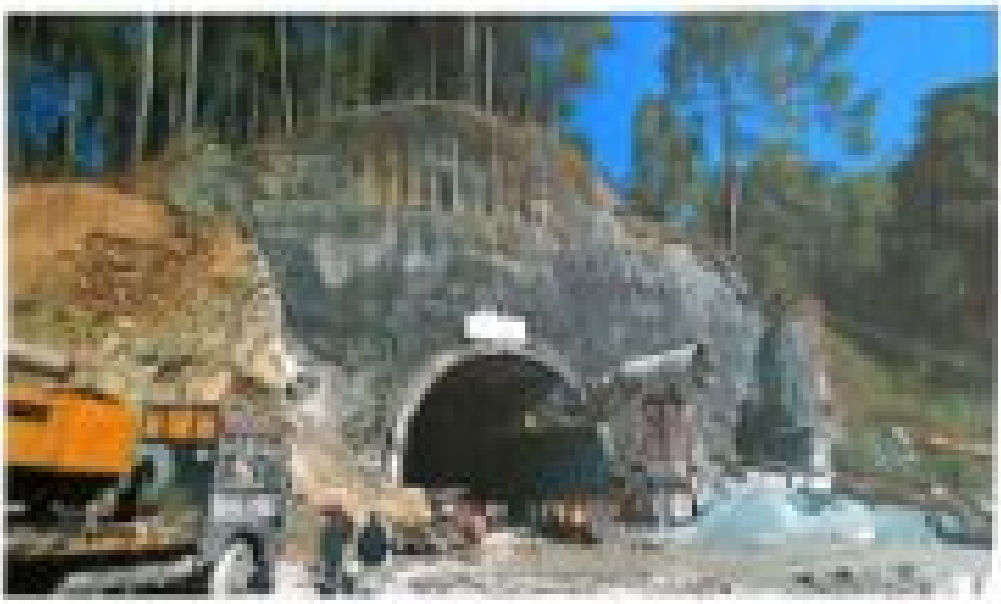
A

Report on

Silkyara-Barkot Tunnel (Uttarkashi) Collapsed Disaster



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1. Introduction

Under the prestigious Chardham Project of the Government of India to join the pilgrim Gangotri and Yamunotri under the Kedi gara area, the Silkyara Tunnel for a length of 4531 meters is under construction by NHIDCL through M/S Navayuga Engineering Company Ltd. for a total cost of Rs. 853.79 crore. The tunnel construction shall immensely benefit the pilgrims and local peoples as it will provide all-weather connectivity and shorten the distance by 26 km and 01 hours of travel time through steep, mountainous, narrow roads prone to accidents and landslides.

2. Incident detail

On November 12, 2023, the construction faced a setback. The excavation work, initiated between Chainage (Ch) 260m and Ch 263m, encountered an unexpected incident around 5:30 AM. A tunnel roof collapse transpired between Ch 205m and 260m, specifically in the area where re-profiling of the right-hand side of the tunnel cross-section was underway. 41 workers were trapped inside the Tunnel.

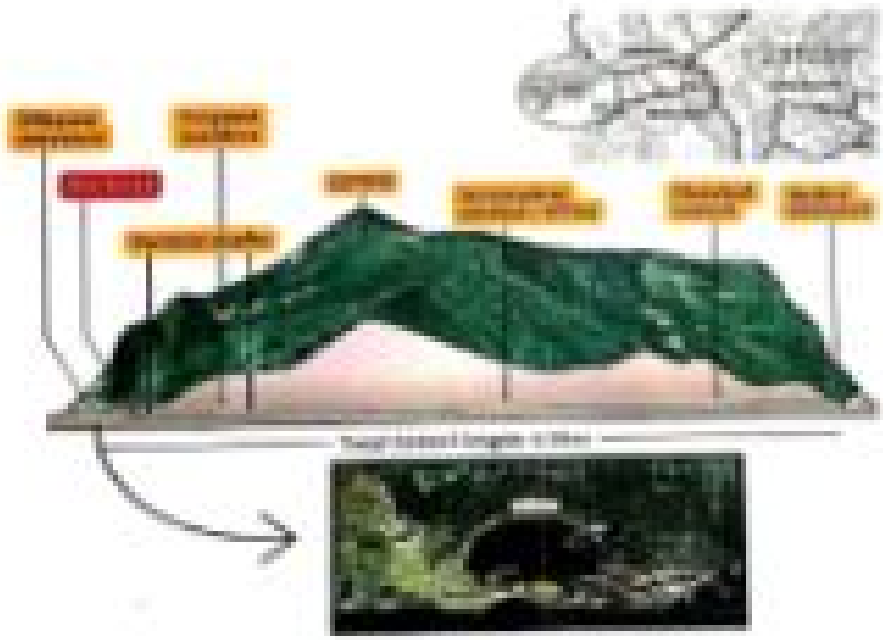


Figure 1: Schematic 3D view of Silkyara Tunnel

3. Profile and Geology

The tunnel alignment lies in vicinity of Indo Tectonic as. (IMT in SW corner and TMT NE corner between Kilpara head and Bukan head passes through Bodi Top and is located 1½ km south of Uttarkashi town (Fig. 3). The slopes have a considerable overburden that supports a thick forest of Oak, Rhododendron, Deodar and Pine. The azimuth of the tunnel alignment is 215±5N. The foliation of the rock has a 45° dip with direction N240°. The alignment of the Tunnel makes a 0° angle with the foliations of the rock, which is parallel (data available from the geological record). The shear zones follow the trend of the foliation plane and run for a considerable distance along the tunnel alignment.

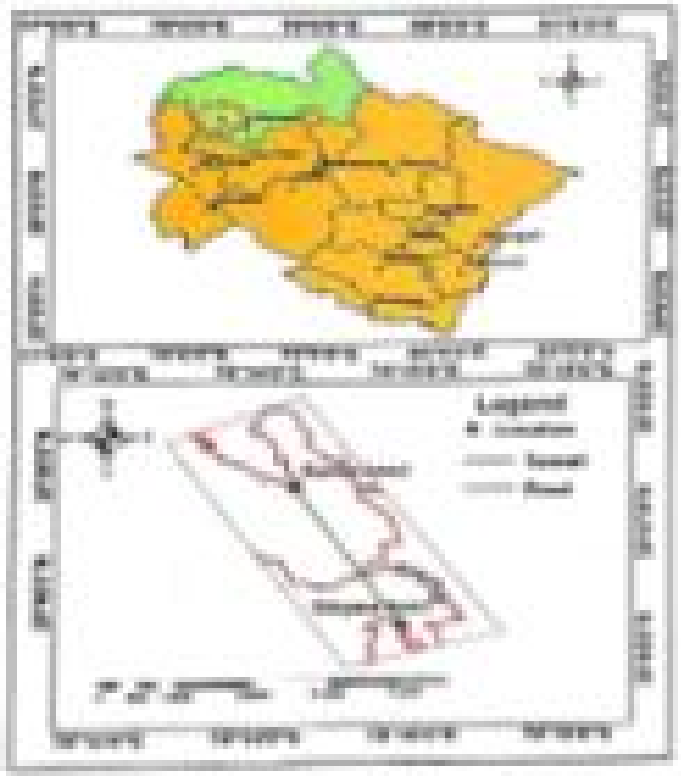


Figure 2: Location map of the Tunnel

The tunnel alignment falls in the inner part of the Lesser Himalaya in Uttarkashi District of Uttarakhand. Geologically, the area is occupied by the rocks belonging to the Garhwal groups of Meso-Proterozoic age and Jaunsar Group and Mesa-Chakrata Formation of Neo- Meso-Proterozoic age and unconsolidated Quaternary deposits of Pleistocene to Holocene age. Mesa-Chakrata Formation has a tectonic contact (North Almora thrust (NAT) with the rocks of

Oxford Group, and the rocks of Oxford Group are dated along the NW–SE axis. The
portion of the study area belongs to the upper Oxford–Chandler Formation of the Jurassic
group of rocks represented by clay, pebbles, gravels, sandstone, and basin limestone (Fig. 3).

Figure 3: Geological Map of the study area (GSI compilation, 2016)

A subsurface fracture zone (SFZ) was identified in the northern part of the study area, trending NW–SE and dipping steeply (~75°) to the NE. The SFZ is interpreted to be a reactivated basement lineament that has influenced the deposition and subsequent erosion of the Oxford Group rocks. Its presence is inferred from a linear zone of anomalous gravity and magnetic lows, and from the alignment of several springs and deeply incised gullies. The SFZ may act as a preferential pathway for groundwater flow, and its hydraulic properties are discussed in Section 4.

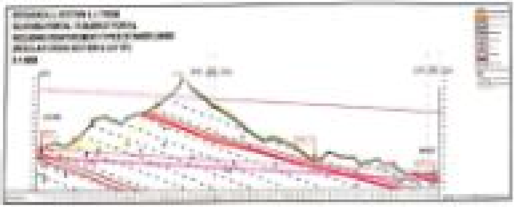
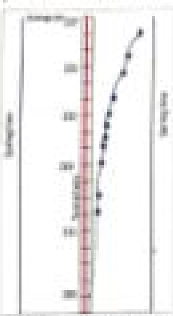


Figure 4: Geological section along the tunnel length

Notably, two distinct shear zones are evident as we move toward the tunnel portal. The first shear zone is marked at 1700 metres from the portal, and the second is identified at 1740 metres, approximately 130 metres from the portal. Both shear zones align parallel to the foliation planes of the rock, emphasizing the significance of geological considerations in understanding and mitigating the risks associated with subsidence and collapse in the tunnel construction project. From the available face logs, the 3D geological log is prepared for the shear zone in this reach to get a first-hand assessment. The shear zone thickness is 100cm at some places containing pulverized and crushed rock mass.



