PRE-STUDY ON COSTS OF DIFFERENT TYPES OF ROADS AND RELATED TOPICS

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PART I - COSTS OF DIFFERENT TYPES OF ROADS

Introduction

The study is based on available Indian Standards.

Methodology

Two sub-radials have been chosen to carry real scale experiment with various types of pavements. They are branching from radial N° 4 and serving Invocation and Madhuca respectively. They will be mentioned herein as SR4-i and SR4-m.

Soils samples have been removed on 3 locations in each of the sub-radials (see drawing N° 1) and sent to Madras for testing.
The following tests have been conducted:

- Consistency tests: Liquid limit, Plastic limit and plasticity index.
- Sieve analysis.
- Proctor test.
- C.B.R.

An enquiry has been conducted on availability and cost of road construction material.

We have directed our research into 3 main types of pavement:

- Rigid pavement: using concrete.
- Flexible pavement using asphalt.
- Semi-rigid pavement using soil-cement as base course.

We have used to determine the thickness of the various layers composing the 3 types of pavement described above, models of road construction for cities of scale similar to Auroville. Based on these models and on the soil test, it has been possible to arrive at some cost estimation.

Construction of roads as ground for testing various types of pavements.

Solutions using concrete, asphalt or bituminous concrete are well documented. The choice among these solutions will depend on factors such as costs, esthetics, future maintenance costs, etc. There is normally no need to put to test in real conditions these solutions whose performances are well documented. However, any solution using soil-cement as sub base and/or base in combination with conventional wearing courses certainly presents an interesting field of research in alternative technology and we may learn a great deal by studying on a small scale how these solutions will fare over time. In order to obtain comparable data the conditions for the experiment have to be similar. This factor has guided the choice of sub-radials SR4-i and SR4-m, which are located closely to each other and are expected to bear the same amount of traffic. It also happens that their sub grade presents similarities in texture and compression ratio.

Soil testing

This study limits itself to the tests that were conducted on SR4-i and SR4-m. The soil taken for sampling is of type 'red silty sand' prevailing in most parts of the city. However other soil condition exits particularly in the Industrial zone where the clay content in the soil is higher. Therefore one should not presume that a uniform solution for the construction of all roads in the city might in the end prevail. In any case the soil of each road will have to be tested.

We learn from the test conducted (see chart page 3) that we are dealing with a fine grained soil of class A4, moderately plastic. The CBR value indicates a soil of satisfactory stability when dry and loss of stability when wet. The unit dry density is above expectancy for this type of soil and confirms it as a good sub grade material. This is an important finding as we can presume that it might be possible to use sand-gravel, or soil-cement mixes as sub base and/or base course instead of the more costly graded crushed aggregates (GCA). This of course in the hypothesis that Auroville's roads will receive medium intensity traffic.

Cost of construction materials

The following chart shows average prices for various construction materials for delivery in our area as of March 2001:

Table 1

No	Material	Unit	Real Delivered Quantity	Lorry capacity	Amount
1	Sand	m³	5	(200 cft)	1100.00
2	Murrum	m³	5	(200 cft)	650.00
3	Gravel	m³	5	(200 cft)	650.00
4	Blue-metal 10 mm	m³	7.5	(300 cft)	3600.00
5	Blue-metal 20 mm	m³	7.5	(300 cft)	4800.00
6	Blue-metal 40 mm	m³	7.5	(300 cft)	3600.00
7	Blue-metal 80 mm	m³	7.5	(300 cft)	2100.00
8	Blue-metal ¾"	m³	7.5	(300 cft)	4050.00
9	Cement (Transport extra)	bag	1	200 bags	200.00
10	Bricks	N°	4000 (Less Breakage≈ 5%)	4000 N°	4400.00

Note: Usually lorries delivering sand in our area contain 200 cft (2 units) or 5,6 m³. In reality after sinking due to transport the real usable quantity of material is 5 m³. There are other factors such as cheating on the quantity transported, which explain the differences between what is paid for and what is really delivered. The same applies to delivery of blue metal. The prices given above reflect the real cost of each material.

Types of pavement

All cases studied herewith relate to the design of urban roads and are based on the understanding that the traffic will be of medium intensity. The thickness of sub base, base and wearing courses are only indicative in the absence of data on existing and future traffic.

