# CHAPTER 6

# REVIEW OF SOCIAL ECONOMIC AND ENVIRONMENTAL CONSEQUENCES OF THE USE OF SULPHUR-BITUMEN BINDER IN ROAD CONSTRUCTION

## 6.1 General

In this chapter, a review of social, economic and environmental consequences of the possible use of sulphur-bitumen binder in road construction in rural areas will be given. However, it should be realized that the social consequences will not arise by the use of such material per se, but rather as a consequence of better road surfaces when the material is used; the better and durable riding surface will enhance the generation of more social trips as well as cultural exchange among rural population. Thus the social consequences in terms of benefits will be discussed in conjunction with economic consequences.

## 6.2 Economic and social consequences arising from the use Sulphur-Bitumen binder in rural road construction

The economic and social consequences from the use of sulphur-bitumen binder will be discussed in two aspects. The first aspect will be the direct consequences of substituting sulphur for part of bituminous binder, i.e. the actual cost of the paving materials. The second aspect concerns the indirect role of SEA in road infrastructure which is one of the major factors that can either stimulate or inhibit economic growth.

### 6.2.1 Economic consequences of using partial sulphur substitution

The commercially available sulphur in Thailand at 1983 price is 6300 Baht per tonne or 274 US $ per tonne( 1 US $ = 23 Baht) while the price of bitumen is 7350 Baht per tonne (320 US $/tonne) in Songkhla, a southern province of Thailand. The price of bitumen is of course varied with locations. The controlled price in Bangkok is 5075.18 Baht per tonne.(34) From The above figues, it is clear that substitution of sulphur for part of conventional asphalt cement binder can result in some reduction of cost of the binder. It is obvious that the amount of saving depends on the proportion of sulphur being used. As an example, Table 32 compares the approximate cost of binders with varying percentage of asphalt cement being replaced by sulphur.

Table 32. Comparison of prices of binder

| Binder | Unit Price (Baht/Tonne) | | % Saving |
|---|---|---|---|
| | AC | SEA | |
| 0-100 (AC) | 7350 | - | |
| 20-80 | - | 7140 | 2.9 |
| 30-70 | - | 7035 | 4.3 |
| 40-60 | - | 6930 | 5.7 |
| 50-50 | - | 6825 | 7.1 |

Note: The comparison is for Songkhla which is in the southern rural areas of Thailand.

From the table it is seen that a maximum saving of 7.1 % in the cost of binder is possible. (Replacement of bitumen with upto 50 % by weight of sulphur is considered by many authorities as the maximum practical limit). For the present investigation, using 40-60 sulphur-bitumen binder, a saving in binder cost of 5.7 % is obtainable. As a rough estimate, Thailand produced 123.685 x $10^6$ litres or 123,685 tonnes of bitumen in 1982,[34] of these, an insignificant amount is exported; if it can be assumed that 90 % of the bitumen goes into road construction then 5.7 % would represent a saving of about 44 million Baht in binder cost. It should also be mentioned that futher saving could be achieved in asphaltic concrete pavement since a substantial reduction in design thickness is possible when SEA binder is used. Moreover, as SEA improves resistance of aggregates to water stripping; cost of pavement maintenance can be reduced. However, the supply of sulphur may pose restrictions for many developing countries if SEA process is used, although on a worldwide basis, the supply is guaranteed and has been forcasted to be in surplus in the next few years, in the case of Thailand, with her ambitious plans for industrial development and abundance supply of natural gas (1982 proven reserves is 12000 x $10^9$ cubic feet[34]), the availability of sulphur from these sources should go a long way in the production of SEA paving materials.

### 6.2.2 Economic and social consequences from improved transport infrastructure

The need to provide all weather road surfaces for low traffic volumes lead to the construction of low-volume rural road. The final decision, regarding surfacing materials, however, depends on economic consideration. Unpaved roads form a significant portion of transport infrastructure in many developing countries, for example in rural areas of Thailand these roads, which provide means of communication between villages as well as serving as market to farm roads, form 99 percent of the country's rural road network.(35) Among the many problems of unpaved roads is the high cost of maintenance to keep them operating at design levels. Sealing of these roads would reduce amount of maintenance work required as well as improve the quality of riding surface. The possibe use of cheaper SEA binder should therefore enhance more surface treatment work to be carried out.

Vehicle operating costs which include items such as fuel, oil, spare parts, and tyres and depreciation, vary greatly between paved and unpaved surfaces, for example a study carried out in Kenya(36) showed that for a vehicle speed of 80 km/hr a car with 1600 cc engine consumed about 22 % more fuel when operated on unpaved gravel road. The same study also found that amount of lubricating oil consumption doubled for passenger cars, light goods vehicles and buses when operated on unpaved roads. Road surface types also have a significant effect on vehicle life as indicated by a study in Thailand.(37) Table 33 shows this effect.

Table 33. Vehicle life (years) on different road types (after Louis Berger Int.)

| Vehicle type | road type | | |
|---|---|---|---|
| | Paved | Engineered Laterite | Earth |
| Mortorcycle | 6 | 5.2 | 4.1 |
| Car | 10 | 8.7 | 6.8 |
| pickup | 8 | 6.7 | 5.5 |
| Truck | 13 | 9.9 | 7.0 |
| Bus | 9 | 6.8 | 4.9 |

It is clear from the above paragraph that a substantial saving in economic costs can be had when road surfaces are paved. The lower cost of SEA binder means that more mileage of road can be payed.

