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Maintenance Design in Road Projects

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MAINTAINABILITY

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1.0 INTRODUCTION

One of the important aspects in design process is to consider maintainability upon completion of the project. This process, which is called maintenance design, identifies the optimal frequency of maintenance for each component of any road project. Thus, maintenance can be planned, scheduled and prioritized for optimal road performance and life cycle cost of the project.

The better the road is built, the slower the rate of deterioration will be and therefore the less maintenance required. A poor road, however, will quickly deteriorate and will need very frequent maintenance. Thus, we need to strike a balance somewhere between the extremes of:

- Design and build a road that needs no repair or routine maintenance over its lifespan, very expensive to build but cheaper to operate; or

- Build a road with very little design input that needs a lot of repair, high maintenance and frequent rehabilitation over its life, very cheap to build but very expensive to operate.

This is where an optimally safe and efficient design can be achieved when design principles are applied in conjunction with the optimal maintenance design. It also provides significant benefits for the road users such as safety, comfort and reduce public complaint.

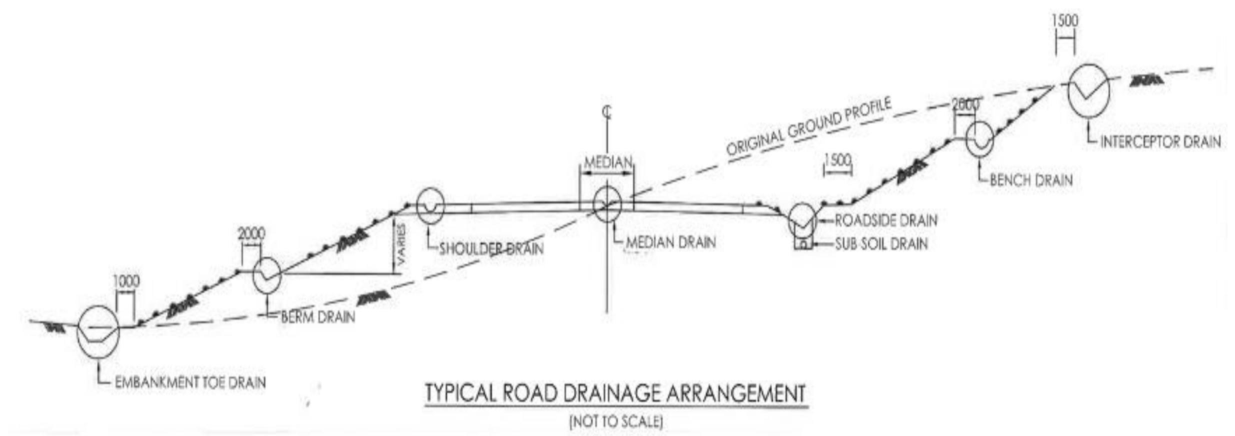
The content of this technical update will try to elaborate on the maintenance issues that commonly occurs in geometric design, pavement design, drainage design and road furniture.

2.0 GEOMETRIC DESIGN

Geometric design is the starting point for any road design and refers to the layout and alignment of road in both the horizontal and vertical. There are three types of ground condition based on topography, i.e. sloping ground, low lying ground or flat area.

2.1 Sloping Ground

The road where constructed on sloping ground, designers have to ensure that the slope in cut and fill embankment is stable. The main failure is caused by water, which in most cases, the level of ground water table on the cut side is close to the formation level. The presence of high ground water table will decrease the bearing capacity of the subgrade.



This is the typical road drainage arrangement for cut and fill embankment. Consideration should be given to the possibility of water flowing towards the roadway, either on the surface or through the water bearing strata. Care should be taken to keep ground water table below the formation surface and prevent erosion or slope failure.

	
<u>Water Seepage Problem</u> The seepage of water into the embankment from the slope adjacent to the road will soften the embankment and leads to slope failure.	<u>Solution:</u> Longitudinal subsoil drain can be used to intercept seepage water and lower the ground water table.

2.2 Low Lying Ground

The drainage system for surface water is often poor in low lying areas. Excessive runoff due to heavy rain that stagnates on the roadway and slowly into the road will, in the long term, affect bearing capacity of the soil. This, coupled with the problem of high-water table will speed up the deterioration of the road.

	
Water Ponding Issue Water ponding issue at low-lying area. Proper design of the storm water drainage outlet should be considered carefully.	Wet Road A high-water table will cause water seepage to the road surface which will cause the road to become wet and further deteriorate. A high-water table can be lowered by the installation of subsoil drainage system.

2.3 Flat Area

Flat area can cause drainage problems where there is a risk for flooding. Natural ground in flat areas does not have any gradient as such, water does not flow away from the carriageway. This can slowly saturate the underlying road structure and leads to bearing capacity problems.

