Secondary and Feeder Road Development Program

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Research aspects of the Secondary and Feeder Road Development Program in Zimbabwe are described. The program includes construction, upgrading, and maintenance of approximately 230 km of low-volume roads. The main research goals are (a) to determine when it may be feasible to seal a gravel road, (b) to assess the feasibility of an improved gravel wearing course, (c) to evaluate whether unsoaked CBRs could be used as design CBRs, and (d) to provide recommendations on new design, construction, and maintenance methods for low-volume roads in Zimbabwe.

The Department of State Roads (DSR) within the Ministry of Transport (MoT) is the road authority in Zimbabwe. DSR delegates some of its power to rural district councils, town councils, and municipalities. The total road network in the country is over 100 000 km. DSR is in charge of construction and maintenance on all main roads and some secondary and feeder roads. These roads have been constructed to a high technical standard, and the road network is considered one of the best in Africa.

Soon after gaining independence in 1980, the government of Zimbabwe decided to open up some previously undeveloped communal areas. The amount of traffic in these areas is low (usually less than 100 vpd), but it is increasing as agricultural output increases. Roads in these areas could not all be built using the traditional high standard for blacktop roads. Therefore, the government decided to look for alternative economical ways of building and maintaining low-volume roads in communal rural areas using methods and materials suitable to the Zimbabwean environment.

In 1986, an agreement was reached between the governments of Zimbabwe and Sweden to implement the Secondary and Feeder Road Development Program (SFRDP). This project was proposed by the Swedish National Road Consulting AB (SweRoad). The study program was presented in 1987, and the design reports for the roads to be constructed were finalized during 1988 and 1989. The construction and upgrading program started in 1989, two roads will be completed in 1990, and the remainder will be completed during 1991. One of the project roads was constructed in 1984 as a demonstration project and is included for maintenance monitoring.

PROGRAM GOALS

The four main goals of this program are to

- Initiate and introduce alternative design, construction, and maintenance concepts for low-volume roads in Zimbabwe;
- Evaluate and analyze these concepts from technical, financial, and economic points of view and arrive at recommendations regarding designs, construction methods, and maintenance strategies suitable for similar roads in Zimbabwe;
- Improve or upgrade some existing roads and tracks to higher standards; and
- Impart technical knowledge to local Zimbabweans on the design, construction, maintenance, and research methods for low-volume roads.

It is hoped that the research will answer the following two questions:

1. Is it feasible to increase the quality of the current gravel wearing course (GWC)?
2. At what traffic volumes would it be financially or economically feasible to upgrade existing earth and gravel roads using the project concept?

PROJECT ROADS

Five project roads located in five provinces servicing communal areas were chosen for the program. These roads are in different climatic, topographical, and geological environments. New road construction is envisaged for some of the roads. Others will be upgraded to a better standard. Descriptions of the roads are presented in Tables 1 and 2.

Originally it was proposed that the project roads include one or two projects constructed by labor-intensive methods to allow comparison of total financial costs, economic effects, technical standards, and benefits. This part of the project has been delayed but may be included in the final evaluation.

The design, construction, and maintenance of these roads differ to some extent from the standard approach in Zimbabwe, and the actual trials will be carried out on a number of test sections along the roads.

PROJECT ORGANIZATION

Because the project contains a large research component, MoT requested and received assistance not only from SweRoad but also from the Swedish Road and Traffic Research Institute (VTI) and the Transport and Road Research Laboratory

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TABLE 1 SFRDP PROJECT ROADS—CHARACTERISTICS

Road	Length (km)	Type	Traffic (vpd)	Remarks
St Joseph-Maphisa km 42 + 500–89 + 100	46	Gravel (completed)	60–70	Upgrading including 10-km seal
Nyika-Zaka km 0 + 000–20 + 000	20	Surfaced	200–250	New construction
Karoi-Binga		Surfaced	110–250	New construction/improvements
km 0 + 000–38 + 000	38			
km 38 + 000–80 + 000	42	Gravel (completed)	10–50	Upgrading/improvements
Headlands-Mayo	11 + 53	Surfaced/gravel (11 km completed)	100	8 km surfaced; 2 km gravel; maintenance on rest
Kamativi-Binga	20	Surfaced (completed 1984)	40	Monitoring of deterioration; maintenance

