B.Sc - Road & Railway Design I. *Lecture 11.*

ROAD CONSTRUCTION TECHNOLOGIES

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PHASES OF ROAD CONSTRUCTION

- PHASE I: *Planning*
  - A road project begins with evaluating the transport system, taking into account statewide priorities, including the road administration's mission and vision and its strategic plans for the State's transport system
  - Using available and reliable data, transportation planners, civil engineers, environmentalists, landscape architects, soil scientists and others identify trends that determine what, where and when, how to build
- PHASE II: *Design*
  - A survey of the area is step two; recently, Global Positioning Systems, laser surveys and other technology have sped up the process and improved accuracy
  - Engineering Firms specialized in road design are preparing studies, preliminary design and approved construction blueprints, in compliance with effective standards and official guidelines, using Computer Aided Design (CAD)
  - With a design in hand, the Road Administration advertises competitive tendering for a contractor to do the actual building; contracts are awarded to the company/consortium presenting the best offer (including bid price)
- PHASE III: *Construction works*
  - Earthworks
  - Paving
- PHASE IV: *Open to traffic*

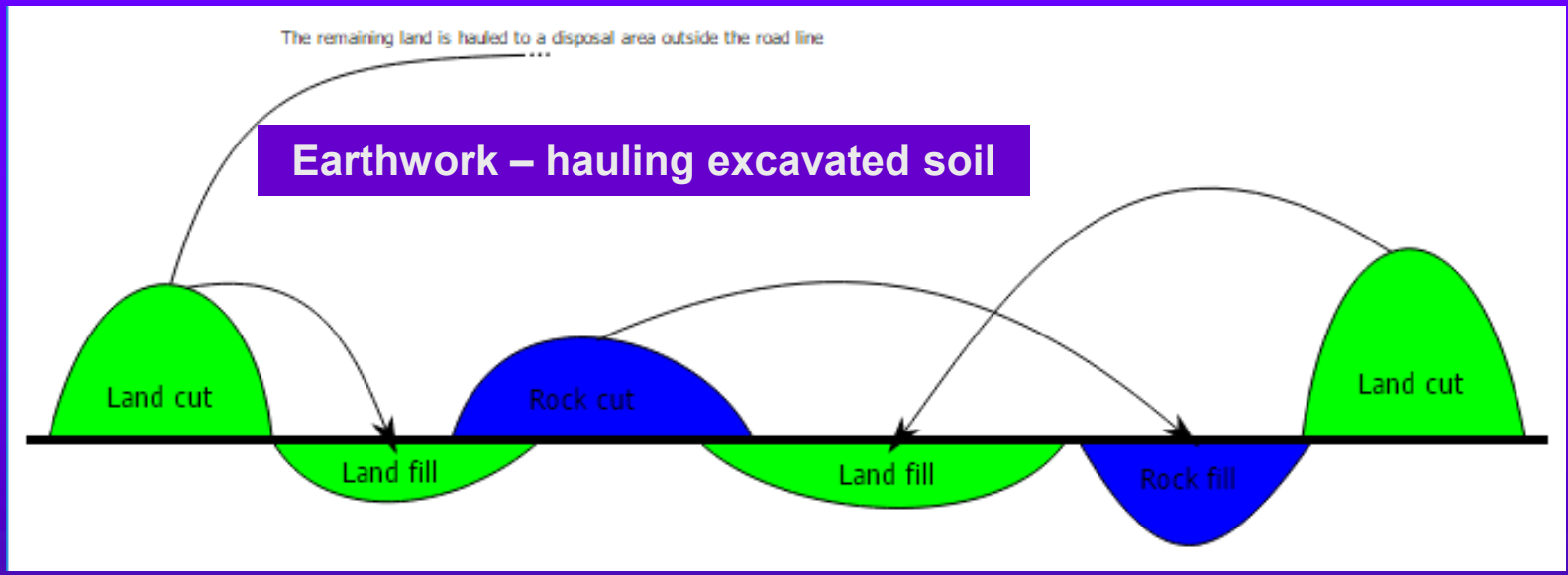
ROAD CONSTRUCTION

- Road construction is a lengthy process that can take several years, depending on the size of the future carriageway
- Construction works involve several specialized crews & plant machinery and require careful decision making, including environmental and structural assessments
- Once works have begun, there are several stages before the road can be used by vehicles
- Special machines are required to carry out each stage of road building process, providing the required result justified by a series of quality control measures approved by an appointed independent engineer

EARTHWORKS 1

- Earthworks include the excavation of existing earth material and any placement of fill material required for constructing the embankment; cut and fill are the terms that are used for the areas of the section
- Highway engineers strive to balance the amount of cut and fill during a highway construction project to avoid costly hauling of materials
- If soil mass excavated from cuts and suitable for construction is less than required mass of fill, additional material is needed from *borrow pits* (an area where material - soil, gravel, or sand - has been dug for use at another location)
- In the opposite case, excavated excess soil unsuitable for construction shall be deposited at designated *waste disposal areas*

