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Module No # 03 Lecture No # 13 Tunneling Safety

So last class, we have discussed about excavation and the major hazard or risk with respect to excavation in terms of safety is primarily cave-ins and fatality with related to cave-ins. So, we have discussed different forms of excavation like for example in bulk excavation or trenches and we have discussed all the safety precautions with regard to the same. So, in continuation now let us discuss some of the other hazards. So, in a way we call it as a confined space.

Confined space is a major hazard when especially when you are doing very narrow excavation or may be in terms of tunnels. A confined space is, a real big hazard so we will discuss about confined spaces first and then the different hazards in regard to tunneling excavation. So, we will talk about different types of tunnel excavation and also on micro tunneling also we will discuss.

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So let us discuss what is confined space OSHA defines confined space as an enclosed space which is partially closed or completely enclosed space which is not intended primarily as a place of work. You cannot work there for 8 hours per day or something like that. So, some of the

characteristic features of a confined space it is large enough for entry or exit maybe for 1 or 2 workers. And it is not designed for continuous worker occupancy.

Which is what I said, you cannot stay there for beyond certain duration unless there is a demand on doing it. Examples for confined space, manhole, borehole or silos then reactors, pits and trenches, sewers or drains and chambers and ducting. So, if a worker has now how do, you say a worker has entered a confined space? If a worker has either put is head or maybe the lower part of body is inside the space.

Or maybe his upper portion or full body is inside the space then he is considered that he has entered the confined space. Then he has to follow all the safety protocols with regard to the confined space. So now is it possible to really list out all the confined spaces generally it is not possible to list out all the confined spaces. Because some places are termed confined only during construction or maybe during fabrication or during modification and so on.

It is not a complete confined space all together so confined spaces should have certain of his characteristic then it is called confined space. And once it is termed as confined space then all the safety protocols of the confined spaces as to follow.

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What are the typical hazards in confined space? You may have flammable atmosphere you may have explosive atmosphere. There may be toxic substances which maybe like dangerous poisonous or gases in the form of gas, vapor or fumes likely to be present. You may have oxygen deficiency or you have oxygen excess also maybe if you have chosen a wrong breathing apparatus that can also be real serious hazard.

And then when you talk about gases different gases can be an; different levels. So, suppose if I have a confined space this maybe the confined space you may have large density gases in the bottom then this. And then there may be 3 layers based on the depth you have to differentiate the layers of the confined space. And do the gas detectors for testing the levels of gases and all these 3 layers. Then only you can really detect the presence of the particular gas which is inside the confined space.

And the worker should be taking a portable gas detector also suppose if the gas levels are changing periodically, they are advised to take portable gas detectors while they are working inside the confined space. Other hazards in confined spaces are engulfment, excess of heat, lack of natural light, no ventilation, restricted entry and exit. So, suppose if there is an emergency, they may not find a place to know quickly come up on hazard.

So that is also a really big danger in terms of a confined space never go into a confined space alone so confined space will have so many risks. Now first thing that we should always we are always talking about is PPE and I have been telling PPE can minimize many of the severe hazards.

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So, what are the required PPE in terms of confined spaces? As usual you have the required PPE minimal PPE which have required and especially for confined spaces there are some additional PPE is recommended. For example, respirators are generally 2 forms when you talk about confined spaces one is supplied air respirators and other one is air purifying respirators. When your oxygen level is deficient then you may have to carry oxygen along with your mask which comes something like this.

And then you may have to enter a tunnel or a confined space sometimes the air maybe toxic or it is not suitable for breathing then you may have to carry an air purifying apparatus which need not come with the cylinder is only for purifying the air. So, the mask will only purify the air which you are breathing in. And other thing is always you know recommended to have a full safety harness and this safety harness along with the life line so as shown in these 2 figures.

So, this safety harness is having a full body safety harness along with the lifeline so which is connected in a tripod format. So, this is a tripod format with which the worker has to enter and there should be a standby worker on the outside. Who should be able to see any signal which is communicated by the worker inside the confined space to the person outside? And this person also should be capable of pulling out the worker in terms of in case of an emergency.

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So now let us talk about before you enter confined spaces first of all you should know what are the hazards? And how to manage all those hazards confined spaces are really a life-threatening danger and entry is generally is only by permit. So, there are 2 types of confined space one is called permit required confined spaces and other one is a non- permit required confined spaces. Non permit required confined spaces also require some restrictions and not everybody is allowed to enter.

But there need not be too much of there is no presence of too many dangerous issues inside in a permit required confined spaces there may be too many suspected to have too many hazards, levels and risks. So, for people to entry and hence you will have restricted entry and exist you may not be allowed to stay for longer time 2 or more workers not be allowed to enter. So, these are some of the issues with regard to permit required entry spaces.

And before you even go for a permit or a non permit better you should really see whether such an entry into confined spaces is really required or not. Suppose if you can alter the work and do the same work outside the confined space then you should go ahead in doing it rather than taking all the risks and entering the confined space to carry out a specific task. So, permit required confined spaces are the most hazardous and required any qualified person to complete a safety check list simply called a permit. Before you enter in the space and trench more than 4 feet depth is generally termed as a permit required confined spaces because it may contain harmful substances and gases. Entry, permit requirement what are the minimum thing you need to have in the entry? Identification and location of the confined space sometimes you may have too many confined spaces you have to have an identification and location.