TABLE 2 SFRDP PROJECT ROADS—ENVIRONMENT

Road	Rainfall (mm)	Soil Type	Economic Activity
St Joseph-Maphisa	400–500	Alkali sand with clay pockets	Agriculture; irrigation schemes; cattle ranching
Nyika-Zaka	600–800	Gneissic sand with clay and sandy clay	Agriculture on subsistence level
Karoi-Binga	800–900	Gneissic sand with clay and sandy clay	Agriculture; fishing
Headlands-Mayo	1000–1200	Granitic and gneissic sands and sandy clay	Agriculture; livestock
Kamativi-Binga	600–800	Expansive shale soils	Fishing; tourism; agriculture on subsistence level

(TRRL) in the United Kingdom. To facilitate cooperation between the supporting agencies and MoT staff and to ensure overall control by MoT, project monitoring was delegated to a special unit within MoT—the Project Monitoring and Evaluation unit (PME). PME is staffed by engineers and researchers from MoT, the Swedish National Road Administration, and VTI, with short-term input from TRRL.

GENERAL APPROACH AND IMPLEMENTATION

Design

The project roads were designed using the existing roads as much as possible but aiming at design speeds of 80 or 60 km/hr depending on road type and terrain. Deviations were allowed where strict adherence to these design criteria could not be justified economically or considering traffic safety aspects. The survey and design were carried out using modern instruments and computers and with a minimum of the standard MoT referencing. The design program used was GEOSECMA (*1*,*2*).

The pavement design for the sealed roads was based on MoT recommendations (*3*), substituting Texas triaxial tests with California bearing ratio (CBR) values as the main design criteria and reducing the number of pavement layers to subbase and base only. There was a possibility that design CBRs taken at equilibrium or optimum moisture content (OMC) could be used instead of using soaked CBRs, not only at designated test sections but also at other places where the conditions were favorable. However, the design consultant could not take advantage of this opportunity because of a lack of reliable data on OMCs and because of unexplained variations in the unsoaked test results achieved through DCP tests. Both of these aspects have been covered in the research program and the PME design for improvements. The latter includes the use of existing GWC as subbase (Headlands-Mayo) or base (Kamativi-Binga), assuming unsoaked conditions (*4*,*5*).

The surface of the sealed roads is being constructed with a graded gravel aggregate known as Otta-seal or YIG (see Figure 1). This surface is used mainly in Scandinavia but also on low-volume roads in Botswana and Kenya (*6*).

The Otta-seal will provide a dense, flexible cover that, depending on the bitumen used, could have self-sealing abilities. Previous experiences in Scandinavia and Botswana indicate that the best results are achieved by using a double seal, with the second seal applied 2 to 15 months later.

The pavement design for the gravel roads is new to Zimbabwe and was based on the specifications presented in Table 3.

The GWC used on the project roads should fall as close as possible to the inner envelope shown in Figure 2, have a PI of 10 to 15, and preferably have a clay content of at least 5 percent.

The project GWC is thinner than the standard layer (10 cm versus 15 cm) but of considerably higher quality than the normal MoT standard, by which gravel roads can have a variable surface quality.

Construction

As mentioned, construction is being carried out using MoT normal construction and improvement units. Assistance is provided for planning and follow-up as well as for direct supervision of the test sections (e.g., conditional approvals of compaction are not accepted). Detailed referencing of the road is carried out during the construction stage.

