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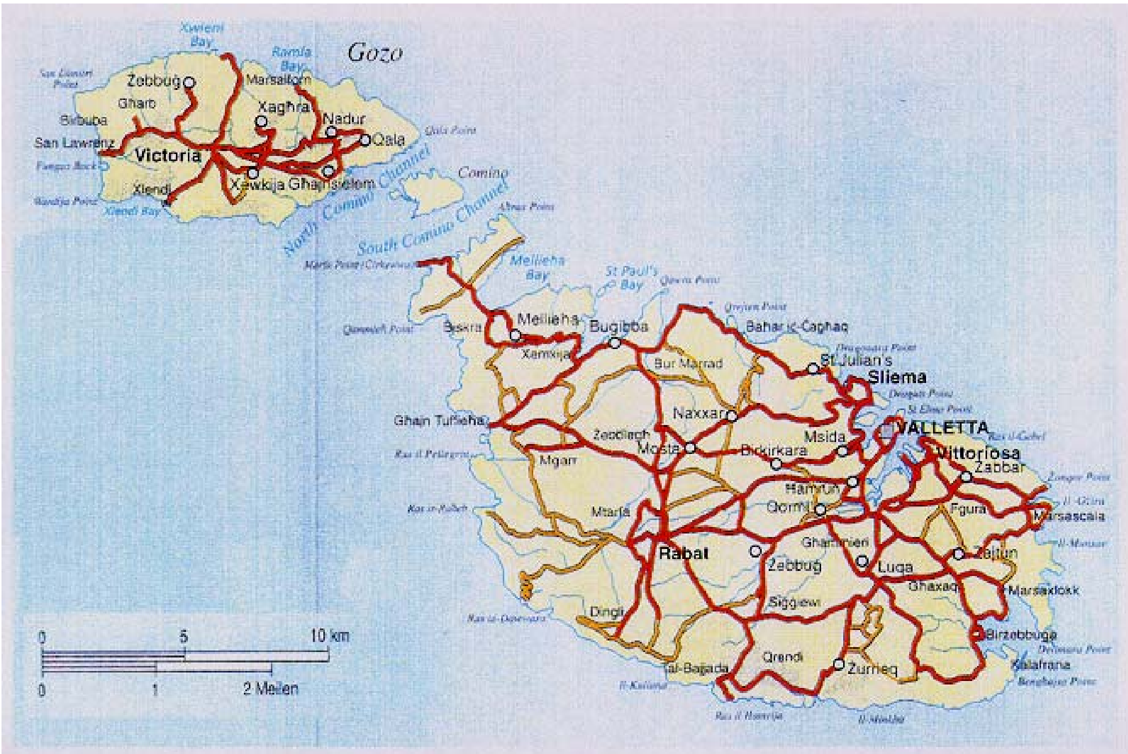

Expertise Regarding Road Engineering for Services to the Government of Malta

Directives for the Standardisation of Pavements for Traffic Areas

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Government of Malta
Ministry for Transport and Communications

Roads Department

Directives for the Standardisation of Pavements of Traffic Areas

Edition 2000

FOREWORD

The Road Engineering Consultants from the German Agency for Technical Cooperation, (GTZ) in association with the Roads Department of the Ministry have now completed the road condition survey of the arterial and distributor roads and also of non urban roads with a linking function. A Road Restoration Master Plan has therefore been drawn up for the upgrading of the roads network.

The Government is now moving to the implimentation phase to address improvement in those sections of the network that these reports have shown to warrant the earliest attention.

Works on certain projects have already commenced whilst others will begin to be implemented in the coming months. Amongst the major road works undertaken are the upgrading of Halfar Road, Mdina Road, Salini Coast Road, Cirkewwa Road, and Mtarfa By-Pass. Works are expected to commence shortly in Psaila Street whilst major works contracts are expected to be adjudicated shortly for the reconstruction of Hompesh Road in Fgura, the Burmarrad – Airport road, the Salini – Iklin road and for the construction of the new north ring road at Mosta.

The implementation of these projects entails substantial financial commitment, the government having allocated seven million maltese liri under the Roads capital allocation for 2000.This is by far the highest allocation ever in this sector and does not include other allocations to Local Councils and Utilities for associated improvements and road works and represents the Governmnet's strong commitment to upgrade the country's road network.

It is the responsibility of the Roads Department, Local Councils and the Utilities to ensure that such works are carried out to the highest standards to ensure the most cost effective returns on investment.

To achieve these aims, it is essential that scientifically proven construction criteria are established and observed throughout the sector. The directives and technical considerations being presented in this publication should therefore serve as sound guidelines to all those engaged in the planning and implementation of road works.

It is a proven fact that the assumed service life of a pavement is only guaranteed if the thickness and the bearing capacity of the structure meet the stresses and strains caused by traffic loading. Only a standardized approach can ensure that construction methods are applied which are both technically and economically optimal.

The correct pavement thickness is chosen from the range of standardized pavements and its selection would be dependent on the proposed construction method being adopted and the road's classification. This procedure ensures that no structural damage will occur during the expected service life of the road infrastructure, which would otherwise reduce the performance value of the trafficked areas.

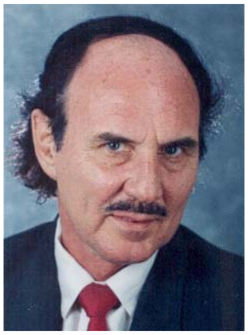
In formulating these directives, Prof. Dr. Klaus Müller has most clearly drawn extensively on his vast professional expertise and experience in this sector and on the results obtained from the detailed structural survey of roads in Malta and Gozo, that was carried out during the last two years.

The directives in this publication regulate new construction as well as the renewal of trafficked areas. In issuing them and their expected adoption by all entities responsible for the conduct of road works the aim is to bring such works practice into line with the latest international developments in road construction technology.

I am certain that they shall serve as the basis for substantial improvement in local road construction and maintenance practices for the overall benefit of all road users.

Ċensu Galea
Minister for Transport and Communications

11th July, 2000



Prof. Dr. Klaus Müller Dipl-Ing., Dipl-Volkswirt, Senior Researcher at the German Federal Highways Research Institute (BASt) is presently serving as Consultant to the Ministry for Transport and Communications Roads Department, under a contract between the Government of Malta and the German Agency for Technical Co-operation (GTZ).

At BASt Prof. Müller was assigned to Division S - Highway Engineering - which covers the fields of highway maintenance, earthworks, soil mechanics and ground investigation, minerals, pavement design, asphalt and concrete construction. Under another assignment to Division A - Research Planning and Co-ordination - he was responsible for evaluation of research work being conducted in Universities and by other consultants in the field of Highway Planning and Traffic Engineering.

Prof. Muller is a member of work committees and study groups of the European Committee for Standardisation –CEN – and German Road Research Association – FGSV. For over twenty years he has served as Government Consultant in Yemen, Saudi Arabia, Burundi, Zaire, Tansania, Kenya, and Namibia and has lectured in universities in these countries.

His assignment in Malta has involved him in extensive research of the local road paving technology, the service condition of paved roads, and the cause of their somewhat rapid deterioration generally. His findings and conclusions have contributed substantially to the adoption of an improved approach to local pavement construction and the formulation of the Roads Restoration Master Plan.

Prof. Muller is also a lecturer at the Faculty of Architecture and Civil Engineering at the University of Malta working with students who are following the newly established BE&A (Hons) road engineering stream.

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1. Introduction

The Code of Practice for the standardisation of pavements of traffic areas, edition 2000, regulates the New Construction and the Renewal for the pavements of traffic areas inside and outside built-up areas. The stage construction is not taken into account except the regulations of paragraph 3.3. Agricultural and forestural roads are also not considered.

This Code of Practice will be used to create and retain a necessary pavement standard for carriageways and other traffic areas of road traffic by the application of technically suitable and economical construction methods. It considers above all the function of the traffic area, the traffic loading, the subgrade conditions, the construction method, the condition of the traffic area to be renewed and also the conditions that result from construction inside and outside built-up areas.

This Code of Practice has been worked out on basis of the German Code of Practice RStO 2000 under consideration of the special Maltese conditions (climate, construction materials, subgrade conditions, and pavement performance). It is the basis for planning, tendering and execution of construction works.

Construction details are regulated by the "Specifications for road and street works, version 3 - 94." Further Code of Practices will be worked out in the future, for example

- Directives for preservation (maintenance, reinstatement).
- Directives for trenching.
- Directives for drainage facilities.
- Directives for asphalt surfacing.
- Directives for sett surfacing and flag surfacing.
- Directives for base courses.
- Directives for earthworks.

2. Fundamental Principles

2.1 Definitions

2.1.1 Structure

The structure of a traffic area is subdivided into Pavement, Embankment (if necessary), Subgrade.

Location, limits and designations of the different courses are presented in figure 1 and 2.

Pavement	:	Surfacing and one or several base courses.
Full depth asphalt pavement	:	Asphalt surfacing and asphalt base course immediately on formation level.
Course	:	Structural element of a pavement constructed with a single material, laid in one or more layers.
Asphalt surfacing	:	Wearing course and binder course or only wearing course.
Binder course	:	Part of pavement between wearing course and base course.
Regulating course	:	Course of variable thickness applied to an existing course to provide the necessary profile for a further course of consistent thickness.
Base courses	:	Support of surfacing, according composition there is distinction between- Base courses without binder: Foundation course (e.g. AASHTO A-1-a) Crushed stone course (e.g. type 1) - Base courses with binder: Cement stabilisation Asphalt base course.
Sett surfacing	:	Cobble stone, bedding course, joint sealing.
Flag surfacing	:	Flags, bedding course, joint sealing.
Combined base/wearing course	:	Asphalt course which meets the function of base course and surfacing.

