Road maintenance
Planning Implementation and monitoring Handout

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Introduction

This handout reflects the content of module 1 of the training program for municipal engineers on street maintenance, organized by USAID-CITIES during 2018 and 2019.

The subject of this first module is the planning, monitoring of street maintenance together with a range of technical issues related to e.g. pavements, underground and drainage. The second module discusses quality management of works or projects. The third and last module discusses contract management in detail.

Each module consists of a handout in English and Arabic accompanied by a power point presentation which is used in the training program.

The training sessions are an introduction to the subject matter at basic level. They are to be followed by coaching and training-on-the-job of municipal staff in order to achieve application of the learned material in daily practice.

Section(A) Preparation of Road Maintenance:

Municipalities are working with tax payers' money and generally they are short of means to carry out maintenance as the desired level. Therefore, planning and programming and careful setting of priorities are very important first steps in the process.

The planning process for construction of new roads or rehabilitation of existing road inside municipalities should consist of the following steps:

1- Assessment of existing road conditions,
2- Define priorities by the municipality,
3- Develop the annual work plan for the municipality,
4- Develop an inspection plan, and carry out regular inspections
5- Coordination with utility companies,
6- Identify factors affecting road development and design process,
7- How do we estimate traffic demand on roads?

(A-1) Road planning process:

1- Assessment of existing road conditions,

This assessment is very important for any planner of maintenance so that he may know what the current technical situation of the roads is, what are the mistakes of the past, and which actions need to be taken to improve the quality of the road system.

This assessment needs:

a) A road data base which includes:
   I. The total number of roads per district/sub-area,
   II. The roads with sidewalks,
   III. The roads without sidewalks,
   IV. The roads with culverts,
b) The current technical state of each road,
c) Description of existing problems,
d) Identify potential solutions and an action plan,
e) Taking photos for documentation,

This data has to be recorded in forms together with recommendations for actions to be taken. This is the "Assessment of Existing Road Condition for Area (X) Year XXX", see annex G-2 Area survey data form.

2- <u>Define Priorities:</u>

One major question that comes to mind immediately is: how do we define priorities?

Defining priorities is group work, involving decision makers, stakeholders, financial and technical professional staff. This process will enhance the quality of the work to be done. The steps are:

1. Consultation meetings are to be held with stakeholders, beneficiaries or end-users, to identify their problems and needs.
2. Technical experts, engineers, should go and investigate the solutions to solve the issues identified, rate the urgency of each work, and prepare estimates of the budget needed for each work.
3. In this stage it is wise to develop selection criteria based on technical perspectives to help the decision makers and the community to prioritize all their needs. These criteria may include at least:
   - Services provided by municipality should benefit large number of people,
   - Service provided by municipality should be nearby governmental institution, crowded places (commercial centers), religious places (mosques) and public places (parks, play areas, hospitals and schools).
   - Services provided should be inside municipality geographical planned areas,
   - This selection criteria should be approved by local community and mayor.
4. The municipality's financial staff will collect all estimates prepared and compare them with the municipal budget to see how available for implementation.
5. Consultation: the selection criteria and the resulting priorities should be both explicitly approved by the Mayor. The local community is to be given the

opportunity (in a consultation meeting) to give its opinion on the criteria and the resulting priorities.

6. Decision Makers, full report should go for approval to the mayor and later on the municipal council.
7. In municipalities with districts the consultations process should be organized per district.

See annex G-3

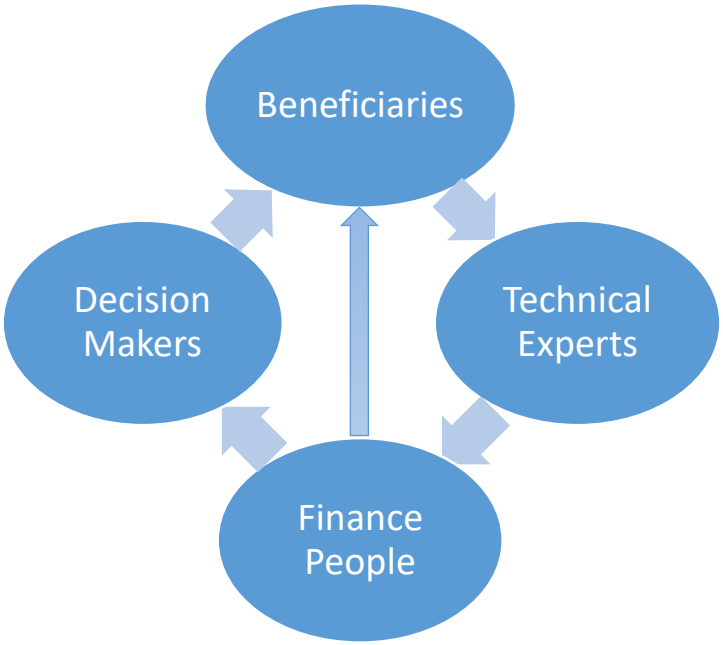

Figure (1) showing the sequence of priority identification Process

3- Develop Annual Engineering Plan:

After all priorities have been defined for each district they should be categorized into:

1- First priority (budget available, can be implemented in the first budget year)
2- Later priority (cannot be implemented, because of lack of budget or due to technical problems)

Municipality technical staff should prepare an annual work plan to combine the first priorities into an action plan with time lines set for the whole of the year based on the budget available.

Budget here means Internal budget (funded by government) for municipalities and external fund for municipality which comes from non-governmental source like foreign donors or local donors.

If the municipality has a clear annual work plan for its interventions, the later priorities that came up from identifying local community needs may be outsourced to external donors. The work plan will help the municipality to ensure:

1- Better coordination with donors
2- Better coordination between municipality and utility companies
3- Better management of expectations of the local community.

See Annex G-4 for templates to be used for the annual work plan.

4- Inspection:

Inspection is of pivotal importance to monitor the quality of all public places, roads, sidewalks parks etc. Regular inspection will enable the municipality to address sudden problems such as illegal works in public roads, or to react quickly to sudden damage to roads or to complaints of the public and will deliver important information for future annual maintenance plans. In Jordan, inspection is very often neglected and this result in unexpected problems and insufficient handling of complaints of citizens.

Inspection plan

Inspection should be carried out on the basis of a plan. Not every road has to be inspected every day. The plan should identify with which frequency each road should be inspected and why.

If the municipality is aware of an on-going work by a private company or a utility company (telecommunication, water, electricity), it must monitor and inspect their work on a regular basis to ensure that:

1- The contractor is implementing all the specification agreed on it,
2- The contractor is taking all safety measurements to reduce incidents,
3- The contractor is not causing and damage for any other service,
4- There are no complaints from local community regarding the work schedule,
5- The contractor is restoring the road in its original condition,

Immediate inspection is mandatory when there is an emergency situation like floods, heavy rain fall, earth quakes. Inspection must be carried out to examine the current situation immediately after the rain or during the floods and to see how effective the culverts and drains are working, and any emergences cases should be reported immediately, so that action may be taken. See annex G-1 weekly inspection form.

5- Utilities Companies and Coordination:

The public infrastructure is the property of the municipality according to "Law of Organizing Cities, Villages and Buildings of 1966 no. (79)" under expressions item no.

20 and 21. In the same way as nobody is allowed to dig in private property without previous authorization by the owner, nobody is allowed to dig in public property (property of the municipality or the government) without the authorization of the owner (the municipality). This also applies to utility companies! The municipality may give such authorization under conditions or refuse it on reasonable grounds.

Excavations and dredging by utility companies are one of the major causes for deterioration of public infrastructure and are a headache topic for municipalities and their local communities. Very often citizens end up complaining to the municipality about:

1- Uncompleted work,
2- Unsatisfactory work,
3- Damage done to their property,

The solutions to the problem is relatively easy, on condition that the municipality behave in the same way as a private property owner. As soon as annual work plan has been approved, a coordination meeting with utilities companies and all private sectors working in the same area (???) who might be affected by the municipality work plan should attend.

In this meeting all partners should present their future plans in the area as below:

1- Municipality should propose all expected works in the coming year categorized by districts targeted,
2- Utilities companies should propose their action plans for the coming year,
3- Conflict districts should be solved between them by setting implementation plan for each one so that no contradiction will occur, each organization will be responsible for its action plan and must complete it within the time agreed upon so that it will not affect other plans,
4- If deviations occur from the agreed plan, the owner of the work must inform all other parties in the coordination meeting immediately
5- Municipality should propose Road Action Plan(RCP) for any contracts to be implemented in the road since it is a municipality property,
6- The municipality makes minutes of the meeting and send them to all parties involved. In the next meeting they must be approved
7- The coordination meetings are to be held monthly or as often as the pace of implementation of works requires

Road Action Plan for any contracts to be implemented within road width: the following conditions for approval by the municipality in its properties shall apply:

1- The utility companies must propose their plans in the area to municipality for approval,

2- The utility companies must submit their tender document for approval including specification and drawings and timing in line with the agreed timing during the coordination meetings,
3- The utility companies must develop a Health and Safety Plan (HSP),
4- The utility companies are responsible of repaving and rehabilitating the roads as required by the municipality and according to agreed specifications and standards,
5- The municipal engineer should sign release documentation stating that the contractor finished all work in the mentioned road as determined in contract, and the approval conditions,
6- The utility companies should submit bank guarantee with agreed amount to the benefit of the municipality minimum one year after completion date, to ensure liability of the utilities companies for the work done.
7- The utility companies must submit as-built drawings for utilities showing the exact location of the underground utilities, depth and specifications to reduce the damage that will be occur when the municipality issue contracts,

6- Identify factors affecting road development and design process:

Essential input data need to be available when making any development for road system:

a) Location (area topography),
b) Type of soil,
c) Land use,
d) Type of traffic in use,
e) Volume of traffic loads,
f) Area populations and economic static for people,
g) Traveling habits for people,

To construct new road or rehabilitate existing roads designer should have a master plan for the area showing, lands usage and district classifications, this master plan helps a lot design engineers to identify:

1- Type of use for the roads,
2- Loads expected on each section of the road.

Road reconstruction process or creating new road network may have one or more of the below items identified as needs for the Process:

1- Area master plan,
2- Topography drawings,
3- Hydraulically study for area that includes:
    a) Rain water intensity,

b) Location of pipe or box culverts,
c) Rain water drainage system to be used like
   i. Open water channels,
   ii. Closed water channels,

4- Location of governmental and public facilities,
5- Traffic crowded areas,
6- Future expansion in road,
7- Maps for existing utilities and roads or any future expansion plans for these utilities,
8- Lighting system to be considered,
9- Signs and information system,

Sustainability, quality and durability are the key factors to any success in Road Construction mechanism that need to be used, most of the time our designer is faced with:

1- Low budget.
2- High public demand.
3- Lack of resources.
4- No master plan available.
5- No adequate prioritization of the demand.

7- How do we estimate traffic demand on roads?

Road traffic demand is affected by:

1- Population,
2- Commerce,
3- Industry,
4- Transportation habits.

Traffic between any two cities is approximately proportional to their populations and commercial industrial interaction and inversely proportional to the distance between them.

Traffic estimation on a route requires a prediction of existing population and future population growth and economic activity type with an estimation of their effects on land use and travel needs, knowledge of any potential transport alternatives. The key variables defining road needs are the traffic volumes, tonnages, and speeds to be expected throughout the road's life.

Once traffic demand has been set, it is necessary to predict the extent of the road needs to handle that traffic. A starting point in these calculations is offered by surveys of the origins, destinations, and route choices of present traffic; computer models are then used to estimate future traffic volumes on each proposed route.

Estimates of route choice are based on the understanding that most drivers select their estimate of the quickest, shortest, or cheapest route. Consideration in planning is also given to the effect of new traffic on existing streets, roads, and parking provisions.

Where feasible, the next step in planning a road system is to refine the selected route to a narrow corridor. The various alignment and more options are drawn, considering the local terrain and conditions. The economic, social, and environmental impacts, benefits and costs of these options are discussed with relevant official and community groups until an acceptable specific route is determined.

Section(B) Pavements:

It is defined as a horizontal structural element which is supported by natural material and designed to carries out road traffic. Pavement design needs to:

a) Investigate existing records, these records must be examined, and subsurface explorations and tests must be conducted.

b) The engineering properties of the local rock and soil are established and identified, particularly with respect to strength, stiffness, durability, susceptibility to moisture, and propensity to shrink and swell over time.

Engineering properties are determined either by field tests, or by empirical estimates based on the soil type, or by laboratory measurements.

In pavement design material is tested in its weakest expected condition, usually at its highest probable moisture content. Performance under traffic is then determined. Unsuitable soil for pavement are identified for removal, suitable replacement materials are earmarked, maximum slopes of embankments and cuttings are established, degree of compaction to be achieved during construction is determined and drainage needs are specified.

