Mine Automation and Data Analytics

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Week-5

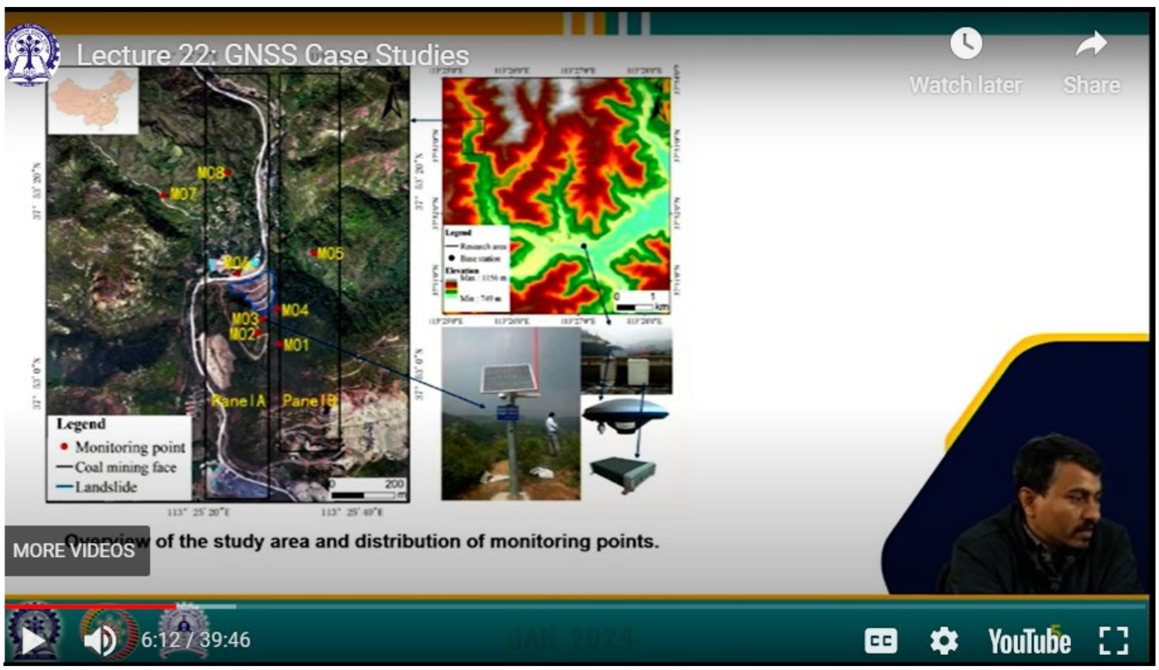
Lecture-22

GNSS Case Studies

Welcome back to my course, mine automation and data analytics. Today, we will show you an important case studies using the global navigational satellite system how we can use it efficiently. Basically, these case studies more concerned for the safety aspect of the surface when some underground mines is going on. So, in this lesson basically, we will try to cover how the working in underground coal mines, basically it is a long wall mine it affects on the surface slope its stability, and we will monitor the stability of the slope in the surface using the global navigational satellite system. So this case study is basically conducted in a mine of in China and basically it is in a hilly terrain the mine is situated in a hilly terrain with rivers and valley, and there were some reports of landslides the first report of a landslide it was around 2017 of February so the mining company decided to install the GNSS system in different suitable locations to measure the impact of the landslides on the advancement of work in two panels basically this particular mines is working consecutively two panels. So we know that in an underground mines, when the underground mines advances, particularly the long wall mines, there are some basically it is conducted in a two-way forward or backward so basically there is an on the upside is basically the return here so in that particular condition it has been observed when the face is advancing the top part of the roof is filled and the GOP is basically filled and because of that, there is a new stress-strain distribution on the strata so that new stress-strain distribution on the strata is basically reached to the surface depending upon the nature of the rock and also the depth cover from the top surface.

So, it was observed for this particular mine this particular mine is situated around 470 meters below from the top surface, so it was been observed that due to the long wall work advancement, the landslide is related so. The company wants to be sure about that how the landslide is basically impacted due to the working of the underground coal mines. So here, this particular yesterday that we are going to discuss is basically use the GNSS system for real-time monitoring and to develop an early warning system as well to prevent the disaster. This basically mining company always want to prevent the disasters by basically what is basically related to the mining work so this GNSS system is used to enhance the stability notion in the mines. So, using the GNSS real-time monitoring was conducted in the long wall mines to analyze the effect of the UG coal mines on the high wall slope it is basically a hilly terrain.