BALANCING EARTHWORKS



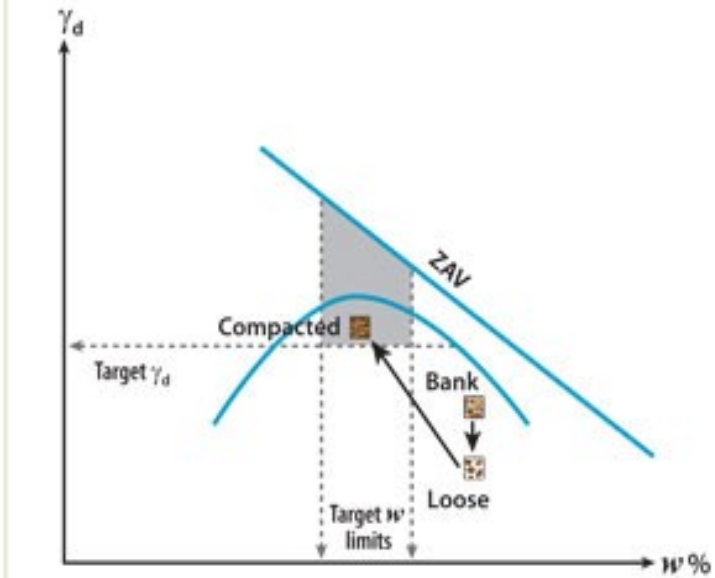
Borrow pit

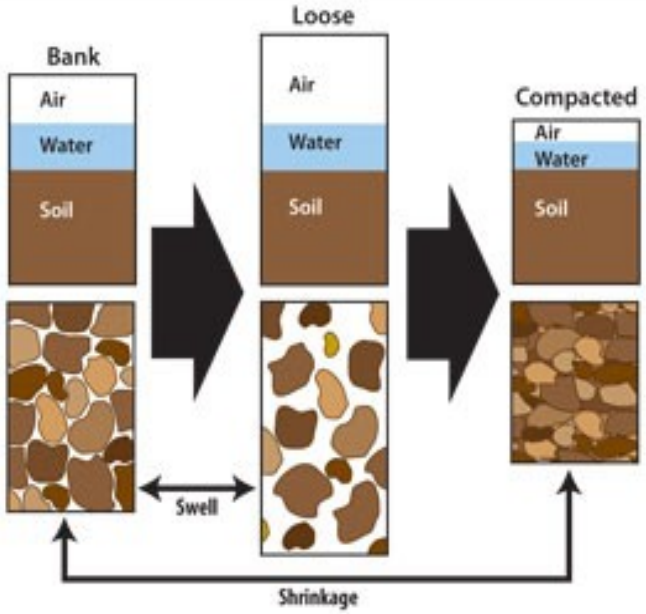
Excess soil disposal area

EARTHWORKS 2

- **Clearing and Excavation**
  - The area on which the road is going to be built on must be cleared of topsoil, and all vegetation, which requires the removal of trees, shrubs and bushes
  - Excavation vehicles will also dig up and remove rocks and stones from the future road's pathway
  - To prevent the land cleared from topsoil from erosion, control devices, including fences, ditches and basins are installed
- **Mounting (cutting and filling)**
  - The road takes shape as *diggers*, *excavators*, *scrapers* and *bulldozers* open cuts and fill gravel and soil over the area where the future pathway will run
  - The surface is then leveled and smoothed by *graders*
  - Culverts and drains, consisting of large concrete pipes are laid to prevent the road from flooding by leading away groundwater, sewage or stormwater
- **Fine Grading**
  - Fine grading requires construction workers to prepare the surface by leveling it according to plans provided by structural engineers
  - Fine grading requires manual labour and digging as well as grading plant machinery, also called *graders*
  - To make the grading last, upper layers of sub-grade have to be duly compacted and stabilized in site with lime or cement, if necessary

EARTHWORKS 3





CLEARING & EXCAVATION

Excavator at work

Bulldozer at work: cleaning

Excavating soil from cut area or borrow pits and moving it to fill area by dump trucks

MOUNTING (CUTTING & FILLING) 1

- A *loader* (also known as: bucket/frontend/pay/scoop/skip/wheel loader and or shovel) is a type of tractor, usually wheeled, sometimes on tracks, that has a front mounted square wide bucket connected to the end of two booms (arms) to scoop up loose material from the ground, such as dirt, sand or gravel and move it from one place to another without pushing the material across the ground

- A *backhoe,* also called a rear actor or back actor, is a piece of excavating equipment or *digger* consisting of a digging bucket on the end of a two-part articulated arm; they are typically mounted on the back of a tractor or front loader

MOUNTING (CUTTING & FILLING) 2

- A *bulldozer* is a crawler (continuous tracked tractor) equipped with a substantial metal plate (known as a blade) used to push large quantities of soil, sand, rubble, or other such material during construction or conversion work and typically equipped at the rear with a claw-like device (known as a ripper) to loosen densely compacted materials