And outside the confined space this permit has to be stuck on the wall or near to the confined space. So that people who are close by should be aware that some people have already entered a confined space and they are actually working inside for this specific task and so on. So, purpose of entering the confined space time at which, the worker is supposed to enter duration of his stay. What are the ventilation arrangements the worker has taken in? What are the lighting arrangements a worker has taken in?

What is the air quality of a particular place all these should be monitored first and it should be listed along with the entry permit? Only when everything is done and proper values, then only the worker is allowed to enter the confined space. Safety inspections gas test also has to be done and this work permit along with the signature of the foreman competent person it actually stuck on the wall near to the confined space.

Confined spaces are dangerous places and never go without a permit most of often it is better to not enter a confined space without the proper work permit.

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Before entering the confined spaces some of the issues number 1, isolation. So, if possible, disconnect and properly lock off the power supply and all other issues and machinery or the part going to work as to be really isolated. So that actually preventing, all the hazards in the confined space entering into a work area. So, disconnect and properly lock off the power supply and the machinery and equipment that could cause hazards in a confined space and blank of pipelines, service lines which can also cause hazards.

So, try to isolate the portion of the area which you want to work in simpler way that is what it is? And try to take effective steps to prevent ingress or in-rush to the confined space of hazardous gas, vapor, dust, fume etc., Cleaning and cooling before entry ensure that no sludge or other deposits will give off hazardous gas, vapor, dust or fume during the course of work. If the steam cleaning is used then sufficient time should be given for cooling of the whole chamber before you enter into the confined space.

When the size of the entrance is too narrow then you should also have a proper airline breathing apparatus and that also should be carried along with you. And when you are taking an air breathing apparatus you should also know that it can restrict the passage or movement of the workers.

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Provision of ventilation increase a number of openings to improve the ventilation mechanical ventilation; maybe necessary in many of the places to ensure adequate supply of fresh air. And do not use oxygen to freshen up the air because this may have a risk of explosion also. Testing of the air should be free from toxic and flammable gases and if there is no deficiency in oxygen then the air is fit to breath you should be testing the air quality properly.

And the testing should be carried out by competent person using a suitable gas detector because the type of gas detectors also is very critical. Because you are detecting the atmospheric condition based on the detector which; should be properly and accurately calibrated. Further precaution better to carry an air monitoring device which is a portable device as and when required should be taken along with the workers. And who should be able to know the air quality in the earth inside the confined space.

Provision of special tools and lighting non sparking tools and specially protected lighting systems are essential and where flammable or potential explosive atmosphere or likely to be present. So before entering the confined space again some more additional instructions number 1 is emergency plan you should have a proper emergency evacuation plan. Again, these emergency evacuation plan also should be properly designed by the competent person and it should be formally you know workable and so on.

Those evaluation policies also as to be cross checked before entering a confined space. And sufficient supply of approved; breathing apparatus vessels containing oxygen or air.

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Then safety harness and audio-visual alarm etc. should all be properly ensured. And the people outside the confined space should also be able to hear some of the signals which is given from the workers who have entered the confined space. So, everything should be properly you know planned in advance before entering the confined space. Apart from that emergency services or procedures like fire services, first aid all should be available at a, close vicinity before a worker as entered a confined space.

Communications and workers who have entered the, who are ready for entering the confined space should know when there is an emergency what is a way to communicate to the stand by workers who are outside the confined space. And how to raise an alarm how to give audio signal or how to you know communicate through some means are the other which is preplanned.

And you know well in placed being the people who are outside the confined space and the workers who have entered the confined space. Shut down in case of emergency which; has already happen what is the way to shut down and what all as to be shut down? All these should be planned in advance before entering a confined space.

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Liaison and rescue, so when the work is being carried out so as shown here so in a confined space, there should be an another standby worker, you can see the standby worker has seen in this photo should be assigned to station outside the confined space. To maintain the communication so there is a worker who is entered confined space and there is a worker who is outside. And both these workers should have all the PPEs including safety harnesses to rescue the worker who has entered.

So, this rescue personnel should be properly trained in rescue physically fit to and readily available to carry out any rescue operations and rescuing the worker in case of any emergency. And there are 6 types of all this rescue practices opening less than 24 or opening greater than 24. It can be side portal it can top portal or it can be bottom portal accordingly you will have rescue devices set in place.

And the rescue generally called tripod rescue it is off 3 categories number 1 is self-rescue. The next one is non-entry rescue and third one is entry rescue. Self-rescue is the worker who has entered the confined space he himself would be able to you know come out of the confined space in case of any danger that is primarily called self-rescue. Non-entry rescue is the standby worker will try to help or assist the worker who has entered the confined space.

But he will not enter into the confined space so without entry he will try to know rescue the worker who is inside the hazard. Third one is entry rescue in this case the standby worker he has

to enter the confined space to rescue the worker who is inside the confined space. Again, there are so many types of rescuing you can have blanket rescue you can have full through legs you can trap the worker and push him out.

Like this there are so many options of rescuing the worker all these instructions and training should be given to the worker before the entry to the confined space happens.

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The primary operation where this confined space is predominant, we will just look at tunneling construction. Because these days metro constructions are really popular and let us now discuss a little, non-hazards with regard to tunneling operation. Tunnel is generally not linked to metro or a railway project tunnel is primarily underground passage. And it can be anywhere it can be through a mountain or beneath the sea or under a waterway or it can be any form.