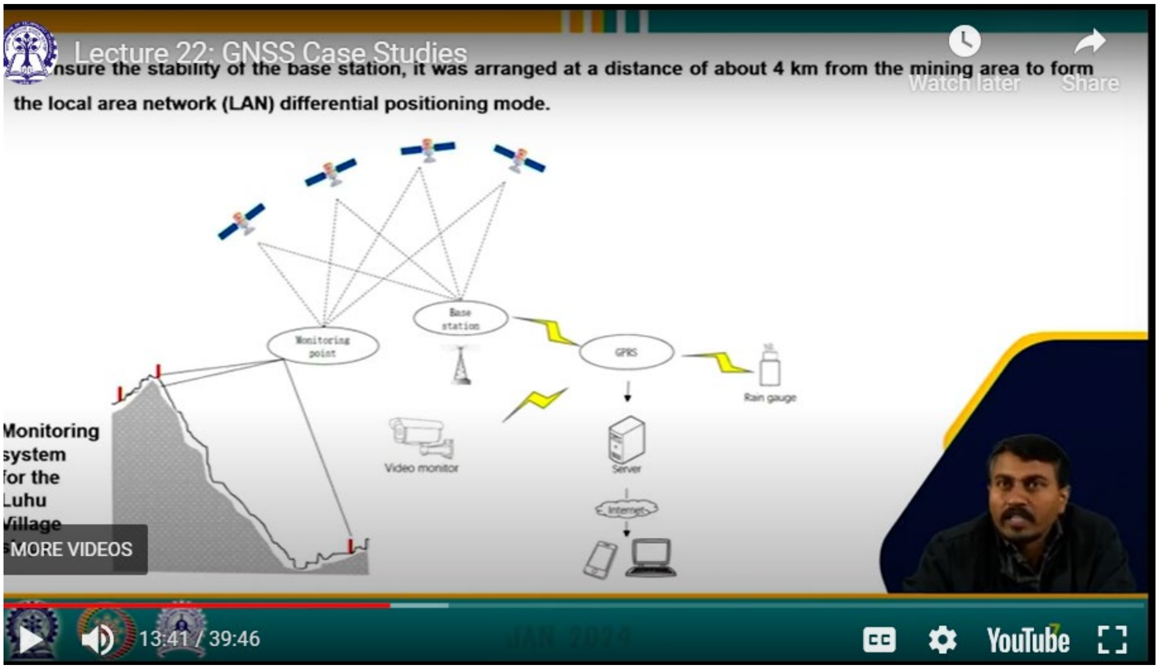
So, in this particular study using the GNSS monitoring station we are more interested to measure the rate of movement as well as the displacement okay at different monitoring points. So, we have observed the rate of movement and the displacement has impact on the development of the cracks developments of tensile crack and development of craving and basically the subsidence. So, because of that we are interested to measure the rate of movement and the displacement at different monitoring site that is installed at the site. So this is the typical mine. So here is this the panel A and here it is the panel B, so both the panel are working okay.



So, the, panel A is working in this direction the advancement of the panel A is going in this direction. The panel B advancement is going in this direction, and they are specially located. Here, we have observed in this particular case study there are eight number of monitoring station is installed. So, this is M1 so these M1 and M4 is basically the on the basically on the above side of the slope and as well as the M2 and M3. M4 is basically on the bottom part of the slope. M5 is also on the top of the slope, okay. M7 and 8 is a little far away, and this and side of the panel A okay.

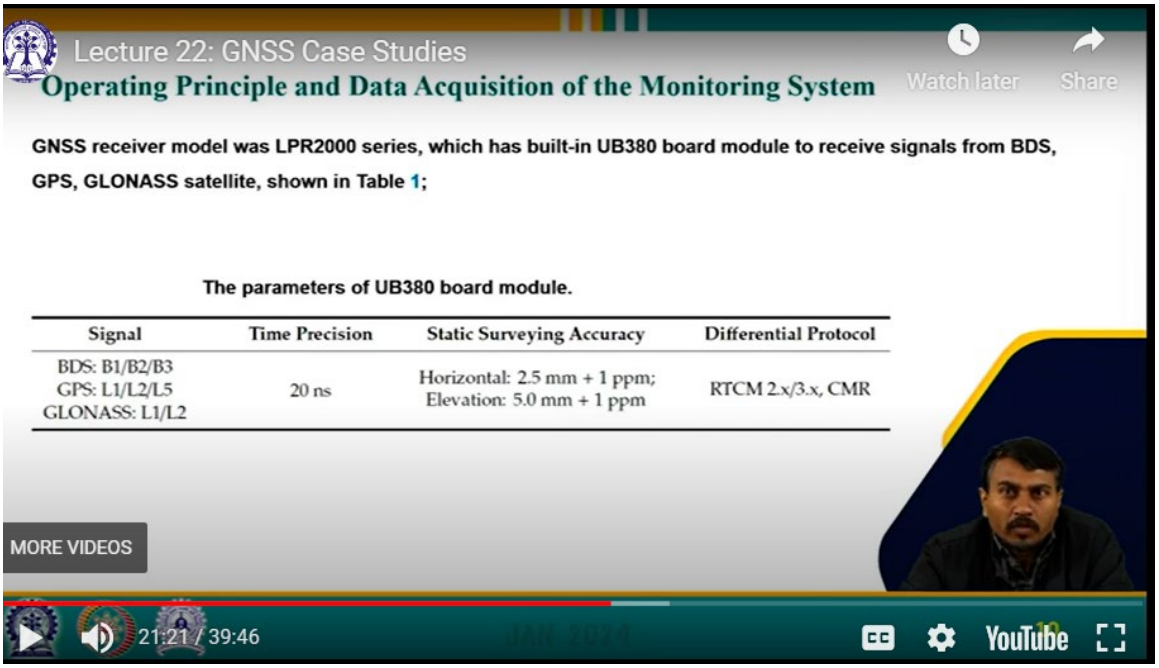
So different monitoring stations are installed to monitor the displacement and not only the displacement the differential displacement as well so that we can pretty assess the role of these underground coal mines in these two block, panel A and panel B, and how it is going to impact and also both the panels are not working in the same direction that is also a concern. So how these opposite direction of advancement of the panels is impacting at the surface level on the surface slope that is basically the main concern and the main contention of this particular study and you can observe from this particular model that this is basically a hilly terrain okay and these hilly terrain on the top top outcrop is basically exposed okay soil layer is very thin and it is exposed and there is not big big trees is observed only small shrubs are there on this particular hilly terrain and it is basically Permian type rock okay and you can observe that in this particular area there is a river going there is a river and on the two side of the river there is embankment okay so it is a very complex topography as concern and it is basically the elevation contour of that particular area it is been shown so our interest area is here so these area is coming here okay and you can see that green side is around 780 meters RL okay and the red is around 1156 RL so our area is basically more on the downside okay and partly it is on the higher side and here in this particular figure we have shown how the GPS stations the receiver stations okay GNS receiver station is installed at different points okay so it is been particularly it is been shown that it is M3 okay and also interesting that here this is the point it is far away from the area of concern area of concern is this area that is magnified here and there is a base station far away located around four kilometers away the base station and that base stations have the setup and that base station also similarly the GNSS receiver then wireless connection as well as land connection and then with the network and the server room okay so this particular station is far away from the working area concern to basically get a better data and also to ensure this base station is not impacted due to the mine working of this particular area that is also an interesting one so the researcher have intentionally see to means located this base station far away from the area of concern to measure a precise amount of rate of displacement in reference to the base station so that a very accurate data and the relative displacement can be acquired very precisely.

