ECONOMIC AND TECHNICAL ASSETS OF CONCRETE OVERLAYS

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The overlay technique is not new and resurfacings of varying thickness were applied to a large number of damaged roads. The first overlays were built with bituminous materials. Concrete overlays are constructed in Belgium since 1960. When a road gets to the end of its service life, it may be rehabilitated either through the destruction and reconstruction of the pavement or through the construction of an overlay. In this report, a comparison is made of both alternatives particularly from an economic point of view, taking into account not only direct construction costs but also maintenance costs and a further parameter recently considered, the user costs due to traffic hindrance. These factors are examined for both asphalt and concrete overlays.
The main reason for the choice in Belgium of continuously reinforced concrete overlays for major roads is the excellent performance of this type of pavement in the long term, the virtual lack of maintenance costs and the reduced user costs.

Road engineers must not only build durable pavements but they must save public money as well. The overlay technique meets these requirements.

Let me briefly recall the two major assets of overlays. At first they are cheaper than removing the damaged infrastructure and replacing it by a new one. But they also considerably reduce construction time and thus the inconvenience for road users.

Costs of construction

Comparison between costs of construction of new infrastructures and those of thick overlays.

Let us first compare the cost of overlays and that of new infrastructures. By way of example let us take the typical cross sections specified by the Road Authorities for class T 3, i.e. roads with an average daily traffic flow of 2000 - 4500 vehicles. These cross sections and their construction costs are shown in the table below :

Table 1.	Thickness in cm	Unit cost $/m³	With flexible pavement $/m²	With CRCP $/m²
Earth-works	64 60	2,5 2,5	1,60	 1,50
Subgrade	20	6	1,20	1,20
Well grad. aggregates	24	10	2,40	
Lean concrete	20	20		4,00
Flexible pavement	20	46(1)	9,20	
CRCP	20	55		11,00
Total			14,40	17,70

(1) 20 $/T = 46$/m³

One can see immediately that the cost of new infrastructures is : 14,40$/m² for black pavement and 17,70$/m² for white pavement. Although I am not an expert in load bearing calculations, I consider that as seen in the context of the above two cross sections, the concrete alternative is by far the most reliable.

It can be considered that the load bearing capacity of an old road is at least equivalent to that of a new well graded aggregate or lean concrete subbase. Thus the cost of overlays is 9,20$ for black pavement and 11$ for concrete. However, if the overlay of a bituminous pavement is preceded by a cutting or a scraping, the price of 9,20$ should be increased by at least 4 x 1$ = 4$. The saving thus made as compared with the "new infrastructure" alternative is about 38% for both black and white pavements.

For information, it should be reported that the cost of an onverlay built with undowelled concrete slabs (20cm) is about 8$/m²; for dowelled concrete slabs it's about 9$/m².

Overlays Technical advantages.

The construction of overlays offers some technical and economic advantages :
- They strengthen existing roads.
- The longitudinal section of old roads is adapted to new safety and comfort standards without altering the structure of existing layers.
- The subgrade consolidated by traffic over the years is maintained.

Why a recent choice of concrete overlays?

While asphalt overlays have been built on a system basis for many decades, concrete ones were not introduced in Belgium until the beginning of the golden 60's. What was the reason for this time lag? A change in the procedure for cost allocation made it possible for Road Authorities to have larger amounts available for the renovation of the road network. The availability of increased resources enabled the road construction departments to develop the number of overlays in concrete slabs or even continuously reinforced concrete.

The advantage of black overlays was the relatively small thickness which could be used for a first resurfacing as well as the low cost of bitumen. A first investment without being too much concerned in maintenance costs or subsequent renewal thus made it possible to rehabilitate large sections of damaged roads. Unfortunately, this alternative did not provide adequate strenghthening of the infrastructure and as a consequence it was thus necessary to make costly repair work as soon as traffic increased even to a small extent.

When we buy a cheap suit, this is because most often we cannot afford an expensive one. On the other hand, when we have enough money available, we examine the strength and life service of the suit before making our choice. The road engineer has been led to reason in a similar way when he wanted to protect the road network against bad weather and above all against the effects of a growingly destructive not to say "rut causing" traffic.

