes 9–26 percent; methane (CH_4), which causes 4–9 percent; and ozone (O_3), which causes 3–7 percent. Clouds also affect the radiation balance, but they are composed of liquid water or ice and so have different effects on radiation from water vapor. Greenhouse gas emissions by country are shown in figure 2.11.

Human activity since the Industrial Revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radiative forcing from CO_2, methane, tropospheric ozone, CFCs and nitrous oxide. The concentrations of CO_2 and methane have increased by 36% and 148% respectively since 1750. These levels are much higher than at any time during the last 650,000 years, the period for which reliable data has been extracted from ice cores. Less direct geological evidence indicates that CO_2 values higher than this were last seen about 20 million years ago. Fossil fuel burning has produced about three-quarters of the increase in CO_2 from human activity over the past 20 years. Most of the rest is due to land-use change, particularly deforestation.

CO_2 concentrations are continuing to rise due to burning of fossil fuels and land-use change. The future rate of rise will depend on uncertain economic, sociological, technological, and natural developments. Accordingly, the IPCC Special Report on Emissions Scenarios gives a wide range of future CO_2 scenarios, ranging from 541 to 970 ppm by the year 2100 (an increase by 90-250% since 1750).] Fossil fuel reserves are sufficient to reach these levels and continue emissions past 2100 if coal, tar sands or methane clathrates are extensively exploited.

The destruction of stratospheric ozone by chlorofluorocarbons is sometimes mentioned in relation to global warming. Although there are a few areas of linkage, the relationship between the two is not strong. Reduction of stratospheric ozone has a cooling influence, but substantial ozone depletion did not occur until the late 1970s. Ozone in the troposphere (the lowest part of the Earth's atmosphere) does contribute to surface warming. Figures (2.12, 2.13) illustrate global warming and greenhouse gas emissions causes.

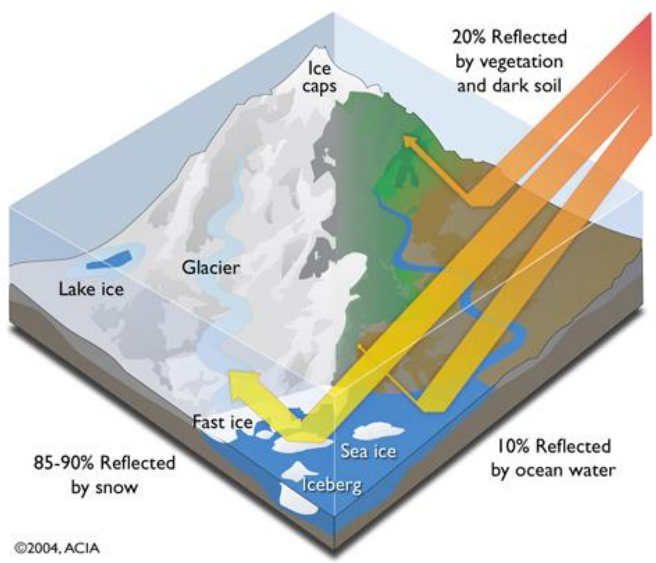

Figure 2.12 Greenhouse Emissions Causes

2.3.4.3 Views on Global Warming

(Banuri et al., 1996) [15]; there are different views over what the appropriate policy response to climate change should be. These competing views weigh the benefits of limiting emissions of greenhouse gases against the costs. In general, it seems likely that climate change will impose greater damages and risks in poorer regions.

1. **Politics:** Developing and developed countries have made different arguments over who should bear the burden of costs for cutting emissions. Developing countries often concentrate on per capita emissions, that is, the total emissions of a country divided by its population. Per capita emissions in the industrialized countries are typically as much as ten times the average in developing countries. This is used to make the argument that the real problem of climate change is due to the profligate and unsustainable lifestyles of those living in rich countries. On the other hand, commentators from developed countries more often point out that it is total emissions that matter. In 2008, developing countries made up around half of the world's total emissions of CO_2 from cement production and fossil fuel use.

2. **Public Opinion:** In **2007–2008 Gallup Polls** surveyed 127 countries. Over a third of the world's population was unaware of global warming, with people in developing countries less aware than those in developed, and those in Africa the least aware. Of those aware, Latin America leads in belief that temperature changes are a result of human activities while Africa, parts of Asia and the Middle East, and a few countries from the Former Soviet Union lead in the opposite belief. In the Western world, opinions over the concept and the appropriate responses are divided. *Nick Pidgeon* of Cardiff University finds that "results show the different stages of engagement about global warming on each side of the Atlantic"; where Europe debates the appropriate responses while the United States debates whether climate change is happening.

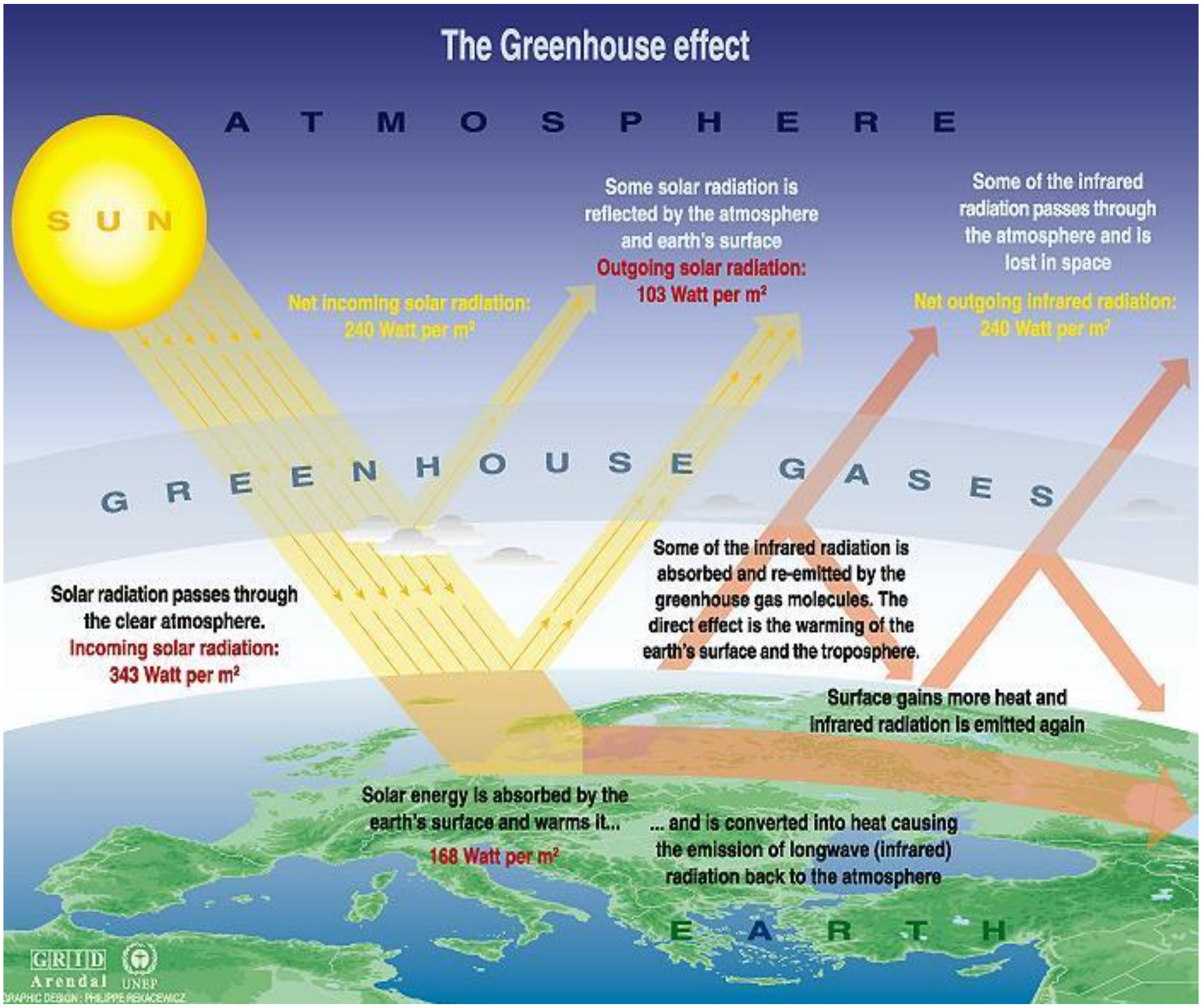

Figure 2.13 The Greenhouse Effect

CHAPTER (3)

GUIDELINES FOR ENVIRONMENTAL IMPACT ASSESSMENT FOR ROAD CONSTRUCTION IN EGYPT

3.1 Environmental Impact Assessment

3.1.1 What is the EIA?

(Guidelines for Environmental Impact Assessment) **[14];** The EIA process is not simply a matter of preparing an environmental impact assessment report and obtaining the necessary approval. EIA, in its widest sense, is the means by which environmental concerns can be taken into account throughout the life of a development project, starting from the initial concept through the detailed design, construction and operation to the eventual restoration and reuse of the land. The EIA is not a scientific research by itself, but it depends on the results of the scientific research and the basics of the decision making process. For this reason, this process should not be considered as a complementary action or a red tape annex for the project, but it should be taken as an essential factor for the establishment of the project and considered in the funding of the project from the very beginning. The EIA is not only a professional support for the project evaluation, but it is also considered as a tool for the management of the development process, thus, the environmental assessment process requires the ability of the contributors to judge the scientific and management performance .

An effective EIA requires the following:

• An accurate description of the project discussing the alternatives for the implementation method.

• Identifying the range and type of required data.

• Identification of potential environmental impacts at the different stages of the project.

• Presenting the data in an effective and gradual manner, to suit each stage of the decision making process.

• Selection of a competent team with regards to technical and management skills, to perform the EIA. It is important, when collecting data, to concentrate on the main issues related to the project; that means surveys should be designed to ensure the objectivity of the data collected. If samples need to be taken for the long term, such as air, water or soil samples, this should begin as early as possible in order to have the longest possible period to assess potential trends.