So the M1 and M2 M1 M2 and M3 and M4 is basically located at the top of the high steep slope here it is basically the location here and the M6 is located at the bottom of the slope this is here and M7 are located at the south of the panel a and while M5 is basically located at the center of the panel B which is basically also the top of the other slope okay it is an hillytenon so each monitoring station is monitoring point monitoring point is basically with a foundation pit of 60 centimeters 60 centimeter and 60 centimeter it is basically the area excavated volume excavated and they have installed a steel bar okay and they feel that area with the concrete okay to form a stable station because a GNSS station should be stable okay we have to ensure that else data might not be good so that is they have done very precisely and very accurately and they have also done some amount of study the amount of which location to be selected and based on that they basically selected eight number of stations and also in this study interesting thing is that the pole have a height of around 2.3 meters so that ensure that the GNSS receiver receive strong signals from the GNSS satellite constellations okay at least more than four number of satellite is easily visible from that particular point so that basically they taken into consideration.

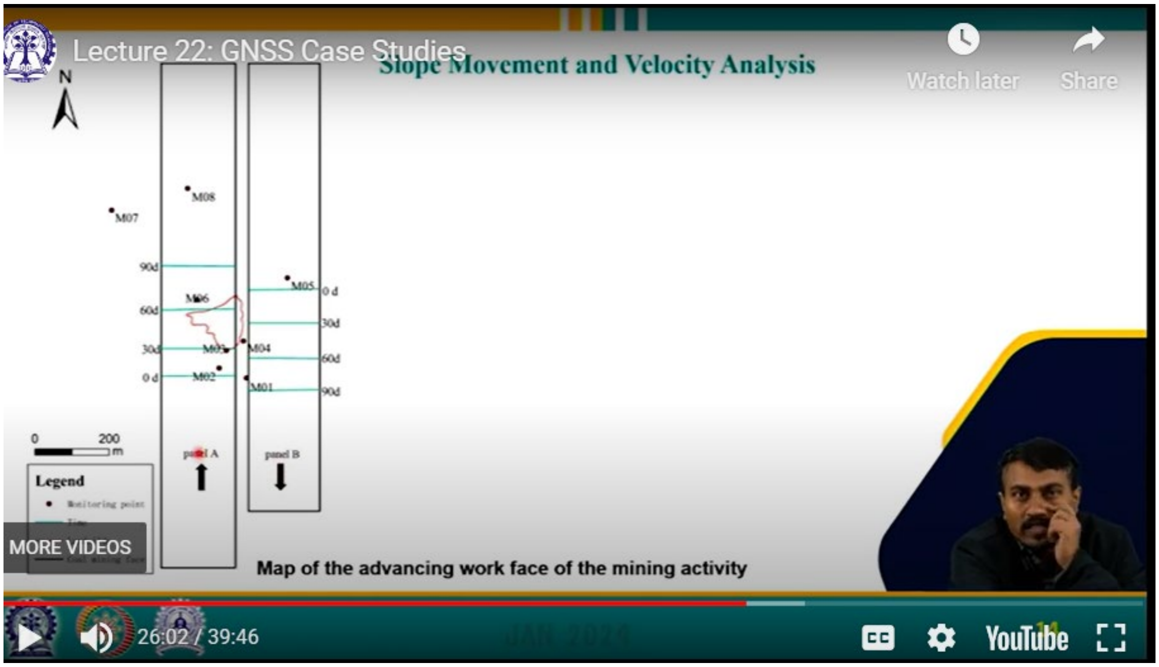


So everything is according to the plan now let's see that the other things of this particular study so the base station is situated four kilometers away and that is connected with the local network connection and local network connection and with the our main aim is not on the precision or accuracy of the absolute displacement or the absolute location of the station because we know pretty well that the station location might be shifted time to time and because of that basically this study is conducted because of the landslide so we are much more interested in this study to observe the relative movement relative movement to one another okay and that will give a clear picture about the impact of the landslide on the surface because of the because of the advancement at the underground mines so this is basically the location of monitoring stations and monitoring stations can very well be observable and can signal get signal from the GNSS constellation of satellites and there is a faraway base station is located okay and that is also have the module of the GPRS and all that is also have the low power consumption 4G connection a radio module that can establish connection with the different stations and also that is connected with the server for the processing of the data and to compare the data and that is connected with the internet and we can we can observe the display we can observe the data using mobile device and the computer and in this study in addition to that they tried to install two new sensors here that is the rain gauge because in this particular study it is been assessed that rainfall also have some amount of influence so this particular terrain is particularly received rainfall around 600 millimeter per year and mostly the rainfall is concentrated in the month of July August and September