Thin concrete overlays.

As far as thin overlays are concerned, Belgian experience is not yet sufficient, as will be seen from the following reports, to give date about actual costs and the overall resulting saving involved.

User costs due to traffic hindrance.

While this reduced investment represents a direct saving, we must bear in mind the other advantages of overlays for the road users, as a whole, who drive through the site while work is in progress.

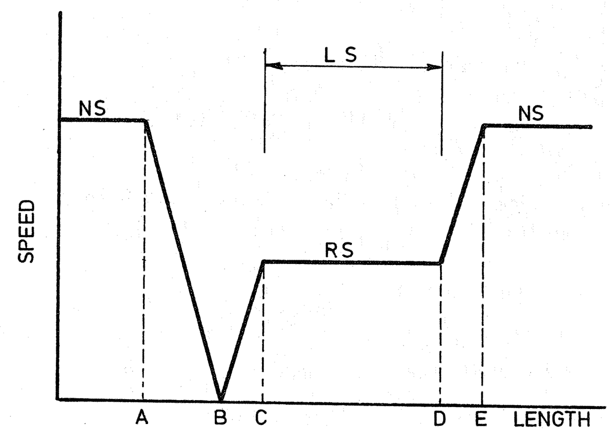
A road site may slow down traffic in different ways :
- First by imposing a maximum speed;
- By forbidding overtaking of slow vehicles;
- By temporarily stopping traffic to allow site manoeuvres;
- By forcing people to stop because the traffic flow capacity of one or even two lanes is not sufficient.

A factor taking into account the increased risk of accidents resulting from traffic disturbance must be added to the user costs. However, its significance cannot be derived from statistical data.

Costs borne by drivers when they have to change their speed

In its 1972 report on "Rehabilitation Materials and Techniques" the Highway Research Board highlights the costs borne by drivers when they have to change their speed and sometimes stop when going through a construction site.

Figure 1.



NS = normal speed
RS = reduced speed
LS = length of the site

On a given road, the user drives at a usually constant and normal speed which we shall call normal speed.

When he sees the site or as soon as signs warn him that he must stop, he slows down over distance AB. He stops at B, then starts again to reach the maximum speed specified on the site : he thus covers the section BC. He goes through the site at reduced speed, i.e. on a section CD, then speeds up to normal speed covering the section DE. Point B does not exist when the user does not need to stop.

Our American colleagues have assessed both the average prejudice to users when they have to alter their speed and the cost of using a vehicle at different speeds. The tables made in Texas in 1972 have been used as a model for Belgian experience in 1984.

Depending on the cruising speed and speed on the site, the costs borne by users when changing speed are shown in Table 2.

Table 2. Costs borne by drivers when they have to change their speed.

Initial Speed (MpH)	Average cost ($) per vehicle by speed reduced to and returned from (MpH)					
	0	10	20	30	40	50
10	0.02					
20	0.04	0.02				
30	0.08	0.05	0.03			
40	0.13	0.10	0.07	0.04		
50	0.19	0.17	0.13	0.10	0.06	
60	0.30	0.27	0.23	0.19	0.14	0.08
70	0.46	0.42	0.37	0.33	0.30	0.20
80	0.71	0.65	0.60	0.53	0.46	0.38

This table is calculated with an inflation of 150% since 1972.

In addition, the cost for both equipment and labour per km covered is given in the table below.

Table 3. Operating and time cost per vehicle - miles at uniform speed.

Uniform Speed (MpH)	Cost ($) per vehicle-miles	Uniform Speed (MpH)	Cost ($) per vehicle-miles
10	0.98	50	0.28
20	0.54	60	0.27
30	0.39	70	0.26
40	0.32	80	0.26

In both tables, an average cost for all vehicles, including heavy lorries in open country has been used. Downtown, these figures would be reduced due to a clearly lower proportion of heavy vehicles.

Costs borne by the drivers during the realisation of a concrete pavement in Belgium.