As per available face logs, this shear zone appeared from Ch. [illegible] km and continued along the foliation trend along the right side of the tunnel arch till Ch. [illegible]m. The tunnel records reported over-breaks and cavity formation between Ch. [illegible] km and [illegible]m. The condition of rock mass found on the face logs is folded strata, indicating deformation suffered by the rock. An attempt has been made to plot the shear zone tentatively from the available face logs with tunnel axis, as shown in Fig. 5

Figure 5: shear zone represented from available face logs with tunnel axis

4.2 Methodology of Tunnel Design

The design methodology encompasses primary support, permanent support, seismic design, and various support elements. Shotcrete, rock bolts, and steel ribs constitute the primary support, while concrete lining is the permanent support. The general steps followed in the design of the Tunnel are as follows:

(a) **Rock Mass (Ground) Characterization and Determination of Excavation & Support:** Site investigations and expert rock evaluations are crucial for characterizing the rock mass. This information informs decisions regarding excavation methods and the type of support required.

(b) **Structural Analysis of Tunnel Supports:** Structural analysis, employing wedge analysis for discontinuous rock, is utilized to predict rock block behavior. This analysis helps determine whether the support measures can prevent local block failure.

(c) **Modeling of Passive Initial Support Arrangements:** Full-bolted passive support is necessary for areas with a low cover or highly fractured rock masses. This typically involves steel ribs or lattice girders embedded in shotcrete to stabilize tunnel sections effectively.

(d) **Seismic Design:** Tunnel structures must be designed to withstand seismic ground acceleration, focusing on ground deformations induced by seismic waves. This design approach assesses the structural integrity of the Tunnel during seismic events.

(e) **Final Lining Design:** The final lining design accounts for external cross loads, self-load of lining, external surcharge, and seismic loading. It aims to provide the Tunnel with a structurally sound and aesthetically pleasing finish.

(f) **Extreme Tunnelling Conditions:** In challenging conditions like the Himalayas, high in-situ stress, and poor quality, weathered rock mass necessitates careful excavation planning. Potential issues such as squeezing and rock bursting phenomena must be considered and mitigated.

(g) **Tunnel Instrumentation:** Instrumentation, including deformation and stress measurements, is crucial for real-time monitoring. Deformation instruments along the tunnel walls and roof track vertical, horizontal, and longitudinal components. Stress measurements provide critical information about the forces acting on the tunnel structure.

4.3 Construction Methodology for Tunnel

(a) The sequential work cycle for tunnel excavation and support installation involves critical steps such as excavation, spoil removal, mesh nets, lattice girder, anchors, shotcreting, and installation of rock bolts. This systematic approach ensures the efficiency and safety of the construction process. Following are the general steps in the construction of a tunnel:

(b) Construction Management: Effective construction management is crucial for successfully executing tunneling projects. This involves meticulous planning, resource allocation, and coordination to ensure the construction process aligns with project goals and timelines.

(c) Construction Sequencing: The order and timing of construction activities play a pivotal role in the efficiency and safety of tunnel construction. Proper sequencing ensures that each step is executed logically and systematically, minimizing risks and optimizing progress.

(d) Monitoring: Installing instrumentation for continuous monitoring is imperative to track the behavior of the excavated tunnel and the surrounding rock mass. Monitoring aids in assessing and optimizing the implied support, contributing to the overall safety and stability of the construction site.

(e) Health and Safety: Prioritizing health and safety measures is paramount in tunnel construction. Comprehensive protocols and practices must be in place to safeguard the well-being of the personnel involved and mitigate potential risks associated with the challenging tunneling environment.

5. Observations on Sillgara Tunnel DPR

The general design methodology for the rock support system followed in the Silgara tunnel is as follows:

Step-1: Evaluation of the rock mass quality (Q) post excavation.

Step-2: Estimate the parameters like the length of rock bolts and their spacing by different empirical relations as per the IS Code method for different rock classes.

Step-3: Calculate road and wall support pressures as per IS Code.

Step-4: Perform detailed calculation and find suitable shotcrete thickness and spacing of rock bolt.

Step 5: Adopt the rock support measures.

Stress Deformation analysis was carried out for all classes of rock mass. The maximum predicted displacement of the Tunnel (in Class F type rock) was 128 mm. Tunnel closure is in the range of 256 mm in the present analysis, which is less than 3% of the excavated span, and it falls under the commonly accepted limit for rigid support systems as per IS Code Standards. Class A, B, C, D, and E tunnel closures in rock mass are 16mm, 28mm, 102mm, and 140mm, respectively, which is well within the allowable limit. It is also observed that the material behavior improves with increasing RMR values. The yielded rock mass zone remained within the rock bolt lengths. Hence, based on the analysis, different support measures were prescribed for different rock mass classes. This includes shotcrete, rock bolts, lattice girders, and pipe roofing. The DPR tunnel rock support design for all five rock mass classes has been given in detail.

The geotechnical design parameters have been recorded from the available DPR. These parameters are used for the analysis and design of rock support structures. It is noted from drill holes' information at both the portals that the UCS values of intact rock were in the range of 80 to 40 MPa, whereas the modulus of elasticity of the same is 25 to 20 GPa. Moreover, the following observations are also recorded in the DPR:

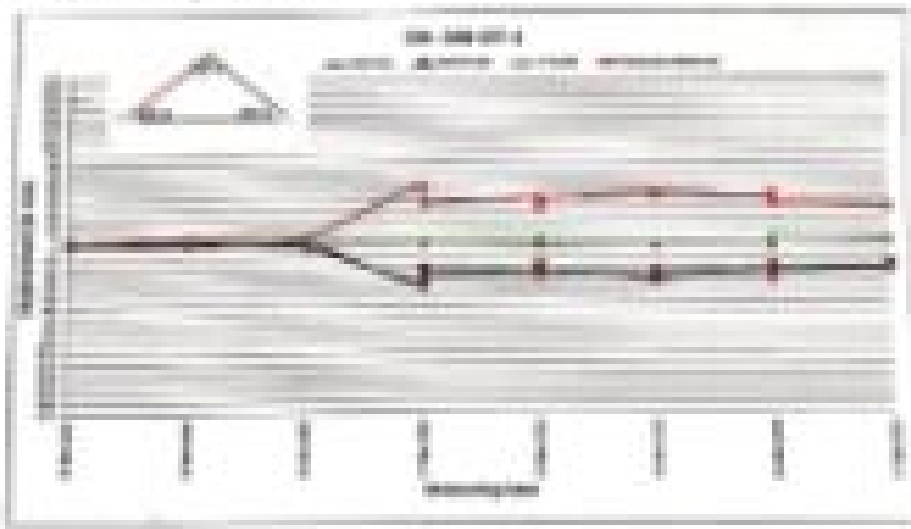
- **Discontinuities & Rock Mass Parameters:** An understanding of discontinuities and rock mass parameters is essential for assessing the stability of the Tunnel. It involves a comprehensive analysis of the structural characteristics and behavior of the rock mass surrounding the Tunnel. For the present Tunnel, three major discontinuities encountered along the tunnel portal area are taken as references for discontinuities along tunnel alignment for doing UnWedge analysis. The direction of tunnel alignment is 011°/5°. The possibility for wedge formations due to the intersection of the joints defined above is also checked with UnWedge software. The formation of wedges due to these joint sets without any support system and with a support system has been analyzed. All these rock mass parameters for all the five classes, A, B, C, D, and E, were determined/estimated. The necessary parameters for concrete lining, rock bolts, shotcrete, and steel ribs have been determined and mentioned in the DPR.
- **Wedge Stability Analysis:** Wedge stability analysis is employed to evaluate the stability of rock wedges within the Tunnel. This method helps identify potential failure mechanisms and informs the design of support systems to mitigate instability risks.

- ***Design of Rock Support:*** As per the geological report, the ground rock mass along the Tunnel was estimated. The values of different geo-mechanical parameters for different classes of rock were adopted for the design of rock support. Support pressures were calculated to assess the ultimate rock support pressure on the roof and wall for squeezing and non-squeezing ground, involving ultimate roof support pressure and ultimate wall support pressure.
- ***Concrete Lining:*** Concrete lining is critical in providing permanent support to the tunnel structure. The design and implementation of the concrete lining are essential for ensuring the long-term stability and durability of the Tunnel.
- ***Shotcrete:*** Shotcrete serves as a primary support measure for tunnel excavation. Its application involves spraying concrete onto the exposed rock surfaces, enhancing the immediate stability of the Tunnel during construction.
- ***Rock Bolting:*** Rock bolting reinforces and stabilizes the rock mass. It involves the installation of steel bolts into the rock, providing additional support to prevent collapses and enhance overall tunnel stability.
- ***Steel Rib:*** Using steel ribs contributes to the support system within the Tunnel. Embedded as elements, steel ribs provide structural reinforcement, particularly in areas with low cover or highly fractured rock masses.
- **Empirical Design of Rock Support:** An empirical rock support design is undertaken based on the geological report. This involves an assessment of the general rating of the rock mass, informing the selection and implementation of appropriate support measures.
- ***Estimation of Support Pressures:*** The estimation of support pressures follows the guidelines outlined in Section 3.3 of IS 11363 (Part-2) 1992, providing a standardized approach to determining the support requirements for the Tunnel.
- ***Ultimate Roof Support Pressure (for Crown):*** This parameter addresses the ultimate support pressure required for the Crown of the Tunnel, ensuring that the roof remains stable under various conditions.
- ***Ultimate Wall Support Pressure:*** Similar to the roof, the ultimate wall support pressure is calculated to determine the necessary support measures for the Tunnel's sidewalls.
- ***Roof Pressure for Different Classes of Rocks:*** Considering variations in rock classes, the roof pressure is assessed differently for each class, ensuring that support systems are tailored to the specific geological conditions encountered.

- ***Stress-Deformation Analysis for Tunnel:*** A stress-deformation analysis is conducted to evaluate how the tunnel structure responds to the applied stresses during excavation. This analysis aids in predicting potential deformations and optimizing support measures.
- ***Support System for Different Rock Mass Classes:*** Different rock mass classes may require distinct support systems. Tailoring the support approach to the specific characteristics of each rock mass class is essential for ensuring effective stabilization.
- ***Wall Support Pressure – Shotcrete and Bolt:*** The assessment of wall support pressure involves the combined use of shotcrete and bolts to reinforce and stabilize the tunnel sidewalls, ensuring the overall stability and safety of the structure.