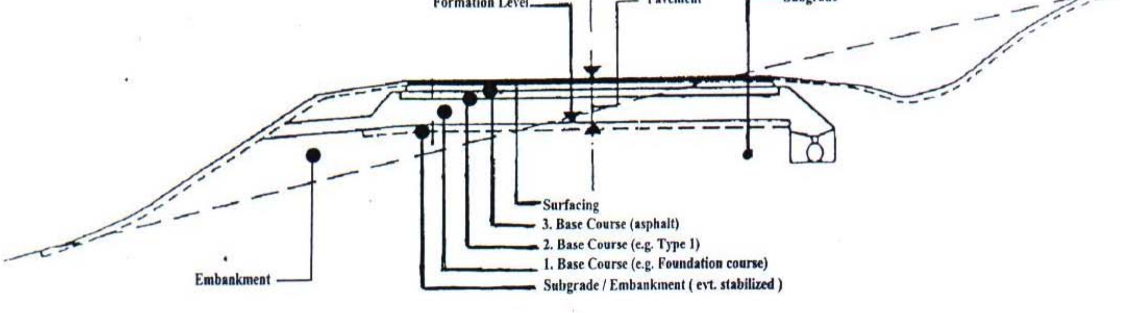


Figure 1: Road cross section with cut and fill outside built - up area (rural area)

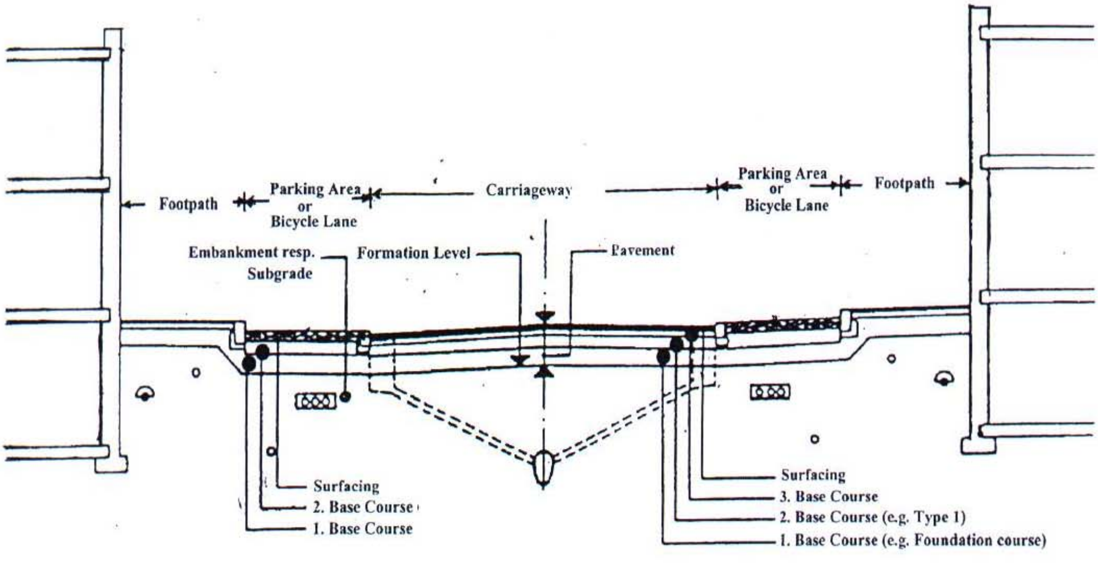


Figure 2. Road cross section in built - up area (urban area)

Embankment	:	Dam construction below pavement.
Subgrade	:	Existing soil or rock immediately below pavement or embankment.
Formation level	:	Surface of subgrade or embankment immediately below pavement, constructed according plan.

2.1.2 Renewal

The following additional definitions are used for the renewal of traffic areas:Renewal	:	Measures for the complete re-establishment of the performance value of an existing pavement structure under adjustment to changed traffic loading conditions if more than the wearing course is concerned.
Renewal by removal	:	Complete replacement of existing pavement.
Renewal by overlay	:	Laying of one or several layers onto the existing traffic area provided that the increase of the total pavement thickness is more than 4cms.

2.1.3 Traffic loading

Heavy traffic	:	Heavy traffic includes the following type of vehicles.
	-	Lorries of permissible total weight of more than 3.5 t without and with trailer.
	-	Tractor trailers
	-	Buses with more than 9 seats.
$ATV^{(HGV)}$	:	Average daily heavy traffic (vehicles/24h).
$ATA^{(HGV)}$	:	Average daily number of axles of type of vehicles of heavy traffic (Axles/24h).

2.1.4 Stress and strain by traffic

Equivalent10t-axle pass	Stress and strain by a road axle pass standardized to the damaging power of a 10t-axle pass.
Design relevantloading B	Number of weighted equivalent 10t-axle passes which are to be expected in the lane of highest traffic loading until the end of service life. Weighting is carried out under consideration of lane factor, lane width factor and slope factor.

2.2 Criteria for thickness determination

The thickness of a road pavement has to be determined in such a way that the entire structure has sufficient bearing performance. Bicycle lanes and footpaths are regulated in paragraph 5.2.

The actual knowledge of subgrade conditions of Malta suggests that sufficient bearing capacity of subgrade can be achieved normally by recompaction. Laying of foundation courses or cement stabilizations will be necessary for unfavourable subgrade conditions.

2.3 Drainage

The thicknesses of a road pavement described in the following chapters require permanent operating drainage facilities especially for the formation level if the subgrade is sensitive to water ingress. The drainage facilities for surface water run-off and the drainage of slopes, embankment and subgrade are described in the "Code of Practice for drainage facilities".

Special drainage facilities can be necessary in sag sections and for renewal and widening measures.

[1)]Equivalence factor = $[\text{Axle load (t)}/10t]^4$

2.4 Assessment and choice of construction methods

2.4.1 New construction

The construction methods with asphalt surfacing (chart 1) have been determined according the principle of technical equivalency that means that the pavement constructions of a construction class can absorb the traffic loading within the scheduled service life without structural damage of pavement. The construction methods with settt surfacing (chart 2) can be inequivalent with regard to bearing capacity and service life among themselves and in comparison with asphalt surfacings of same construction class. These construction methods have been determined especially under consideration of the requirements to roads inside built-up areas.

The construction methods for bicycle lanes and footpaths (chart 4) are also not equivalent.

The choice of construction methods has to consider local conditions, technical and economical aspects and environments conditions, for example;

- Use of local materials;
- Stage construction;
- Use of industrial side products and recycled material;
- Effects to preservation expenditure.

2.4.2 Renewal

If the evaluation of the residue substance of the traffic area has provided the result, that

- Renewal will be necessary and/or;
- Pavement thickness has to be adapted to increased traffic loading,

a suitable and economical renewal method has to be chosen which considers the local situation and the traffic management during construction.

Other criteria besides economical aspects:

- Improvement of gradient and cross slope;
- Level constraints;
- Widening of cross sections;
- Traffic management (suitability of diversion lanes);
- Lane renewal;
- Stage renewal;
- Loadability of building constructions and pipes;
- Renewal of pavements according line 4 and 5 (chart 1);
- Suitability of existent layers concerning their future function after renewal (e.g transformation of wearing course to binder course by overlay;
- Reuse of removed material.

2.5 Construction classes, stress and strain by traffic

Traffic lanes and other traffic areas, except bicycles lanes and foothpaths, are assigned to the construction classes HD and I to VI according the stress and strain by traffic.

2.5.1 Carriageways

The design relevant loading B is as a rule the basis for the assignment of traffic lanes to a construction class according table 1. B can be determined on basis of ATV $^{(HGV)}$ by means of road class specific load collective quotients or by means of detailed axle load dates (appendix 1). B will be calculated for the lane with the highest traffic loading by heavy traffic under consideration of:

- Number of lanes in the cross section;
- Lane width;
- Longitudinal slope.

If decisions are necessary about reinforcement thicknesses, similar calculations can be carried out for the determination of previous pavement loadings (stress and strain by traffic). Reinforcement thickness during service life will be determined under consideration of the existing pavement (construction class) and the previous and future number of equivalent 10*t* axle passes (appendix 2, example 3).

An example for the calculation of B is presented in appendix 2, (example 1).

Table 1: Design relevant loading B and related construction class (Appendix1).

Line	Design relevant loading B in million equivalent 10 t-axle passes	Construction class
1	over 32	HD
2	over 10 up to 32	I
3	over 3 up to 10	II
4	over 0.8 up to 3	III
5	over 0.3 up to 0.8	IV
6	over 0.1 up to 0.3	V
7	up to 0.1	VI

The design relevant loading B of the highest loaded lane is decisive for junctions.

Service time will be assumed to be 30 years as a rule. In special cases like uncertainty of traffic forecasting or utilities management reduced service times can be chosen.