and how the rainfall is impacted the slope stability and also the intensity of the rainfall and the duration of the rainfall how it is impacting the landslide that is also the contention that is why this rain gauge is also installed and also the there is a video monitoring of the slope so continuously the video is capturing the surface of the slope so that from that also using the change detection. We can assess how much amount of movement is occurred on these monitoring stations so this particular study was continued for 90 day and data frequency was once in a day okay. So operating principle and data acquisition of the monitoring system so the system consisted of a monitoring module so monitoring module is the GPS and the GNSS receiver power supply module that we ensured constant power supply to these receivers and other accessories and we have the video monitoring module that captures the image of the slope time to time continuously and also we have the rainfall monitoring module and its detailed compositions so these monitoring module consisted of the GNSS receiver the antenna the general packet radio services that is GPRS data transmission module and also it is 4G and an early warning and alarm module so early warning and alarm module is it will it will activate when the rate of displacement according to the schedule one according to the decided one that some critical value is already decided the if the rate of displacement is goes beyond this alarm will be activated okay and system was solar-powered and was equipped with a battery storage system and it ensured that if there is a rainfall and it is not received sufficient amount of sunlight it can run up to five days okay it can support the station monitoring station continuously for five days

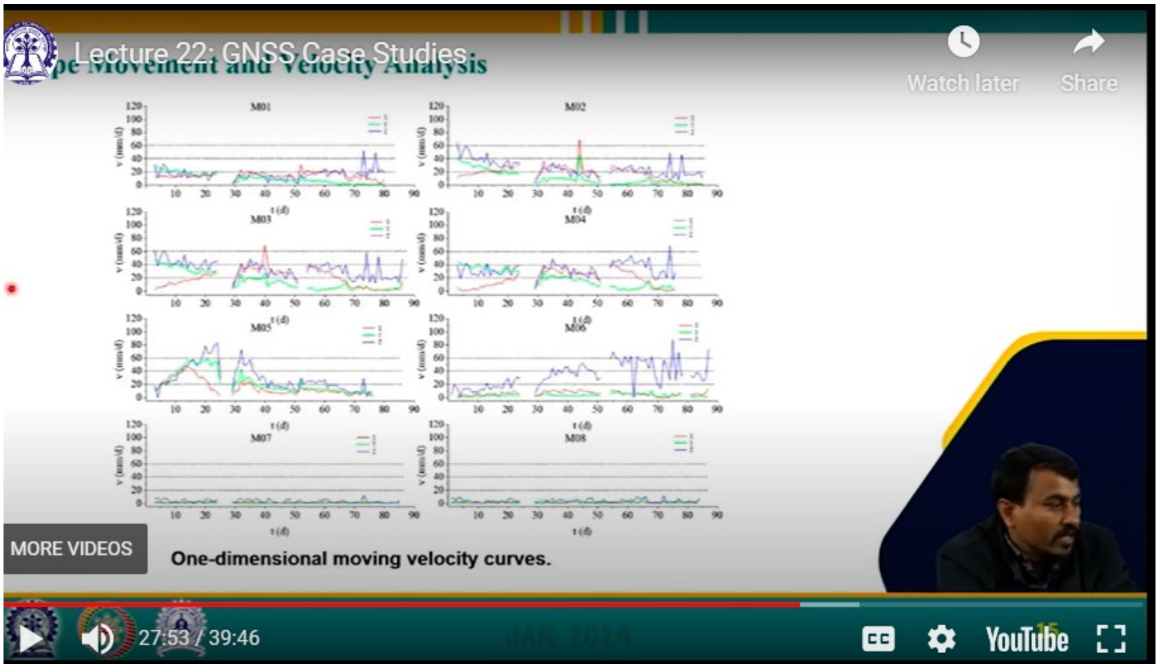
So, the system could obtain real-time data and the accuracy of this data for an one hour static observation it can reach up to millimeter level and we know that in a GNSS receiver you have to you have to allow and you have to give time to the GNSS receiver to settle so for this one hour static observation so for one hour it is kept constant it is observed and finally the data is been taken so that accuracy is millimeter level accuracy with the available setup that been used. In this particular study, the precision of the GNSS PPP precise point positioning and the real-time RTK kinematic and the static baseline positioning based on the landslide monitoring are better than the six centimeter six millimeter and three millimeter respectively so this is basically the accuracy of the three system of the monitoring system that is used here and you can see that it is rich at up to the millimeter level and it is more more particularly in the spatial direction X and Y the GNSS monitoring system use its position functions to determine the location of the monitoring points we have discussed in the earlier lecture in 11A how the location of the points is estimated through the functions so these system have that facilities and that functioning is basically used to estimate the location of the monitoring points so here the details about the setup use in this particular study