6. Monitoring of Tunnel by Instrumentation

Instrumentation has to be installed to monitor the behavior of the excavated Tunnel and the rock mass around the Tunnel. Monitoring assists in determining and optimizing the required support and also helps in making decisions regarding safety measures. NHIDCL monitors the movement in different sections of the Tunnel by collecting periodic data through the total Station. NHIDCL mentioned that they do the monitoring survey and collect data every week. NHIDCL provided displacement data of some sections after the collapse from 14 to November 21, 2021. The displacement monitoring data of Tunnel left, right axis, and crown for chainage 180 and 190 are shown below (Figures 6 to 11). The absolute deflection has been seen in the provided sections. The past monitoring data of the Tunnel and other engineering data from Chainage 190 to 270 are required to ascertain the actual cause of the tunnel collapse. Proper investigation reports from expert agencies (GSI, ITA, CBRI, Works, etc.) shall be asked for future action and safety measures.



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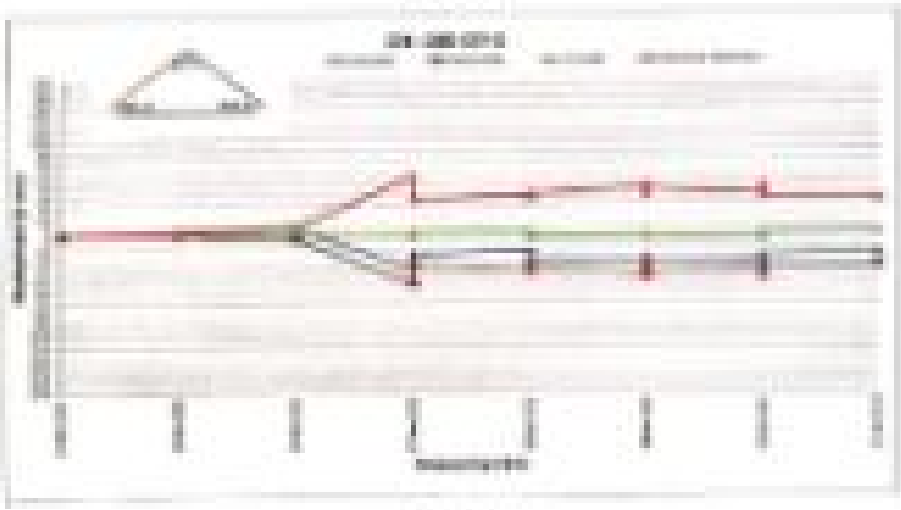

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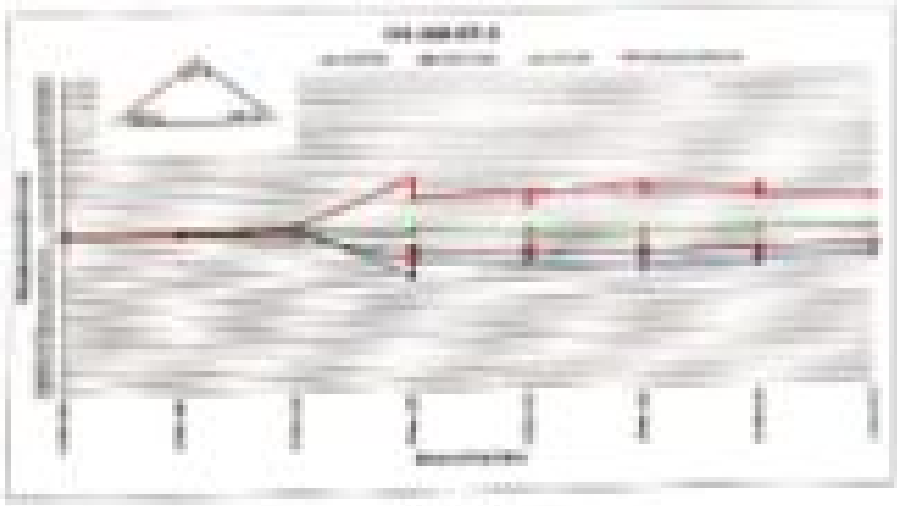

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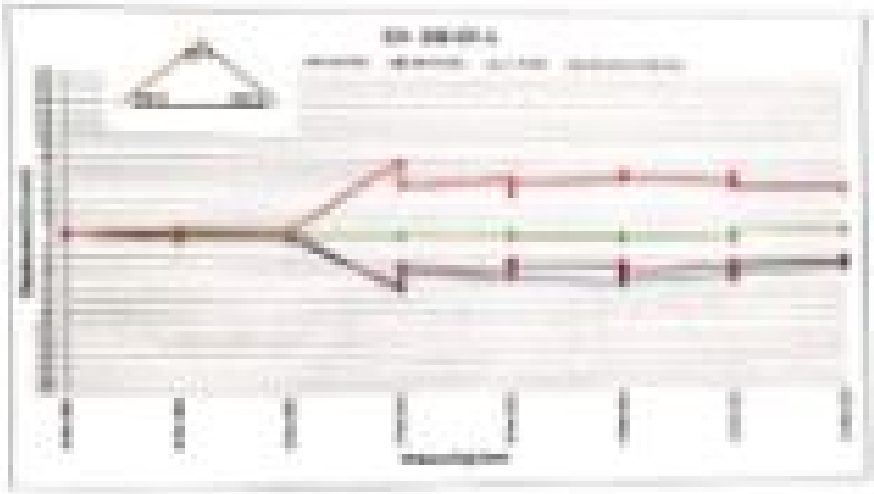

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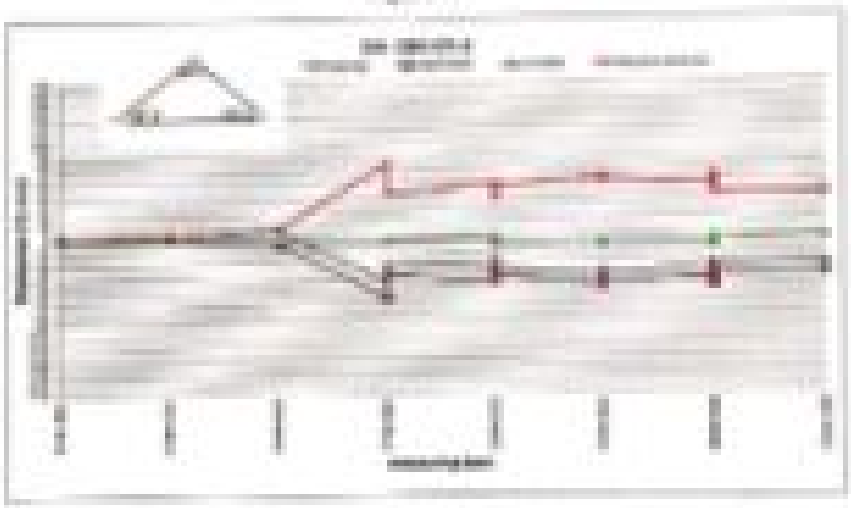

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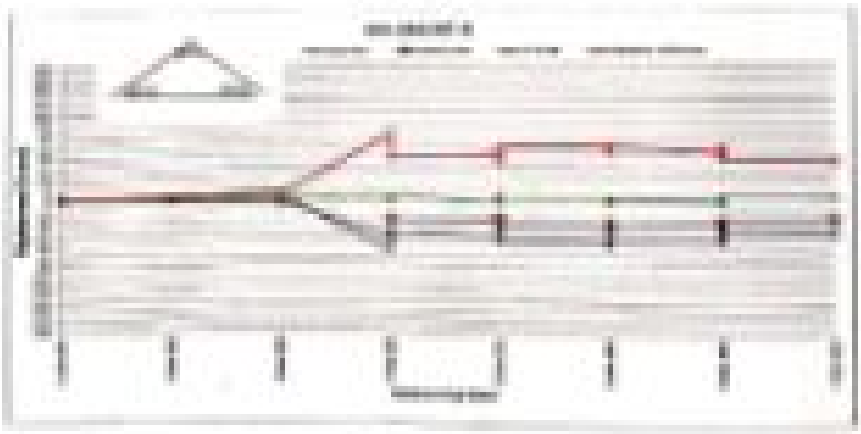

Figure-11

7. Search and Rescue Operation for Collapsed Silkyara Tunnel

In the aftermath of the tunnel collapse incident, a series of urgent and coordinated rescue and relief efforts were initiated to address the situation and ensure the safety of the trapped workers. The combination of these rescue measures demonstrates a comprehensive and strategic approach to address the challenges posed by the tunnel collapse. The collaborative efforts of experts and the deployment of specialized equipment underscore the commitment to ensure the safety and well-being of the individuals affected by the incident. Through a "Whole of Government" approach, the rescue of all trapped workers was successfully carried out. Many state and central government agencies deployed resources and expertise in a cohesive team spirit. The successful conduct of such a complex rescue operation provides a great learning experience for all the different domain agencies that worked during the operation. The following central, state, and private agencies are deployed in this operation:

1. Ministry of Road Transport and Highway (MoRTH), Govt of India
2. Government of Uttarakhand (All Concerned Departments like Disaster Management, District Administration, Police, SDRF, PWD, Health, Water Supply, Civil Aviation, Geology and Mining etc.)
3. NDRF
4. Indian Army
5. Geological Survey of India (GSI)
6. Coal India Ltd.
7. NHIDCL
8. ONGC
9. GVFL
10. BVSL
11. THDC
12. DRDO
13. BRO.
14. Navayuga Construction
15. Private agencies and skilled worker

8. Approaches for Rescue Operation

8.1 Life Support to the Trapped Workers

Immediately after the Tunnel collapsed, the main focus was to provide a life support system to the stranded workers. Two horizontal directional drilling (HDD) machines were mobilized to create a pilot tunnel through the debris for the insertion of 100mm/150mm/200mm MS pipe to ensure the following:

- Supply fresh air continuously
- Supply of drinking water
- Establish communication with personnel inside the Tunnel

After successfully inserting one 6-inch/100 mm pipe, water, food, and oxygen were pumped inside the pipe with compressed air. The life support essential requirement has been successfully received by the stranded workers. All the stranded workers are safe, as they communicated.