(B-1) Type of pavements:

There are two types of pavements:

1- Rigid Pavements,
2- Flexible Pavements,

Rigid pavement and flexible pavement are the two types of road pavement design methods. The pavement surface should be durable and it can withstand the load acting from the wheel tires.

(B-1-a) Rigid Pavement

Rigid pavements are made of cement concrete or reinforced concrete slab. The concrete slab ranges in thickness from 20cm to 35cm. It is laid by a paving machine or mechanical installation, often on a supporting layer (basecourse or Subbase) prevents the pressure caused by traffic from pumping water and natural formation material to the surface through joints and cracks. Concrete shrinks as it hardens, and this shrinkage is resisted by friction from the underlying layer, causing cracks to appear in the concrete. Cracking is usually controlled by adding steel reinforcement in order to enhance the tensile strength of the pavement and ensure that any cracking is fine and uniformly distributed. Transverse joints are used for this purpose. Longitudinal joints are used at the edge of the construction run when the whole carriageway cannot be cast in one pass of the paving machine.

(B-1-a-1) Types of Rigid Pavements:

I. Jointed Reinforced Concrete Pavement (JRCP),
II. Jointed Plain Concrete Pavement (JPCP),
III. Continuous Reinforced Concrete Pavements (CRCP),

Figures from 2-6 explains details about rigid pavements

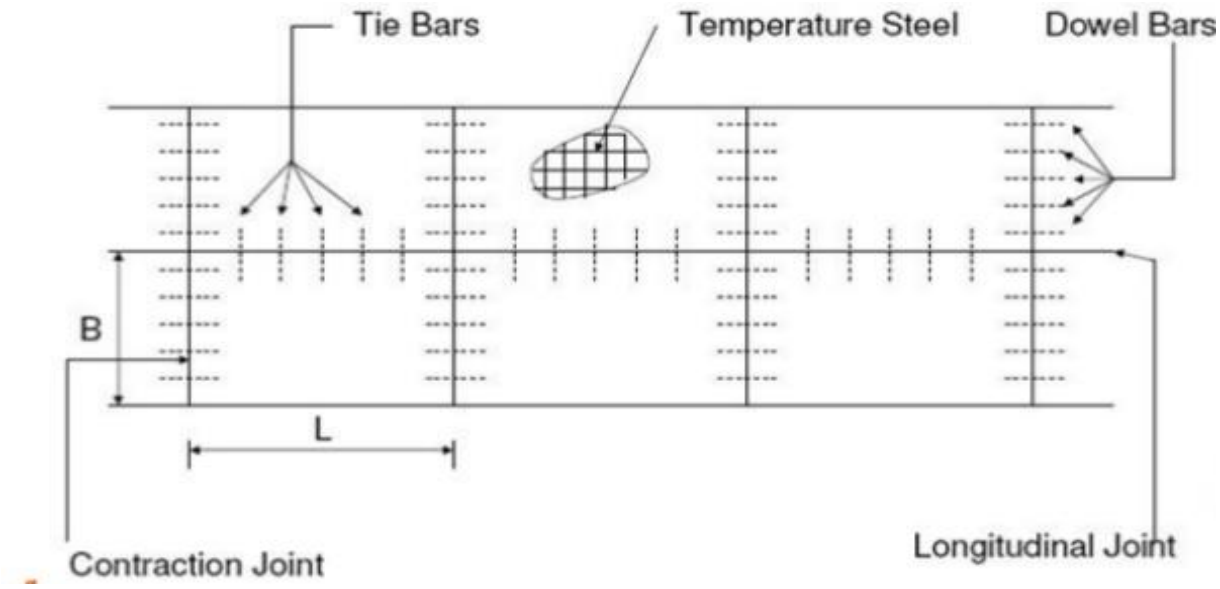

Figure (2) Jointed Reinforced Concrete Pavement (JRCP)

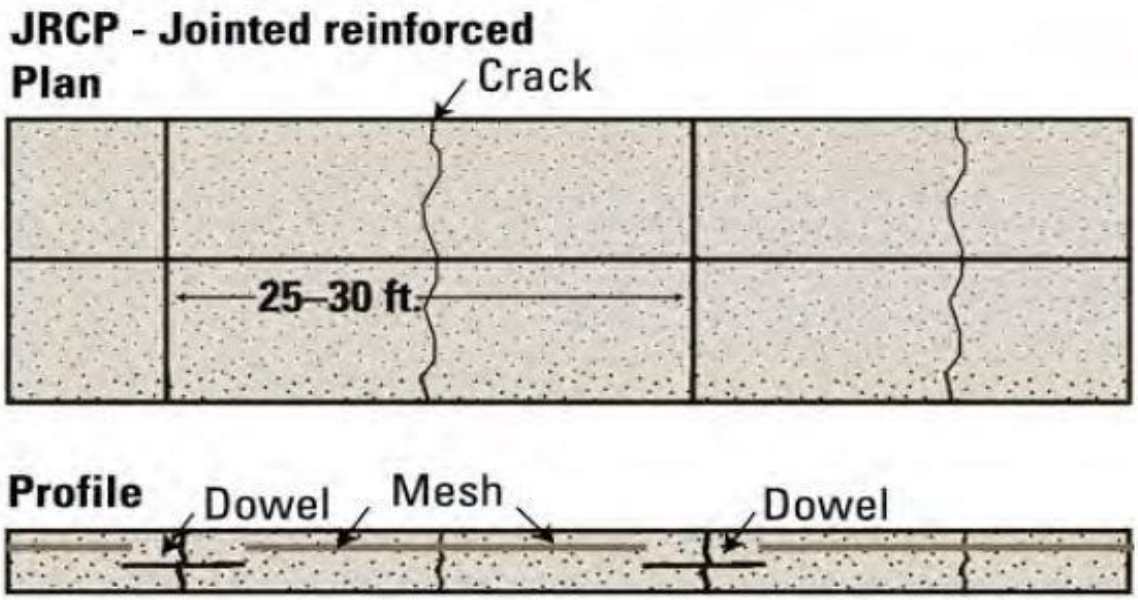

Figure (3) Plan and Elevation for JRCP

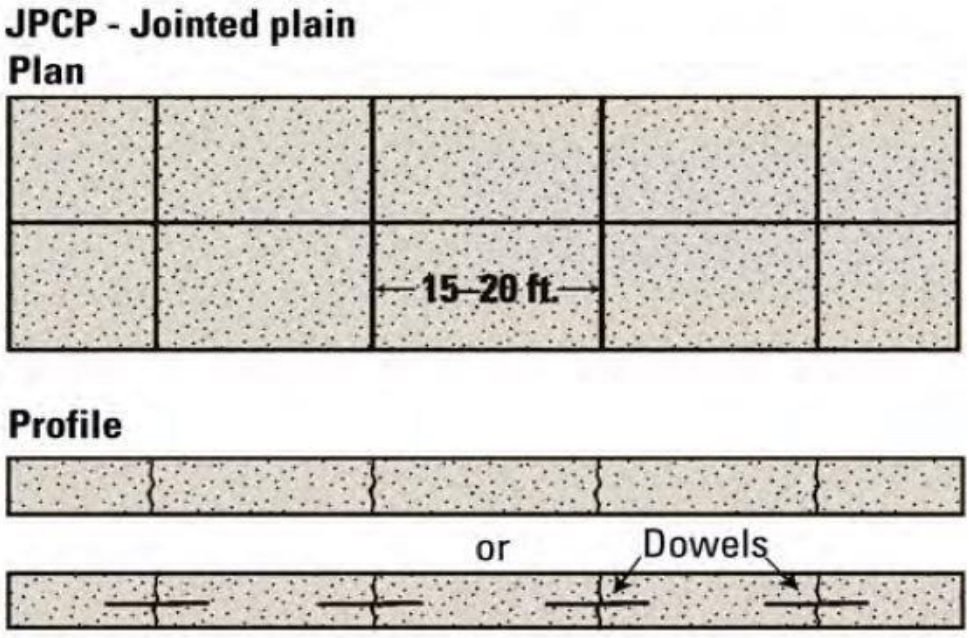

Figure (4) Jointed Plan Concrete Pavement

Figure (5) Continuous Reinforced Concrete Pavements (CRCP)

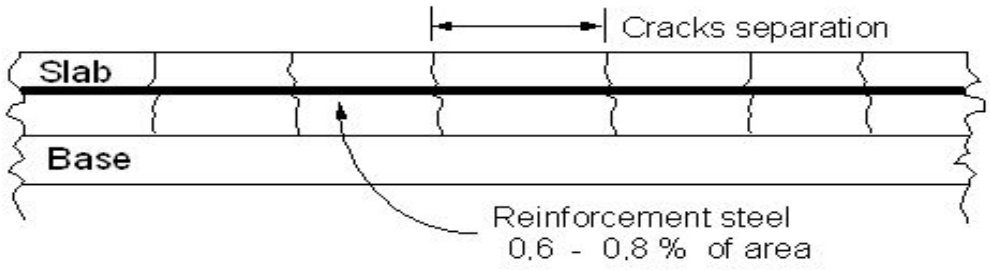

Figure (6) Elevation Plan for CRCP

(B-2) Flexible Pavement

Flexible pavements are those which are surfaced with bituminous or asphalt materials. It's flexible since the total pavement structure bends or deflects due to the traffic loads. Generally, this type of pavement requires some sort of maintenance or restoration every 10 to 15 years.

A flexible pavement structure is typically composed of several layers of material. The layers consist better quality materials will lay on top where the intensity of stress from traffic loads is high and lower quality materials will lay at the bottom where the stress intensity is low. Flexible pavements can be analyzed as a multilayer system under loading. A typical flexible pavement structure consists of the surface course and underlying base and sub base courses. Each of these layers contributes to structural support and drainage.

When hot mix asphalt is used as the surface course, it is the stiffest and may contribute the most to pavement strength. The underlying layers are less rigid but are still important to pavement strength as well as drainage and frost protection. When a seal coat is used as the surface course, the base generally is the layer that

contributes most to the structural stiffness. A typical structural design results in a series of layers that gradually decrease in material quality with depth.

Flexible pavements have base courses of broken stone pieces either compacted into place in the style of McAdam or glued together with bitumen to form asphalt. To maintain workability, stones forming base layers are chosen with specific gradation influenced by designer and it should be of crushed stones. Initially the bitumen must be heated to temperatures of (300–400 ^{0}F) (150°–200^{0}C) in order to make it fluid enough to mix with the stone (In Jordan max heating temp. is170 ^{0}C). At the road site a paving machine (Asphalt Finisher) places the hot mix in layers about twice the thickness of the stone size so that it can be coated with bitumen. The layers are then thoroughly rolled (rubber and steel roller) before the mix cools and solidifies. Figure (7) explains layers of rigid and flexible pavements.

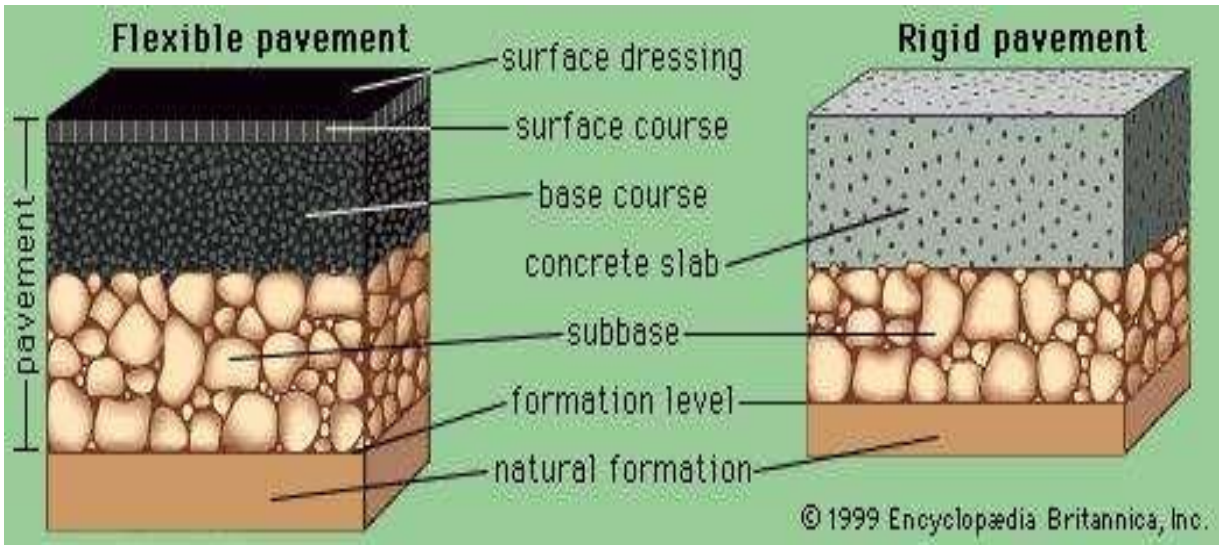

Figure (7) Cross sections of modern pavements (Left) Flexible asphalt-based pavement. (Right) Rigid Portland-cement concrete

(B-3) Difference between Flexible and Rigid Pavements:

1- Flexible pavement differs from rigid pavement in terms of load distribution. In flexible pavements load distribution is primarily based on layered system. While, in case of rigid pavements most of the load carries by slab itself and slight load goes to the underlying strata.