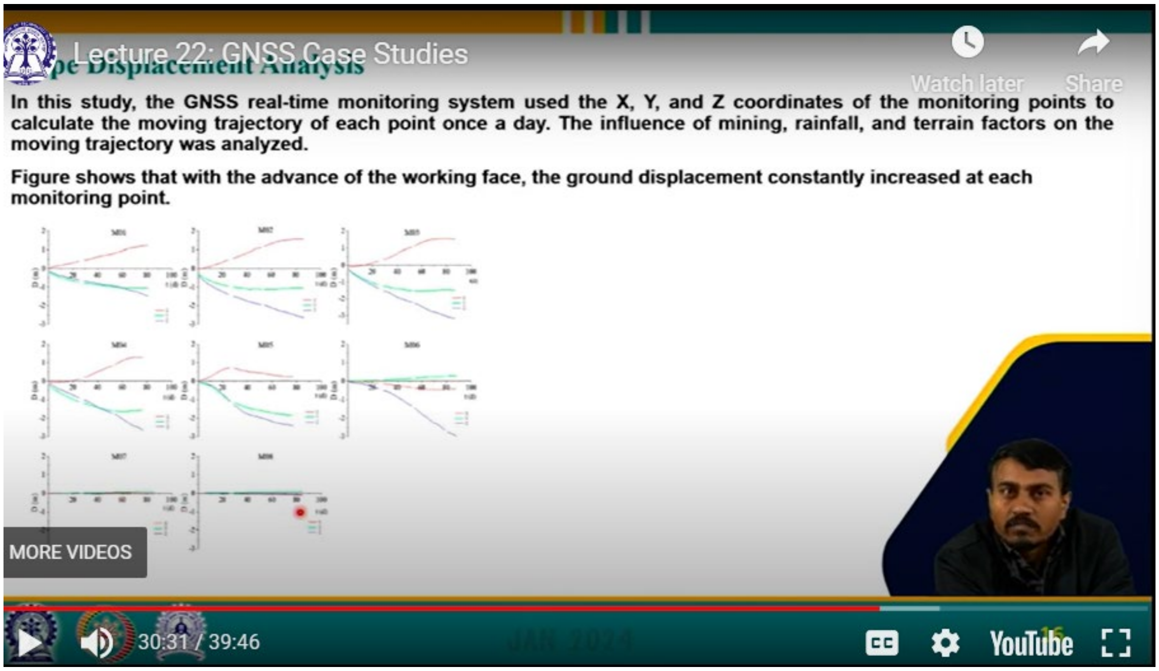
So, this study used the LPR 2000 series GNSS receiver and which is inbuilt of ub380 board module to receive signal from BDS that is the Bido and the GPS that is the American GPS GNSS system and the GLONASS Russian GNSS constellation of satellites so this particular table is shows that these particular receivers are capable of receiving the B1 B2 B3 signal from the BDS l1 l2 and l5 from the GPS and l1 and l2 from the GLONASS and the time precision is 20 nanosecond and the horizontal accuracy is going 2.5 millimeter plus minus plus 1 ppm 1 parts per million and the elevation is 5 millimeter so horizontal spatial location accuracy is high in the GNSS system so the GNSS receiver module has built-in low-power radio to support differential data transmission between stations okay and equipped with the GPRS 4G module to support remote interface control and remote data transmission to realize remote monitoring to measures the points and the AC monitor software is used in this particular study for GNSS data processing it has the advantage of using the nonlinear Kalman filtering of double differential and three differential algorithms the improved ionospheric correction model and supporting the multi reference station solution and real-time independent baseline network adjustment so this particular software has inbuilt atmospheric corrections models and the horizontal accuracy is above 3 millimeter and the elevation accuracy is above 5 millimeter so the calculation of the coordinate was done at a speed once per 5 second and achieving millimeter level accuracy and the solution data is transmitted to the server from the monitoring station at a speed once for 5 second through the GPRS 4G system medium and the coordinates and the displacement speed and acceleration calculation of the monitoring points can be read and downloaded at the port of the webpage version of the ground disaster monitoring system so in this particular study they have developed a portal web base website and where the data is stored and which also sent the relevant alert information to the user by detecting whether the deformation data was greater than the warning value critical threshold value.