Realizing the extended period of the rescue operation and anticipated future challenges, on November 18, 2023, construction of an additional pipeline (8-inch/150 mm) for life support at the right side of the Silkyara end of the Tunnel was started. After the 3rd attempt, another 150 mm diameter steel pipe lifeline service was pushed through the debris on November 21, 2023. Over this life support line, the stranded workforce established the video connection. Also, proper food packets of Dal, Rice, Roti, Sabji, dry fruits, and medicines were sent regularly through this pipe. The timeline of complete rescue operation is also annexed with this report to capture the complete story (Annexure-B).

8.2 Excavation and Shotcreting of Tunnel Line

Initially, after the crown of the collapsed Tunnel, debris/muck removal from one side of the Tunnel and shotcreting of the exposed face commenced. Excavation with shotcreting was done for 45 meters of the collapsed Tunnel. However, after observation of cavities formed 10 meters above the Crown on both the left and right sides, mucking and shotcreting were stopped.

8.3 Rescue Plan

The most suited and early rescue option is horizontal drilling of MS steel pipe through the debris at the Silkyara end tunnel. A decision has been made to use a 900 mm/800 mm diameter

MS Steel Pipe with the assistance of a Hydraulic Jack to create a pathway for evacuating the trapped workmen. Various options for auger machines have been explored. The first auger machine was found incompatible with horizontal drilling. After that, another high-power drilling machine was imported from New Delhi. Fabrication of base for installation of auger machine has been done so that proper pushing of pipes can be executed with slightest vibrations.

On November 19, 2023, after 33-meter pipe pushing and during the positioning of the 34th pipe, it was reported that the auger machine could not push further as the machine was getting tilted and the bearings of the machine were damaged. Therefore, it was planned to fix the machine with welders to avoid uplifting. After a detailed discussion, it has been decided and agreed by the expert executing agency that 900 mm diameter pipe pushing can only be feasible if the auger machine and pipe both are on the same inclination. After that, additional plates are put up below the platform to modify the machine mounting platform. During the further execution of the drilling at mid-day, the workforce agencies, security personnel, and local police heard a large-scale cracking sound, and the team working inside the Tunnel created a panic situation in the Tunnel and the team working. Consequences of the incident: The General Manager, NHIDCL, has described similar cracking sound/noise/symptoms on many previous occasions of cavity formation/collapse in the vicinity from chainage 100 to 200. Accordingly, pipe-pushing activity has been stopped.

Further, a meeting was called with all officials and other experts from various organizations to take future actions and cope with the situation. On November 08, 2023, senior officers from PMO, MoRTH, State Government, and NHIDCL visited the Tunnel and the top of the tunnel road to take further action. After that, a meeting was organized under Shri Bhaskar Kulbe (IAS) and all senior officers from GoI and State, representatives of various organizations (BRO, RVNL, RITES, IOTPL, THDC, etc.), and tunnel experts. Finally, after discussing various rescue operations options, five plans were decided to evacuate the stranded workers as soon as possible. The line diagram of parallel rescue plans is given below (Figure 11), and the details of each plan are subsequently discussed.

Section Plan - 1: Strengthening of Tunnel and construction of escape route by HSDC (Jullapur Jungle - 3.7 m, from Ch. 333.10 to 340)

Rescue Plan – 3 (B): Vertical drilling (8") by RVNL at Silkyara end

Envisaging the threats of failure in various rescue operations, another life support project has been planned through a vertical drill hole over the Silkyara tunnel end at Chainage 220. The vertical drilling of an 8" pipe was given to RVNL. BRO has completed the access road of 1150 meters and handed it over to RVNL on November 26, 2023. Also, an electric connection has been provided to RVNL. The machine for vertical drilling has been towed to the location by BRO. The platform for the drilling rig was completed on the morning of November 26, 2023, and drilling was started immediately after this. A total length of 72 meters was drilled till November 28, 2023.

Rescue Plan – 4: 24" Vertical Drilling at Barkot End by ONGC

The other end of the Tunnel on the Barkot side was also taken as one option for the rescue operation. The ONGC team has taken responsibility for vertical drilling at Barkot's end. The team head of drilling with experts visited the site on November 26, 2023. After the reconnaissance survey, BRO has prepared the road alignment to reach the drilling site. ONGC has transported the air drilling rig from Indore. All the associated material of the air hammer drilling rig was mobilized by ONGC and on standby at Rishikesh for further instructions, waiting for BRO's finishing of the approach road. Out of the 1600-meter road stretch, the BRO team has completed 1050 meters of approach road by November 28, 2023. Further operation was stopped because of the breakthrough at Silkyara's end.

Rescue Plan – 5: 480-meter tunnel construction by THDC at Barkot end

The escape tunnel from Barkot's end was considered one option to rescue the trapped workers. The total length of the uncompleted Tunnel at this end is 480 meters. THDC was allocated this task to make an escape tunnel. THDC made a site assessment and brought their workforce and machinery. Micro-tunneling machines were mobilized, and a rib cage of 2mx2m was started. THDC started drilling work at the Barkot end, and the first blast for the Tunnel was done on November 26, 2023. After each blasting, mucking was done, and drilling for rock bolts and rib erection work in the portal area was executed. This option took more time, and till November 28, 2023, the excavated length of shift was only 11.20 meters. Fabrication work of 18 numbers of ribs has been completed during this time span.

Rescue Plan - 6: Creation of side Drift inside Tunnel through the debris at Ch. 203 by Indian Army

From the right end of Silkyara, drift inside the Tunnel through the debris at Chainage 203 was considered, and the army was deputed for design and fabrication work. The section of 1.2mX1.5m design has been finalized, and fabrication started on November 21, 2023, by army welders. 22 numbers of frames have been fabricated and completed by November 28, 2023.

9. Deployment of Manpower, Resources, Expertise and Technical Knowhow in Rescue Operations

In the aftermath of the collapse of the Silkyara tunnel, the state government immediately activated the incident response plan. The State Emergency Operation Centre (SEOC) and District Emergency Operation Centre (DEOC) are continuously in touch with officials of NHIDCL and contractor M/S Navyuga Construction. The rescue efforts focused on the 2 km section of the Tunnel, with completed concrete work ensuring the workers' safety. Various government agencies worked tirelessly on each assigned specific task to ensure the safe evacuation of the workers. National and international experts were also mobilized at the site to advise on the rescue operation.

The state government launched Operation "Zindagi" (means life) to save the trapped workers. Continuing their unwavering commitment to saving lives, the Central and State governments have actively engaged in the rescue operations at the Silkyara Tunnel in Uttarkashi, where 41 workers were trapped. The district administration of Uttarkashi has set up an onsite disaster operation center with all other line departments supporting the rescue operation. The District Magistrate (DM) and Superintendent of Police (SP) of Uttarkashi stayed at the Silkyara site and continuously monitored the rescue operation. Secretary, Disaster Management & Rehabilitation, Government of Uttarakhand, reached the site immediately after the event. SDRF, BRO, ITBP, Health, and Police reached the site, and the government of Uttarakhand has formed a six-member expert committee to investigate the cause of the tunnel collapse. The support provided to state government departments is given below and annexed at end of this report (*Annexure C & D*).

9.1 State Disaster Response Force (SDRF)

Immediately after the tunnel collapse incident, the state government positioned SDRF at the site. Commandant SDRF and around 50 skilled SDRF personnel were deployed onsite to evacuate 41 trapped workers safely. SDRF used various types of machines and equipment with sufficient quantity onsite. The expertise and technical knowhow deployed during the entire operation by SDRF in the Silkyara Tunnel collapse are as follows:

- **Search and Rescue:** Proficient SDRF search and rescue teams worked in the rescue operation, dealing with confined spaces and extracting individuals from collapsed structures.
- **Communication setup:** SDRF has established a modified and prompt communication system through which regular communication has been made to the trapped workers.
- **Logistic Management:** SDRF's skills in managing resources, equipment deployment, and swiftly coordinating personnel on site were a great boon.
- **Emergency Response Planning:** SDRF's expertise in creating and executing emergency response plans helped during the final evacuation of trapped workers through the escape rescue tunnel.
- **Leadership Communication:** Communication between leaders and government officials of different agencies to coordinate and strategize rescue operations.
- **Collaborative Rescue Operations:** Joint operations involving specialized teams like SDRF, NDRF, MEPCL, ONGC, etc., with the deployment of specific equipment.
- **Counseling and Morale Boosting:** SDRF provided psychological support and counseling to the trapped individuals to maintain high Morale during the crisis.
- **Safe Extraction:** SDRF utilized trolleys and specialized equipment to extract trapped workers safely.

9.2 State Police

The state police force has worked brilliantly to maintain law and order and manage traffic plans near the Silkyara tunnel. SP of Uttarkashi district himself made his availability at the rescue site along with all subordinate officers and police personnel. Police have set up a unified command center (Police Control room) at the site. The details of activities carried out by the police force are as follows:

- **Control room setup:** 14 technical personnel deployed for the police control room for smooth communication and coordination between control agencies and field units, providing handsets and static police wireless.
- **Police Chauki (Outpost):** A dedicated police chauki near the Silkyara tunnel was established. The police also set up the tented accommodation and mess.
- **Access Control:** Unified ID cards were issued by the police to identify the right persons and can only be entered by the site.
- **Maintenance of law and order:** Deploy local volunteers/ Apda Sakhis amongst the villagers to bond the trust deficit and respect the local deity (Bouddhaj Devta). A local intelligence unit has been activated for effective law and order control.
- **Providing Green Corridor:** Deployment of traffic police 24*7 in narrow and sliding patches with practical communication sets and deployment of road opening machines (JCBs) for track removal in sliding zones.
- **Management of Media:** Continuous and authentic content has been provided to avoid adverse reporting. A separate media gallery has been set up near the incident site to facilitate the media personnel. Proper access control was in place for media personnel. Also, effective social media monitoring teams were deployed to keep a check on rumors and fake news.
- **Safe Passage of Rescued Workers & Ambulances up to CHC Chinyalisaur:** A 'Green Corridor' was provided by police with an uninterrupted traffic route. The rescue ambulances were sent in Convoys with proper escort and 02 vehicles. Properly armed police operated the health center at Chinyalisaur, and effective monitoring with drones was carried out.
- **Access Control for Mobile and Cameras:** Proper sign boards were in place, and a mobile collection center was set up at the main gate of the Tunnel.
- **Contingency Helipad:** The police team has set up a contingency helipad at Syalsaur, nearly 7.5 Km from the incident site, foreseeing the requirement in the rescue operation.