If the design relevant loading B cannot be determined for traffic areas inside built-up areas, the construction classes of table 2 can be assigned to the various type of roads.

Table 2: Type of road and assigned construction class

Line	Type of road	Construction class
1	Arterial road, industrial road	I or II
2	Distributor road, road in industrial area	II or III
3	Urban road, pedestrian area with transport traffic	III or IV
4	Local road, residential street, pedestrian area	V or VI

2.5.2 Bus traffic areas

The assignment of construction classes to the various bus traffic areas is to be found in table 3.

Table 3: Bus traffic area and assigned construction class

Line	Bus traffic area	Design relevant loading B for	Construction class at least
1	Lane also used by buses	Traffic lane	1)
2	Bus stops in traffic lane of carriageway and in bus lane	Traffic lane	III 2) 3)
3	Bus lanes	Bus lane	III 2)
4	Bus bays	Bus bay	III 2) 3) 4)
5	Bus stations	Traffic lane Stop lane	III 2)III
6	Bus parking places	Traffic lane Parking place	III 2)III

1) It has to be checked if special loading might arrive (see paragraph 2.6).
2) A higher construction class should be chosen if traffic loading is higher than 150 buses per day.
3) It may be useful to choose the construction class of the traffic lane if higher.
4) A lower construction class has be chosen if traffic loading is below 15 buses per day.

2.5.3 Parking areas

The assignment of construction classes to parking areas may be carried out according table 4.

Table 4: Parking area and assigned construction class

Line	Type of traffic		Construction class
1.1	Continuously used parking area	Heavy traffic	III [1] or IV [1]
1.2		Passenger car with low percentage of heavy traffic	V
1.3		Passenger car	VI
2.1	Occasionally used parking area	Heavy traffic	IV or V
2.2		Passenger car with low percentage of heavy traffic	V or VI
2.3		Passenger car	2)

1. It has to be checked if special loading might arrive (paragraph 2.6).
2. According necessity, see also paragraph 5.3.

2.5.4 Other traffic areas

Merging and demerging lanes are constructed as a rule like traffic lanes of the carriageway.

Emergency lanes are constructed like the adjoining traffic lanes.

Crossings of centre lines are constructed according construction class III if the carriageway is constructed according a higher traffic class.

2.6 Special loadings

Traffic areas can be subjected to special loadings by heavy traffic, e.g.

- Channellized traffic (tracking);
- Curves with low radius;
- Slow traffic;
- Frequent deceleration and acceleration;
- Junctions and mergings
- Traffic jam or "stop and go" traffic.

The influence of channellized traffic and traffic on longitudinal slopes to the pavement thickness is considered by the factors f_2 and f_3 (appendix 1).

It has furthermore to be checked if the special loadings have to be considered at the choice of construction materials, the mixture composition and the manufacture of the various layers of the pavement. Details can be found in the relevant Codes of Practice (Paragraph 1).

3. New construction of carriageways and their renewal by removal

3.1Subgrade/embankment

The presented thicknesses in chart 1 to chart 3 are determined by traffic loading (equivalent 10*t*-axle passes) and require a subgrade/embankment strength at formation level of

- $E_{V2} \geq 120$ MN/m^2 or $E_{V2} \geq 100$ MN/m^2 : Construction methods 1 to 3 of chart 1 and 2
- $E_{V2} \geq 45$ MN/m^2 : Construction methods 4 of chart 1 and 2 and full depth asphalt pavement according chart 3.

If $E_{V2} < 45$ MN/m^2 a cement stabilization of 15cm thickness is necessary according construction method 5 of chart 1 and 2.

The soil groups of the subgrade or the embankment are distinguished according the classification of subgrade strength of table 5.

Table 5: Classification of subgrade strength of soil groups

	Subgrade strength	Soil groups (DIN 18196)
SS1	High subgrade strength	GW, GI, GE, SW, SI, SE
SS2	High to middle subgrade strength	GU, GU, GT, GT, SU, SU, ST, ST
SS3	Low subgrade strength	UL, UM, UA, TL, TM, TA

A reaction modulus of $E_{V2} \geq 120$ MN/m² can be achieved as a rule for compacted SS1 soils.

Subgrade strength of SS2 soils depends on consistency and the fraction by weight of components with grain sizes of less than 0.06mm. For a reaction modulus of 45 MN/m² < Ev_{2}, <120MN/m² a foundation course will be laid.

Fine grained cohesive SS3 soils achieve especially under unfavourable water conditions no sufficient strength. A cement stabilisation of a minimum thickness of 15cm will be laid. It may be checked if an increase of the foundation layer up to a thickness of 60cm will provide the required strength at formation level. Unfavourable water conditions are:

- Ground water table continuously or temporarily higher than 2m below formation level.
- Water can infiltrate to the water sensitive soil from the side (eg. verges) or through the pavement.

3.2. Pavement

3.2.1 Pavement constructions and thicknesses

The standardised pavement constructions with asphalt surfacing and settt surfacing on SS1, SS2 and SS3 soils are included in chart 1 and chart 2 for the relevant construction classes. Sett surfacing is not applied for construction classes HD, I and II.

The standardised pavement constructions for full depth asphalt pavement on SS3 soils and eventually SS2 soils are included in chart 3. Soil stabilisation of the subgrade respectively of the embankment may be necessary for SS3 soils and under unfavourable water conditions also for SS2 soils.

Examples for the calculation of the design relevant loading B and the choice of a pavement are to be found in appendix 2. The charts can also be used for an estimation of service time reduction by increased traffic loading (appendix 3) or pavement design under consideration of utilities (appendix 4)

3.2.2 Modification of thicknesses

The thickness of the asphalt base course can be reduced if the thickness of the binder course is increased by the same value. The minimum laying thickness of the asphalt base course must however be achieved.

If the thicknesses of the surfacing of chart 1 and chart 3 are modified, requirements to minimum and maximum thickness of laid material have to be considered. A thickness difference will be compensated as a rule by the underlying layer. The binder course with a thickness of 4cm may be left under the following conditions:

- Special traffic loadings according paragraph 2.6 are not to be expected;
- The thickness of the base course is increased by 4cm;
- High resistance to deformation of the base course mixture;
- Surface of the base course meets the requirements to regularity.

A combined base course/wearing course may be replaced by a base course of at least 8cm or 6cm thickness and a wearing course or a surface protection layer.

Pavement thicknesses with sett surfacing are presented in chart 2: the sett paving may be carried out by cast concrete stone, clinker stone or natural stone. Higher thicknesses of the sett paving may be chosen. Lower thicknesses may be chosen according local experience under consideration that the minimum thickness of 6cm must be respected; the thickness difference is then compensated by the underlying layer. The thickness of the bedding course must not exceed 5cm; higher thicknesses than 3cm don't lead to a thickness reduction of the underlying layer.

3.3 Traffic areas inside built-up areas

The regulations of paragraph 3.2 apply also for traffic areas inside built-up areas. Stage construction may be chosen for development areas under consideration that the

first stage has to transmit the site traffic. If unbound base courses are chosen, they have to be covered by a surface protection layer, e.g. sand asphalt. Asphalt base courses will be chosen as a rule for the first stage. The pavement condition has to be considered according paragraph 4 at the final construction stage.

The determination of the construction class has also to consider the site traffic if no stage construction will be carried out.

In case that no stage construction will be adopted the type of construction class chosen must always allow for site traffic.

Chart 1: Standardization for pavements with asphalt surfacing of traffic areas

Pavement Construction	Construction Class / Equivalent 10 t - axle passes (mil)	HD	I	II	III	IV	V	VI
	B	>32	>10 - 32	>3 - 10	>0.8 - 3	>0.3 - 0.8	>0.1 - 0.3	≤ 0.1
1 Asphalt	Wearing Course Binder Course Base Course	▼120 4 / 8 / 22 34	▼120 4 / 8 / 18 30	▼120 4 / 8 / 14 26	▼120 4 / 6 / 12 22	▼120 4 / 14 18	▼120 4 / 10 14	▼120 10 [1] 10
2 Asphalt Type 1	Wearing Course Binder Course Base Course Type 1 (15 cm)	▼150 ▼120 4 / 8 / 18 / 15 45	▼150 ▼120 4 / 8 / 14 / 15 41	▼150 ▼120 4 / 8 / 10 / 15 37	▼150 ▼120 4 / 6 / 8 / 15 33	▼150 ▼120 4 / 10 / 15 29	▼120 ▼100 4 / 8 / 15 27	▼120 ▼100 10 [1] / 15 25
3 Asphalt Type 1	Wearing Course Binder Course Base Course Type 1 (20cm)	▼180 ▼120 4 / 8 / 16 / 20 48	▼180 ▼120 4 / 8 / 12 / 20 44	▼180 ▼120 4 / 8 / 8 / 20 40	▼180 ▼120 4 / 5 / 7 / 20 36	▼180 ▼120 4 / 8 / 20 32	▼150 ▼100 4 / 8 / 20 32	▼150 ▼100 8 [1] / 20 28
4 Asphalt Type 1 Foundation course	Wearing Course Binder Course Base Course Type 1 Foundation Course	▼180 ▼120 ▼>45 4 / 8 / 16 / 20 / 30 78	▼180 ▼120 ▼>45 4 / 8 / 12 / 20 / 30 74	▼180 ▼120 ▼>45 4 / 8 / 8 / 20 / 30 70	▼180 ▼120 ▼>45 4 / 5 / 7 / 20 / 30 66	▼180 ▼120 ▼>45 4 / 8 / 20 / 30 62	▼150 ▼100 ▼>45 4 / 8 / 20 / 20 52	▼120 ▼>45 10 [1] / 30 40
5 Asphalt Type 1 Cement Stabilization	Wearing Course Binder Course Base Course Type 1 Cement stabilization	▼180 ▼<45 4 / 8 / 16 / 20 / 15 63	▼180 ▼<45 4 / 8 / 12 / 20 / 15 59	▼180 ▼<45 4 / 8 / 8 / 20 / 15 55	▼180 ▼<45 4 / 5 / 7 / 20 / 15 51	▼180 ▼<45 4 / 8 / 20 / 15 47	▼180 ▼<45 4 / 8 / 20 / 15 47	▼120 ▼<45 10 [1] / 15 / 15 40