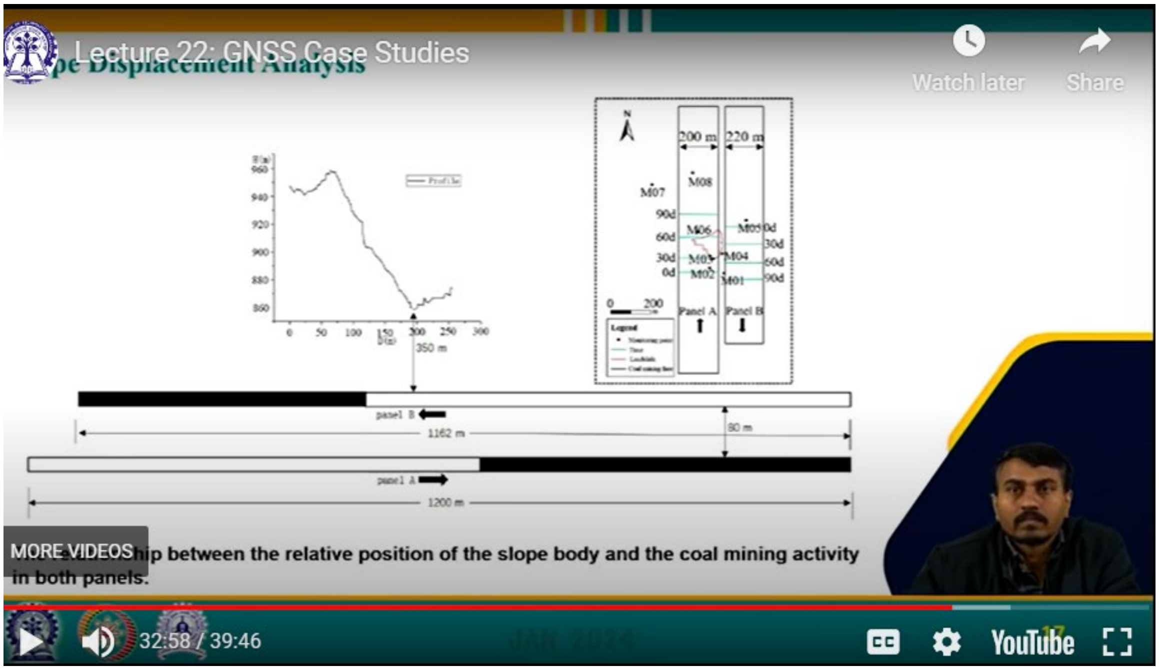
So similarly the rainfall sensor data and the video sensor data is also transmitted in real time through that same network so the data were transmitted in the same way to the GNSS monitoring module the end user can obtain deformation and the rainfall information as well as other data through the internet and via mobile phones the land differential location of the data of the monitoring system was obtained for a 90 days period in this study and was with an acquisition frequency of once a day so this is basically the slope movement profile okay and here you can see the panel a advancing in this direction so from 0 to 90 days this is basically the advancement of the panel a and the panel B started from this location to this location it reach after 90 days so now the contention is how these critical movement of these two panels is affected on the landslide prone zone and that we are measuring through these monitoring station M1 M2 M3 M4 M6 M7 and M8 okay and as I as I express that in this particular study the researcher are more interested to know the relative displacement of these monitoring point okay rather than the accuracy so relative displacement is very important here because of the opposite direction movement and the advancement of the panels okay and it has been observed that it has a very critical influence on the landslide and the surface movement and the development of the crack and fissures on the surface because of this complex plan of these two panels that is operated in the mine site so in this study the dynamic deformation of slope and the active state of overlying strata were assessed by setting real-time GNSS monitoring points according to the XYZ coordinates of each monitoring point the displacement and moving velocity of the monitoring points because monitoring points observed that it is moving okay in the 3D space were calculated and the factor influencing the deformation of the slope body in the mining area were analyzed in this particular study so this is the complex graphs that shows the displacement velocity of the different monitoring points.