Dozer grading out stone.mp4

Dozer Grading a 2_1 slope.mp4

Bulldozers at work: embankment fill

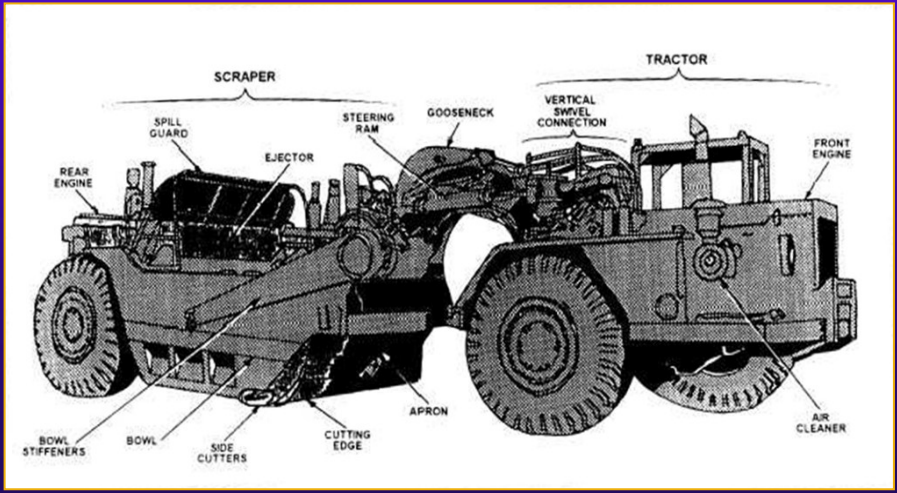
MOUNTING (CUTTING & FILLING) 3

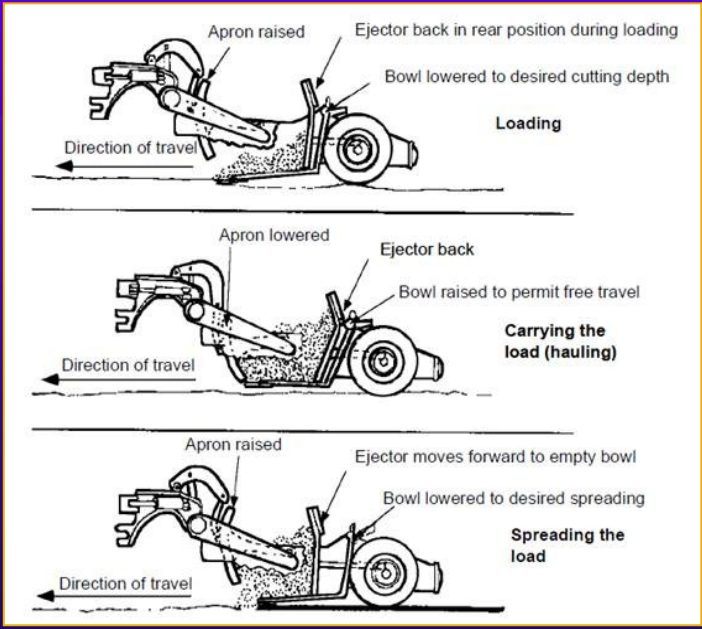
- ***Excavators*** **are machines with multiple uses. They are primarily used for digging, demolition, forestry work, grading, landscaping, heavy lifting, and brush cutting. The important features on these heavy pieces of equipment are hydraulic powered motors or rams, sealed cab on rotating platform, head attachments (such as a bucket), which are used for different purposes. These attachments can change the functionality of the machine instantly from a trench digger to a logger. The rotating platform adds convenience for other machinery. For example a dump truck can be located directly behind the excavator and it can still easily deposit material by swinging around on a 180 degree pivot**

Trenching

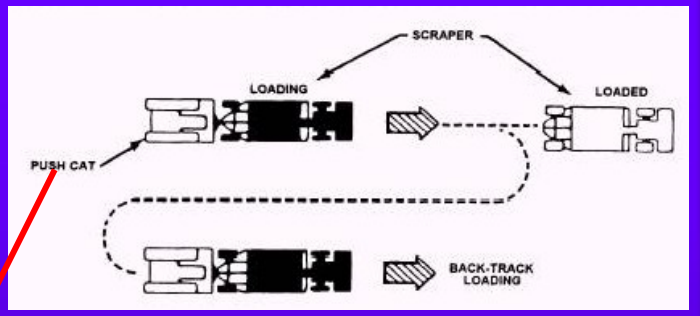
MOUNTING (CUTTING & FILLING) 4

- In engineering, the dominant machine for moving earth over short distances (up to about 3 kilometers) over relatively smooth areas is the *scraper*
- Either self-propelled or towed, it consists of a wagon with a gate having a bladed bottom; the blade scrapes up earth as the wagon pushes forward and forces the excavated material into the wagon
- When the wagon is filled, the gate is closed, and the material is carried to the place of disposal





MOUNTING (CUTTING & FILLING) 5



Big loads – small clip.mp4

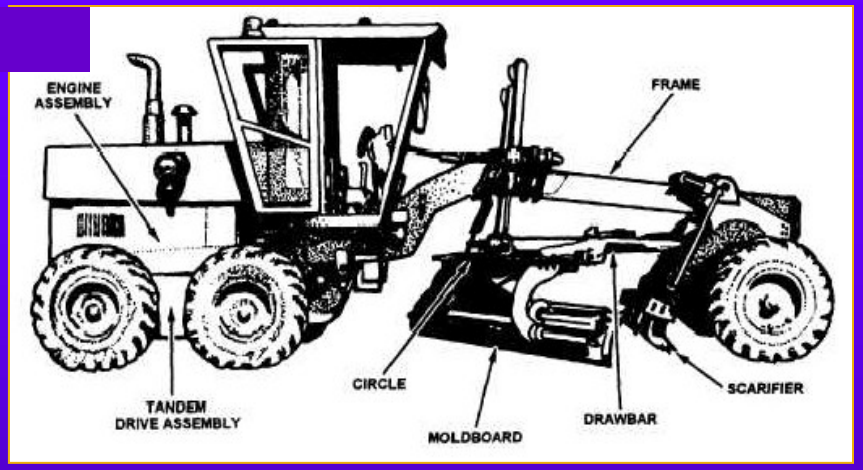
Scrapers at work

FINE GRADING 1

- A *grader*, also commonly referred to as a road grader, a blade, a maintainer, or a motor grader, is a construction machine with a long blade used to create a flat surface
- Typical models have three axles with the engine and cab situated above the rear axles at one end of the vehicle and a third axle at the front end of the vehicle, with the blade in between (some construction personnel refer to the entire machine as "the blade„)
- In civil engineering, the graders purpose is to "finish grade" (refine, set precisely) the "rough grading" performed by heavy equipment or engineering vehicles such as scrapers and bulldozers
- In fill areas, subgrade below the top 150 mm is often considered adequate if it is compacted to 90 percent relative density - in order to achieve these densities the subgrade must be at or near its optimum moisture content (the moisture content at which maximum density can be achieved)
- Usually *compaction* of in situ or fill subgrade (using various types of rollers) will result in adequate structural support
- Stabilization may improve the binding characteristics of subgrade materials, i. e. it generally increases load-bearing capacity of the subgrade
- Typically, lime is used with highly plastic soils (plasticity index greater than 10), cement is used with less plastic soils (plasticity index less than 10) and emulsified asphalt can be used with sandy soils, if necessary

FINE GRADING 2

Graders



volvo motorgrader g930.mp4

Cement stabilization of granular soil subgrade

Using lime and fly ash as soil (clay, silt) stabilizers

PAVING

- The component layer of a flexible pavement laid over subgrade are:
  1. Granular sub-base (GSB)
  2. Granular base course
  3. Bituminous binder course and
  4. Bituminous surface course
- GSB serves as an effective drainage layer to drain off the water entering into the pavement layers, leading to the longitudinal road side drains such that only a very small proportion of water enters into the subgrade
- Materials used for GSB layer are:
  1. Crushed stone aggregates
  2. Gravel
  3. Coarse sand and
  4. Selected soil such as moorum with less fine and very low plasticity
- The sub-base material is spread to uniform thickness and specified cross slope using a motor grader by adjusting the blade of grader