Revisions of the sufficiency of the gathered data should be done throughout the preparation of the study to fill in the gaps promptly. The following table (3.1) shows the required groups to make the report:

Table 3.1 Required groups to make an EIA report [14]

Scope of work	Tasks
1. Environmental Monitoring	• Taking samples of air and water Quality. • Updating of land use. • Monitoring of the run off water
2. Plan Review	• Zoning • Layout review • Service plan review
3. Environmental Assessment	• Preparation of the report • Prediction of alternative impacts • Evaluation of the plan • Hazards evaluation
4. Facility Planning	• Planning of water treatment • Planning of water supply • Planning of highways
5. Land Use Planning	• Environmental inventory • Site selection & evaluation • Land use and capacity studies
6. Development Planning	• Constraints & Potentialities • Site planning and design • Feasibility studies
7. Waste Disposal Planning	• Solid wastes • Site treatment and rehabilitation • Evaluation of impacts
8. Public Health Planning	• Monitoring and controlling of diseases • Monitoring of water quality • Environmental analysis
9. Energy Planning	• Evaluation of energy alternatives • Analysis of energy budget and deduction of new solutions

Table 3.1 Continued

Scope of work	Tasks
10. Environmental Design	• Streetscape • Planning of riversides • Studies of microclimate
11. Park and Recreation Planning	• Site selection & evaluation • Identification and evaluation of impacts • Landscape design
12. Landscape Management	• Control of run off water • Control of evaporation and sedimentation • Dealing with flatlands.
Environmental Information Services	• Legislative consultants. • Scientific materials • Workshops of concerned groups

3.1.2 Description of Project

The definition of the project from the point of view of the location and characteristics has a great effect on assessing the change of land uses, infrastructure and different activities. The description as well as the visual changes in the landscape should contain:

1. The Authorities concerned with the project and its management.

2. The location of the project.

3. The general layout, land use plan of the site, roads and structures.

4. Any relation of the site with the surrounding economic activities such as agriculture and industry.

5. The different stages of the project during its lifetime and the duration of each.

6. The construction and operation stages and the accompanying activities such as the dredging, landfilling and transportation of the equipment and the workers.

7. The rehabilitation of the site area after the project is completed.

3.1.3 Description of the Environmental Background and Identification of Impacts

In this stage, the present and future environmental situations are described according to each of the proposed alternatives including the no project alternative. Also, taking into consideration the changes that occur as a result of natural events or human activities in the region. The relationships between the environmental situations and the different alternatives could be identified through different tools. The simplest of which is the use of matrices identifying the main activities and the main environmental impacts resulting from road projects, where other elements and activities could be added according to the type of the planned road.

To prepare an accurate description of the environmental backgrounds identifying the main impacts, it is essential to implement the following:

1. Study the type of impacts resulting from similar projects which helps in making a list of the factors that need to be studied

2. Use other sources of information, such as EIAs, for similar projects.

3.1.4 Considering Alternatives

Early appraisal of alternatives is essential; this helps the decision-makers to recognize different approaches to solution and to evaluate the project.

These alternatives would be:

1. No project, this could be relative to the need of the project.

2. Alternative locations for the project to obtain maximum profit from the economical, planning and environmental points of views.

3. Different scales for the project and the flexibility of its size.

4. Different alternatives for land use to reach the ultimate environmental performance.

5. Different alternatives for the construction process: day or night to avoid noises i.e. suitable time for work with minimum impact.

In considering and evaluating alternatives, cost should be taken as an essential factor, preferring those alternatives with minimum impact, which minimize the costs of mitigation and management.

It is also to be mentioned that the selection of alternative will be based on the economical sustainability, planning and environmental criteria.

3.1.5 Screening

This is the task of deciding whether or not a formal EIA is required for a particular project. Relevant legislation and guidelines **(Law 4/1994 on the Environment and the EEAA guidelines on Egyptian Environmental Impact Assessment)** identify the projects which must have an EIA and those where an EIA is discretionary or not required.

The **EEAA** Guidelines classify projects into three groups to reflect the potential severity of environmental impacts:

- White list projects “A”: those likely to have minor environmental impact. The developer applies to the CAA before construction works are initiated, with a letter of intent, accompanied by Environmental Screening Form “A”. An EIA is not required for these projects.

- Grey list projects “B”: Those, which may result in significant environmental impact. The developer applies to the CAA before construction works are initialed, with a letter of intent accompanied by Environmental Screening Form “B”. A scoped EIA for such projects or for parts of such projects may be required at the discretion of the **EEAA**.

- Black list projects “C”: Those projects, which require complete EIA due to their potential impacts. The developer applies to the CAA before construction works are initiated, with a letter of intent, accompanied by the scoped EIA. The **EEAA** Guidelines include in sectoral guidelines for establishments that need full EIA.

After studying the list of projects listed by the **EEAA** it was important to check in which category asphalt production and road construction are considered …

It is observed in the following table (3.2) Asphalt Mixing Plants are considered category "B" Grey List Projects by the **EEAA** [14]

Table 3.2 Category "B" Projects. [14]

Ministry of State for Environmental Affairs
Egyptian Environmental Affairs Agency (EEAA)
Environmental Management Sector
Central Administrative for Environmental Impact Assessment

A List of Some of Category (B) Projects

	5- Wooden products industry
29-	Wood factories with soaking processes (chemical treatment of wood)/artificial wood manufacturing plants
30-	Manufacturing wooden products such as windows, doors, accessories, furniture and desks
	6- Refractory, mining, building materials and plastics industry
31-	Recycling of used glass to produce glass products
32-	Marble and granite cutting, polishing and finishing factories
33-	Manufacturing cement products including painting processes
34-	Manufacturing bricks, plasters, and clay and sand bricks plants
35-	Lime and gypsum kilns/ potteries
36-	Plants carrying out asphalt mixing and producing construction and road paving materials and reinforced concrete mixer

It is also clear according to table (3.3) that all road projects including runways, helicopter landing areas, large transportation systems, and even internal highways in cities are considered category "C" Black List Projects by the **EEAA** [14]

Table 3.3 Category "C" Projects. [14]

Ministry of State for Environmental Affairs
Egyptian Environmental Affairs Agency (EEAA)
Environmental Management Sector
Central Administrative for Environmental Impact Assessment

A List of Some of Category (C) Projects

50-	Intercontinental transmission lines
51-	Hydropower plants
52-	Power plants with associated power lines
53-	Nuclear power plants
54-	Generation of electricity using wind or by solar energy, including power lines
	2- Infrastructure
55-	Wastewater treatment plants including sanitation systems
56-	Public/central Construction of water treatment or desalination plants
57-	Establishment of quays
58-	Airports and runways and helicopter landing areas
59-	Large transportation systems and highways, including the underground, bridges and tunnels
60-	Internal highways in cities

3.1.6 Scoping

Scoping is the identification of those matters that need to be covered in the EIA. Not all issues will be equally important for all proposals and the EIA process must focus its attention on the key issues of concern.

Scoping should result in:

• A list of all issues with a preliminary estimate of the relative significance of their impacts

• Identification and prioritization of the key issues and how they are to be assessed.

• An explanation as to why other issues are considered to be less important.

3.1.7 Prediction of Impacts and Evaluation of Mitigation Strategies:

This point deals with the prediction of the nature and extent of the impacts on the environment, as a result of the project, compared to the original environmental situation. It also discusses the effectiveness of the mitigation strategies. The changes due to road construction areas are:

1. Changes in population size, site layout, surrounding environment, and historical and cultural zones.

2. Impact of the development on the flora and fauna, such as damage or the total loss of a plant or animal species.

3. Impact of the development of land including topography, soil, and land use

4. Impact of the development on water (quality, quantity and level), whether surface or groundwater.

5. Impacts on air and climate (changes in temperature, humidity, concentration of suspended particles in air, smells, noise, etc.)

6. The indirect impacts such as traffic flow and means of transportation, the impact on another development activity parallel to the project, or the impact on the economic base and the work market in the surrounding area…etc.

Impact prediction should consider:

• The scale of the impact

• The duration of the impact

• How widely spread the impact is spread.

• Whether impacts are direct or indirect

• Both beneficial and adverse effects

• Whether impacts are temporary, reversible or permanent.

• Public interest and political echo of the impact.

The accuracy of the predictions depends on the available sources of the database.

After screening the environmental impacts, a number of mitigation measures could be identified at three levels:

1. To avoid the expected side effects before they are here

2. To minimize their impact.

3. To mitigate the effects that could not be avoided

3.2 Guidelines for Writing the EIA Report

These guidelines provide advice on the content of formal EIAs for developers, planners and consultants involved in road construction. The guidelines are not exhaustive. They are intended to identify the main issues of concern related to the road construction. Developers must carefully assess each individual proposal to ensure that all issues relevant to the site have been identified.

The main text of the EIA report should be around 60-70 pages, and certainly no longer than 100 pages in addition to the schematic and planning drawings. For more technically complex projects, technical appendices can be used to achieve this. Any individual technical appendix should be no longer than 20 pages (excluding plans, photos, and drawings).

The following list sets out the key chapters that are required in an EIA for road construction projects:

a. Non-Technical executive summary.

b. Description of the proposed road construction project.

c. Background Information covering the legislative framework, methodology, consulting of public sentiment and consideration of alternatives.

d. Description of the existing environment - the baseline.

e. Prediction of impacts and evaluation of significant environmental effects.

f. Mitigation including the environmental management plan and monitoring.

g. Conclusions.

h. References.

3.2.1 Non-Technical Executive summary

The non-technical summary should be in around 4 pages, and not exceed 10 pages in addition to plans and photos. The summary should give an overview of the proposal, the alternatives considered, the potential environmental impacts and their effects, and proposed mitigation measures. It should be written in nontechnical language to help all readers to understand it.

