IRC:SP:76-2015

GUIDELINES FOR CONVENTIONAL AND THIN WHITETOPPING

(First Revision)

INDIAN ROADS CONGRESS

ESTABLISHED 1934

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INDIAN ROADS CONGRESS
2015

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Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

June, 2015

Price : ₹600/-
(Plus Packing & Postage)

First Published : March, 2008
First Revision : June, 2015

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3.	Secretary General, Indian Roads Congress	Nahar, Sajjan Singh

GUIDELINES FOR CONVENTIONAL AND THIN WHITETOPPING

1. INTRODUCTION

1.1 IRC:SP:76 "Tentative Guidelines for Conventional, Thin and Ultra-Thin Whitetopping" was first published in 2008. The Composite Pavement Committee (H-9) of IRC felt the necessity to revise this document. The revised draft document prepared by the H-9 committee was discussed in series of meetings. The H-9 Committee finalized the draft document in its meeting held on 19th December, 2015 for placing it before the Highways Specifications & Standards Committee. The HSS Committee in its meeting held on 12th January, 2015 approved this document. The Council in its 204th meeting held at Bhubaneshwar (Odisha) on 19th January, 2015 approved the draft revision of IRC:SP:76 "Guidelines for Conventional and Thin Whitetopping" after taking on board the comments offered by the members.

The Composition of Composite Pavement Committee (H-9) is as given below:

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Secretary General, Indian Roads Congress	Nahar, Sajjan Singh

1.2 Background

1.2.1 Whitetopping is defined as a Portland Cement Concrete (PCC) overlay constructed on the top of an existing bituminous pavement. Whitetopping is thus PCC resurfacing (overlay) as a rehabilitation or structural strengthening alternative on bituminous pavement. The PCC overlay may or may not be bonded to the layer below.

1.2.2 Rutting of bituminous pavement is a real problem in hot climate like India, with heavy truck loads, operating under frequent start/stop conditions. A PCC overlay is commonly applied where rutting of bituminous pavements is a recurring problem. Concrete overlays offer the potential for extended service life, increased structural and functional capacity, reduced maintenance requirements, and lower life-cycle costs when compared with bituminous overlay alternative.

1.2.3 Concrete overlays have been used to rehabilitate both the existing bituminous (flexible) pavement since 1918 and existing concrete pavement since 1913. Whitetopping in its various forms has been used in the USA and Europe on Airports, Inter-state roads, Primary & Secondary Highways, Local Roads, Streets and Parking lots to improve the performance, durability and riding quality of deteriorated bituminous pavement surfaces. There has been a renewed interest in whitetopping, particularly, in Thin Whitetopping during the last two decades. This has been possible due to several successful high profile projects executed in USA, Europe and India. Their effectiveness has further renewed interest in them because they satisfy the demand caused by rapidly deteriorating highways confronted with limited fund availability. Conventional Whitetopping, and Thin Whitetopping (TWT) with 15-20 years of design life offer immense potential as a rehabilitation strategy for Indian roads. Several successful projects have been executed at Pune, Mumbai, Delhi, Nagpur, Jaipur and Bangalore in the last few years. The performance of these sections has been found to be satisfactory.

1.2.4 PCC overlays are also placed on existing concrete surfaces, as rehabilitation/ strengthening measure. Such overlays, even though used on experimental basis for rehabilitation of existing concrete roads are not called whitetopping (as the existing surface is not bituminous) and accordingly, do not fall under the scope of this guideline.

1.3 Benefits of Whitetopping

Whitetopping on existing bituminous pavements provides many additional benefits as compared to conventional bituminous overlay alternative. Some of the benefits are:

- Long life, low maintenance, low life-cycle cost, improved safety and environmental benefits.
- Bituminous overlays exhibit a more rapid loss of serviceability as compared to concrete whitetopping at some critical locations. The lives of successive bituminous overlays become progressively shorter after the first overlay.
- Deformation like rutting and cracking predominant in case of bituminous pavements is normally absent with concrete surfaces of whitetopping. This is particularly true in a hot climate like India.
- Conventional Whitetopping improves structural capacity of existing bituminous pavement, if built on a strong base course, and it impedes structural distresses.
- Whitetopping requires much less maintenance and as such involves much less frequent lane closures of road, as compared to bituminous surfaces.
- Whitetopping is quite cost-effective to tackle annual budget constraints and high traffic levels. It is, therefore, quite relevant to Indian conditions.
- Whitetopping can uniformly fill ruts in the wheel path of bituminous pavements more effectively because concrete is far more stiff and consistent at high temperature than bituminous mixes. Broadly, for similar reasons, the occurrence of cracks is also relatively much less in case of whitetopping.
- Concrete is relatively light in colour and hence concrete surface is more reflective to light, absorb less heat and reduce the urban heat island effect. Improved reflection of lights from vehicles enhances safety, lowers energy requirement of external lighting, lower contribution to heat in environment.
- Fuel consumption on concrete roads has been found to be less than the bituminous roads.

1.4 Types of Whitetopping

Whitetopping is classified into three types. This is based on the types of interface provided i.e. degree of bonding between the underlying bituminous layer with PCC overlay and the thickness of the overlay; three types of interfaces are:

- Bonded interface
- Unbonded interface
- Partial bonded interface

i) Conventional Whitetopping

It consists of a PCC overlay of thickness 200 mm or more (on the top of existing bituminous layer) which is designed and constructed without consideration of any bond between the concrete overlay and underlying bituminous layer. Conventional whitetopping is designed and constructed like a new rigid pavement without assuming any composite action. Conventional whitetopping treats the existing bituminous surface as a sub-base like Dry Lean Concrete (DLC) and to this extent the condition of existing bituminous surface does not matter significantly, except that bituminous surface should not suffer from any isolated damages like subsidence or material related problems.

ii) Thin Whitetopping (TWT)

PCC overlay of thickness greater than 100 mm and less than 200 mm is classified as Thin Whitetopping (TWT). The bond between the overlaid PCC and underlying bituminous layer is often a consideration but it is not mandatory. The bonding consideration may be ignored in the design. High strength concrete with fibres is commonly used. Joints are at shorter spacing of 0.6 to 1.25 m.

iii) Ultra-Thin Whitetopping (UTWT)

PCC overlay of thickness equal to or less than 100 mm is classified as Ultra-Thin Whitetopping (UTWT). Bonding between underlying bituminous layer and overlaid PCC layer is mandatory in case of Ultra Thin Whitetopping. Milling the existing bituminous surface to an average depth of 25 mm is normally used to provide the bonding at the interface between the existing bituminous surface and PCC overlay. Such bonding can be provided by some other methods also, but milling is considered desirable because effective bond between the existing and overlaid surface is absolutely essential for a better performance of UTWT.

High strength concrete with fibres is normally provided with closely spaced joints (at interval of 0.6 to 1.25 m). Ultra thin whitetopping of 50 mm to 75 mm i.e. less than 100 mm is generally not recommended for Indian condition. Good construction technology in small urban towns to lay such thin high grade concrete may not be available. Besides the possibility of overloaded truck plying intermittently due to construction activities cannot be ruled out. However, for colony internal roads where traffic is restricted and controlled and good quality control is exercised during construction, the thin white topping can be considered.

1.5 When Whitetopping is not an Option

For all kinds of whitetopping, continuity of the subgrade/sub-base support is to be ensured and whitetopping should not be done at locations where availability of continuity of support is in doubt. The condition of the existing bituminous surface should be sound and free from wide cracks, material related distresses, isolated subgrade related problems.

1.6 Relevant Definitions

General terms used in the Guideline are defined under Appendix I.

2. BEHAVIOUR MECHANISM

TWT overlays are designed on the principle of a composite pavement structure which distributes traffic and environmental loading in a different manner than done in case of conventional PCC or flexible pavement. In case of such bonded system due to the composite action between concrete and flexible layer, the neutral axis shifts downward with the result that much of the area of PCC slab comes under compression and therefore a lesser thickness is required to carry the load than in the case with conventional PCC layer.

The other factor in case of TWT is that spacing of joints is considerably reduced due to which both curling and warping stresses are much less.

Although a fully bonded system is ideal, the same, however, is very difficult to be realized and usually a partial bond is realized. As such, stresses lie somewhere in between the two extreme cases of unbonded and bonded.

3. MATERIALS

3.1 Cement

Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer:

i) Ordinary portland Cement, 43 Grade, IS:8112

ii) Ordinary Portland Cement, 53 Grade,IS:12269

iii) Portland Pozzolana Cement, IS:1489

iv) Portland Slag Cement, IS:455

Preference should, however, be to use 43/53 Grade cement, as the grade of required concrete is M40 or more than M40. Lesser cement content means less water and, therefore, lesser chances of shrinkage cracks.

While using 53 Grade Cement, fly ash upto 25% by weight of cementitious material may be added.

3.2 Admixtures

Admixtures conforming to IS:6925 and IS:9103 may (upto 2% by weight of cement as per IS: 456) be used to improve workability of the concrete or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete with respect to strength, volume change and durability.

3.3 Air Entraining Agents

The air entraining agents may be added upto 6.5% to increase the durability of the pavement in freezing and thawing regions.

3.4 Fibres

These shall be of steel/polypropylene/polyester/polyethylene/nylon fibres and shall be uniformly dispersed in the concrete mass. Use of fibres in concrete reduces its tendency to plastic shrinkage cracking and increases its ductility and abrasion resistance. Polymeric micro fibres with low elastic modulus are not expected to increase the load-resisting capacity of the concrete significantly, at low dosages (0.3% by volume of concrete). Structural fibre reinforced concrete prepared with macro polymeric fibre has enhanced strength, toughness and endurance without significantly changing the modulus of elasticity of concrete. Macro polymeric fibres, 30 mm to 60 mm length and more than 0.2 mm dia should be used with dosage of 0.5% to 1.5% by volume of concrete (4.5 to 14 kg/m^3). These shall be added at the time of preparation of concrete. The synthetic fibres are slender and elongated filaments in the form of bundles, networks, strands of manufactured material that can be distributed thoroughly in the freshly mixed concrete. (ASTM C 1116)

The diameter of polymeric fibres normally varies from 10-70 micron and specific gravity is in the range of 0.91 - 1.34. The melting point of these fibres shall not be less than 160^{o}C. The aspect ratio generally varies from 200-2000.

