SITOK

DEEP DIVE

UPSC MAINS

TARGET 2027

SEISMIC RISK

SCAN ACTIVE

LIVE FEED

UPSC MAINS | TARGET 2027

EARTHQUAKES

61% land. 75% people. One governance test.

GS-I Geography

GS-II Governance

GS-III Disaster Management

Contents

The Core Argument

Read this first — it changes how you read everything else

Central Thesis

India's earthquake deaths are not a seismology problem. They are a construction governance problem. The earth cannot be predicted. The building can be engineered. Every major Indian earthquake death toll is a failure of enforcement — not a failure of science. Until this distinction is clear in policy and in practice, no seismic zone map will save a single life.

On June 24, 2026, the Venezuelan capital Caracas was struck by a rare 'doublet' earthquake [two earthquakes hitting almost simultaneously — just 39 seconds apart] — a 7.2 magnitude shock followed immediately by a 7.5 magnitude mainshock. Over 920 people died in the first 48 hours. Thousands are still missing. The cause of death was not the earthquake. It was the buildings.

India sits on one of the world's most seismically active [earthquake-prone] zones. 61% of our land area and 75% of our population live in moderate-to-extreme earthquake risk zones. The question is not whether a major earthquake will hit India. It is whether our buildings will stand when it does.

Fact Sheet

Numbers every aspirant must know

India's Risk	61% of land area in moderate-to-extreme seismic hazard zones (IS 1893:2025)
Population at Risk	75% of India's population lives in moderate-to-extreme earthquake zones
Non-Engineered Buildings	90% of India's building stock has no structural engineering input
Seismic Zones	Now 5 zones (I removed, VI newly added in 2025 update)
Zone VI (New)	Entire Himalayan arc — designed for earthquakes above Magnitude 8.0
NCS Monitoring Stations	Expanded from 80 (2014) to 168 stations under National Centre for Seismology

Venezuela Doublet (2026)	7.2 + 7.5 magnitude within 39 seconds — 920+ deaths, $6.7 billion damage
Koyna Earthquake (1967)	Mw 6.3 — triggered by reservoir filling — India's most famous RIS event
Gorkha Earthquake (2015)	Mw 7.8 — Indian plate thrusting under Eurasian plate — 9,000 deaths in Nepal
Bhuj Earthquake (2001)	Mw 7.7 — 20,000 deaths — 90% buildings in affected zone were non-engineered
NDRF Battalions	16 battalions across India for rapid disaster response
Aapda Mitra Scheme	1 lakh community volunteers trained in earthquake-prone districts
Amendment 2024	Disaster Management (Amendment) Bill 2024 — adds Urban DM Authorities
Golden Hour Rule	72 hours — the critical window for finding survivors alive under debris