3.2.2 Description of the Proposed Road Construction Project

3.2.2.1 Objectives and Scope of the Proposal

There should be a clear statement of the objectives and scope of the proposal including:

• A general description of the proposed road construction or the land uses expected.

• The reason and / or need for the project;

• The expected project life;

• Land ownership/tenure;

• Any designations such as protected areas, which affect the site.

3.2.2.2 The Location

A site description and maps, plans or photographs should be provided clearly identifying the location of the proposed project relative to:

• Land uses in the surrounding area, both urban and rural, e.g., housing agriculture;

• Water bodies and surface water, e.g., rivers, lakes and canals and the use made of these, e.g. fishing, drinking water supply, navigation, irrigation;

• Habitats both natural and man-made for flora and fauna;

• Infrastructure including transport and utilities

• Any local or regional strategy such as management plans for nature conservation areas (natural protectorates)

• Any historical sites or environmental protectorates.

3.2.2.3 Detailed Description and Layout of the Proposed Project

The following information should be provided:

• Site plans which must show the maximum land area affected by the proposal;

• Layout plan of the project showing buildings, roads, parking, and infrastructure including all utilities;

• Power supply requirements and proposed energy conservation measures;

• Proposed usage and sources of water supply including discharges from any desalination plants and options for water recycling and reuse;

• Quantities of solid and liquid waste generated and the arrangements for collection, recycling treatment and disposal;

• Road system and pedestrian walkways.

• Identification of the proposed means of surface water drainage (e.g. rain, etc…)

• The anticipated employment in operation.

3.2.2.4 Site Preparation and Construction

Describe the construction works required prior to commencement of project operation including:

• Timing, staging and hours of construction work;

• Proposed construction methods including temporary construction works, the equipment to be used and methods of transport of the equipment and workers to the site;

• Proposals for environmental management during construction, e.g. erosion and sediment control system, waste water holding tanks, noise mitigation strategies;

• Any stabilisation structures or earthworks including the dredging, reclamation, excavation or landfilling associated with these;

• Quantities of material to be moved to or from the site, the method of disposal of excess material, and the sources of material to be brought to site;

• Details of the construction workforce, including source, expected numbers and fluctuations throughout the construction period;

• Accommodation of the working team.

3.2.3 Background Information

3.2.3.1 Legislative Framework

This section should set out the laws considered during the planning of the project, e.g. Law No. 4/1994 on the Environment and its executive regulations, Governorate orders, land use, etc. A list of all approvals and licenses required, under any legislation, should be included. This list should identify the relevant authorities involved in the assessment and regulation of all aspects of the proposal.

3.2.3.2 Methodology

The procedures or methodology used in the EIA should be outlined. The basic methodology of EIA is to:

• Establish the baseline or existing situation and any changes anticipated without the project concerned.

• Predict the impacts that will occur with the project.

• Evaluate the effects of those impacts for people, flora and fauna and for things i.e. environmental resources such as land, water and the atmosphere

• Evaluate how mitigation can be used to reduce the effects of a project.

• Describe the residual effects after mitigation.

• This chapter should include details of:

• How the impacts have been predicated

• The criteria used for assessing the significance of effects for both people and environmental resources.

• This should be supported where necessary with:

• Relevant guidelines issued by government authorities, provisions of any relevant environmental protection legislation, and relevant strategic plans or policies

• Relevant research or reference material, meteorological data and relevant preliminary or prefeasibility studies.

• Those issues, which will not need a full analysis in the EIA but which still, need to be addressed in a limited way.

The outcome of the screening and scooping process should be summarised including:

• All issues identified;

• The key issues, which will need a full analysis in the EIA but which still, need to be addressed in a limited way.

3.2.3.3 Public Participation

The EIA should list who has been consulted, how they have been consulted and what their views are. Consultants should include relevant government agencies, NGOs and the public. A brief description of the reason for consultation and the outcome should be included, agencies that must be consulted are those with regulatory powers or responsibilities in relation to planning the control on roads and traffic, waste disposal, discharge limits into fresh waters, emissions to air, and historic monuments, and conservation of natural resources. These will include, as a minimum, the Egyptian Environmental Affairs Agency (**EEAA**), Governorate representative, Ministry of Housing, Ministry of transport, Ministry of Health, and relevant Community Development Associations (CDAs).

3.2.3.4 Consideration of Alternatives

The EIA should include a summary of alternatives to the project and the reasons why the proposed project is preferred. Alternatives will include:

• The “no project” alternatives

• Alternative locations

• Alternative uses for the land. Project elements may be modified through mitigation

• Alternative management or operational practices, these may be modified further under mitigation.

3.2.4 Description of the Existing Environment "The Baseline"

3.2.4.1 The Overview

An overview of the existing environment should be provided in order to place the proposal in its local and regional context. More detailed baseline information is needed for those issues identified as potentially important in the EIA for project proposals and this is likely to include:

• Land Characteristics and Use

• Landscape characteristics of the surrounding area and Existing Views

• Habitats, Flora and Fauna

• Water including Hydrology, Groundwater and Water Quality

• Air Quality

• Noise Levels

• Antiquities and other Sites of Historic and Cultural Significance

• The Social and Economic Context

• Traffic flows and Transport Infrastructure

• Utility Services.

Data must be relevant to the proposed project. The level of detail should match the level of importance of the issue in decision-making. To make the EIA report easier to read, it may be sensible to include the specialized detail for each of the report sections as a technical appendix to the report, with a summary of each section in the main EIA report.

3.2.4.2 Land Characteristics and use

Most of the road projects involve taking land. The baseline includes:

• The existing surface characteristics are topography, solid characteristics, terrain stability and susceptibility to erosion or landslip

• The existing land uses occupying the site

• The existing surface characteristics of the surrounding area

• The existing land uses occupying the surrounding area and particularly those land uses which would be sensitive to road construction (industry, protectorates, etc…).

Note that the land characteristics and uses will also be relevant to other parts of the baseline, e.g. landscape and visual character.

3.2.4.3 Landscape Character and Existing Views

Landscape quality can be affected by intrusion of road construction and by loss of attractive features such as vegetation and hills. The baseline needs to describe:

• The existing character of the landscape both on the site and in the surrounding area

• Views of the site from adjoining properties and public areas particularly where these are sensitive, e.g. residential, and recreational or tourist areas, especially if the project contain industries.

3.2.4.4 Flora and Fauna

Flora and Fauna can be affected by emissions from existing industries and by loss of habitats such as vegetation and water bodies. The baseline needs to describe:

• The existing habitats – terrestrial, aquatic or marine – both on site and in the surrounding area.

• The flora and fauna species present, their populations and their value, which may reflect rarity, economic value and attractiveness.

3.2.4.5 Water including Hydrology, Groundwater and Water Quality

Road construction may impact on the hydrology of an area and waterborne emissions may place the quality of both surface water and groundwater at risk. There is a need to understand the surface water drainage in the area even if this is very intermittent, e.g. flash floods every 50 years. Baseline data includes:

• Existing drainage. This includes the location and capacity of wadis, canals, drains and rivers; identification of areas prone to flash foods; depth of groundwater surface level.

• Surface water and groundwater movement patterns. This includes groundwater hydrology, the range of water levels and daily flushing regime in canals, drains and rivers; tidal ranges and wave climate in coastal areas and sediment transport processes.

• The quality of groundwater concerning its possible use.

3.2.4.6 Air Quality

Baseline conditions include:

• Meteorological data particularly prevailing wind direction and strength for each Season.

• Existing air quality, particularly dust loading, and existing sources of air emissions in the area. Existing air quality cannot be determined with any precision without sampling over an extended period. This is rarely practical and a descriptive approach based on prevailing weather conditions and identification of the main local emission sources affecting air quality, e.g. road traffic, major heavy industries with stacks, is often a better approach. The most appropriate approach to atmospheric impacts is generally to prevent them at source.

3.2.4.7 Noise Levels

Noise levels are relatively easy to establish and this is best undertaken at the nearest sensitive receptor location, e.g. residential areas or schools. If noise-measuring equipment is available noise can be monitored over a number of 15minute periods during a typical working day. Ideally, 4 or 5 periods should be monitored at each sensitive receptor location. This will establish the background noise levels and the extent to which these are exceeded during the period monitored. Where noise monitoring equipment is not available a descriptive approach identifying the main sources of existing noise and the extent to which these cause nuisance may be adequate.

3.2.4.8 Antiquities and Other Sites of Historical and Cultural Importance

Existing sites may be directly disturbed by road construction. Furthermore the accumulation of ground water, the emission due to traffic may have adverse effects on the setting of antiquities. The baseline will need to:

- Identify any items of historical or cultural significance (both above and below water) on or in the area surrounding the site.
- Indicate the vulnerability of these to impacts from road construction.
- Describe the use made of these sites, e.g. site frequented by tourists.
- The surface level of the historical sites relative to that of the project enabling the study of the impact of ground water.

3.2.4.9 Social and Economic Context

Road construction will generally impact on the local economy and may result in social change in areas according to their economic base. The baseline includes:

- A general description of the economic situation. This includes: Employment levels, wage levels, existing industries in the local area, and other proposed developments.
- The general social context including educational levels in the local population, participation in formal economic activities - particularly by women- and local cultural values.

3.2.4.10 Existing Transport Infrastructure and Traffic Flows

Traffic is almost always an issue for road construction projects. The baseline includes:

• Existing transport infrastructure including roads, railways, ports and canals.

• Existing traffic flows on that infrastructure and anticipated changes which would take place even if the construction did not proceed.

3.2.4.11 Existing Utilities Infrastructure and Usage:

Road construction will usually place demands on existing utility infrastructure notably water supply, sewerage and waste water treatment, and electricity. The baseline includes:

• Existing utilities infrastructure.

• Existing demands on utilities infrastructure.