1) Combined base course/wearing course or asphalt construction in two layers

Chart 2: Standardization of pavements with sett surfacing of traffic areas

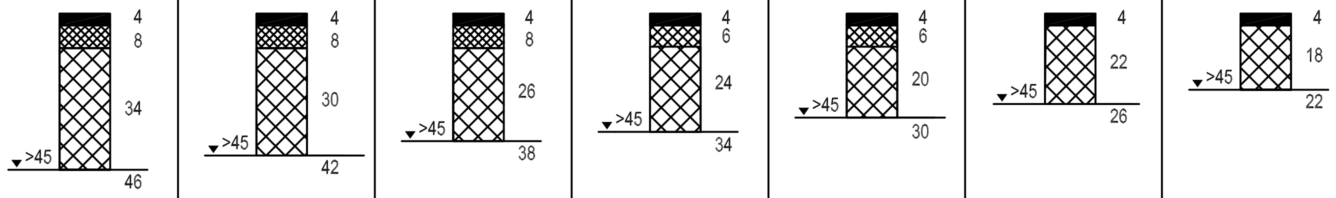
Pavement Construction	Construction Class		III	IV	V and VI
	Equivalent 10 t - axle passes (mil)	B	> 0.8 - 3	> 0.3 - 0.8	≤ 0.3
1 Type 1	Sett paving [1)] Bedding course Type 1		▼180, ▼120 10 3 25 38	▼180, ▼120 8 3 20 31	▼120, ▼100 8 3 15 26
2 Asphalt	Sett paving [1)] Bedding course Asphalt base course		▼120 10 3 14 27	▼120 8 3 12 23	▼100 8 3 10 21
3 Asphalt Type 1	Sett Paving [1)] Bedding course Asphalt base course Type 1		▼150, ▼120 10 3 10 15 38	▼150, ▼120 8 3 8 15 34	▼120, ▼100 8 3 8 15 34
4 [2)] Asphalt Foundation course	Sett Paving [1)] Bedding course Asphalt base course Foundation course		▼120, ▼>45 10 3 14 30 57	▼120, ▼>45 8 3 12 30 53	▼100, ▼>45 8 3 10 20 41
5 Asphalt Type 1 Cement Stabilization	Sett Paving Bedding course Asphalt base course Type 1 Cement Stabilization		▼150, ▼<45 10 3 10 15 15 53	▼150, ▼<45 8 3 8 15 15 49	▼150, ▼<45 8 3 8 15 15 49

1) Thickness of cobble stone may be chosen higher according to type of traffic and local situation (Directives for sett surfacing and flag surfacing)
2) Asphalt (line 2) instead of line 1 to reduce pavement thickness (utilities) and to reduce water ingress

Chart 3: Full depth asphalt pavement [1] of traffic areas

Construction Class		HD	I	II	III	IV	V	VI
Equivalent 10 t - axle passes (mil)	B	>32	>10 - 32	>3 - 10	>0.8 - 3	>0.3 - 0.8	>0.1 - 0.3	≤ 0.1

Wearing Course
Binder Course
Base Course



1) Instead of construction method No.4 or No.5 of Chart 1 to reduce excavation (utilities)
2) Minimum values of E_{v2}(MN/m²)
3) Thicknesses in cm

4. Renewal of carriageways

The renewal of carriageways by removal has been regulated in paragraph 3.

4.1. Renewal of carriageways by overlay

4.1.1. Evaluation of residual value of existing pavement

The following criteria are used to evaluate the residual value of the existing pavement and to determine a renewal construction method which is technically and economically suitable:

- **Surface condition;**
- Bearing capacity;
- Type and condition of the existing pavement including the condition of the
- subgrade / embankment;
- Condition of the existing drainage facilities.

4.1.1.1 Surface condition

The evaluation of the surface condition with regard to the bearing performance will be carried out by means of the following condition indicators:

- Crocodiling, crack accumulation (also longitudinal cracks besides the wheel passes but not thermally induced transversal cracks);
- Longitudinal irregularity (except settlements of subgrade/embankment);
- Rutting (not as a result of insufficient resistance to deformation of hot asphalt paving mixture);
- Chipping and mortar loss, repaired areas, potholes.

These condition indicators can occur separately or in combination.

These condition indicators (substance value) are also decisive for the assignment to a renewal class if the renewal will be carried out by asphalt layers.

The recorded condition indicators necessary for preservation (maintenance, reinstatement) such as skid resistance or regularity in transversel direction have also to be considered for the choice of a suitable renewal construction method. This concerns also **I** damages and their causes.

4.1.1.2 Bearing capacity I

The determination of the bearing capacity of an existing asphalt pavement may complete the evaluation of the pavement condition, e.g.

- Identification of weak points which are not observed visually;
- Limits of renewal section of the same bearing capacity.

If there is sufficient experience, test results of bearing capacity measurements may be used directly for the determination of the necessary thickness of the layers to be renewed (appendix 5).

4.1.1.3 Type and condition of existing pavement

The choice of renewal classes based on indicators and the determination of a suitable renewal construction method also requires:

- Identification of the causes which have created the existing surface condition;
- Verification of the suitability of the existing pavement, including the various layers and the subgrade/embankment.

Observations must include:

- Type, thickness and properties of the various layers;
- Type of subgrade/embankment (especially subgrade strength class, water conditions);
- Bond between the layers.

4.1.1.4 Drainage facilities

Studies are necessary to evaluate the condition, the effectiveness and the efficiency ol' the drainage facilities, e.g. by video camera. Conditions of outfalls and the upkeep ol' the system have also to be checked. Decisions will then be possible to what extent renewal has to be carried out.

4.1.2 Renewal classes I

4.1.2.1 Renewal by asphalt pavement construction

If renewal by overlay is to be carried out by asphalt pavement constructions, a renewal class according to table 6 will be chosen according to condition indicators which separately or in combination indicate a structural damage of the existing pavement.

It may be necessary to remove layers which are unsuitable for overlay and then to choose the required pavement thickness.

Table 6: Renewal classes dependent on condition indicators of the existing pavement

<table>
<tr><th rowspan="2">Renewal class</th><th colspan="2">Existing asphalt pavement</th></tr>
<tr><td>Main indicator</td><td>Additional indicator</td></tr>
<tr><td>Rl</td><td>• Crocodiling
• Crack accumulation[1])</td><td rowspan="2">• Rutting 2)
• Longitudinal irregularity
• Repaired areas
• Chipping -, mortar loss
• Repaired areas
• Chipping -, mortar loss</td></tr>
<tr><td>R2</td><td>• Longitudinal irregularity
• Rutting 2)</td></tr>
</table>

l)Longitudinal cracks also besides the wheel passes.

2) Rutting because of reduced bearing capacity not because of reduced resistance to deformation of asphalt mixtures.

The determination of the two renewal classes is based on indicators which have a condition (structural) value of 3.5 or higher. Analysis of the causes which have created the condition in question should be carried out.

4.1.2.2 Renewal by sett paving construction I

There is no distinction between renewal classes with regard to the pavement thickness for the renewal by overlay for pavements with sett surfacing.

4.1.3 Construction

4.1.3.1 General

The choice between renewal by asphalt pavement construction or sett paving construction depends on technical, economic and local aspects, e.g.

- Aesthetic considerations;
- **Traffic management during execution of works;**
- **Construction time;**
- **Length of renewal section.**

The regulations of paragraph 3 are correspondingly also valid for the renewal of carriageways by overlay. Road sections with inadequate bearing capacity or inadequate regularity should be prepared separately before overlaying.

The minimum cross slope of *2.5%* may be reduced to 1.5% especially if no rutting is to be expected during service life.

4.1.3.2 Asphalt pavement construction

The thicknesses for renewal by overlay are presented in chart 4 for the various renewal classes and construction classes. The directives for preservation have also to be observed.

4.1.3.3 Sett paving construction

Renewal by sett paving construction is only possible if the underlying foundation has sufficient strength, regularity and water permeability. Filter stability of the bedding course and the unbound base course has to be proved.