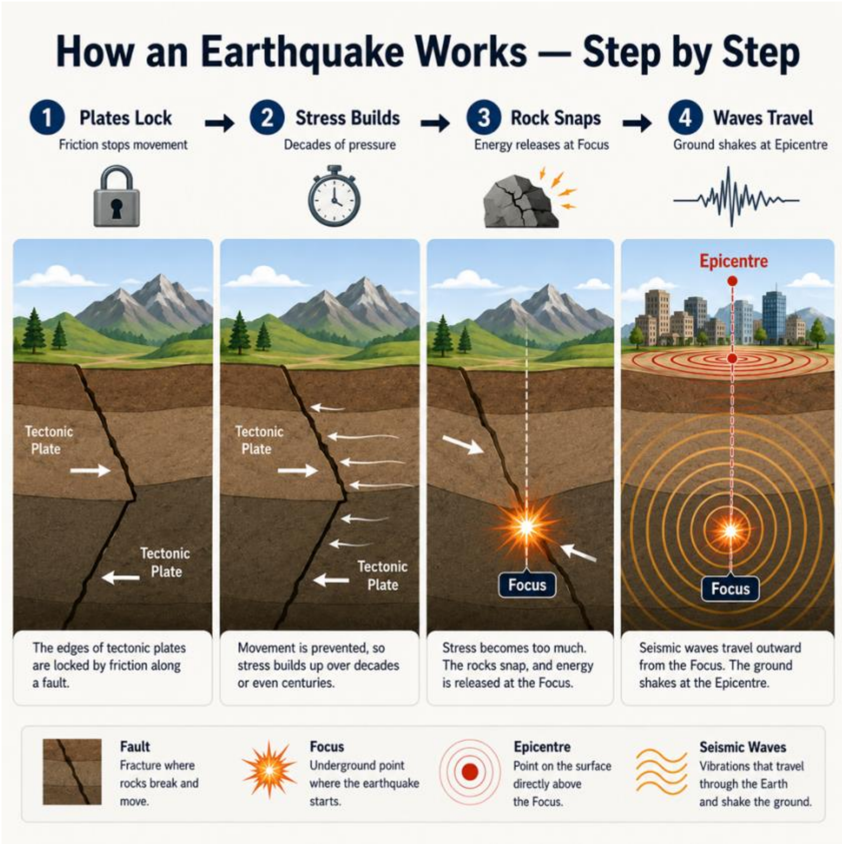
Understanding Earthquakes

Simple concepts, clearly explained

Our planet's outer shell is not one solid piece. It is broken into giant puzzle pieces called tectonic plates [massive slabs of rock that make up the Earth's outer crust]. These plates move constantly — very slowly, about the same speed your fingernails grow. Where they meet, they get stuck due to friction [resistance between two surfaces]. But the plates keep pushing. Over decades or centuries, stress [built-up pressure] grows until the rock suddenly snaps — releasing enormous energy in all directions. That snap is an earthquake.

How an Earthquake Works — Step by Step

Plates Lock *Friction stops movement* → **Stress Builds** *Decades of pressure* → **Rock Snaps** *Energy releases at Focus* → **Waves Travel** *Ground shakes at Epicentre*



Key Terms — Simply Explained

- **Fault Line:** The fracture [crack] in the Earth's crust where two blocks of rock slide past each other. Every earthquake happens along a fault line.
- **Hypocenter / Focus:** The exact point inside the Earth where the rock first breaks and energy is released. Think of it as the 'source' of the earthquake.
- **Epicentre:** The point on the Earth's surface directly above the hypocenter. This is usually where shaking feels most violent — and where we see the most damage.
- **Seismic Waves:** Ripples of energy that travel outward through the ground — like ripples in a pond when you throw a stone. These ripples are what shake buildings and break roads.
- **Magnitude:** The measurement of an earthquake's strength. Each whole number increase means about 32 times more energy released. A magnitude 7 earthquake is 32 times stronger than a magnitude 6.
- **Focal Depth:** The depth at which the earthquake originates. Shallow-focus earthquakes (under 70km) cause the most surface damage because the energy has less distance to travel.

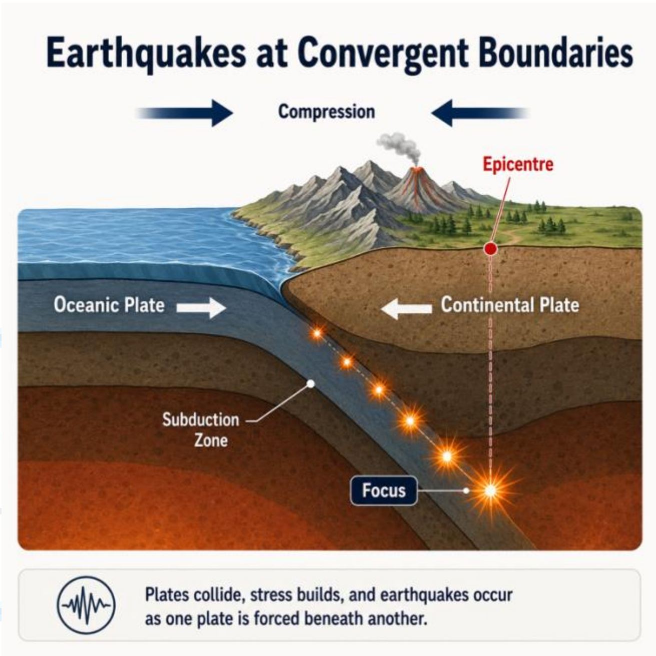
Causes of Earthquakes

Natural and human-made

Most earthquakes happen because of movement at the boundaries [meeting points] of tectonic plates. But human activity can also trigger earthquakes — a fact that is increasingly relevant for governance.

