# OLD CONCRETE MAKES WAY FOR NEW ASPHALT

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## ABSTRACT

Back in the middle seventies, the latest civil pavement engineering techniques and technology transformed the old single carriageway trunk road which linked the Western Cape towns of Cape Town and Somerset West together as well as connecting them to the eastern part of the country. This transformation changed this road into a modern dual carriageway facility. This new facility was constructed with the then latest technology involving slip form paved concrete. All went well until a new phenomenon involving the interaction of sodium monoxide in cement and the alkali minerals in the local crushed rock caused the concrete to expand and evidenced severe failure.

Although this early failure was kept in check for over 40 years, the section of this road which forms part of the transport hub at Cape Town International Airport, has finally been reconstructed giving way to a highly modified bituminous binder based pavement. The new pavement consists of an asphalt base, surfacing and friction course all produced with modified bituminous binders. The supporting layers have been constructed by recovering and crushing the old concrete and combining with further cement to form the stabilised supporting layers. This is regarded as a fully green approach to salvaging old problematic pavement materials.

With minimal effort and modification sound subbase layers have been created to provide the necessary support to the construction of modern asphalt layers to produce a more flexible pavement alternative for safe travelling on this busy route.

## 1. INTRODUCTION

The Cape Town metropolitan centre has a very important role in the South African economy. Any metropolitan centre needs an efficient transport hub connecting all modes of transport of which the road interchanges outside of Cape Town International Airport is just such a hub. This transport hub with the national route 2 as a major artery has suffered from severe congestion just like most other major transport hubs around the country, except that this major hub has not received upgrading and improvements for over 20 years or more.

This paper goes into a brief history of the concrete pavement that forms one of the main links between the Cape Town metropolitan centre and the other centres of the Western Cape. The paper details the transport challenges that lead to the project to upgrade a crucial part of this transport hub. The paper then goes into broad specifics of the project design and construction with the main focus on the recycling of material by the process of down-cycling in order to facilitate the construction of a modern asphalt pavement. Finally the paper deals with a few of the lessons learned.

## 2. BACKGROUND

### 2.1 Concrete Pavement

The jointed concrete pavement linking the suburbs of Cape Town with Somerset West in the province of the Western Cape is probably one of the oldest jointed concrete pavement freeway constructed to a national route standard in South Africa and probably in Africa. The road pavement project was completed in the very early 1970's by a highly skilled team of engineering participants, namely, Regional Engineer of Department of Transport Cape Town, Hawkins Hawkins and Osborn Consulting Civil Engineers and Savage and Lovemore Civil Engineering Contractors (Hawkins Hawkins & Osborn Consulting Civil Engineers, 1972).

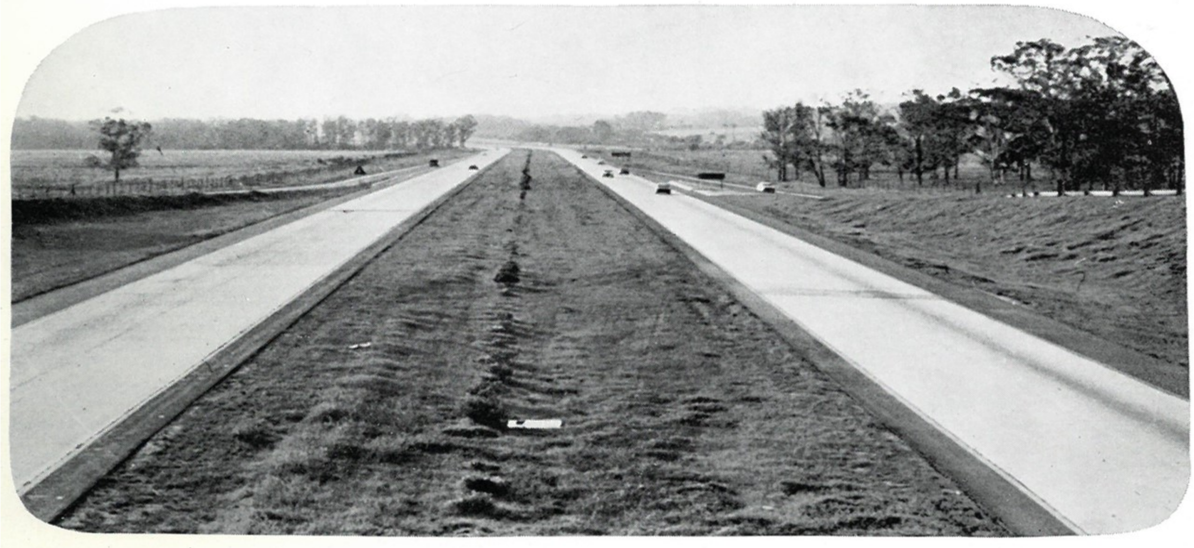

**Figure 1: Old National Route 2 prior to 1974**

The existing national route before the 1970's project was implemented was a two lane single carriageway road constructed from granular materials and sealed with a stone seal. The 1970's project upgraded this facility to a four lane dual carriageway. The interesting engineering challenge however was to construct the project using jointed concrete and utilising a slip-form paving train. A batching plant that could batch up to two thousand cubic metres of concrete per day was set up and concrete using the local hornfels stone was produced.

