Transportation Engineering

Course Code –CE-422

Contact Hours -3+3

Dr Hassan Mujtaba

Introduction to OBE System

OBE => Outcome Based Education

Outcome => Output => Result / Product =>
University Product => Performance of Graduates & Alumni

OBE is a process that involves assessment and evaluation practices in education to reflect the attainment of expected learning and showing mastery in the program area.

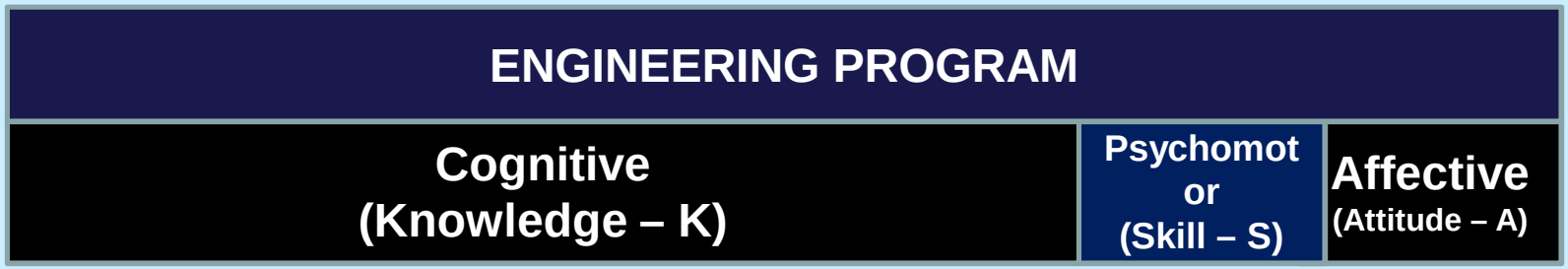
Program	**=> Civil Engineering**
Students	**=> Learning in a program**
Graduates	**=> Just passed the program**
Alumni	**=> Ex-students, now working**

Domains of Engineering Program

(1) Cognitive => Engineering Knowledge

(2) Psychomotor => Skills learnt by moving body parts

(3) Affective => Attitude / ethical values / manners



Benefits of OBE

1. **More directed & rational curriculum.**
2. **Graduates will be more “relevant” to the industry / field.**
3. **Enhances public relations.**
4. **Improve avenues for internships and jobs.**
5. **After 2016, no OBE, no Accreditation.**
6. **Continuous Quality Improvement (CQI) is in place.**

Objectives / Outcomes

PEOs => Program Educational Objectives
(Assessed from Alumni after 4-5 years of graduation)

PLOs => Program Learning Outcomes
(Assessed from graduates at the time of graduation)

CLOs => Course Learning Outcomes
(Assessed from students after each course)

Program Educational Objectives (PEOs)

1. **The alumni have exhibited their proficiency of applying the knowledge (mathematics, science, engineering) & skills (modern tools) to solve at least one complex engineering problem related to civil engineering.**

2. **The alumni are working as successful civil engineers for socio-economic, environment-friendly development at national and/or international level.**

3. **The alumni are able to lead and promote the team work to tackle the complex engineering problems.**

4. **They exhibit good communication skills, high professional ethics, and continuous urge to enhance their knowledge.**

Program Learning Outcomes (PLOs)

At the time of graduation, the graduate must be able to have:

S. No		PLOs
1	PLO 1	Engineering Knowledge
2	PLO 2	Problem Analysis
3	PLO 3	Design/Development of Solutions
4	PLO 4	Investigation
5	PLO 5	Modern Tools Usage
6	PLO 6	The Engineers and Society
7	PLO 7	Environment and Sustainability
8	PLO 8	Ethics
9	PLO 9	Individual and Team Work
10	PLO 10	Communication
11	PLO 11	Project Mangement
12	PLO 12	Life Long Learning

Note: Each student has to achieve passing score in each PLO

Course Learning Outcomes (CLOs)

After passing the course of Transportation Engineering, student will be able to:

Sr. No.	CLO	PLO 1 (Engineering Knowledge)	PLO 3 (Design/Development of Solutions)
1	To describe different system of road network and structure of roads, railways and runways in Pakistan	100	
2	Discuss various factors influencing geometric design of roads, railways and runways		100
3	To explain material characterization (binder, aggregates & mixtures) and existing laboratory equipment for characterization of ballast material & asphalt concrete		100

What difference students feel with OBE?

1. Now in the first lecture, teacher tells us about the CLOs of the each course.
2. Now Psychomotors are being assessed in the laboratories.
3. Now safety measures are being adopted in labs while performing experiments.
4. Now teacher tells us about the ethical values to be practiced in the field.
5. Now there is considerable improvement in facilities and infrastructure.
6. Now after 4-5 years of the graduation, the performance of the alumni is assessed and evaluated.
7. There is Continuous Quality Improvement (CQI) in education system.

Reference Books

- Highways 4th Edition
  - C.A.O Flaherty
- Principles Of Highways Engineering and Traffic Analysis 2nd Edition
  - Fred I. Mannering and Walter P. Kilareski
- Introduction to Transportation Engineering
  - James H. Banks.

Reference Books (cont'd)

- Transportation Engineering 3rd Edition
  - C. Jotin Khisty and B. Kent Lall
- Highway Engineering 6th Edition
  - Paul H. Wright
- Highway Engineering 4th Edition
  - Clarkson H. Oglesby
- A Policy on Geometric Design of Highways and Streets 2004 (GREEN BOOK) (Latest 2011)

Reference Books (cont'd)

- Ways and Works Manual
  - Pakistan Railways
- Railway Tracks
  - K. F. Antia
- Railway Engineering
  - Satish Chandra and M.M Agarwal
- Airport Planning and Design
  - Robert Horenjeff

Course Content

- Introduction to Transportation Engg
- Elements of typical cross section of road
- Types of cross sections
- Design Speed
- Lane capacity
- Capacity reducing factors
- Horizontal and vertical curves

Course Content (cont'd)

- Grade line
- Super elevation
- Transition curve
- Curve widening
- Sight distance requirements
- Principles of intersection design for at grade and grade separated intersections
- Channelization

Course Content (cont'd)

- Highway construction materials their properties and tests
- Characteristics of drivers, vehicles and road ways
- Traffic surveys
- Traffic controlling devices
- Highway illumination
- Parking
- Accident studies

Course Content (cont'd)

- Elements of railway track/ permanent way
- Types of rail gauges
- Type of rail sections
- Rail joints
- Creep & wear of rail, Fish plates, bearing plates and check rails
- Types of sleepers, their merits and demerits, sleeper density