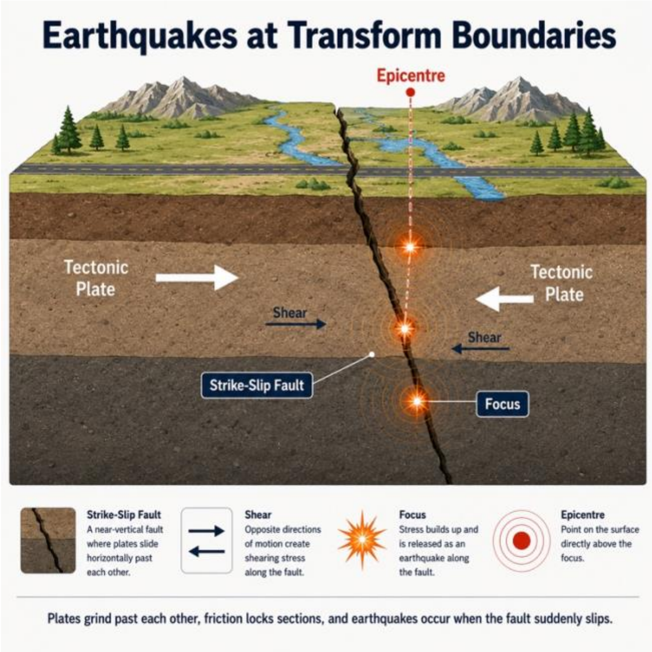
Natural Causes

- **Convergent Boundaries:** When two plates are driven directly into each other, the crust buckles. The denser plate sinks below the lighter one in a process called subduction [one plate sliding under another into the Earth's mantle]. This creates the world's most powerful earthquakes. There are 3 kinds of convergent boundaries- Ocean Continent, Continent Continent and Ocean Ocean. Below image is Ocean Continent.



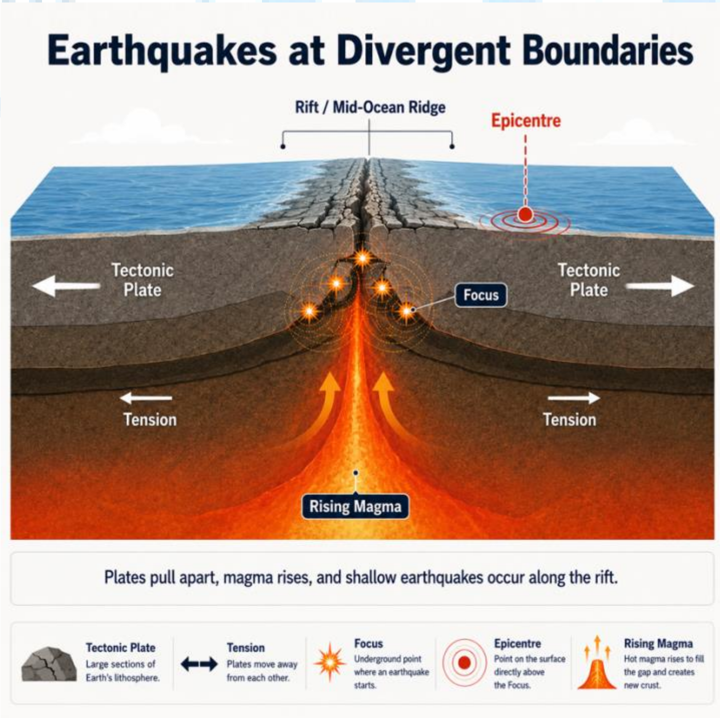
Example: The 2015 Gorkha earthquake (Nepal) happened because the Indian Plate is continuously pushing underneath the Eurasian Plate along the Main Himalayan Thrust [the main fault line under the Himalayas].

- **Transform Boundaries:** Plates slide horizontally [sideways] past each other. The edges are rough and jagged, so they catch and lock for decades. When they finally slip, the sudden lateral [sideways] movement releases massive energy.



Example: The June 2026 Venezuela doublet earthquake happened along the Bocono strike-slip fault — the same type of boundary as California's San Andreas Fault.

- **Divergent Boundaries:** Plates pull away from each other, stretching and thinning the crust. As the crust tears, it creates frequent but usually smaller earthquakes. Most of these happen underwater and do not affect humans — except where the ridge reaches land.



Example: Iceland sits directly on the Mid-Atlantic Ridge [the underwater mountain range where the American and Eurasian plates pull apart] and experiences constant small earthquakes.

- **Volcanic Earthquakes:** When magma [molten rock] forces its way upward beneath a volcano, it fractures surrounding rock. These tremors [small shakings] often serve as a warning before volcanic eruptions.

Human-Caused (Anthropogenic) Earthquakes

This section is highly relevant for UPSC Mains — it connects disaster management with governance, industrial policy, and infrastructure. Examiners have asked about this repeatedly.

- **Reservoir-Induced Seismicity [RIS]:** When massive reservoirs [artificial lakes behind dams] fill with water, the enormous weight changes the stress [pressure] on underground rocks. Water also seeps into cracks, lubricating [making slippery] fault lines. This can trigger earthquakes in areas that were previously stable.