Chart 4: Renewal by overlay (asphalt)

Renewal Class	Construction Class		HD	I	II	III	IV	V	VI
	Equivalent 10 t - axle passes (mil)	B	>32	>10 - 32	>3 - 10	>0.8 - 3	>0.3 - 0.8	>0.1 - 0.3	≤ 0.1
R1	Wearing Course Binder Course Base Course [3] Existing Pavement		4 8 ≥16 ≥28	4 8 ≥12 ≥24	4 8 ≥8 ≥20	4 5 ≥7 ≥16	4 ≥8 ≥12	4 ≥6 ≥10	8 [1] 8
R2	Wearing Course Binder Course Base Course [3] Existing Pavement		4 8 ≥12 ≥24	4 8 ≥8 ≥20	4 5 ≥7 ≥16	4 ≥8 [2] ≥12	4 ≥6 ≥10	4 ≥4 ≥8	8 [1] 8

1) Combined base course/wearing course or asphalt construction in two layers
2) If there are special loadings, then asphalt binder course instead of asphalt base course
3) Base course as regulating course

4.2 Renewal of carriageways by partial replacement of the existing pavement

A partial removal of the existing pavement will be necessary if the pavement and/or the sub grade/embankment show unacceptable defects. The thickness of the courses to be laid have to be determined following the charts 1 to 3 dependent on the type and the condition of the layer which will be used as base for the new courses (appendix 2, example 4).

5. New construction and renewal for other traffic areas

5.1 Bus traffic areas

The assignment of a construction class to a bus traffic area is to be carried out according to table 3. Pavement construction methods and thicknesses are chosen according to charts 1 to 4

5.2 Bicycle lanes and footpaths

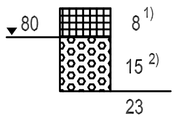
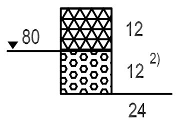
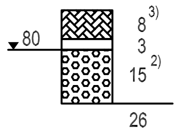
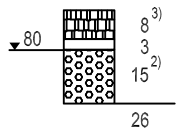
The standardized pavement constructions for bicycle lanes and footpaths are indicated in chart 5. The pavement construction methods and the thicknesses have been determined in that way that these areas are only accessible to maintenance vehicles. Use by other vehicles even occasionally is not considered. Regularity and drainage of the surface have especially to be considered.

Pavement thickness should be adapted to traffic loading in transition areas for vehicles. Pavement thickness should not change in the intermediate sections if there is a frequent sequence of transition areas. Flag stone surfacing should not be used for transition areas as a rule.

Low cost construction methods (e.g. unbound wearing course) ma)' be sufficient besides the construction methods according to chart 5 in special cases.

SS3 soils and exceptionally SS2 soils ma)' require a foundation course to achieve a reaction modulus of $Ev_2 \geq 8OMN/m^2$. It is useful for drainage reasons to continue the formation level and the foundation course of the carriageway below the bicycle lane and the footpath if these lanes are on the lower side of the carriageway.

Chart 5: Standardization for bicycle lanes and footpaths

Construction method with	Asphalt surfacing	Concrete surfacing	Sett surfacing	Flag surfacing
Surfacing Type 1				

1) Combined base/wearing course or asphalt construction in two layers
2) Layer of type 1 may be left for SS1 soils
3) Lower thickness possible if pedestrian and/or bicycle traffic only

5.3 Parking areas

The assignment of a construction class to a parking area will be carried out according to table 4. Pavement construction methods and thicknesses are chosen according to charts 1 to 4.

Traffic lanes between the parking places may be paved differently as the parking places.

Low cost construction methods (e.g. unbound wearing course) may be applied for occasionally used parking areas. Aesthetic and design aspects may furthermore be considered by the choice of a suitable paving type.

5.4 Fire brigade lanes

Fire brigade lanes may be constructed according construction class VI, turf stone pavement or low cost constructions of sufficient bearing capacity.

APPENDIX

Appendix 1: Determination of design relevant loading B

Two methods are used for the determination of design relevant loading B (weighted equivalent 10t-axle passes).

Method 1 to be used if there are only ATV $^{(HGV)}$ - data.

Method 2 needs the knowledge of detailed axle load data.

Both methods can be simplified by constant factors.

Method 1 - Determination of B by ATV $^{(HGV)}$ - data

Method 1.1 - Determination of B by variable factors

Determination of B will be carried out according the following formula:

N	: Service time, 30 years as a rule.
q_{Bm}	: Load collective quotient assigned to a road class (table A1.2). The quotient expresses the road class specific mean stress and strain created by the axle passes.
f_3	: Slope factor (table A1.5).
ATV $^{(HGV)}$	: Average daily heavy traffic in the year i (vehicles /24th).
ATA $^{(HGV)}$	: Average daily number of axle passes of heavy traffic in the year (axles/24th).
f_{Ai}	: Average number of axles per vehicle of heavy traffic (axle number factor) in the year *i* (table A1.1), axles per vehicle.
f_{1i}	: Lane factor in the year i (table A1.3).
f_{2i}	: Lane width factor in the year i (table A1.4).
p_i	: Annual growth of heavy traffic in the year i (table A1.6). For the first year $p_1 = 0$.

Quotient q_{Bm} has been chosen on basis of the German specification RStO 2000.Axle number factors can also be determined by traffic counts of heavy traffic.

Method 1.2 : Determination of B by constant factors

The total service time N can be subdivided into partial time periods n_i with constant values for f_1, f_2, f_3, f_A, q_{Bm} and p for each time period. The calculation is simplified for each time period (n > 1).

$$B = n \cdot ATA^{(HGV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365 \qquad \text{with } ATA^{(HGV)} = ATA^{(HGV)} \cdot f_A$$

If no growth of heavy traffic is considered during the first year, then

$$fz = \frac{(1+p)^N - 1}{P \cdot N}$$

If also for the first year growth of heavy traffic is considered, then

$$f_Z = \frac{(1+p)^N - 1}{p \cdot N} \cdot (1+p)$$

Annual growth factors fz of heavy traffic are to be found in table A1.7

Method 2 : Determination of design relevant loading B by axle load data

Method 2.1 : Determination of B by variable factors

If there are detailed axle load data, B can be calculated according the following formula:

B : Equivalent 10t-axle passes during service time.
N : Service time, 30 years as a rule.
f_3 : Slope factor (table A.1.5).
$EATA^{(HGV)}$: Average daily number of equivalent axle passes of heavy traffic in the year i.

$ATA^{(HGV)}_{i}$	: Average daily number of axle passes of heavy traffic in the year i (Axles/24h)
k	: Load class, defined as group of single axles.
L_k	: Mean axle load for load class k.
L_o	: Reference axle load : 10t.
f_{1i}	: Lane factor in the year i (table A1.3).
f_{2i}	: Lane width factor in the year i (table A1.4).

Method 2.2 - Determination of B by constant factors

The total service time N can be subdivided into partial time periods *ni* with constant values for f_1, f_2, f_3 and p. The calculation is simplified for each time period (n>1).

$$B = n \cdot EATA^{(HGV)} f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

If no growth of heavy traffic is considered during the first year, then

$$f_Z = \frac{(1+p)^N - 1}{p \cdot N}$$

If also for the first year growth of heavy traffic is considered, then

$$f_Z = \frac{(1+p)^N - 1}{p \cdot N} (1+p)$$

Annual growth factors f_Z of heavy traffic are to be found in table A1.7

Table A1.1: Axle number factor f_A

Line	Road Class	Factor f_A
1	Arterial road	3.7
2	Distributor road	3.1
3	Local road	2.5

Table A1.2: Load collective quotient q_{Bm}

Line	Road Class	Quotient q_{Bm}
1	Arterial road	0.20
2	Distributor road	0.18
3	Local road	0.15

Table A1.3: Lane factor f_l

Line	**Number of lanes, recorded by ATV(HGV)**	**Factor $f1$ by recording of ATV(HGV)**	
		in both directions	Separated for each direction
1	1	-	1.00
2	2	0.50	0.90
3	3	0.50	0.80
4	4	0.45	0.80
5	5	0.45	0.80
6	6 and more	0.40	0.80

Table A1.4: Lane width factor

Line	Lane width (m)	Factor f_2
1	< 2.50	2.00
2	2.50 to < 2.75	1.80
3	2.75 to < 3.25	1.40
4	3.25 to < 3.75	1.10
5	3.75 and more	1.00

Table A1.5: Slope factor

Line	Maximum longitudinal slope	Factor f_3
1	< 2	1.00
2	2 to < 4	1.02
3	4 to < 5	1.05
4	5 to < 6	1.09
5	6 to < 7	1.14
6	7 to < 8	1.20
7	8 to < 9	1.27
8	9 to < 10	1.35
9	10 and more	1.45

Table A1.6: Annual mean growth of heavy traffic

Line	Road Class	p
1	Arterial road	0.03
2	Distributor road	0.02
3	Local road	0.01

A1.7: Mean annual growth factor of heavy traffic f_z

Now traffic growth in the first year:

$$f_Z = \frac{(1+p)N - 1}{p \cdot N}$$

	Mean annual growth of heavy traffic p		
N	0.01	0.02	0.03
5	1.020	1.041	1.062
10	1.046	1.095	1.146
15	1.073	1.153	1.240
20	1.101	1.215	1.344
25	1.130	1.281	1.458
30	1.159	1.352	1.586

If there is also traffic growth during the first year to consider then

$$f_Z = \frac{(1+p)^N - 1}{p \ N} \quad (1+p)$$

	Mean annual growth of heavy traffic p		
N	0.01	0.02	0.03
5	1.030	1.062	1.094
10	1.057	1.117	1.181
15	1.084	1.176	1.277
20	1.112	1.239	1.384
25	1.141	1.307	1.502
30	1.171	1.379	1.633

Appendix 2: Examples for the determination of design relevant loading B and choice of pavement

Example 1: Design of a pavement for an arterial road

1. Data

1.1 General planning data

- Service time : N = years
- Number of lanes (constant) : 4; f_1 = 0.45 (table A1.3)
- Width of lanes with highest traffic loading (constant) : 3.75m; f_2 = 1.0 (table A1.4)
- Maximum longitudinal slope : 4%; f_3 = 1.05 (table A1.5)
- Site investigations carried out by the Benkelman Beam and the Plate Bearing Test have provided a subgrade strength of E_{v2} = 135 MN/m^2 and a relation of $E_{v2} / E_{v1} = 1.9$.