Course Content (cont'd)

- Stiffness of track
- Type of ballast, requirements for good ballast and Renewal of ballast,
- Formation of single and double track formation failures
- Selection of site for railway station
- Layout of station and yards
- Points and crossing

Course Content (cont'd)

- Signaling and interlocking
- Modern methods for construction of track
- Maintenance, tools and organization
- Airport requirement
- Site selection for Airport
- Airport classification
- Aircraft characteristics
- Runway length and runway configuration

Course Content (cont'd)

- Runway lighting
- Airport drainage system
- Payload versus range chart
- Wind rose
- Orientation of runways

Lecture Delivery Plan

Week 1	Introduction to Transportation and Transportation Engg, Advantages and Disadvantages of Good Transportation System, Modes of Transportation, Factors affecting selection of mode, Merits of Highway + Introduction to Railways, Brief History of Railways, History of Pakistan Railways, Components of railway track, Functions of various track components, Requirements for ideal track and Track capacity
Week 2	Classification of Highways, Functional and Administrative Classification, Materials for construction of Highway + Rail gauges and their types, history of Rail gauges, Factors affecting choice of gauge, Problems associated with the use of different gauges in the same country, Loading gauge and Construction gauge
Week 3	Elements of Highway, Design vehicle, X-section of Highway in Cut anf fill + Gradient, Ruling gradient, Pusher gradient, Curves, Compensation for curvature, Turntable, Numericals related to compensation for curvature
Week 4	Horizontal alignment of Highways + Super elevation (S.E), How to attain S.E, Deficiency in S.E, Negative S.E, Level crossing, Formation, Material for formation, Formation failures
Week 5	How to provide Super Elevation for Highways + Ballast, Types of ballast, function of ballast, Packing of ballast, Boxing of ballast, renewal of ballast and material train
Week 6	Super elevation runoff, Super elevation diagram + Sleepers, Function of sleepers, Types of Sleepers, Sleeper density and center bound sleepers
Week 7	Sight distance, How to provide Sight distance, Stopping Sight Distance, Passing Sight Distance, conditions for safe over taking, Decision sight distance, Applications of Stopping sight Distance + Rail, Different types of rails, Function of rails, Fish Plates, Joints in rails
Week 8	Quiz 1 + Mid Semester Exam

Lecture Delivery Plan

Week 9	Highway construction materials, their properties and testing + Creep of rails, Causes of creep, Factors governing direction of creep, Coning of wheels, Bearing plates, Wear of rails
Week 10	How to provide Stopping Sight Distance on curves + Points and crossing, Components of points and crossings, Left Hand Turnout, Right Hand Turnout
Week 11	Vertical Alignment, Types of Grades, Vehicle operating characteristics on grade, Control length of grade for design, Special facilities for heavy vehicles on Highways + Crossing, Size of Crossing, Methods to set out crossing angles, Switches, Types of switches, Different types of crossings,
Week 12	Vertical curve, how to set out vertical curve, SSD on crest vertical curve, PSD on crest vertical curve, Sag vertical curve, Sag vertical curve on underpass + Stations and yards, Marshalling Yards, Layout of marshalling yards, Requirements for stations and yards, Site selection for railway, Various methods to lay out track, Organizational Setup for Pakistan Railways, Maintenance of track
Week 13	Traffic Engineering, Various parameters used in Traffic Engineering, + Airport, Layout of airport, Regulatory Authorities, Site selection for Airport, Classification of Airports
Week 14	Quiz-2
Week 15	Traffic Control Devices, traffic signs, Traffic signals, Introduction to geometric design + Orientation of Runways, Runway configuration, Wind rose Diagrams, Airport drainage
Week 16	Exam Preparation

Lab. Experiments

Week 1	Determination of Flakiness and elongation index for given aggregate sample
Week 2	Determination of Flakiness and elongation index for given aggregate sample
Week 3	Determination of angularity number for given aggregate sample Determine specific gravity and water absorption for aggregates
Week 4	Determination of angularity number for given aggregate sample Determine specific gravity and water absorption for aggregates
Week 5	Perform LOS ANGLES Abrasion test on Aggregates Measurement of surface frictional properties using British Pendulum Skid Resistance Tester
Week 6	Perform LOS ANGLES Abrasion test on Aggregates Measurement of surface frictional properties using British Pendulum Skid Resistance Tester
Week 7	Determination of Flash and Fire point of Asphalt Determination of specific gravity of bituminous materials
Week 8	Quiz 1 + Mid term Evaluation
Week 9	Determination of Flash and Fire point of Asphalt Determination of specific gravity of bituminous materials
Week 10	Determination of viscosity of liquid Asphalt by Engler's viscometer Determination of softening point of Bitumen
Week 11	Determination of viscosity of liquid Asphalt by Engler's viscometer Determination of softening point of Bitumen
Week 12	To perform ductility test on Asphalt
Week 13	To perform ductility test on Asphalt
Week 14	Perform Marshall Stability test
Week 15	Perform Marshall Stability test
Week 16	Quiz 2 + End term Evaluation

What is Transportation Engineering

- Transportation engineering is the application of scientific principles to the planning, design, operation, and management of transportation systems.
- Transportation engineering is a subspecialty of civil engineering.

What is Transportation Engineering

- The transportation system is a functional system in the context of society as a whole because it provides a service i.e the movement of goods and people from place to place.

Transportation System

- Transportation system is a major functional system (consisting of various components) as it is essential feature in the economy and personal lives of people everywhere in the world.
- A highly developed transportation system makes possible the abundance and variety of goods and the high level of personal mobility that are the hallmarks of a wealthy society.

Transportation System (Functional Point of View)

- Physical facilities
  - Streets, roads and highways, railroads, airport, sea and river ports pipelines and canals
- Fleet of vehicles, vessels and aircrafts
- Operating bases and facilities
  - Including vehicle maintenance facilities and office space

Transportation System (Functional Point of View)

- Organizations
  - Facility orientated organization are involved in planning, designing, constructing, maintaining and operating fixed facilities.
  - Operating Organization also known as carriers are concerned with operating fleet to provide transportation services.
- Operating Strategies including vehicle routing, scheduling and traffic control.

Negative Effects

- Transportation accounts for almost two-third of the petroleum consumption.
- Transportation is a major contributor of environmental problems such as air pollution, noise, and destruction of natural habitats.