In the total absence of contour level maps and any decision regarding the future MSL reference points within the township, it is not possible to know what the shape of the cross slope will be. They may anyway vary depending on each road location and the topography of the land they cross. Further, many more parameters than topography such as rain fall, maximum traffic speed and others, will decide whether the roads will be constructed in embankment, in cutting or in flushing as is usually the case in urban area. Therefore, the cross sections in all drawings referred hereafter are only theoretical and not indicative of any set choice on the part of the consultant.

1) Rigid pavement

Solution 1 - see drawing N° 2.
- Sand gravel mix, 15 cm thick.
- Water bound Macadam (WBM) 1st layer, 10 cm thick.
- WBM 2d layer, 7.5 cm thick.
- Cement Concrete 1:3:6, (M 10) for pavement, 10 cm thick. Plus 100-µ polythene sheet.
- Cement Concrete 1:1½:3, (M 20) for pavement, 15 cm thick including dowel rod and expansion joints

Solution 2 - see drawing N°3:
- Soil-cement mix @ 7% cement, 20 cm thick.
- M 20, thickness 20 cm.

Advantages: This solution is preferred for its longevity if executed properly. It requires little to no maintenance. The concrete can be colored thereby offering many possibilities for design to architects. If solution 2 is retained most of the work can be executed by Auroville Road Service (AVRS) with locally available machinery.

Inconveniences: This solution is more costly than conventional bitumen/asphalt roads. The dilatation joints must be executed with great care as otherwise the resulting work will be below standards. Cement surface when exposed to abrasive stress generates dust, which may make this solution quite unpopular. However there exist products like epoxy resin which when applied on concrete surfaces reduce and even stop the formation of dust particles.

2) Flexible pavement

Solution 3 - see drawing N° 4:
- Sand gravel mix, 15 cm thick.
- WBM 1st layer, 10 cm thick.
- WBM 2d & 3d layers, each 7,5 cm thick.
- Bituminous tack coat 0,75 kg/m².
- Bituminous tack coat 0,50 kg/m².
- Bituminous macadam, 7,5 cm thick.
- Asphalt concrete, 4 cm thick.

Solution 4 - see drawing N° 5.
- Graded crushed aggregates (GCA) 0/31,5 mm, 30 cm thick.
- Bituminous concrete using bitumen 80/100, 6 cm thick.

Advantages: It is a cheaper solution when compared to cement concrete (CC). Any local contractor can execute it, provided the work is closely monitored and tests performed to avoid cheating on quality of components.

Inconveniences: It needs quite a lot of maintenance. The cost of it adds in the long run to make it a less cost efficient solution when compared to cement concrete. The presence of naphtha in the material present a danger of pollution to ground water which is all over the world overlooked for obvious economic reasons. We'll have to resort to tender procedure, as the cost of equipment is so huge that unless AVRS becomes a contracting agency taking jobs in the region, it is preferable to resort to outside contractors to do the job. This means contractors would be called in whenever resurfacing jobs would have to be done and only pothole repairs would be done by AVRS. The temperature stress particularly in summer makes the use of asphalt wearing course less user friendly than CC.

3) Semi-rigid pavement

Solution 5 - see drawing N° 6.
- Soil-cement mix-in-place for sub-base @ 7 % cement, 20 cm thick.
- Borrowed soil-cement mix for base @ 7%, 20 cm thick.
- Bituminous surface, 2 cm thick.

Advantages: The base material is available in plenty at little costs. In this solution after removing topsoil, the sub grade is scarified, pulverized and wetted in situ, then processed with cement. No transport of material is needed except when borrowed soil has to be imported to obtain a given thickness as in solution 5. Even so, when excavation of the lake around Matrimandir goes on, there will be supply of soil aplenty with relatively marginal transportation added cost.

Inconveniences: It is important in this type of technology that the cement content in the soil after construction appears to have been evenly spread. The mixing of soil and cement can be done by hand but it is a lengthy and costly process. If done manually it is likely that the resulting mix will be uneven and that on some spots the proportion of cement might be insufficient thus reducing the desired strength. It is therefore highly recommended that the work be done using a stabilizer/recycler and the proper compactor. However, this type of machine is very costly and we'll have to use the service of an outside contractor or rent the machinery. Further, it has not been so far possible to discover during our study a better wearing course than the bituminous surfacing. Inconveniences of using this material are discussed in solution 3 & 4.

Note: There exist chemicals which when mixed with earth may increase the mix resistance to friction. It might be possible in light traffic condition to obtain a wearing course that will be strong enough not to turn rapidly into dust. We have not come across any convincing solution so far and this is a field which has to be explored further and will necessitate a lot more research.