3.2.5 Prediction of impacts and evaluation of significant environmental effects

3.2.5.1 Basic Methodology

This chapter should include a discussion of impacts both:

• During construction of any built or engineered environment,

• In operation

Examples of potential impacts of road construction and their significant effects include:

• Land use leading to the loss of ecological habitats with negative effects on flora and fauna populations

• Construction works which directly damage the existing landform and add to the impacts by land take

• Dust generated during construction or operation which may affect human, plant and animal growth

• Gaseous emissions to air either from vehicles or industrial areas – if exists-resulting in negative effects on the health of the local population

• Disposal of solid waste, when, inefficient leads to its accumulation affecting therefore the comfort and general health conditions.

• The surface and underground water pollution resulting from the discharge of effluent and untreated water.

• Noise, resulting from traffic or power plants, which may disturb people in their homes, schools or other place of sensitive uses.

• The need for private and public transportation, its effect on traffic as well as road accidents and traffic noise.

• Power supply and its effect on the surrounding milieu.

• Economic impacts during construction, which may create opportunities and activate local business sector.

• Economic impacts during operation and which may create long term benefits, such as the creation of job and opportunities and the activation of the business sector which have positive effects on the economic welfare of the local population.

• The provision of proper services and infrastructure with wider benefits to those living and working in the local area.

• Impacts on existing utility infrastructure and possible benefits as a result of an improved infrastructure.

There is a need to distinguish between impacts, which are:

• Positive or negative

• Reversible or irreversible

• Temporary or permanent

• Short term or long term

• Direct or indirect

In assessing environmental impacts and the significance of their effects:

• Which elements affect and which are affected

• How the elements are affected.

• These effects must be evaluated against a set of consistent assessment criteria. Criteria for evaluating the significance of impacts and their effects should be set in advance. They should be based on local standards wherever possible. Where these are not available, acceptable international standards should be used (e.g. WHO, USEPA, etc. guidelines). In all cases of choice of the appropriate standard must be robust, defensible and relevant to the local situation. If no suitable existing standard is available, then the criteria developed and used must be clearly explained in the EIA. The use of matrices can be very helpful in co-ordination and summarizing information for this section of the EIA report. In this part of the report impacts should be considered before or without mitigation, except where the mitigation concerned is an integral part of the design and operation of the project.

3.2.5.2 Land take

Road construction always involves the development of land. Landtake may result in the partial or complete loss of:

• Ecological habitats with negative effects on flora and fauna populations

• Attractive landscape with negative effects on landscape character and the views enjoyed by people

• Antiquities and sites of historical and cultural interest

• Land in other uses, e.g. agricultural land or community facilities, with resulting impacts on people livelihoods or social life.

Note that even where land is taken for road construction careful design can reduce impacts by retaining residual areas in their natural or existing state. Landtake is normally evaluated on the basis of the area of land lost and the suitability of that land for other uses, e.g. agriculture, recreation or others.

3.2.5.3 Construction Works

The impacts of construction works are generally identified on the basis of damage to existing environmental resources and the value of those resources.

These impacts are notified in two stages:

First, during the construction some impacts may occur such as:

- Direct damage to the existing landscape in addition to landfill and construction
- Construction waste accumulated at the site.
- Ground water resulting from the drilling actions and the methods of disposal
- Dust resulting from operating the construction work.
- Noise resulting from operating the construction equipment.
- Traffic pressure on roads due to the transportation of materials and equipment.
- The effects on the neighboring structure – if existing - due to vibrations.

Second during the operation: The main features of the site are affected as follows:

- The geological and physical features of land by inducing of new structures.
- Visual effects resulting from the change of the natural view from the surrounding areas.
- Surface water features – if existing.
- Existing vegetation.
- Traffic pressure on roads.

• Sewage disposal and its impact on the groundwater.

3.2.5.4 Economic Impacts during Construction

All new road projects will involve some expenditure on construction. Where local contractors undertake this work there is an obvious benefit to the local economy, this is likely to be strengthened where the contractor makes purchases from other local businesses. In some cases contractors from outside the local area may win the construction contracts; while the benefit may be less, employment of local labor and purchases from local businesses will still benefit the local economy. Estimates of benefits to the local economy can be based on an estimate of the number of local people employed during construction, the average duration of employment and the average rate of pay. Benefits to local businesses can be based on an estimate of the proportion of construction spending which is spent in the local economy.

3.2.5.5 Economic Impacts during Operation

In operation road construction generally results in:

• Benefits improvement of the economic activities in the area due to the migration of new population to the area.

• Created job opportunities their types and their effects on local activities.

Estimating the negative impacts on existing business is more difficult. The presence of a number of similar businesses is often beneficial for a local area because it gains a reputation concerning this activity.

3.2.5.6 Dust

Dust may be generated during road construction.

During construction dust most often arises from vehicle movements on unsealed roads and from earthmoving operation using construction plant such as excavators. Dust can also occur as a result of winds or storms or neighboring industries such as cement or marble.

Existing dust levels in Egypt are strongly affected by weather and particularly the strength of winds from the desert areas to the east and west of the Nile Valley.

The accurate prediction of dust impact is very difficult given the changing natural dust levels; an appropriate way of dealing with this subject is:

• To identify the main sources of dust attributable to the road construction and the scale on which dust may arise;

• To identify the people or resources that may be affected by this dust and the level of any nuisance caused; and

• To consider what measures should be taken to reduce dust from sources associated with the road construction to an acceptable level.

This approach is effectively based on reducing any emissions to the level, which will not cause nuisance, rather than attempting to predict impacts with precision.

3.2.5.7 Gaseous emissions to air

In road construction gaseous emissions are mainly generated from asphalt plants, construction vehicles, asphalt placing and any other emissions from neighboring industrial areas.

Existing air quality in Egypt is strongly affected by weather and particularly the strength of the winds from the desert areas to the east and west of the Nile Valley. The accurate prediction of air quality impacts is very difficult given the changing natural dust levels; an appropriate way of dealing with this subject is:

• To identify the main sources of gaseous emission attributable to the road construction, the scale on which this may arise; the likely presence of harmful gases and the worst case concentrations likely to arise in the atmosphere given the dispersion characteristics of the site;

• To identify the people or resources that may be affected by these emissions and the level of any nuisance caused.

As with dust, this approach is effectively based on reducing any emissions to a level, which will not cause nuisance, rather than attempting to predict impacts with precision.

3.2.5.8 Discharge to Water

Emission to surface water and groundwater may be generated both during construction and in the operation. Waterborne effluent may reduce water quality with impacts on:

• Human health particularly where water is used for irrigation or public water supply.

• Freshwater and marine flora and fauna.

Water quality impacts are easier to predict than air quality impacts. Existing water quality can be measured using a number of criteria such as the biological oxygen demand (BOD) level. Predictions of changes in water quality can be based on:

• Anticipated effluent discharges including volume, the concentration of suspended solids, concentration of harmful substances, etc…

• Baseline data for the recipient water resources both surface and underground.

The criteria for judging the significance of impacts will include the people or resources that may be affected by changes in water quality. An alternative approach can be taken, based on improving effluent quality and reducing effluent volumes to levels, which will not result in a significant impact on the water resources concerned.

3.2.5.9 Waste Disposal

Disposal of waste can potentially have adverse effects on amenity, water quality, on crops and peoples' health. Issues to consider include:

• The existing condition of any water body or groundwater that may be changed as a result of waste disposal both during construction and in operation.

• Potential liquid and solid wastes to consider include:

-Run-off from consolidated areas such as fuel storage facilities, roads and parking areas.

-Waste disposal (litter or solid waste),

-Littering and garbage disposal.

3.2.5.10 Noise

The potential sources of noise associated with road construction need to be identified; these are likely to include:

• Construction noise (e.g. blasting, brushing, compressors, etc.);

• Operation noise (e.g. vehicle movements).

An assessment will need to be made of:

• Baseline conditions (including relevant meteorological and topographical factors)

• Proposed working hours during construction and operation

• Where these impacts will be most important (e.g. residential or sensitive natural areas).

3.2.5.11 Traffic

A traffic study may be required where vehicle movements, on street parking, boat navigation, train movements, etc., may significantly affect the community. Issues to consider include:

• Assessing the impact of traffic generated during construction and operation on the local and regional transport network; issues to consider include:

-Vehicle, train or boat size and types,

-Frequency of movements at various times of day and year (including the need for restrictions at night or peak periods),

-Safety issues.

• Estimating the average and peak parking demand including the adequacy of on-site facilities during construction and operation.

3.2.5.12 Services and Infrastructure

The provision of proper services and infrastructure for road construction may have wider benefits for those living and working in the local area. However the reverse can be true where road construction takes place without adequate investment in services and infrastructure may become overloaded and the local community may be adversely affected. In general the impact on services and infrastructure is likely to be fairly neutral; a significant benefit is only likely to occur where the road construction enables a major improvement to local infrastructure.

These impacts are generally dealt with by:

• Describing the anticipated changes in services and infrastructure provision,

• Setting out how those changes may benefit or harm the local community.

3.2.5.13 Risk Assessment

Considering road construction, hazards can be assessed by:

• Floods pathways which have to be identified and treated either by changing of direction or simply avoidance.

• Windy and Dusty storms.

• In cases of existing neighboring industrial areas, it is essential to identify the possible hazards affecting the workers and the resources and how to prevent them.

3.2.6 Mitigation

3.2.6.1 Mitigation Strategy

This section considers the mitigation strategy, including the consideration of alternative options, and the extent to which this will avoid or reduce significant effect. The evaluation of the strategy will take into account its:

• Sustainability

• Integration

• Feasibility

• Compliance with statutory obligations under other licenses or approvals.

The mitigation strategy should outline the environmental management principles to be followed in the planning, design, establishment and operation of the proposed road. It should include specific location, layout, design or technology features, and an outline of ongoing management and monitoring plans.

3.2.6.2 Specific Mitigation Measures

These include proposed mitigation and management measures to control impacts on:

• Land quality-measures include:

- Stabilization works for digging, embankments and open canals

- Erosion and sedimentation control structures.