Modes of Transportation

Transportation system is often analyzed based on their mode of transportation

- Highway
- Rail
- Air
- Waterways

Mode Classification Scheme

	Freight	Passenger
Urban	Truck (Highway)	Private auto (Highway) Transit (Highway/ Rail)
Intercity	Truck (Highway) Rail Ocean Shipping Inland Water Pipeline Air	Private auto (Highway) Bus (Highway) Rail Air
Special Purpose	Conveyor Belt Cable System	

Manual Labour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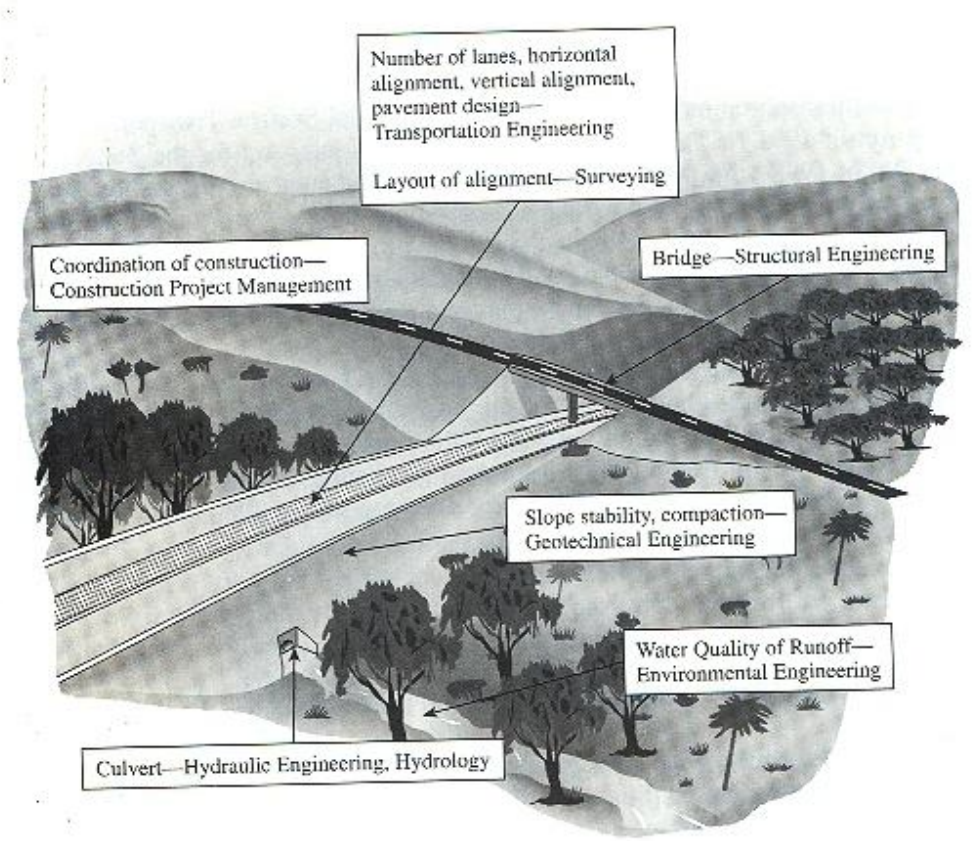
Civil Engineering Involvement in Transportation

Civil Engineering involvement in transportation engineering is primarily for the provision of physical facilities.

- Transportation Engineering- sizing and geometric design of highways
- structural engineering - Design and construction of bridges and other structures

Civil Engineering Involvement in Transportation

- Hydraulic and hydrologic engineering- drainage design
- Geotechnical Engineering- Earthwork compaction and slope stability



However, Civil engineering activity related to planning and operation of the transportation system may be referred to as system engineering.

Civil Engineering Involvement in Transportation

- System engineering in transportation engineering involves analysis of transportation demand, analysis of system capacity and operating capacity, design of traffic control and operating strategies.
- Transportation engineering is unique among the civil engineering specialties in the importance of its system engineering.

Importance of Highways

- Good highways are so important and interwoven with every phase of our daily activities that it is almost impossible to imagine what life would be without them.
- We depend on highways for the movement of goods, for travel to and from work, for services, for social and recreational purposes, and for other activities necessary to the functioning of our complex society.

Importance of Highways

- The planning, design, construction, operation, and maintenance of highways depend largely on the efforts of the highway engineer, who must translate the desires of the people for better highway transportation into physical being.

The Development of Highways

- Origin before recorded history, even before invention of wheel i.e 10,000 years ago.
- Stone paved streets of Ur in the Middle East was constructed ca 4000 BC.
- Brick paving in Subcontinent started ca 3000 BC.
- In Europe wooden and stone pathways were constructed ca 2000 BC. [ca - circa]

The Development of Highways (cont'd)

- Streets of the city of Babylon were paved as early as 2000 B.C.
- Roads for Pyramid of Egypt 3000 years B.C.
- The greatest road network was constructed by Romans.
  - Roads were commonly constructed at least 4.25 m wide. It was common practice to reduce gradients by cutting tunnels. The roads were built on embankments 1 m to 2 m high.

European Development

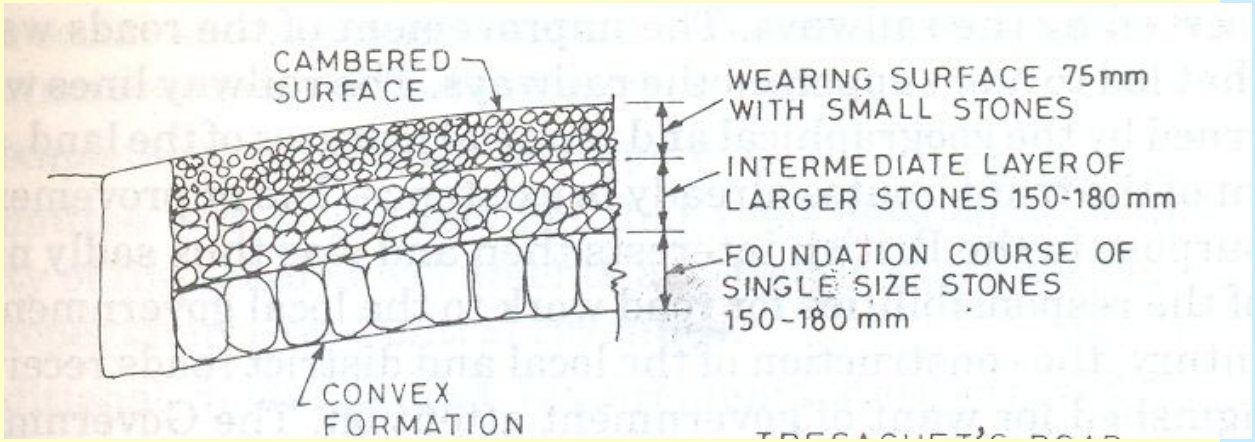
- Industrial Development in Europe created accelerated demand for transport.
- Wheeled vehicles began to make their appearance on the roads in the sixteenth century.
- The disruption of the road bed caused by movement of animal passenger cart and good wagons gave a spurt to scientific design of roads.

