HINDUSTAN ZINC
Zinc & Silver of India

HZL Standard

"Ground Control in Underground Mines"

	Issued by	Approved by
Name	Chairman, SRP Sub Committee	Corporate Council Chairman
Sign.		
Date		

DOCUMENT CONTROL DETAILS

Revision	Date	Reason for Issue	Compiled by	Approved by
0	11/03/2020	First edition	Alex Vyazmensky	
1	31/12/2022	Secord edition	Ayan Giri	
Next Review Date	01/01/2024			

User Notes: - The Corporate Safety Council (CSC) is the custodian of this document and is responsible for the Administration and Authorization of this Standard. CSC is responsible for confirming the accuracy and integrity of content and proposed changes to the Standard.

Controlled copy of the current version of this document is held at CSC and also available on its portal. Any printed / electronic copy of this document is uncontrolled. It is recommended that users verify that the version being used by them is the current version by referring to the controlled version.

DOCUMENT ISSUE

The "Ground Control in Underground Mines" Standard is issued by the Corporate Safety Council on behalf of Hindustan Zinc Limited management and forms a part of the HZL Integrated Management System.

Name: Vinod Jangir

Signed:

Date:

ACKNOWLEDGEMENTS

Contributions of the following individuals in the development of the standard are acknowledged:

Zone / Location	Members
Corporate	Praveen Sharma Vijay Goyal
Zone-1: DSC	Ambareesh Jha Ankur Mandawat Ashok Godugu Bikramjit Chanda Dipanjan Chakraborty Mukul Sharma Sanjay Inani Scot Clyde
Zone-3: RAM/Kayad	Elamurugan Dinesh Paneri Manish Meghwal Sandeep Narade Swagat Sahoo Toms Joseph
Zone-4: Zawar	Ayan Giri Dinesh Verma
CSRP Champion	Alex Vyazmensky

CONTENTS

1. SCOPE AND FIELD OF APPLICATION

Fall of Ground is one of the greatest hazards to the underground mining personnel. The objective of the standard is to eliminate the risk of fatalities and serious injuries resulting from Fall of Ground incidents in underground mines across Hindustan Zinc Limited (HZL).

This standard specifies mandatory requirements for all existing HZL underground mining operations, new acquisitions, shafts and adits, including those developed for exploration or mine construction purposes. This standard applies to all contractors and subcontractors who provide works or services to HZL underground mines.

The mandatory requirements of this standard are signified using the word “shall”.

All operations, under HZL management control, shall comply with local regulations in addition to the requirements of this standard.
Key elements to this regulatory compliance include the assessment of the workplace by appropriately qualified and trained personnel, inspecting the work environment and managing hazards identified through established processes. All designs are to be completed by appropriately qualified persons and shall adhere to all statutory requirements.

If any employee or contractor is found to be involved in violation of the requirements of this standard, disciplinary action shall be taken, as per the appropriate site HR policy.

2. REFERENCES

- Indian Metalliferous Mines Regulations, 1961 / 2018 draft
- DGMS Circulars
- HZL HSE Policy
- HZL Safety Principles
- Vedanta Safety Performance Standard. Ground Control – Underground Mines.
- Vedanta Guidance Note GN33 – Fall of Ground.
- ‘Geotechnical Considerations in Underground Mine’ Guidelines, 1997 (Australia)
- ‘Best Practices for Assessing Ground Control Hazards in the Workplace’, 2016 (Canada)

3. MANAGEMENT RESPONSIBILITIES

The Unit Head is responsible for providing all required resources to implement this standard and enforce continuous conformance with its requirements.The Mine Manager shall ensure that:

• A process is in place for assessing ground to be secure.
• All new mining excavations conform to the standard ground support profiles as a minimum.
• All new mining excavations are based on approved design issued prior to excavation.
• All new mining excavations and ground control activities comply with all site safe operating procedures (SOPs) and standards.
• Any planned decrease in ground support to be installed in a given area which is a departure from the applicable ground support standard for that area shall be agreed by the Head Geotechnical and approved by the Mine Manager.
• The Mine has effective scaling and ground support rehabilitation processes.

4. DEFINITIONS

Fall of Ground is an uncontrolled fall (detachment or ejection) of any rock size that causes (or potentially causes) personnel injury or equipment damage.

Ground Control is the methodology applied to eliminate, or reduce as far as reasonably practicable, the risks associated with various forms of ground movement in surface and underground mines.

Hazard is an energy source, or a situation, with the potential for harm in terms of human injury or health, damage to property, damage to the environment, or a combination of these.

Risk is the chance of an unwanted event happening that will have a negative effect. The level of risk reflects the likelihood of the unwanted event, and the potential consequences of the unwanted event.