- Landscaping and re-vegetation proposals.

- Control and disposal of solid waste.

• Water quality – measures include:

- Treatment of liquid effluent and re-use in irrigation.

- Sewage system with no impacts on ground water.

• Air quality – measures include:

- Plant barriers against gaseous emissions.

- Control in fuel inputs in case of existing industry.

• Noise, where measures include:

- Segregation of heavy traffic.

- Sound attenuation measures such as walls and banks.

• Habitats, Flora and Fauna measures include:

- Compensatory planting or restocking of indigenous species.

- Provision of new appropriate habitat.

- Opportunities for colonization.

• Historical and Cultural Features – measures proposed should mitigate impacts and conserve antiquities and areas of historical or heritage significance during all stages of the road construction. All measures must be compatible with the provisions of all relevant acts and laws.

3.2.6.3 Environmental Management Plan

An environmental management plan (EMP) is a document designed to ensure that the commitments in the EIA and subsequent conditions of any approval or license are fully implemented. The EMP should demonstrate that sound environmental practices will be followed during the establishment, operation, rehabilitation and after use of the development. It should cover the following:

• Management of construction impacts (e.g. landscape management plants).

• Management of operational impacts (e.g. buildings, infrastructure, transport and parking management maintenance and site security plans, emergency and contingency plans).

• Strategies and action plans to feed information from monitoring into management practices.

• Public awareness and training programs for operation staff.

• Indicators of compliance with licensing and approval requirements.

An EMP should include a Monitoring Plan that should be carefully designed and related to the predictions made in the EIA and the key environmental indicators. The EMP should outline the need for monitoring its duration and reporting procedures. Parameters, which may be relevant, include:

• Performance indicators in relation to critical operational issues including:

-Physical characteristics of the site

-Water quality whether fresh or marine

-Shoreline morphology and sediment budget

-Soils and sediments

-Noise and air quality

-Public health indicators

-Land surface and hydrology

-Flora and fauna

• Waste management performance indicators in relation to recycling and reuse;

• Monitoring of received complaints.

Monitoring procedures should cover the following:

• The key information that will be monitored, its criteria and the reasons for monitoring

• The monitoring locations, intervals and duration

• Actions to be undertaken if the monitoring indicates a noncompliance or abnormality

• Internal reporting and links to management practices and action plans

• Reporting to relevant authorities and, if appropriate, to the consent authority or the community.

3.2.7 Conclusions

This should summarize the prediction and evaluation of impacts, proposed mitigation and alternative processes, and residual effects after mitigation. It will emphasis:

• The more important impacts

• Who or what these will affect

• How significant the effect will be

• Whether mitigation is possible

• The likely success of mitigation measures adopted or recommended alleviating those impacts.

This information can be presented either as text, or as summary tables if desired.

After mitigation measures have been assessed, residual and/or cumulative effects may remain. It is useful to set these out in a table in which the level of significance of each effect is given.

3.2.8 References

A list of all references should be attached to the report.

CHAPTER (4)

WARM MIX ASPHALT

4.1 Introduction

Environmental awareness has been increasing rapidly over the past years. Extensive measures like air pollution reduction targets set by countries with the Kyoto protocol have encouraged efforts to reduce pollution. Warm Mix Asphalt (WMA), a new paving technology that originated in Europe, is one of those efforts. It allows a reduction in the temperatures at which asphalt mixes are produced and placed. Its benefits are reduction in energy consumption and reduced emissions from burning fuels, fumes and odors generated at the production plant and the paving site. This chapter investigates the potential use of warm mix asphalt and specifically how countries like Egypt, can benefit from this technology.

The primary objective of this research is to find out whether warm mix asphalt is a viable option for the paving industry in Egypt. In the process of answering that question, warm mix asphalt's advantages and disadvantages compared to traditional hot mix asphalt (HMA) are explored. The conclusions of this paper are primarily drawn from a literature review that was conducted on warm mix asphalt to evaluate what is known about its performance. Conditions and paving practices in Egypt are also explored to give an understanding of common paving issues in Egypt. Hopefully this chapter can assist potential warm mix asphalt users to understand the basic differences in the available methods and how they are differently suitable for the different situations that can come up.

4.2 Background

4.2.1 History of Warm Mix Asphalt

The discussion of lowering the heat used to produce asphalt mixes is not new. The idea of saving energy and lowering emissions in the asphalt industry has been discussed for decades.

(Muthen, K. M., 1998) [16]; In 1956, Dr. Ladis H. Csanyi, a professor at Iowa State University, realized the potential of foamed bitumen for use as a soil binder. Since then, foamed asphalt technology, which allows lower mixing temperatures, has been used successfully in many countries. The original process consisted of injecting steam into hot bitumen.

(Muthen, K. M., 1998) [16]; In 1968, Mobil Oil Australia, which had acquired the patent rights for Csanyi's invention, modified the original process by adding cold water rather than steam into the hot bitumen. The bitumen foaming process then became more practical.

(Maccarone, S. Cold, 1994) [17]; In 1994, Maccarone examined developments in cold mixed asphalt based on the use of foamed bitumen and very high binder content emulsions. He wrote that around the world the use of cold mixes for use on road works are gaining greater acceptance. Such systems are energy efficient and environmentally friendly. Cold mixes do not emit hydrocarbons and use less fuel in manufacturing.

Despite many good properties, cold mixes have not affected hot mix asphalt's position as the primary road surfacing material because they have not achieved the same overall long-term performance as hot mixes.

(Jenkins, K.J., J.L.A. de Groot, M.F.C. van de Ven & A.A.A. Molenaar,1999) [18]; In 1999, Jenkins et al. introduced a new process, half-warm foamed bitumen treatment. Their paper explores the considerations and possible benefits of heating a wide variety of aggregates to temperatures above ambient but below 100°C before the application of foamed bitumen.

(Australian Asphalt Pavement Association (AAPA), 2000) [19]; A warm asphalt mix process (WAM) has been developed in Europe and was reported by Harrison and Christodulaki at the First International Conference of Asphalt Pavements in Sydney, 2000. A more complete report was given by Koenders et al. at the Eurobitume congress in 2000. Their paper describes an innovative warm mixture process that was tested in the laboratory and evaluated in large-scale field trials (in Norway, the UK and the Netherlands) with particular reference to the production and laying of dense graded wearing courses. Their work resulted in the development of WAM Foam, Warm Asphalt Mix with foamed bitumen.

(Barthel, W., J.P. Marchand, M. Von Devivere, 2005) [20]; At the Eurobitume congress in 2004, Barthel et al. introduced the use of a synthetic zeolite additive to produce warm mix asphalt. The zeolite creates a foaming effect that results in a higher workability of the mix. Warm mixes have received some attention in Europe and Australia since around 2000. The pavement industry in North America started to give warm mixes some interest a few years later and in June 2005 the **National Center for Asphalt Technology (NCAT) [21]** published two reports about the use of Sasobit, a synthetic wax, and Aspha-min, a synthetic zeolite, in warm mix asphalt.

4.2.2 Potential Warm Mix Asphalt Benefits

In the following sections, the benefits that are usually publicized in literature as WMA's main benefits and issues are briefly discussed. These are the emissions reductions, reduced energy consumption and decreased viscosity.

4.2.2.1 Energy Consumption

(Cervarich, M. B., 2003) [22]; The reduction in energy consumption is the most obvious benefit of WMA and is generally marketed and discussed in literature as one of the two main benefits of WMA. Studies have shown that energy consumption reductions of about 30% can be achieved by lowering the production temperatures at the asphalt plant. The reduction in energy consumption reduces the cost of the asphalt production but there can also be an added cost involved in using the WMA process, i.e. for additives and/or equipment modification. How much that additional cost is depends on the WMA method used. Another side benefit of the reduction in production temperatures sometimes mentioned is less wear and tear of the asphalt plant.

4.2.2.2 Emissions

The other main benefit of WMA is the reduced emissions because of the reduced production temperatures. According to literature, WMA production significantly reduces emissions, fumes and odor compared to a regular HMA production. Emissions from asphalt production and placement can, at certain elevated levels, be harmful to health. In 2000, the **National Institute for Occupational Safety and Health (NIOSH) [23]**, in USA published a hazard review on Health Effects of Occupational Exposure to Asphalt.

In this review, NIOSH evaluated the potential health effects of occupational exposure to asphalt. In 1977, NIOSH determined the principle adverse health effects to be irritation of membranes of the conjunctivae and the respiratory tract. NIOSH also acknowledged that evidence from animal studies indicated that asphalt left on the skin for long periods of time could result in local carcinomas. On the basis of this evidence, NIOSH recommended the following exposure limit (REL): “NIOSH recommends minimizing possible acute or chronic health effects from exposure to asphalt, asphalt fumes and vapors, and asphalt-based paints by adhering to the current NIOSH REL of 5 mg/m^3 [measured as total particulates] during any 15 min period and by implementing the following practices:

- Prevent dermal exposure.
- Keep the application temperature of heated asphalt as low as possible.
- Use engineering controls and good work practices at all work sites to minimize worker exposure to asphalt fumes and asphalt-based paint aerosols.
- Use appropriate respiratory protection.”

In 1988, NIOSH recommended that asphalt fumes also be considered a potential occupational carcinogen. Since then, additional data have become available from studies of animals and humans exposed to asphalt. A direct quote from the main findings of the hazard review from 2000 follows: “The findings of this hazard review continue to support the assessment of the 1977 NIOSH criteria document on asphalt fumes, which associated exposure to asphalt fumes from roofing, paving, and other uses of asphalt with irritation of the eyes, nose, and throat. Furthermore, in studies conducted since then […] these symptoms have also been noted among workers exposed to asphalt fumes at geometric mean concentrations generally below 1 mg/m^3 total particulates and 0.3 mg/m^3 benzene-soluble or carbon disulfide-soluble particulates, calculated as a full-shift TWA [time-weighted average]. Recent studies also report evidence of acute lower respiratory tract symptoms among workers exposed to asphalt fumes.”