Bills of quantity

We are giving below the bills of quantity for three of the main solutions presented above.

Cost estimate

I. ASPHALT ROAD

Table 2

S.No.	Description	Rate (m²) (Rs.)
01	Excavation up to 40 cm depth	25.50
02	Sand Gravel mix (15 cm thick)	54.00
03	WBM first layer (10 cm thick)	84.00
04	WBM second & third layer (2 x 7.5 cm thick)	134.00
05	Bituminous tack coat 0.75 Kg / m² over WBM surface.	19.50
06	Bituminous tack coat 0.50 Kg / m² over asphalt surface	11.50
07	Dense bituminous macadam – 7.5 cm thick	245.00
08	Asphalt concrete - 4 cm thick	140.00
	TOTAL COST PER M²	**713.50**

II CONCRETE ROAD

Table 3

S.No.	Description	Rate (m²) (Rs.)
01	Excavation up to 40 cm depth	25.50
02	Sand Gravel mix (15 cm thick)	54.00
03	WBM first layer (10 cm thick)	84.00
04	WBM second layer (7.5 cm thick)	67.00
05	M 10 for pavements (10 cm thick)	198.00
06	100 micron polythene sheet	17.50
07	M 20 for pavements (15 cm thick) including dowel rod and expansion joints (excluding reinforcement)	593.00
	TOTAL COST PER M²	**1039.00**

Reinforcement for concrete work if specified would cost **Rs.21,500/MT**

III SOIL-CEMENT ROAD

A. Satprem whose report is attached to the Annex has provided the only reference on costs we could find for this type of solution. The estimate presented in his report comprises shoulder and drainage. The cost of cement and asphalt roads mentioned above relates to the carriage way only. Also the experiment in question deals only with making a base course of 20 cm thickness in stabilized earth. Construction of a wearing course on top of the base course was not part of the experiment. Further, the soil used for the work was borrowed, increasing the cost due to transportation. This and other factors like untrained labor bring the overall picture on to the higher side. We extrapolated from these data an approximate cost for the carriageway only, using cement mix at 7%, of Rs 215,00/m². The cost of making a base course for a CC road (see Table 3) runs at Rs 420,50, and Rs 272,00 for an asphalt road respectively, excluding cost of excavation.
Therefore, using soil-cement as base course would run at:

- In case of an asphalt toping: **Rs 637,00**
- And using CC toping: **Rs 833,50**

More data is needed to arrive at a precise estimate. But the above data gives a fair idea of comparison.

The total carriageway area being 227 637,50 m², we would need **Rs 189 735 856,25** to build roads using the soil-cement/CC wearing course solution, nearly 19 crores.
This of course does not include costs of shoulder, drainage, speed breakers, parking space, rotaries, kerbs and other infrastructures.

Conclusion

If a reliable stabilizer of soil-cement, which hardens the upper layer to the point of making it wear-proof can be found, then we can envisage to build roads made of soil-cement mix only. This supposes that the traffic will be of light intensity so that the wearing course will not generate dust. At this stage no reliable technology is in sight and however much we would like to experiment in this direction we feel that it should be set-aside for the moment.
One argument against 100% earth-roads lies in the fact that for a long time to come most axes will be utilized for transportation of large amount of construction materials. Therefore, we recommend going for a solution of type N ° 2, soil-cement as sub base and/or base with cement concrete wearing course. It has the advantages of being long lasting, necessitates no maintenance, can be made dustproof and can be colored. It will also be able to withstand a heavy traffic load.
If this suggestion is accepted we shall then design 2 models of soil-cement/CC pavement using various compositions of single- or multi-layered soil-cement mix as sub base and base courses combined with CC wearing courses of different thickness, for experimenting on sub-radials SR4-i and SR4-m.
Finally it must be emphasized that any experiment will have to contain an element of monitoring the effect of diverse stress factors over a given period of time.

PART II - RELATED TOPICS

Topography

To complete the study on road construction feasibility we depend heavily on the topographic survey. Since Auroville exists no thinking has been done on a minimum common plinth level to be imposed for all buildings public and residential. This will lead in future to difficulties in designing longitudinal profiles for drainage of the roads. There is also bound to be problems when we will have to connect new carriageways to existing driveway entrances. Therefore a decision on a general reference level for the city as to be taken urgently.