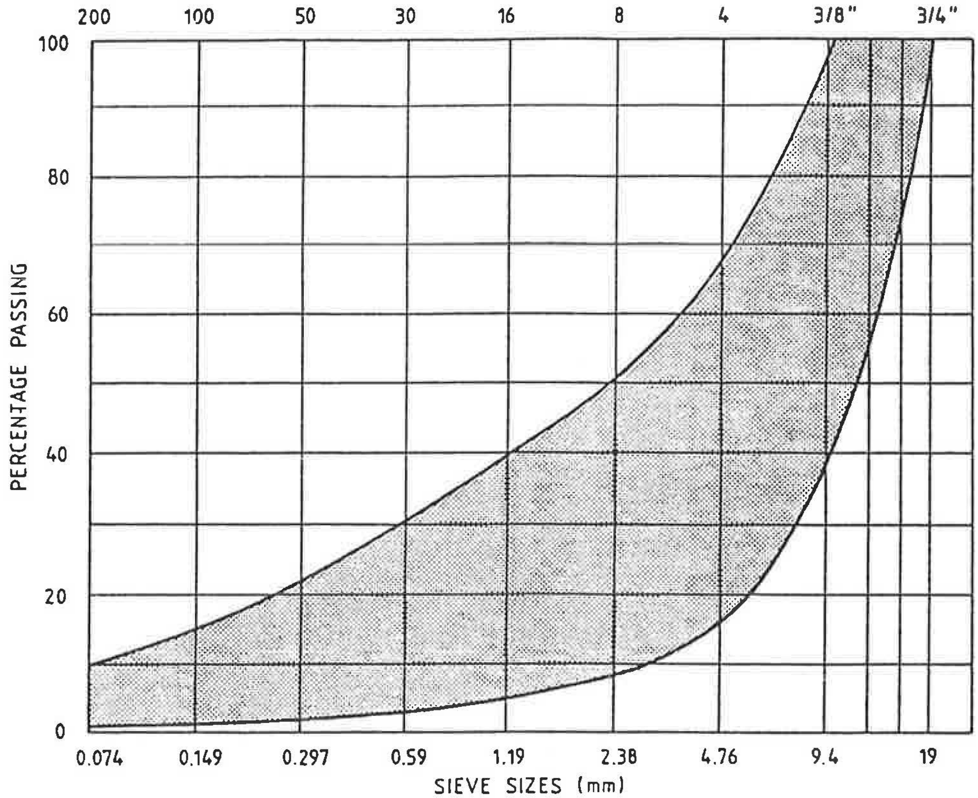

FIGURE 1 Grading envelope for specification of Otta-seal.

TABLE 3 PAVEMENT DESIGN FOR GRAVEL ROADS

Subgrade Condition	Thickness of Wearing Course (mm)	Thickness of Selected Fill or Subbase (mm)	Total Thickness (mm)
>SG 9	100	0	100
SG 5	100	125	225
SG 3	100	200	300
<SG 3	100	300	400

NOTE: Pavement standard design = 0.05 M. SG 5 = subgrade with 5 percent < CBR < 9 percent. The subgrade condition will be assessed from soaked CBR tests carried out at a compacted density of 90 percent modified AASHTO and at the modified AASHTO OMC. The subgrade will be compacted to a density of 90 percent or greater of modified AASHTO maximum dry density. The selected fill or subbase will be compacted to a density of 93 percent or greater of modified AASHTO maximum dry density. The wearing course will be compacted to a density of 95 percent or greater of modified AASHTO maximum dry density. The moisture content used for compaction of the wearing course and the selected fill or subbase will be within 2 percent of the OMC for the modified AASHTO compaction. This specification is only applicable for the test sections.

The maximum stone size for the GWC was set at 20 mm (Scandinavian specifications). Adherence to the envelope will normally require that the GWC be crushed or screened, or both. Therefore, mobile crusher/screener suitable for the conditions in Zimbabwe was procured for the project. The importance of controlling the maximum stone size has been supported by other research in the region (*7*). In addition to crushing or screening, the gravel material must be mixed with clay in some areas to meet the PI requirement.

Compared with existing MoT standard design and construction methods, construction costs for the project are about the same for the gravel roads but are lower for the bitumen roads. Available figures (excluding Nyika-Zaka) are presented in Table 4.