1.2 Traffic datas

- ATV $^{(HGV)}$ in the first year : 1900 vehicles/24h; $p_1 = 0$
- Mean annual growth of heavy traffic from the first to the fourth year : $p_{2,3,4} = 0.02$
- From the fifth year : p_5 to p_{30} = 0.02 (table A1.6)
- Average number of axles according traffic counts : $f_A = 3.2$
- q_{Bm} : 0.20 (table A1.2)

2. Calculation

Method 1.1:

$$B = 365 \cdot q_{Bm} \cdot f_3 \cdot \sum_{i=1}^{N} [\, ATA^{(HGV)}_{i-1} \cdot f_{1i} \cdot f_{2i} \cdot (1 + p_i)]$$

Calculation is presented in table A2.1

Method 1.2

The service time of 30 years is subdivided into two time periods (n_1 : year 1 to 4 and n_2 : year 5 to 30).

$$B = n \cdot ATA^{(HGV)} \cdot q_{Bm} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_z \cdot 365$$

For the years 1 to 4 (no traffic growth in the first year):

$$f_z = \frac{(1+p)^N - 1}{p \cdot N}$$

$B_{1-4} = 4 \cdot 6080 \cdot 0.20 \cdot 0.45 \cdot 1.0 \cdot 1.05 \cdot 1.030 \cdot 365$
$= 0.86$ Million

For the year 5 to 30:

$$f_z = \frac{(1+p)^N - 1}{p \cdot N} \cdot (1+p)$$

$B_{5-30} = 26 \cdot 6452 \cdot 0.20 \cdot 0.45 \cdot 1.0 \cdot 1.05 \cdot 1.527 \cdot 365$
$= 8.84$ Million

$B_{1-30} = 0.86$ Million + 8.84 Million = 9.7 Million

3. Result

The design relevant loading according both methods arrives at 9.7 Million equivalent 10t-axle passes. This corresponds to construction class II (chart 1).

Under consideration of cost reduction (fig. 2, page 49) and lack of level constraints (utilities deeper than 70cm), pavement construction No 3 (20cm asphalt, 20cm type I) had been chosen.

Table A2.1 : Calculation of design relevant loading B for example 1 according method 1.1

Year	p_i	$ATV^{(HGV)}_{i-1}$	F_A	$ATA^{(HGV)}_{i-1}$	Q_{bm}	f_1	f_2	f_3	days/year	$1+p_i$	B_i
1	-	1900	3.2	5080.0	0.20	0.45	0.10	1.05	365	-	209714.40
2	0.02									1.02	213908.69
3	0.02									1.02	218186.86
4	0.02									1.02	222550.60
5	0.03									1.03	229227.12
6	0.03									1.03	236103.93
7	0.03									1.03	243187.05
8	0.03									1.03	250482.66
9	0.03									1.03	257997.14
10	0.03									1.03	265737.05
11	0.03									1.03	273709.17
12	0.03									1.03	281920.44
13	0.03									1.03	290378.05
14	0.03									1.03	299089.40
15	0.03									1.03	308062.08
16	0.03									1.03	317303.94
17	0.03									1.03	326823.06
18	0.03									1.03	336627.75
19	0.03									1.03	346726.58
20	0.03									1.03	357128.38
21	0.03									1.03	367842.23
22	0.03									1.03	378877.50
23	0.03									1.03	390243.82
24	0.03									1.03	401951.14
25	0.03									1.03	414009.67
26	0.03									1.03	426429.96
27	0.03									1.03	439222.86
28	0.03									1.03	452399.55
29	0.03									1.03	465971.53
30	0.03									1.03	479950.68
$B_{1\text{ to }30}$ = 9701763.29 $B_{1\text{to }30}$ (Million) = 9.70											

Example 2: Design of a pavement for a local road

1. Data

- Design relevant loading B : 0.22 Million equivalent 10t-axle during service time of 30 years.
- Site investigations : Dynamic Plate Bearing tests in combination with Static Plate Bearing tests have shown that E_{v2} = 85MN/m^2 and E_{v2}/E_{v1} > 2,2; subgrade consists of cohesive material (composite soil according DIN 18196).
- Utilities : it cannot be ensured by the suppliers that no trenching will arrive within the next ten to fifteen years (service time of wearing course).

2. Pavement construction

According traffic loading, construction class V has to be chosen. If a value E_{v2} > 120MN/m^2 would have been achieved, 10cm base course and 4cm wearing course could have been laid (paragraph 3.1) As E_{v2} = 85MN/m^2, pavement construction No 4 (chart 1) has to be chosen to achieve sufficient bearing capacity of the pavement.

3. Result

As an economical solution has also to consider the future trenching works, a stage construction was therefore preferred with regard to bearing capacity and rideability. That means:

- Excavation of 52cm and recompaction of the subgrade;
- Laying of 20cm foundation course and 20cm type I;
- Tack coat (approximately 1l/ m^2);
- 2cm sand asphalt 0/5mm.

The final pavement construction will be carried out after arrangement of the utilities (8cm base course 0/25mm and 4cm wearing course 0/12.5mm.

Example 3: Increased traffic loading during service time because of traffic deviation

1. Data

1.1 General planning data

- Existing road before traffic deviation

  - Construction class IV
  - Service time : N = 20 years
  - Begin of traffic deviation : 12 years after opening to traffic
  - Duration of traffic deviation : until end of service time

- Number of lanes (constant) : 2 $\rightarrow f_1 = 0.5$ (table A1.3)
- Width of lane (constant) : 3.5 $\rightarrow f_2 = 1.1$ (table A1.4)
- Maximum longitudinal slope : < 2% $\rightarrow f_3 = 1.0$ (table A1.5)

1.2 Traffic data

- Year of opening to traffic

  - ATV (HGV) : 200 vehicles/24h
  - q_{Bm} : 0.18
  - f_A : 3.1
  - Traffic growth : 0.01

- During traffic deviation

  - ATV (HGV) : 1000 vehicles/24h
  - q_{Bm} : 0.20
  - f_A : 3.7
  - Traffic growth : 0.03

2. Calculation

Calculation of B has been carried out in table A2.2

3. Result

The total loading arrives at 1.61Million equivalent 10t-axles passes which requires a pavement construction according construction class III. The existing pavement, construction class IV, has to be reinforced by at least 4cm asphalt (chart 1)

Table A2.2 : Calculation of design relevant loading B for example 3 according method 1.1

Year	P_i	$ATV_{i-1}^{(HGV)}$	f_A	$ATA_{i-1}^{(HGV)}$	q_{Bm}	f_1	f_2	f_3	days/year	$1+p_i$	B_i
1	-	200.00	3.1	620.00	0.18	0.50	1.1	1.0	365	-	22403.70
2	0.01									1.01	22627.74
3	0.01									1.01	22854.07
4	0.01									1.01	23082.55
5	0.01									1.01	23313.38
6	0.01									1.01	23546.57
7	0.01									1.01	23781.98
8	0.01									1.01	24019.80
9	0.01									1.01	24260.00
10	0.01									1.01	24502.60
11	0.01									1.01	24747.62
12	0.01									1.01	24995.10
13	-	1000.00	3.7	3700.00	0.20	0.50	1.1	1.0	365	-	148555.00
14										1.03	153011.65
15										1.03	157602.00
16										1.03	162330.06
17										1.03	167199.96
18										1.03	172215.96
19										1.03	177382.44
20										1.03	182703.91

$B_{1\ to\ 12}$ (Million) = 0.28
$B_{12\ to\ 20}$ (Million) = 1.32
$B_{1\ to\ 20}$ (Million) = 1.61

Example 4: Renewal of an asphalt pavement for an arterial road outside built-up area by overlay

1. Basic data

1.1 General planning data

- Service time since construction : 35 years
- Planned service time after renewal : 30 years
- Planned pavement construction : construction class III

1.2 Evaluation of the residual value of the existing pavement

- Surface condition

The substance value arrives at 4.2 and exceeds the warning value of 3.5. The high value is achieved by crocodiling (approximately 20% of the road surface), repaired areas (approximately 10% of the road surface) potholes (5%) and single longitudinal cracks. Rutting (3mm) can be neglected. The indicator crocodiling exceeds already the limit value of 10% (4.5) so that the road section can be assigned to the renewal class R1.