2- Structural capacity of flexible pavement depends on the characteristics of every single layer. While, the structural capacity of rigid pavements is only dependent on the characteristics of concrete slab. This is so, because of low bearing soil capacity of underlying soil.

3- In flexible pavements, load intensity decreases with the increase in depth. Because of the spreading of loading in each single layer. While, in case of rigid pavement maximum intensity of load carries by concrete slab itself, because of the weak underlying layer.

4- In flexible pavement deflection basin is very deep, because of its dependency on the underlying layers. While in case of rigid pavement, deflection basin is shallow, this is because of independency of rigid pavement on the underlying layers.

5- Flexible pavement has very low modulus of elasticity (less strength). Modulus of elasticity of rigid pavement is very high, because of high strength concrete and more load bearing capacity of the pavement itself. Than compared to flexible pavements.

6- In flexible pavements, underlying layers play very important role. Therefore, more role is playing only underlying layers. In case of rigid pavements, slight function of underlying layers. Maximum role is playing by the top layer (that is slab) by itself.

Table below summarize the Difference between Rigid and Flexible Pavement:

Flexible Pavement	Rigid Pavement
Have low flexural strength	Have high flexural strength
Have low construction cost but high repair cost	Have low repair cost but high construction cost
Damaged by oil and chemicals	Dose not affected by oil and chemicals
Load transfer from grain to grain to the lower layer	Load transfer by slab action
High thickness	Low thickness
Design depend on the physical characteristics of the material forming Sub-base, Base-course and Subgrade.	Design depend on the concrete strength for the slab.
Design Life is 15 Years	Design Life 30 Years
Design Based on load distribution factor	Design based on flexural strength or slab action

Flexural strength, also known as modulus of rupture, or bend strength, or transverse rupture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength represents the highest stress experienced within the material at its moment of yield.

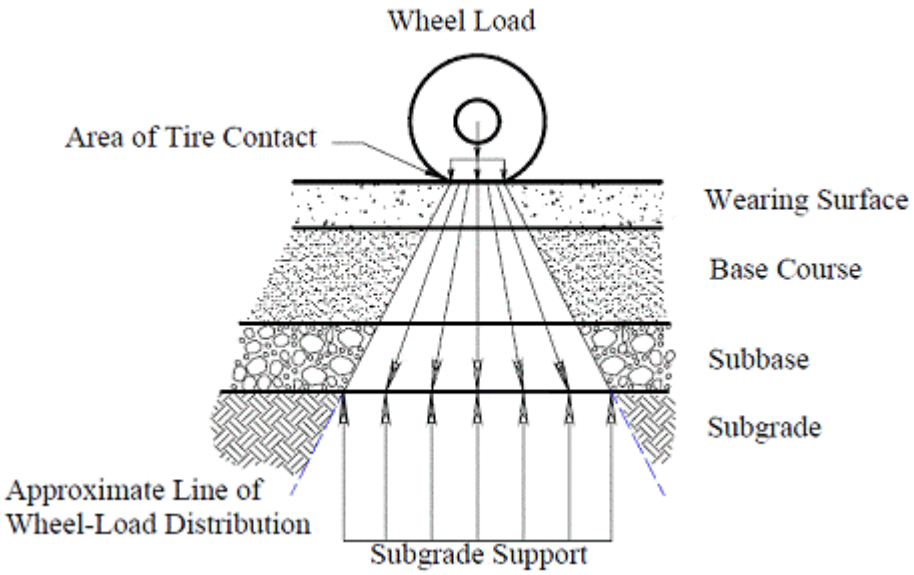

Figure (8) Wheel Load Transfer in Flexible Pavements

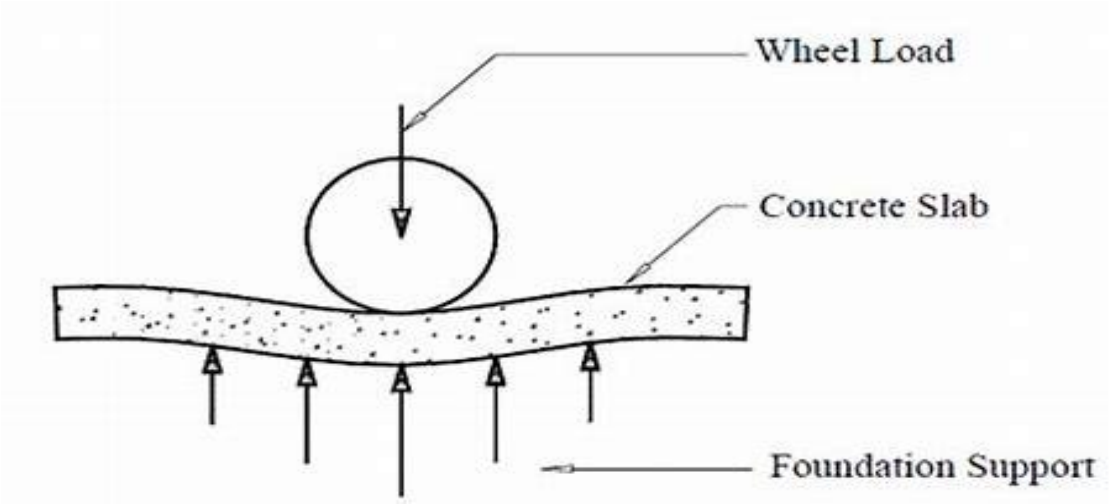

Figure (9) Wheel Load Transfer in Rigid Pavements

Section (C) HMA Pavement Layers:

HMA Pavements stands for "Hot Mix Asphalt" and it is classified as flexible pavement and sometimes it is called "Bitumen Pavement", it is a combination of approximately 95% stone, sand, or gravel bound together by asphalt cement, a product of crude oil. Asphalt cement is heated aggregate, combined, and mixed with the aggregate at an HMA facility, flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out and then passes on these loads to the next layer below. Figure (10) Shows typical basic type of HMA pavements.

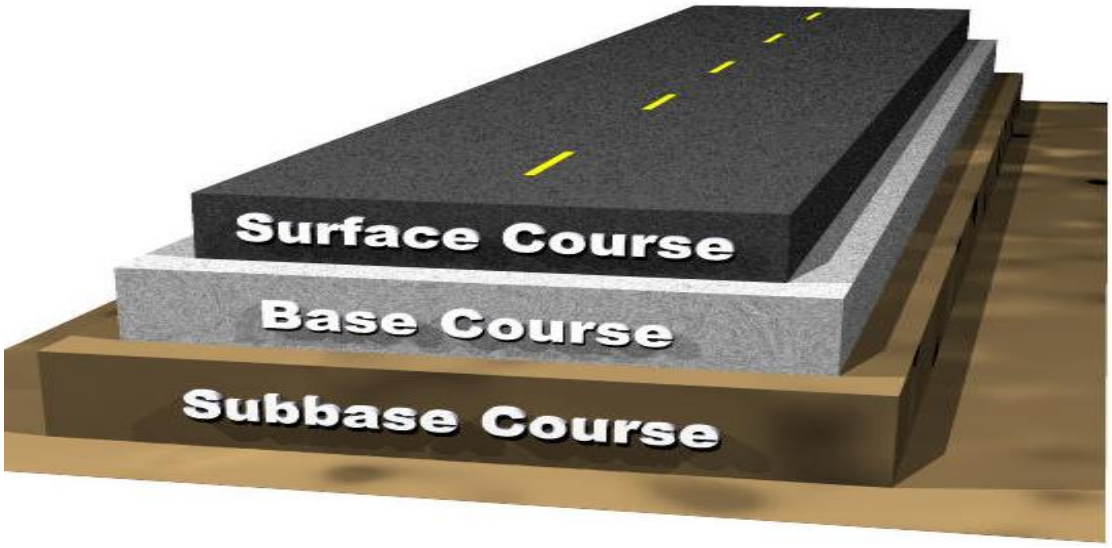

Figure (10) Basic Components of HMA Pavements

Flexible pavement layers depend on pavement design, but it can contain part or all the below items:

- Wearing asphalt layer,
- Binder wearing asphalt layer,
- Base-course layer,
- Sub-base layer,
- Sub-grade layer,

(C-1) Wearing Course:

Wearing course is a road asphalt top layer which is in direct contact with traffic loads and it is called the surface layer. It is meant to take the brunt of traffic wear and can be removed and replaced as it becomes worn. One function for the pavement is to provide a waterproof covering for the lower pavement structure. This can be achieved if the pavement is impermeable and has no cracks.

The wearing course must also have an adequate cross fall to lead water (from rain, melting snow or ice) immediately away from the road surface. On a straight road cross fall will range between 3 and 5 %. On asphalt the recommended cross fall is 3 %, and for gravel roads it is 5%. On a straight road cross fall is normally applied as a crown section. See annex G-7

(C-2) Binder Course:

It is an asphalt layer composite of Mid-size aggregate bounded by bituminous materials, it is laid between the surface layer (wearing course) and base course layer. It is added for high loaded road where traffic is heavy and sometimes when the soil is too weak. See annex G-7

(C-3) Base Course:

It is the layer immediately under the wearing surface or binder course (Applies whether the wearing surface is bituminous or cement concrete). As base course lies close under the pavement surface it is subjected to severe loading. The material in a base course must be of extremely high quality and its construction must be done carefully.

The base course serves as the principal structural component of the flexible pavement. It distributes the imposed wheel load to the pavement foundation, the sub base, and/or the subgrade.

The base course must be:

1- Sufficient material quality,
2- Adequate thickness to
    I. Prevent failure in the subgrade and/or sub base,
    II. Withstand the stresses produced in the base itself,
    III. Resist vertical pressures that tend to produce consolidation and result in distortion of the surface course,
    IV. Resist volume changes caused by fluctuations in its moisture content.
3- Materials selected must be hard and durable aggregates, the requirements of a satisfactory soil aggregate surface are;
    I. Stability,
    II. Resistance to abrasion,
    III. Resistance to penetration of water,

The quality of the base course is a function of its composition, physical properties, and compaction of the material.

Basecourse layer shall be ideally 250mm thick, if deign is more than that and less than 500mm basecourse layer must be placed by two equal layers in thickness.

Tolerance of the layer between +10mm to -15mm for each 20m long and deviation of 4m long straight edge in any direction should not be more than 12mm. See annex G-5

(C-4) Subbase:

This layer is can be considered as a foundation of the road and used in areas where:

1- Frost action is severe or
2- Subgrade soil is extremely weak.

Subbase material is a very excellent layer for the life time of the road which can be outlive the life of the surface, which can be scrapped off and after checking that the subbase is still in good condition, a new layer can be applied. The material requirements for the subbase are not as strict as those for the base course since the sub base is subjected to lower load stresses.

Subbase is classified in A and B based on gradation, ideal situation for subbase layer is to be 20 cm in thickness, if the design subbase layer with thickness of less than 50 cm, it must be laid and placed in two layers with equal thickness.

Finished surface deviation must not exceed 10mm for 3m long straight edge in any direction and tolerance of +10mm to – 20mm for each 10m intervals in longitudinal direction, the 20mm minus will be compensated in the next layer.

See annex G-6

(C-5) Subgrade:

The subgrade is the compacted existed soil layer that forms the foundation of the pavement system and have no thickness. Subgrade soils are subjected to lower stresses than the surface, base and sub base courses. Since load stresses decrease with depth, the controlling subgrade stress usually lies at the top of the subgrade. That's why they call the top 20 cm of the subgrade is the effective layer of subgrade even if it was more than that.

The combined thickness of sub base, base, and wearing surface must be great enough to reduce the stresses occurring in the subgrade to values that will not cause excessive distortion or displacement of the subgrade soil layer.

Maintenance of finished subgrade surface should be done regularly to ensure stability and drainage of rain water, if installing the second layer which is subbase delayed more than 14 days per approval need to be taken for engineer.

Subgrade material can be rock fill or selected topping soil tolerance for finished surface is as shown below:

Rock fill Subgrade	Tolerance (+ or - 50 mm)
Selected fill material soil or excavated surface	Tolerance (+10 or - 30 mm)

(C-6) Bituminous Pavements:

Consists of combination of mineral aggregate with bituminous binder ranging from inexpensive surface treatment about 1/4 or less in thick of asphaltic concrete. For good service throughout the full life bituminous pavement must retain following qualities.