Fibre reinforced concrete shall be free from fibre balls when delivered. Tolerance in slump may be ± 15 mm for a slump of less than 50 mm and ± 25 mm for a slump greater than 50 mm but less than 100 mm. The tolerance in mixing time shall be ± 3 Sec for time of mixing 15 s, and ± 5 s for time of mixing of more than 15 s. For more details on specifications of fibres and their testing, ASTM C 1116 and ASTM 1399 may be referred.

IRC:SP:46-2013 should be referred for the use of fibres in concrete.

3.5 Aggregates

Aggregates for pavement concrete shall be natural material complying with IS:383 with a Los Angeles (LA) Abrasion/Aggregate Impact Value (AIV) not more than 35%. The limits of deleterious materials shall not exceed the requirements set out in IS:383.

The aggregates shall be free from chert, flint, chalcedony or silica in a form that can react with the alkalies in the cement. In addition, the total chlorides content expressed as chloride ion content shall not exceed 0.06% by weight and the total sulphate content expressed as sulphuric (SO_3) shall not exceed 0.25% by weight of dry aggregates.

3.5.1 Coarse Aggregates

Coarse aggregates shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. Aggregates should normally be rough textured and cubical in shape. Use of modern crushing technology for producing aggregates is considered desirable. The maximum size of coarse aggregates shall not exceed 31.5 mm. The combined flakiness and elongation index of aggregates shall not be more than 35 percent. No aggregate which has water absorption more than 2% shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS:2386(Part V). After 5 cycles of testing, the loss shall not be more than 12% if sodium sulphate solution is used or 18% if magnesium sulphate solution is used. If aggregates are doubtful for alkali aggregate reactivity, IS:456 may be referred.

If the aggregates are not free from dirt, the same may be washed and drained for at least 72 hours before batching. In such a situation the absorbed moisture content shall be carefully taken into account while calculating free water content in the mix.

3.5.2 Fine Aggregate

The fine aggregates shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregates shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter. The fine aggregates shall not contain substances more than the following:

Clay lumps	1.0%
Coal and lignite	1.0%
Material passing 75 micron sieve	3.0%

Although IS:383 permits the fines passing 75 microns upto 15% in case of crushed sand, this provision should be used with caution.

3.6 Water

Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456. Potable water is generally considered satisfactory for mixing and curing.

3.7 Mineral Admixtures

In case of Conventional Whitetopping, and Thin Whitetopping following materials may be added as mineral admixtures as per their availability:

i) Fly ash grade I (as per IS 3812-2003),

ii) Granulated blast furnace slag (as per IS: 12089)

iii) Silica fume (as per IS: 15388-2003 and IS:456-2000, IRC:114-2013)

The silica-fume as per design is used where high performance concrete is the requirement of the design. It shall be added in suitable dozes normally @ 3-10% by weight of cementitious material.

To improve the ductility and fatigue resistance of high performance/high strength concrete, polymeric fibres may be added in the concrete 0.2-0.4% by weight of cement and/or steel fibres as per IRC:SP:46-2013.

Polymeric fibres shall have water absorption less than 0.3% and shall not affect the properties of concrete (i.e reduction in the strength not more than 5%). Entrapped air content in the concrete shall not be more than 3%, except where freezing and thawing is taking place. At such locations, provision shall be regulated by Para 3.2.

Use of above additional materials including admixtures and air entraining agents in the conventional concrete improves the following properties of concrete:

i) Improvement in toughness,

ii) Reduction in shrinkage cracks

iii) Long term mechanical properties,

iv) High early strength,

v) Ease of placement, cohesiveness and consolidation,

vi) Volume stability and longer life,

vii) Less abrasion, and least permeability,

viii) Improvement in load transfer at the joints due to improved aggregate interlocking

ix) Improvement in bond between aggregate - cement mortar and existing bituminous layer with fresh concrete.

4. MIX PROPORTIONING AND STRENGTH OF CONCRETE

4.1 Following designed concrete mixes may be used for construction of both conventional and thin whitetopping:

i) Conventional cement concrete,

ii) Fibre Reinforced concrete using fibres viz. polypropylene, polyethylene, nylon, polyester, steel (IRC:SP:46) etc.

iii) High Performance concrete using silica fume upto 3-10% by weight of cementitious material with and without using fly ash (upto 20%) or slag up to 70% by weight of cement, (IRC:SP:70)

iv) High performance fibre reinforced concrete using specified fibres and mineral admixtures as per IS: 456 using a dose of chemical admixture @ upto 2.0% by weight of cement.

4.1.1 Concrete mixes used are so proportioned that the concrete mix generally produces concrete of minimum characteristic compressive strength M40 or more than M40 at 28 days. High performance concrete of compressive strength M50 is normally preferred. The high strength high performance concrete is essential for fast track construction which is achieved by using early setting cements with microsilica as an essential additive. The cardinal principle is that two third of the concrete strength should be developed within a period of 48 hours. Such a pavement can be opened to traffic within 72 hours of its laying.

4.1.2 UTWT/TWT projects are generally constructed with concrete of mix, having lower water/cement ratio, less than 0.40. It is, however, preferable to have a water cement ratio around 0.30 to 0.38. The workability/slump requirement (25-50 mm) may be conveniently achieved by the use of high range water reducers (super plasticizers). The mixes may have high cement content (but not greater than 450 kg/m^3). Extra precautions are required while using very high cement content with regard to the heat of hydration. The higher strength is derived not by increasing the cement content but by reduced water content.

When designing concrete pavements, the flexural strength (modulus of rupture) of concrete is used rather than its compressive strength, as concrete fails in flexure rather than in compression. The mixes shall be designed as per IRC:44 or IS:10262. The minimum flexural strength or modulus of rupture (Third point loading) of the concrete shall be 4.5 MPa which corresponds to the minimum grade of concrete i.e. M40 at 28 days. It is, however, preferred to have a flexural strength of 5.0-6.0 MPa (Third Point Loading).

4.2 Self Compacting Concrete

Use of high workability, high flow or free flow or self compacting concrete can be used for overlays. Free flow concrete can be with slump flow 350 to 450 mm. This type of concrete require high cohesiveness, hence more fines (below 75 µm i.e. cement, mineral admixtures and additives etc.) and more fine aggregate (well graded), but all particles shall be well graded and higher dosages of superplasticizers are required. Requirement of the degree of cohesiveness will increase with the distance of haulage of ready mixed concrete. If dosages of superplasticizers increase beyond 1.5%, it may be advisable to use poly-carboxylic-ether based superplasticizers. Mineral admixtures like flyash, silica fume, GGBS (ground granulated blast furnace slag), metakaoline, and additives like lime stone powder etc. are required. The total mineral admixtures and additives should be increased to 35% of cementitious matter, for optimum results; and up to 50% while GGBS is used. The common methods of concrete proportioning as applicable to normal concrete shall need modifications. Mix proportioning and production of such concrete is the specialized activity and should be done under the supervision of experienced expert in that field with good amount of tests and trials. Such concrete may have higher shrinkage, requiring higher dosages of fibers.

High flow concrete may have the nominal maximum size of aggregate lower than the normal concrete. High flow concrete may have higher shrinkage and hence it will require higher fiber content for controlling shrinkage cracks.

Such concrete may have advantage of reducing the equipment needed for laying, compaction and the related noise during construction. It could therefore be preferred option for urban area even at higher price.

4.3 High Strength Concrete

Early opening concrete overlays can be designed such that it can be opened to traffic at a predetermined age (say 12 hours, or one to 3 days), also termed as “fast-track” concrete paving. This system requires a concrete which can gain specified design strength at the time of opening to traffic. An option may be to permit initially only light traffic for few days to keep fatigue damage factor low.

For early age flexural strength of concrete, the mix proportioning is to be done for achieving a specific strength at a specified small age. High flexural strength needs a limitation on nominal maximum size of aggregate (say 20 or 16 mm), a tighter tolerance for flakiness of aggregate fraction below 10 mm, a good gradation of particles up to micron size, a tighter control over lower tolerance in particle gradation, use of enough supplementary cementitious materials (SCM) like silica fume, flyash, ground granulated blast furnace slag, metakaoline, additives like lime stone powder etc., and total free water ≤ 150 kg/m³ (including the aqueous solution of admixtures). SCM's improve the particle grading below 10 micron (μm) size, improves the transition zone on the surface of aggregate and improves the strength contribution of binder.

Further for monitoring, the concept of 'maturity of concrete' is to be practiced with little additional tests and regular temperature record. With early opening to traffic, methods of wet curing are to be practiced while traffic is on the pavement. Concrete with high early strength also has higher shrinkage, hence, specific effort is required to reduce and control shrinkage related cracks.

Early Age Behaviour: The early-age period is up to 96 hours after construction. During this period, the PQC strength is relatively low, and the stresses in the slab can be significant due to the large volumetric changes that occur due to temperature and moisture conditions in the slab. This is especially true for thin overlays, due to the high surface area to volume ratio. Early steps for curing (within one hour of laying concrete) and sufficient fibre dosage to control plastic shrinkage are required. Few demonstration projects have been successfully implemented.

5. CONVENTIONAL WHITETOPPING

5.1 General Considerations

Conventional whitetopping, including inlays (at specified locations of weak sub-grade) have been extensively used in USA and Europe during 1940's to 1960's for overlaying existing flexible pavements. Various concrete thicknesses have been used depending upon the expected traffic loads.