- Bearing capacity

Benkelman-beam measurements have been carried out with the following results:

	Xmin (mm)	Xmax (mm)	X (mm)
Cracked areas	0.73	2.09	1.29
Uncracked areas	0.24	0.88	0.56

- Type and condition of the existing pavement

  - Existing pavement
    6.0cm asphalt 0/19mm
    8.0 cm sub-base 0/63mm (unbound)

  - Subgrade
    Type of soil according DIN 18196 : GU (SS2)
    CBR after four days soaked : 10%

  - Compaction degree (modified Proctor)
    Sub-base : 88.9%
    Subgrade : 80.2%

- Bitumen
  Heavy ageing during service time because the needle penetration arrives at only 11 (1/10mm)
- Drainage facilities
  Cross slope of 1.5% is sufficient because drainage is directly possible to the sea (Coast Road) and rutting will not influence the traffic safety.

2. Choice of renewal method

Overlay according chart 4 cannot directly be carried out because of the insufficient compaction of the unbound base course and the subgrade. Chart 4 would require an asphalt thickness of 16cm and chart 1 would require an asphalt thickness of 22cm (line 1), 18cm in combination with an unbound base course of 15cm thickness (line 2) or only 18cm of asphalt if the base achieves $E_{v2} = 150 MN/m^2$.

The following construction method was chosen:

- Scarifying of 10cm deep and immediate relaying followed by compaction with heavy equipment;
- 8cm asphalt base course 0/25mm;
- 4cm wearing course 0/12.5mm.

The performance of the pavement has to be observed in the future.

3. Test results during construction

Plate bearing tests on the scarified and relaid material have
provided(mean) : $E_{v2} = 165 MN/m^2$
: $E_{v2} / E_{v1} = 3.2$

Benkelman-beam measurements on the finished road surface (same points like before renewal) have provided the following results.

	Xmin (mm)	Xmax (mm)	X (mm)
Cracked areas before renewal	0.25	0.58	0.42
Uncracked areas before renewal	0.33	0.63	0.46

Appendix 3: Service time reduction by overloading

Pavement construction No 1 of chart 1 can be used to illustrate the reduction of service time if lower pavement thicknesses are exposed to traffic loadings for which the pavement had not been designed. Figure 1 includes the relations for three loadings; similar plots can be developed for different loadings.

That means for example : a pavement constructed according construction class III (>0.8-3 Million equivalent 10t-axles passes) with an asphalt thickness of 22cm has a service time of 30 years (curve No 2). If a pavement of 14 cm thickness will be loaded by the same traffic, service time will be only 3.2 years. Or with other words, thickness reduction of 53% leads to a service time reduction of 89%. The cost benefit relation is drastically reduced.

The curves can also be used to determine pavement thicknesses for a chosen service time, for example 10 years:

- Traffic loading HD : 28cm
- Traffic loading III : 18cm
- Traffic loading IV : 13cm

Estimations of service times can be carried out in special cases by method 2, appendix 1.

Example:

- A local road has been constructed according construction class V for a service time of 30 years.
- Traffic loading increases:
  100 lorries daily of 40t (2 axles);
  50 lorries daily of 30t (2 axles).

- B per day:
  $B = 200 \cdot (20/10)^4 + 100\ (15/10)^4 = 3706$ equivalent 10t-axle passes

- Service time : 300 000/3706 = 81 days
- That means also : increased axle loadings cause especially high damages in lower construction classes.

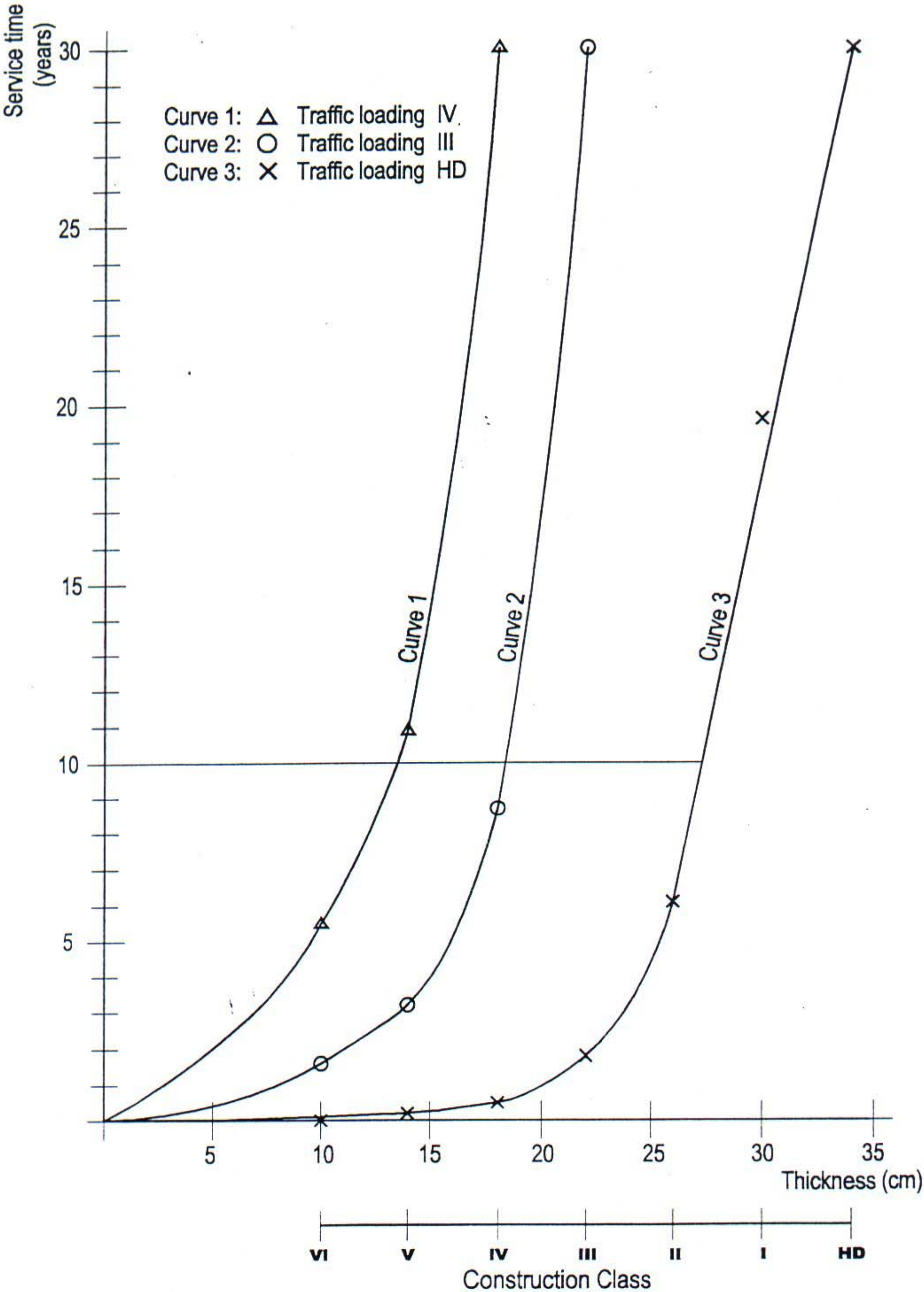


Fig. 1 Relation between service time and pavement thickness for various traffic loadings

Appendix 4: Pavement design under consideration of utilities

Pavement design would be optimal if no trenching arrives during the service time of pavement (N = 30 years) or not at least before reinstatement (for example wearing course ten to fifteen years after construction). If these requirements cannot be achieved, design will be carried out under consideration of construction costs (table A4.1 and table A4.2, presented in figure 2 and 3).
Deciding factor for example : pavement construction costs are equal to cost of utilities.

Example:

- Cost of utilities : Lm7.15/m^2.
- E_{v2} of subgrade : 120MN/m^2.
- Construction method No 3 will be chosen because costs are the lowest
- Construction costs of construction class IV (18cm asphalt) are the same like the costs for the utilities according figure 2.

Service time of the pavement:

- Traffic loading according IV : 30 years
- Traffic loading according III : 9 years

The graphs in figures 1 to 3 are recommended to find an optimal solution between road construction and utilities management.