	
Low Formation Level Proper design of the formation level and drainage outlet should be considered carefully to avoid flooding. Designer must check the freeboard level to make sure it does not exceed the formation level.	Solution: When raising the formation, there is a need to provide multiple balancing culverts spread over the flood plain area to balance the level and flow of water.

3.0 ROAD CROSS-FALL

Road surfaces are normally crowned or superelevated to facilitate the removal of surface water. Special consideration must be given to determining when to use the desirable rates of cross-fall to minimize water ponding on flat sections. Horizontal and vertical alignment should be coordinated to avoid flat spots where curves and superelevation transitions coincide.

	
Insufficient Road Cross-fall The cross-fall of road should be sufficient to minimize ponding of water on pavement.	Solution: A well-designed cross fall is not only for super elevation purposes but also essential for keeping the road surface dry.

4.0 ROAD PAVEMENT DESIGN

Road structural design concerns the ability of the road to carry the imposed loads without the need for excessive maintenance or rehabilitation. Pavement thickness and surface type should be designed according to the road geometric and traffic condition especially at the high stress location induced by heavy vehicular traffic and areas of high acceleration and braking such as intersection, climbing lanes, sharp curves and ramp.

	
Road Failure Due To Various Factors Road failure occurs due to either geotechnical problem, pavement structural problem or compaction of structural layers problem.	Solution: Appropriate selection of pavement type and thickness will reduce the cost and frequency of maintenance.

5.0 DRAINAGE DESIGN

Drainage system is critical for optimum road performance. Water on the road or in the road layers will lead to poor road conditions and ultimately road failures, which subsequently requires higher maintenance.

5.1 Surface Drainage

All road design must incorporate features or elements to drain water off the road without causing siltation and erosion. The road drainage is designed so that it will produce the desired velocity of flow that is high enough to prevent silting and lower the erosion potential.

	
Low Water Flow Velocity Roadside drains are often built to match the road grade. On a flat grade, the low water flow velocity makes fine materials easily deposited and further blocking the water flow.	High Water Flow Velocity Scouring occurs due to high velocity of flow in unlined drain. The roadside drain on a steep gradient should be lined with concrete to resist the effect of scouring.

	
Improper Location Of Drainage Outlet Improper roadside drain outlet that merges directly at the culvert opening will cause maintenance problems due to scouring.	Solution: The roadside drain outlet that is located some distance away from the culvert opening will avoid scouring or sedimentation.

5.2 Maintenance Access Requirement

Access requirement shall take into consideration the design of bench/berm drains located on high and steep slope areas for ease and safety when inspection and maintenance works are carried out. The practical rise step of stairway (most cases using cascade drain with steel handrail where appropriate), maintenance track and others can be considered during design stage.

	
No Maintenance Accessibility Safe access is not available for maintenance and inspection work of drainage and slope.	Solution: Safe access with steel handrail is essential for inspection and maintenance works.

5.3 Kerb Opening Inlets

A lack of attention in the design and selection of inlet types create many pavement drainage problems as it is common to find cases where ponding is excessive on roadway. Capacity of kerb opening inlet depends on how efficient the water flows towards the kerb opening inlets. The common problem faced is the insufficient opening size, or whether the head available to force gutter flow into the inlet is too low.

	
Poor Kerb Opening Inlet A round or half round inlet is inefficient to drain water off the surface road and leads to blockage.	Solution: Kerb opening inlet with large dimensions should be designed to prevent silt & debris being trapped at the inlet.

5.4 Culvert

Inlet, outlet, joint, bedding and sizes of culvert must be carefully designed. For the purpose of maintenance, the minimum size of a culvert is related to the length of culvert. The minimum size of a culvert is 1.5m height or diameter for a length of culvert more than 18m as specified in **Table 2.1 (REAM 3/2002 Vol. 2).**

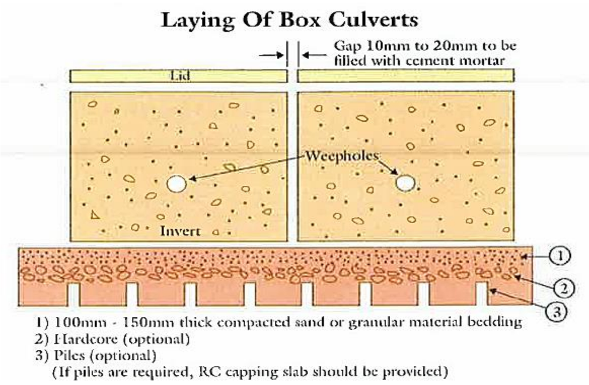
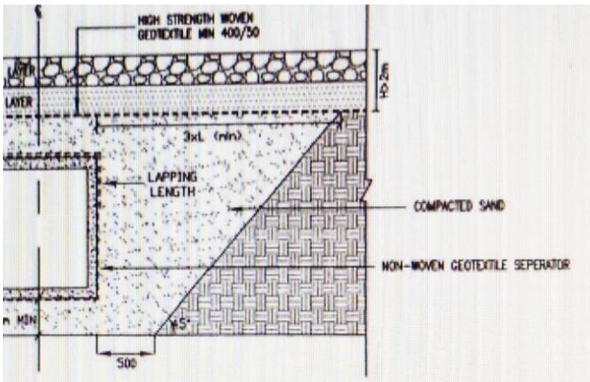
	
Small-sized Culvert The culvert diameter is clearly too small and this is one reason for these culverts choking and causing road failure.	Solution: Appropriate size of culvert is important as it makes them accessible and maintainable.