Whitetopping overlays are most appropriate for asphalt pavements that are extensively deteriorated. Pavements with excessive rutting, shoving, or alligator cracking are considered good candidates for Conventional Whitetopping overlays because these problems are not easily corrected with a hot-mix asphalt overlay. The condition of the existing pavement, however, affects the thickness design of Whitetopping overlays.

Most of the conventional whitetoppings have been constructed as Jointed Plain Concrete Pavements (JPCP). The use of Continuously Reinforced Concrete Pavement (CRCP) and Fibre Reinforced Concrete Pavements (FRCP) have been practiced in USA from 1970's onwards. The thickness of both JPCP and CRCP resurfacings has ranged from 150 to 250 mm. Longitudinal steel reinforcement in CRCP has ranged from 0.5 to 0.6%.

In Conventional Whitetopping, polythene sheet or de-bonding layer is not provided. The PCC overlay can be laid directly on the existing bituminous surface. A white wash/ white curing compound may be used to minimize the temperature of existing bituminous pavement. Whitewash prevents heat build-up in a black interlayer surface as it essentially provides a white surface, which will absorb minimum sunlight. Whitewash consists of either white-pigmented curing compound or lime slurry.

During summer months the temperatures are generally greater than 35°C. Paving becomes difficult on soft layers at temperatures above 35°C. Paving of concrete overlays at such high temperature (> 35^0C) should not be done. Salt addition to a lime slurry white washing shall be avoided as the use of salt in whitewashing could be damaging to the overlay concrete and steel.

Curing compound, if used as a whitewash, should conform to AASHTO specification M148. (Apply the compound to the resurfacing area at a rate of 2-3 ml per 100 cm^2). The whitewash mixture and the rate of application shall produce a uniform colour on the surface. After whitewashing, interlayer surface will be allowed to cool adequately before starting the paving operation.

Conditions on the job site may create the need for a second application of whitewash. Rain or construction traffic can fade or wear away the whitewash colour. If a majority of the surface area is no longer coated, apply a second coat to faded areas. Some tracking by construction traffic is not detrimental. A uniform colour and coverage is preferred.

If deformed reinforcement is in place during application of a second coat, maintain caution to avoid significant contact of the whitewash with the deformed bars. The reinforcement should be cleaned if a significant amount of whitewash is inadvertently applied.

5.2 Pre-overlay Repair

Conventional Whitetopping overlays do not require extensive pre-overlay repairs, but the repair of certain types of distresses may be important to avoid localized failures. In general, the condition of the underlying pavement is more critical to the performance of CRCP whitetopping overlays as compared to JPCP. ACPA (American Concrete Pavement Association) has published guidelines for whitetopping pre-overlay repair (ACPA 1998). The same is reproduced in Table 1.

Table 1: Guidelines for Whitetopping Preoverlay Repair (ACPA 1998)

General Pavement Condition	Recommended Repair*
Rutting {< 2 in. (50 mm)}	None or milling+
Rutting {≥ 2 in. (50 mm)}	Milling or levelling
Shoving	Milling
Potholes	Fill with crushed stone cold mixture or hot mixture

Subgrade failure	Remove and replace or repair
Alligator cracking	None
Block cracking	None
Transverse cracking	None
Longitudinal cracking	None
Raveling	None
Bleeding	None

Note:

* Other factors to consider: adding edge drains, cost of direct placement on unrepaired pavement versus milling, or levelling

+ Consider deeper than standard joint sawing depth in the whitetopping pavement

5.3 Pavement Evaluation

The evaluation of the existing pavement is an essential part of any overlay design including conventional whitetopping. Field evaluation typically consists of a visual distress survey, deflection testing using Benkelman Beam or Falling weight deflectometer and coring. Foundation support value (k) is key information for thickness design. The sugrade support value (k) for the existing bituminous surface can be back calculated from the resilient modulus (MR). 'k' values to be used can be taken from deflection test on the existing bituminous surface or by determining 'k' value from load test on the subgrade and thereafter using Correlation Charts. Any other suitable method may also be adopted connecting 'k' value of the subgrade to the modified 'k' value of bituminous subbase. For assessing the condition of existing pavement following information should also be collected:

- Type and thickness of the existing layers by taking cores or trial pits and collection of soil samples
- Type and extent of distresses
- Restriction on Finished Road Level (FRL)
- Width of existing pavement and proposed concrete overlay
- Presence of treacherous soil like Black Cotton soil
- Drainage condition, drainage requirements and sub-surface drainage
- Traffic survey data

5.4 Surface Preparation

For Conventional Whitetopping, no special efforts are made to encourage bonding between the overlay and the underlying bituminous surface; however, some steps for surface preparations may be required to address distresses in the existing surface of the bituminous pavements or to correct surface profile. Three methods of surface preparation and overlaying are normally used for whitetopping:

- **Direct Placement** – The concrete overlay is placed directly on the existing hot bituminous surface after sweeping. Any ruts in the existing pavement are filled with concrete, resulting in a thicker concrete pavement in the rutted areas.
- **Milling** – The existing bituminous surface is milled to obtain a uniform surface. Milling can be used to remove surface distortion like cracks in the top portion and adjust cross slopes. The removal of thickness should be between 25 to 50 mm. Milling can also be selectively used with direct placement to treat the isolated stretch suffering from distortion in the project road. Milling is not mandatory.
- **Placement of Levelling Course** – Sometimes a levelling course of bituminous mix is used to produce a uniform surface for paving. A levelling course typically consists of minimum 50 mm of Bituminous Macadam (BM). Exact quantity will depend upon the undulations. When the distortion/rutting depth exceeds more than 50 mm, the option of milling as an economical alternative may be evaluated. It is also a practice of laying levelling course along with concrete overlay.
- **DLC/ PCC Levelling Course** – Levelling/ profile correction can be done by using PCC (say M10 grade) or DLC layer. The minimum thickness may be 75 mm, average 100 mm and maximum 125 mm. At portions requiring > 125 mm PCC, a leaner concrete (say M5 or CC 1:4:8 or leaner DLC) may provided in thickness such that over it PCC or DLC will be minimum 75 mm. While profile correction is done by lean concrete (or DLC), a combination of milling in some portion can be opted to reduce the finished road level (FRL). A separation layer is to be used between DLC/PCC and concrete overlay. For separation layer, impermeable membrane of virgin (without filler material) low density polyethylene (LDPE) can be used. Geo-textile (non woven polypropylene blanket typically 0.45 to 0.55 kg/m^2) about 3 to 4 mm thick may also be used as a separation membrane. Research and project experience has shown that nonwoven geotextiles provide uniform elastic support to the concrete overlay, reduce pumping processes and prevent reflective cracking. The separation layer (or sheet) may not be provided where joint spacing is ≤ 12 (18 for structural FRC) times the thickness of PQC even if the PQC layer is designed as un-bonded pavement.

5.5 Inlays

Concrete pavements are sometimes placed in a trend milled out of a thick asphalt pavement, in the form of concrete inlays. This is used where it is desired to remove and replace only the deteriorated lane (s). It is also effectively used where minimum vertical clearance requirements of structures like road-over-bridges prelude raising of the existing level of the road. In such cases, sufficient depth of the old pavement is milled out so that the concrete is levelled with, or only slightly higher than the existing shoulder or adjacent asphalt lane.

For whitetopping in the form of inlays, thickness design and jointing practices to be adopted are the same as followed in case of normal pavement design practices as per IRC:58 and IRC:15. Dowels or reinforced concrete pavements for such inlays may be used, particularly, where heavy traffic and wet climatic conditions exist.

5.6 Thickness Design

The design principle adopted for conventional whitetopping is similar to those of normal concrete pavements as provided in IRC:58 "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways" and IRC:15 "Standard Specifications and Code of Practice for Construction of Concrete Roads". These standards may be followed for design of Conventional Whitetopping, except determination of modified/effective/support modulus of subgrade reaction ("k" value). The correlation between CBR and 'k' value for the subgrade as given in IRC:58 can be used for the design.

Rigid pavements in India, at present, are mostly constructed on a sub-base of Dry Lean Concrete (DLC). Table 3 and 4 of IRC: 58 accordingly have been provided for correlating "k" values of soaked subgrade to the effective "k" values over granular/cement treated sub-bases. IRC:58 does not furnish any correlating table for determining effective "k" values for bituminous sub-base which will be the actual sub-base for conventional whitetopping.

American Concrete Pavement Association (ACPA) in its engineering bulletin (EB210.02P) has given two charts for the determination of modified 'k' value on the top of bituminous pavement.

One chart is for the case when the existing bituminous pavement is atop a granular base and the other chart is when the existing bituminous pavement is atop cement treated base. These charts are reproduced to assist the designer of Conventional Whitetopping to choose the modified 'k' value for the existing bituminous top. For this purpose, two alternative methods to determine the modified value of 'k' are suggested in this guideline. One method is to determine the 'k' value of the existing subgrade by plate load test and then the modified 'k' value for the bituminous top can be found out from the Figs 1 and 2 depending upon whether asphalt surface is on the granular base or on cement treated base. The plate load test being cumbersome is normally avoided by the Field Engineers and more reliance is placed on the deflection on the top of bituminous surface by Benkelman Beam Deflection (BBD) test. The graphical method given in Appendix III can be used for determining 'k' value with respect to the characteristic deflection of BBD test as per IRC:81. The rest of the design can be done with the help of existing IRC:58 by using the "k" values determined from the **Figs. 1 and 2** or Appendix III. Conventional Whitetopping should have a joint spacing of 4 to 4.5 m as per the normal concrete pavement with dowels at junctions regularly. Construction shall be as per IRC:15. Conventional whitetopping is expected to provide an alternative solution to the problems of rehabilitations of many flexible pavements constructed on the medium to heavily trafficked arterial roads.