Secure ground is ground that is supported in accordance with the ground control plan or unsupported ground, which has been assessed as not requiring support in accordance with the ground control plan.

5. GEOTECHNICAL CONSIDERATIONS IN MINE DESIGN

5.1. GEOTECHNICAL ANALYSIS

Geotechnical analytical tools, techniques for selecting appropriate data, engineering principles and specifications shall be used as the basis for:

- Defining geotechnical domains within the mine
- Defining the engineering properties of the rock mass in each geotechnical domain
- Developing and maintaining a geotechnical model of the operation of suitable quality to describe the complexity of the mining environment
- Assessing the potential modes of failure by applying appropriate design methods (kinematic, empirical, deterministic, numerical)
- Analyzing stress regimes during different stages of development and production
- Assessing the rock mass response to mining
- Assessing response of structures to mining
- Assessing the response of the hydrogeology to mining
- Evaluating the influence of blasting and seismic activity on the rock mass, ground support systems, and stability of excavations
- Reviewing the geotechnical incident history and conducting back-analyses.

5.2. MINIMUM GROUND SUPPORT STANDARDS

All underground excavations shall have ground support designed by a qualified Geotechnical Engineer. Ground support should be installed as part of development cycle and no excavation shall be left unsupported. As a minimum, excavations shall be supported with rock bolts.

Ground support design methodology shall be based on empirical (RMR or Q rock mass classification systems) and/or numerical analysis to evaluate ground support capacity vs. demand. Three-dimensional wedge stability analysis shall be used to verify that support is adequate against potential wedge formations.

Ground support designs shall match the ground conditions and the excavation geometry for the life of the excavation and must take into account both inherent and mining-induced stresses.

Mine development ground support requirements shall be tabulated (sample summary table format is provided below).

Excavation Type	Excavation Dimensions	Ground Conditions Category	Minimum Support Requirements	Comments

All excavations with spans larger than 6m and stope brows shall have secondary support in addition to the primary development support. Sequence of secondary support installation should be clearly specified.

Drawings shall be developed for each ground support design and signed-off by Head Geotechnical, Head Mine Planning and Mine Manager (example is provided in Appendix A).

Supervisors and personnel installing the ground support shall assess the ground conditions and place additional support over and above the stated minimum design requirements, if ground conditions warrant.

To minimize exposure to the Fall of Ground hazards during development, the distance between last row of bolts and the drive heading shall not be more than 0.6m.

All ground support elements/materials shall be subjected to QA/QC testing for physico-mechanical properties and/or installed support capacity, as per procedures defined in the mine Ground Control Management Plan (GCMP).

QA/QC process for the installed resin grouted rock bolts shall include the following, as a minimum:

- A representative sample of installed rock bolts shall be pull tested. The sample shall include bolts in different geotechnical domains and mine sections. Rock bolts located in the excavation walls and backs shall be tested in equal proportion.
- As per requirements of MMR 112 Section 3.5, at least 10% of all installed rock bolts shall be pull tested against the performance criteria, defined in GCMP, on a campaign basis. Tested bolts should be identified with red paint and applied load marked. Failed bolts shall be clearly marked and replaced.
- If a rock bolt fails prior to reaching test target an investigation shall be completed by a Geotechnical Engineer as to the root and contributing causes that resulted in the bolt failure. Recommendations from the investigation shall be implemented accordingly.
- Pull testing equipment shall be subjected to regular maintenance and calibration.
- Rock bolt pull testing records shall be maintained in a special journal and analyzed by the Geotechnical Engineer. The Mine Manager shall regularly review and sign-off the testing records.

5.3. MINE PLANNING, DESIGN AND SCHEDULING

Formal processes shall be in place to integrate the geotechnical data collection, analysis, risk assessments, ground control and stability issues into the mine planning. This process shall include:

- Systematic mine design process using an integrated team approach with sign-off by mine planning, geology, geotechnical, survey, operations personnel, and Mine Manager
- Formal process for designing ground support systems.
- All underground excavations shall be designed to specified and documented minimum stability criteria for all relevant rock types. The design shall ensure that all personnel work in a secure environment.
- Non-standard development will have an individual geotechnical assessment for ground conditions, ground support requirements and monitoring.
- Where pillars are required for reasons of safety they shall be engineered and clearly marked on all mine plans and sections.
- Identification of exploration, and other drill holes that may connect workings to other workings, groundwater aquifers, or to the surface
- Scheduling/sequencing of development, stopes, pillars, backfill based on geotechnical constraints.
- The design shall consider local and regional hydrology and hydrogeology to ensure that the potential for major water ingress is identified and prevented.
- Identifying and assessing backfill requirements for stability, and preparing fill notes with all QA/QC, reticulation, and barricade requirements.
- Addressing potential environmental impacts during mine lifecycle.
- Consideration for mine closure issues such as: stability of walls, voids, accesses and safety to the public.
- Geotechnical monitoring systems that allow for early warning of ground movement, including surface subsidence.