- Freedom from cracking or raveling.
- Resistance to weather including the effect of surface water heat and cold.
- Resistance to internal moisture, particularly to water vapors.
- Tight impermeable surface or porous surface (if either is needed for contained stability of underlying base or subgrade).
- Smooth riding and non-skidding surface.

Bitumen is a viscous liquid or solid or semi liquid consisting essentially of hydrocarbons and their derivatives which is soluble in carbon disulphide, is substantially non-volatile and softens gradually when heated. It is black or brown in color and possesses adhesive and water proofing qualities.

Section (D)Tests, Definitions and Road Concepts:

Roads reconstruction and rehabilitation contracts mainly deals with materials so if we want to have better road quality we need to know the characteristics for those materials and the nature of test operated on those material while executing the contract.

Important definitions that always come up while dealing with Roads:

(D-1) Abrasion Test:

Test for the aggregate toughness and soundness, aggregates are subjected to forces due to the friction produced between car wheels and the surface top layer of the road and these forces is transferred into all layer forming the road body, these forces cause abrasion of the aggregates so in our selection criteria for the road aggregate material it has to be with certain abrasion resistance value.

There are many types of abrasion test used world wild like:

1- Los Angeles Abrasion Test, this type is used in Jordan
2- Deval Abrasion Test,
3- Dorry Abrasion Test,

Los Angeles test is done on lap by machine which is metal drum of 50cm width and 70cm depth of drum or interior drum diameter, inside the drum there is a metal shelf placed with 125mm in the direction of rotation below the door of the rum. Figure (11) below shows the instrument.

Figure (11) Loss Angeles Abrasion Machine

Sample should be placed in an oven for 2-4 hours in (110-120) C, 12 steel balls with 48mm diameter and weight between (39-45) gm will be placed in the rotated drum with sample according to the gradation of the sample. Rotation of the drum can be calibrated to 100, 500 or 1000 rpm.

Loss Angeles abrasion value = (Passing Sieve No.12(1.7mm))/Total Sample Weight).

This test is based on AASHTO T96 Standards which is stands for (American Association of State of High Way and Transportation Officials)

(D-2) Plasticity Index Test:

A fine-gained soil can exist in any of several states; which state depends on the amount of water in the soil system. When water is added to a dry soil, each particle is covered with a film of adsorbed water. If the addition of water is continued, the thickness of the water film on a particle increases. Increasing the thickness of the water films permits the particles to slide past one another more easily. The behavior of the soil, therefore, is related to the amount of water in the system.

Plasticity Index is simply the numerical difference between the liquid limit and the plastic limit for a material and indicates the magnitude of the range of moisture content over which the soil remains plastic.

Liquid Limit(LL): Minimum amount of water content in which soil in liquid state and has strength over flowing. With reference to the standard liquid limit device, it is defined as the minimum water content at which a part of soil cut by a groove of standard dimensions, will flow together for a distance of 12 mm under an impact of 25 blows in the device.

Plastic Limit(PL): Minimum water content in which soil start to crumble when rolling in 3mm diameter rod.

It is a measure of the cohesive qualities of the binder resulting from the clay content. Also, it gives some indication of the amount of swelling and shrinkage that will result in the wetting and drying of that fraction tested. If some soils do not have sufficient mechanical interlock they require amounts of cohesive materials to give a satisfactory performance. A deficiency of clay binder may cause raveling of gravel wearing courses during dry weather and excessive permeability

Indicate the percentage of fine aggregates passing sieve No. 200, which contains sand fines and clay, any increase of plasticity index may affect the strength and durability of the mix casing a water channels can be formed through the hot mix and not enough asphalt coating for the aggregate. It should not be more than 4% to 6%.
Test performed Based on ASSHTO standards T89 & T90.

(D-3) Flakiness and Elongation Test:

The type of rocks and the type of crushing machine highly determine the shape and size of the aggregates produced. Elongated and flaky stones are normally not very suitable for road works since the shape and the size make them difficult to compact. As such the flakiness and elongation test must be carried out to determine the suitability of the material. These tests indicate a weak point at asphalt mix during rolling that cases stone to crush due to the load and low workability at a concrete design mix.

Flakiness test for aggregates is determined based on gradation for the designed layer so this test is done for all sieves and we take the amount of aggregate passing through sieve No. X and retained on next sieve let's say No. Y and we weight it, then we use flakiness gauge to determine the amount passing through certain width on that gauge and weight it based on the sieve opening, Flakiness gauge width is calculated by (3/5 *(Y+N)/2).

Elongation test for aggregates is determined for all Sieve included in the design for certain layer, we take the amount of aggregate passing through Sieve No. N and retained on next sieve let's say No. Y and we weight it, then we use elongation apparatus gauge to determine the number of aggregates retained on certain openings, elongation apparatus gauge opening is calculated by (9/5 *(Y+N)/2).

Figure (12) Elongation and Flakiness Equipment

(D-4) Sand Equivalent Test:

The sand equivalent test quantifies the relative abundance of sand versus clay in soil also determines percentages of dust and clay in fine aggregates, the test sample should be of aggregate passing sieve No. 4 (4.75mm), large dust and clay may contribute in lack of stability and not enough asphalt coating for aggregate which causes a weak ponding in asphalt mix. The higher the sand equivalent the cleaner the sample is.

In the sand equivalent test, a reduced sample based on T2-42 of aggregate passing sieve No. 4 (4.75 mm) with an amount of 1000-1500 g then reduce th sample to testing size of 500-750 g, one liter of flocculating solution (Calcium Chloride), irrigation tube, mechanical shaker, graduated plastic cylinder, sample cans and timer.
Steps:

1- Put sample into a mixing pan and pour small amount of water to the sample until it is dam enough to hold a cast. Then cover sample with cloths for 15 min to allow aggregate to absorb moisture.
2- Place the sample over mixing plastic sheet and mix it using the diagonal corners.
3- Get the sample cans and fill it by manually through the center using hands and get red off the excess material.
4- Place 100 ml of Calcium Chloride into a graduation cylinder then place the sample in tap using your hand at the bottom of the cylinder to release any air voids, keep it for 10 min to calm down,
5- Shake the cylinder manually then place it into mechanical shaker for 45 seconds,

6- Remove the cylinder and add more of the sedimentation solution into the cylinder using irrigation tube until it reaches 380 ml during addition twist the irrigation tube so that the sand and dust will be mixed into the sedimentation solution and the crushed aggregates will be at the bottom, leave the sample to sit undisturbed for 20 min.
7- Measure the reading of the clay then use weighted foot assembly and measure the sand reading.

SE= Sand Reading/Clay Reading X100%
Based on ASSHTO T176

(D-5) Soundness:
It is a resistance against disintegration or we can say it is the ability of aggregates to resist the change in volume due to change in physical conditions (freezing, thawing, temperature change in normal condition).

The soundness test is done on clean dry aggregate sample using Sodium Sulfate (Na_2So_4) or Magnesium Sulfate (Mg_2So_4) solutions.

The clean aggregate is weighted and counted then it will be Submerged in Solution of sodium sulfate or magnesium sulfate for (16-18) Hrs. then it will be oven dried to 105-110 C this will be one cycle, the aggregates are examined to see if there is any loss or disintegrated in weight so after Five cycles the amount loss due:

- Sodium sulfate should not be more than 12%
- Magnesium sulfate should not be More than 18%,

This process causes salt crystals to form in the aggregate's water permeable pores. The formation of these crystals creates internal forces that apply pressure on aggregate pores and tend to break the aggregate.

(D-6) Void in Mineral Aggregate(VMA):
Voids in Mineral Aggregate (VMA) is the volume on intergranular space between particles of compacted paving mixture, it includes air-void spaces that exist between the aggregate particles in a compacted paving mixture and spaces of asphalt that *is not absorbed by aggregates* or what we call effective asphalt content.

VMA = Vair + Vua

Vair = air voids in compacted soil,

Vua = Volume of un absorbed asphalt,

VMA represents the space that is available to accommodate asphalt as a binding agent and the volume of air voids necessary in the mixture to obtain elasticity mode. The more VMA in the dry aggregate, the more space is available for asphalt film which is the coating of the aggregates. Thicker the asphalt film on aggregate particles

the more durable the mix, specific minimum requirements for VMA are specified in most specifications. Minimum VMA values should be adhered to so that a durable asphalt film thickness can be achieved.

Adequate VMA is needed to ensure that adequate amount of asphalt could be added to the mixture without overfilling the voids and resulting in asphalt bleeding.

Durability of HMA, is the ability of the mix to retain its original properties, this includes first resistance to load and second abrasion resistance.

Load resistance become impaired when:

- Asphalt becomes hard and brittle (cannot withstand strains any more without fracturing),
- Asphalt debones from aggregate, see figure (13) below

Figure (13) Asphalt debones

Abrasion resistance:

- Voids content is high allowing air and water prematurely harden asphalt,
- Asphalt and aggregate are not compatible, and design is not integrating these important elements together properly,
- Asphalt films is not thick enough to withstand the abrasion load created by tires,

The effective asphalt content affects the durability which also effect the VMA, so if we want to enhance the durability of the mix we should consider the most effective asphalt content has the most influence on the asphalt film around the aggregate, for certain asphalt content film thickness can be increased by making the gradation of the aggregate coarser or decreasing the fine aggregates,

Asphalt content in the design mix is divided into:

1- Absorb asphalt by aggregate,
2- Binding agent between aggregate or what we call effective asphalt,

$V_{ta} = V_{aa} + V_{ea}$

Vta = Total volume of asphalt in mix

Vaa = Volume of absorbed asphalt by aggregate

Vea = Volume of effective asphalt content

Another factor affecting the durability is the asphalt film thickness which can be described as the dimensions of the asphalt binder coating aggregates particles, the thinner film causes low binding between aggregates causing "Dry Mix" and also the amount of air voids entering the mix will be oxidized and causing asphalt mix to be brittle, if the aggregates is hydrophilic so if a thin layer of film is constructed it will be easily penetrated by water causing deboning or stripping of asphalt binder from aggregate.