Let us apply both these tables to the overlay sites on the major road RN 4 between Namur and Marche. Each site was 6 miles long and its cost amounted to approximately 3 million $. Construction lasted over 400 days. The driver speed was reduced to 40MpH on a section of about 3 miles.

Traffic, which in normal circumstances could use 4 lanes, was channelled through three lanes, i.e. two in one direction and one in the other and vice versa, depending on rush hours. Drivers moving in the same direction as the progress of the overlay were sometimes stopped by finisher feeding operations. Therefore, it is not excessive to go on the assumption that 3/4 of the vehicles did not stop but moved at 40 MpH over a 3 miles section and that 1/4 had to stop and then cover the same distance at 40 MpH.

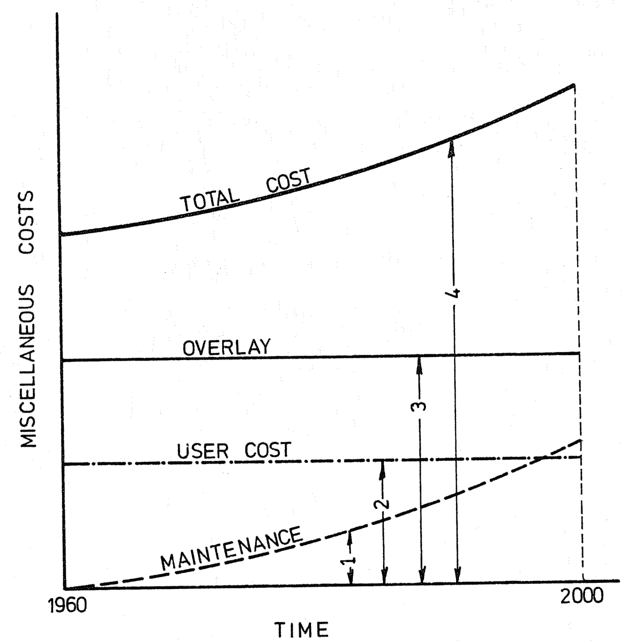
The average daily traffic flow on the major road RN 4 was 17 000 vehicles. The speed reduction from 80 MpH to 40 MpH represented for drivers as a whole additional expenses amounting to (0.32 $ - 0.26 $) x 400 x 17000 x 3 = 1,224,000 $. The cost for the community of the slowing down and acceleration of 3/4 of the drivers (80 down to 40 and 40 up to 80) was 0.46 $ x 400 x 17 000 x 3/4 = 2,346,000 $. The cost of the stop of 1/4 of vehicles was 0.71 $ x 400 x 17 000 x 1/4 = 1,207,000 $ making a total of $ 4,774,000.

If a new formation level had been normally prepared, this would have increased the temporary inconvenience for drivers and the construction time would have been more than twice as long. Thus we can claim that the construction of a 300 million overlay enabled to save more than 4 million $ for the community.

Incidence of the pavement nature and the overlay life on the costs borne by the drivers.

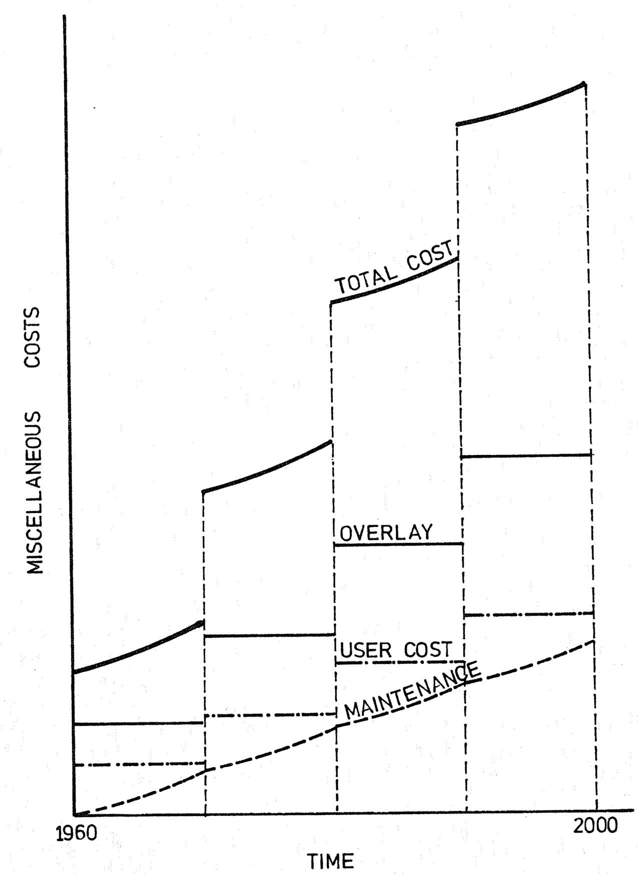
A diagram can be plotted in which the abscissae represent the observation period and the ordinates the cumulated costs since the completion of the overlay. This gives the following :