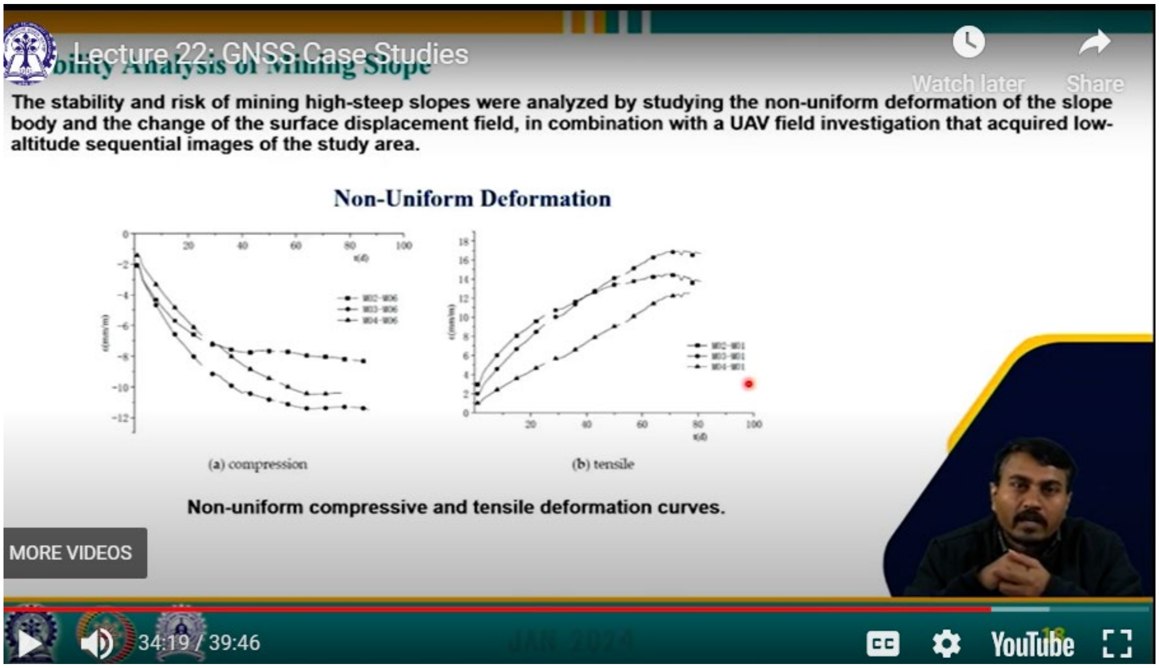
So, the red is basically the X profile X velocity profile and the green is basically the Y velocity profile and the blue is basically the Z displacement profile as velocity profile so these velocities measured with the unit of millimeter per day okay so you can pretty well see that the pattern of the M2 monitoring station M2 and M3 is bit similar bit similar so and in fact because 7 and 8 is located far away from the active working environment active working panel of the mine so it has been observed that there is no impact of the movement in this particular area 7 and 8 okay so there is huge amount of influence in M6 okay in the Z direction okay and in both also here also in the M5 Z direction velocity is very high so these data has been saved for the 790 days so now these data were analyzed and is a statistic been tried to develop and we have compared with the baseline data the rate of displacement between the points of stations so what is the rate of displacement of the point 2 3 4 2 3 4 in reference to 1 because 1 is situated at the top on the top side of the slope and 6 is situated at the bottom of the slope so what is the rate of displacement of the 2 3 4 station in reference to point 6 so that is the interesting study of this particular study been conducted for and they have observed an interesting data for this particular data with this data so this is the interesting data you can see that continuously we are measuring the displacement of the monitoring station 1 monitoring station 2 monitoring station 3 and after the monitoring station 8 and you can observe pretty well the displacement in the 7 and 8 is very very less okay.



So, it is it is obvious that it is not been impacted and also the pattern of the 2 and 3 and the displacement also more or less same in the velocity we have seen that it is the same but amplitude that is the value is is little is up and down okay so now we are trying to assess the trajectory of the terrain how it is impacted due to the work of the underground mines with this data and with this data we are basically compare with the one station data with the other station data and how there was a relative displacement and when there is a relative displacement is observed between the station on the surface you can pretty well assess that maybe the station coming closer to each other so that would be the compression so epsilon compression this study has calculated and also it has this study also calculated that some of the station is going far away from each other so there is a tension okay so that rate is also been calculated so there is an interesting study so to understand that study very well now we are elaborating you the two different patterns that is operating panel B going in this direction panel A going in this direction and panel A is around 1200 meter length okay and panel B similar 1162 meter and it is basically panel A is around of four to five meter height C my it is 2.6 meter panel height and both with these more or less 200 meters okay and it is exactly situated below of this particular surface so now we want to know because this is the red zone is this is the landslide prone zone that is already reported in February 2017 so we are now conducting this study to to know how much impact at the bottom point at the top point due to the advancement in the two panels panel A and panel B.