Surveys

a) Traffic
One essential parameter in any road design study is the amount and nature of traffic the road will have to accommodate. Angad who has shown great interest in this topic has provided us with suggestions on how to conduct this survey and with a traffic survey sheet, which is attached to the Annex. Here, in his own words, is what he proposes:

" The traffic survey should essentially count the number of vehicles passing any given point in a certain direction. The same count should be done at each point in the opposite direction. In order to this properly I estimate at least 2 persons to man any given post covering 2 directions. The idea is also to measure the frequency or density of traffic. Initially it can be done in two-hour intervals but this really first need to be tested. After testing we can modify the forms to maybe record one hour intervals or if necessary even at half hour intervals. Let's first start with 2 hr slots. The surveyors simply count the vehicles of certain types going in one direction and mark the numbers in by vertical strokes and then crossing the previous four each time 5 is completed. Once a time interval is passed then the data is entered in the next row. The columns correspond to the main types of vehicles classified according to size and therefore also weight; totally 7 columns. I have made a prototype survey sheet but it is too large to print on A4 paper. Ideally it can be done on A3 size. Each sheet represents data on traffic in one direction at one point.

At each station there should be a desk, chairs and a clock. Also the stations should be for example near road junctions. In Kuilapalayam for example we can have three tables and we require 6 persons and a supervisor or spare person. We can do with less people during the slack traffic hours but this needs to be tested. The shifts should be 4 to 6 hours each with relief being provided and also with refreshments or food being distributed there. I personally feel the traffic surveys should be done at least 4 times a year and can cover three or four consecutive days. One idea is to do them on Saturday, Sunday, Monday and Tuesday, or if that is too much then just Sun, Mon, Tue. As far as dates in the year are concerned, I'd think one should definitely be during the birthday week, one in December end, one in April-May and one in the monsoon or if not then, then in Aug-Sept. If possible one can include one extra survey to be done whenever there is a special weekend or cluster of holidays when we do have a perceptibly greater flow of tourist traffic into Auroville as for example last weekend."

There exist many ways of conducting traffic surveys and as many survey forms. What he proposes is in tune with Auroville's particular situation. What is important is that it be done without delay. Preferably the survey should be conducted during the next 2 years. We concur with Angad's proposal as to the location to be chosen for the surveyors to take their record:

”I feel there should be one on the East Coast Road entrance, three points in Kuilapalayam, one at the entrance to the Green Belt from the Djaima road, One at the Certitude corner and tar road, One at the information Center. I would also have one at the Ganesh Temple entrance, One at the Industrial Zone entrance at the Alankuppam Kolam, one at the triangle near the Matrimandir/Center Field, One at the crossroads near Kottakarai, Auroshilpam and one on the stretch of road between Transition and Surrender area, one from the entrance to the residential zone opposite the solar kitchen."

The question of traffic generates a lot of interest in the Community. It is likely that we will find many people willing to help. The above proposals, of course, have to be discussed and become the object of a series of meeting to develop an ad hoc format.

b) Vehicle
Another survey is getting prepared for the Auroville Vehicle Service. It concerns itself with the behavior of Aurovilian, type of vehicle used, when and what-for. It aims at discerning pattern in transportation and evolving solutions that reduce the need for individual mode of transport. It was not possible to add this documentation to the present study as it is in a development stage for the moment. But we are in contact with Wazo who will keep us informed of future progress.

c) Mode of Transport
We are attaching to the Annex a study that was conducted by Priya in November 1999. Its object was to survey the number of cars presently plying Auroville's roads. This was prompted by the fact that ownership of cars is on the increase and this creates already problems such as lack of parking space, which is felt at some public location like the Solar Kitchen, Pour Tous, etc. There is a general understanding that polluting traffic will not be permitted within City limit, as this is part of the guidelines extended by the Mother. At some point a decision in this regard has to be taken as it raises the question of the design of future roads in the city.

d) Traffic coming from outside
The study of the design of future access roads to the Township will necessitate a survey of the traffic going to and fro the village and of vehicles bringing visitors to the City. This is an extension of the survey proposed by Angad which will need specific design parameters. These roads should be designed with a view that the perspective plan has been made for the 2025 horizon, period which will see a steady increase in traffic along with the development of the City.