Figure 2.



The same reasoning applies when several overlays have been constructed over the years.

Figure 3.



To compare black and white pavements, it is first necessary to choose a period for cost analysis which will be at least as long as the service life of the pavement which is most resistant and less liable to deformation, i.e. concrete.

Considering the highly satisfactory condition of many reinforced concrete pavements built several years ago, it may be assumed that such pavements will last for more than 40 years free from any notable deteriorations or high maintenance costs.

To assess the average life service of a black pavement,one needs only to observe the frequency of replacements or resurfacings of black pavements.
In the Province of Namur the surface area of concrete pavements is 2.5 million m² whereas that of black pavements excluding surface dressings is about 9.6 million m². This surface area of black pavements represents 1,273 km of two lane roads. A systematic survey of the bituminous network condition made in January 1980 shows that deformations start to appear in some pavements as early as the 7th year and that nearly all pavements over 10 years of age deformed.

This 10 year service life is confirmed by real-life experience on the major road RN 4 south of Namur. Here is a statement of expenditure on this route from 1969 to 1978.

Table 4. Maintenance costs of asphalt pavements on the RN 4 up to 1978

Years	Cost in $	Years	Cost in $
1969	267,000	1974	50,200
1970	66,700	1975	50,000
1971	167,000	1976	82,500
1972	0	1977	116,000
1973	66,700	1978	233,000

Total = 1,091,000

The construction of the original pavement was finished in 1968. Therefore it can be concluded that the maintenance cost required for 17 miles of the RN 4 for 10 years amounted to $ 1,100,000. If the Road Authorities had laid a bituminous top layer with a thickness of 5 cm over the whole 17 miles section, the cost would have been of $ 816,000. The real life example expressed in figures of the RN 4 thus confirms the justified argument of a black pavement every 10 years.

Those pavements can be laid according to two different methods:

- First case : they are laid on the existing infrastructure without scraping or cutting. The first overlay must then be laid in two layers - a binder course and the pavement itself. The three other layers to be laid during the analysis period of 40 years may be considered as single layers. Five layers will thus be laid but in shorter times and on smaller temporary working sites as would be required for concrete overlays.

- Second case : the deformations of the old pavement may be such that a grading or cutting is necessary before the overlay can be put in place. This progresses speed of the work as well for the black as for the white exceeds rarely 600 to 700m per day. For a bituminous pavement it may be considered that the length of the temporary working site corresponds to a day's work i.e. 700m. On the other hand, for a concrete overlay, the hardening of this last implicates to the user a quite longer travelling along the site.

If we take into account the following hypothesis is :

1. Laying of an overlay of 10.000m length and 7,5m wide in one pass;
2. Opening to traffic of the concrete after 7 days;
3. Laying of continuously reinforced concrete 4 days a week (700 m per day). The traffic will be disturbed on a length of 4 x 700 m to which must be added approximately 700 m for the placement of the reinforcement; together 3.500m.