9.3 State Health Department

After the aftermath of the event, state medical teams were positioned near the tunnel site. A specialist team of doctors was deployed at the site with all relevant para medical staff and life support ambulances. The nearby medical facilities at CHC Chinyalisaur and the district hospital

of Uttarkashi were ready to tackle any adverse situation. The following tasks were carried out by the department:

- **Regular Site Visit:** The team of the specialist medical team regularly visited the tunnel site. Counseling was done by a Physician and two Psychiatrists twice daily for the trapped personnel, and as per advice, medicines were accordingly provided to the trapped workers.
- **Emergency Services and Counselling:** Regular 24*7 OPD with emergency services was conducted near the tunnel site for the persons of different departments on duty, media staff, and staff of the tunnel company. Also, counseling and assurance of family members of the trapped persons was done regularly. Diet for the trapped workers was provided as per the advice of a specialist.
- **Medical Relief Post (MRP):** A temporary Medical Relief Post (MRP) was established inside the Tunnel at a safe location with appropriate equipment, infrastructure, and personnel deployed. All 41 trapped workers after the rescue were examined at MRP by the team of specialists and, after that, shifted via ambulance to CHC Chinyalisaur for appropriate management.
- **Ambulance Support:** 41 ambulances (10 ALS and 31 BLS) with well-equipped and trained staff were stationed near Silkyara. An Air Ambulance facility was also deployed at Chinyalisaur helipad. The AIIMS Rishikesh specialist also examined the trapped workers before being handed to the respective state authorities and family members.

9.4 Public Works Department

The Public Work Department (PWD) has regularly provided workforce and machinery support during the rescue operations. The engineering division of Uttarkashi Bhawan consisted of an executive engineer, assistant engineers, and junior engineers managing the transit of various officers and experts from various agencies at the site. PWD was also communicating with the families of workers trapped inside the Tunnel. The PWD accomplished the following works:

- **Deployment of machines:** During the rescue operations, different heavy machines were deployed at the site; therefore, PWD did the immediate road widening and cleaning of road works.
- **Construction of Temporary Helipad:** PWD constructed a temporary helipad at Brahma, nearly 1.5 Km from the incident site.

9.5 Water Supply Department

The water supply department provided support on drilling works. Senior officials of the department were deputed in the rescue operation work. The following tasks have been carried out by the water department (Uttarakhand Jal Sansthan & Uttarakhand Peyjal Sansathan Vikas & Nirman Nigam):

- **Availability of HSDPE Pipes:** A sufficient number of 600mm diameter and 800mm diameter HSDPE pipes were available from Ghaziabad (UP).
- **Auger Machines:** The water department provided the auger machine with parts and other accessories.
- **Tubewell Drilling and Water Supply:** A 1000-meter-long and 80mm diameter pipeline was established for the vertical boring machine. Also, the department has ensured the availability of drinking water for various rescue teams and people working day and night at the site.

10. Progress Monitoring of Rescue Operation

Senior officers from PMO, MoRTH, State Government NHIDCL, Army, and various tunnel expert agencies were present during the rescue operation. The experts monitored the progress of work with their total effort. Central government agencies, State government departments, district administration, Indian Army, NDRF, SDRF, BRO, THDC, ONGC, BVSL, SJVNL, RITES, and other experts have closely monitored the rescue operation. Mr. Arnold Dix from Australia (President of the International Tunneling Association), Nigel Weiss (Tunnel Safety from the UK), and Chris Cooper (Micro Tunneling Expert-UK) also provided their expert advice to the various agencies engaged at the site during the rescue operation. Hon'ble Chief Minister of Uttarakhand and General (Dr.) V.K. Singh (Retd.) Hon'ble Union State Minister for Road Transport & Highways and Civil Aviation, personally monitoring the rescue operation. Many PMO and State government senior officials also visited the site, provided their support, and advised during the operation for early evacuation.

11. Challenges encountered during the Silkyara Tunnel Rescue operation.

Silkyara tunnel rescue operation is unique and faces many challenges. The standard rescue operation procedure did not help much because they encountered several obstructions during the rescue operation. Also, the site location is in a fragile Himalayan mountainous region that caused unidentified hurdles. Some of the challenges that occurred during the rescue operation are listed below: -

1. The Tunnel has confined spaces and limited access points, making reaching the affected area challenging for the rescue team.
2. Due to the absence of a senior most local official or technically competent person in the initial phase of the rescue operation to decide the search and rescue methodology, the operation was delayed. This also made timely media briefings difficult.
3. Further collapse occurred during the initial removal of debris, adversely affecting the rescue operation.
4. Poor telecom connectivity at the site hindered smooth communication and coordination. The issue was resolved after a week by augmentation of network strength with the intervention of district administration and DOT.
5. Due to the non-availability of specialized equipment near the incident location, the initial few days were spent determining the required mobilization of resources. Handling logistics at the site was the major challenge in the rescue operation.
6. Transportation of some heavy machines and equipment was a significant challenge, considering the narrow road stretches, dramatic slide zones, and steep gradients.
7. Rescuers initially faced uncertainty about the conditions inside the collapsed Tunnel, including potential hazards such as hazardous materials, electrical issues, or unstable structures. Cold weather at the incident site, especially at night, posed a challenge.
8. During the rescue operation, dignitaries and senior officers visited the incident site, which was managed with limited resources.
9. It is a big challenge to work against time to reach and extract trapped individuals while ensuring their safety.

iii. The risk of further collapse of the Tunnel reveals the safety of rescue teams. Managing the risk of additional collapse or instability raises concerns while planning the rescue operations.

iii. Addressing the psychological impact on trapped individuals and rescue teams during the crisis was one of the critical tasks during the operations.

12.Innovations/ Measures Undertaken during Rescue Operations:

The Silkyara tunnel rescue was a unique operation, and numerous innovations and measures were undertaken during the rescue work. These innovative approaches and collaborative efforts played a crucial role in successfully conducting the rescue operations. A few solutions have been used for the first time and complemented the efforts. A few of them are enlisted below:

1. Underwater cable arrangement: SDRF has innovatively used underwater cables inserted through pipes to facilitate wireless communication.
2. Use of different sizes of MS pipe: During the insertion of 900mm diameter pipes, some obstacles were noticed, which obstructed pipe pushing work. Experts thought wisely and later used the safe pipe length of inserted 900 mm inner diameter MS mm pipes were pushed to avoid the other obstructions.
3. Parallel Rescue Approaches: For the first time in the tunnel rescue operations, parallel approaches were worked out, and such possibility was explored to save the lives of trapped workers.
4. Rescue inside the pipe: Trapped workers were extracted safely using specialized rescue equipment and stretcher trolleys inside the pipe.
5. Joint Rescue Operations: Collaborated with multiple teams like SDRF, NDRF, PSUs, private agencies, etc., for combined and synchronized rescue efforts.
6. Leadership and Counselling: The Government has worked holistically to make a successful rescue operation. Commitment from the top to bottom was shown in each and every step of the rescue operation. Leaders and senior officials were provided counseling and boosted the Morale of trapped workers and rescue personnel.

13.Lessons learned in the Silkyara Tunnel Rescue operation.

Many important lessons are learned to tackle similar types of rescue operations in the future. Some of these lessons, but not limited, are given below:

1. Keep the inventory details updated during work planning (capacity, details and availability of Machinery) which can be used in an emergency.
2. Identify and develop a temporary helipad facility near the vicinity of critical work sites, which can be used during emergencies.
3. Ensure the primary medical facility is near the work site during the commencement of work.
4. Identify the nearest Railhead and transportation facilities of heavy machinery to the work site. If there is any bottleneck at several locations on the highway, then maintain a record and take necessary remedial measures by the respective departments to transport these machinery.
5. Identify all resources (workforce and machinery) in the government, public sectors, and private agencies regarding their expertise and strength.
6. Ensure the workers engaged in such projects must be highly skilled and experienced. Also, keep the detailed information (inventory) of such skilled workers.
7. Implement stringent safety protocols in tunnel construction to prevent such mishaps.
8. Implement regular inspections and tunnel infrastructure maintenance to detect and promptly address potential risks.
9. Different telecom service providers must provide a robust telecommunication system at the work site.
10. Install robust and redundant communication systems within the tunnels for uninterrupted emergency communication.
11. Ensure sufficient stock of technical materials such as Steel pipe, transformers, steel pipes, HDPE pipes etc., and emergency funds for immediate response in a disaster/emergency.
12. The cause of the Silkyara tunnel collapse is a landslide, and the provisions of Disaster Act 2005 can be utilized for notification and fund allocations.

tunnel-related geological and construction concerns and operational setbacks in rescue operation plans. Several technical, managerial, and administrative observations/recommendations are outlined below to comprehensively understand future risk mitigation and improve preparedness for tunnel rescue operation methods.