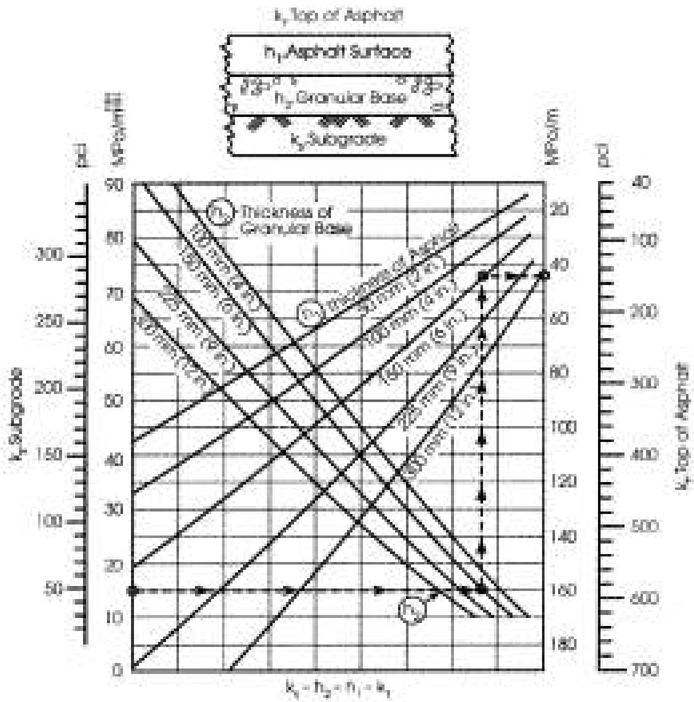

Fig. 1: Chart for Determination of Modified "k" value on top Bituminous Pavement atop of Granular Base

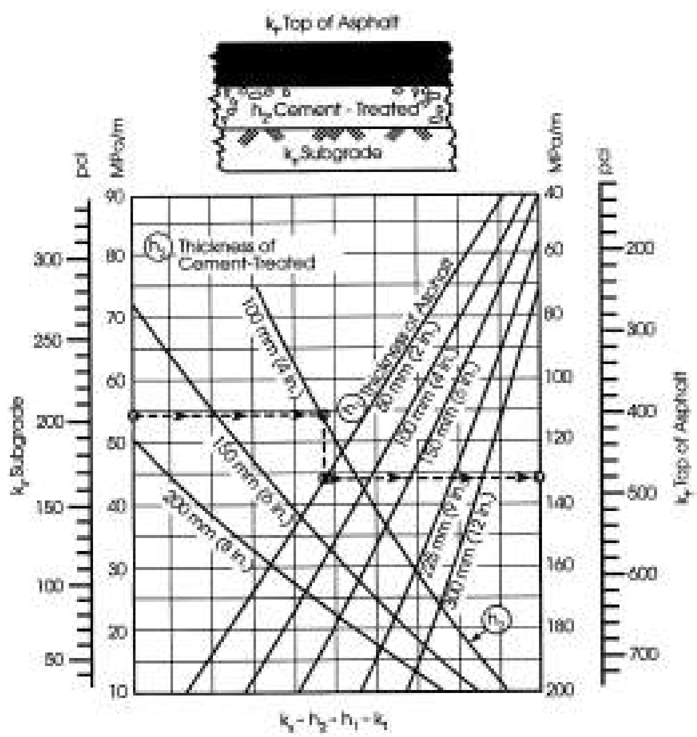

Fig. 2: Chart for Determination of Modified "k" value (modulus of support) on the top Bituminous Pavement atop of Cement Treated Base

6. THIN WHITETOPPING (TWT)

6.1 Introduction

Thin Whitetopping is an innovative design concept that has emerged in the 1990's. The first overlay of 90 mm of concrete pavement was placed over existing asphalt on two projects in Kentucky (USA) in 1988. In 1990 in Colorado (USA) number of sections of thickness of 90 mm and 125 mm were placed. Fiber reinforced concrete sections of 50 and 90 mm thickness with 0.6 to 1.8 m joint spacing were slip formed on top of a deteriorated asphalt pavement in USA. Many of these slabs were instrumented to measure strains and deflections under the loads of many heavy trucks.

The performance of these thin slabs was outstanding. These remarkable performances had subsequently generated a renewed interest in Thin Whitetopping across the developed world. The use of TWT has grown rapidly in last one and a half decades. From 1990 to 1996 more than 800 projects, representing about 1 million sq.m have been placed in North America alone. Majority of data available from several projects have indicated good performance of TWT.

6.2 Salient Features Thin White Topping

The development of an effective bond between PCC overlay and the existing bituminous pavement is desirable for the better performance of TWT because the strength of the existing bituminous pavement is being relied upon to carry part of the traffic load.

i) Extensive surface preparation to promote significant bonding between the concrete overlay and the bituminous pavement is required. Some times chiselling may also be tried gently at certain locations where milling is difficult to make the bituminous surface rough. (Excessive roughened surface, however, should be avoided as this could enhance the frictional forces)

ii) Use of short joint spacing (generally between 1.0 and 1.5 m). Square spacing (e.g. about 1.0 m x 1.0 m) are preferred. Rectangular spacing wherever given should have a ratio not exceeding 1.2 between the long and the short arms.

iii) The minimum thickness of hot mix bituminous pavement is 75 mm (net excluding the milled thickness) for TWT. However, it is preferable to have this minimum thickness of 100 mm or more to ensure a reliable strong bituminous base.

6.3 Suitable Sites for TWT

Some of the sites for TWT overlays are given as:

i) Rural Roads

ii) Medium to Moderately Heavy Volume Roads (e.g. MDR, SH, Low Traffic NH)

iii) Intersections

iv) Minor Airports Pavements

v) Toll plaza

vi) Heavy density corridors

vii) Low volume metalled village roads

viii) New roads for heavy traffic as an alternate to flexible pavement/conventional rigid pavement

ix) Bus bay and truck lay-bye

TWT should be used only when the condition of the existing bituminous surface is fair without wide cracks and without material/sub-grade related problems. Isolated locations with distresses related to material/sub-grade failure or heavy rutting should be replaced by lean concrete (Grade M10) by full/partial depth repair before laying TWT.

7. PRE-OVERLAY DESIGN REQUIREMENTS

7.1 Evaluation of Existing Pavement

A thorough examination of deficiencies of the existing pavement including assessment of the causes of deterioration should be done before selecting TWT as an alternative treatment. TWT is generally intended to be placed on the existing bituminous pavement that is exhibiting rutting, shoving and other similar surface distresses, but do not have much wide cracks.

7.2 Surface Preparation

For TWT, top of sub base surface should be prepared by milling and thereafter thorough cleaning of the milled material to ensure effective bonding. TWT can also be laid on prepared bituminous layer by process of levelling if the thickness of bituminous layer is adequate and it is in sound condition. Milling the existing bituminous surface is, however, quite desirable to enhance the bond and also to remove any surface distress or distortions.

7.3 Lane Closure

At many intersections like urban location, underpasses lane closure times may be somewhat restricted and possibility of detouring the traffic may not be quite possible. In all such situations, the use of fast track paving may be considered to minimize lane closure time. Early opening to traffic concrete could be used wherever, feasible. The specialist literature may be consulted for this purpose.

7.4 Overhead Clearance

Matching of adjacent shoulder and traffic lane elevation are often a problem with rehabilitation projects. These locational problems are effectively tackled by resorting to suitable milling in case of TWT projects.

8. THICKNESS DESIGN OF TWT

8.1 Composite Action

Structural behaviour of TWT is quite complex. Design is based on composite action of the bituminous layer and PCC overlay. Pavement should, therefore, be analysed as composite system in which the concrete and bituminous layers are characterised by their thickness and elastic properties, all on top of a 'k' value for the subgrade. The degree of composite action assumed in the analysis has significant influences on the stresses developed. The results of mechanistic analysis suggest that load stresses depend upon the slab size (joint spacing) and bonding of PCC layer with asphalt pavement. There is a substantial reduction in load stress as slab size decreases. This is also true for curling and warping stresses which occur due to temperature and moisture gradient in the concrete slab.

In case of very short slabs and without substantial thickness of bituminous layer and base course, both deflection and vertical strains are high. This could lead to excessive permanent deformation in the foundation with time due to load repetitions. There is, therefore, always an optimum joint spacing for which stresses are reduced but deflections are not excessive. Considering the above aspect, the joint spacing between 1.0 to 1.5 m for Indian condition is recommended.

Due to composite action as shown in **Fig. 3**, load stresses are reduced due to shifting of neutral axes near the interface.

Some attempts have been made to develop such design procedures to estimate the load carrying capacity and service life of projects based on instrumentation of slab, field performance results and three dimensional finite element model. In all these design procedures, developed so far, consider the critical stresses both at the corner and joint locations of a slab, besides incorporating the temperature effect. For further details, literature at Sr. No. 9 and 24 of references may be referred.