And it may be for a pedestrian cyclist or road traffic motor vehicles railway traffic or a canal and some tunnels are constructed primarily for carrying water also of a sewers or other hydro-electric purposes or may be for even telecommunication cables and so on. The choice of tunnel again it depends on geological condition hydrological conditions cross section and length of the tunnel all these matters.

Limits of surface disturbance and how you want to put up the equipment and so on accordingly the choice of tunneling happens.

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Now if you broadly see there are several types of tunneling construction methods number 1 is cut and cover method. We will discuss about drilling and blasting and also on TBM method of excavation, immerse tube tunnels. These are the 4 types I am going to show here in cut and cover there are simple I made the process into simpler 4 steps as given in literature. Number 1 first you have to put the sheet piles or diaphragm walls so these are the sheet piles and diaphragm walls.

And are pipe walls so who are installed to support the excavation step number 2 when the excavation starts continuing here to the bottom of the tunnel. Temporary road decks as seen here maybe put up or placed on the put road surface. And this road can be you know opened up for smooth vehicle or pedestrian flow. So simultaneously what happens construction of station concourse and platforms will start continuing underneath the temporary road decks.

And in parallel you may have you may also continue with other areas of excavation and the process starts continuing. Once the roads surface is reinstated and after the construction of station concourse and platform is fully completed. You can do the backfilling and make the permanent roads so that the normal road is actually made available. This is primarily called pattern cover method primarily you are cutting and covering and then allowing the movement of tunneling construction to happen.

The next is drilling and blasting, even today this is a very popular method but once the advent of TBM has been launched drilling and blasting is not done very frequently in almost all tunnels. So, before the launch of TBM, drilling and blasting was one of the methods when you want to build up a tunneling.

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So, before the advent of TBM, this was the only economical way of excavating long tunnels where any type of material inside the soil strata (19:54) was visible. Even including hard rock digging is not possible. So here again there are 4 simpler steps drill the holes in the tunnel put proper holes and then start installing the explosives. So, keep the explosives like this and detonate the explosives.

So, it starts blasting and all the debris and the soil spoil you actually take it up through dumb trucks and it is transported away. Number fourth step is install and support the proper tunnel with tunnel lining and you are ready for the next blast to happen keep moving with the tunnel construction progress.

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The next is TBM, TBM is nothing but tunnel boring machine so it works underground with less noise, dust, vibration. And TBM is generally preoccupied with all the equipments and setup. So, you need not have an additional setup for transporting and doing anything because it can do the hole, operation with the machine on its own. And disruption and minimize the impact on the community and traffic.

So, it is highly efficient compared to other methods due to several work procedures it can occur simultaneously. It itself can cut and take off all the mud outside and deposit in an, other place. And you can also have concrete pre-case segments with which it is forms a tunnel lining also is generally placed with the TBM itself. Now what are the 4 steps here also? So primarily you have to put a launching shaft under retrieval shaft.

So, shaft is nothing but the first initial excavation you do vertically down so that the TBM can be placed. So, you have to have 2 locations launching and retrieval shaft. Then second step is to assemble the TBM in the launching shaft, so like this the TBM setup is done you bring parts from different parts of the world and assemble and keep it ready in that place. The third step start cutting and excavating the tunnel as it is seen here and it starts moving ahead.

So, this excavation of tunnel is happening without any disturbance to the any of the buildings or any adjoining structure which is above the tunneling. And the TBM starts moving arrives at the receiving shaft and it then dismantle for transportation. If it has to continue then it keeps on continuing like this so recently this is a very famous method of tunneling construction. The next one is immersed tube tunnels wherein you have to do a tunnel placing of a tunnel inside or under the sea bed or inside a, water body that is a main issue here

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So typically an immersed tunnel is made up of sinking precast concrete boxes so these are the precast concrete boxes generally you use lot of ship to guide the setup you bring it to the place where it has to be dropped and it is own self weight (22:57) it just gets dropped down and with the help of lining agents it just becomes water tight and seals of the water so that there is no ingress on water inside.

So, first step you have to do trench dredging and first you clear of the soil below you can use any equipments like for example your clamp shells or drag line anything is used. This is primarily a clamp shell and you start immersing a, tube units with the help of lay barge first fix the direction and set up this. And then you place all the precast box units together along with the seal and it starts getting water types seal.

And then you can start backfilling the earth over it, so that it is a steady as a tunnel. Now safety precautions especially in terms of tunneling now let us talk about safety personnel. (Refer Slide Time: 23:53)



There are primarily 2 safety personnel, one is competent person and other one is certified workers. Competent person, we call it as a competent foreman so this foreman should be able to execute all the operation inside the tunnel or a shaft very safely. Shafts are the vertical excavation which we do and tunnel is primarily the horizontal excavation which we do. So, whether it is inside a shaft or inside the tunnel the competent foreman should be able to execute the job very safely.

In larger jobs, responsibilities and functions in the respect of safety arrangements maybe delegated to an independent qualified and the competent supervisor. Safety committee shall also be appointed when there are 100 or more workers are employed in tunneling operation. And this committee has to meet once in 15 days to discuss all the safety problems in the site work. Certified workers and these workers are specially trained for to take of themselves in terms of even self-rescue and so on.