  Example: The 1967 Koyna earthquake in Maharashtra (Mw 6.3) — one of the world's most famous cases — was directly triggered by the filling of the Koyna dam reservoir. This is now a textbook example in global seismology [the science of earthquakes].

- **Induced Seismicity from Fracking [High-Pressure Fluid Injection]:** In shale gas extraction [drilling to extract gas from rock layers], millions of litres of chemical wastewater are injected at high pressure deep underground. This reduces friction [grip] on old, buried fault lines, triggering earthquakes in regions that had no history of seismic activity [earthquake activity].

  Example: Oklahoma, USA, saw an unprecedented [never seen before] spike in earthquakes after large-scale wastewater injection from oil and gas operations began — from 1-2 significant quakes per year to over 900.

- **Mining and Collapse Earthquakes:** When old mine tunnels and underground caverns collapse, they cause small but local tremors. These are not large earthquakes but can be dangerous for workers and nearby communities.

  Example: Heavy coal-mining regions in Jharkhand and Chhattisgarh experience localized micro-tremors when deep mine galleries [underground tunnels] buckle under the weight of soil above.

Global Distribution

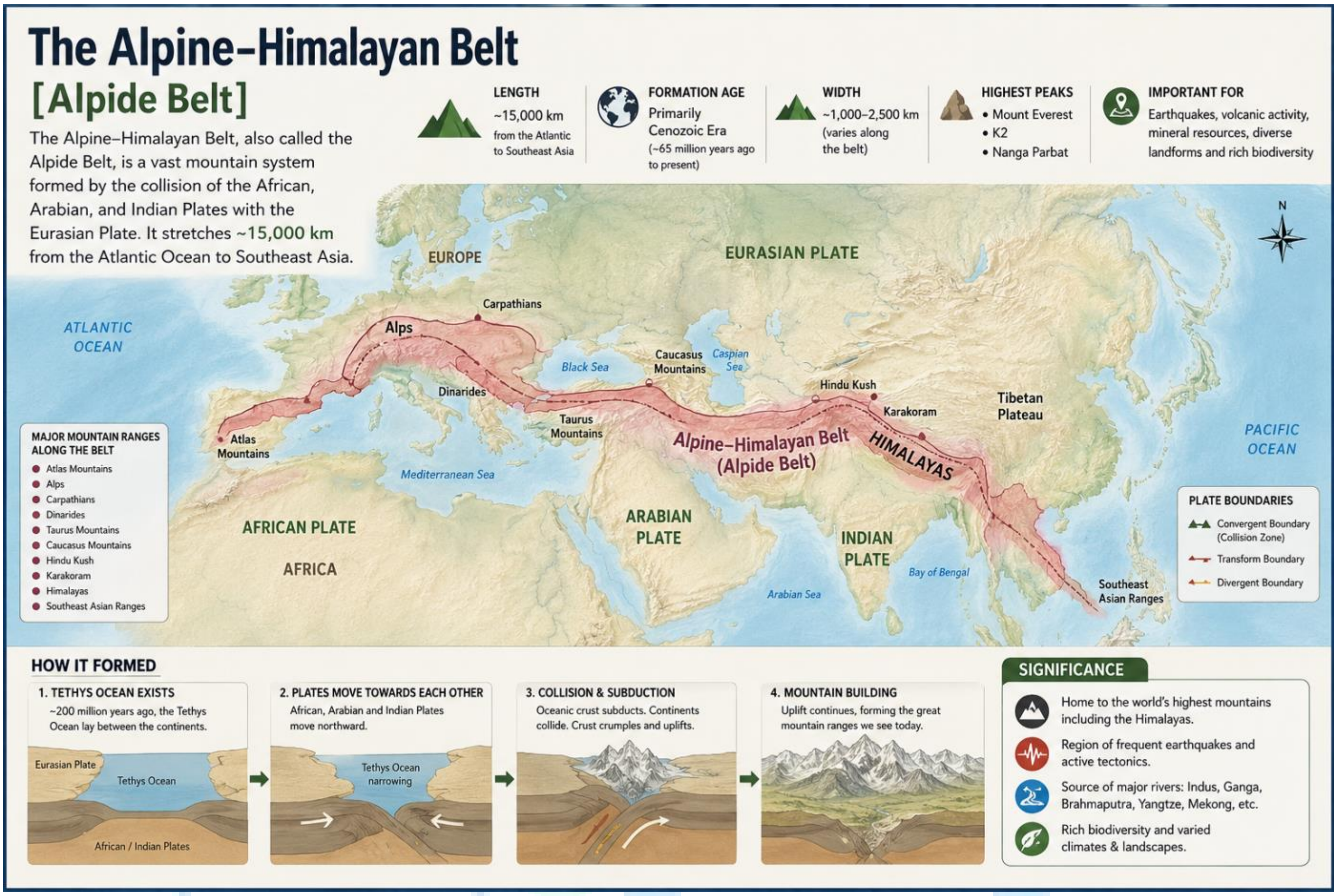
Where earthquakes happen — and why

Earthquakes do not happen randomly. They follow very specific patterns that match the edges of tectonic plates. Understanding these patterns is essential for both Prelims and Mains.