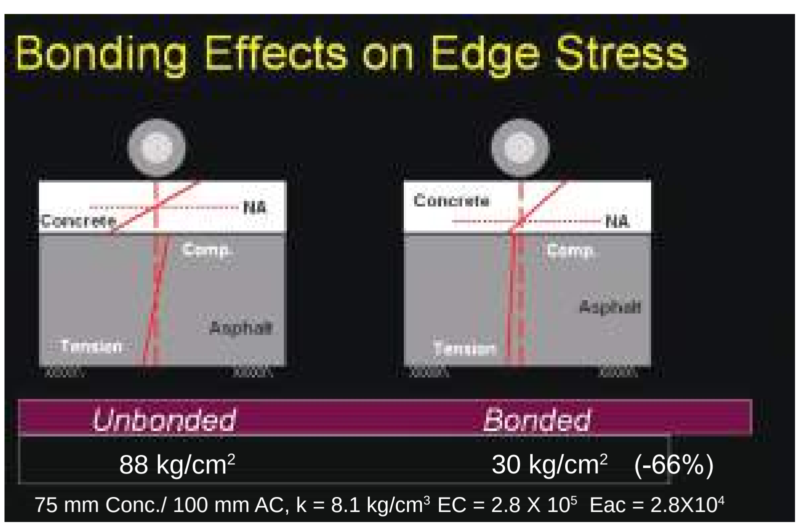

Fig. 3: Stress Diagram in Case of Bonded and Unbonded TWT

8.2 Design Factors

8.2.1 Traffic

The volume and character of present and anticipated traffic generally determines the number and width of traffic lanes. The weight and frequency of the wheel loads of this traffic form the basis of the slab's structural design. The procedure given in IRC:58 may be followed for calculating the traffic frequency of wheel loads.

8.2.2 Subgrade and Sub-bases

Subgrade strength may be evaluated, if required on the basis of either CBR or modulus of sub grade reaction (k) value (as per IS:9214-1974). For more details, para 5 may be referred.

8.2.3 Sub-Base Course

8.2.3.1 Layer of sound bituminous pavement of minimum 75 mm thickness after milling,

8.2.3.2 Layer of bituminous pavement of thickness less than 75 mm with profile correction course of bituminous macadam to have total minimum bituminous pavement thickness of 75 mm can be considered an exception.

8.2.3.3 Before laying profile correction course, tack coat is required as per MORTH Specifications.

8.2.3.4 Any distress in the sub base layer shall be repaired with suitable materials. Location/stresses having isolated damages shall be removed up to full depth and rectified as per the specifications/drawings to make up atleast 75 mm thickness of bituminous pavements.

8.2.3.5 Benkelman Beam as per IRC:81 in case of flexible pavement may be referred. Appendix V may be used to convert test result of Benkelman Beam deflection data into modified 'k' value. Figs. 1 and 2 may be adopted for determining 'k' value on the top of asphalt pavement, if Benkelman Beam Deflection tests are not carried.

8.2.3.6 The maximum 'k' value shall preferably be 15 kg/cm^2/cm.

8.3 Critical Stress Location

Primary distresses exhibited on TWT projects have been observed to be the corner breaks. These corner breaks are frequently but not always preceeded by debonding between concrete overlay and underlying bituminous layer. The debonding mainly occur due to upward curling at corners during night time. The corner breaking being the primary distress suggests that the critical stress location for design of TWT is the corner and corner stresses due to load as well as curling are the critical stresses. Edge load and temperature stresses which cause top-up transverse cracking in the middle of the slab in conventional rigid pavement slab are not critical in short TWT panels.

8.4 Stresses Due to Temperature Curling

8.4.1 Negative temperature gradients (top cooler than the bottom) produces tensile curling stresses on top of the slab at the corner. The temperature curling stresses σ_T at the top of the slab corner can be computed by the equation 1 (Mack et al. 1997). The equation has been adopted by modified ACPA design procedure for whitetopping overlays (Riley, 2005).

$$\sigma_T = 1.933\text{-}241000(\alpha\,\Delta T) + 1.267(L/l_e)......1$$

where,

σ_T = curling tensile stress at corner, kg/cm^2

α = coefficient of thermal expansion, /^{o}C

ΔT = negative temperature differential, ^{o}C

L = length of square slab, cm

l_e = radius of relative stiffness, cm

8.4.2 Maximum negative temperature differential measured through 30 cm to 34 cm thick instrumented concrete slabs in India was observed to be 0.17^{o}C/cm at Kota, 0.23^{o}C/cm at Siliguri, and 0.21^{o}C/cm at Allahabad with an overall average of 0.20^{o}C/cm. For thinner slabs of TWT, a lesser value of 0.15^{o}C/cm can be adopted for calculating the tensile curling stresses at the corner of the slab.

8.5 Stresses due to Load and Temperature

The primary distresses exhibited by the TWT projects have been corner cracks. The corner breaking being the primary distress suggests that the critical stress location for design of TWT overlays is the corner stress. The corner tensile bending stress in a slab for 8T single axle load and 16T tandem axle load can be computed by equation 2 and equation 3 respectively (Mack et al. 1997).

$$Log(\sigma_8) = 3.6525 - 0.465log(k) + 0.686log(L/l_e) - 1.291log(l_e) \quad ......2$$

$$Log(\sigma_{16}) = 3.249 - 0.559log(k) + 1.395log(L/l_e) - 0.963log(l_e) - 0.088(L/l_e) \quad ....3$$

where,

σ_8 = bending tensile stress at corner for 8T single axle load, kg/cm^2

σ_{16} = bending tensile stress at corner for 16T tandem axle load, kg/cm^2

k = modulus of subgrade reaction, kg/cm^3

L = length of square slab, cm

l_e = radius of relative stiffness, cm

The corner bending tensile stresses for other single and tandem axle loads can be computed proportionately by using σ_8 and σ_{16} values respectively. If the panel size is less than 1.30 m, then two axles of a tandem axle vehicle will not fall on the same panel simultaneously, hence, stresses should only be considered for single axle. The possibility of wheels of two adjacent vehicles simultaneously placed on one panel is also excluded.

8.6 Stress Ratio and Fatigue of Concrete Slab

Fatigue criteria based on Miner's hypothesis and IRC:58 has been considered. The fatigue resistance not consumed by repetition of one load is available for repetitions of loads from other vehicles (other loads). In the design, total fatigue should not generally exceed 100 percent. The concrete fatigue criterion based on stresses ratio and allowable repetitions are given in IRC:58. Stress ratio is computed as the load stresses divided by the flexural strength or Modulus of Rupture (MOR) of the concrete. If structural fibre reinforced concrete is used then stress ratio is given by the following equation.

$SR = \text{Flexural Stress}/\text{MOR}(1 + R_{150})$

Where, R_{150} is the residual strength ratio which characterizes the contribution of the structural fibre reinforcement. It is recommended that the residual strength ratio should be determined following ASTM C 1609 or IRC:SP:46-2013.

8.7 Steps for Design Procedure

i) Find traffic in terms of commercial vehicles per day (CVPD) and their percentages of the total traffic including single axle and tandem axles.

ii) Evaluate soaked CBR/k value of sub grade

iii) Find Modified 'k' value or support modulus (from Appendix III/Figs. 1 or 2 as for conventional whitetopping or) on sub base of asphalt pavement from the modulus of subgrade reaction of the subgrade.

iv) Assume a trial thickness and joint spacing (say 1 m or 1.2 m)

v) Find Temperature Stresses

vi) Find corner load stresses and curling stresses using equations 1 to 3. Calculate stress ratio using corner load stresses and find out total fatigue life consumed which should be less than one.

vii) Calculate total of maximum load and curling stresses at corner. It should be less than the flexural strength of concrete.

viii) Formula for determining flexural strength at third point loading as per IS 516-1959 is given below:

$$\text{Flexural Strength at third point loading} = [Pl/bd^2]$$

where,

l is effective length of beam, or distance between two supports in cm

b&d are breadth and depth of beam in cm

P is the load at failure of the beam in kg

ix) Determine fatigue consumed, which shall be less than one.

x) A typical, design example is given in Appendices II.

9. STEPS OF CONSTRUCTION

9.1 Milling

The milling of the existing asphalt pavement provides removal of rutting, a roughened surface to enhance the bonding between the new concrete overlay and the existing asphalt pavement. The depth of milling (25–50 mm) depends upon the types and severity of distress especially the depth of rutting or other surface distortions and the available thickness of asphalt pavement. Hand grinding/Light Chiselling may also be used gently for making the roughness in top surface of asphalt pavement at difficult locations. In case of non availability of the required machinery, a profile correction course of bituminous macadam (of minimum thickness 50 mm) may be laid over existing bituminous pavement after applying tack coat as per MORT&H Specifications so as to have a net bituminous thickness of 75 mm.

9.2 Repair to Existing Pavement

The milled pavement shall be repaired in respect of cracks and wherever the cracks are too many indicating failure of subgrade, the pavement shall be replaced and simultaneously the subgrade will also be re-compacted.

Existing bituminous layer after milling shall be in good condition to minimize reflection cracks or sympathetic cracks. If locally any distress/defects/cracks are observed, these shall be repaired/ sealed using properly designed dense bituminous mixes. The top of milled surface and repaired portion shall be in level with each other. The cracks shall be repaired first with hot bitumen of any suitable grade, before laying PCC and the surface is then broomed by compressed air/vacuum pump to remove debris prior to placing of concrete. The surface of the asphalt shall be flushed with water to aid in cleaning, before overlay is applied.

9.3 Cleaning

After milling or providing the profile correction course, atop the existing asphalt pavement, the top surface is cleaned to ensure bonding between the existing asphalt pavement and the new concrete overlay. Different methods of cleaning to remove foreign particles are given as:

- Air blasting/vacuum cleaner
- Power brooming
- Water blasting
- Sand blasting
- Chiseling

9.4 Placing, Finish, Texturing and Curing using Conventional Paving Techniques and Materials

After the milling operation/laying profile correction course, form work using steel channels or girder are fixed and stability of these is ensured simultaneously. Cement slurry may be applied before placement of PCC. Concrete is placed, finished and cured using conventional paving techniques and materials. After the laying of PCC, runner beam shall simultaneously be provided without causing vibration/disturbance to the newly laid TWT. Use of kerb stone as form work is not preferred. Use of semi mechanized method, slip form paver or fixed form paver may be adopted as per IRC:15 based on size of project and availability of the space and equipment. Curing compound/ water should be applied twice the normal rate, because TWT is thin concrete slab which has high surface area to volume ratio and can loose surface moisture rapidly due to evaporation.