And when there is any accident or something they should be also trained to report same accident to the site supervisor and any incident what all as to be informed. And how to take of themselves in case of any hazard approaching the tunnel all these workers are generally trained well in advanced. And they are primarily called certified workers. The next issue when you are entering a tunnel is you should have a proper first aid arrangement. A first aid arrangement has to be kept for any injured worker so it should be maintained in every work site. And it should be available for emergency at a quick reach it has to be reaching to the injured worker.

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Depending on magnitude of the work availability of ambulance also should be available at a very short notice shall be there. And at least one experience first aid attendant should be there and who can take of these injured workers. It is recommended generally the workers, foreman, supervisors also should know how to deal with first aid methods to avoid any serious impact on to any of the accidents which happen inside.

Stretches other equipment necessary to remove the injured workers also should be available. And when there are more than 50 persons working in a shift artificial respiratory arrangement also should be provided. And PPE all the person who are entering tunnel should wear a proper PPE. Now next comes, sanitation and drinking water. So, sanitation facilities shall be provided close by now it depends on the length of the tunnel.

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Sanitation and Drinking Water Sanitation Sanitation facilities shall be provided close by Dry closets or water closets or closet cars shall be provided in the tunnel at the scale of one unit for each fifty men in the shift unless it is impracticable Closets shall be effectively and regularly cleaned, and disinfectants provided In any case the entire tunnel shall be treated with disinfectants periodically to eliminate unhygienic conditions Drinking water, at least Slitre per person employed in the shift, shall be provided near the portal and inside the longer tunnels It shall be stored in a clean container provided with tight fitting lid The use of salt tablets shall be encouraged

At what interval you want to keep the closets. So dry closets or water closets or closet cars can be provided in the tunnel at the scale of one unit for every 15 men in the shift unless it is practically impossible. Closets shall be regularly cleaned and they should be effectively cleaned disinfectant also should be provided in any case the entire tunnel should also be treated with the disinfectant periodically to have any unhygienic situations removed.

Next drinking water so at least 5 liters per person employed in a shift drinking water facility should be given in the tunnel. And especially when you are inside a very tunnel and it should be stored in a clean container with the tight fitting lid and material handling.

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So, those material required for the work in progress alone should be kept inside the tunnel and all other material shall be removed and kept outside. Even if there is any sufficient space still all the other material which are, not required for the work progress should be all kept outside. And the workers should be able to have clear space free of any obstacles to escape in case of any mishap which happens inside the tunnel.

Especially when you are having a flammable liquid or something which is required should not be stored inside a tunnel and it should be under the supervision of a qualified person. All the combustible material including rubbish should be continuously removed from such areas. And spills of flammable liquid all shall be cleared up immediately. Containers of all the flammable liquid shall be tightly capped and closed.

So, all sources of ignition shall be prohibited in areas where flammable liquids are stored, handled and processed. Fire extinguishers and fire buckets also should be provided in case of all these hazardous materials are present. Next is communication facilities, communication can be of different formats.

Communication facilities **Telephone System**

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Number 1 is telephone system and the warning signals telephone it shall be provided to ensure a positive and quick method of communication. So, between all control locations and portal of the tunnels and when you are longer than 500 meters and for shafts when it is longer than 50 meters in depth. Warning signals so irrespective of length and the bends in the tunnel should have a

proper arrangement for transmitting and communicating any message you want to give to the people outside.

It can be electrically operated bells or it can be a walkie-talkie so whatever form you can still you should be able to communicate the people outside. So up to 100 meters length of the tunnel only one of the systems mentioned above shall be provided. And whereas when you have a tunnel length which is more than 100 meters at least 2 or more communication systems and warning systems should be in place.

Red and green lights of adequate sites brightness and provide a suitable intervals and straight lengths curves, cross over points etc. to regulate the construction traffic. Red is primarily for stop or green is to for slowing down. So, like this communication is primarily given for the all the locomotives and other traffic which comes inside the tunnel. Communication systems shall be subjected to daily check whether it is properly serviced or whether it is properly you know maintained.

Otherwise, the service is required and it should be in place every day before the tunneling operation starts the communication systems should be properly checked. Now what about electrical installation and lighting?

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So, all parts of electrical installations shall be constructed installed and maintained to prevent of any electric shock fire hazard and so on. And it should also be having adequate strengths and that it is not you know getting damaged with the underground conditions and other issues like a water, dust and thermal reaction or chemical action and so on. Wherever possible which should be properly insulated and shall have all live parts enclosed.

So primarily in terms of switch boards there should be a passage of not less than 60 centimeters wide should be maintained in front of the switch boards. And rubber mats we place in front of the switch boards and no person should be using the switch board as like the clock room or change room or a locker room or a storage room. And it there should be totally prohibited and non-electrical equipment shall bare the essential details of voltage, amperes and circuit diagrams and so on.

As far as possible the combustible material should not be used in any room where there is electrical apparatus kept there. No flammable materials are also shall be stored in rooms, recesses or compartments, which contains electrical apparatus. So, try to you know segregate the hazards which are put together. Adequate fire extinguisher equipment suitable for using on all live parts should also be readily kept and that should be kept at least once in a month. When fire breaks out, the supply of electricity should be cut off immediately.