The paving train placed two full lanes around 8 metres in width in one operation, firstly placing a 100 mm layer of cement stabilised basecourse on top of a 75 mm layer of granular subbase and secondly placing a 200 mm layer of concrete. The concrete placement was combined with the insertion of polythene tape to separate the two concrete lanes with a centre longitudinal construction joint and used automatic tie-bar inserting techniques to place high tensile steel tie-bars down the split middle. At the end of each working day, steel dowels were placed for continuity to form keyed dowelled transverse construction joints. The surface of the concrete was textured using a hessian drag and sprayed with a curing compound. Transverse joints were cut to form weakened plane joints at approximately 4 metre intervals which resulted in the panel layout structure of the jointed concrete pavement.


**Figure 2: Concrete Construction Train**

The jointed concrete pavement was meant to operate for up to 40 years with very little maintenance, if not for the appearance of some distress after a couple of years of operation. This distress was visible as fine cracks which, although not fully understood at the time, was an engineering material phenomenon that would later become known as aggregate alkali reaction or aggregate sulphate reaction. In this chemical reaction and process, water that seeped into the concrete began a reaction with the Sodium Monoxide in the cement and the minerals in the hornfels rock. In this reaction the concrete swelled slightly and the action caused minor cracking on the concrete surface but significantly more severe reaction at the concrete joints. At the joints the concrete swelling caused bursting and subsequent joint failure.

Rehabilitation was needed and so a significant number of the joints were repaired, certain drains were installed and the concrete surface was overlaid with asphalt to attempt to seal the pavement from the effects of water. The overlay was made up of firstly a Stress Absorbing Membrane Interlayer (SAMI) constructed from a bitumen rubber single seal to deal with concrete movement and secondly an asphalt wearing course overlay (National Department of Transport, 1996).

### 2.2 Transport Situation

The transport modelling and planning investigation around the Cape Town International Airport transport hub identified, firstly the need for additional capacity in the main access from the national route and secondly the need for diversified mobility in the forms of transport, other than traditional vehicle access such as motor cars and traditional busses.

## 3. PROJECT DESIGN

### 3.1 Transport Planning

During the past 10 years, an integrated bus rapid transit system different to the traditional bus transport systems has been rolled out in the Cape Metropolitan area linking the Cape Town centre with many of the outer suburbs. This system has pushed into the corridor of the national route 2 and is both a solution to congestion and a catalyst for development with a demand for infrastructure upgrades. The basic layout for the transport hub serves to both improve the congestion on the routes as well as produce nodes for future transport links.

The new overall project that morphed out of this investigation and planning process involves both adding a median lane to both of the carriageways of the national route to improve the carrying capacity of the major transport artery as well as laying the groundwork for an upgraded relocated interchange. This groundwork involved the early works for replacing one of the existing interchanges in this transport hub with a new interchange. The new interchange is designed to accommodate both traditional bus transport as well as the more modern integrated bus rapid transit systems.

Economics dictated that only a partial stage of this new transport plan could be implemented in 2016 and so the overall project was reduced to essentially just provide rehabilitate the existing length of road as well as provide the additional median lane between the Borcherds Quarry Interchange and the Swartklip Interchange, a distance of 4.4 kilometres. The project being mainly a road widening project did include the necessary widening of the existing Borcherds Quarry Interchange Bridge but also included the construction of the foundation piles for the future relocated Interchange for future traffic accommodation convenience. The future planned interchange is located just to the east of the existing interchange.

## 3.2 Geometric Design

No significant changes were effected in the vertical alignment of the section of road. The cross section was altered from two lanes and paved shoulders, one of the outside edge and also in the median per carriageway to a cross section with three lanes and outside edge and median paved shoulders per carriageway.

## 3.3 Pavement Design

The pavement design phase of this project covered a full rehabilitation assessment, rehabilitation design and new pavement design. Also carried out was a detailed project level economic analysis.

### *3.3.1 Pavement Assessment*

As-built information was obtained from both the Provincial Government, South African National Roads Agency and the original consulting engineers describe under Background of this paper. A full visual assessment was carried out and particular focus was on the geometry of concrete jointing reflecting through the bituminous surfacing and SAMI. Falling Weight Deflectometer (FWD) testing was carried out with drops at both the centre and on the transverse joints of the concrete panels.