The timing of the texturing operation is important. If done too early or too late, the desired skid resistance will not be obtained. The best time for texturing is just after the water sheen has disappeared and just before the concrete becomes non-plastic

For low speed, municipal or urban projects, a burlap drag, turf drag, or coarse broom texture is sufficient from lower side to upper side. For high-speed interstate and other primary routes, tining provides excellent long-term skid resistance.

9.5 Drainage

Drains, inlets and manholes must be raised to match the elevation of the new pavement. Drainage pipe shall be below the drainage layer, if provided. The slabs around the manhole shall preferably be with Reinforced Cement Concrete (RCC) using nominal reinforcement of 10 mm dia plain bars at 150 mm c/c at neutral axis.

9.6 Due to special problems of urban areas, construction practices and detailing need to be evolved. Additional corner steel at man hole, paver block surface along edges for future services, cross pipes at regular interval for future services etc. have to be properly planned. Overlay invariably raises the road level and hence slight re-planning of storm water system or reverse camber at the entry to houses etc. will have to be planned. Typical photographs are given in Appendix IV and V.

10. JOINTS

The ratio of the length (longest dimension) to width (shortest dimension) of any given panel is recommended to be not more than 1.20. Following types of joints are being adopted in the construction of conventional rigid pavement.

i) Contraction Joints

ii) Expansion Joint

iii) Construction Joint

iv) Longitudinal Joints

In the case of TWT, construction of these joints is slightly modified because of small size panel and bonding or partial bonding of TWT layer with the sub base layer:

10.1 Initially, 3-5 mm wide joint may be cut within 6-18 hours (depending upon the grade of concrete being used and admixtures added) to a depth of 1/3 of the slab’s depth.

10.2 Tie bars are designed to withstand tensile stresses only. The maximum tension in the tie bars across any joint is equal to the force required to overcome friction between pavement and subgrade, from the joint in question to the nearest free joint. The term free joint is applied to any type of pavement joint that has no tie bars or bonded reinforcement across in it. Deformed steel tie bars of length 500 mm, 10 mm diameter and spacing of 750 mm shall be provided at longitudinal construction butt joint.

10.3 Dowel bars are mechanical load transfer devices built as an integral part of certain transverse joints to permit the joint to open and close but to hold the slab ends on each side of the joints, as nearly as possible, at same elevation. The deflection of one slab under the load is resisted (through the dowel) by the other slab which, in turn, is caused to deflect and thus to carry a portion of the load imposed upon the first slab.

10.4 In case of TWT, the pavement is divided into relatively short panels by contraction joints which are so spaced to prevent formation of intermediate cracks. In case of TWT when thickness is less than 150 mm, provision of the use of dowel bars may be omitted. When TWT thickness is 150 mm to 200 mm and where pavement joins a structure such as a bridge, at the intersection with other pavement or for any transverse butt type joints viz. construction joints, plain mild steel dowels with plastic sheathing of 25 mm dia and of length 500 mm at spacing of 300 mm c/c. may be provided.

10.5 Short joint spacing is critical for the good performance of TWT projects. Acting like a paver block system, it reduces curling stresses and bending stresses in concrete slab due to loads.

Load transfer is provided by aggregate interlock, which is further enhanced by short joint spacing and by the support of the underlying pavement. Compared to conventional pavements, load transfer is not as critical for concrete overlays because the underlying pavement provides considerable support to the joints.

For TWT, extra concrete thickness is needed near the joint at the transition to the asphalt roadway. Similar practice is continued near the taper joint (**Figs 4 & 5**).

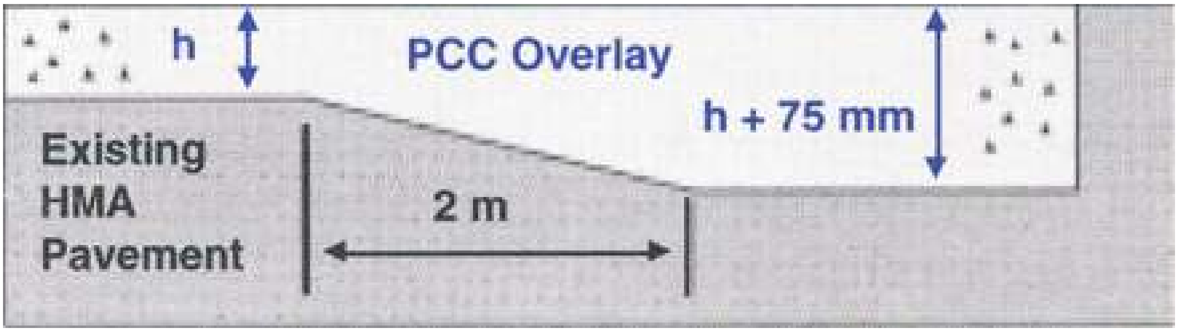

Fig. 4 : Cross Section View of the Transition Slab Adjoining Asphalt Pavement

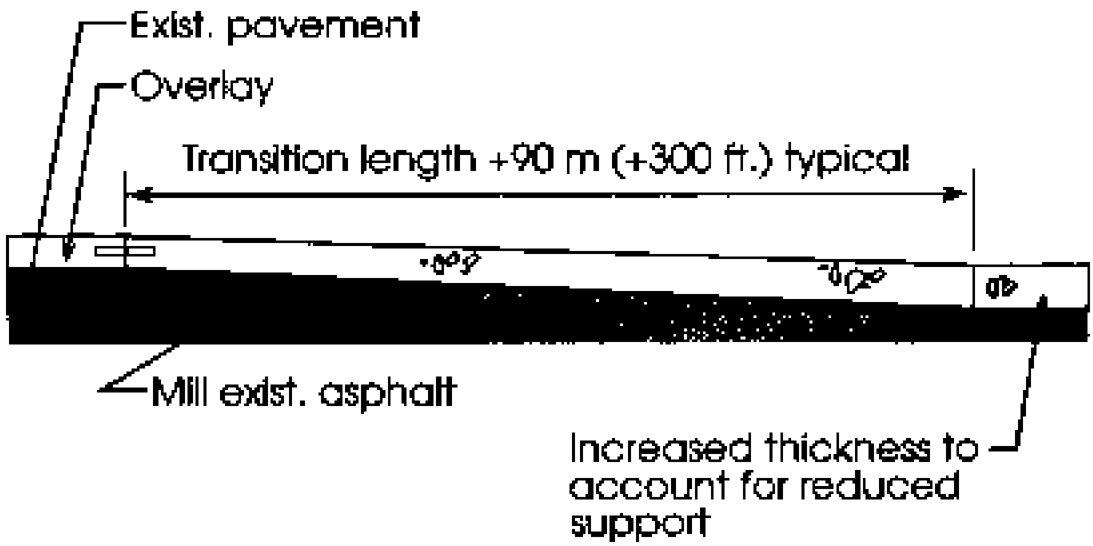

Fig. 5: Cross Section of TWT at Taper

Timely joint cutting (with in 6-18 hours of laying of TWT) prevents cracking, minimizes curling and warping stresses. Early cutting of joint is desirable. Since more number of joints are required to be cut because of close spacing, it is preferable to resort to skip-sign to avoid cracking. The intermediate joints shall be cut after the skip sawing is completed. The sawing should be started when the pavement is able to bear the weight of the saw cutting machine and the crew. Higher rate of strength development may need Joint cutting after 5 hours or so. Each properly aligned tie bar shall be at least 50 mm away from the joint/free edge. The minimum concrete cover around steel bars shall be about 50 mm

It is preferred to first dip the tie bars in the cement slurry before using in the TWT to minimize corrosion and have adequate bond with concrete.

An approved high-quality sealant shall be used to seal joint reservoirs and prevent moisture and incompressible infiltration into the overlay system. Sealants should be installed following manufacturer's instructions.

Details of the joints and their sealing with sealant or preformed seals as shown in **Fig. 6** are given in IRC:15 and IRC:57.

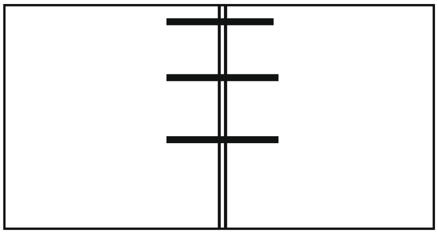

Fig. 6 (a): Plan of Two Adjoining Slabs (UTWT/TWT) at Butt Type Longitudinal Joint

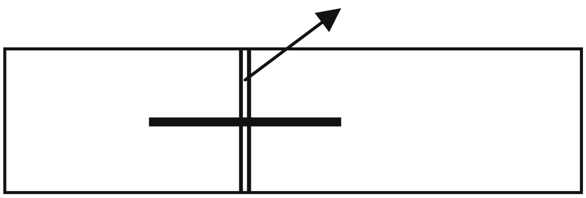

Fig. 6 (b): Cross Section View of Butt Type Longitudinal Joint

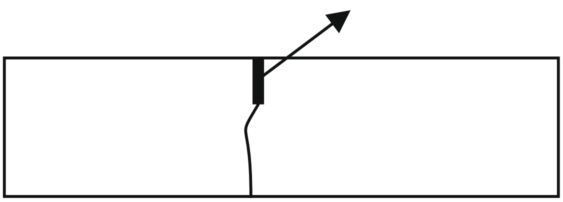

Fig. 6(c): Cross Section View of Contraction/Longitudinal Joint

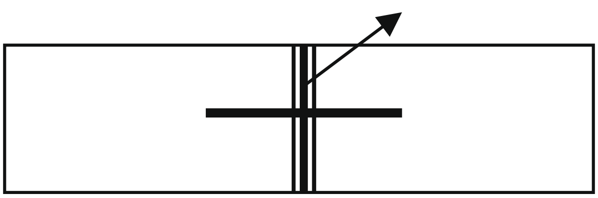

Fig. 6 (d): Cross Section View of Construction Butt Joint (Transverse Joint)

The photographs of construction practice adopted for dowel bars and tie bars are attached. Dowel bars are normally provided at the construction joint in white topping technology as panel size are small. Similarly if roads are executed in half width then for central joint tie bars are provided

10.6 Drainage is an important consideration for the efficient functioning of Whtietopping like any rigid pavement. The field engineers should make suitable drainage provision. It should be ensured that drainage along the carriageway is efficiently handled, so that no water is intercepted underneath the slab. For this purpose, any arrangement being followed in normal road projects can be adopted.