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And the fire should be attacked as soon as possible and reported to the nearest available supervisor. All places where electrical apparatus is installed shall be adequately ventilated in order to ensure proper cooling of the apparatus and dilution of the flammable gases are ensured. Minimum of 50 lux is maintained inside the tunnel and shaft headings especially while drilling, mucking or other scaling operations. The lighting in general inside the tunnel or outside an approach road shall not be less than 10 lux.

This is how the lighting efficiency is calculated. Emergency lights there shall be installed at the working faces and at intervals along the tunnel to help escape of workmen in case of accidents. All supervisors and gang-mates shall be provided with a cap lamps or hand torches. And at least a check crew of 50 or 10 people should be accommodated with hand torch or a cap torch. Temporary lights most tunnels are wet or damp and providing a perfect so you should provide with a proper grounding material for to prevent short circuits.

Electrocutions in tunnels are too frequent so all switches located inside the tunnel should be properly grounded and earthed. Hand lamps should also be having a strong cover glass and transparent material and it should also be of water proof material.

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Communication inside a tunnel, notices and signs, so there should be a very big notice board of 45 by 30 centimeters which shows about unauthorized person entering electrical equipment rooms or maybe handling or interfering with electrical apparatus. A notice on the notice board of

size 60 by 90 centimeters should be placed for direction in case of fire and directions to rescue of persons in contact with live conductors.

And for restoration of people entering suffering from electric shock and also there should be sufficient sign boards to notify in case of electrical accident or dangerous occurrences. Suitable warning should be placed at most of the places where contact with proximity to electric equipment's can cause danger. Telephone line should always be placed in the opposite of an electric side in the tunnels.

And no blasting line shall preferably be laid within the 3 meters of the light and the power line. All supervisors and electricians shall be adequately trained in the manual application of artificial respirations to person suffering from electric shock and it should be aware of the necessity to immediate and continued application. A board of instructions for artificial respirations shall also be hung at a visible place for so that people are aware of how to use the respirators.

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Now let us discuss about shaft excavation, so head frame so it shall be preferably of steel structure because it has to with stand the heavy load. And the sufficient; head room and strong enough for possible overload and impact due to sudden drops. Hoisting equipment, there should be at least once in a week and maintained. Suitable stand by supply power supply arrangement or alternate means of working on the hoist shall also be provided.

A limit switch under non-falling automatic brakes shall provide on the hoist to control the speed there shall be fencing around the shaft opening at least 90 centimeters high. And it shall comprise of at least 2 rail guards and a toe board 15 centimeters high to prevent material from falling into the shaft. And the gate provided there shall be closed except when used for entering or leaving the shaft or emptying the buckets.

And the gate should preferably automatic, so that by mistake you do no leave the gate open. Access through shaft per person shall not be lowered or raised in bucket used for mucking and there should be proper man raider which should be available for accessing the people from entering the shaft and leaving the shaft. Reliable means of communication such as bells or vessels shall always be maintained between the bottom of the shaft and the surface and telephone can also be used wherever possible.

Any other code of signal used should also be conspicuously exhibited near the workplace or entrance. Especially when you are doing on shaft excavation handling water so as when you start excavating you know water can be accumulating and it is very serious hazard.

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So, study of boring data and geological formation shall as to be properly taken care of to have an indication of location where water can be expected. Water inflow can be reduced or entirely it should be stopped by several means of water expulsion methods. In case of steady flow of water

from the roof of the head of the tunnel the flow shall be deflected down the sides to sumps by metal sheets.

And wherever possible you should have a permanent shielding of water entering into the shaft area. In case of steeply inclined tunnels step should be taken for quick exist in case of failure or haulage. And cutters and sumps shall be kept clean so that you are actually you know taking of the water and diverting the water accumulation.

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Ventilation in tunnels

- The ventilation is required to remove polluted air, gases and smoke produced by explosives, dust formed by the disintegration of rock, exhaust gases from the diesel operated equipment like locomotives, dumpers, trucks, shovels, etc., and to ensure temperatures of not more than 40°C dry and 29°C wet at the working place
- Mechanical ventilation shall be adopted where necessary to force the air in or exhaust the air out from the working face to the portal through a pipe to achieve the safety
- Ventilation and exhaust system for tunnel and shaft excavation shall be of sufficient capacity to maintain an adequate supply of funcontaminated pure air at all points in the tunnel or shaft.

Ventilation in tunnels ventilation is required because it is totally a confined space to remove polluted air flammable gases or toxic substances. Even dust which is caused with the help of disintegration of rock or through drilling and other processes. And sometime you may also have exhaust gases because of equipment like locomotives, dump truck and shovels etc., are actually entering in and leaving.

So, ventilation is very critical in terms of tunneling mechanical ventilation shall also be adopted wherever necessary to force the air in or exhaust the air out from working space. To the portals, to the pipe and ventilation to exhaust systems for tunnel and excavation shall be of sufficient capacity. To maintain adequate supply of uncontaminated pure air, at all times in the tunnel or in the shaft.

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Dust control, again you have to periodically inspect the quality of air inside the tunnel and most wherever applicable try to go for wet drilling methods because dust will not be too much in a wet drilling method. Periodical medical checkup of the workers is also to be ensured so that you know actually safe with all the pollution cost because of dust. And these checkups should be done at least once in 3 months.