Conclusions regarding potential carcinogenicity of paving asphalt fumes were: “Data regarding the potential carcinogenicity of paving asphalt fumes in humans are limited. […] Although genotoxicity assays using laboratory generated and field-generated fumes have been conducted, only the laboratory-generated fumes were genotoxic. Therefore, NIOSH concludes that the collective data currently available from studies on paving asphalt provide insufficient evidence for an association between lung cancer and exposure to asphalt fumes during paving. The available data, however, do not preclude a carcinogenic risk from asphalt fumes generated during paving operations." A discussion about the possible risk of cancer at other sites than lungs mentions that a few studies have reported an association between cancers at sites other than lungs and occupations having the potential for exposures to asphalt, but concludes by saying:

"Because of lack of consistency among studies and issues of the confounding effects of other substances, the evidence for an association between exposure to asphalt and non-respiratory cancers is weak and requires further confirmation [...]". It is also mentioned in the hazard review that positive mutagenic responses obtained from animal studies using laboratory-generated paving asphalt fumes are a cause for concern and support the need for further research.

The NIOSH hazard review also reports a study conducted in 1993 where fumes were collected from a storage tank at a hot mix plant at a temperature of 149°C (300°F) and from a laboratory generation at temperatures of 149°C and 316°C (300°F and 601°F). The fumes were analyzed for selected PACs (Polycyclic Aromatic Compounds). The concentration of four-ring Polycyclic Aromatic Hydrocarbons (PAHs) was highest in fumes generated in the laboratory at the highest temperature. Several of the four-ring PACs are carcinogenic. These results and results from other similar studies indicate that asphalt fumes generated at high temperatures are probably more likely to generate carcinogenic PAHs than fumes generated at lower temperatures. Although the two temperatures that are compared in this study are higher than the temperatures used for WMA and HMA productions, this might indicate an additional advantage of the reduced emissions; i.e. it is possible that the fumes themselves become less hazardous with the decreased production temperature. This has not reportedly been examined for WMA.

4.2.2.3 Viscosity

The functionality of WMA technologies is based on reducing the viscosity of the asphalt binder at a certain temperature range. The reduced viscosity allows the aggregate to be fully coated at a lower temperature than what is traditionally required in HMA production. Because of the reduced viscosity, the WMA processes can work as a compaction aid and some benefits related to this are often mentioned in relation to WMA discussions, such as easier handling, extended paving season, longer haul distances and a reduction in necessary roller compaction.

4.3 Warm Mix Asphalt Technologies

(Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, J. Johansen, 2002) [24]; several new processes and products have been developed to reduce the mixing and compaction temperatures of HMA without compromising the quality of the mixture or the resulting pavement. This section discusses the warm mix asphalt concept and a few of the different processes that have been developed. Traditional HMA is usually produced at temperatures between 140 and 180°C (284 and 356°F) and compacted at about 80 to 160°C (175 to 320°F). The temperature of the asphalt mix has a direct effect on the viscosity of the asphalt cement binder and thus compaction. As hot mix asphalt temperature decreases, its asphalt cement binder becomes more viscous and resistant to deformation, which results in a smaller reduction in air voids for a given compaction effort. Eventually, the asphalt binder becomes stiff enough to prevent any further reduction in air voids regardless of the applied compaction effort. The temperature, at which this occurs, the cessation temperature, is considered to be about 79°C (175°F) for dense graded HMA mixes. These high temperatures for hot mix asphalt are required to achieve the right balance between:

- Low viscosity of the bitumen to obtain full aggregate coating;
- Good workability during laying and compaction;
- Rapid increase in mechanical strength, and;
- Durability during traffic exposure.

The goal of the WMA process is to reduce the high temperatures at which traditional asphalt mixes are produced and placed without adversely affecting these properties. Its benefits, as currently marketed and addressed in literature, are reduction in the energy consumption that is required to heat traditional HMA to temperatures above 150°C (300°F) at the production plant, and reduced emissions from burning fuels, fumes, and odors generated at the plant and the paving site. There are primarily three technologies that have been observed to produce WMA in Europe.

- WAM Foam (Warm Asphalt Mixes with Foam). A two component binder system that introduces a soft and hard foamed binder at different stages during plant production;
- Aspha-min zeolite. The addition of a synthetic zeolite during mixing at the plant to create a foaming effect in the binder;

- Sasobit wax. The addition of a Fischer-Tropsch paraffin wax during mixing at the plant to decrease the viscosity of the mix;
- Other methods mentioned in literature include for example Asphaltan B, a low molecular weight esterified wax, and Evotherm, a process based on a chemistry package that includes various additives.

All these technologies appear to allow the production of WMA by reducing the viscosity of the asphalt binder at a given temperature. The three methods that have been most prominent in literature and research, WAM Foam, Aspha-min zeolite and Sasobit wax, are discussed one by one in the following three sections. The other methods are not as prominent.

The amount of research and type of reports that are available for the three methods varies somewhat. For the WAM Foam, the process itself is patented and it requires considerable equipment modifications. That may affect the amount of independent research conducted because no reports of independent studies were found or were pointed out by the developers. Therefore, all the information about WAM Foam is based on research conducted by the developers themselves. Although there cannot be seen any specific indications of biased results or discussions in those reports, this needs to be kept in mind when evaluating the results and comparing the three WMA methods.

For both the Aspha-min zeolite and Sasobit wax methods the situation is different. More information from independent studies is available which might be because for these methods the process itself is not patented and equipment modifications are not necessary, although both methods are based on the use of patented additives. For example, the National Center for Asphalt Technology (NCAT) in the USA conducted laboratory studies on both the Aspha-min zeolite and Sasobit wax methods and reported them in 2005. Those two reports, along with a Sasobit wax performance evaluation done for the Maryland State Highway Administration, give detailed and unbiased information about various properties of the two methods.

4.3.1 WAM Foam

(Olof Kristjansdottir, 2006) [25]; WAM Foam (Warm Asphalt Mixes with Foam) is a patented process developed jointly by Shell Global Solutions and Kolo Veidekke in Norway. In the WAM Foam production process, two different bitumen grades, soft bitumen and hard bitumen, are combined with the mineral aggregate. This process makes it possible to produce the asphalt mixture at temperatures between 100 and 120°C (212 and 248°F) and compact it at 80 to 110°C (176 to 194°F). A WAM Foam modified asphalt plant first mixes the soft bitumen with the mineral aggregate in order to achieve pre-coating and then the foamed bitumen, i.e. the hard grade, is introduced in the second step. The viscosity of the soft bitumen is chosen such that at temperatures below 100°C (212°F) it can fully coat the mineral aggregates. The hard component is added in the form of a foam and must have a penetration at 25°C (77°F) between 1 and 10 mm so standard penetration grades such as 10/20, 20/30, 35/50, 40/60 and 70/100 are suitable hard components. The blend ratio of the soft and hard binder components is determined by the required penetration level of the final binder. If required, an adhesion improver can be used in the binders to reduce water sensitivity. The rate of dissolution of the hard component into the soft component is important because it determines the workability of the mixture and the initial binder composition and properties. The thought behind this mixing procedure is to obtain a good distribution of the bitumen in the mixture and a good workability during paving.

Studies have used dense graded asphalt mixtures but in principle the WAM Foam process is equally applicable to other asphalt mixes such as open graded and gap graded mixtures.

Foamed bitumen is produced by injecting cold water at a level between 1 and 5% into hot bitumen. When it contacts the hot bitumen, the water turns into steam that produces a large volume of foam which slowly collapses with time and the bitumen resumes its original properties. The volume expansion ensures the bitumen is distributed evenly in the asphalt mixture and coats the aggregates.

At early stages in the development of WAM Foam, the hard bitumen added was in the form of a powder, an emulsion or foam. The use of hard bitumen powder gave good results in the laboratory but it was not considered practical to implement due to safety issues. Hard bitumen emulsions gave promising results but the use of hard bitumen foam showed good asphalt properties while not having the drawbacks that powder (safety issues) and emulsions (cost) have.

4.3.1.1 Environmental Benefits

On Shell's webpage, it is stated that carbon dioxide emissions are reduced to half in the WAM Foam process, and fumes emitted from the bitumen are halved for every ten degree reduction in temperature.

As a part of Shell and Kolo Veidekke's studies on WAM Foam, the emissions at an asphalt production plant were measured and compared to a hot mix production. Fume emissions, both organic and inorganic parts were determined as Total Particulate Matter (TPM). The organic part, known as Benzene Soluble Matter (BSM) was also determined.

Bitumen and their fumes contain traces of Polycyclic Aromatic Compounds (PAC) originating from the crude oil. Some of these compounds are irritants and other are suspected to have carcinogenic properties. Attention was also given to PAC's in the gas phase, called Semi-Volatiles (SV).

A more recent fuel consumption and gas/dust emissions measurement from an asphalt mix production (with 15% recycled asphalt used in the mixture) in a drum plant in Norway shows that the WAM Foam production resulted in a:

- 40% reduction in diesel consumption;
- 31% reduction in CO_2 emissions;
- 29% reduction in CO emissions and;
- 62% reduction in NO_x emissions,

compared to the hot mix (at identical production rates).

In the 2001 road experiment on FV82 in Norway mentioned previously, fuel consumption was measured and showed a 31.5% reduction.

4.3.1.2 WAM Foam Details

WAM Foam is a patented process that allows asphalt to be produced at temperatures between 100 and 120°C (212 and 248°F) and compacted at 80 to 110°C (176 to 230°F).

A WAM Foam modified asphalt plant first mixes soft bitumen with the mineral aggregate in order to achieve pre-coating and then foamed bitumen, a hard bitumen grade, is introduced in a second step. With this procedure, good distribution of the bitumen is obtained and good workability during paving. Dense graded mixes have mainly been used but open graded and gap graded mixes are equally applicable.