European Development (cont'd)

- Interest in the art of road building was revived after Romans in Europe in the late eighteenth century. During this period, French Engineer, advocated a method of road construction utilizing a broken stone base, covered with small stones.
- The regime of Nepoleon in France (1800 – 1814) gave a great impetus to road construction, chiefly for military purposes, and lead to the establishment of a national system of highways in the country.

European Development (cont'd)

- Pierre Tresaguet of France was the first to recognize the importance of drainage and methodical maintenance.
  - He observed the effects of moisture on the performance of roads
  - Camber was introduced in the roads during this time.



European Development (cont'd)

- John Metcalf is associated in building good and stable roads in eighteenth century.
  - He used boulders to achieve strong foundation for roads and spread gravels as a surface layer.
  - He pioneered the construction of good roads on soft ground using a sub-base of bundle of heathers.

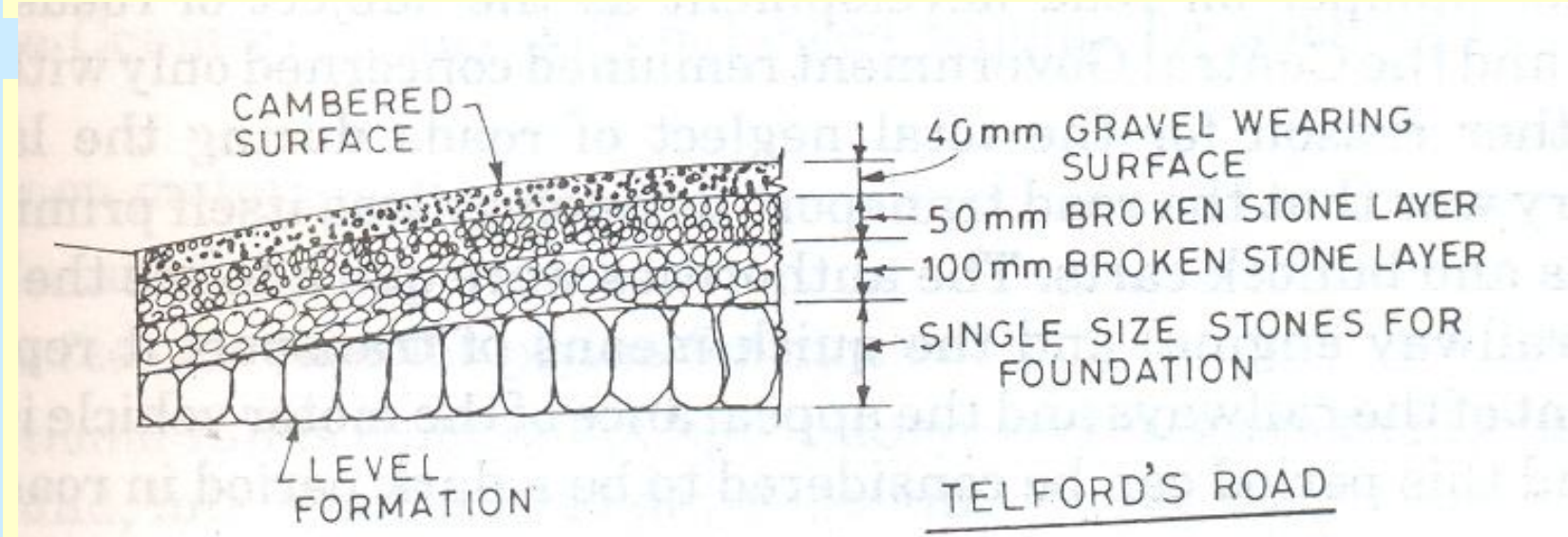
European Development (cont'd)

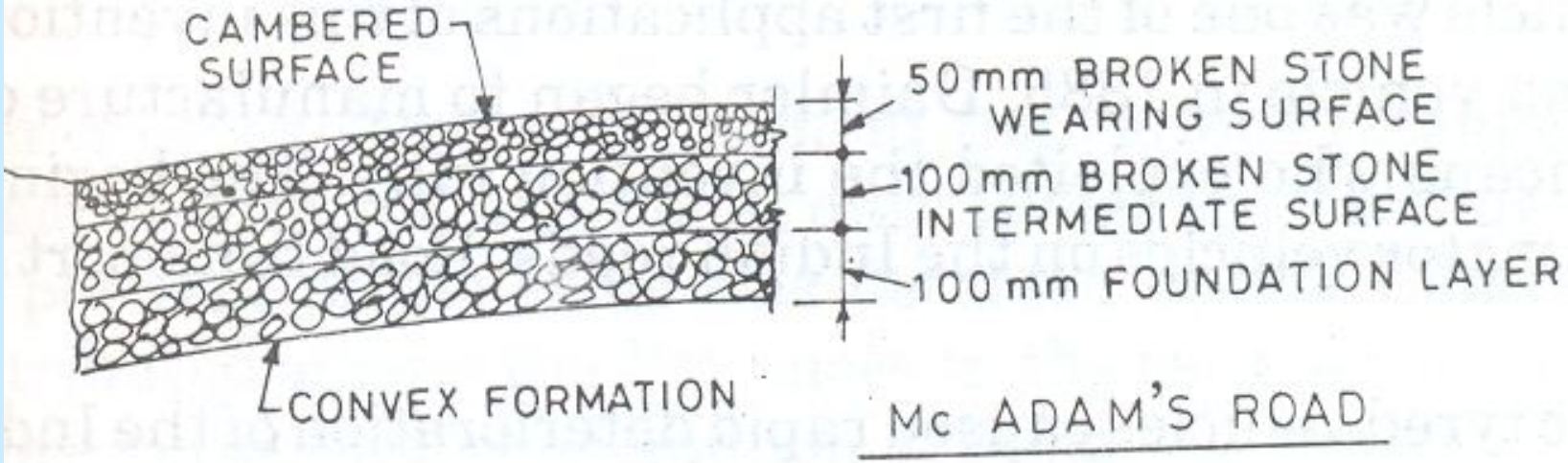
- At about the same time in England, two Scottish engineers, Thomas Telford and John L. McAdam, developed similar type of construction.
- Telford urged the use of large pieces of ledge stone to form a base with smaller stones for the wearing surface.
- The base is known as Telford base.