Maintenance

The project will include evaluation of different maintenance policies, especially for routine gravel road maintenance. The surface width (6 m) was selected on the basis of studies that used graders with mounted windrow eliminators, which increased grading productivity by 60 percent in Zimbabwe (*8*).

Another grader attachment used successfully on the improvement projects is the ditch plough, which is mounted directly on the grader blade and has proven to be very cost efficient with loose and normal materials. The windrow eliminator and ditch plough are now manufactured in Zimbabwe.

RESEARCH PROGRAM

Main Goals

To be able to provide well-founded and objective recommendations, a sizable research program was added to the project. The program was designed to allow comparisons and use of results from similar research (e.g., in Kenya, India, and Brazil). The research will be concentrated on the following issues and objectives:

- Determination of when it may be feasible to seal a gravel road,

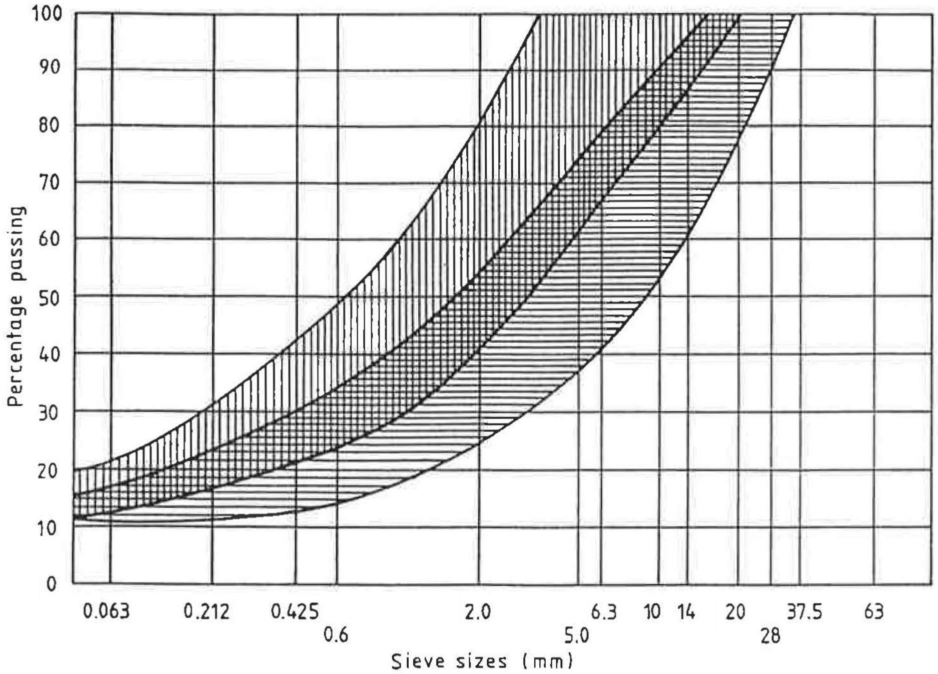

FIGURE 2 Grading envelope for gravel wearing course.

TABLE 4 CONSTRUCTION COSTS BY ROAD TYPE

Road Type	Width (m)	Construction Cost (Z$ per km)
Bitumen MoT design	6/7[a]	315 000
Bitumen, Project Design 1	6/7	210 000
Bitumen, Project Design 2	6/6	110 000
Gravel MoT	0/6	110 000
Gravel, Project Design	0/6	110 000

[a]6-m seal on 7-m formation.
NOTE: Costs reflect 1991 prices. For bitumen roads, Project Design 1 = standard design done by SweRoad and Project Design 2 = design by PME on improvements, using unsoaked design CBR (normally one step lower in the design table) and without deviations from existing road alignment.

- Determination of the feasibility of an improved GWC,
- Evaluation of whether unsoaked CBRs could be used as design CBRs for low-volume sealed roads in certain parts of Zimbabwe,
- Determination of the feasibility of using DCP tests or the Clegg hammer to obtain design CBR values as a supplement to normal methods,
- Evaluation of new construction and maintenance methods, and
- Development of and recommendations for design charts for low-volume roads in Zimbabwe.