The Three Major Seismic Belts

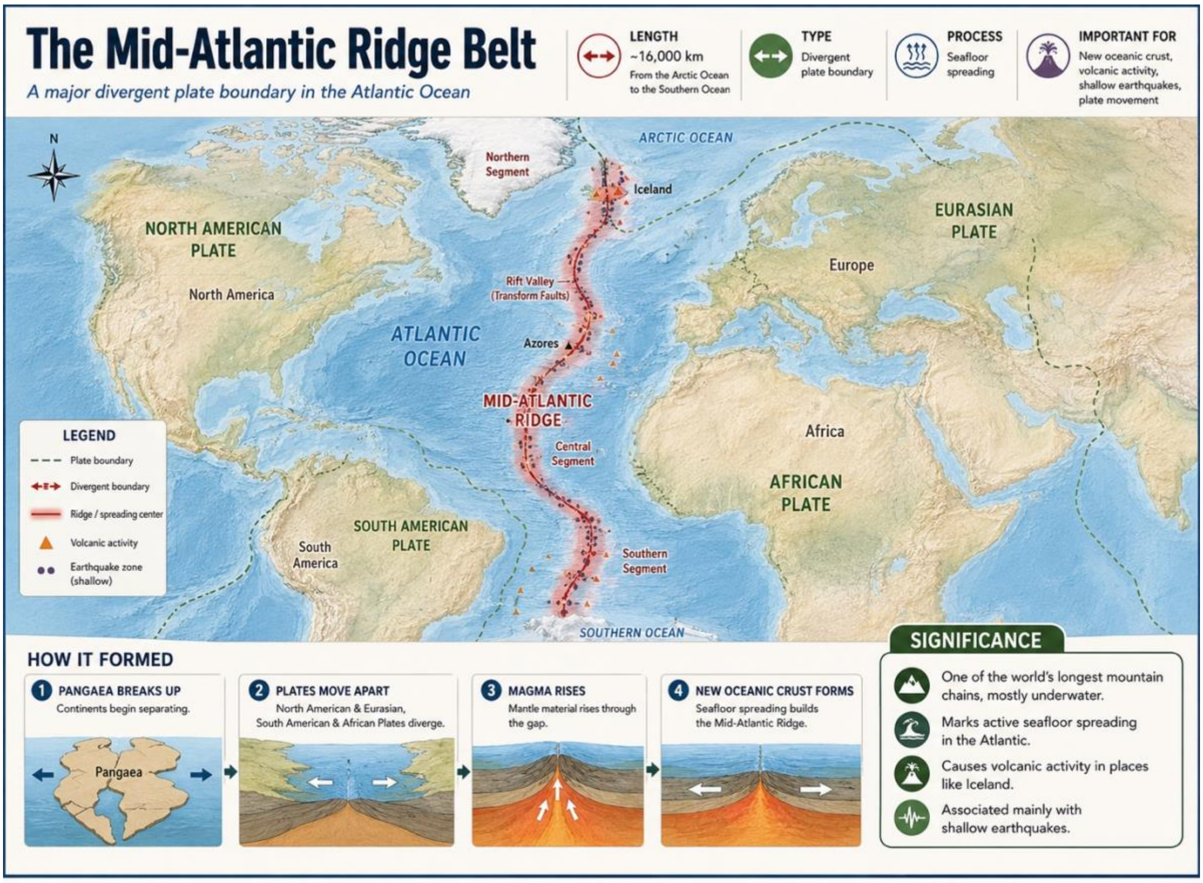
- **The Ring of Fire [Circum-Pacific Belt]:** A massive horseshoe-shaped zone around the rim of the Pacific Ocean — stretching along the western coasts of North and South America, up through Alaska, Japan, the Philippines, and New Zealand. It produces roughly 81% of the world's largest earthquakes. Dominated by convergent boundaries and subduction zones [where one plate dives under another]. Japan, Indonesia, and Chile sit on this belt.