BUILDING GSB

- The moisture content of the GSB material is checked and the additional quantity of the water required to bring up to optimum moisture content is *sprinkled*
- The loose GSB layer is compacted by *rolling*, if the compacted layer thickness is less than 100mm than ordinary smooth wheel roller may be used; for compacted thickness is more than 100mm than compaction is done by vibratory roller of static weight 10 tons or more
- Rolling is done starting from lower edge and proceeded toward the center, rolling speed is limited to less than 5 km/h; rolling is continued till at least 98% of maximum density of the material is achieved
- Minimum one moisture content test is to be carried out per 250 m^2 area and minimum of density test per 500 m^2 area on each compacted area

BUILDING THE SUB-BASE

Sprinkler

Rolling

Vibrating roller

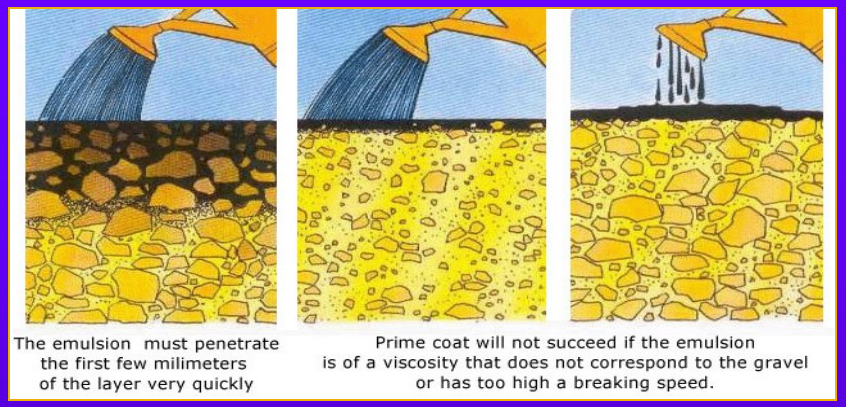
BITUMINOUS LAYERS

- Bituminous pavement layer forms an important part of the flexible pavement layer system; it consists of three different components: (*i*) *Base course*; (*ii*) *Binder course*, and (*iii*) *Surface course*
- Thin bituminous layer is provided for low traffic load and thicker one is provided for heavier one
- It is essential to provide an appropriate type of *interface treatment* before laying any type of bituminous layer over the another one
- If the bituminous layer is to be laid over a sub-base layer, the prime coat and tack coat are applied; if the bituminous layer is to be laid over an existing bituminous surface then only tack coat is applied

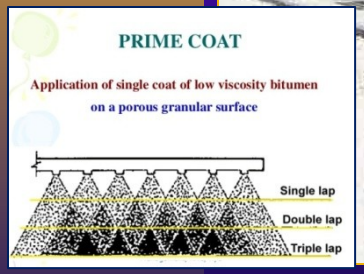
PRIMING & TACK COATING 1

- Spraying of liquid bituminous binder of a low viscosity over a GSB is called application of prime coat or *priming*; its objective is to penetrate deep into the surface and seal the void, coat and bond the loose particles on the surface thus providing water resis-tance
- *Tack coat* - application of a small quantity of liquid bituminous binder of low viscosity over either a prime granular surface or existing bituminous surface - is to be applied to provide proper adhesion between base and bituminous pavement layer
- Main types of base course:
  - Bituminous Macadam (BM)
  - Penetration Macadam (PM)
  - Dry Lean Concrete (DLC)

PRIMING & TACK COATING 2



R-1 Aggregate Chip Spreader on road.mp4



Prime coat

Good tack coat coverage

ASPHALT PREMIX

- *Bituminous mix* (BM) consist of crushed aggregate and bituminous binder heated and mixed in a hot mix plant at specified temperature depending on the grade of the bitumen used, transported to the site in insulated covered truck, laid with mechanical paver and compacted by appropriate rollers
- The *hot mix asphalt* (HMA) used to build bituminous layers of the *binder course* and the *wearing (surface) course* are produced using a similar process
- The *aggregate* to be used for the asphalt mix shall comply with the gradation specified by the relevant standards or guidelines
- HMA shall be laid and compacted in layers, which enable the specified thickness, surface level, regularity requirements and compaction to be achieved

BUILDING A ROAD BASE

Consolidation of the base of a flexible pavement

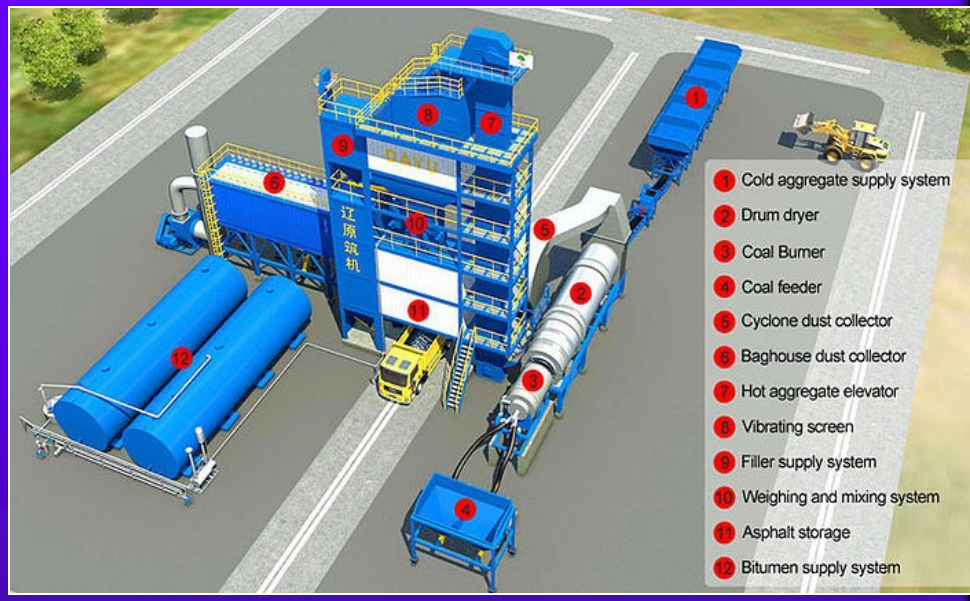
Laying of *dry lean concrete* (DLC)