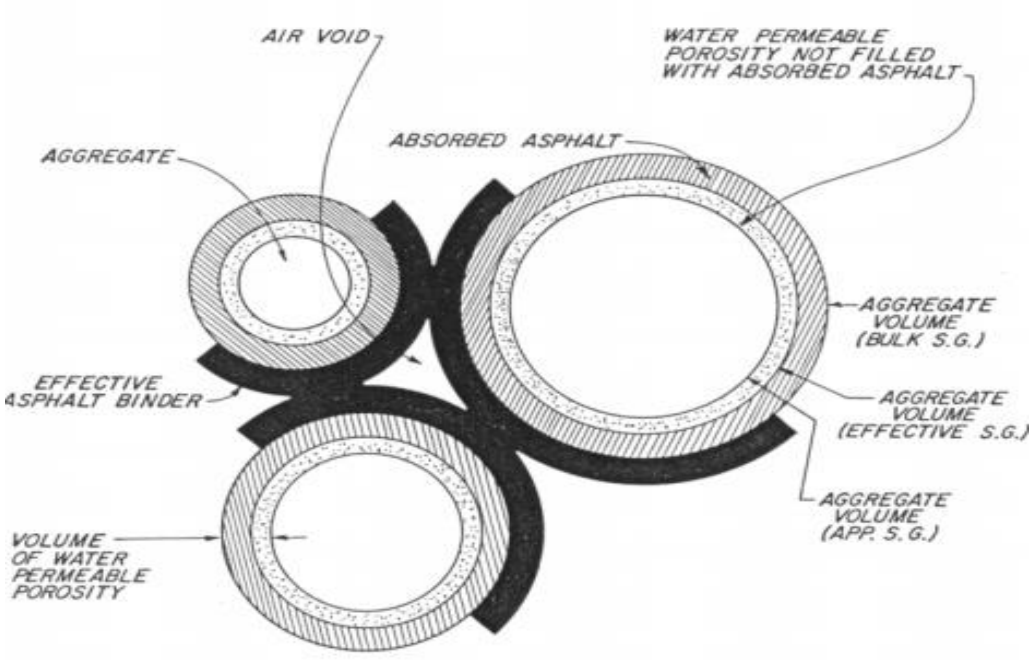

Figure (14): Explain VMA between particles

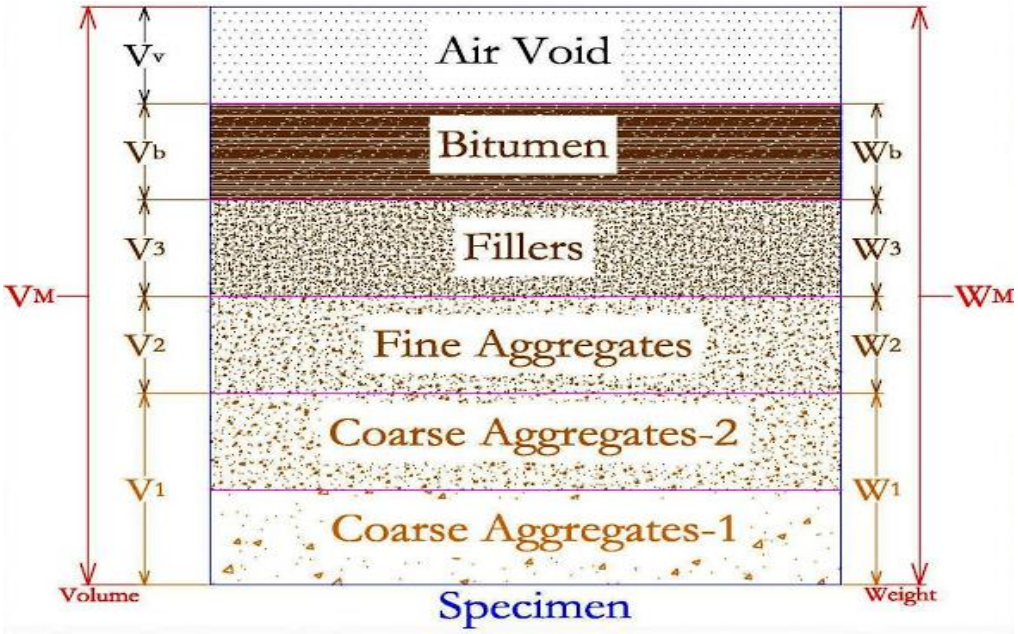

Figure (15): Volume of Bitumen Specimen

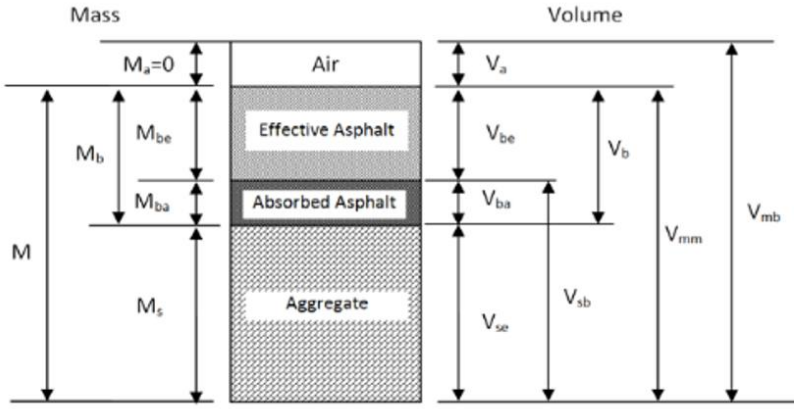

Figure (16): Volumetric Diagram of Bitumen Sample

(D-6-a) Factors affecting VMA

Table below summarize the most important factors affecting VMA:

Factor	Effect on VMA
Aggregate gradation (Aggregate size distribution)	Corser gradation increase VMA
Aggregate shape	Rounded aggregate decrease VMA
Aggregate texture	Smooth or polished aggregate decrease VMA

Asphalt absorption	Increase asphalt absorption lower VMA for the same level of compaction
Dust content	Increase fines and dust increase the surface area, decreases film and lower VMA
Plant production temperature	High plant temp. decrease asphalt binder viscosity, more asphalt absorption, low effective asphalt content, low VMA, (120-165) °C
Temperature of HMA during paving	High temp. creates soft Mix, Bleeding, low air voids and low VMA and causing stripping

In this table we are taking on certain asphalt content for mix design

(D-6-a-1) Aggregate Gradation:

Changing the gradation (particle size distribution) of a mixture will influence the amount of space in the aggregate skeleton. The effect of gradation is separated from shape and surface texture effects if all sized particles have the same shape and texture.

Lowering the dust content in a mixture will increase the VMA. This effect may not be entirely from the effect of gradation, but never the less it has one of the stronger effects on VMA. Reducing dust content to the lower end of the specification will maximize the amount of VMA which can be obtained.

Dust and fine Source:

1- If the dust is coming from mineral filler adjusting the gradation can be simply a matter of reducing the amount being used.
2- If the dust is coming predominately from one of the aggregate stockpiles, say screenings, try to reduce the amount of that stockpile. If the screenings are the only manufactured fines coming into the mix it may be necessary to wash them or blend them with a washed screening. But first check out other easier ways of increasing VMA.

These fines will reduce VMA of the produced mixture because they tend to increase the surface area and reduce the volume of air voids.

Finally, coarser gradation will increase the space to allow the asphalt film and air voids to follow in, finer gradation will increase the percentage of fines in the mix casing high surface area and reduce the thickness of the film around the aggregate and reduce VMA. NOTE we are taking for the same amount of asphalt content.

(D-6-a-2) Aggregate Shape:

Generally, it is desirable to have aggregate particles with a somewhat angular shape in asphalt mixtures in certain percentage. Flat and elongated particle shapes are undesirable. In compacted mixtures, particles that are cubic in shape exhibit greater interlock and internal friction, resulting in greater mechanical stability than flat and elongated particles, mixtures with flat and elongated particles tend to densify under traffic, ultimately leading to rutting due to low voids and plastic flow.

Higher quantities of crushed aggregates and more angular crushed aggregates will generally produce a higher VMA. The increase in VMA results from the angular aggregates creating more void space during compaction due to the increased number of sharp edges and fractured faces. Since VMA includes air voids and the effective asphalt content, increasing the air voids in the compacted mixture will increase the VMA and allow more asphalt into the mix.

Experimentally, determined that higher quantities of rounded, natural sands and more rounded aggregates will generally result in a lower VMA. Round particles have the potential to fit very densely together because the smoothness of the surface and the lack of angular edges, which together reduce the internal friction. The decrease in internal friction and the ability of uncrushed aggregates to compact more easily into a dense arrangement reduces void space, which ultimately leads to a reduction in VMA.

(D-6-a-3) Aggregate Texture:

Aggregate surface texture is qualitatively described by the degree to which the aggregate is polished. Polished aggregate particles have smooth surfaces. As with rounded aggregate particles, this contributes to a lack of internal friction, the ability to compact in a dense arrangement, and a decrease in void space and VMA. Aggregates with rough surface textures have a high level of internal friction, higher air void contents, and higher VMA. In addition, rougher aggregates also have the potential for improved adhesion of the asphalt binder to the aggregate due to the jagged surface texture.

Another aspect of aggregate surface texture is the amount of surface area. Generally, the rougher the surface is, the greater the surface area. Therefore, rougher aggregates tend to require more asphalt binder to coat the individual particles. This decreases the overall film thickness without necessarily decreasing the VMA as the effective asphalt content remains the same. However, durability problems can arise from the reduction of film thickness, regardless of the VMA of the mixture.

(D-6-a-4) Absorption

The amount of asphalt binder absorbed by an aggregate dependence on:

1- Aggregate porosity,
2- Void volume,
3- Pore size of the aggregate,
4- Asphalt viscosity of the asphalt binder.

Porosity is directly influenced by the void volume and pore size. Aggregates with larger pore sizes allow for increased asphalt binder absorption. However, aggregates with small pores have the potential for selective absorption of the lighter asphalt binder fractions. This accelerates premature aging and can create a lack of durability.

Asphalt binders that are more viscous tend to limit absorption by aggregates due to a lack of fluidity and an inability to fill aggregate pores. Alternatively, asphalt binders that are not as viscous have a greater ability to fill aggregate pores.

(D-6-a-5) Plant Production Temperatures

HMA plants produce mixes at temperatures ranging from 120 to 165 °C (250 to 325 °F). As the temperature of the mixture increases, the asphalt binder viscosity decreases and the potential for the asphalt binder to be absorbed into the aggregate increases. Therefore, if a plant produces an HMA at temperatures that are higher than needed for compaction, the aggregate will absorb more asphalt binder, resulting in a lower effective asphalt content and low VMA.

After a mix is produced at an HMA plant, the mix is transported to the paving site. At this point, the mix is unloaded into the paver or on the roadway in front of the paver. The paver forms the mix into a paved mat.

The temperature of the mix at the end of this process is important in determining if adequate compaction can be obtained. Compaction has a great effect on the strength and durability of an HMA pavement. The main objective of pavement compaction is to achieve density so that the pavement will gain the desired strength and durability. The compatibility of HMA is related to the viscosity of the asphalt binder, which changes with temperature. If the temperature behind the paver is too cool, the mat will not achieve adequate density, resulting in poor stability and durability.

Hauling time is the interval between the loading of the HMA from the plant into the truck until the time the mix is run through the paver and compacted. A long hauling time can result in a mix that is too cool for adequate placement and compaction.

(D-7) Air voids

Small airspaces or pockets of air that occur between the coated aggregate particles in the final compacted mix. A certain percentage of air voids is necessary in all dense-graded highway mixes to allow for some additional pavement compaction under traffic and to provide spaces into which small amounts of asphalt can flow during this subsequent compaction. The allowable percentage of air voids (in laboratory specimens) is between 2.0 percent and 4.0 percent for most surface course mixes or as required by designer.

Asphalt durability is a function of the air-void content. This is because the lower the air-voids, the less permeable the mixture becomes. Too high an air-void content provides passageways through the mix for the entrance of damaging air and water. A

low air-void content, on the other hand, can lead to flushing, a condition in which excess asphalt squeezes out of the mix to the surface.

Density and void content are directly related. The higher the density, the lower the percentage of voids in the mix, and vice versa. Any HMA design allows certain minimum amount of air voids according to compaction, aggregate characteristics, temperatures and any other specifications required for pavement that allows.

(D-8) Voids Filled with Asphalt VFA:
The portion of the voids in the mineral aggregate that contain asphalt binder. This represents the volume of the effective asphalt content. It can also be described as the percent of the volume of the VMA that is filled with asphalt cement.

If the VFA is too low, there is not enough asphalt to provide durability and to over-densify under traffic and bleed. Thus, the VFA is a very important design property.

(D-9) Asphalt Content:
The proportion of asphalt in the mixture is critical and must be accurately

Determined in the laboratory and then precisely controlled on the job. The optimum asphalt content of a mix is highly dependent on:

1- Aggregate characteristics such as absorptiveness, texture and shape.
2- Aggregate gradation is directly related to optimum asphalt content. The finer the mix gradation, the larger the total surface area of the aggregate and the greater the amount of asphalt required to uniformly coat the particles. Conversely, because coarser mixes have less total aggregate surface area, they demand less asphalt.

The relationship between aggregate surface area and optimum asphalt content is most pronounced where filler material (very fine aggregate fractions which pass through the No. 200 (0.075 mm) sieve is involved.

Small increases in the amount of filler in a gradation can literally absorb much of the asphalt binder, resulting in a dry, unstable mix. Small decreases have the opposite effect, too little filler results in too rich (wet) a mixture. Variations in filler content will cause changes in mix properties, from dry to wet, arbitrary adjustments to correct the situation are likely to worsen it. Instead, proper sampling and testing should be done to determine the cause of the variations and, if necessary to establish a new job-mix design.

Total asphalt content is the amount of asphalt that must be added to the mixture to produce the desired mix qualities. Effective asphalt content is the volume of asphalt not absorbed by the aggregate; the amount of asphalt that effectively forms a bonding film on the aggregate surfaces. Effective asphalt content is calculated by subtracting the amount of absorbed asphalt from the total asphalt content. The absorptiveness of an aggregate is obviously an important consideration in

determining the asphalt content of a mixture. It is generally known for established aggregate sources but requires careful testing where new aggregate sources are being used.

Aggregates in asphalt mix design should be of crushed stones the aggregate contains:

1. Coarse aggregate: the crushed stone retained ion sieve No. 4 these aggregate gives hardness and durability for the mix.
2. Fine aggregate: the crushed stone passing sieve No. 4 and retained on sieve No. 200.
3. Mineral filler: passing Sieve No. 200

As the air void of the Hot Mix Asphalt (HMA) decreases, the fatigue life or number of repetitions of load to failure of that mix increases. Tests have shown that reducing the air-void content of a given asphalt-concrete mix from 8% to 5% can double the fatigue life of the pavement. Thus, for a given thickness of HMA as part of the pavement structure, the ability of the mix to carry load can be increased significantly when the mix is compacted to a lower air-void content. The air-void content of the mix is reduced to less than 3%, an increase in the rate of rutting of the mix can result.

(D-10) Marshall Stability Test:

The basic concepts of the marshall mix design method were originally developed by *Bruce Marshall* of the Mississippi Highway Department around 1939 and then refined by the U.S. Army. Currently, the Marshall method is used in some capacity by about 38 states. The Marshall method seeks to select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values.