Table A4.1: Construction costs excluding excavation (Lm/sq.m)

Class / Pavement	HD	I	II	III	IV	V	VI
1	16.66	14.75	12.83	10.83	8.83	6.91	5.05
2	15.65	13.73	11.81	9.81	7.81	6.85	5.95
3	14.99	13.07	11.15	9.15	7.15	7.15	5.24
4	15.89	13.97	12.05	10.05	8.05	7.75	5.95
5	16.79	14.87	12.95	10.95	8.95	8.95	7.75

Table A4.2: Construction costs including excavation (Lm/sq.m) with mechanical excavation

Class / Pavement	HD	I	II	III	IV	V	VI
1	17.26	15.28	13.29	11.22	9.15	7.16	5.23
2	16.44	14.45	12.46	10.39	8.32	7.32	6.39
3	15.83	13.84	11.85	9.75	7.71	7.71	5.73
4	17.26	15.27	13.28	11.21	9.14	8.66	6.65
5	17.89	15.90	13.91	11.84	9.77	9.77	8.45

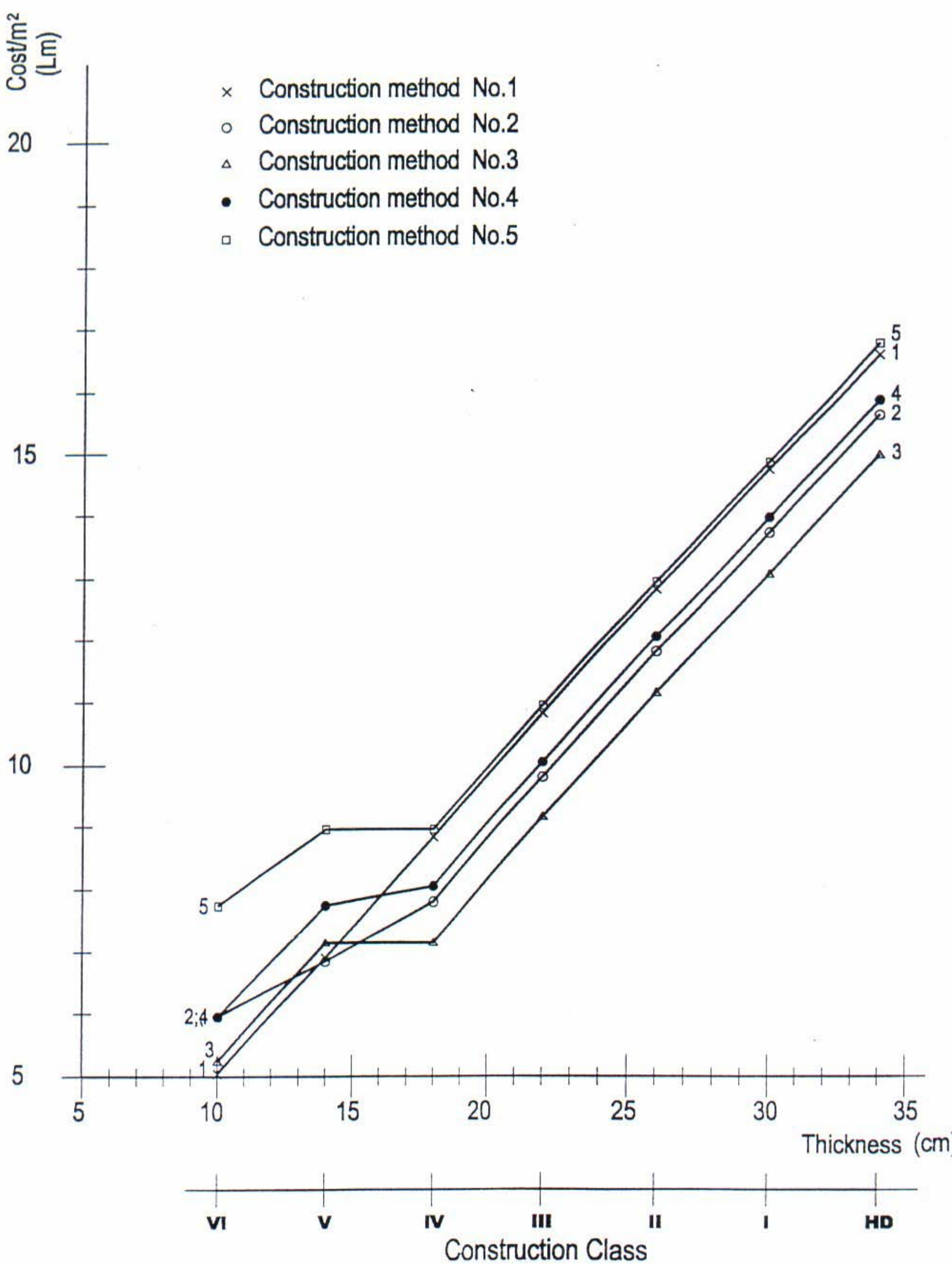


Fig. 2 Relation between construction costs (Lm/m²) and construction method (thickness) excluding excavation

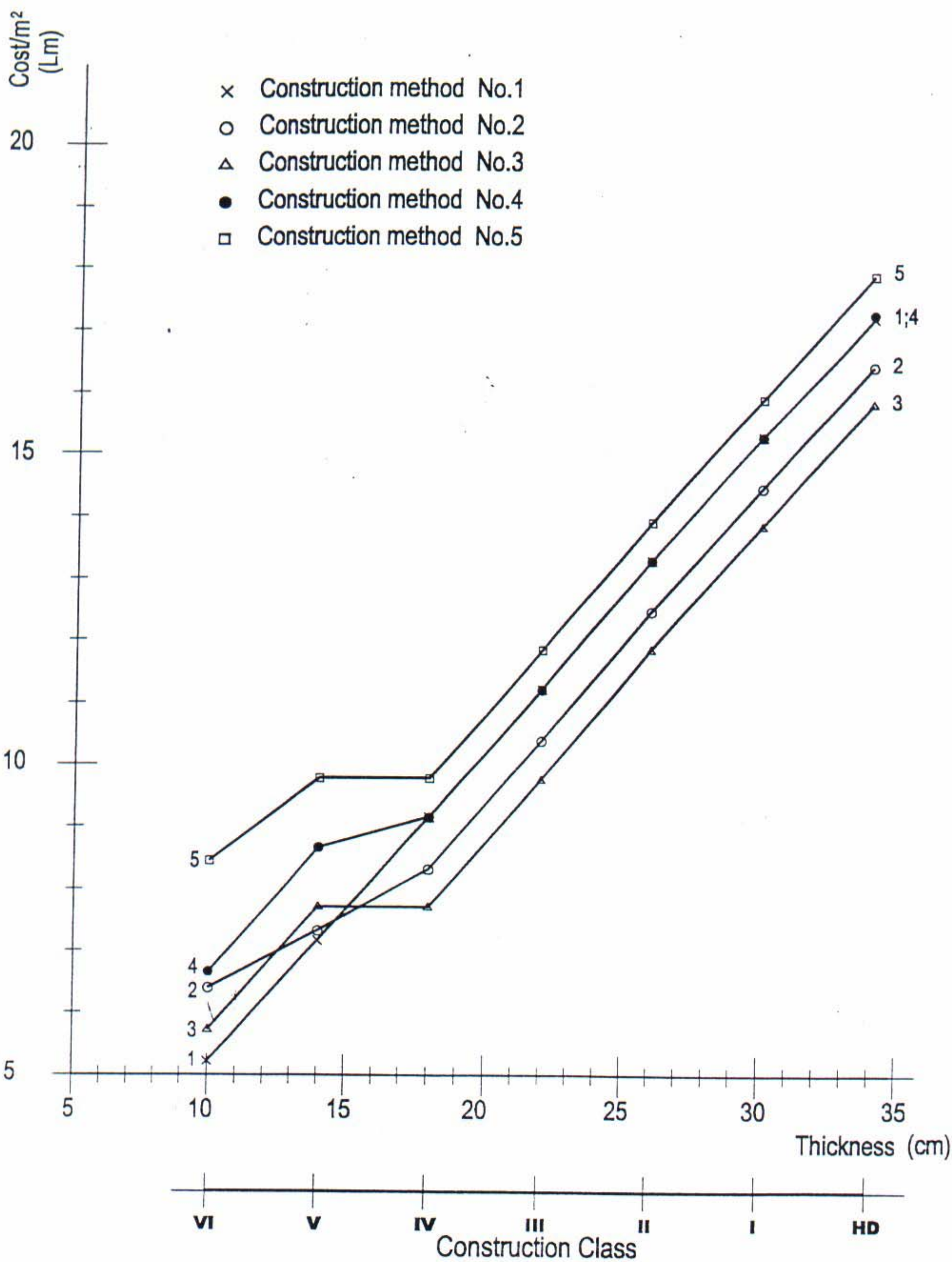


Fig. 3 Relation between construction costs (Lm/m²) and construction method (thickness) including excavation

Appendix 5: Bearing capacity by Benkelman-beam measurements

Benkelman-beam test results can be useful in combination with a condition survey/structural survey which study also the causes of damages.

The Federal Highway Research Institute (BASt) of Germany had published test results of measurements for pavements according RStO chart 1, line 1. These values have never been used in specifications (table A.5.1)

Table A5.1: Benkelman-beam deflection (mm)

Construction class	I	II	III	IV	V	VI
Deflection (mm)	< 0.33	< 0.36	< 0.41	< 0.48	< 0.58	< 0.72

Since recently there has been a proposal to assign existing asphalt pavements to renewal classes according the Benkelman-beam deflections: [1)]

Table A5.2: Relation between renewal classes and deflection (mm)

Renewal Class	Construction class						
	HD	I	II	III	IV	V	VI
R1	> 0.55	> 0.60	> 0.60	> 0.65	> 0.70	> 0.80	>0.90
R2	0.28-0.55	0.31-0.60	0.34-0.60	0.37-0.65	0.43-0.70	0.51-0.80	0.63-0.95

Studies by the Roads Department, Ministry for Transport & Communications, Malta have provided the following results:

Table A5.2: Test results of the Roads Department

Road Section	Hal Far	Salina	Qormi	Cirkewwa	Mtarfa
Service time (years)	23	38	14	-	-
Construction class	V	VI	VI	IV	<VI
Traffic loading	I	III	II	III	V
Renewal class	R1	R1	R1	R1	R1
Substance value	4.7	3.7	4.4	4.7	4.5
Deflection (mm)	0.27	0.41	0.35	0.26	0.50

1) Wolf, A.: Project 96342, Federal Highway Research Institute, Bergisch Gladbach 1998