The user costs will be calculated as follows :

1. For a concrete overlay :

- reduced speed of users
  (0,32 - 0,26) x 17 000 x 3,5 = $/day 3,750
- slow down and acceleration
  0,46 x 17 000 x 3/4 = $/day 5,865
- stop and restarting
  0,71 x 17 000 x 1/4 = $/day 3,017

$/day 12,632

The work site will last for 32 days which can be detailed as follows :

a) $\frac{10.000}{700}$ m = 14,28 = 15 days for laying concrete;
b) preparation of reinforcement : 1 day;
c) stopping the works for 3 weekends x 3 days = 9 days;
d) hardening of concrete on the last section = 7 days.

The sustained inconvenience for the user reaches therefore 32 days x 12,632$/day = $ 404,224.

Taking into account that the total area of the pavement is 75.000m², the user cost reaches a value of

$$\frac{404,224}{75,000} = 5,39\ \$/m^2$$

2. For a bituminous overlay without cutting or grading :

- reduced speed of the users
  (0,32 - 0,26) x 17 000 x 0,7 = $/day 714
- slow down and acceleration $/day 5,865
- stop and restarting $/day 3,017
  or a total of 9,596 $/day for an area of 700 x 7,5 = 5.250m².

The user cost will thus be

$$\frac{9,596}{5.250} = 1.83\$/m^2 \text{ for one layer}$$

or 1.83 $/m² x 5 = 9.15 $/m² for the analysis period of 40 years.

3. For a bituminous overlay with cutting or grading. The length of the work in this case is 1.400 m and furthermore the interference of the weekends during which the user has to sustain an inconvenience must also be taken into account.

- reduced speed
  (0,32 - 0,26) x 17 000 x 1,4 = $/day 1,428
- slow down and acceleration $/day 5,865
- stop and restarting $/day 3,017
  or a total of 10,310 $/day

The working site will have to last for :
15 days for laying the bituminous pavement,
1 day for the cutting or grading,
3 weekends x 3 days = 9 days
or in total 25 days.

The user costs reach therefore
10,310 x 25 = 257,750 \$
For a total area of 75.000m² i.e.3.44 \$/m²
For the period or analysis the user cost
reach therefore : 13.76 \$/m²

Costs of maintenance of concrete overlays.

Finally, it remains to examine the maintenance costs of concrete overlays.

On the assumption that such pavements were properly built, maintenance costs are of little significance. I shall quote a few examples.

The Louvain - Diest section was built in 1960 with concrete slabs on 6,500m and three traffic lanes. Recent and detailed inspection of this pavement revealed 11m of longitudinal cracking, 78m of transverse cracking, 28 edges broken. A transverse joint had to be broken down and made again (repair on 50cm width and 3.50m length). Finally, a joint filling operation was carried out around 1970.

The Rivière - Sart-St-Laurent section - concrete slabs with dowels built in 1970 did not need any maintenance work.

The continuously reinforced concrete placed in Bierwart in 1967 did not need any maintenance work.

Some pavements, however, had to be given a surface dressing due to their defective roughness resulting from the use of too soft crushed stones or faulty execution. Nevertheless, these are failures that cannot be taken into account when judging the overlay technique.

Conclusions

From all the informations collected at the Price Board of the Belgian Ministry of Public Works and the real life experience on various overlay sites, the following conclusions can be drawn from an economic point of view :

1. The construction of any thick overlays of whatever type allows a direct saving of about 40% as compared to the execution of a new formation level and construction of a new infrastructure at least in open country.
2. The cost of continuously reinforced concrete overlay remains higher than that of an asphalt overlay of the same thickness. On the other hand, the cost of an overlay with dowelled concrete slabs is exactly the same. Undowelled concrete slabs prove to be cheaper.
3. User costs are clearly lower for concrete than for black alternatives.
4. Maintenance costs of concrete overlays are practically non-existent.
5. It is still too early to judge the techniques of thin concrete surfacing from the point of view of initial and maintenance costs.

Such an alternative appears to be of interest for non-structural rehabilitations in which the thickness parameter plays an important part. In addition, the cost figures available at present are not fully accurate as account should be taken of the fact that sites completed so far were experimental ones, which somewhat distorts prices. It must also be remembered that preparatory works as well as the use of special and expensive materials such as steel fibres, latex and other additives may vary from one site to the next.