In the concentration of various gases as given by the IS code and other SOPs. (39:17) Oxygen not less than 19.5%, carbon monoxide not less than 0.005%, carbon dioxide not more than 0.5%. Nitrogen fumes not more than 0.0005% methane not more than 5% any place in the tunnel and hydrogen sulfide not more than 0.001%. So, these levels have to be maintained and testing should be carried out after 24 hours or at least after every blast or major rock fall or any hazard has happened inside the tunnel.

Now there are certain entrance requirements which are required for people entering a tunnel. (**Refer Slide Time: 39:57**)



For example, without a proper PPE the workers are not allowed to enter inside a tunnel. For example, like helmet, safety shoes, eye visibility vest and other hearing protection and all. They are not allowed to enter inside a tunnel although there is a proper work permit, Single person are not allowed to work inside a confined space. Visitors are allowed only with the permission along with the guides after attending safety induction course.

Then only they are allowed even then maximum of 5 visitors at one time into the TBM only allowed. And also, there is a tally board which shows how many people have entered the tunnel and what is the count of number of workers inside a tunnel? So, these tally boards will have an out column and an in column and lot of tokens. So, you pick up 2 tokens against your name and put it as out or in as per whether you are entering or leaving the tunnel.

And as soon as you enter the tunnel you can token in some place on the notice board and again you can use it for putting the tally marks. This is like compulsory when you are entering into your tunneling space.

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The next one is entries generally with the help of passenger hoist. So, this passenger hoist capacity is, maximum of 12 persons as seen here. And the safe load is cantilever platform is generally 6 persons. So, when you are hiding the hoist, stay and keep clear from moving pots and so on. And non-smoking is compulsory in certain tunneling space, shaft safety bottom, do not stand under the loads being lifted or lowered.

When you hear or see any warning signs there are lot of communication signals like this inside a shaft all the signals at all times. And be aware of sensitive to any locomotive movement also when you are inside the tunnel warning light for lifting.

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So, you can see here these are the warning lights which are kept when the lighting operation is carried away. This is primarily a shaft opening so red light will turn on automatically when the crane is on top for any lifting operations. And ensure no lifting when you cross the shaft or otherwise you should wait till the lifting operation is completed. The access and egress in the tunnel use proper walkway as provided you can see here it is all brightly colored so that it is visible.

Do not walk on the train track and only ride in the man rider capacity is 22 persons at any point of time. Tunnels are always wet and slippery always stay in the designated areas and not venturing out into the tunneling space. Be aware of materials spills from wagons or conveyors they all take of the material. Conveyor, generally use to collect the mud and other you know spoils from after the TBM machine has cut.

So, these are generally carried by conveyers and wagons also help it for travelling taking these spoils outside the tunnel. So should be very careful with the spillage so that you are not slipping and falling into the tunnel. And every time, you should be very alert on the tunnel haulage equipment which comes in along the trucks. Hauling equipments always have a right of way so you should always strictly follow the procedures and maintain the right of way distance.

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Warning signs, obey all warning signs posted in the various locations inside the tunneling spaces there will be visible and audible warnings signs also when hazards operations are carried out. General tunnel safety rules, operate equipment or plant if you are authorized otherwise, you should not be trying out operating any equipment. Do not tamper with equipment and mess with the functioning of the same equipment.

Do not walk in tunnel invert, always use walk ways or man rider so not throw any materials from heights. Keep clear of welders working area do not look directly at the arc during the welding operations. And report all accidents or incidents to safety department so these are all general instructions.

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Now safety into the tunnel's location of emergency telephone so primarily the fire alarm box or intercom, telephones you should know the location and places. Location of fire extinguishers and fire hose reels so fire extinguishers generally of the ABC type is generally available. At the TBM, locomotives, man riders, shaft bottom and hoist and transformers a standard hose reel of 30 meters is available at fix at every 50 meters.

And location of self-rescuers 25 numbers of self-rescuers are provided in the TBM and these notices regarding the proper use of self-rescuers are posted near the storage area. So that when there is any emergency the workers will know how to use the self-rescue equipment and come out of the hazard.

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Location of first aid boxes and all, the first aiders list is also available in the notice board. So, what are the tools inside the first aid box are also listed outside the first aid box.

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The locomotive and train traffic so only trained and authorized people are supposed to operate the locomotives. This is what we have seen early here? And obey all the instructions from the locomotive drives do not sit on locomotives or rolling stocks which are not designed for man riding. But only for material transportation do not use it and do not stand behind the reversing wagon or a, locomotives. And the train speed empty train going into your TBM 15 kilometers per hour.

Full train coming from the TBM 10 kilometers per hour full train approaching within 100 meters, of shaft bottom or TBM. 5 kilometers per hour and when a machine is entering a TBM it should be coming in a dead slow speed. And when it is moving through a track switch it should again be a dead slow. Again, there are lot of warning signals one horn blast for locomotives stopping, 2 horn blast moving in and 3 horn blast for moving out and so on. And also, there are lots of issue in signals also available.

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Rules and regulations for man riders, maximum of 22 persons are allowed to travel during normal operation. All doors should be closed before the loco movement do not place hand or head outside the man rider and board or alight only when locomotive has stopped. Then railway tracks again no track works are permitted when the crew is in operation and also red signals for stop and green signal for slow speed.

And there should be for lookout person also who has a proper lamp or torch to give proper signals to the locomotive driver. And who should be position at 50 meters on either side so there will be lot of lookout persons.