Up-to-date mine plans shall be maintained in locations that are easily accessible to the workforce. Any potential Ground Control hazards shall be clearly identified on these plans.

6. GROUND CONTROL MANAGEMENT PLAN[1]

Each underground mining operation shall establish a site-specific Ground Control Management Plan (GCMP). The purpose of the GCMP is to:

- Summarize geotechnical information that impacts the development of ground control systems.
- Establish minimum ground control standards for all underground excavations.
- Develop guidelines for use of ground control systems, including quality assurance programs.
- Detail the responsibilities and requirements of all personnel involved in ground control.
- Provide easy access to all information related to ground control.

GCMP shall include the following, as a minimum:

- Background geological and geotechnical information of the operation, including rock types, structures, geotechnical parameters, and hydrogeological conditions.
- Roles and assigned responsibilities for managing ground control processes.
- List of all relevant technical reports, presentations and information, with a reference to storage locations.
- Reference to the Regulations applicable for the jurisdiction of the operation.
- Fall of ground events statistics.

[1] Equivalent to Strata Control and Monitoring Plan (draft MMR 2018).

• Input parameters and assumptions utilized in modelling and design of excavations, stopes and support methods.
• List of relevant standard operating procedure for all relevant ground control management practices.
• Specification of methods, materials certification, and quality criteria for ground control materials used at the site.
• QA/QC protocols for testing installed rock bolts, cables and other support elements along with the record keeping.
• Void management process and QA/QC protocols.
• Where applicable, fill strength requirements for vertical and horizontal exposures and in-paste development.
• Stope barricade design basis.
• Frequency and responsibility for inspecting, monitoring, evaluating and reporting on ground conditions in all man access ways, including:
  - Active work places i.e. development ends and stopes, etc.
  - Shafts, declines, access ramps, airways, escape ways, etc., and
  - Other key sections of the mine i.e. workshops, stores, shaft stations, etc.
• Protocols for rectification where deficiencies or issues in ground control are identified, including rehabilitation of ground support.
• Scaling regime for working areas and access ways
• Elevated platform shall be used for manual scaling or jumbo/boomer/scaler for mechanical scaling, if height is more than 3.5 meters.
• Trigger Action Response Plans (TARPs), which shall be developed for all geotechnical hazards and shall include risk assessments for non-standard operations and changes in management.
• Geotechnical monitoring plan, including position and type of instruments, frequency of measurements and TARP trigger limits.
• Ground fall hazard isolation and reporting protocols.
• Specifications of monitoring equipment for type, location, and frequency of data collection and review.
• Protocols for ground fall hazard risk assessments.
• Workforce training requirements.

GCMP shall be prepared by qualified and appropriately experienced Geotechnical Engineer, with input from mine technical services and operations. It shall be reviewed by an independent third party to ensure objectivity and signed-off by the Unit Head.

GCMP shall be reviewed:

• When ground control hazards change, new geotechnical hazards are identified, existing key assumptions are updated because of new information or practices adopted.
prior to the mine being extended into any new area, including extension at depth or along strike which was not considered as part of the mine design at the time of approval.
• Following any ground control related incident, where established controls are deemed inadequate.

Any change to the Ground Control Management Plan shall be reviewed and signed-off by the Unit Head.

GCMP and its implementation shall be regularly peer-reviewed. An annual internal review shall be conducted to monitor compliance. An external review shall be undertaken on a two year cycle to ensure that the GCMP is appropriate to the operation.

7. FALL OF GROUND PREVENTION AT WORKPLACE

All persons working in the underground mine are integral to successfully managing Fall of Ground Hazards and shall adhere to the following requirements:

- No person is to enter unsecured ground at any time for any reason.
- All personnel have a duty of care to ensure that excavations are stable whenever entering an underground heading / access / work area.
- All personnel shall report any hazard relating to the stability of the underground excavations.
- All personnel shall barricade areas immediately and report uncontrolled falls of ground and ground control hazards.
- Personnel shall not be allocated or undertake tasks for which they have not been assessed as competent by the Mine Manager or nominated delegate, unless they are working under direct supervision of a competent person.