Tandem roller

Placing a *HMA base layer* with a road paver

HOT ASPHALT MIXING PLANT 1

1. *Cold aggregate supply system*: difference size of the to store the materials, according to the machine capacity to feeding material by the control system, usual have four bins



2. *Feeding belt conveyor:* feeding the belt system to collect the materials from the cold bin and then transfer them into the dryer drum

3. *Drying drum*: for heating the material and make the stone temperature reach 160℃

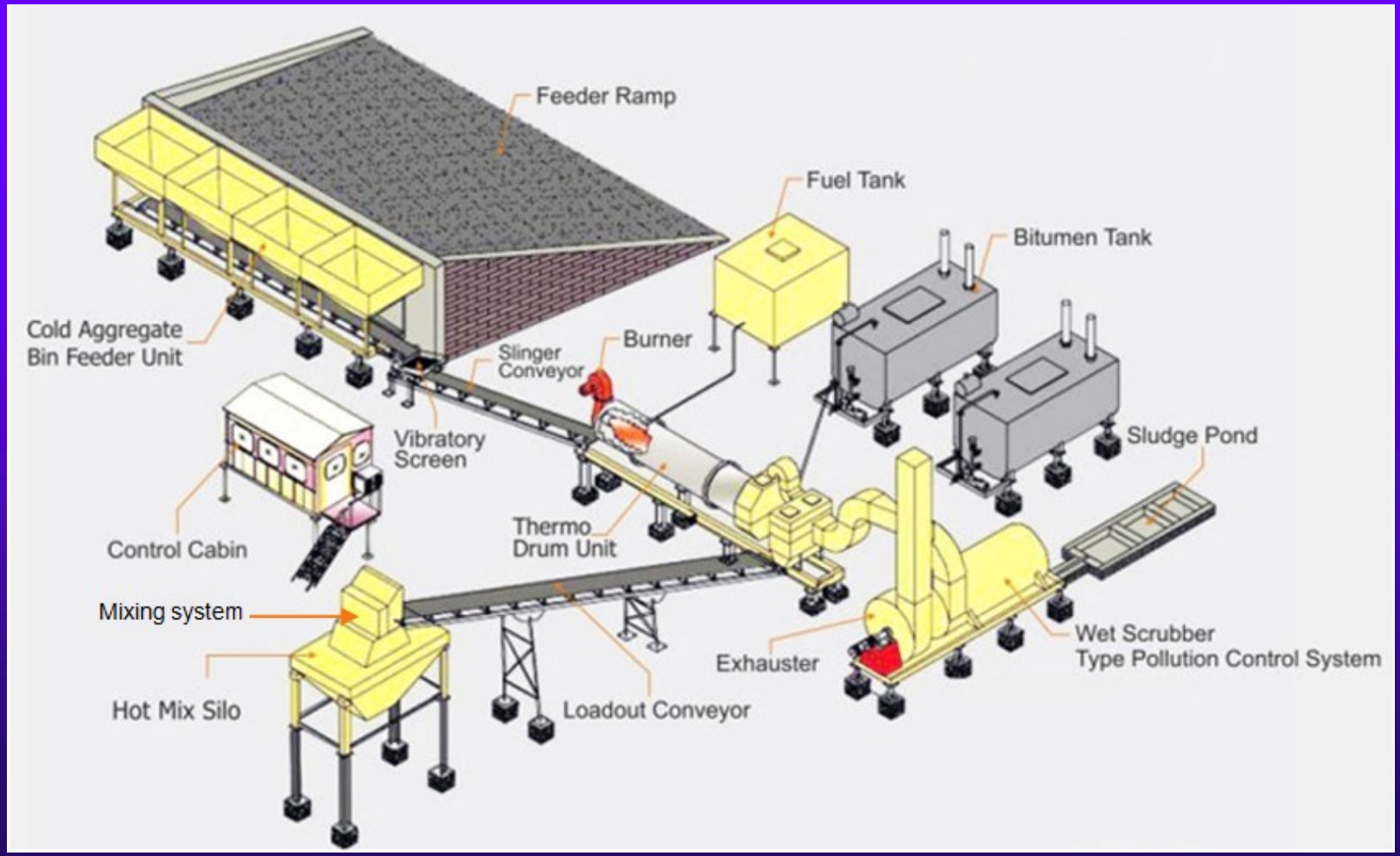
4. *Hot aggregate elevator:* it is the part use the bucket to collect the hot material from the dryer drum, and elevating it in the main

5. *Vibrating screen*: with the different screen net to vibrate the different size material again, and store it in the hot aggregate silo