Marshall Stability Test is identified as the optimum asphalt content at which the asphalt mix can with stand the max load at 60°c,

1. Heat a selected aggregate sample of 1200 g (this amount will be sufficient to create 63.5mm sample) with specific gradation in the oven for temp. (175-190) °C that the aggregate should be clear of water, aggregate sample should be weighted, bitumen will be added to the aggregate mix with known amount in temp (120-140) °C,
2. Fill the asphalt Mix into a selected mould (10 cm diameter and 7 cm height) arranged on the compaction pedestal.
3. Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mould and keep it in room temp for 24 hrs.

4. Remove the specimen from the mould and cure it at 60 °C for 30 min after that take the weight of the sample in water.
5. A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (5 specimens).
6. Test the specimen in the stability test by applying load at constant rate of 5mm per min. until failure then record the marshal stability for each specimen.

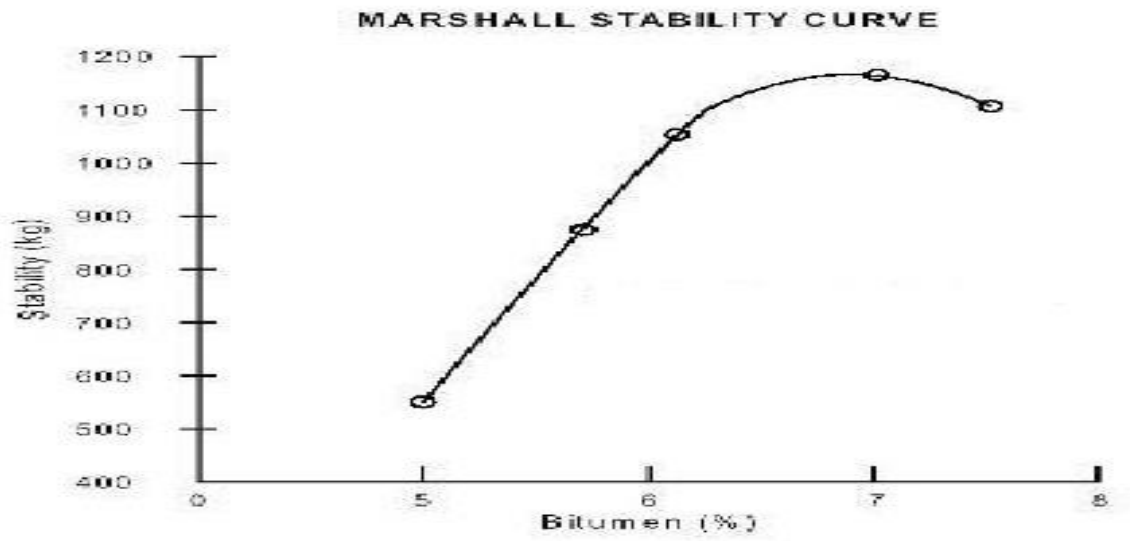

Figure (17) shows the optimum asphalt content based on Marshall Stability Test

(D-11) Marshall Flow Test:

The Marshall Stability and Flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute (2 inches/minute). Basically, the load is increased until it reaches a maximum then when the load just begins to decrease, the loading is stopped, and the maximum load is recorded.

During the loading, an attached dial gauge measures the specimen's plastic flow. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time the maximum load is recorded.

Figure (18) Marshall flow apparatus

Any bitumen mix of asphalt mix the mix is composed usually of course, fine Aggregate with filler and bitumen as a binding agent between them. The design of asphalt paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

The desirable properties of asphalt mixes are:

1. Stability, the resistance of deformation under the repetitive application of wheel load, the mix should not distort when subjected to traffic loads. The resistance to deformation is more important at high temperatures.

2. Flexible, mix should resistance to crack under heavy loads or fatigue resistance, the mix should not crack when subjected to repeated loads over a period.

3. Resistance to low temperature cracking, this mix property is important in cold regions.

4. Durability, the mix should withstand under adverse conditions and repetitive action of traffic, mix should contain sufficient asphalt content to ensure an adequate film thickness around the aggregate particles.

5. Skid resistance.

6. Workability, the mix must be capable of being placed and compacted with reasonable effort.

7. Should have sufficient air voids to prevent bleeding, if we have low air voids and more content of Bitumen binder this will cause bleeding.

(D-12) Bitumen

Bitumen is a black or dark colored liquid or semi-solid viscous substance consist chiefly of high molecular weight hydrocarbons delivered from petroleum refinery by complicated process of distillation process, solvent extraction process may be used to produce bitumen of different consistency and other desirable properties.

Depending on the sources and characteristics of the crude oils and on the properties of bitumen required, more than one processing method may be employed. Bitumen has adhesive properties and is soluble in carbon desulphated.

If bitumen is stored in the working Site it should be kept in place where temperature range is within (50-60)^{0}C, in any application Bitumen should not be heated to temperature 10 degrees more than maximum application point identified in specification or 170 ^{0}C whichever is less.

Penetrated bitumen grades depend on the penetration of standard needle of 100g weight falls into bitumen surface sampled placed in steel cans with dimensions of (50.5X30.5) mm for 5 seconds at temperature of 25^{0}C, three trials must be done for each sample then average is taken, distance of 10 mm must be between trials. According to AASHTO M20. Grades (40/50, 60/70, 80/100)

Bituminous materials or asphalts are extensively used for roadway construction because of:

1- Excellent binding characteristics between aggregates,
2- Water proofing properties,
3- Relatively low cost,

Two main components can be derived from bitumen:

1- Cutback Bitumen:

Normal practice is to heat bitumen to reduce its viscosity. In some situations, preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the

bituminous material will evaporate and the bitumen will bind the aggregate. Cutback bitumen is used for cold weather bituminous road construction and maintenance. The distillates used for preparation of cutback bitumen are naphtha, kerosene, diesel oil, and furnace oil.

Asphalt cutbacks or cutback bitumen uses petroleum solvents for dissolving asphalt to reduce the viscosity of the bitumen. The solvents used are called ***distillate, diluents or cutter stock***.

If the used solvent in making cutback asphalt is highly volatile, it will evaporate quickly escaping from the material leaving bitumen on the surface. Solvents of lower volatility evaporates more slowly. Based on the speed of evaporation cutback asphalts are divided into three types: rapid curing (RC), medium curing (MC) and slow curing (SC).

2- Emulsion Bitumen:

Bitumen emulsion is a mixture of water & bitumen. But we know that bitumen is an oil product and it cannot be mixed with water. That is why we add an emulsifier (a surface-active agent) with water before adding bitumen. Addition of emulsifier with water facilitates breaking of bitumen into minute particles and keeps it dispersed in suspension.

Based on the surface charge we have two types of Emulsion Bitumen:

1- Anionic Bitumen Emulsion
2- Cationic Bitumen Emulsion

In case of an anionic bitumen emulsion, bitumen particles are electro-negatively charged, whereas for cationic emulsions, bitumen particles are electro-positively charged. Now days cationic bitumen emulsion is most commonly used.

The bitumen content in the emulsion is around 60% and the remaining is water with emulsifier. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of setting depends upon the grade of bitumen.

There are three types of emulsion bituminous based on the setting time, which are rapid setting (RS), medium setting (MS), and slow setting (SS). Bitumen emulsions are ideal binders for hill road construction. Where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

The advantage cutbacks have over emulsions is a much higher residual bitumen percent, typically over 80% compares with over 40-65% for emulsion bitumen. The result is more Bitumen left on the roadway after curing, for the same volume of binder applied.

Cutback Bitumen Classification

Cutbacks are divided into three classifications, Rapid-Curing (RC) and Medium-Curing (MC), Slow-Curing (SC) depending on the solvent used. They are further defined by a number which indicates the minimum kinematic viscosity (fluidity) of the cutback.

MC (Medium Curing) cutback bitumen means solvent used is medium curing and will evaporate not so fast and not slow. MC70 cutback bitumen for example is one type of dissolved bitumen. To produce this type, solvent oils such as Kerosene are used to change bitumen into dissolved bitumen or liquid pitch, so that, during consumption process, the solvent oil evaporates and the bitumen residue to obtain the desirable adhesion.

Cutback Bitumen types and application temperature

RC Cutback Grade	Spraying Temp. 0C	MC Cutback Grade	Spraying Temp.0C	SC Cutback Grade	Spraying Temp.0C
RC-70	40-75	MC30	21-63	SC70	45-80
RC-250	65-105	MC70	45-80	SC250	70-110
RC-800	90-115	MC250	70-110	SC800	95-125
RC-3000	105-135	MC800	95-125	SC3000	110-145
		MC3000	110-145		

Information taken from Jordan National Building Council Volume(III) Section 4

Section (E) Road Drainage System:

The primary purpose of a road drainage system is to remove the water from the road and its surroundings. The road drainage system consists of two parts:

- Dewatering,
- Drainage

Dewatering: Means the removal of rainwater from the surface of the road or allowing the surface of the road to drain water by having good slopes and good design for the road sections that helps in this operation which we call it water runoff covers the water flowing from the surface of the pavement via road shoulders and inner slopes to the ditches.

Dewatering consists of following elements:

- Cross fall,
- Road shoulders,
- Impermeable road surface materials

Drainage: Means all the different infrastructural elements to keep the road structure dry and protect it from rain water like (culverts, ditches, shoulders, and open water canal).

Drainage system consists of following elements:

1. Side ditches,
2. Outlet ditches or open canals,
3. Culverts (box or pipe),
4. Inner/outer slopes,
5. Road structures (Longitudinal Slopes,
6. Underdrains

(E-1) Side Ditches:

Earth man made side road structure created with certain slopes to collect road water and lead it onward to outlet ditches and are especially important when road is in cut or it is made of construction material like gravel and cement based on the nature of the area and rain fall in that area. If the road is on a high embankment, side ditches are not always necessary, and their need must be evaluated case by case. The longitudinal gradient of side ditch should be at least 4 ‰ (4 mm/m) to allow adequate flow of water inside.

The depth of the side ditch should be measured from the bottom layer of the sub base or the upper surface of the sub grade, depth from (20-35) cm and minimum 50cm from the edge of the wearing layer to the bottom of the Ditch.

Side ditches has two basic shapes, V-Shape and trapezoidal shape.

Figures 19 & 20 explain the nature of the side ditches.