### *3.3.2 Road Rehabilitation Design*

Using the Rubicon software, back-analysis was performed on the pavement deflection measurements to estimate the elastic moduli of the pavement layers. The layer strengths were used as input into the cncPAVE software to predict remaining pavement life and required additional concrete thickness to provide future design life. The additional concrete thickness required to satisfy the future design life requirement was converted to bituminous overlay thickness.

The requirement of either a concrete or asphalt overlay with associated risks and inconveniences of either a single approximately 150mm bonded concrete overlay or time-related bituminous overlays totalling around 250mm were debated. The outcome of the debate was to rebuild the pavement as a flexible pavement utilising all the existing materials as supporting layers to an asphalt base and surfacing pavement.

*3.3.3 Economic Analysis*

The modelling of the economics and cost benefits for the project was carried out using both a combination of the Cost Benefit matrix approach as well as the accepted HDM4 economic evaluation software. This double barrelled approach was used to evaluate up to four alternative project strategies related mainly to the local network and route economics and benefits using essentially the single pavement strategy of full re-use with concrete re-cycling and new asphalt upper layers.

3.4 Structures Design

This paper will not detail the structural design for either the Borcherds Quarry Interchange bridge widening, nor the piling for the future interchange of this project. This phase of the project is not yet fully completed.

## 4. CONSTRUCTION

4.1 Construction Program

Budget constraints as well as uncertainties from the role players resulted in the project excluding the full construction of the new interchange and only the piles were installed for the future planning.

4.2 Reclaiming of Concrete

Within the 4.4 km of the existing road prism, 13 000 cubic metres of concrete material and 5 000 cubic metres of asphalt material (SAMI and asphalt overlay), was available to be recovered from the existing layer-works. This approximately 50mm layer of Reclaimed Asphalt Material (RAP) was all fully recovered for re-use in the new pavement layer-works.

**Figure 3: Reclaiming RAP**

The specifications surrounding the re-use of the concrete are quite simplistic, are carried out in accordance with COLTO (Standard Specifications for Road and Bridge Works for State Road Authorities, 1988) specifications and are broadly summarised below:

- Provision of a stockpile site and haul to and from the stockpile site to the work zones;
- Complete breakdown and crushing of recovered concrete and RAP to conform to minimum of COLTO G5 specifications;
- Allowance to add fines during the crushing process to ensure sufficient materials in the sand and dust grading regions.


**Figure 4: Breaking up Concrete**

## 4.3 Crushing and Blending Process

The specifications required the concrete material to be broken down and crushed at a stockpiling site to comply with COLTO G5 material classification in terms of grading modulus. This requirement was to provide either COLTO G5 material that could be used for both upper selected pavement layers or for the aggregate for the COLTO C3 cement stabilised subbase layers. The specifications allowed the existing bituminous surfacing materials which were part of the reclaiming process to be included in the final material mix. The processing of the reclaimed material took place close to the site on private commercial property and did not trigger any environmental responses.

**Figure 5: Crushing and Blending Concrete and RAP**

The RAP was blended with crushed concrete. No additional sand was necessary to be added to the blend. Approximately 500 tons of concrete and 200 tons of RAP was put through the two stage crusher and blended on a daily basis.

## 4.4 Supporting Layer-works Processing

### *4.4.1 Blended Concrete and RAP*

The Blended concrete and RAP material was used for both un-stabilised selected layer-works complying with COLTO specifications, G6 and G5, as well as cement stabilised subbase complying with COLTO C3 standards. The grading modulus of the blended aggregate was around 2.6 on this project, achieved with two stage crushing. This fairly high grading modulus resulted in the material being more difficult to work with and test. The blended material exhibited no plasticity. Optimum moisture contents (OMC) were between 10 and 12 as expected in recovered material but adequate compaction was achieved at 50% to 60% OMC.


**Figure 6: Stabilising Blended Material**

The blended material un-stabilised exhibited good CBRs as a result of the good grading and complied with COLTO G4 specifications. All testing on the project was in accordance with TMH1 (Technical Methods for Highways, Standard Methods of Testing Road Construction Materials, 1986). The blended material exhibited good and adequate UCS and ITS results. The blended material was easily combined with cement, processed as a stabilised subbase and compacted to 98% modified AASHTO density. UCS results always exceeded 1.5 MPa, meeting COLTO C3 specifications and often achieving over 3.0 MPa as well as uniformly recorded adequate ITS results around 200 kPa to 250 kPa.