Culverts should be placed on bedding material of sand, gravel or concrete. When culverts are liable to settle due to high fill or poor ground condition, it is proposed to use cast in situ box culvert, which can withstand the anticipated unequal settlement.

	
Poor Soil Condition This picture shows unequal settlement occuring due to poor ground condition.	Solution: It is proposed to use Reinforced Concrete Bedding in areas where culvert is located on soft ground to avoid unequal settlement.

Precast box culverts are normally manufactured with butt ends. To prevent particles' migration from the surrounding, attention must be given to the joints in order to ensure no leakage occurs because it can endanger the embankment integrity by way of washout of the soil mass.

	
Gap Between Culverts Precast box culvert should be laid without a gap between walls to prevent water leakage which can cause a wash-in of backfill material.	Solution: All joints should be wrapped round with suitable drainage geotextile to prevent a wash-in of backfill material.

	
Insufficient Culvert Installation Details Detailing of culvert installation shown in the supplier's catalogue is not sufficient enough.	Solution: Cawangan Kejuruteraan Geoteknik (CKG) has produced typical drawing showing the use of geotextile and sand back-fill to minimize water leakage and settlement of the box culvert.

The stream velocity is also an important factor. If the stream velocity is low, sand and gravel will be deposited and it will be an important maintenance operation to clear the culvert when the amount of materials deposited has reached a predetermined level. According to MSMA 2011, flow velocity below about 0.5 m/s will cause settlement of fine to medium sand particles.

5.5 Bridge Drainage

Bridge drainage design concerns the ability to function without the need for excessive maintenance. Some reserve in size is necessary because there is a high possibility of accumulation of debris in the pipe.

	
<u>Choked Outlet Downpipe</u> Water ponding on a gentle gradient bridge due to blockage of outlet pipe.	<u>Solution:</u> Bridge with proper gradient design and well-maintained downpipe can help water flow naturally.

	
<u>Drainage Pipe With Too Many Bends</u> Pipe with too many bends and buried in the concrete is difficult to maintain.	<u>Solution:</u> Design pipe with less bend and located outside the concrete for easy maintenance.

	
<u>Small-sized drainage pipe</u> Size of pipe should be verified by design calculation.	<u>Solution:</u> Some reserve in size is necessary to prevent clogging of the pipe.

6.0 ROAD FURNITURE

When road furniture and signages are introduced, it will clearly require maintenance. Unnecessary furniture should be avoided and if there is any, the design must allow for their continuing maintenance. Other than that, mistakes in selecting the road furniture type and its position, may cause unnecessary hazard and incur cost to the government.

	
<u>Wrongly-placed Signboard</u> Wrong position of signboard may cause hazard to road users and incur cost to the government for repair works.	<u>Non-durable Materials</u> It's good to have flexible posts as an extra precaution to motorist but this type is not preferable due to its maintenance problem.

7.0 PEDESTRIAN BRIDGE

Polycarbonate is the most popular roofing type for pedestrian bridge. Its lightweight properties and simple method of construction makes it favorable to the designer. The ability to withstand in hot weather may last for quite a while before showing its aging and tear-off sign.

	
<u>Unsuitable Roofing Material</u> Polycarbonate roofing panels tend to show aging and tear-off sign in a short period of time.	<u>Solution:</u> Metal deck is one of the less-maintenance type of material for roofing system and it is suitable for pedestrian bridge rooftop.

8.0 CONCLUSION

Roads and bridges should not be designed without consideration being given to its optimal maintenance aspect because the maintenance design can identify the optimal frequency of maintenance to prolong the life span. Thus, maintenance can be planned, scheduled and prioritized for optimal road performance and life cycle costs of the project.

There is a need to inculcate maintenance culture among the designers, incorporating maintenance aspect in every road project. Designers must not only know how to use road guidelines and design software but also learn through lesson learnt processes based on past design experiences and its effectiveness during construction and service life.

The responsibility of designers, checkers and approver is to ensure that the maintainability aspect during the design process or at the review, verification and validation stage is never ignored. By careful consideration of maintenance aspect in the design stage, it can result in a better quality road and cost of maintenance will be subsequently reduced during its service life.

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