As one of the functions of a road is for human and social liason; the improved road,no doubt will encourage more cultural, social, political and administrative exchange among the rural populations and between government officials and the people. The consequences are improvements in the well-being of the rural populations through better education and sanitary conditions, better protection by the public authorities etc.

## 6.3 Environmental consequences of the use of Sulphur-Bitumen binder in road construction

The environmental consequences from the use of sulphur-asphalt binder in pavement construction may be divided into two classes. The first results from accumulation of secondary sulphur from industrial activities such as power generation, coal liquification and gasification and de-souring of oil and natural gas. The extraction of sulphur from these sources can be made part of pollution control programmes.Commercial use of sulphur in road construction may be considered as a major dumping ground for sulphur; thus industry could be encouraged to extract sulphur from emissions and other industrial activities. As a result, the pollution of atmosphere from sulphur dust and other sulphur derivatives can be controlled. The second class of environmental consequences concerns air, soil, and run-off water in the vacinity of road construction, hot mix production and road in service. The environmental aspects of the second type will be reviewed in greater details. The parameters which are of concerned are hydrogen sulphide ($H_2S$), sulphur dioxide ($SO_2$) total hydrocarbons, particulates, elemental sulphur and sulphuric acid acid aeroso ($H_2SO_4$). The discussion that follows is based on the work of Taylor and Kennepohl[38] of Gulf Canada limited.

### 6.3.1 Hot mix production

There are two common types of mixing facilities for manufacturing hot mix, namely the pugmill and the rotary drum mixer. The former can be of either a continuous or a batch type pugmill.

For the pugmill type, measurements of emissions indicated that low, but significant levels of $H_2S$, $So_2$ and elemental sulphur were present. The levels increases with mix temperatures. For temperatures above 150°C, the amounts of $H_2S$ and $SO_2$ were detected to increase tremendously; reported figures were above 2 parts per million (ppm) and 5 ppm respectively while 0.10 ppm of $H_2S$ would cause eye irritation and 5 ppm of $SO_2$ would cause immediate irritation to nose and throat. Details on toxicity levels of both gases are given in Table 5 of chapter 6. As for the occupational environment, Taylor and Kennepohl found that all levels measured in the vicinity of the pugmills met the required occupational threshold limit values. However, eye and throat irritation were experienced by the loading operator who was continually exposed to the vapour from the open hopper.

With drum mixer emissions, it was found that levels of $H_2S$ were significant at temperature around 150°C and rose rapidly once the temperature got much above 160°C. The results suggests that SEA binder or hot mix should not be stored for long period (e.g. overnight) to minimize $H_2S$ build-up in vapour space in the storage facilites. The rapid build-up of $H_2S$ would lead to explosion or to exposure of personnel working in the vicinity of the storage facilities.

6.3.2 Road construction

Measurements at road construction sites indicated that the 1 hour average $H_2S$ levels (5 to 30 ppb) occasionally exceeded the Canadian Acceptable Air Quality objective of 10 ppb. However, it was noted that the paving operation is a mobile source and it is unlikely that these levels would persist at any given location for much longer than an hour. The level of $SO_2$ detected was 0.010 ppm and well below the Canadian standard of 0.34 ppm for 1 hour period.

Levels of $H_2S$, $SO_2$ and sulphuric acid aerosol measured at the paver and the roller were all lower than the relevant occupational threshold limit values. Hydrocarbons were also found to be reasonably low and comparable with those levels monitored during regular asphalt operations.

Despite the acceptable levels noted above, varying degrees of eye, throat and chest irritation were reported by workers at the test road sites. The use of goggles and breathing masks was found to be effective in lessening the irritation which was caused by elemental sulphur.

Odours of sulphur were noted in the vicinity of SEA roads, usually in hot weather after rain. This was found to be associated with the evolution of $H_2S$ from road surface.

Analysis of water used to spray the SEA mix indicated that the sulphur content was less than 0.2 ppm which poses no threat to the environment. The effect of SEA paving on soil quality was tested by taking soil samples adjacent to the SEA sections and also adjacent to conventional asphalt sections. Acidity and sulphur measurements on samples indicated that there were no significant change in soil characteristics before and after SEA road construction.

## CONCLUSIONS

The following major conclusions can be made :

1. The optimum content of sulphur in sulphur-bitumen binder used in mix design by the Marshall method is 40 percent by weight, in other words the desired SEA binder percentage is 40-60. Fifty percent substitution appears to be the practical limit.
2. The stability of the mixture increases rapidly at the percent sulphur above 40.
3. The flow decreases slightly at higher percentages of sulphur i.e. from 40 onwards but remains within the specified limits.
4. The mixture is temperature-sensitive when the percentage by weight of sulphur in SEA binder is greater than 40. For this percentage and above, compaction should be carried out at temperatureabove 130°C to obtain high levels of stability.
5. The unit weight of mixture is sensitive to compaction temperature. A significant gain in unit weight can be achieved at compaction temperature above 130°C.
6. The use of sulphur to substitute for part of asphalt cement in conventional bituminous binder can result in a saving of between 2.9 to 7.1 percent of binder cost for the case of Thailand.
7. The lower cost of binder means that more roads could be paved. The improved roads bring to the rurral populations, better quality of life, by enhancing cultural and social exchange as well as better education and better protection by public authorities.
8. The environmental consequences of using sulphur in bituminous binder as measured by the levels of hydrogen sulphide, sulphur dioxide, total hydrocarbons, elemental sulphur and sulphuric acid aerosol were generally found to be within both environmental and occupational specifications.
9. Emissions of $H_2S$, $SO_2$ and elemental sulphur from SEA mix are temperature dependent. Below 150°C, the emission level are acceptable.