European Development (cont'd)

- McAdam advocated the use of smaller broken stones throughout.
- This type of construction is still in extensive use, being the forerunner of various types of modern macadam bases and pavements.

European Development (cont'd)





Principles Used for Construction of roads by Thomas Telford and John Loudon McAdam

- Raise the foundation above the surrounding ground so that ground water will not soften the sub-grade
- Crown the earth sub-grade and drain the surface water into side ditches
- Use clean, free draining stone, which will drain the water and not be affected by frost.
- Construct the roadway to suit the anticipated traffic loadings.

Principles Used for Construction of roads by Thomas Telford and John Loudon McAdam

- All the components of modern highway design were being utilized by 1320 in England.
- Telford used a masonry surfacing and lateral drains every one hundred feet while McAdam used a one size stone wearing surface.
- McAdam favoured smaller pieces of stones with angular faces while Telford favoured large hand packed boulders.
- The use of these principles rapidly spread to the United States with construction of the Boonesborough Turnpike road in 1823.

Definition of Common Terms in Highways

- Highway- is an arterial road facility designed for high speed and high volume traffic in non-urban area.
- Road- is line of communication between places for use of foot passengers, riders and vehicles
- A street- is urban road facility

Definition of Common Terms (cont'd)

- Expressway- is superior type of highway facility with full or partial control of access and generally grade separated at intersections.
- Freeway- is superior type of highway facility with full control of access and grade separated at all intersections.

MOTORWAYS

Motorways of Pakistan

- The Motorways of Pakistan are a network of high-quality, international-standard limited access highways in Pakistan, which are maintained and operated by the National Highway Authority .
- Pakistan's motorways are either six-lanes or four-lanes and are 'limited-access' with a minimum speed limit of 80 km/h and a maximum speed limit of 120 km/h.

Motorways of Pakistan (cont'd)

- They have a central median and are fenced on the outside for safety and to prevent unauthorized access.
- By 2015, operational motorways in Pakistan had a combined length of 866 km with another 2960 km is planned or under construction.

Motorways of Pakistan (cont'd)

- Entry to all motorways in Pakistan is restricted to fast moving vehicles only.
- Two wheelers (motorcycles and bicycles) and slow moving traffic modes are not allowed. However, the Motorway Police personnel use heavy motor bikes for patrolling purposes.
- Construction and agricultural machinery is also restricted.

History of Pakistan Motorway

- The construction of motorways in Pakistan was first proposed by Nawaz Sharif between Lahore and the twin cities of Rawalpindi and Islamabad.
- The idea behind a motorway was supported by many in the country, however, many wanted the first motorway to be built between the two largest cities in Pakistan (Lahore and Karachi) .

History of Pakistan Motorway (cont'd)

- However, the plan went ahead and Pakistan's first motorway, the M2, was completed in 1997 and was the first motorway to be built in South Asia.
- The contract was awarded to the Korean firm Daewoo.
- It has six-lanes and links the federal capital Islamabad with Punjab's provincial capital Lahore and its length is 367 km.

History of Pakistan Motorway (cont'd)

- Since then, the network has been further extended to Sargodha and then to Faisalabad with the M3, which has four-lanes and a length of 53 km.
- The M1 from Islamabad to the KPK capital Peshawar was completed in 2007. It has six-lanes and a length of 154 km.

National Highways of Pakistan

- Pakistan has a nationwide system of national highways distinct from the motorways, which are currently being built.
- The National Highway Authority are responsible for all the national highways. National Highways begin with the letter *N*, followed by 2 numerals and a hyphen in between, e.g.: N-75. Some National Highways however also begin with the letter *S* or *E*, followed by 2 numerals separated by a hyphen.
- N for National, S for Strategic and E for expressway

karachi to Torkham (N-5)

- Extends from karachi to Torkham via Hyderabad, Multan, Lahore, Rawalpindi and Peshawar.
- Lahore Peshawar section also known as GT or Grand Trunk Road.
- The British-built GT Road also extends east to the Indian border (and subsequently continues all the way to Calcutta).
- Total length = 1819 km

Karachi to Gwadar (N-10)

- Extends along the Arabian Sea coast from Karachi to Gwadar
- Also known as Makran Coastal Highway.
- Total Length = 653 km.

Mansehra to Chilas (N-15)

- Extends from Mansehra to Chilas via Naran and Jalkhand
- Total Length = 240 km

Karachi to Chaman (N-25)

- Extends from Karachi to Chaman via Bela, Khuzdar, Kalat and Quetta.
- Also known as (Regional Cooporation for Development Highway linking karachi and Quetta) of RCD Highway.
- Total Length = 813 km.

Hasan Abdal to Khunjerab (N-35)

- Also known as the Karakoram Highway.
- Total Length = 806 km
- Extends from Hasan Abdal to Khunjerab via Abbottabad, Thakot and Gilgit.

List of National Highways of Pakistan

Symbol	Description	Length
N-50	Kuchlak to Dera Ismial Khan via Zhob	531 km
N-55	Kotri to Peshawar via Shikarpur, Dera Ghazi khan and Kohat	1264 km
N-65	Sibi to Sukkur via Shikarpur, Jacobabad, Jaffarabad and Nasirabad	385 km
N-70	Qila Saifullah to Multan via Loralai and Dera Ghazi Khan	447 km
N-75	Islamabad to Kohala via Murree	90 km
N-80	Islamabad to Kohat via Fateh Jhang	146 km
N90	Khwazakhela to Besham via Alpuri	64 km

List of National Highways of Pakistan

Symbol	Description	Length
N-95	Chakdara to Kalam via Mingora, Madvan and Bahrain	135 km
S-1	Extends from Gilgit to Skardu	167 km
S-2	Extends from Kohala to Muzaffarabad	40 km
S-3	Extends from Muzaffarabad to Chakothi	55 km
E-3	Extends from Wazirabad to Pindi Bhattian	100 km
E-4	Extends from Faisalabad to Jhang	91 km
E-5	Extends from Khanewal to Lodhran	120 km

N-5 (Grand Trunk Road)

•The National Highway 05, part of the Grand Trunk Road, runs from Karachi to Torkham.

•It is 1819 km in length and runs north, from Karachi located in Sindh to Hyderabad, Moro and Khairpur before crossing Punjab where it passes through Multan, Sahiwal, Lahore, Gujranwala, Gujrat , Jhelum and Rawalpindi.