Asphalt plants need to be modified with a foaming device and a good air extraction system is needed to compensate for the pressure build-up in the mixer while foaming. The equipment modifications for this process are therefore relatively extensive compared to the methods described in the next two sections. In a batch asphalt mixing plant the foamed bitumen is produced by injecting water into the bitumen pipe in a special nozzle system, just before the bitumen enters the mixer and an airgun is used to blow the foaming chamber and pipes clean after each foam injection. The production capacity of the plant can be maintained for all types of mixtures.

Laboratory studies and field trials that have been conducted and reported by the developers seem to show very similar results for WAM Foam productions and regular HMA production for typically monitored properties such as percent air voids, rut depths, smoothness, surface texture, skid resistance, stiffness modulus and fatigue. The first field trial was carried out in May 1999 in Norway, where many of the following trials have been conducted. Therefore, the performances of the pavements, some of which have been placed in cold weather, have been monitored for a few years. Energy consumption measurements indicate a 30 to 40% reduction and emissions measurements indicate a 30 to 90% reduction, the most reductions being for NOx, BSM (Benzene Soluble Matter) and PAC (Polycyclic Aromatic Compounds) emissions.

4.3.2 ASPHA-MIN ZEOLITE

(Olof Kristjansdottir, 2006) [25]; Aspha-min zeolite is a product of Eurovia GmbH, Germany. It is a manufactured natrium-aluminum silicate which has been hydro-thermally crystallized. It contains approximately 21% water by weight and is released in the temperature range of 85

180°C (185-360°F). Eurovia recommends adding Aspha-min to an asphalt mixture at a rate of 0.3% by mass of the mix, which enables approximately a 30°C (54°F) reduction in production and placement temperatures.

When Aspha-min is added to the mix at the same time as the binder, water is released which creates a volume expansion of the binder that results in an asphalt foam and allows increased workability and aggregate coating at lower temperatures.

Eurovia states that all known bitumen, polymer modified bitumen and recycled asphalt (RAP) can be used in this process. Also, all normal mineral aggregates and fillers can be used and therefore no modifications to a normal mix design are needed. The addition into the mixing process is done through special devices with a similar procedure as adding certain types of fibers and does not prolong the mixing process.

Figure 4.1: Feeder (right) and an existing fiber addition line for Aspha-Min zeolite.

4.3.2.1 Environmental Benefits

Measurements conducted and reported by Eurovia GmbH showed a 30% reduction in energy consumption because of a 30-35°C (86-95°F) reduction in mix temperature. Measurements also indicated a 75% reduction in fume emissions resulting from a 26°C (47°F) reduction in production temperature. Measurements at the application site indicate over 90% reduction in fume emissions when the mix temperature was reduced from 175°C (347°F) to 140°C (285°F) and in all cases when zeolite has been added and temperatures been reduced, odor has significantly reduced and crew members have confirmed improved working conditions.

4.3.2.2 Aspha-min Zeolite Details

Aspha-min zeolite is a crystalline hydrated aluminum silicate and contains approximately 21% water by weight. It is recommended to be added to an asphalt mixture at a rate of 0.3% by mass of the mix, which enables approximately a 30°C (54°F) reduction in production and laying temperatures. When it is added to the mix at the same time as the binder, water is released which creates a volume expansion of the binder that results in an asphalt foam and allows increased workability and aggregate coating at lower temperatures.

The addition into the mixing process is done through special devices with a similar procedure as adding certain types of fibers and does not prolong the mixing process. Therefore, if a plant is equipped with a feeder to add fibers to a mix, it can be used but if specially designed feeders are preferred they are available. Either way, equipment modifications are at least not as extensive as for the WAM Foam method.

Laboratory studies and field trials that have been conducted and reported by the developers seem to give very similar results for the mixtures with zeolite and the regular hot mixtures. Exceptions were that the zeolite additive lowered the measured air voids in the gyratory compactor and improved compaction over the control mixture but lowered the tensile strength ratio value although resulting in an acceptable value. An anti-stripping agent may be desirable to counteract moisture damage and rutting potential with decreasing temperatures.

During paving, crew members have observed that the Aspha-min zeolite warm mix is more workable than the control mix and that odors are significantly reduced. Energy consumption measurements indicate a 30% reduction and emissions measurements indicate a 75% to 90% reduction.

4.3.3 SASOBIT WAX

(Olof Kristjansdottir, 2006) [25]; Sasobit wax is a product of Sasol Wax International and has been marketed in Europe and Asia since 1997. Sasobit is a mixture of long chain hydrocarbons produced from coal gasification using the Fischer-Tropsch synthesis and is also known as a FT paraffin wax.

Sasol Wax states that it does not contain ash-forming materials (metals) and contains no hetero-atoms such as chlorine, sulphur, nitrogen and oxygen. Therefore, it is stated that it has good oxidation and ageing stability and may be stored indefinitely.

Sasobit's melting point is at about 100°C (212°F) and it is completely soluble in bitumen at temperatures above 120°C (248°F), and it does not separate out on storage. It reduces viscosity at working temperatures which makes the asphalt easier to process, provides the option of reducing working and mixing temperatures and thereby reducing fume emissions, saving energy and reducing production cycle times. Sasol Wax states that Sasobit makes it possible to upgrade softer grades of asphalt to harder grades while at the same time working to overcome deformation and bleeding at high performance temperatures. According to Sasol Wax the optimum addition of Sasobit has been found to be 3% by weight of the bitumen.

Sasobit's ability to lower the viscosity of the asphalt binder, during both the asphalt mixing process and placement, allows working temperatures to be decreased by 18-54°C (32-97°F). Below its melting point it forms a crystalline network structure that may add stability.

Sasobit can be combined with polymers which contribute to elasticity at low temperatures. This ability led to the development of Sasoflex which is a compound of Sasobit, polymer and a cross-linking agent (Sasolink). The Sasobit component (a plastomer) improves high temperature stiffness, while the polymer component (an elastomer) maintains the flexibility at lower temperatures.

Figure 4.2: Sasobit Wax Pellets.

Figure 4.3: Pellet packets and distribution box (blue box in the center).

Figure 4.4: Plant retrofitted for Sasobit wax addition.

Figure 4.5: Distribution box with part of augers showing.

Figure 4.6: Sasobit flowing from distribution box to feeder tube.

Figure 4.7: Surface course mix with Sasobit wax.

Figure 4.8: Surface course mix without Sasobit wax.

On its webpage, Sasol Wax counts 143 road projects and trials that have been constructed. Most of them are in Germany, but also in Czech Republic, Denmark, France, Hungary, Italy, Malaysia, Netherlands, New Zealand, Norway, UK, South Africa, Sweden and Switzerland.

4.3.3.1 Environmental Benefits

Sasol Wax states that a 20°C (68°F) reduction in production temperature results in a 20% reduction in energy consumption. No information was found about emissions measurements.

4.3.3.2 Sasobit Wax Details

Sasobit wax is a FT paraffin wax, a mixture of long chain hydrocarbons produced from coal gasification. Sasobit's ability to lower the viscosity of the asphalt binder at working temperatures makes the asphalt easier to process and provides the option of reducing working and mixing temperatures (by 18-54°C (32-97°F)) and thereby reducing fume emissions, saving energy and reducing production cycle times. Sasol Wax states that the optimum addition of Sasobit has been found to be 3% by weight of the bitumen. Below its melting point (100°C (212°F)) it forms a crystalline network structure that leads to added stability.

The wax can be added directly to the aggregate mix or premixed with the binder and it can be blended with the binder at the terminal and blown directly into the mixing chamber. This indicates that the equipment needs are similar as for the Aspha-min zeolite addition, i.e. not great, at least not as extensive as for the WAM Foam method.

Laboratory studies and field trials that have been conducted and reported by the developers seem to show more prominent differences between the control mix and the warm mix than those for WAM Foam and Aspha-min zeolite. Sasobit wax; lowered the measured air voids, reduced aging of the binder, lowered compaction temperature, improved compaction, lowered sensitivity in terms of rutting for the decreased production temperatures, indicated good performance in terms of moisture susceptibility and rutting and marginally increased high temperature stiffness. Sasobit as a compaction aid in high RAP content mixtures had no adverse effect on pavement performance.

4.4 Warm Mix Asphalt's Advantages

As can be seen the amount of testing that has been done for the methods varies; some have been tested extensively and even put in commercial use but others have not been reportedly tested as much. From the main research done so far and their findings, it seems safe to say that the quality of WMA is comparable to hot mix asphalt in most ways. However, it is only about 3 to 8 years (depending on method) since the earliest WMA field tests were started and therefore its long-term performance is still unproven. A pavement life can be 15 to 20 years or more and therefore there is still quite some time before WMA's effect on the pavement's service life will be fully known.

4.4.1 Emissions

From the measurements that have been conducted and reported, it is clear that fume emissions during WMA production are significantly lower than during hot mix asphalt production. For paving projects that are not in open air, for example in tunnels, workers exposure to emissions is multiplied and therefore the reduced emissions of WMA could be especially desirable for such situations as well. The importance of this WMA property will greatly depend on environmental awareness and regulations in each country and at each location within a country. Where emission regulations are getting stricter, which is the case for most countries participating in the Kyoto Protocol for example, the reduced emissions can become a very important benefit. Within each country, the reduced emissions are likely to especially encourage WMA usage in densely populated areas where day to day air quality is most important, and according to the considerations above, perhaps also in non-open air situations.

4.4.2 Energy Consumption

The reduced energy consumption is another benefit of WMA that is greatly emphasized in literature. Where the energy consumption for a WMA production was measured, it was 60-80% of that for HMA production, depending on how much the production temperature was lowered. The importance of this benefit depends on what sort of energy is used for the production process and how polluting and expensive it is. In most countries the energy cost is relatively high and therefore this benefit can be very important for the asphalt producer. Where sustainable and/or relatively inexpensive energy sources are used for asphalt production, this benefit is less important. It also needs to be taken into count that there is additional cost involved in using WMA, i.e. equipment modifications and patent fees for the WAM Foam method and cost of additives for the Aspha-min zeolite and Sasobit wax methods.