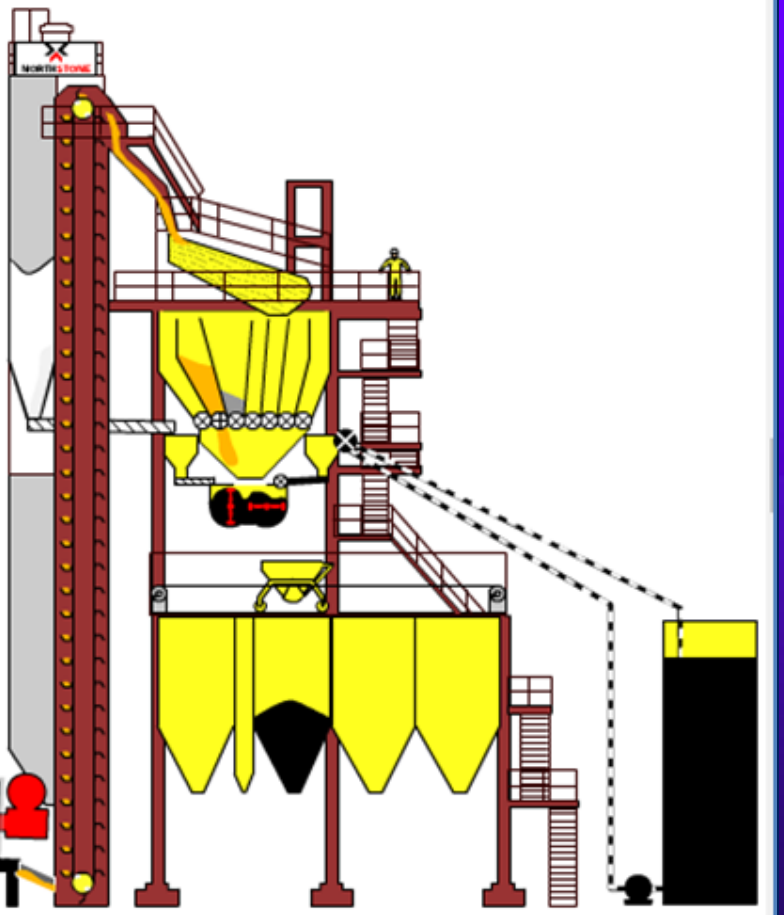
HOT ASPHALT MIXING PLANT 2

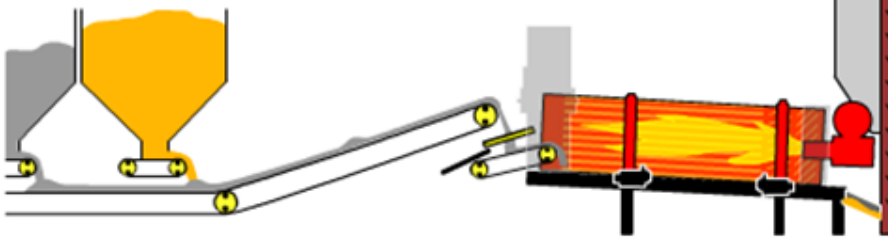
6. *Hot aggregate silo*: it is the place to store the aggregate after heating, and waiting for weighting
7. *Measuring system*: use cell meter to weigh the aggregate, bitumen, filler, according to the formula to weighting it
8. *Mixing system*: the part mix the bitumen, aggregates, filler together in the mixer, 45 second one batch
9. *Finished products storage silo*: the silo to store the finish storage, have the under type and side type
10. *Control system*: the control cabinet to control all part, using appropriate software
11. *Asphalt heating supply system*: it is the part for heating the bitumen, have two types: conduction oil heating and direct gas heating
12. *First grade gravity filter*: use the gravity principle to clean the dust
13. *Second grade bag filter*: use the air blow principle to clean the dust
14. *Filler storage supply system*: the tank to store the limestone powder, and supply it to the main frame for weighting and mixing
15. *Burner*: the heating way use for the dryer, always have two kinds, one is for coal or gas burner, and another is for the fuel oil burner

HOT ASPHALT MIXING PLANT 3



HOT ASPHALT MIXING PLANT 4





HOW AN ASPHALT PLANT WORKS 1

- The collecting belt transfers the aggregate into a rotary drum dryer. The dryer is a large, slightly inclined, rotating cylinder with a large burner at the end opposite the aggregate feed. Inside the drum, shelf-like lifters are fitted along its length. When the drum rotates, these continually lift up and drop the aggregate through the burner flame.
- The heated and dried aggregate leaves the dryer via the collecting ring at the burner end. The hot aggregate is then lifted in a chain bucket elevator to a screen mounted in the next section of the mixer. This screen sorts the aggregate into its component sizes and directs it into corresponding hot bins below. Coating plants can have up to seven hot bins.

Batch mixing process (en) - Asphalt mixing plant Uniglobe - Ammann Group.mp4

HOW AN ASPHALT PLANT WORKS 2

- Situated below the hot bins is the weigh bin. This is suspended on load cells which measure the weight of aggregate fed into it from the hot bins. The hot bins are opened separately in sequence and closed when the required weight is reached.
- At the same time that all this is going on, hot liquid bitumen is pumped from the storage tank to a small weigh hopper, or 'kettle', mounted directly over the mixer. The bitumen may be heated up to 150 – 177 ^{o}C and the aggregate temperature should not differ by over 14 ^{o}C from the binder temperature. Load cells on the kettle shut off the bitumen when the correct amount has been weighed. If hot rolled asphalt, or a mix requiring filler to be added, is being made, limestone filler is drawn from a tower silo by an auger screw feeder to a filler weigh-bin.

HOW AN ASPHALT PLANT WORKS 3

- When the aggregate has been weighed up to make a batch, it is dropped from the aggregate weigh-bin into the mixer. At the same time that the aggregate arrives at the mixer, the bitumen (and filler if required) is injected and all constituents are mixed together. A typical batch plant mixer is a horizontal shaped double trough with two horizontal rotating shafts with paddles attached. The paddles are interleaved.
- At the end of the mix cycle the mixed batch is dropped out of a hatch in the bottom of the mixer into a winch hauled skip which then transfers it to heated storage bins for subsequent discharge into waiting insulated dump trucks below. The mix is carried to the location, where it is spread by a mechanical paver at a temperature of 121-163 ^{O}C and compacted by rollers.

BATCH PRODUCTION

- The camber and the thickness of the layer are accurately verified continuously
- The control of the temperatures during the mixing and the compaction are of great significance in the strength of the resulting pavement structure.
- Batch production is flexible as the recipe for the mixture can be changed for each batch; a greater mixing quality can be achieved due to the more precise quantities added and adapted mixing cycles
- In Europe, the batch production process is the most widespread type of asphalt production

FROM THE QUARRY TO THE PAVED ROAD

HMA PRODUCTS 1

- *Dense Base (Roadbase)* - is a layer made up of a graded mix of 0/32 mm crushed rock aggregate. Dense Base has 1% less bitumen compared to binder course. Dense Base is used as the first bound base layer in major road construction where high strength and stiffness in the total construction is required. Layer thickness is between 100 to 230mm, depending on the volume of traffic, particularly heavy goods vehicles, that will use the road.
- *Binder Course* - is a layer made up of a graded mix of 0/32 mm or 0/20 mm crushed rock aggregate, but with 1% more bitumen than dense base. This more cohesive material is used as the supporting or base layer to the surface course. It also serves to even-out any undulations. Layer thickness is between 50 to 70mm.