The asphalt pavement layers for the median widening were supported by a 250mm cement stabilised crushed stone of COLTO G5 quality material stabilised with 3% CEM II 32.5 cement. The stabilised subbase layers of the median widening were supported by 150mm new commercial selected layer of COLTO G6 quality.


**Figure 7: Final Processing of Blended Material**

The asphalt pavement layers for the remaining cross section where the concrete was recovered were supported by a 250mm for the middle lane and 300mm for the slow lane cement stabilised recovered processed concrete material with around 10% of recovered asphalt material stabilised with 3% CEM II 32.5 cement. The stabilised subbase layers of this cross section were supported by 150mm of selected layer produced from un-stabilised recovered processed concrete material also with around 10% of recovered asphalt material.

*4.4.2 Subgrade Layers*

The subgrades in all cases was mainly sandy material of COLTO G8 quality found in-situ in the road prism. In the case of the slow and middle lanes, the upper zone of 200mm was stabilised with 3% CEM II 32.5, to render the outside edges of the corridor resistant to the burrowing of local vermin.

## 4.5 Asphalt Pavement Layers

The asphalt pavement layers consisted of, firstly a continuously graded base mix with 37,5mm maximum stone size with a polymer modified binder of TG1 A-P1 specification (Technical Guideline 1, 2015) at 4.1%, secondly a continuously graded surfacing mix with 13mm maximum stone size and a polymer modified binder of TG1 A-E2 specification at 5.3% and finally an ultra-thin friction course (UTFC) with 13mm maximum stone size with a polymer modified binder of TG1 A-E2 specification at 4.3%.

These mixes were placed mainly in the months excluding the traditional winter embargo months in the Cape Town area, however some lots of asphalt base were placed during the embargo months.

**Figure 8: Placing Asphalt Base**

**Figure 9: Placing Asphalt UTFC**

The larger stone continuously graded base mix with 37,5mm maximum stone size as used on this project is not often used anymore in the Cape due to differing preferences by the authorities. It has however been successfully used on many projects with negligible distress such as deformation and cracking on industrial and town roads for over 20 years. This material is also well placed to assist in the accommodation of traffic with changing road closures, especially in the wetter months of the year as long as the surface is protected with a bituminous fog if necessary.

## 5. LESSONS LEARNED

### 5.1 Economics

Because the crusher site was located in the nearby town of Philippi as opposed to the road reserve, the cost per cubic metre of using recycled material, rather than commercially available material, was around 20% more expensive. Haulage of the material to the crusher site was significant due to the difficulty of accessing the lanes furthest away. If crushing were to have taken place in the road reserve of the site, significant savings of at least 30% from haulage could have been realised which would have made the recovered material cheaper than commercial materials.

Further indirect costs benefits to the City of Cape Town are important when considering the operational costs of landfilling spoil material which can be around R400 per ton. If one assumes a density of 1.6 tons per cubic metre, this project may have resulted in an indirect cost saving of over R8million for the concrete aggregate, and over R3 million for the milled SAMI and RAP.

### 5.2 Materials

Recovered concrete from any pavement structure, even with AAR/ASR damage is useful for reuse in pavement supporting layers, many times with no further addition of fine make-up aggregate fractions. This use can be for high quality upper pavement layers such as natural or stabilised subbases used to support high quality asphalt base and surfacing layers.

Targeting a grading modulus for recovered blends for use in subbase layers of at least 2.3 is recommended. The higher grading moduli achieved on this project blended material resulted in the material being more difficult to work with. Using South African National Standards, SANS 3001 (South African National Standards, 2017) over TMH1 gives a more conservative recovered material quality result. In this case the recovered blend tested as COLTO G5 when following SANS rather than COLTO G4 compliant when following TMH1. Crushing to 37 mm for this COLTO G5 target is recommended, as crushing to a larger particle size of 53 mm made testing of the material more difficult with higher variability in the results.

Recovered and crushed material such as this hornfels aggregate blended with the asphalt exhibited higher OMC than most local commercial crushed hornfels stone aggregates. These blended aggregate were typically easier to compact than the local commercial hornfels crushed aggregate at lower moisture contents of up to half of the OMC.

The use of RAP in high quality recovered materials such as concrete generally does not improve the CBR strengths at the lower compactions due to the lack of cohesion between asphalt particles and the remainder of the mix. Blending RAP into recovered aggregates is however a useful place for accommodating this potential spoil, reducing cost of spoil and need for new aggregate. As demonstrated during the project, the required material performance can still be achieved when such asphalt is included in the blends.

5.3 General

Local concrete found in pavements must not be classified as building rubble not desirable to be used in high quality pavement layer-works as some practitioners in the past have suggested. On the contrary, the use of these materials with correct management should be encouraged.

## 6. REFERENCES

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