RACI matrix for Fall of Ground prevention:

Activity Description	All UG empl.	Area Super-visors	Section In-charge	Head Geotech	Mine Manager	Unit Head	CSC
Identify and isolate Ground Control hazards	R	R/A	A	A	A	A	
Address Ground Control hazards		R/A	R/A	A/C	R/C	I	
Develop and implement site specific GCMP		I	I	R/A	R/C	I	I
Provide resources for effective implementation of GCMP				C	R/A	R/A	I
Adherence to Ground Control SOPs a and TARPs	R	R/A	R/A	C	R/C	I	
Audit/inspection, QA/QC and monitoring for Compliance of execution			R	R/A	C	I	I
Ground Control related training				R/A	C	I	

R	Responsible - expected to actively participate in the activity and contribute to the best of his/her abilities.
A	Accountable - ultimately responsible for the results.
C	Consulted - contributes to decision making.
I	Informed - kept informed, but do not necessarily participate in the effort.

8. GEOTECHNICAL MONITORING

Each mine shall develop a comprehensive geotechnical monitoring program to monitor mine stability on a global and local scales, it shall include:

1. Visual inspections to identify Fall of Ground hazards and qualitatively assess changes in ground conditions, as per inspection matrix provided below.

Inspection period	Type of Inspection	Observation Records Keeping
Shift	Mining Mate inspection of active working areas	Mining Mate via Statutory Diary
Daily	Shift Supervisor inspection of active working areas	Shift Supervisor via Statutory Diary
Weekly	Declines Production levels	Assistant Manager/s via Statutory Diary
Monthly	All active mining areas for the month including declines and stockpiles. Workshops, inactive mining areas, electrical substations, pump stations, fan installations.	Head Geotechnical or his delegate via U/G Inspection Log Book

2. Instrumental monitoring to measure changes in ground response due to mining activities to:
   - Assess and verify the performance of the mine geotechnical design.
   - Calibrate models and constrain design calculations.
   - Identify hazardous trends.

3. In case of any rock noise it should be monitored at the utmost priority.

To address these tasks, Geotechnical Engineers shall utilize a range of instruments, such as:

- Uniaxial Vibrating Wire Stress meters allow to measure change in stress magnitude in one direction and are typically installed in mine pillars with a well-defined loading regime.
- Multi Point Borehole Extensometers (MPBX) measure axial ground movements in stope side walls and crowns, and sill pillars.
- Tape Extensometers measure the change in distance between pairs of eyebolts mounted on the walls of excavation and shall be used for convergence monitoring.
- Telltale Extensometers are used for monitoring displacements in the excavation roof and are designed for visual displacement reading in mm with traffic light warning system.
- Cavity monitoring systems produce accurate three-dimensional laser scans of mine excavation. Superimposition of wireframes of scans at different intervals allows to quantify geometrical changes.
- Earth Pressure Cells (EPC) are utilized to measure stress against back fill barricade walls in stopes.
- Borehole cameras for video surveys of drillholes, ore passes, and ventilation raises.

For each geotechnical instrument mine Head Geotechnical shall define critical monitoring thresholds, which shall be utilized in Ground Control related TARPs.

9. STANDARD IMPLEMENTATION

9.1. STANDARD AUDIT

- HZL Corporate Safety Department shall organize regular audits of standard implementation as part of its HSE audit program.
- External Audits shall be done bi-annually for all mines from external party (CIMFR, NRIM etc.)

9.2. REVISION PROCESS

HZL Corporate Safety Department shall review adequacy of the standard on a yearly basis and/or following a serious fall of ground incident.

Revisions to this standard shall be signed off by HZL HSE Head, all revisions must be documented.

9.3. TRAINING

All employees and contractors working underground shall be trained by the Geotechnical Engineers in ground control hazard awareness and in identifying and communicating rock fall hazards.

Supervisors shall undergo specific training and be competent in rockfall hazard identification and mitigation.

Only trained, competent and authorized persons are permitted to conduct scaling and to install ground support.

Training records shall be maintained by the site safety department, refresher training shall be carried out on a yearly basis.

9.4. CUSTODIAN AND CONTACT

The custodian for this standard is Corporate Safety. The contact for this standard is the site standard rules and procedures sub-committee.

Technical questions with respect to implementation of this standard can be directed to:

Head Geotechnical - HZL	Alex Vyazmensky	alexander.vyazmensky@vedanta.co.in 9116190563
Head Geotechnical - RDM	Ambareesh Jha	ambareesh.jha@vedanta.co.in 9001541812
Head Geotechnical - Zawar	Ayan Giri	ayan.giri@vedanta.co.in 9001291351

10. APPENDIX A. GROUND SUPPORT DESIGN DRAWING EXAMPLE