HMA PRODUCTS 2

- *Surface Course* - is a layer made up of a graded mix of the smaller sizes (0/14 mm, 0/10 mm, 0/6 mm) crushed rock aggregate. Aggregate size / layer thickness varies according to end-use (25-40 mm). Due to the larger surface area of the aggregate to be coated, bitumen content of surface course is 1% higher than in the binder course
- *Surface Course Hot Rolled Asphalt* (HRA, used mainly in Great Britain) - has a lower stone content (30% or 15%) than base course asphalt. HRA can be made with either 6.3/14 mm or 4/10 mm stone. Its strength and resilience comes from the mortar. It has a smooth surface, therefore to give grip to the road, *pre-coated chippings* (PCCs) are distributed evenly over the hot asphalt immediately after it is laid

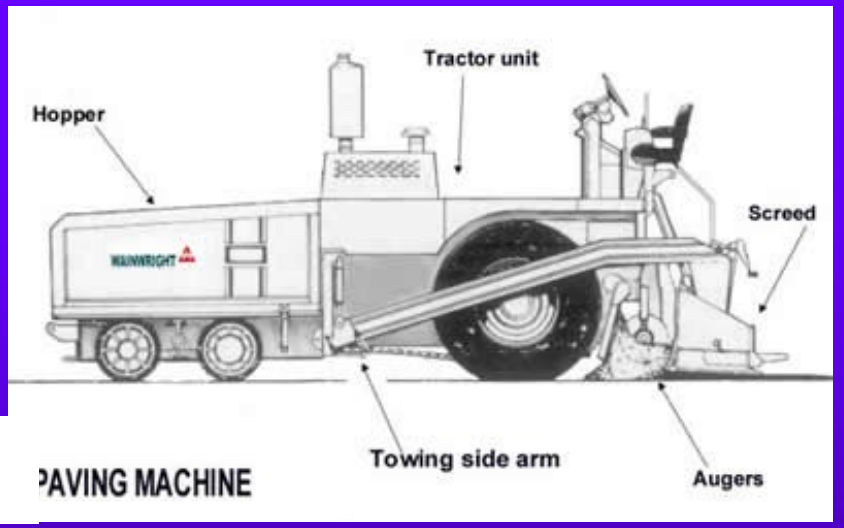
PAVER 1

- A *paver* (asphalt finisher) is a machine / vehicle used to lay asphalt on roadways; it lays the asphalt flat and provides minor compaction before it is compacted by rollers
- The asphalt is added from a dump truck or a material transfer unit into the paver's *hopper*. The *conveyor* then carries the asphalt from the hopper to the *auger*. The auger places a stockpile of material in front of the *screed*. The screed takes the stockpile of material and spreads it over the width of the road and provides initial compaction. In order to provide a smooth surface the paver should proceed at a constant speed and have a consistent stockpile of material in front of the screed (the reason why a transfer unit is used).
- To conform to the elevation changes for the final grade of the road modern pavers use automatic screed controls

The First Asphalt On The New Motorway.mp4

PAVER 2

Tatra 815 S1 + podavač Vögele MT1000-1 + finišer Vögele Super 1900 - part 2_3.mp4



THIN LAYER MATERIALS

- Thin layer materials are thin surface overlays that are between 20 mm and 30 mm thick. They add little structural strength to the road, but are designed primarily to restore surface texture and grip. They also improve ride quality, and, due to their inverted surface texture, both reduce noise and surface water, reducing water spray and increasing visibility in wet weather.
- A hot mix composed of basically 10 mm aggregate (with sufficient fines to increase the binder film) is laid on a thick polymer modified binder layer sprayed immediately ahead of the hot mix by an emulsion tank and spray bar built-in to a purpose built machine.

OTHER ASPHALT PRODUCTS

- ***Lower quality asphalt*** **is prepared on the site, for roads of weak traffic load, spreading warm *cutback bitumen* or *bitumen emulsion* on top of compacted base course**
- ***Mastic asphalt concrete*** **is produced by heating hard grade blown bitumen (oxidation) in a cooker (drum-mixer) until it has become a viscous liquid after which the aggregate mix is added and cooked (matured) for around 6–8 hours at a temperature of 240-260 ^{o}C; it is laid to a thickness of 20-30 mm for footpath and road applications**
- ***Cold Mix Asphalt Concrete*** **is produced by emulsifying the bitumen in water with soap prior to mixing with the aggregate; the emulsion will break after enough water evaporates and the cold mix will, ideally, take on the properties of cold HMA (it is used as a patching material and on lesser trafficked roads)**

COLD MIX & MASTIC ASPHALT

Cold Mix Asphalt **used for patching and levelling a manhole cover**

Mastic Asphalt **cooker and using its product for bridge repair**

DRY LEAN CONCRETE (DLC)