- **The Alpine-Himalayan Belt [Alpide Belt]:** Runs from the Mediterranean Sea through Turkey, Iran, the Himalayas, and into Southeast Asia. Responsible for about 17% of the world's largest earthquakes — but because these happen under densely populated land [not under oceans], they are often more destructive per event. India lies entirely within this belt.



Example: The Himalayan region is seismically active because the Indian Plate has been driving north into the Eurasian Plate for 50 million years — at about 47mm per year. The entire Himalayan mountain chain is the result of this ongoing collision.

- **The Mid-Atlantic Ridge Belt:** A long underwater mountain chain running north to south through the Atlantic Ocean. Plates are pulling apart here, creating frequent but mostly shallow and low-damage earthquakes. Because it is deep underwater, it rarely affects human populations — except in Iceland, which sits directly above it.



Other Notable Zones

- **The East African Rift System:** The African continent is slowly splitting into two smaller plates — the Somali and Nubian sub-plates. This active tearing [rifting] creates regular seismic activity across East Africa. Relevant for questions on African geography and UN disaster response.

India's Seismic Zones

IS 1893:2025 — the new code that matters

The Bureau of Indian Standards [BIS — the government body that sets safety standards] completely revised India's earthquake risk map in 2025 under IS 1893:2025. This is one of the most important recent government decisions in disaster management — and has direct Mains relevance.

India's Seismic Zones — IS 1893:2025 (Revised)

Zone	Regions Covered	Likely Magnitude	Risk Level
Zone VI (New — 2025)	Entire Himalayan Arc: J&K, Ladakh, HP, Uttarakhand, Sikkim, Arunachal	> Magnitude 8.0	EXTREME

Zone	Regions Covered	Likely Magnitude	Risk Level
Zone V	Northeast India (Assam, Manipur, Nagaland), Andaman & Nicobar, parts of Gujarat	7.0 – 8.0	VERY HIGH
Zone IV	J&K foothills, Delhi NCR, parts of Bihar & UP, Mumbai coastal belt	6.0 – 7.0	HIGH
Zone III	Parts of Kerala, Goa, West Bengal, Andhra Pradesh, Rajasthan	5.0 – 6.0	MODERATE
Zone II	Remaining parts of peninsular India	< 5.0	LOW

Key finding: 61% of India's land area and 75% of its population now fall in moderate-to-extreme hazard zones under the new code.

What Changed in IS 1893:2025 — Key Reforms

- **Zone VI Introduced:** A new highest-risk category called Zone VI was created specifically for regions that can experience earthquakes above Magnitude 8.0. The entire Himalayan arc — from J&K to Arunachal Pradesh — has been placed in this zone. This is a first in Indian seismic [earthquake-related] policy.
- **Boundary Rule — No More Blindspots:** If a town or city sits on the boundary between two zones, it is automatically placed in the higher-risk zone. Previously, administrative [official] borders could leave a town in a lower-risk category even when the geology [underground rock structure] suggested higher danger.
- **Geology-Based Mapping, Not Administrative Borders:** The new map is based on subsurface lithology [the type of rock and soil underground], active fault systems, and GPS-measured strain accumulation [how much pressure is building up]. Previously, district boundaries were used — which had nothing to do with actual geological risk.
- **PSHA Adopted:** India has officially adopted PSHA [Probabilistic Seismic Hazard Assessment — a mathematical method to estimate future earthquake likelihood and ground motion]. This replaces the old method of simply looking at historical earthquake records — which is unreliable because many fault lines haven't ruptured [broken] in recorded history but remain dangerous.
- **Non-Structural Elements — Now Legally Regulated:** For the first time, the national code legally requires that heavy non-structural items [things not part of the main building frame, like overhead water tanks, false ceilings, and facades] must be securely anchored if they make up more than 1% of the building's total weight. These items cause enormous damage and injuries during earthquakes even when the building itself stands.

- **Mandatory Retrofitting of Lifeline Structures:** All older buildings classified as lifeline structures [buildings that must function during and after a disaster — hospitals, fire stations, schools, bridges, power stations] must now undergo mandatory structural auditing [inspection] and retrofitting [strengthening] to meet new safety standards.

Impacts of Earthquakes

How one event cascades across sectors

A high-intensity earthquake does not just damage buildings. It triggers a chain reaction across every sector of society — humanitarian, economic, environmental, and political. UPSC Mains answers on this topic are stronger when they show this cascade.