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Safety in the TBM, conveyor hazards maintenance and repair work should be done because conveyors are generally carrying out the material and also the precast panels. So should be very careful with the conveyor hazards and it should be properly maintained so that it is transporting. There should be proper emergency stop rope also provided in case of emergency to stop the conveyor belt.

Restarting of belt should be from TBM operator cabin only and be aware of mucks spillage and keep hands and body clear of conveyors where protective gear whenever advised. And operators are advised to wear snug fitting clothing so that you know the clothing his not getting caught into the conveyor belts.

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Safety in TBM, you will primarily have segment handling segment direction and thrust or jacking rams. Segment handling only authorized people are allowed to handle these segments and persons must stay out of the area beneath the hanging or supported loads. Segment erection crossing of safety barriers are not allowed and be aware of crushing, pinching or impacting processes which happens there.

And during ring construction the zone around the erector must be visible to the erector. So primarily this is how the tunneling happens. And if you want to show the cross section, this is how the TBM looks like. And these are the blades different sort of the blades which starts cutting out the earth which is in front. And there are 2 conveyors here one for taking out the debris or the soil and other one is for transporting all your precast panels.

Once the soil is cleared or excavated these panels are placed all along the tunnels so that lining is maintained. This is primarily called segment and this is the erection of the segments so crossing of safety and here. So, during the ring constructions this is the ring constructions the zone around the erector must be visible to the erectors so that is properly placing all the lining parts. And do not stay in the zone when the concrete lining is happening when the tunnel lining is happening.

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Safety in TBM, operation of grout pumps only authorized person are allowed to enter or operate and grout pumps. Never reach into moving parts when the motor is running this is primarily called a grout pump. And operator must inform unnecessary people to keep out of the danger zone never try to open while the grout is under pressure. Hoist and lifting gears in TBM, the hoist must only be used for transport of material.

Do not lift people with the help of hoist and do not stand under the suspended loads and only authorized people are allowed to operate and maintain the lifting hoist and lifting gears. Electrical parts again all electrical safety precautions should be maintained in a TBM.

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Emergency in Tunnels
> Types of Emergency
 Ground collapse at the face
Failure of temporary or permanent support
 Flooding or leaking from utilities
 Gas release, Fires and Explosion
Oxygen deficiency
 Building/Surface subsidence
 Accidents from moving equipment
 Plant and power failures/collapse
Electrical hazard
In the event of emergency
 Evacuation may be necessary
 Procedures are established to assist you
Trained Rescue personnel are available
Look for the symbol
NPTEL

Emergency in tunnels, types of emergency which you can force in a tunnel or ground collapse failure or temporary or permanent support. Flooding or lacking from utilities gas releases fires and explosion oxygen deficiency, building or surface subsidence, accidence from moving part of the equipment. From moving equipment plant and power failures are collapse, electrical hazard in case of emergency evacuation is necessary.

Procedures should be well established before you enter the confined space trained rescue personal also you should be available for rescuing all the workers. And look for all the symbols and all the warnings when you are inside the tunneling space.

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Evacuation procedures maybe by man cage and emergency access ladders. The evacuation procedure is generally by the supervisor or the foreman who knows the procedure of evacuating the people. And he should have a formal plan well in advance as to how the evacuation has to happen.

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Now let us move on to trenchless construction methods, so every time there is no need to dig a trench maybe for pipe laying or something else. So even now there are lots of trenchless construction methods which are available wherein you have to dig open only a small launching shaft. Put the micro tunneling boring machine and then you can use pipe jacking for all your processes and you can go ahead laying off small diameter tunnels.

These trenchless construction methods are again of 2 categories one is trenchless construction method, other one is trenchless rehabilitation method. Trenchless construction method always has a, micro tunneling processes which we use with the help of MTBM which is called micro tunnel boring machine and along with the pipe jacks. Pipe jacks are nothing but small diameter pipes which are all precast it starts fixing up and tunneling is completely done once you start cutting of the earth.

The other method is trenchless rehabilitation methods you primarily use it for pipe bursting of a pipe jetting processes. And when you want to repair a pipe line you need not break out cut the earth and then look for pipe and take out the old pipe. And then insert the new pipe you can actually know force the new pipe along the same line where the old pipe is there. And with the help of the bursting process that is why it is called as pipe bursting.

The new pipe gets align in the same place as the old pipe and the old pipe get broken in its own place. Generally, we do not remove the old pipe, the debris are generally inside the soil only.

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So, this is right now a very powerful approach wherein lot of construction or underground constructional rehabilitation works. Primarily for smaller diameter or small depth of excavation people prefer trenchless construction. So, there is also a saying why to dig a trench when there is a trenchless operation available. So, this is primarily the MTBM and the way it is done this is the launching shaft this is the receiving shaft.

And here compared to the TBM there is no process of cutting the earth in drive mechanism. Here water is sprayed and as such water gets mixed with the soil in front and it becomes sticky and as a result the soil is cut. The process of cutting the earth itself is very different compared to TBM machine. And also, they have small some of cutter blades here but it cuts along with the water.

So, there are 2 lines which enters in one is for water and other one is from the water mixed with soil which is actually transported outside. And with the help of all the signals given from the top there is a pipe jack these are all the pipes. And with the help of you know proper launching mechanism these pipes shall start fitting and with the hydraulic pressure and starts getting moved and as and when the tunneling operation is proceeded.