11. OPENING TO TRAFFIC

The traffic can be opened when the TWT has attained the desired strength depending on the traffic loading condition. Usually, traffic may be opened after 28 days (or at the age at which minimum compressive strength of 28.0 MPa is achieved) of casting Paving Quality Concrete (PQC)/PCC slabs.

12. DISTRESSES IN WHITETOPPING

Due to reduced maintenance cost the white topping is now accepted by public as well as authorities. There are typical distress conditions in this technology but as most of them are localised and may not affect the riding quality the same is generally tolerated by public. Photographs showing these distresses, causes and remedial measures are attached in Appendix VI.

13. SPECIAL CASES OF WHITETOPPING

13.1 Presently the technology is used for existing roads in urban area carrying low volume traffic. However by properly designing the overlay thickness the technology can also be adopted for heavy density corridors. In the white topping technology curling/temperature stresses are minimum and panels are designed for corner stresses. The panel size is kept less than 1.5 m x 1.5 m and preferably 1.25 m x 1.25 m. The dowels can be omitted.

13.2 The exiting metalled or damaged village roads are commonly revived by first putting a WBM/WMM overlay followed by carpet and seal coat. As an alternate a concrete overlay of 75 mm to 100 mm with panel size of 1 m x 1 m would meet the need and prove an economical alternative.

13.3 New roads carrying heavy traffic can also be designed as thin concrete pavements with thicknesses in the range of 180 to 200 mm and maximum panel size of 1.5 m x 1.5 m. Drainage cum granular sub-base and dry lean concrete base of adequate thicknesses should be provided for such pavements.

FUTURE RESEARCH

Following activities may be considered in future R&D Projects:

- Development and adoption of a mechanistic method for the design of concrete overlay is needed. The method should consider the capability of each layer in the pavement system as well as the foundation itself.
- Additional data are needed regarding the performance of fibrous, pozzolona admixed and prestressed concrete overlay under repeated loading applications and environmental effects. In addition, studies leading to improved handling and construction methods for these materials are needed to improve their economic competitiveness with other types of concrete overlays. These materials have many of the properties ideally suited for resurfacings, especially the resurfacing of existing pavements that are structurally distressed.
- Although many unbonded concrete resurfacings have been constructed, there have been few studies to define the desirable properties of the unbonding medium. Studies to define the minimum and maximum thicknesses, stiffness requirements, types of materials, frictional characteristics, etc., are needed.
- The collection and rigorous analysis of performance data from the large number of concrete overlays that have been constructed are needed to provide guidance and confidence in the selection, design and construction of the various concrete overlay alternatives.

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APPENDIX I

DEFINITIONS

Aggregates: General term for the mineral fragments or particles which, through the agency of a suitable binder, can be combined into a solid mass e.g. to form a pavement.

Asphalt Concrete or Bitumen Concrete: A graded mixtures of aggregate, and filler with asphalt or bitumen, placed hot or cold, and rolled.

Base Course or base: The layer or layers of specified or selected material of designed thickness placed on a sub-base or subgrade to support a surface course.

Composite Pavement: A pavement consisting of both flexible and rigid layers with or without separating granular layers.

CBR (California Bearing Ratio): The bearing ratio of soil determined by comparing the penetration load of the soil to that of a standard material evaluation of the relative quality of subgrade soils but is applicable to sub-base and some base course materials.

Flexible Pavement: A pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particles friction, and cohesion for stability.

Overlay: An additional surface course placed on existing pavement either with or without intermediate base or sub base courses usually to strengthen the pavement or restore the profile of the surface.

Pavement or Pavement Structure: The combination of sub-base, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the subgrade.

Portland Cement Concrete (PCC): A mix (mix of) graded aggregate with Portland Cement, and water.

Rigid Pavement: A pavement structure that distributes loads to the subgrade having as its surface course a PCC slab of relatively high bending resistance.

Sub Base Course or Sub base: The layer or layers of specified selected material of designed thickness placed on a subgrade to support a base course.

Subgrade or Foundation Formation: The upper part of the soil, natural or constructed, which supported the loads transmitted by the pavements.

Wearing Course or Surface Course: The top course of a pavement structure.

APPENDIX II

DESIGN EXAMPLE

1. Design Parameters

i) Design Life : 20 Years

ii) Traffic Growth Rate, r : 0.075

iii) Commercial Traffic : 1842 cvpd

iv) Grade of Concrete : M40

v) Cumulative Repetitions in 20 Years : $1841 \times 365[(1.075)^{20} - 1]/0.075$ = 29099230

vi) Design traffic : 25% of 29099230 = 7274808 cvpd

vii) CBR : 4%

viii) Corresponding 'k' value : 3.4 kg/cm^3

ix) 'k' value is determined from a graph developed by Corps of Engineers (Appendix III) against a Benkelman Beam deflection value of say 0.94 mm obtained in the field and it was found that 'k' value of existing layers is 10.0 kg/cm^3 before applying a profile correction course.

x) Profile Correction Course minimum 50 mm thickness of Bituminous Macadam (using VG30 bitumen) as per MORT&H Specifications, is suggested to correct the profile and for repair of existing bituminous pavements.

xi) A minimum value of modified modulus of subgrade reaction 10 kg/cm^3 has been considered in the design.

1.1 Percentage of different Axle Loads assumed are given in Table 1:

Table 1: Percentages of Axle Load for the Design of TWT

Single Axle Loads		Tandem Axle Loads	
Axle Load Class, Tons	% of Axle Loads	Axle Load Class, Tons	% of Axle Loads
15-17	0.5		
13-15	0.7	26-30	0.2
11-13	1.0	22-26	0.5
9-11	24.5	18-22	1.0
7-9	40.0	14-18	3.0
Less than 8	25.0	Less than 14	3.6
	91.7		8.3

1.2 Expected Repetitions are given in Table 2:

Table 2: Expected Repetitions for Axle Loads

Single Axle Loads		Tandem Axle Loads	
Axle Load in Tonnes	Expected Repetitions	Axle Load in Tonnes	Expected Repetitions
16	36374	28	14550
14	50924	24	36374
12	72748	20	72748
10	1782328	16	218244
8	2909923	Less than 16	261893
Less than 8	1818702		603809
	6670999		

Trial Thickness : 18 cm

Subgrade Modulus : 10 kg/cm^3

Design period : 20 Years

Modulus of Rupture : 45 kg/cm^2

Load Safety Factor : 1.0

1.3 Analysis of Fatigue Life Consumption:

Table 3: Fatigue Life Consumed for Single Axle Load

Axle Loads, Tonnes	Load Stress, kg/cm^2	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed
16	23.44	0.52	36374	326000	0.11
14	20.51	0.46	50924	14335000	0.004
12	17.58	0.39	72748	Infinity	0.0
10	14.65	0.32	1818702	Infinity	0.0
8	11.72	0.26	2909923	infinity	0.0
Less than 8			1818702	infinity	0.0
					0.114

Table 4: Fatigue Life Consumed for Tandem Axle Load

Axle Loads, Tonnes	Load Stress, kg/cm^2	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed
28	27.23	0.61	14550	23400	0.62
24	23.34	0.52	36374	326000	0.11
20	19.45	0.43	72748	Infinity	0.0
16	15.56	0.35	218244	infinity	0.0
Less than 16			261893	infinity	0.0
					0.73

The cumulative life consumed both by single and tandem axle is 0.84 which is less than 1; the design is safe for the traffic proposed from fatigue consideration.

1.4 Temperature Curling Stresses:

$\sigma_T = 1.933\text{-}241000(\alpha\,\Delta T) + 1.267(L/l_e)$

ΔT = - 0.15°C/cm x Thickness of white topping overlay

= - 0.15 x 18

= - 2.7°C

$\alpha = 10 \times 10^{-6}$

L = Length of square slab = 150 cm

l_e = Radius of relative stiffness = $[Eh^3/12(1-\mu^2)k]^{0.25}$ = 62.15 cm

Thus, $\sigma_T = 1.933 - 241000[10 \times 10^{-6}\ (-2.7)] + 1.267\ (150/62.15)$

= 11.49 kg/cm^2

Total flexural stresses due to load and curling = Maximum load stresses + curling stresses