•At Rawalpindi, it turns eastwards and passes to Attock before crossing the Indus River into KPK where is passes through Nowshera and Peshawar before reaching the border town of Torkham.

N-5 (Formerly G.T. Road)	
Length	1819 km
Lanes	4
Direction	South - North - West
Start	Karachi
Important destinations	Hyderabad, Multan, Lahore, Rawalpindi, Peshawar
End	Torkham
Construction dates	N/A - N/A
Highway junctions	M-1, N-55, N-45, N-35, N-75, M-2, M-4, N-70, M-9
Owner	NHA
Operator	NHA

N-5 (Grand Trunk Road)

- It's total length is 1819 km, 1021 km in Punjab, 671 km in Sindh and 127 km in KPK. It is managed by National Highway Authority of Pakistan.
- The N-5 is built on the ancient Grand Trunk Road (commonly known as G.T. Road).
- After the partition, a vast portion of the Grand Trunk Road came under Pakistan. Thus developments of this road took place and in 1990's, the road was converted in an international standard highway.

New G.T. Road

- In Pakistan, the old GT Road ends at the suburban town of Wagah near Lahore, at the Pakistan-India border.
- There were some routes in Pakistan which were known as GT Road (Peshawar to Lahore), Multan Road (Lahore to Multan), Rahim Yar Road (Bahawalpur to Rahim Yar Khan) and Karachi road (Sukkur to Karachi).
- NHA planned to combine these roads into one highway, thus N-5, or NEW G.T. Road came into existence.
- A huge upgrade took place on these routes in mid 1990's and N-5 was converted into a 4 lane, 1819km long highway.
- N-5 is now Pakistan's longest and most important highway.

Makran Coastal Highway

Makran Coastal Highway (N-10)

Makran Coastal Highway is located primarily in Balochistan. It follows the Arabian sea coast from Karachi to Gwadar.

Previously there was a muddy track linking Karachi with Gwadar. Journeys between the two could take several days as the safest route was to travel via Quetta.

The journey time has now been reduced to six or seven hours with the construction of the N-10.

N10 (Makran Coastal Highway)	
Length	653 km
Lanes	2
Direction	East/West
Start	Karachi
Important destinations	Lyari, Ormara, Pasni
End	Gwadar
Construction dates	2001 - 2003
Highway junctions	N25
Owner	NHA
Operator	NHA

Makran Coastal Highway (N-10)

- The highway was built as part of an overall plan to improve transport facilities in southern Balochistan; other parts of the plan include the new seaport and international airport at Gwadar and the construction of a road linking Gwadar to Khuzdar

Makran Coastal Highway (N-10)

- In the coastal areas of Balochistan, the main livelihood is fishing. The catch could not be sold in Karachi because the fish would rot by the time they reached Karachi.
- However, the new highway has improved people's livelihoods by giving them the opportunity to sell fish in major markets in Karachi.

Karakoram Highway (N-35)

The Karakoram Highway (KKH) (شاہراہ قراقرم, Chinese : 中巴公路) is the highest paved international road in the world.
It connects China and Pakistan across the Karakoram mountain range, through the khunjerab Pass, at an altitude of 4,693 m/15,397 ft.
It connects China's Xinjiang region with Pakistan's Northern Areas and also serves as a popular tourist attraction.
Due to its high elevation and the difficult conditions in which it was constructed, it is also referred to as the "Ninth Wonder of the World."

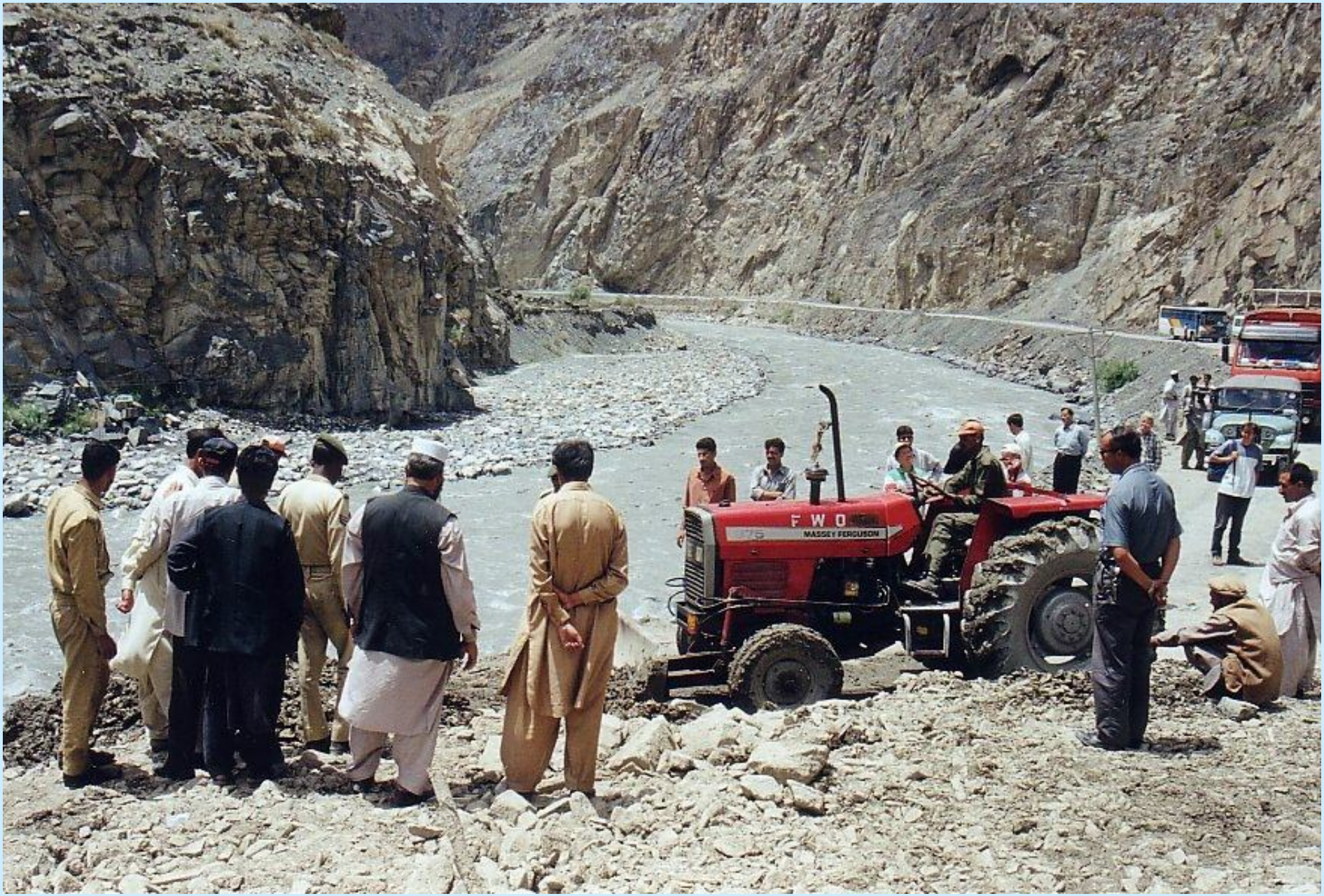
N 3 5 (K a r a k o r a m H i g h w a y)	
L e n g t h	1 3 0 0 k m / 8 0 6 k m i n P a k i s t a n , i n C h i n a 4 9 4 k m
L a n e s	2
D i r e c t i o n	n o r t h - s o u t h
S t a r t	H a s a n A b d a l
Im p o r t a n t d e s t i n a t i o n s	H a s a n a b d a l , A b b o t t a b a d , T h a k o t , C h i l a s , G i l g i t , K a r i m a b a d , S u s t , K h u n j e r a b P a s s , K a s h g a r
E n d	K a s h g a r
C o n s t r u c t i o n d a t e s	1 9 6 6 - 1 9 8 6
H i g h w a y j u n c t i o n s	N 5 , N 1 5
O w n e r	N H A , S A S A C
O p e r a t o r	N H A