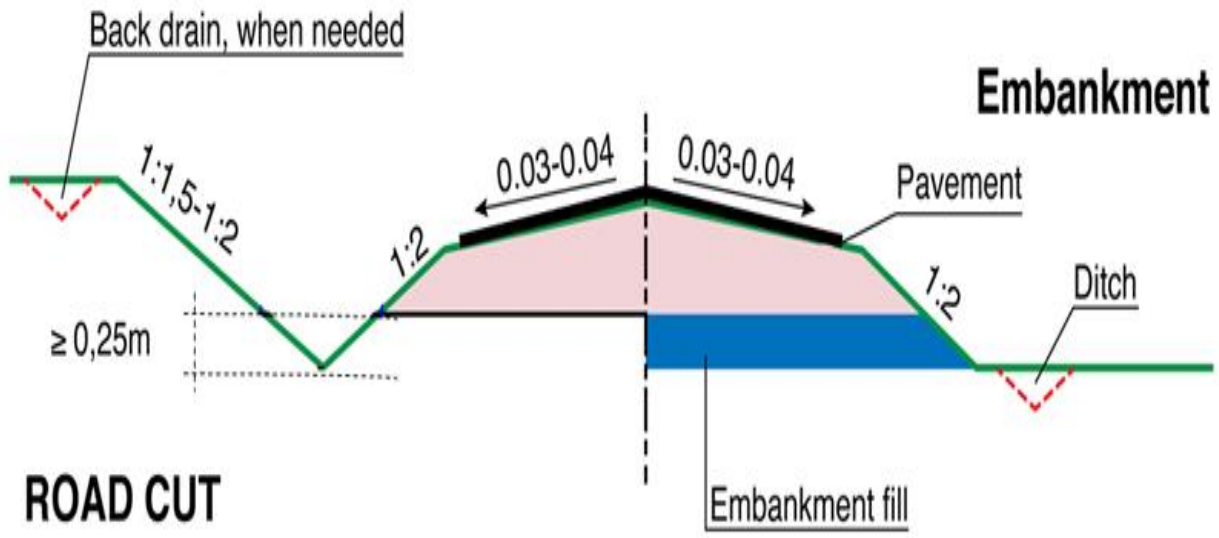

Figure (19) General Cross sectio for Road Cut Section

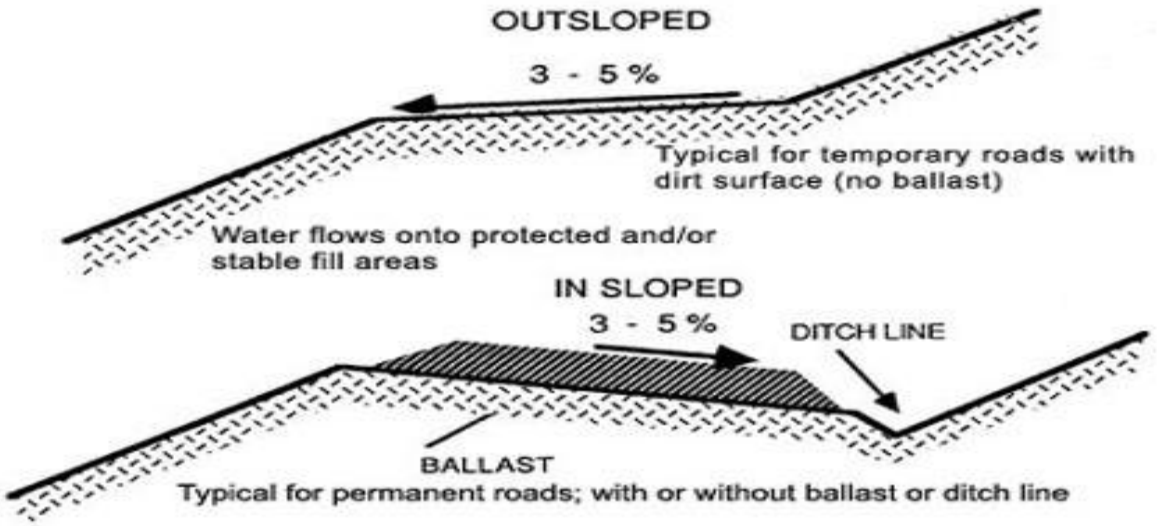

Figure (20) side ditches used on curves, cross fall is applied in the form of super elevation, also called "one-sided cross fall" which has slope from one side. Also, it is applied on narrow roads where there is no space is available to apply both side ditches and when it is difficult to create and maintain a crown section due to the available width. So, it is usually more effective to implement full cross fall (in-sloped or out-sloped road) rather than a crown. The minimum requirements for cross fall on curves must be determined on a case by case basis. The cross fall will depend for example on the speed

limit and the geometry (curve radius) of the road. The cross fall of curves is important also for driving dynamics.

(E-2) Outlet Ditches

Outlet ditches are drainage structures designed to lead the water from the side ditches away from the road area. The water from outlet ditches normally discharges to existing waterway systems, such as river channels and lakes or valleys. The Outlet ditch is a critical part of road drainage system but often ignored. If the outlet is clogged, it can create significant problems to the road over a large area. Outlet ditches are normally located outside the road area with the result that the road administrator may not always own the land that they pass through.

It is recommended that the longitudinal gradient of an outlet ditch should be at least 4‰. In practice this may require to be reduced to a lower gradient to suit the local circumstances.

Outlet ditches should be excavated in such as fashion to discharge into a natural watercourse at the same level as the bottom of the natural channel. If there is no natural channel, the outlet ditch should be excavated for a suitable distance to minimize any accumulations of silt, mud or other harmful materials.

(E-3) Road Culverts

Culverts are important hydraulic structures used to convey water across a road corridor or in one of a range of other situations. Culverts must be designed to convey this flow in an acceptable way, considering the hydraulic conditions and the required performance (level of flood immunity) of the road. Environmental and/or other requirements may also need to be considered/incorporated, depending on the specific circumstances.

The shape of a culvert is usually a round pipe, but culverts can also be pipe arch, structural arch or box. The shape depends on the site, the required area and the allowable height of soil cover.

A culvert is a structural element used to enable the collected rain water to be drained under the cross section of the Roads, culverts are divided into:

a) Pipe Culvert,

The main advantages of pipe culverts are:

- It can be constructed of any desired strength by proper mix design, thickness, and reinforcement.
- They are economical.
- These pipes can withhold any tensile stresses and compressive stresses.
- The crossing of water is under the structure.

The main disadvantage of pipe culvert is that it can be easily corroded at the crown because of bacteria 's organic matter and release of harmful gas, which is known as Crown corrosion.

b) <u>Box Culvert,</u>

Box culverts are economical for the reasons mentioned below:

- The box culvert is a rigid frame structure and very simple in construction,
- It is Suitable for non-perennial streams where scrub depth is not significant, but the soil is weak.
- The bottom slab of the box culvert reduces pressure on the soil.
- Box culverts are economical due to their rigidity and monolithic action and separate foundations are not required.
- It is used in special cases, weak foundation.

If the culvert clear opening is less than 2m it is considered as a culvert and if more than that we consider it as a bridge. If the construction is a large pipe with a clear opening of 2-4 m, the culvert is defined as a pipe bridge.

Pipe culverts, sometimes can be used for cross-drains in intersected roads which can be susceptible to clogging and require cleaning. That is why, when planning the installation of a culvert, the most important thing to keep in mind is to make sure that the culvert is adequately sized and has overflow protection. Culverts should also be installed in accordance with the manufacturer's instructions and suitably protected from erosion, scour and road maintenance equipment.

Culverts can be classified also based on the direction of the stream as shown in the figure below:

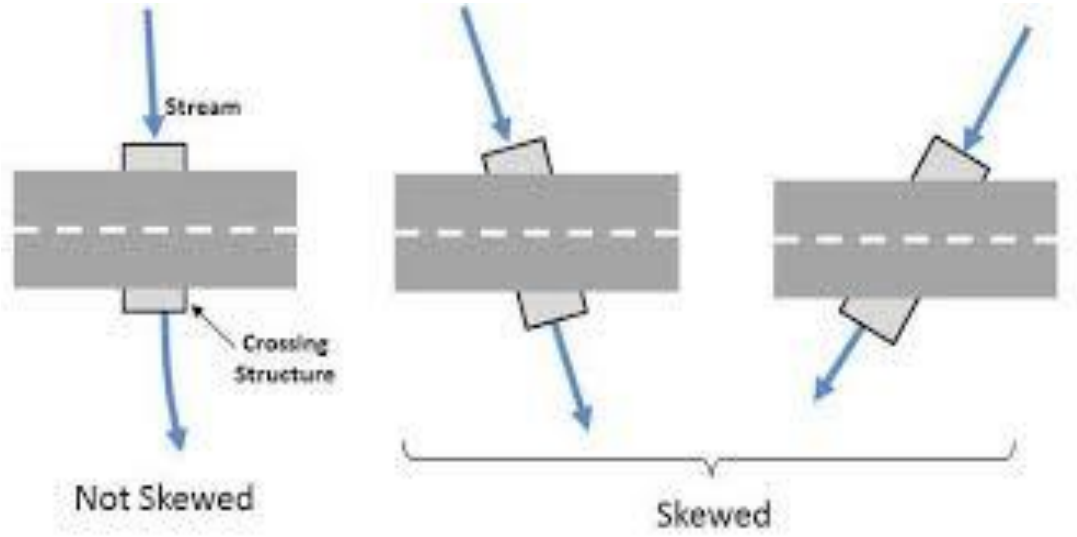

Figure (21) shows the direction of the flow with respect of the Center Line of the Street

Culverts has three important elements:

- Inlet,
- Outlet,
- Culvert Body,

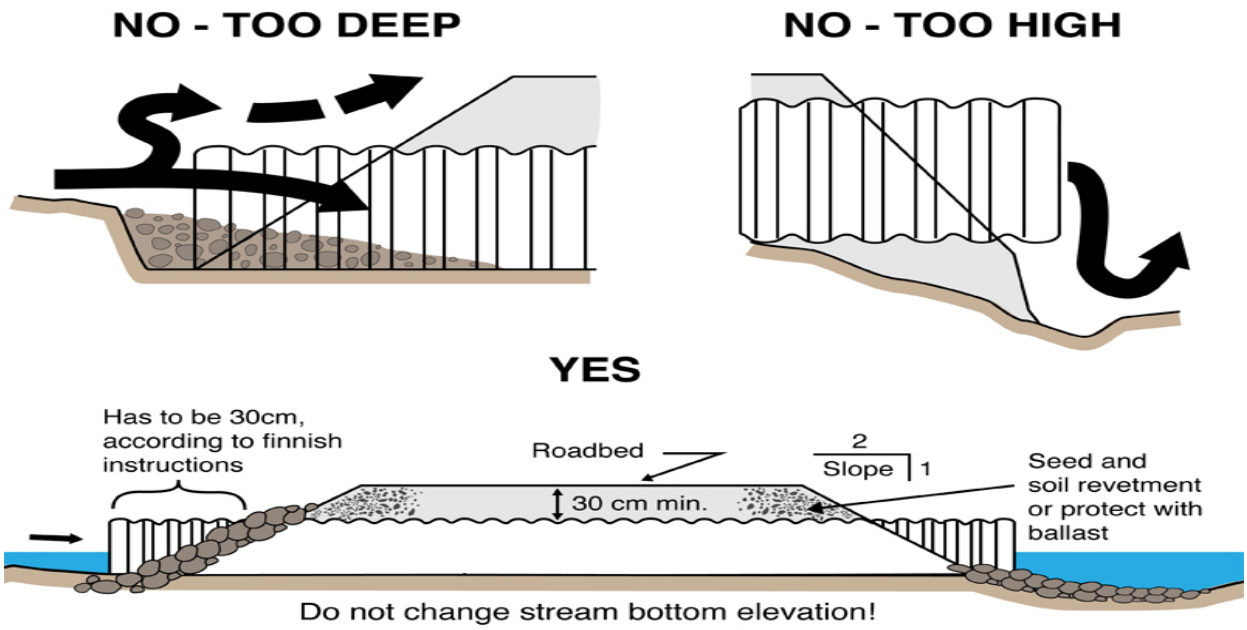

Figure (22) shows pipes best installation process

Main road culverts should be installed in the lowest point of the terrain. The rule of thumb when installing a culvert is that natural channel modifications should be minimized, and that any constriction of the channel flow width must be avoided. This can be done by maintaining the natural grade and alignment of the channel through the culvert.

Culverts should normally be installed orthogonally to the road alignment. They can also be installed at an angle to the road alignment if required by local circumstances.

When designing the size of culvert, a number of matters should be taken into account,

- Size of drainage area or catchment area,
- Surrounding terrain type,
- Rainfall intensity,
- Type of soil
- Type of the back filling surrounding the pipe culverts,

The outlet of a culvert should ideally be in a stable, non-erosive area. Well-vegetated or rocky areas are good places to locate a culvert. Water flowing from a culvert can cause erosion problems where it discharges directly on to erosive soil. Channel protection, riprap or other structural solutions are not as good as a correctly sized and well-placed pipe.

Section (F) Road Engineering Contracts:

Road maintenance
Planning Implementation and monitoring Handout

The process of reconstruction and rehabilitation of roads needs to have several stages to reach out to best result so in this section we will go into details of all steps,

1- Design,
2- Procurement,
3- Execution of Contract,
4- Maintenance period, Defect Notification Period (DNP),

(F-1) Design:

Road contracts are type of contracts that needs an expert in preparing the designs and specifications because each area has its own characteristics regarding soils type, road demand and road classifications (Urban, rural or agricultural).

Design must pass through several stages:

1) Data collection,
2) Design module,
3) Draft design,
4) Final design,
5) Preparing tender documents,

(F-1-a) Data Collection:

To have a proper design, designer should have or what we call it design input:

1. Land survey. Consultant need to make existing land survey to show:
    a) Land topography,
    b) Existing roads,
    c) Future expansion of selected Road,
    d) Location of the existing Utilities (water manholes, electrical Light units, electrical power station or pump station).
    e) Land acquisition,
    f) Estimated length for each road section,

2. Soil tests, previous conducted tests or consultant need to do new soil test.
3. Hydraulic studies. In areas where there is a huge amount of rain fall and consultant is afraid of floods,
4. Traffic loads.
5. Type of roads according to the master plan (agriculture, rural or urban)

(F-1-b) Design Module:

After gathering all the information and before conducting any effort in the design consultant had to make design module to show:

i. Typical section for road,
ii. Drainage system to be used,
iii. Road width,
iv. Road specifications,
v. Construction method if needed,
vi. Expected contract budget,

All these data have to be in front of client for approvals, this method is considered one of the most effective business practices that reduces cost and meet the expectations of the client and reduce the effort that is needed for design and cut down time.

Approval needs to be in documented in writing.