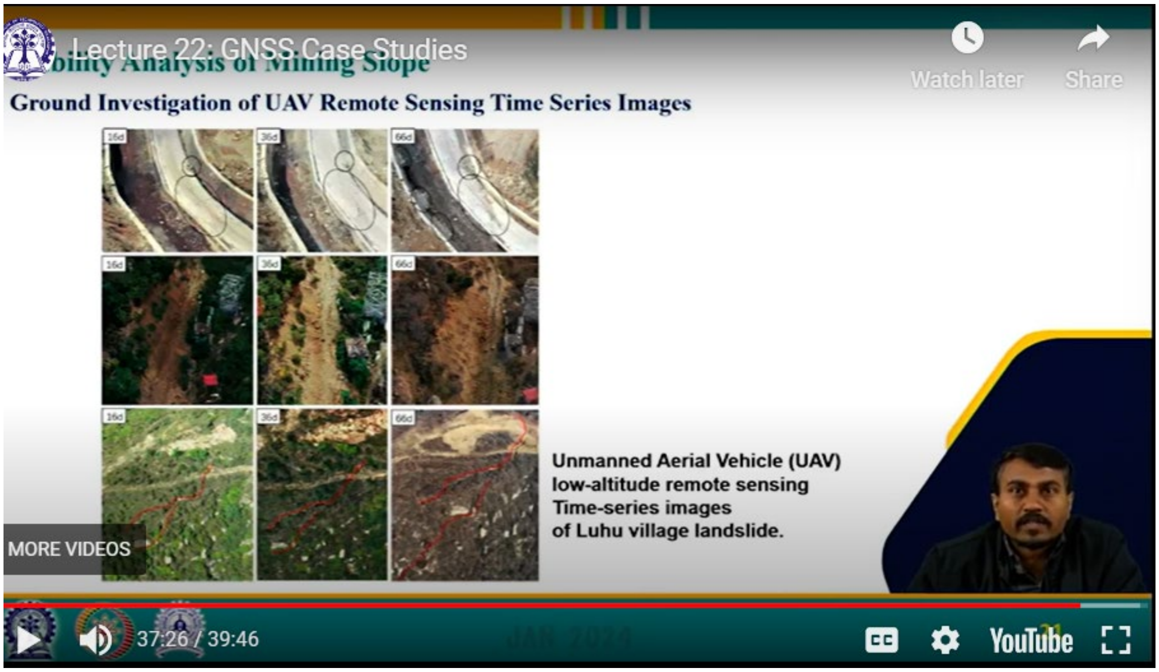


So, this is the interesting one as I express that this been observed that monitoring station 2 3 & 4 monitoring station 2 3 & 4 with reference to monitoring station 6 it is compression okay so monitoring station 6 is situated at the bottom so movement is going in this direction okay so it is contraction so the rate of contraction is measured in millimeter per meter millimeter per meter the distance between these points location okay and also the con tension station 1 is located at the top that is the monitory station 1 and the movement of 2 3 4 it is going towards the M6 so there is a tension is also developing so this non-uniform distribution of the displacement is basically the cause of the surface crack developed and the landslides occur that is basically the end analysis that is found out this from this study.



So, this particular study also accurate the data using the UAV and also the low height remote sensing technology they accurate the data and checked it the accuracy of the gene access data and it is pretty well matched what is been observed here and you can easily understand because of this compression and the tension in the same site in opposite direction cracks basically developed so this is also an another interesting study from this particular study that these observed the contour of the map of that particular terrain this is basically the landslide prone zone and you can pretty well understand the maximum minimum displacement minimum displacement around this location on the side of the landslide prone zone and here it is the maximum prone displacement in this particular site blue site and it is after 16 days of the work that we have given you the table that work started from 0 day to the 90 day and 36 day 66 days and 90 days and after 90 days you can observe some cracks are developing on the on the upside of the slope on the upside of the slope because after of the slope we have observed from the monitoring station 1 to monitoring station 2 3 4 there was a tensile deformation is developed mm per meter distance ok so because this is basically the reason of the development of the cracks

So, this particular study also conducted an UAV study and UAV data acquisition and that has been verified that in the point a you can see point a is located near to the west side of the point 2 ok and here it is the cracks developed and these cracks have been observed that around 20 meter length it is cracked is developed some of the some of the cases and the crack depth is around and the crack width around 30 to 50 centimeter as well ok and also there was a some differential displacement ok so point B on the road it is cracked developed so B is between point 1 and point 2 ok and is at the foot of the slope that is M2 that is this is basically the point and this is the D is basically the toe of the body slope so there was a some compression and the road has been dislodged and E and M located at the road of the slope foot near the point M6 these are basically the road being being damaged so this side ok so this is basically the impact of the working and that is being captured from the GNSS monitoring stations so this is from the UAV remote sensing time series analysis data that has been captured in this particular study after 16 days you can see that some of the cracks developing after 30 days another crack developed and the 66 days cracked developed and like so and so you can see the development of the crack in different zones on this particular area in the 66 days in this particular Luhu village of this particular mine site.



So, this is the reference.

That is the case studies we have used and let me conclude in few sentences what is basically the outcome of the study so we have seen that GNSS receiver stations capturing very accurately the displacement and the rate of displacement in in the hilly terrain where underground mines is going on and we now been able to understand that if there was a displacement 20 millimeter per day then there is a possibility of developing landslides so they this study has basically developed the threshold value of the rate of displacement so 20 millimeter per day displacement if they are then it is developing a landslide and it was found that rainfall impact is not very high only when during the rainfall intensity is 15 millimeter per day above that and it is infiltrate then impact is been basically observed in the in the movement of the surface and also in this study we have conducted the non-uniform distribution and the deformation analysis and we have observed that it has a direct impact and based on that it has been found that deformation was uniform when there was a when there was a slow movement in the in the mine and it is found that non-uniform and asynchronous deformation was mainly concentrated in the influence zone ahead of the working area and the history take influence zone behind the working phase was the main area of surface of students.

Thank you