History of Karakoram Highway (N-35)

The Karakoram Highway, also known as the Friendship Highway in China, was built by the governments of Pakistan and China, and was completed in 1986, after 20 years of construction.

810 Pakistani and 82 Chinese workers lost their lives, mostly in landslides and falls, while building the highway. The route of the KKH traces one of the many paths of the ancient Silk Road

On the Pakistani side, the road was constructed by FWO (Frontier Works Organization), employing the Pakistan Army Corps of Engineers.


F W O
MASSEY FERGUSON

HIGHWAY MATERIALS

- Soils
- Aggregates
- Bituminous materials/ Binders

Aggregates

- The term "aggregate" refers to granular mineral particles that are widely used for highway bases, subbases, and backfill.
- Aggregates are also used in combination with a cementing material to form concretes for bases, subbases, wearing surface and drainage structures.
- Sources of aggregates include natural deposits of sand and gravel, pulverized concrete and asphalt pavements, crushed stone, and blast furnace slag.

Properties of Aggregates

- Particle size and gradation.
- Hardness or resistance to wear.
- Durability or resistance to weathering.
- Specific gravity and absorption.
- Chemical stability.
- Particle shape and surface texture.
- Freedom from deleterious particles or substances

Particle Size and Gradation

- A key property of aggregates used for highway bases and surfaces is the distribution of particle sizes in the aggregate mix.
- The gradation of aggregates, that is the blend of particle sizes in the mix, affects the density, strength, and economy of the pavement structure. A grain-size analysis is used to determine the relative proportions of various particle sizes in a mineral aggregate mix.

Particle Size and Gradation

The grain-size analysis data are usually plotted on an aggregate grading chart, as shown in Figure.

With the aid of such a chart, engineers determine a preferred aggregate gradation and require that the gradation of aggregates used for highway projects conform to the limits of a specification band.

Particle Size and Gradation Chart

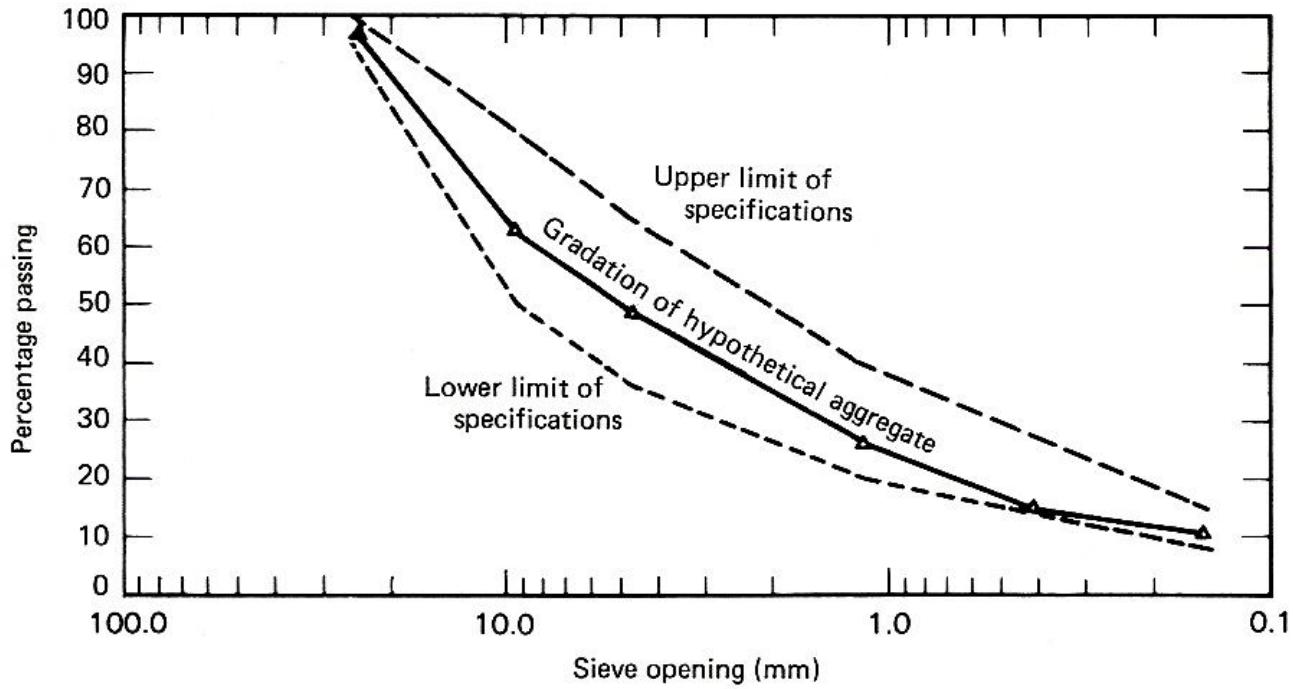


FIGURE 15-6 Aggregate gradation specification chart.

Resistance to Wear

- Materials used in highway pavements should be hard and resist wear due to the loading from compaction equipment, the polishing effects of traffic, and the internal abrasive effects of repeated loadings.
- The most commonly accepted measure of the hardness of aggregates is the Los Angeles abrasion test.
- The machine used in the Los Angeles abrasion test consists of a hollow steel cylinder, closed at both ends and mounted on shafts in a horizontal position .