Variables

The variables to be considered in the research program are as follows:

Gravel Roads

- Improved-quality wearing course,
- Reduced thickness of wearing course with improved-quality material,
- Different maintenance strategies,
- Different traffic levels (depending on the siting of the test sections),
- Different climate (depending on the siting of the test sections), and
- Use of dust palliatives (i.e., surface binders).

Sealed Roads

- Different bituminous seals including priming and surface treatment,
- Different pavement thickness designs,
- Different quality materials for road base,
- Different shoulder treatment,
- Different traffic levels (depending on the siting of the test sections), and
- Different climate (depending on the siting of the test sections).

Table 5 presents details on variables and measurement methods.

Test Sections

The program includes 26 test sections, of which 9 are located on gravel road sections, 14 on designed bitumen sections, and 3 on improved sealed sections. The gravel road test sections (1 km each) are further subdivided into three subsections with variable maintenance levels. Most of the test sections are straight and level with uniform subgrades and include control sections of standard MoT design. An example of the test sections selected for one of the project roads, Headlands-Mayo, is shown in Figure 3.

TABLE 5 MONITORING OF ROAD SECTIONS

Variable	Frequency	Method/Equipment	Applicable Road Type
Traffic composition	Twice/year: 7 days, 6 am to 6 pm	Manual (MoT)	G;S[a]
Traffic volume	7 days, 6 am to 6 pm	Manual plus counters (MoT)	G;S
Traffic loading	7 days, 6 am to 6 pm	Loadometers (MoT) or weighbridges	G;S
Traffic speed	Before and after maintenance	Radar pistol and clocks	G;S
Pavement strength and condition	Beginning and end of wet season and middle of dry season (G); twice a year (S)	Instructions for measurements separately issued	G;S
In situ CBR	Beginning and end of wet season and middle of dry season (G); twice a year (S)	DCP	G;S
Density	Beginning and end of wet season and middle of dry season (G); twice a year (S)	Troxler or CPN Strata Gauge	G;S
Moisture content	Beginning and end of wet season and middle of dry season (G); twice a year (S)	Troxler or CPN Strata Gauge	G;S
Impact value	Beginning and end of wet season and middle of dry season (G); twice a year (S)	Clegg Impact Tester	G
Indicator tests	Immediately after construction, after 1 year, then yearly	Samples for grading, PI, standard tests (in transition zones between test sections)	G
Deflection	Once before construction, then twice a year (end of dry season and end of wet season)	FWD	G;S
Deformation (G)	Before and after maintenance plus monthly	Instructions in appendix	G
Corrugation	Before and after maintenance plus monthly	Assessment, photos, and sketch	G
Potholes	Before and after maintenance plus monthly	Assessment, photos, and sketch	G
Dusting	Before and after maintenance plus monthly	Assessment	G
Looseness	Before and after maintenance plus monthly	Assessment	G
Rutting (maximum rut depth)	Before and after maintenance plus monthly	2-m straightedge over wheel tracks in several cross sections along test sections	G
Deformation (S)	Twice/year	Instructions in separate report	S
Cracking	Twice/year	A frame (1 m^2) at each deflection chainage point.	
Rutting (maximum rut depth)	Twice/year	2-m straightedge over wheel tracks in several cross sections along test sections.	
Surface texture	Twice/year	Preferably the Mini Texture Meter (TRRL); otherwise, UCON sand patch test in each wheel track and one in centerline along each test section	
Roughness	Before and after maintenance plus monthly	Bump Integrator and Abay beam	G
Roughness	Twice first year, then reassessed	Bump Integrator and Abay beam	S
Gravel loss	• Sections with nil maintenance: 3 times/ year (4-month interval)	Leveling in cross sections with optical instruments. Cross-sections initially have	G