Immediate Impacts

- **Structural Collapse:** When horizontal seismic waves [side-to-side shaking] pass through a dense city, they twist building foundations. Unreinforced [not strengthened with steel] masonry [brick and stone] buildings pancake [collapse floor by floor]. The Venezuela 2026 doublet damaged over 1.7 million structures in Caracas and surrounding states.
- **Mass Casualties and the 72-Hour Window:** People trapped under debris [rubble] face the '72-hour golden window' — the period within which survival rates are highest. After 72 hours, survival rates fall sharply. The Venezuela event confirmed over 920 deaths and 3,360 injuries within the first 48 hours.
- **Natech Events — Industrial Disasters within Disasters:** Ground shaking ruptures [breaks] underground gas pipelines, petroleum storage tanks, and chemical facilities. This triggers what experts call Natech events [Natural Hazard-Triggered Technological disasters] — fires, toxic leaks, and explosions that compound [add to] the original disaster.

  Example: The 2011 Tohoku earthquake in Japan damaged the Fukushima Daiichi nuclear plant, triggering a Level 7 [the highest] nuclear meltdown — the worst nuclear accident since Chernobyl.

Secondary and Long-Term Impacts

- **Soil Liquefaction:** When prolonged shaking hits loose, water-logged soil, the ground temporarily behaves like liquid. Buildings sink and tilt. Roads split. This process is called soil liquefaction [bhumi-dravikaran in Hindi]. It is particularly dangerous in river delta regions — which includes much of northeast India.
- **Economic Shock and the Insurance Protection Gap:** The 2026 Venezuela earthquakes caused an estimated $6.7 billion in direct physical damages — roughly 6% of the region's GDP. Developing

countries face a massive insurance protection gap [most people have no earthquake insurance], meaning the entire cost falls on families and the government.

- **Loss of Lifeline Utilities:** Sub-surface displacement shears [cuts] underground water pipes, sewage lines, electricity cables, and fibre-optic communication networks. Survivors are left without clean water, power, or the ability to call for help — exactly when they need all three most.
- **Tsunamis:** When high-intensity earthquakes cause massive vertical displacement [upward or downward movement] of the seafloor along subduction zones [areas where one plate dives under another], they push enormous volumes of water upward — creating tsunami waves [giant ocean waves].

  Example: The 2004 Indian Ocean earthquake triggered tsunamis that struck 14 countries, killing over 2.3 lakh people — many of whom were thousands of kilometres from the earthquake's epicentre.
- **Disproportionate Social Impacts:** Damage falls disproportionately [much more heavily] on low-income families, women, children, and elderly people. Displacement [forced movement from home] into temporary camps disrupts livelihoods [income], schooling, and mental health for years. PTSD [Post-Traumatic Stress Disorder — severe anxiety after surviving a traumatic event] is widespread among survivors.

Government Response

India's disaster management framework

India shifted from a reactive [responding after disaster] to a proactive [preparing before disaster] approach with the Disaster Management Act of 2005. This act created a three-tier [three-level] institutional structure.

India's Three-Tier Disaster Management Structure

NATIONAL LEVEL — NDMA
Chaired by the Prime Minister | Sets national policy & guidelines

↓

STATE LEVEL — SDMA
Chaired by the Chief Minister | Implements state disaster plans

↓

DISTRICT LEVEL — DDMA
Chaired by the District Magistrate | Ground-level response & relief

Supporting bodies: NDRF (rescue force) · NIDM (training & research) · NCS (seismic monitoring)

Key Institutions

- **NDMA — National Disaster Management Authority:** Apex [highest] policy body chaired by the Prime Minister. Sets national guidelines and approves state plans.
- **NDRF — National Disaster Response Force:** India's specialized rescue force — 16 battalions trained for search and rescue in collapsed buildings, floods, and other disasters. First deployed in 1-2 hours after a major event.
- **NIDM — National Institute of Disaster Management:** Research and training arm. Trains officers, documents case studies, develops curricula for engineering colleges.
- **NCS — National Centre for Seismology:** The nodal [central coordinating] agency for earthquake monitoring. Expanded its station network from 80 (2014) to 168 stations for better real-time [live] data.

Recent Policy Updates

- **Disaster Management (Amendment) Bill, 2024:** Adds Urban Disaster Management Authorities [separate bodies for big cities] specifically for major metro areas and state capitals — recognising that dense urban areas face unique, complex risks.
- **National Seismic Risk Mitigation Programme (NSRMP):** Central programme focusing on strengthening vulnerable infrastructure, mapping local risks, and building technical capacity in high-risk states (Zones IV, V, VI).
- **BhooKamp App:** Real-time [instant] mobile application by Ministry of Earth Sciences giving citizens location-based earthquake alerts, epicentre information, and safety protocols.
- **Earthquake Disaster Risk Index (EDRI):** NDMA project that systematically evaluates hazard [danger], vulnerability [weakness], and population density across 50 major urban centres to guide safer town planning.
- **Aapda Mitra Scheme:** Trains 1 lakh [100,000] community volunteers in earthquake-prone districts for first response, search, basic rescue, and first aid — before formal NDRF teams arrive.
- **Techno-Financial Regime:** RBI advises financial institutions to check building code compliance before disbursing [releasing] housing loans — tying financial access to structural safety.