Resistance to Wear

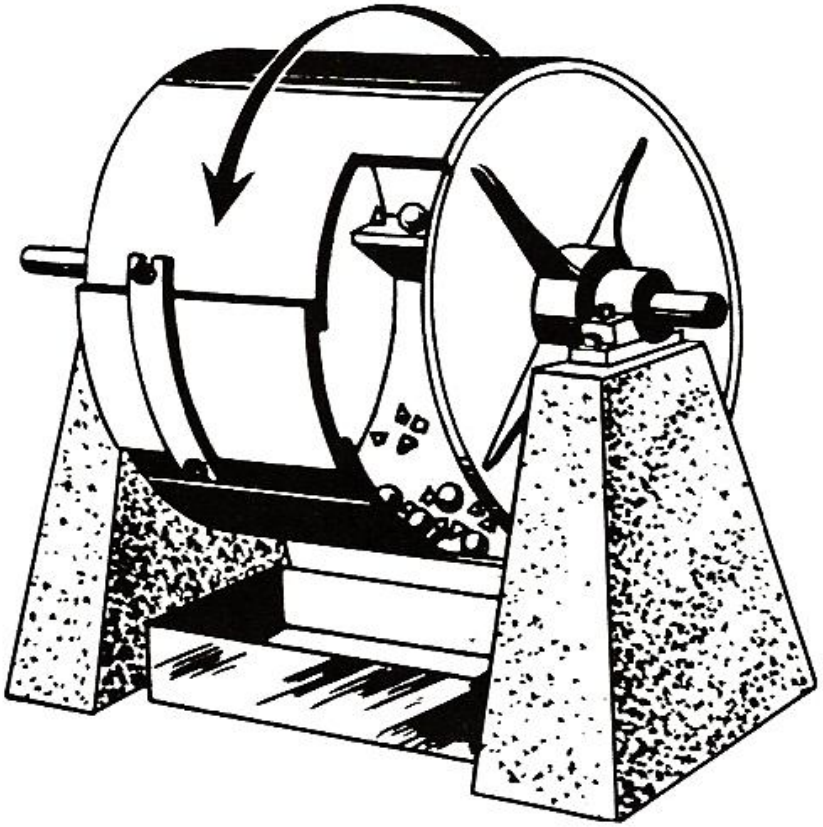


FIGURE 15-7 Los Angeles abrasion testing machine. (Courtesy The Asphalt Institute.)

LOS Angeles Abrasion Testing Machine

- A removable steel shelf extending the length of the cylinder is mounted on the interior surface of the cylinder.
- To perform the Los Angeles abrasion test, a clean sample of the aggregate to be tested is placed in the cylinder along with a standard weight of steel spheres as an abrasive charge. The drum is then rotated at a speed of 30 to 33 rpm for 500 revolutions, after which the aggregate sample is removed and sieved on a No. 12 (1.70 mm) sieve.

LOS Angeles Abrasion Testing Method

The material retained on the sieve is washed, dried to a constant mass, and weighed.

The difference between the original mass and the final mass of the sample, expressed as a percentage of the original mass, is reported as the percentage of wear.

Durability or Resistance to Weathering

- The durability of aggregates is commonly measured by a soundness test, as described in AASHTO Method T l04 .
- This test measures the resistance of aggregates to disintegration in a saturated solution of sodium or magnesium sulphate. It simulates the weathering of aggregates that occur in nature.

Durability or Resistance to Weathering

- The test is made by immersing sized fractions of the aggregate to be tested in a saturated solution of sodium or magnesium sulphate.
- The aggregate is then removed and dried in an oven to a constant mass. This process is repeated for a specified number of cycles, typically five.
- After the repeated cycle of alternate wetting and drying, the aggregate is divided into fractions by sieving, and the percentage weight loss is determined for each fraction.

Durability or Resistance to Weathering

- The percentage loss is expressed as a weighted average. For a given sieve size, the percentage weighted average loss is the product of the percentage passing that sieve and the percentage passing that sieve in the original material.
- The total of such values is the percent loss test value.

Specific Gravity and Water Absorption

- The specific gravity and absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes.
- The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because aggregates may contain water-permeable voids, two measures of specific gravity of aggregates are used: *apparent* specific gravity and *bulk* specific gravity.

Apparent Specific Gravity (G_A)

- is computed on the basis of the net volume of the aggregates, that is, the volume excluding the water-permeable voids. Thus,

$$G_A = \frac{M_D}{V_N \gamma_w}$$

Apparent Specific Gravity (G_A)

$$G_A = \frac{M_D}{V_N \gamma_w}$$

where

M_D = dry mass of the aggregate

V_N = net volume of the aggregates, excluding the volume of absorbed water

γ_w = density of water

Bulk Specific Gravity (G_B)

- The bulk specific gravity, G_B, is computed on the basis of the total volume of the aggregates including the water-permeable voids:

$$G_B = \frac{M_D}{V_B \gamma_w}$$

V_B = *where* total volume of the aggregates, including the volume of absorbed water

Diff b/t Bulk and Apparent Specific Gravity

- The difference between the apparent and bulk specific gravities accounts for the water-permeable voids of the aggregates.
- One can measure the volume of such voids by weighing the aggregates dry and in a saturated, surface dry conditions, that is, with all permeable voids filled with water. The difference between the two masses is the mass of the absorbed water, M_w. The absorption of water is usually expressed as a percentage of the mass of the dry aggregate,

Problem

- The dry mass of a sample of aggregates is 1982.0 g. The mass in a saturated, surface dry condition is 2006.7 g. The net volume of the aggregate is 734.4 cm^3. Find the apparent specific gravity, the bulk specific gravity, and the percentage absorption.

Solution

$$Mass\ of\ absorbed\ water = 2006.7 - 1982.0 = 24.7g$$

$$Volume\ of\ absorbed\ water = \frac{24.7g}{1\,g/cm^3} = 24.7cm^3$$

$$Bulk\ volume = 734.3 + 24.7 = 759.1cm^3$$

$$Apparent\ Specific\ Gravity = G_A$$

$$G_A = \frac{1982.0/734.4}{1\,g/cm^3} = 2.699$$

Solution

$$Bulk\ Specific\ Gravity = G_B$$

$$G_B = \frac{1982.0 / 759.1}{1\ g/cm^3} = 2.611$$

$$Percentage\ absorption = \frac{24.7}{1982.0} * 100 = 1.25\%$$