TABLE 5 *(continued on next page)*

TABLE 5 *(continued)*

Variable	Frequency	Method/Equipment	Applicable Road Type
	• Sections with one heavy grading: before and after treatment • Sections with two heavy gradings: before and after each treatment	c/c 5 m for comparison. A change to c/c 50 m over whole length of test section might be proposed after some experience.	
Permeability in pavement	Once/year	Not yet specified	S
Groundwater	If necessary	Monthly recording of GWL in pipes in open ground adjacent to road	G;S
Rainfall	Daily during wet season	Rain gauge installed at some official buildings (e.g., a school close to project roads)	G;S

[a]G = gravel roads; S = surfaced roads.
NOTE: Visual inspections will also be carried out two or three times per year to subjectively assess the road conditions according to standardized inspection forms used in the 1985 and 1989 Zimbabwe Road Condition Surveys.

TEST SECTIONS ON ROAD 239 HEADLANDS - MAYO (HSMO)

GRAVEL SURFACED KM 9 - 11

TEST SECTION NO	1			2
CHAINAGE	KM 9 +000 - 10 +000			10 +000 - 11 +000
LENGTH / WIDTH	1000 M / 6 M			1000 M / 6 M
SURFACING	WC 100 MM ACC. TO PROJ.			WC 100 MM ACC. TO MOT
SUBBASE / SELECTED FILL	175 MM			175 MM
SUBGRADE	SG 5			SG 5
MAINTENANCE / LENGTH	NIL 300 M	1 GRADING 300 M	2 GRADINGS 300 M	ACC. TO SECTION 1'

SEALED SURFACED KM 0 - 9

TEST SECTION NO	1'
CHAINAGE	KM 5 +800 - 6 +300
LENGTH / WIDTH	500 M / 6 M
SURFACING	SINGLE OTTA SEAL
BASE	150 MM
SUBBASE	0
SUBGRADE	SG 9

FIGURE 3 Test sections on project road.

Detailed preinvestigations have been performed on all test sections. The preinvestigations included soil classifications, layer thicknesses, in situ and laboratory CBR tests, moisture contents, PI values, Clegg hammer and DCP values, falling weight deflectometer (FWD) data, and roughness data over time.

Time Schedule and Resources

The field measurements will require at least three field assistants supported by two full-time researchers in the PME during the first phase, which should end in mid-1992. At that time, research on the gravel roads should be complete and a preliminary report on the sealed roads should be made available.

The final report on the sealed roads cannot be expected until at least 5 years after the roads have been constructed, and the final answers on some questions may only be available after 8 to 10 years or when a complete overlay is required.

Intermediate Conclusions

From the preinvestigations and subsequent monitoring of the test sections, the following preliminary conclusions have been made:

- The lowest in situ CBR values (down to 600 mm) generally exceed the laboratory soaked CBR values, indicating that a pavement design that is based on the latter would be very conservative. The results tend to support upgrading the subgrade classification by at least one step (*9*).
- Current design methodology, which is based on a limited number of soaked CBR values and grouping of subgrade samples, is unreliable (*9*).
- A design methodology that is based on a large number of DCP values taken in March and assessed statistically would be more informative for the designer (*9*).
- A good correlation between DCP and CIV has only been established in sand. For other materials, it has not been possible to establish a general relationship (*10*).
- The performance of the Kamativi-Binga and Headlands-Mayo roads supports the view that low-cost sealed roads are more cost efficient than standard gravel roads in Zimbabwe (*4–6*).

EVALUATION

Evaluation of the alternatives will be based both on performance (i.e., assessments of standard and rate of deterioration) and on financial and economic costs. The economic costs will be calculated using both the HDM III and RTIM 2 computer models. In addition, checks will be made with the NTS (*11*). Accident costs will probably not be included in the economic calculations because their influence will likely be marginal.

The more detailed performance evaluations and individual relationships found may possibly be reported continuously, at least on the gravel road trials. Findings and results documented during 1990 and 1991 will be presented at the TRB 5th International Conference on Low-Volume Roads.

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