= 27.23 + 11.49

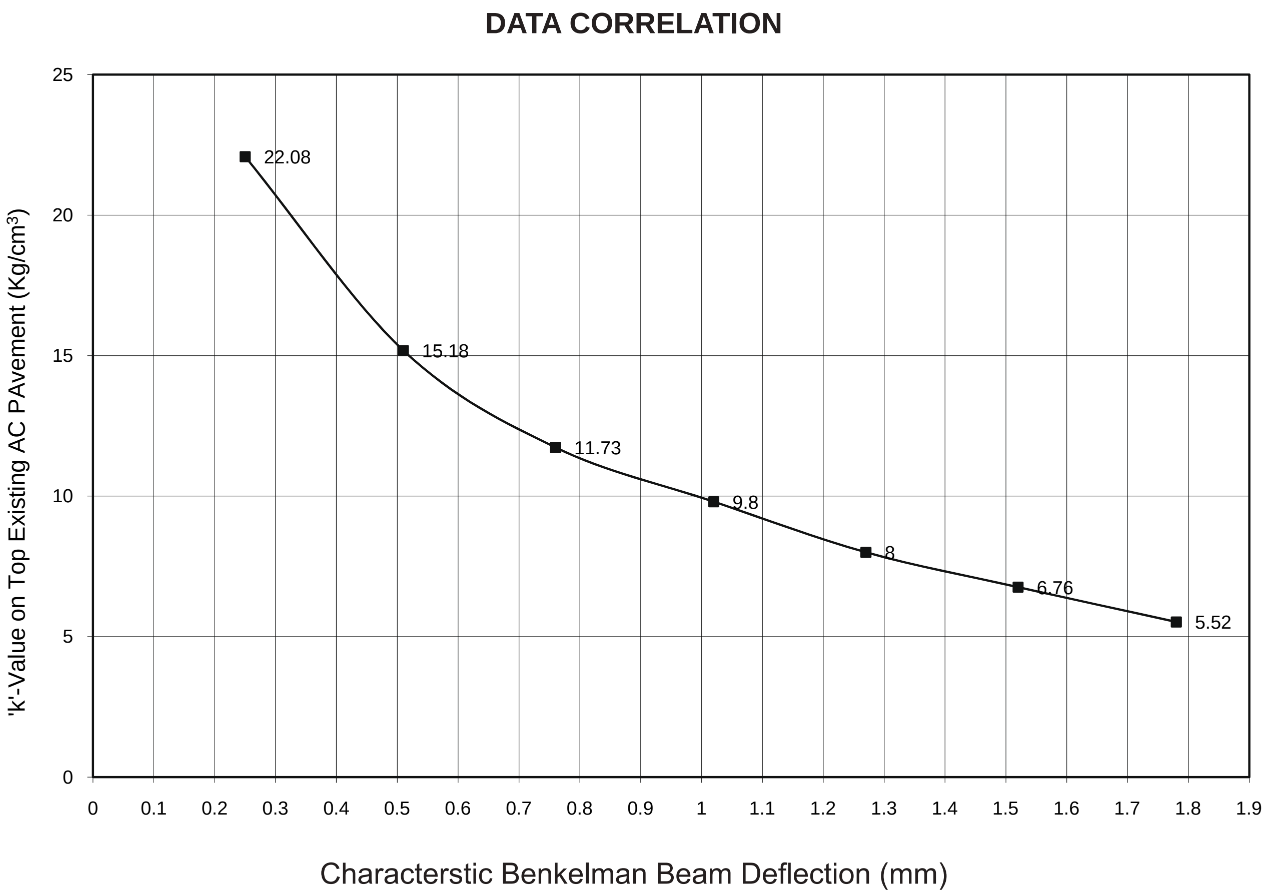
= 38.72 kg/cm^2

This is less than the minimum flexural strength of 45 kg/cm^2.

Hence, design is safe. White topping thickness of 18 cm can be adopted.

APPENDIX III

RELATION BETWEEN BENKELMAN BEAM DEFLECTION AND MODULUS OF SUBGRADE REACTION ON THE TOP OF ASPHALT PAVEMENT



(Source : Corporation of Engineers/Portland Cement Association (PCA), USA and Canadian Good Road Association data Ref: 21; ClibPDF-www.fastio.com)

Note: *Chart has been converted in Metric units by using the relation, 1 pound/ sq in / in = 0.0276 kg/cm^3*

APPENDIX IV

DEMONSTRATION PROJECT OF TWT

Whitetopping in Pune City

Pune city has adopted the Thin White Topping (TWT) treatment for internal roads as well as wider roads with higher traffic volume. Started in 2008, Pune city has constructed above 75 to 80 km of roads (approx. 9 lakh sq m) with TWT technology. The TWT overlay, 125 mm thick, constructed in 2008 are still in excellent condition. Recently roads with heavy traffic have also been overlaid with 175 mm thick TWT. The project features in brief are as follows:

- **Location:** Road in front of Shivajinagar State Transport depot. Total length of the road is 1.26 km and carriageway width is 11.00 m ROW is 15/18 m.
- **Type of Treatment:** Thin White topping with thickness 175 mm M40 grade concrete overlaid on top of existing bituminous road after milling of 50 to 60 mm.
- **Panel Size:** 1 m x 1 m panels created by saw cutting joints within 24 hours of casting. Width of TWT treatment is 8 m and hence 4 m wide concrete is cast first and then the balance 4 m width is cast after completion of curing and joint sealing (approx. 21 days) on other side. Longitudinal joint is not saw cut and butt joint is kept as it is.
- **Dowel Bars and Tie Bars:** Dowel bars are used only at the construction joint (25 mm bars at 250 mm c/c). Tie bars are used only at the center of the road (longitudinal joint 12 to 16 mm tor steel at 400 c/c)

- **Existing Road Details:** The existing road is in use for more than 25 to 20 years and consisted of well consolidated bituminous treatment of approx. 150 -160 mm thickness underlain by WBM of 250 to 300 mm thickness. Storm water arrangement in the form of 600 and 900 mm RCC pipes was present on the road. There were some locations with failure of base due to leakage of water supply line. The utilities like water supply main, distribution lines, sewer lines run along the carriageway edge and electrical cables, telephone cables, OFC etc run along the footpath. The road caters to traffic of above 5000 buses daily on account of state transport and the city transport depots on this road.

- **Assessment of Existing Road:** The Benkelman Beam Deflection study was carried out on the existing BT surface to design the bonded overlay treatment as per IRC:SP:76 and IRC:58 guidelines.
- **Milling Operation and Pretreatment:** Milling of existing BT road was done with a milling machine and 50 to 60 mm bituminous layer removed to lower the level of the road as well as creation of bond for concrete overlay. The portions which showed structural defects and settlement (approx. 1 to 2 percent of area) were completely excavated and new layers of hard moorum, GSB and DLC were provided.
- **Mix Design:** M40 grade concrete was used for the work with fibrillated Polypropylene fibers. On-site slump of concrete, prepared in a RMC plant, was kept below 40 mm. The cement content and w/c ratio were kept at 420 kg per cum and 0.37 respectively.

- **Construction Operation:** Concrete was transported with transit mixer and placed, compacted with screed and needle vibrators. The mechanical trowel/ float was used for floatation and finishing operation. The texturing was done with the help of locally available brush. The joints were cut for 1/3rd depth within 24 hours and concrete was cured with water ponding for 21 days. Joints were sealed with polysulphide sealant after 21 days and opened to traffic.
- **Cost Breakup:** Total project cost was Rs.7.24 crore with breakup is as follows:

S. No.	Work Item	Cost (Rs Crore)	Per sqm cost (Rs)
1	TWT pavement	1.91	**946**
2	RCC pipes, chambers, Storm water drainage	1.40	**692**
3	Footpath/ Paver Blocks and ancillary work	3.06	**1516**
4	Utilities (water supply, sewer, Electrical)	0.88	**437**
	Total	***7.24***	***3591***

APPENDIX V

TYPICAL CONSTRUCTION PRACTICES ADOPTED IN URBAN AREAS

1. RCC cross pipes of 300 mm and 450 mm dia are provided at every 50 m interval in congested area to cross utilities at a later stage without cutting the road. The area above pipes is paved with paver blocks.


2. RCC piles are also provided in the longitudinal direction along the road edge to house utility lines like OFC cables, Electrical cables etc and chambers with openable covers are provided at every 15 m interval. The pipe section is also provided with 100 mm removable paver blocks on a concrete bed.


3. Adequate storm water drainage arrangement in the form of collection chambers in individual property, ramps in direction opposite to property entrance (to prevent water entry in property) are provided.

4. Dowel bars are provided only at construction joint and the tie bars only at central longitudinal joint.

5. The RCC mesh of 12 mm dia 150 mm c/c (single mesh) is provided around the sewer/manhole chamber frame for a section of 1.5 m X 1.50 m for strengthening of the section around the manhole chamber cover.

APPENDIX VI

TYPICAL DISTRESSES IN TWT/UTWT PAVEMENTS - CAUSES AND REMEDIAL MEASURES

CORNER BREAK/CORNER CRACKING	Cause	Remedy
  	Corner cracking appears to be the primary failure mode, and fatigue cracking is believed to be the primary failure mechanism in TWT/UTWT. Bonding is an important factor to long-term performance of the overlay. TWT/ UTWT provides small joint spacing to minimize restraint stress. However, joint locations and traffic loading should be given significant consideration. In case of loss of support from the underlying HMA layer over time, corner breaks are likely to occur under heavy wheel load.	Full-panel replacement is common repair strategy for the distressed panels of TWT/UTWT such as Corner breaks

TRANSVERSE CRACK		
	Late joint sawing, misalignment of the dowel bars at construction joints leads to transverse cracking.	Make 8-10 mm wide groove along the crack for a depth of 20 mm and refilling with approved sealant.

DAMAGED UTILITY CHAMBERS	Cause	Remedy
	Use of masonry to raise the utility chambers to the road level during overlay operation. Improper workmanship and lack of adequate protection of the edges of the utility chamber.	Raising of utility chambers likely to come in the carriageway should be done in concrete (preferably whole chamber should be recast in concrete). Adequate protection of 0.3 m portion around the chamber should be strengthened using nominal steel mesh
DAMAGED LONGITUDINAL JOINT		
	Poor workmanship, bent steel formwork during construction and unprotected concrete edge after construction results in zigzag longitudinal joint which later on opens up and prone to damage after saw cutting.	Use good and strong formwork during construction and make sealing groove along the longitudinal construction joint

SHATTERED PANELS		
	Settlement and damage of underlying bituminous layer leading to cracking and shattering of panels	Full depth repair of damaged panels

(The amendments to this document will be published in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)