1. **Specific SOPs:** Project-specific Standard Operating Procedures (SOP) for each incident/accidents should be formulated, and the workers will be provided with proper training.
2. **Technical Advisory Committee (TAC):** Constitution of Technical Advisory Committee (TAC) consisting of GSI, technical agencies like NGRI, Wadia etc., and experts of geotechnical and underground works agencies (SMEC, BVSL, etc.). Ensure the visit of TAC at regular intervals, and the committee's recommendations must be followed up.
3. **Comprehensive Emergency Plans:** Develop detailed and scenario-specific emergency response plans tailored for Tunnel collapses, focusing on rapid communication, coordinated rescue operations, and leadership strategies.
4. **Interdepartmental Coordination Committee:** Form an interdepartmental coordination committee at the National, State, and district levels for regularly monitoring critical infrastructural projects, especially in fragile Himalayan regions.
5. **Safety Guidelines:** Form guidelines for safety measures in underground works and regular checks/reviews of safety standards at the district/State level technical committee.
6. **Geological Cross-Section Analysis:** The geological cross-section reveals the intersection of three joint sets at 250m from the Silkyara portal, indicating a potential risk of wedge formation and roof collapse.
7. **Presence of Rock Bolts:** During the site visit, the presence of rock bolts was observed. These bolts reinforce and stabilize the rock mass, contributing to overall tunnel safety.
8. **Absence of Subsidence or Movements:** Notably, there were no indications of subsidence or movements at the top of the collapsed section, suggesting that the collapse might be localized.
9. **Detailed Geotechnical and Geophysical Investigation:** The Design Project Report (DPR) lacks detailed geotechnical and geophysical investigations. Future projects should prioritize comprehensive site studies to minimize unforeseen geological surprises.

10. **Comprehensive Geological Surveys:** Conducting thorough geological surveys before initiating tunnel projects is critical. This includes assessing rock formations, seismic activity, and potential risks to ensure that tunnels are designed to withstand the geological challenges of the region.
11. **Real-Time Instrumental Monitoring:** A critical gap is a lack of real-time instrumental monitoring for deformation and stress measurements. Implementing a continuous monitoring system can provide early warnings and enhance overall safety.
12. **Analysis of Instrumentation Data:** Utilizing data from installed instruments, such as multi-head extensometers, load cells, and strain gauges, can provide insights into squeezing zones and deviations from expected outcomes.
13. **Manual Monitoring vs. Real-Time Monitoring:** Manual monitoring, conducted periodically, may not provide timely insights into evolving situations. Shifting towards real-time monitoring can offer proactive responses to dynamic conditions within the Tunnel.
14. **Real-Time Warning System:** Installing a real-time warning system with Wi-Fi enabled data transmission for continuous tunnel deformation monitoring is recommended. This system can serve as an early warning mechanism for potential risks. These days, various advanced techniques are available for real-time monitoring.
15. **Implementation of an Alarm System:** Incorporating an alarm system for evacuation is essential to ensure the safety of workers in the event of a collapse.
16. **Evaluation of Previous Collapse Measures:** Assessing measures taken after the previous collapse incident is essential for learning and improving safety protocols.
17. **Identification of Collapse Causes:** Determining the cause of the collapse is paramount for implementing preventive measures in future tunnel constructions.
18. **Consideration of Collapse Scenarios during Construction:** Evaluating collapse scenarios during construction phases is crucial for pre-emptive planning and risk mitigation.
19. **Evacuation Plan Provision:** Implementing an evacuation plan, such as installing concrete Hume pipes, is essential to facilitate quick evacuation in the event of a collapse tragedy.
20. **Adherence to Construction Standards:** Strict adherence to construction standards and the use of high-quality materials are imperative. Robust quality control

measures during the construction phase can significantly reduce the risk of structural failures.

21. **Prescribed Rate of Tunnel Excavation:** Adhering to the prescribed rate of tunnel excavation is vital to maintaining stability and preventing unforeseen ground deformations.

22. **No Compromise with Safety:** Safety should never be compromised to meet the completion targets. Prioritizing safety measures is paramount in tunnel construction projects. Hence, a detailed 320 years Indian road tunnel safety audit is essential.

23. **Seismic Design Considerations:** Given the seismic activity in the Himalayan region, tunnels must be designed with seismic considerations in mind. Implementing state-of-the-art seismic design practices can enhance the resilience of tunnels to earthquakes.

24. **Geological Surprises and Regular Inspection:** Recognizing the possibility of geological surprises, design engineers should conduct regular inspections to identify deviations and implement corrective measures.

25. **Investigation of tunneling Sequence:** Investigating the tunneling sequence and time gaps between excavation, primary support installation, and final lining completion is crucial for understanding ground deformation dynamics.

26. **Exploration of Critical Geological Features:** The number of boreholes during the DPR stage appears insufficient. Conducting more exploratory boreholes and geophysical investigations can identify critical geological features and minimize risks during construction.

27. **Regular Monitoring and Maintenance:** Establishing a comprehensive system for monitoring the structural health of tunnels post-construction is crucial. Regular inspections, maintenance, and timely repairs can prevent minor issues from escalating into significant structural problems.

28. **Public Awareness and Preparedness:** Increasing public awareness about the risks associated with tunnel construction in the Himalayas is essential. This includes educating local communities about safety measures, evacuation procedures, and the importance of adhering to guidelines during construction.

29. **Specialized Rescue teams:** Specialized Rescue training in case of tunnel collapse to the personnel of Army/NDRF/ITBP/SDRF/Police.

30. **Compliance with labor laws:** Ensure proper compliance with labor laws/acts/ps at the work site.

Addressing the challenges associated with Tunnel collapses in the Indian Himalayas requires a comprehensive approach that involves improved planning, construction practices, and ongoing maintenance. The proposed recommendations aim to address the gaps identified in the Silkyara tunnel project, enhance safety measures, and inform future tunnel construction in challenging geological conditions.

In Figure 1, ample security measures have been implemented at the entrance gate of the tunnel, ensuring a robust presence to safeguard the area.

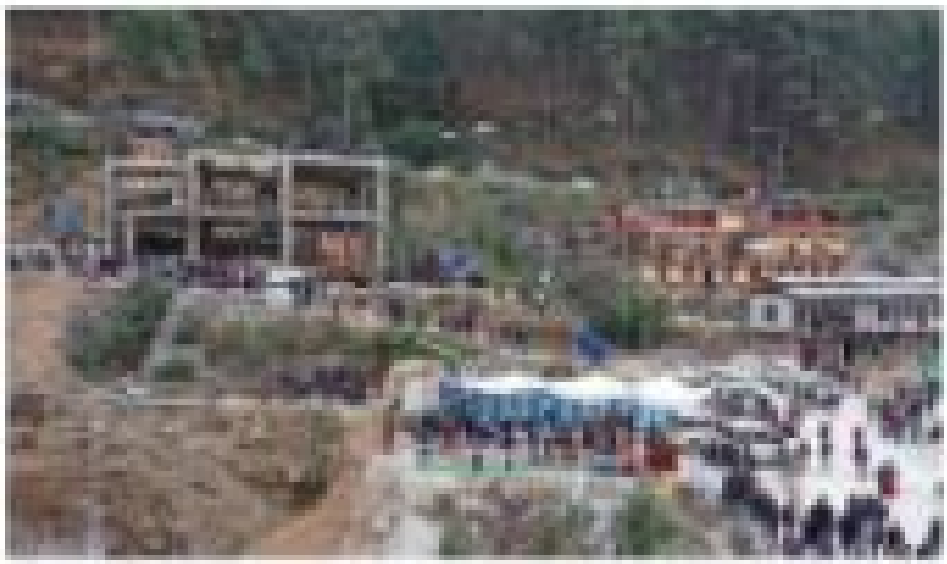

Figure 2 illustrates a prompt and coordinated response from various departments at the site.

Figure 3 illustrates the Help Desk and Tablet's desk designed to provide prompt support and facilitate coordination

Figure 4 depicts the Silkyara Site Control Room established by SSRM's Uttarkashi

In Figure 9, the images of the upper portion of the tunnel provide a visual representation, showcasing the total length of the tunnel at 4556.5(+) meters.

The figure is the aerial view captured by a drone, offering an overview of the surrounding area.

Figure 7 Miners in the tradition while in tunnel on December 14, 2015

Figure 8 shows the Electrical Logic Machine arriving at the tunnel site and weighing for establishment.

Figure 7 Planning is underway for the removal of debris, and the procedure is being explained.

As Figure 10, dated November 14, 2023, the Auger Machine Shaft has been positioned to facilitate horizontal drilling, marking a significant step in the operational process.

Figure 11 captures the commencement of the Legal Marketer's operation, signalling the initiation of its functional activity.

Figure 11 captures the commencement of the Legal Marketer's operation, signalling the initiation of its functional activity.

In Figure 13, the initial pipe has been removed and manually inserted, marking a pivotal stage in the building process.

In Figure 14, a successful communication link has been established with both robots. As more components are operated, this operation will significantly increase the overall system efficiency.

Figure 17 depicts the provision of food supply facilitated by the use of packaged bottles.

In Figure 16, the process involves transferring packed food bottles from one end to the rugged end, thereafter using a commuter procedure for delivering sustenance to the affected area.

Figure 17 portrays the displacement of an ambulance at the site location, ready to assist in road incident prompts in any epidemic or emergency situations.

In Figure 18, the car is portrayed with a red coloured circle highlighting a vehicle maintenance issue the ground. This allows concerns was addressed promptly at that specific moment.

In Figure 10, the image showcases the health facilities available at the site for the well-being of their citizens. An ambulance is prepared, and both have been assigned to accommodate all individuals who were injured.

Figure 11 depicts the Honourable Chief Minister, YK, conducting press conferences. In this image, the Chief Minister is graciously addressing the media, providing valuable information and updates.

Figure 29 The relevant Chief Minister of Uttarakhand, accompanied by a medical professional.

In figure 24, the respective Chief Minister of Uttarakhand is engaged in a comprehensive assessment of the overall management.

In Figure 19, the researcher (left) discusses with a community member a cropped field, providing encouragement to persevere and maintain mental resilience during challenging circumstances.

In Figure 20, an additional plot is currently in progress, demonstrating simultaneous operations. This visual showcases the execution of multiple plots concurrently to achieve efficient and coordinated work.

Ile Ile Ilgiar IN. Ile ieieaaed Ilael Iiaeiie ai Iiieaiiaed aael a Iieiiai Iiaeie Ieaa Ile Ieieaaeai ai Iaeie aei iiaiiiai Ie a aeiiag iiIi Ile ieieaed aeiiieaa.