And at the end of the receiving shaft the MTBM machine is taken out this is the general setup of the micro tunneling processes. Now what are the safe-procedure in trenchless construction? (**Refer Slide Time: 55:23**)

Sops - Trenchless Construction All trenchless crossing of pipelines through roadways/highways/Railways/ underground water shall have prior documented permissions from the respective regulatory authorities Emergency preparedness and specific training of the workmen on the job are mandatory All workmen shall be provided with minimum of mandatory and specific PPE's as per the requirement, Adequate Ventilation, illumination and other requirements as per the environment Soping, Shoring or any suitable technique shall be adopted to prevent collapse of soil The machines & equipment used in this process shall be kept at a distance, which is not less than the depth of the pit Pits shall be hard-barricaded and light reflecting tapes shall be pasted on the barricade to warn pedestrians and drivers Adder shall be used to enter or leave the pits Power supply to the Hydraulic Machine and the hand lamps shall be taken from IP-55 board which is provided with RCCB Voltage for the hand lamps shall be restricted to 24V and machine shall be earthed

All trenchless crossing of pipelines through roadways, highways, railways all should be properly unidentified and there should be a proper permission also from the proper authorities before you start doing the trenchless work. Emergency preparedness specific training of workmen or the job, are mandatory. All workmen should provide with basic mandatory and specific PPEs for doing all these works.

Apart from ventilation, elimination and other requirements as per the environment in the sloping and shoring or suitable techniques or preventing collapse of soil also should be in place. The machines and equipment used in this process shall be kept at distance which is not less than depth of the pit. And the pits are all hard barricaded light reflecting tapes in order to prevent other obstruction entering into the construction processes.

Ladder or suitable device for escaping from the entry are all provided for entry and leaving the pits. Power supply also should be maintained hand lamp also should be used inside and voltage for the hand lamp shall be restricted to 24 volts and all the equipments shall be properly earthed. (Refer Slide Time: 56:42)



SOP for the shaft construction, before construction you have to note down the underground utilities. And with the range of excavation and the work must be commenced proper work permit and all clearances are required from the local authorities. The traffic management procedures are should be adopted to suit the requirement particular to the site. Again, workmen should have proper PPE, proper ventilation even for the shaft construction.

And most of the others are looking like same and proper access and egress arrangements are all provided with the ladders. And ensure LOTO is there LOTO is lock, out and tag out procedures we will discuss along with the electrical hazards. Ensure weekly inspection of shaft covers against displacement, disorder, deformation or other defects.

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Jacking installation, jacking equipment and other machinery can be installed by using cranes. And the cranes shall be operated from at least a depth of 6 meters away from the shaft depth. Or at least a distance of at least 6 meters away with depth is greater than 6 meters trained person has to be employed for signaling the crane operator. Ensure there is no movement of workmen within the swing area of the crane.

Rotating parts of the crane shall be shielded, the crane is equipped with the back horn, deenergize power source while working under live cable. Noise protection equipments shall be provided to the workmen. Based on the noise level during the jacking operation air quality has to be checked and other proper precautions on vibration, heat effects all should be there. Better to have the workers done in shifts so that this will be a better solution for all these hazards.

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Recap, on confined space if you are required to work in a tank, manhole, a well or a cold storage, culvert, pipeline or vault, tunnel and so on. Then you are actually working in a confined space you may have lack of oxygen or even high dosage of oxygen. Toxic atmosphere temperature extremes fire and explosion, uncontrolled energy collapse of solid or liquids like this there are more hazards which may be available.

Work safely in confined spaces you should know about stand by worker and also about rescue operations types of rescues also we have seen. And there should be a proper SCBA which is nothing but self-contained respiratory apparatus alarm on everything should be there outside the confined space also. Testing the atmosphere is compulsory when you are centering a confined space which also, we have discussed.

Isolation, try to isolate the portion which you wanted to work fire and explosion prevention should be maintained. And fire alarms, fire explosive devices all should be in place including first aid services and so on. Ventilation is compulsory especially when you are working in a confined space. So confined space entry by permit identifying hazards of the permit spaces deenergize and lock out all energy sources.

Drain clean and ventilate the confined space isolate the confined space oxygen level should be between 19.5 to 23%. Flammable gases less than 10% all substances below establish permissible

exposure limit. Prepare personal protection devices as respirator protective clothing, lifeline safety harness. Attendant and rescue equipment should be place outside the confined spaces.

Review communication procedure and obtain an authorized permit in nutshell we have discussed all of these things in this particular lecture. And I have prepared this complete lecture based on all these references.

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References
> IS : 4756- 1978 Safety for Tunnelling work
> OSHA QuickCard: Permit-Required Confined Spaces
OSHA FactSheet: Confined spaces in construction: Crawl spaces and Attics
> OSHA FactSheet: Confined spaces in construction Pits
OSHA FactSheet: Guidelines for Safely Entering and Cleaning Vessel Sewage Tanks
> Sops - DMRC & L&T
https://www.labour.gov.hk/eng/public/os/D/Safe_Work_in_ Confined_Spaces.pdf

IS code on 4756 safety for tunneling and more of OSHA material on quick card and fact sheets on permit required; confined spaces. Confined spaces in construction crawl spaces and attics construction pits and so on and lot of safe operating procedures given from DMRC and L & T. Thank you.