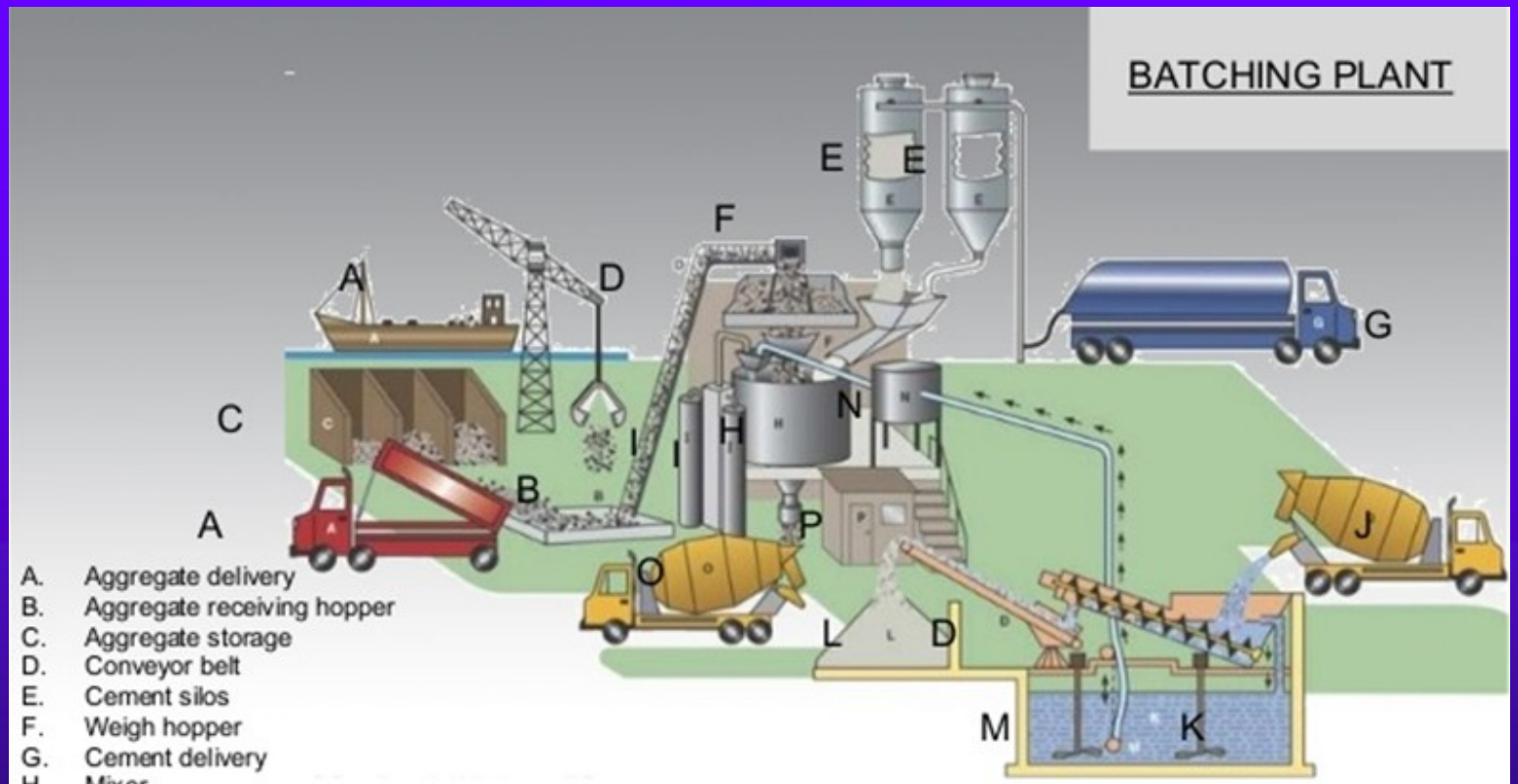
- *Dry Lean Concrete* (DLC) is a mix where the amount of cement is lower than the amount of liquid present in the strata, which makes it ideal as a base layer where other kinds of either asphalt or cement concrete layers are placed on top
- *DLC* is commonly used in road construction, since after curing its surface is covered by thin alligator cracks, which are advantageous, since they will not traverse the asphalt layers laid over it
- *DLC* is usually laid by commonly used cement concrete slipform paver machines
- *DLC* provides an excellent provisional pavement for traffic related to construction of upper layers

LAYING OF DLC

CEMENT CONCRETE, OR BATCH PLANTS

- A cement concrete plant, also known as a batch plant or batching plant, is a device that combines various ingredients to form cement concrete
- Inputs include sand, water, aggregate (rocks, gravel, etc.), fly ash, potash, and cement.
- There are two types of concrete plants:
  - *Ready mix plant* (it combines all ingredients except for water; this mixture is then discharged into a ready mix truck (concrete transport truck); water is added to the mix in the truck and mixed during transport to the job site
  - *Central mix plant* (it combines some or all of the ingredients at a central location) and the final product is then transported to the job site, offering to the end user a much more consistent product, since all the ingredient mixing is done in a central location and is computer-assisted to ensure uniformity of product.

CEMENT CONCRETE BATCHING PLANT



CONSTRUCTION OF CEMENT CONCRETE PAVEMENT 1

- There are four types of concrete pavement:
  - Plain pavements with dowels that use dowels to provide load transfer and prevent faulting
  - Plain pavements without dowels, in which aggregate interlock transfers loads across joints and prevents faulting
  - Conventionally reinforced pavements that contain steel reinforcement and use dowels in contraction joints, and
  - Continuously reinforced pavements that have no contraction joints and are reinforced with continuous longitudinal steel
- Once the sub-base has hardened sufficiently to resist marring or distortion by construction traffic, dowels, tie-bars, or reinforcing steel are placed and properly aligned in preparation for paving

CONSTRUCTION OF CEMENT CONCRETE PAVEMENT 2

- There are two methods for paving with concrete - slipform and fixed form
  - In *slipform paving*, a machine rides on treads over the area to be paved, similar to a train moving on a set of tracks; fresh concrete is deposited in front of the paving machine which then spreads, shapes, consolidates, screeds, and float finishes the concrete in one continuous operation, which requires close coordination between the concrete placement and the forward speed of the paver
  - In *fixed-form paving*, stationary metal forms are set and aligned on a solid foundation and staked rigidly; once concrete is deposited near its final position on the subgrade, spreading is completed by a mechanical spreader riding on top of the preset forms and the concrete, it is followed by one or more machines that shape, consolidate, and float finish the concrete

JOINTS CONTROL CRACKING

- After placing and finishing concrete pavement, joints are created by sawing to control cracking and to provide relief for concrete expansion caused by temperature and moisture changes; once joints have been inserted, the surface must be textured, to obtain the desired amount of skid resistance
- Texturing should be done just after the water sheen has disappeared and just before the concrete becomes non-plastic; it is done using burlap drag, artificial-turf drag, wire brooming, grooving the plastic concrete with a roller or comb equipped with steel tines, or a combination of these methods
- As the concrete pavement hardens, it contracts and cracks; if the contraction joints have been correctly designed and constructed, the cracks will occur below the joints

CONSTRUCTION OF CEMENT CONCRETE PAVEMENT 3

Continuous reinforcement assemblies with steel rebars

Highway Concrete Machines At Work.mp4

Paving Concrete Roads with a GOMACO Commander 3 and a GOMACO 9000 Placer.mp4

PCC PAVED MOTORWAY BEFORE OPENING (M0, HUNGARY, 2013)