Annexure-"H": Chronology of Rescue Operation in Silkyara Bend-Barkot Tunnel Collapse

S. No.	Date	Activities and tasks
1.	12.11.2023	• Around 05:30 AM collapse occurred from Ch. 260 to 265 • 41 persons trapped inside tunnel. • Excavation of debris started • Cavity of around 10 m above the centre observed on left side of Tunnel
2.	13.11.2023	• On night 13.11.23 Seventeen options for evacuation adopted • Excavation of loose muck • Finding of alternate Auger Machine with help of Hyderabad based Auger operator • Horizontal water pipeline activated, oxygen and dry food pumping started in tunnel for victims • Blue tube / Jet grouting done with Chief Secretary visited the site • Secretary, Disaster Management & team visited site. Directed NDRF Dy. Cd. Nigam Prabhakar to organize search & rescue operation. Machine
3.	14.11.2023	– First Auger Machine (Hyderabad) incompatible with site requirement. – Right patner Auger could be 2 meters as Auger but have Aand but at Delhi and prepared for switch
4.	15.11.2023	• Auger Machine was additional from Patna airport to Delhi (30 aircraft), loaded at Chinook (IAF) • Auger Machine was transported to site via helicopter (IAF)
5.	16.11.2023	• Auger machine started operations after dispersion and pipe welding. – Secretary Dr. V K Singh, MoS, PMNA Civil aviation and Secretary, MoRTH visited the site
6.	17.11.2023	• 22 m of 900 mm dia pipes pushed out by drilling using Auger Machine using 24 Nos of pipes • Around 45-47 Pkt. rescue team moved inside the tunnel

		work) & 'R' was diplaced/removed through 'RT'/spot and from broken. • Rescue operation temporarily stopped as a safety precaution & observations.
C	08.11.2021	• Existing jetties shifted to safe place. • Safe passage provided to local supply point. • Mooring under the custody of Sri Bhaskar Reddy along with crane officers of IMD, BRO/BPSL, SPCB, GMAC and NIOT/L engineers. • 7 action plans were formulated.

[A] Rescue Action Plan-1:

Hydraulic Lifting of Grounded Crane at Location of Leak in 24" Pipeline

(collapse length: 4.5 m, Area: Ch. 203 to 208)

S.No	Date	Activities and tasks
1a.	29.10.2021	• 4.5 m of 24"inch LSAW w.t.(g.) 9 mm Ascertained pipe identified. • Safety passage of 6 meters length from Ch. 197 to 203 (20 m) Crossing of Oil Culverts, Water Pipe and Swamps constructed.
1b.	30.10.2021	• Completion of 24"inch LSAW pipe completed (five sections of 4.5 m). • Field welding work Started
1bb.	31.10.2021	• Field welding work Started through 4th Shift • 2 Nos pipes of the length each 6.0 m were cleaned and the pipes of 5.5 m were cut in the others through existing 24" inch diameter pipe
1 c.	31.10.2021	• Super drilling started at 06:00 Hrs on 31.10.2021. Weld pipe of 6 m length five Nos (normal cut 4.5 Nos). The total length of pipe assembly is 44 meters. • Metallic object & debris pipes were removed by the front of the pipe and the pipes were cut by Gas cutting Machine. For cutting of the same with gas cutters, the 'CREST CREST' team were mobilized. • Modified communication system with inter connectivity has already been developed by SPBU and through which clear

		[illegible] • People inside reported that they are safe.
[illegible]	[illegible]	• [illegible] • [illegible] • [illegible]
[illegible]	[illegible]	• [illegible] • [illegible] • [illegible] • [illegible]
[illegible]	[illegible]	• [illegible] • [illegible] • [illegible] • [illegible]
[illegible]	[illegible]	• [illegible] • [illegible] • [illegible] • [illegible]

16th	27.11.2023	• Auger of length up to 46.90 m pulled out. • Erection of 3 numbers of Ribs for [illegible] area completed. Manual pushing of pipes after completion of cutting of damaged pipes started at 1540 hrs. • 1.9 m of 800 mm pushed using manual excavation and pushing by Auger machine.
17th	28.11.2023	• Pushing of 800 mm pipe after manual excavation in a length of 10.10 m completed on 28.11.2023 at 1345 hrs. • **Additional pipe of [illegible] length pushed up to 1850 hrs. Manual excavation continued followed by pushing of pipe and pipe has been inserted successfully up to the desired length at around 1920 hrs and the site has been handed over to the NDRF for further rescue operation in assistance with the District Administration.** • All 41 workers rescued safely.

(B) Rescue Action Plan -2

1.2 meter diameter vertical drilling of bore hole by SJVNL at Silkyara end

S. No.	Date	Activities and tasks
8th	19.11.2023	• BRO completed access road and hand over site to SJVNL by 1700 hrs on 19.11.2023.
9th	21.11.2023	• Drilling Machineries arrived at site.
10th	22.11.2023	• Drilling Machineries installed at site.
11th	23.11.2023	• Additional Drilling Machineries arrived at site. • Platform for [illegible] of drilling machine has been completed. • Marking of drilling point over the tunnel has been finalised at Ch. 305 after discussion with GSI, RVNL & ONGC. • Assembly of machine started at 1915 hrs on 23.11.2023.
12th	24.11.2023	• Assembly of machine ongoing.
13th	25.11.2023	• Shifting up of machine [illegible] from tunnel portal to drilling site.
14th	26.11.2023	• Drilling started at 1200 hrs and 19.80 m of vertical drilling completed.
15th	27.11.2023	• Vertical drilling up to a cumulative length of [illegible] m completed.
16th	28.11.2023	• Vertical drilling up to a cumulative length of [illegible] m completed. • Drilling work stopped at 0945 hrs.

		• Backfilling started after breakthrough of Pass-1
17th	29.01.2022	• Backfilling continued
18th	30.01.2022	• Backfilling completed at (-)90 Mtr.

(vi) Rescue Action Plan-2:

(C-I) 170 meter Tunnel construction by RVNL:

S.No.	Days	Activities and tasks
1st-1	26.01.2022	• Platform-2 construction started. Survey of the completed
1st-2	31.01.2022	• Equipment from Dudak reached site at 1000 hrs. •
1st-2	22.01.2022	• Removing equipment from Dudak to site and erection etc
2nd-1	23.01.2022	• Work began as held
2nd-1	24.01.2022	• Work began as held
2nd-2	25.01.2022	• Work began as held
3rd-1	26.01.2022	• Work started on Platform construction and progress
3rd-2	27.01.2022	• The work of making of Platform completed • Reinforcement & concreting work is under progress
4th-1	28.01.2022	• Reinforcement & concreting work is under progress • Work stopped at (-)90 Mtr.

(C-II) Vertical drilling (R") by RVNL at Silkyara end:

S.No.	Days	Activities and tasks
1st-1	26.01.2022	• BRO completed access road upto RVNL at (-)30 meter.
1st-2	31.01.2022	• Electric Connection has been provided to RVNL.
1st-2	22.01.2022	• Machine for drilling moved to location by BRO.
2nd-1	23.01.2022	• Platform under construction.
2nd-2	24.01.2022	• Platform under construction.
3rd-1	25.01.2022	• Platform for vertical drilling has been completed.
4th-1	26.01.2022	• Vertical drilling started at 0400 hrs. • 71 m of vertical drilling completed. • Vertical drilling stopped due to machine breakdown. Drilling work stopped at (-)90 Mtr.
5th-1	27.01.2022	• Vertical drilling in progress

[illegible]	[illegible]	• Vertical drilling to continue after breakthrough of Plate-1 (no backfilling planned)
[illegible]	[illegible]	• Backfilling completed at 1500 Hrs.

(D)Reason Action Plan -6:

20" Vertical Drilling at Bucket End in ONGC.

S.No.	Date	Activities and tasks
[illegible]	[illegible]	• ONGC drilling from vessel for six
[illegible]	[illegible]	• Preparation of report by ONGC ongoing.
[illegible]	[illegible]	• As Drilling Rig from Sabtco has reached site.
[illegible]	[illegible]	• Preparation of report by ONGC ongoing. • Survey has been completed by SBM. • Equipment of SBM placed at existing point and construction of approach work has started.
[illegible]	[illegible]	• RM center of vessel could not been constructed out of hole center.
[illegible]	[illegible]	• ONGC vessel not conveniently for construction from Rajahmundry to Mahesh the vessel is cutting the major blades and stuck reached Rajahmundry Airport. • Arrangements for their air lift are in progress.
[illegible]	[illegible]	• All the associated material of six Hanson Drilling Rig mobilized to ONGC areas nearby at Kakinada. • For securing or cutting the major blades & shaft, ONGC has also arranged a "Bigger cutter" machine. • Team with machinery reached at site at 1000 hrs.
[illegible]	[illegible]	• All the associated material of six Hanson Drilling Rig mobilized to ONGC areas nearby at Kakinada.
[illegible]	[illegible]	• All the associated material of six Hanson Drilling Rig mobilized to ONGC areas nearby at Kakinada. Work stopped at 1900 Hrs.

(E)Reason Action Plan -7:

400 meter tunnel construction for ESDV at Bucket end

S.No.	Date	Activities and tasks
[illegible]	[illegible]	• ESDV made site movement & brought their equipment and machinery

		• Micro tunnelling machine mobilized • Micro tunnelling (1.5 m x 2.0 m) started from Shaft for Tunnel(outward)
9th	31.10.2023	• Second blast was taken first resulted as total 4.5 m drift followed by rock surveying, initial layer of shotcrete applied • Preparation of second layer of shotcrete to be progress. Pull length 6 m progress • Further marking is in progress
10th	22.11.2023	• 4th blast taken at 1229 Hrs on 22.11.2023 for a pull length of 1.20 metres. • Total structural length of drift is 9.10 meters
11th	13.12.2023	• Muck curing ongoing • Drilling for rock bolts and rib concrete work as per tel arm is progress.
12th	14.12.2023	• Rib concrete for 9.10 metres completed and shotcrete for balance work is in progress.
13th	19.12.2023	• Rib Concrete is under progress
14th	26.12.2023	• 5th blast taken at 0737 hrs for a pull length of 1.2 m. • Total structural length of drift is 10.4 m. • Fabrication work of 16 numbers of ribs has been completed.
15th	27.12.2023	• 6th blast has been taken at 0137 hrs for a pull length of 1.2 m. • Total structural length of drift is 11 meter • Marking in progress
16th	30.12.2023	• 7th blast has been taken at 0900 hrs for a pull length of 1.20 m Total structural length of drift is 12.30 m • Marking in progress. • Muck stopped at 1430 hrs.