(F-1-c) Draft Design:

After approving the design module consultant will proceed in making a draft design for approval that contain:

1. Drawing list,
2. Site layout for the roads showing the location in certain areas,
3. Stations for each road. Station should not be for more than 20m and it is desirable to be for each 10m so that it makes the profiles more accurate.
4. Profile drawings showing elevations for each road and distinguishing between the existing road and new road,
5. Drawing showing the cut and fill area for each station in the roads.
6. Calculation drawing sheets for the cut and fill area,
7. Details design drawings showing the typical cross sections,
8. Hand out for the quantities calculated for each road,

Draft design is submitted for approval and address any comments, there must be sufficient of time in this stage for client to review all designs. All these comments need to be documented in writing.

(F-1-d) Final Design:

After rectifying all comments addressed in the draft design stage consultant makes the final design accordingly. All drawings need to be stamped with "*Approved for Construction*"

(F-1-e) Preparing Tender Documents:

After completing and approving final design hired Consultant is responsible for all tender documents and makes it ready for procurement,

Bid documents for tendering:

a) Tender documents,
b) Specification,
c) Drawings,
d) Bill of quantities (BOQ),
e) Method of measurements,
f) Cost estimate for contract,

(F-2) Procurement:

Request for Quotation (RFQ) is prepared for the purpose of public advertising in newspaper, during procurement we should make sure that in the request for quotation RFQ is sent to bidders properly:

- By hand, contractor needs to sign on a paper saying that he had received the RFQ properly with all the bid documents.
- Or email, the sender needs to clarify in his email that he had sent documents (a, b, c, …) and contractor needs to reply that he had revived all the bid documents.

What contractor is expecting to see in the RFQ from the client?

1. Specifications,
2. Drawings,
3. BOQ,
4. Method of measurements,
5. Location of the project,
6. Tender entrance bond,
7. Date for site visit, ***it should be mandatory***,
8. Last date for questions,
9. Last date for answers,
10. Final date for receiving bids (time, date, location and how to submit)
11. Contract Data or Appendix to Tender where we show:
    A. Minimum allowable payments,
    B. Contract duration,
    C. Defect Notification Period,
    D. Performance bond,
    E. Delay damages,

F. Communication language,
G. Profit,
H. Working hours,
I. Currency,
J. Advance payment,
K. Advance payment Grantee,
L. Maintenance bond,
M. Retention Money,
N. Any other information that client thinks Contractor needs to be aware of before submitting his technical and financial offer.

(F-3) Execution of Contract:

After selection of winning contractor, client need to send letter of award (LOA) explaining in it that contractor (X) his bid is selected to perform the tasks, in this letter you need to give contractor time to:

- Submit performance bond,
- Pay all taxes and royalties as mentioned in the law,

If the selected contractor did not comply with the above points, client has the right to call for the tender guarantee then go with the second contractor in the proposal, client or engineer who deals with this process cannot give back all submitted contractor tender grantee unless he has a performance bond from contractor.

After submitting performance bond, site hand over need to be done and both parties will agree on the commencement date, then contractor will proceed with the work items as mentioned in the BOQ and as the proposed Work schedule submitted that should be submitted within 28days after the commencement date and approved from engineer.

When contactor complete all his contractual obligations as required from him and the facility is ready for occupation and operation then he calls for taking over for the Works.

During paving we need to have clear idea about what we are going to inspect or what we should do, so below is a checklist with the most important items need to be considered during paving.

(F-3-a) Inspection Checklist (before applying asphalt),

1- Document control,
Check specification, BOQ, contract data, amendments, special provisions and contractor liability.

2- Coordination with community, public sector, private sector and utilities companies,
3- Field review, making sure that all surface is ready for paving and no need for any correction plan,
4- Equipment check, in this stage I would prefer to set a meeting with contractor to discuss all the needed equipment's

Equipment Used:

- Vibrated steel roller, this one produces mix compaction, water nozzle need to be checked, check the smoothness of the drum and scribers.
- Wheel roller, force the bitumen to surround all aggregate particles and form binder film, so the pressure of the wheel should be equal, water nozzle need to be checked.
- Trucks, (rear dump, conveyor dump and belly dump) you need to make sure that no oil or Gas is leaking from the truck and you need to notify contractor to replace it because it will affect asphalt mix, check truck back alarms. Make sure that trucks should be all covered.
- Finisher or pickup machine, calibration, heating of plate, cleanness of the bottom plate.
- Mechanical brooms,
- Mechanical spraying machine of tack coat, need to check the Nozzle opening and the direction of the opening also check the height of the nozzle.
- Temperature gauges, review contract specification regarding the required applied temperature.
- Manual hand tools,
- Water tank,
- Standby equipment in case of failure,

5- Traffic control,
6- Weather conditions, check specifications.
7- Tack coat application,

(F-3-b) Inspection check list during paving

1- Mix delivery, collect each truck tickets and mark each one with the place of Installation and time, truck tickets show volume and time truck left plant, check mix temperature, make sure that the contractor has enough truck to maintain same speed of paving in same temperature.
2- Placement,
3- Compaction, contractor has to satisfy the design compaction of the mix by providing the required roller, roller speed should be controlled so that it will

not damage the surface of the mat usually it should be as walking speed, compaction Should produce uniform homogenous smooth surface.

4- Transvers joints,
5- Lab technician,

Section (G) Annexes

(G-1) Weekly Inspection Report,

Weekly Inspection Report		
Municipality:		
District:		
Date of Inspection:		
Inspection Site:		
Inspection made of:		
Inspection Findings:		
Related Department to involve:		
Prepared by:		Signature:
Date:		
Title:		

(G-2) Area Survey Data form,

Area Survey Data								
General Information								
Municipality:								
District:								
Date:								
No.	**Str. Name**	**Str. Length (m)**	**Str. Width (m)**	**Status of Roads**	**Needed Action**	**Available Sidewalk**	**Last Time Rehabilitated**	**Technical Advice**
1								
2								
3								
4								
5								
6								
7								
8								
No.	**Culvert Location**	**Culvert Type**	**No. of Culverts**	**Culvert Length (m)**	**Status of Culvert**	**Needed Action**	**Last Time Rehabilitated**	**Technical Advice**
1								
2								
3								
4								
5								
6								
Prepared by:								
Date:								
Title:								

Under Column Road Status fill with (Good or Poor)

Under Column Needed Action for roads with fill with (Rehabilitation or Reconstruction)

Under Column Available Sidewalks fill with (Yes or No)

Under Column Culvert Type fill with (Pipe Culvert or Box Culvert)

Under Column Culvert Status fill with (Stable or Not Stable)

Under Column Needed Action for culverts, fill with (Extension, Rehabilitation or Reconstruction)

Under Column Technical Advice fill with (Urgent or Not Urgent)

(G-3) Priority Identification Form

Priority Identification Sheet						
General Information						
Municipality:						
District:						
Priority Identification						
No.	**Proposed Work**	**Community Priority**	**Technical Feasibility**	**Justification**	**Expected Cost (JOD)**	**Priority of Proposal Based on Finance**
Total						
Prepared by:						
Date:						
Title:						
Reviewed by:						
Date:						
Title						
Approved by:						
Date:						
Title:						

Under column community priority fill it with number between (1-5), 5 is the most important

Under column technical feasibility, fill it with (Applicable or Not Applicable)

Under column priority of proposal based on finance, fill with (No Available Fund or Fund is available)

(G-4) Annual Work Plan,

Annual Work Plan							
General Information							
Municipality:							
District:							
Contracts Break Down							
No.	**District**	**Village**	**Contract No.**	**Type of Contract**	**Contract Scope**	**Contract Expected Duration**	**Contract Expected Budget(JOD)**
Total							0.00
Prepared by:							
Date:						Signature:	
Title:							
Reviewed by:							
Date:						Signature:	
Title							
Approved by:							
Date:						Signature:	
Title:							

Under Column type of contract Type fill with (Road Reconstruction, Road Rehabilitation, Parks, Building Rehabilitation, Building Construction, Beautifications, Sidewalks and Culverts)

(G-5) Base Course Check List, (This form need to be filled be municipality site engineer and to be send for his supervisor for approval)

Road maintenance
Planning Implementation and monitoring Handout

Check List for Base Course

Project Name:	Contractor:
Project No:	Municipality Site Engineer:
Date :	Senior Municipality Engineer:
Municipality: Village:	Road Name/section:

No	SUMMARY OF SITE VISIT	YES	No	Remarks
A	The Contractor provided material to Site.			
b	Did the sample sent for laboratory testing ?			
c	Did the Sample Submitted for testing Engineer ?			
d	The aggregate used as per specification and according to laboratory specification.			
e	What is the layer thickness of the formation__cm. What is the thickness per specification____cm.			
f	Did Contractor Submit Shop Drawing for Approvals?			
g	Did Contarctor applied Compaction?			
h	Did contractor applied watering the layer before and while compaction?			
i	Did contractor applied Compaction test after finishing?			
j	**Comments:**			

Checked By	Approved By
Name : _____	Name : _____
Date :_____	Date :_____
Sign :_____	Sign :_____

(G-6) Sub Base Course Check List, (This form need to be filled be municipality site engineer and to be send for his supervisor for approval).

Check List for Sub Base Course				
Project Name:		Contractor:		
Project No:		Municipality Site Engineer:		
Date :		Municipality Senior Engineer:		
Municipality: Village:		Road Name/section:		
No	**SUMMARY OF SITE VISIT**	YES	No	Remarks
A	The Contractor provided material to Site.			
b	Did the sample sent for laboratory testing ?			
c	Did the Sample Submitted for testing Engineer ?			
d	The aggregate used as per specification and according to laboratory specification.			
e	What is the layer thickness of the formation__cm. What is the thickness per specification____cm.			
f	Did Contractor Submit Shop Drawing for Approvals?			
g	Did Contractor applied Compaction?			
h	Did contractor applied watering the layer before and while compaction?			
i	Did contractor applied Compaction test after finishing?			
j	**Comments:**			
	Checked By Name : _____ Date :_____ Sign :_____		Approved By Name : _____ Date :_____ Sign :_____	

(G-7) Asphalt Check List, (This form need to be filled be municipality Site engineer and to be send for his supervisor for approval)

Check List for Asphalt				
Project Name:		Contractor:		
Project No:		Municipality Site Engineer:		
Date :		Municipality Senior Engineer:		
Municipality: Village:		Road Name/section:		
No	SUMMARY OF SITE VISIT	YES	No	Remarks
A	Did Contractor submit Asphalt Mix Design for Approval?			
b	Did asphalt sample sent to laboratory for testing while performing the work ?			
c	The material used as per specification.			
d	Did testing conduct perform before sprawing of MC and RC ?			
e	What is the thickness of the formation__cm. What is the thickness per specification____cm.			
f	Did contractor submit shop drawing for approval?			
g	Did contractor's shop drawing approve by engineer?			
h	Did Contractor Applied Compaction?			
i	Did Contractor applied Compaction test?			
j	**Comments:**			
	Checked By Name : _____ Date :_____ Sign :_____		Approved By Name : _____ Date :_____ Sign :_____	

(G-8) Change Order Request Form, this form should be filled by municipality site engineer when project progress is 50% and 85%, in this report site engineer explains to management what the changes are and why and justification for that change for approval.

Change Order Request Form-First Page

Project Name	Contract Number	Change Order No.	Todays Date
Original Start Date	**Original Finish Date**	**Current Finish Date**	**Time Extension**
Municipality		**Area**	**Project Type**
Original Contract	**Changes to Date**	**Current Contract**	**Requested Change**

Description of Work and Cost Estimate *(continue on separate sheets if necessary):*

Changes Required:

Time Extension:

Original Contract Value	-	
Changes to Date	-	

Current Contract Value including all changes to date	**-**	
Total Value of this Change Order	-	
(Negative value for negative changes the contract)	----------	
New Contract Value including this Change Order	**-**	
Percentage Change of current contract value	**#DIV/0!**	
Time Extension (if required)	**0**	**Days**
New Contract Completion Date	**0-Jan-00**	**No Extension**

Requested By:	Name:	Signature:	Date:
Contractor			
Recommended By:	Name:	Signature:	Date:
Municpality Site Engineer			
Approved By:	Name:	Signature:	Date:
Mayor			

Change Order Request Form-Second Page

Project Name:	
Contract number:	
Municipality:	
Contractor :	
Date:	
Original Contract start date	
Original Contract end date:	

		ORIGINAL CONTRACT				CHANGE ORDER				
						ADDITIONAL		DEDUCTION		TOTAL PRICE (JOD)
	Item Description	**Unit Rate**	**Unit Price (JOD)**	**Qty**	**PRICE (JOD)**	**Qty**	**PRICE**	**Qty**	**PRICE (JOD)**	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
	TOTAL				**SDP -**		**SDP -**		**SDP 0**	**SDP 0**
	PERCENTAGE				#DIV/0!					#DIV/0!

Proposed by:	**Prepare by**	**Approved by:**
Contractor	**Municipality Site Engineer**	**Finance Department**
(_____)	(_____)	(_____)