4.4.3 Mixture Viscosity

Other possible benefits that have not been as prominent in literature as the reduced emissions and energy consumption are various benefits related to the lower viscosity of the warm mixtures. Generally, improved workability can have various effects throughout the production and placement process. For example, the improved workability has the potential of allowing the following benefits.

1. Lower working temperatures, leading to:

- Energy savings during production.
- Reduced emissions.

- Decreased cooling rate due to smaller difference between ambient and compaction temperatures.

2. Increased temperature gap between mixing and compaction (by using regular

HMA mixing temperatures), allowing:

- Increased haul distances;
- Increased time available for compaction, thereby for example extended paving season into the colder months of the year.

3. Easier compaction (by using regular HMA mixing temperatures), which are beneficial:

- During extreme weather conditions;
- For stiff mixes and mixes with RAP;
- For reducing amount of necessary roller compaction.

4. A combination of items 1 and 2 or items 1 and 3, by reducing production temperatures by some amount and increasing the temperature gap or facilitating compaction by some amount.

The effect the three warm mix methods have on viscosity and the information available varies somewhat and this is therefore discussed more thoroughly for each method.

4.4.4 Summary of Advantages and Disadvantages

The importance of the reduced emissions greatly depends on environmental awareness and regulations in each country and at each location within a country. Where emission regulations are getting stricter, the reduced emissions can become a very important benefit. Within each country, the reduced emissions are likely to especially encourage WMA usage in densely populated areas where day to day air quality is most important and in non-open air paving. However, unless there are requirements from authorities or special incentives for asphalt producers to lower emissions, there is not a direct benefit for the asphalt producer and if there is not an economical benefit for the producer, the realistic importance of this WMA benefit in practice is limited.

Where the energy consumption for a WMA production was measured, it was 60- 80% of that for HMA production, depending on how much production temperature was lowered. The importance of this benefit depends on what sort of energy is used for the production process and how polluting and expensive it is. In most countries the energy cost is relatively high and therefore this benefit can be very important for the asphalt producer. It also needs to be taken into count that there is additional cost involved in using WMA, i.e. equipment modifications, patent fees or cost of additives.

Generally for all the WMA methods it appears that cessation temperatures stay relatively similar as for HMA but the viscosity of the mixture is decreased at lower temperatures, i.e. until the mix cools down to its cessation temperature. Therefore, the mix can be allowed to cool closer to its cessation temperature without compromising adequate compaction. The effect on the cessation temperature can be stated with more confidence about the Sasobit method than the others since the amount of available information about its effect on viscosity is much more thorough than for the other two methods.

The reduced viscosity of the WMA methods has some other possible advantages than to lower production temperatures, especially if regular HMA production temperatures are used, but then the benefits of reduced energy consumption and emissions are sacrificed. These are benefits related to increasing the temperature gap between mixing and compaction and using WMA as a compaction aid for various conditions. These other application possibilities achieved by using regular HMA production temperatures have been most prominently marketed (and are therefore best understood) for Sasobit wax and least for WAM Foam, whose marketing has solely focused on the environmental benefits.

According to available tests it seems that Sasobit and WAM Foam give satisfactory rutting resistance results but results for Aspha-min indicate that it does not negate the increased rutting susceptibility from the lower temperatures as well as the other two methods without the assistance of anti-stripping agents. Research indicates that Sasobit wax reduces the aging of the binder which further indicates that Sasobit may increase the pavement's durability.

None of the three methods were found to affect the resilient modulus of a mixture, i.e. the stiffness. Generally, the lower temperatures used for WMA can result in incomplete drying of the aggregates and the resulting trapped water in the coated aggregates may cause moisture damage. In the NCAT tests, both Aspha-min zeolite and Sasobit wax resulted in acceptable performance in terms of moisture susceptibility after anti-stripping agents were added and then rutting resistance was also increased. No reported research on the moisture susceptibility of WAM Foam was found but according to information from the developers, visual inspections of the road do not indicate that moisture susceptibility should be an issue.

These moisture susceptibility considerations are probably descriptive of possible difficulties that WMA producers may have to deal with. Finding the right balance between lowering the production temperatures, applying anti-stripping agents and achieving a sufficiently moisture resistant asphalt mixture might be a challenge when using WMA.

4.5 Economical Issues

In this section a cost comparison is made between traditional hot mix asphalt production in Egypt and the three WMA methods; WAM Foam, Aspha-min zeolite and Sasobit wax. The reduction in fuel usage to produce WMA can decrease the cost of transportation construction projects, but there is also additional cost involved in equipment modification and royalty (WAM Foam) and the use of additives (Aspha-min zeolite and Sasobit wax).

According to information from Kolo Veidekke there is nothing in the WAM Foam production process itself that will increase the cost compared to hot mix asphalt. It is possible to maintain the same plant capacity as for hot mix production and no additives are used in the process. There is however an initial investment cost in installing the foaming device which can vary greatly depending on how the asphalt plant is set up. For fairly new plants, control systems can normally be modified quite easily. To give an idea, Kolo Veidekke has had costs of about $30,000-40,000 for plant modifications.

There is also a royalty for using the method, first an upfront fee of $15,000 per company and then a fee of $5000 per plant per year. Also, after a free first year there is a royalty of 30 cents per ton produced (starting to run after the value is above $5000). Savings in fuel consumption for WAM Foam are in the drying process where the documented savings are about 30%.

According to information from the developers of Aspha-Min zeolite, the extra cost when applying Aspha-min zeolite in Europe is about 2 to 3 EUR per ton. It has to be shipped from Europe to Egypt, so shipping rates are a large part of the price calculation for the Egyptian market. We should add at least 1 EUR per Ton for shipping costs, 2.5 EUR +1 EUR = 3.5 EUR per Ton.

Sasol Wax gave a price range estimate of about 1.75 to 2.00 EUR per kg. The price in the USA was given as $1.72 per kg ($0.78 per pound). The recommended use of Sasobit wax is 3% by weight of total binder. For a mix with 5% binder by weight, the amount of Sasobit needed is about 1.5 kg for a ton of mix. This gives up approximately $1.72 X 1.5 kg = 2.5 $ per Ton of asphalt. We should add at least $2 per Ton for shipping costs, $2.5 + $2 = $4.5 Per Ton.

In the following calculations for cost of energy consumption, a 30% reduction in consumption will be used for all three WMA methods. For all three methods the energy consumption reduction is in the aggregate drying process and in Egypt diesel oil or fuel oil is generally used for the drying. According to information from asphalt plants in Egypt, approximately 8-12 liters of oil are used to produce one ton of mix. The price in Egypt for diesel oil for industrial companies is 1.1. LE per liter, for example, for one ton of HMA the average energy cost is: (10liters × 1.1 LE per liter) = 11 LE per Ton.

A typical total cost for a ton of hot mix asphalt in Egypt is 330 LE per Ton.

Assume a maximum of $10,000 for equipment installation costs for Asphamin and Sasobit.

The cost calculations for HMA and other WMA methods for May 2011 are shown in table (4.1)

Table 4.1 Cost Comparison between HMA and WMA methods

	HMA	WAM Foam	Asphamin	Sasobit
Additional Cost (LE/Ton)	-	$0.3 X 5.9 = 1.8	3.5 EUR X 8.4= 29.4	$4.5 X 5.9 = 26.6
Reduction 30% in Energy (Oil & Electricity) (LE/Ton)	-	0.3 X 11 = 3.3	3.3	3.3
Cost (LE/Ton)	330	328.5	356.1	353.3
Equipment Installation Cost (LE)	-	236,000	60,000	60,000
Example 50,000Ton/Year (Starting Year)	16,500,000	16,661,000	17,865,000	17,725,000
Difference in Cost for Starting Year	-	+1 %	+8.2 %	+7.4 %
Example 50,000Ton/Year (after Starting Year)	16,500,000	16,425,000	17,805,000	17,665,000
Difference in Cost after Starting Year	-	-0.45 %	+7.9 %	+7 %

CHAPTER (5)

FIELD RESEARCH & SURVEY

5.1 Field Research

Field research involves the collection of primary data or information. This is collected through site visits, surveys and questionnaires that are made out specifically for this purpose.

Field studies were conducted in the region of Cairo which is the largest urban area in the country. In this chapter two asphalt paving projects were studied which required the visit of the following:

- Two asphalt mixing plants
- Two road construction sites

The advantages of field research are that people are closer to real world conditions and that the business can design the research in the best way to discover the particular information required. Business can also be sure that the information gathered is up to date. Disadvantages of field research are that it takes time for the business to gather the information and that it is likely to be of a small sample size due to the high costs and time it takes.

Field research is expensive and involves more and experienced resources as compared to desk research which is not as accurate as field research. Being expensive it is required to perform the research in efficient manner and obtain or determine only specific information and answer only particular questions as irrelevant data will be of no use for further research processes.

5.2 The New Runway Project (Cairo International Airport)

Construction of a new runway for the Cairo International Airport including new taxiways, the total paved area of approximately 520,000 m^2 of heavy structure for aircraft and 550,000 m^2 shoulder pavement construction as shown in figures (5.1,5.2).

Owner: Cairo Airport Company

Contractor: Nasr General Contracting Company (Hassan Allam)

Project Consultant/ Engineer: Dar Al Handasah Consultants

Figure 5.1 the New Runway Project (North)

(Cairo International Airport)

Figure 5.2 the New Runway Project (South)

(Cairo International Airport)

5.2.1 The Asphalt Mixing Plant

5.2.1.1 General Information:

Type: SIM Automatic Plant.

Origin: Italy

Capacity: 170 Ton/Hour

Figure 5.3 the New Runway Project

(Cairo International Airport) Asphalt Plant