(C) Alternate Safety passage (Escape Pipe Sh)

Creation of side Drift towards Tunnel through the debris at Ch. 202 in Indian scale:

S. No.	Date	Activities and tasks
07	30.11.2023	• Design completed
08	31.12.2023	• Fabrication started for Array members • 02 Arrays have been fabricated

[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible]
[illegible]	[illegible]	• [illegible] • [illegible]

Annexure "C" Manpower, Resources, Expertise and Technical knowhow deployed as per timeline

Sr. No.	Dates	Agency / Department	Manpower / Equipment deployed	Work progress completed	Technical values achieved as per report	Experts engaged	Total Manpower	Work done
1	[illegible]	Health	[illegible] Medical Team 3 Med. Officers (1 Physician, 1 Surgeon, 1 Obstetrician/Gynaecologist), 6 Nursing Staff, 2 Lab Technicians, 1 Pharmacist, 1 Ambulance [illegible]	[illegible] patients examined, [illegible] referred to [illegible]	[illegible] camps conducted, [illegible] patients treated, [illegible] referrals made, [illegible] lab tests done, [illegible] medicines dispensed	[illegible]	19	Camps held in [illegible] villages. Common ailments: [illegible]. Referrals made to [illegible] Hospital. Health education on [illegible] given to [illegible] persons.
2	[illegible]	Police	Security Personnel [illegible], Vehicles [illegible], Barricades [illegible]	[illegible] checkpoints established, [illegible] vehicles inspected	[illegible] persons screened, [illegible] arrests made, [illegible] seized		100	Checkpoints established at [illegible] and [illegible]. Traffic diverted via [illegible]. Coordination with [illegible] Hospital and Rescue 1122 teams. Emergency vehicles allowed to pass without delay.
3	[illegible]	NGO	Volunteers [illegible], Medical Kits [illegible], Transport [illegible]	[illegible] meals served, [illegible] kits distributed	[illegible] beneficiaries	[illegible]	50	Meals served at [illegible] and [illegible].
4	[illegible]	Rescue	Rescue Personnel [illegible], Boats [illegible], Life Jackets [illegible], Ambulance [illegible]	[illegible] persons rescued, [illegible] evacuated	[illegible] beneficiaries		40	Rescue operations carried out in [illegible] and [illegible].

5		[illegible]	Structural Beams Equipment, Iron & Light Diffuser Industry - 01	1 x Crane rail screw rail	1 x Box		27	Earned Revenue & Grant Management
6		[illegible]	Beams Equipment Ltd. Manufacturing and Architecture 1 Office & Visitor - 02	1 x quarter rail screw rail and anchor & connection	1 x Beam		20	Earned Revenue & Grant Management
7	[illegible]	Cars	Bus Industry & Office Equipment, Iron & Light Diffuser Industry - 01	2 x Electrics			21	Secure for policy arrangements a assistant who as well as a Independent dog, rail are temporary hospital and CSS Chief services.
8		Police vehicles	[illegible] - 01	10 x	1 x Beam		7	Provides, implementation, and therefore the police vehicle cross all can.
9		[illegible] Beam or [illegible]	1 Beam Bar manufacturer, Body Desk Cruiser Equipment, ancient metal, body in rail - 01 Differentiation Area - Access & Professional 1 major [illegible] Equipment for night Area - [illegible] - 01	1 - 1 Shelf	27 - 100 Lane	Investigation	110	Coordinated with implementation time rules electrical and, new government for between for implementation during the operation. Compliance among different Beam agencies or multi as civilian operator program. Assist organisation by Beam agencies. Managed and transportation and rail rail of airport and CCTV, organised warning, serving, agencies, airports, rail officials. Arranged staff plan's and other equipment of rail agencies. Environment Plan several cross, Body Desk, Cruiser Emergency Operations trained, CCTV control cross rules, audience control of the, a Beam BY work for all Agencies. Maintaining

								Acceptance and processing requests
10		Validate User Credentials	Verify user credentials against stored data. Return a success or failure response. Handle invalid credentials. Log authentication attempts. Lock account after 3 failed attempts.	1.5 hrs	Dr. Alan Turing	Intermediate Specialist	10	Ac Alan Turing is responsible for validating user credentials against stored data. Ac Alan Turing must handle both successful and failed login attempts. Ac Alan Turing must log all authentication attempts. Ac Alan Turing must lock accounts after 3 failed attempts.
11		Implement Password Hashing	Use a secure hashing algorithm (e.g., bcrypt). Store only the hashed password. Never store plain text passwords. Salt passwords before hashing. Verify hashed passwords during login.	3 hrs	Dr. Alan Turing	Senior Cryptographer	20	Ac Dr. Alan Turing must use bcrypt for password hashing. Ac Dr. Alan Turing must store only hashed passwords. Ac Dr. Alan Turing must salt passwords before hashing. Ac Dr. Alan Turing must verify hashed passwords during login.
12	12	Create Authentication API	Define API endpoints for user registration, login, and logout. Use JSON for request and response bodies. Implement proper error handling. Return appropriate HTTP status codes. Document API endpoints.	2 hrs	Dr. Alan Turing	Senior Cryptographer	15	Ac Dr. Alan Turing must define API endpoints for registration, login, and logout. Ac Dr. Alan Turing must use JSON for request and response bodies. Ac Dr. Alan Turing must implement proper error handling. Ac Dr. Alan Turing must return appropriate HTTP status codes. Ac Dr. Alan Turing must document API endpoints.

[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		Grievance Agency [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19		Social Security Agreement	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]							[illegible]	

Annexure "B": Manpower and Resources deployed at Silkyara, Uttarkashi for Collapse Incident Rescue Operations

S.N.	Department	Item Particular	Qty Unit	Days of Deployment
1	State Disaster Response Force			
	Manpower	Commandant SDRF alongwith present 01 skilled SDRF personnels		4 Days
	Resources	Doctorate	20	4 Days
		Nurse	16	4 Days
		Police Singh	15	4 Days
		Police Teethra	14	4 Days
		Police Double	13	4 Days
		Mason	10	4 Days
		Tent Installer	9	4 Days
		Fish hook hanging	15	4 Days
		Combined glove type	14	4 Days
		Combined screw type	14	4 Days
		Tap set type	9	4 Days
		Long nosing	10	4 Days
		Thermal flag	9	4 Days
		Rope	20	4 Days
		Knee pad	9	4 Days
		Heavy duty gloves	9	4 Days
		Armoklav hard with strap	16	4 Days
		Folding stretcher	08	4 Days
		Multi purpose stretcher	14	4 Days
		Eye glo contact	14	4 Days
		SCC spanner	11	4 Days
		Crow along	12	4 Days
		Screwdriver	14	4 Days
		Bulb light double head	08	4 Days
		Pencil light	08	4 Days
		Dragon light	08	4 Days
		Power Accessible	11	4 Days
		Rope stretcher	11	4 Days
		Angle cutter	14	4 Days
		SS saw	08	4 Days
		Steel cutter	08	4 Days
		Boiler chain saw	10	4 Days
		Chain saw	08	4 Days
		Auger	08	4 Days
		Piggyback	08	4 Days
		Claw hook	16	4 Days
		Hilman	11	4 Days
		Head torch	11	4 Days
		Crow bar	08	4 Days

		Theatre plan	01	
		Civil Int.	01	
4	**Health Department**			
	Magazine	**Armed Site:**		
		Physician	01	1/2 day
		Chest Physician	01	-do-
		Anaesthetist	01	-do-
		Eye Specialist	01	-do-
		Psychiatrist	01	-do-
		Medical Officers	12	-do-
		Pharmacists	08	-do-
		Nursing Officer	01	-do-
		Ward Boys	02	-do-
		Eye Technicians	01	-do-
		LRB / Hazardous:		
		Physician	01	1/2 day
		Surgeon	02	-do-
		Anaesthetist	01	-do-
		Eye Specialist	01	-do-
		Psychiatrist	01	-do-
		Medical Officers	12	-do-
		Staff Nurses	08	-do-
		Eye Technicians	01	-do-
		Lab Technicians	04	-do-
		X-Ray Technician	01	-do-
		Pharmacists	01	-do-
		Regular medical staff		-do-
		Patient Hospital Evacuate		
		Will engaged nearest Wards, CCU, ICU, Pathology Lab, Blood bank, Ultrasound, CT scan with specialist team 24x7		1/2 day
	Kamaraj	Ambulance (will engaged with Govt. vehicle) (01 Base 108 and 10 from Health Department) Ltd. of 4+, 10 (G.S and 10 BLS)	40	-do-
5	**Public Works Department**			
	Magazine	Executive Engineer, Assistant Engineer, Junior Engineer		1/2 day
	Resources	Excavator with breaker		02
		Compressor		08
		Dozer		02
		JCB		02
		DG Set 62		02
		Roller		04
		Grader		02
		Dumpers		04
		Water Tanker		02

4	**Police Department**			
	Manpower	SP	01	At Cost
		Dy SP	04	-do-
		Inspector	12	-do-
		SI	22	-do-
		ASI	18	-do-
		HC	45	-do-
		Const	90	-do-
		PSC	02	-do-
		PSI	04	-do-
		Local Volunteers (upto 30hrs)	20	-do-
		Technical personnel for Police Control Room	04	-do-
	Resources	Vehicles (for "GREEN CORRIDOR" system alongwith prompt arrangements, patrolmen) and VVIPs)	02	-do-
		Two wheelers	20	-do-
		Wireless (Fixed and Emergency Services)	04	-do-
		Setting up of Police Chowki (Outpost)		-do-
		Setting up of Police Control Room		-do-
		Setting up of Emergency Hotspot & Strobe		-do-