Circulation plan

At present vehicles delivering construction materials such as bricks, pebbles, sand and cement to the building sites are using the existing access from Certitude towards the Residential zone and Center, from Visitor center to the International zone and to a lesser -

extend from Allankuppam pond to the Industrial and Cultural zones. This generates a lot of hardship to the residents and a solution must be found. These solutions can emerge only when there is a consensus on the type of roads we wish to build. For example, if it is decided to use GCA or WBM as base material, it is then possible to let the lorries use accesses where only base course has been laid. If the shoulders have been properly done and are well maintained the base will only benefit from the compaction provided by the plying lorries. Now if soil-cement base is chosen we face a situation where abrasion will take place and dust will be generated. Further during monsoon even stabilized soil will be damaged by lorry traffic. In this case it would be safer to let lorries roll on the finished wearing course.
A plan should be evolved to segregate traffic from entry points onwards and reserve certain accesses for lorry traffic and other for commuting Aurovilians. We could for a while use the old accesses mentioned above to accommodate lorry traffic and newly developed radials for commuting residents, or a combination of both solutions. But any plan necessitates that all the land is being purchased otherwise the whole purpose of creating circulation plans will be defeated.
To illustrate our purpose we show in drawing N° 7, a purely theoretical way to serve part of the Residential Zone during construction of new blocks.

Auroville Road Service

To find out what will be the role of Auroville Road Service in the development of a road network we interviewed Sukrit on the present position of his service. We expect him to remit soon a full report on his activities. Here in a nutshell is what he confided to us.
AVRS is doing mostly repair and maintenance work of existing ways. It does also open new ways like the recently developed section of the inner ring road between Surrender and Khalabhumi. Whenever material becomes available like for instance when AVWS dredges silt from local ponds, the extracted material is used as filling material in order to strengthen the base course. Other materials such as broken bricks left over from new construction sites are also utilized to reinforce existing bases. The service has a very small budget of Rs 15 000,00/month. Whenever some of this money is left over, it is used to produce precast RCC slabs. It is planned to lay these slabs on 30 m length from the Eucalyptus Grove towards the Solar Kitchen. This experiment comes in continuation of the one realized by A. Satprem and is an attempt to learn how materials are faring in similar conditions of exposure.
If AVRS is to grow into a service fully able to take up construction of roads in a large scale the Community will have to invest large sums in its development. Even now it would be well inspired to help this service to develop not only in terms of machinery but in terms of training young Aurovilians in road technology as this aspect of our development is bound to become rapidly one main area of focus.
For example, all sort of tests are needed before, during and after road construction. It will be convenient and economical to develop our own laboratory. This will be an important task to be performed by AVRS.
Even if it proves more economical to build roads using the services of outside contractors, someone will have to supervise the work closely and therefore we'll need a well-trained personal for this work.

We can suggest one area that will eventually make AVRS if not profitable at least self-supporting: the manufacturing of kerbs. We'll need kilometers of them, in various shapes and sizes. This is not a product that is readily available in the market. Most kerbs in our region are either not there at all, and if they exist, are precast for a particular working site or cast in situ. A unit producing kerbs industrially is sure to find a market with the local PWDs. This in itself is a field of research that merit to be explored. The same applies to prefabrication of visiting chambers, manholes, gullies and infrastructure ducts.

Miscellaneous

It is well understood that preferably distribution of energy, water supply, rainwater drainage, etc., will run parallel to the roadways. At this stage, due to the lack of contour maps, it can only be said that design of these infrastructures will have to run concomitantly to the design of the roads. One very good reason for a close coordination of the different studies involved, will be to avoid digging cross section trenches in completed carriageways for the laying of pipes or cables which might have been overlooked when new blocks come in for development. Therefore provision for reserve feeder ducts will have to be made at regular intervals. We are showing in drawing N° 8, as an example, how to lay a Ø 150 mm drainage pipe under bituminous concrete carriageway.

For memory only let us mention the need to look now for solution to the need for street lighting. There exist lanterns in the market that use autonomous power supplies via solar energy. A study on the availability and costs of such equipment in India has to be done.
Questions have to be answered by the town planners about the likelihood that phone booths will be made available to the public. The question of fire fighting equipment has to be studied and location of fire hydrants has to be looked into.

Finally let us mention the question of the cycle path system which can not be developed independently from the main axes, as crossing points between the 2 grids will have to be looked into in detail. At present the existing cycle paths are only dust tracks offering little comfort and security. The cycle paths will not only run parallel to the main roads, they'll meander through the parks, green corridors and settlements as well as through the Green Belt. Their mode of construction has to be studied. In discussions with A. Satprem the idea emerged to use stabilized mud interlocking pavers, which could present a cheap, reliable solution.