The Six Pillars of Earthquake Management (NDMA)

01	02	03	04	05	06
Earthquake-Resistant Construction	**Retrofitting Old Buildings**	**Regulation & Enforcement**	**Public Awareness & Preparedness**	**Capacity Development**	**Emergency Response**
New buildings must follow BIS seismic codes	*Strengthen existing structures before they collapse*	*Municipal bodies enforce building bylaws strictly*	*Teach Drop-Cover-Hold; run regular drills*	*Train engineers, masons, and volunteers*	*Early warning systems, NDRF, community first aid*

Key Challenges

Why policy does not reach the ground

India has good policies on paper. The problem is the gap between policy and practice. This gap is where lives are lost. UPSC examiners specifically look for this distinction in Mains answers.

- **90% Non-Engineered Building Stock:** A staggering [shockingly large] 90% of India's building stock [total number of buildings] consists of non-engineered, informal structures — built without any input from certified structural engineers. These buildings have no seismic [earthquake-resistant] features whatsoever. Bhuj 2001 proved this: 90% of deaths occurred in non-engineered buildings.
- **Cost and Scale of Retrofitting:** Retrofitting [strengthening existing buildings] of public structures like hospitals and schools is urgently needed but extremely expensive. Without dedicated funding models or national subsidies [government financial support], state departments and private owners routinely delay [keep postponing] necessary work.
- **Weak Enforcement — The Paper Tiger Problem:** Municipal corporations [city governments] often lack trained staff to check whether buildings actually follow IS seismic codes during construction. Structural safety certificates are treated as a bureaucratic formality [paperwork ritual] rather than a real safety check.
- **Unplanned Urbanisation and Illegal Construction:** Rapid urbanisation [cities growing fast] leads to dense, vertical construction on narrow lanes. Unauthorised extra floors [illegal additions on top of weak buildings] create catastrophic structural liabilities [dangers]. Emergency vehicles cannot reach collapsed buildings because lanes are blocked.
- **Cascading Hazards in the Himalayan Arc:** In the Himalayan arc [mountain zone], earthquakes trigger secondary hazards [additional dangers] — massive landslides and mudflows that block roads, collapse bridges, and cut telecommunications. This isolates [cuts off] remote communities exactly when rescue is needed most.
- **Untrained Masons — The Last Mile Problem:** India's informal construction sector relies on local masons [construction workers] who have no formal training in seismic safety features — like horizontal reinforcing bands [horizontal steel rods that hold walls together] or vertical reinforcing rods [vertical steel that prevents walls from collapsing sideways]. There is no nationwide licensing [certification] system for masons.
- **Public Complacency Between Events:** Because major earthquakes happen decades apart in any one region, people forget. Drills are not practised. Buildings are not inspected. The complacency [false sense of safety] that builds between events is itself a disaster risk factor.
- **Impossibility of Short-Term Prediction:** Unlike cyclones or floods, earthquakes give zero warning. No technology exists that can predict the exact time, location, or magnitude of an impending

[coming] earthquake. This makes structural resilience [ability of buildings to withstand shaking] the only reliable defence.

Way Forward

What an intelligent Mains answer should argue

A strong answer on this topic argues a framework: India must move from zone mapping [identifying risk on paper] to enforcement reality [actually making buildings safe]. The science is done. The governance is missing.

Earthquake Response — Before · During · After

BEFORE	DURING	AFTER
• Seismic micro-zonation mapping • Enforce IS 1893:2025 building codes • Retrofit hospitals, schools, bridges • Community drills — Drop, Cover, Hold • Install Early Warning Systems (EEW)	• NDRF rapid deployment • Search & rescue — golden 72 hours • Emergency communication activation • Mobile hospitals deployed • Gas/power line shutdown protocols	• Damage & needs assessment • Temporary shelter & relief camps • Psychosocial support for survivors • Long-term reconstruction — build back better • Lessons-learned audit for next event

- **Certify Engineers and Masons:** All local municipalities must create a formal, competency-based licensing [certification based on skill tests] system for structural engineers and masons. Horizontal reinforcing bands and seismic ties [connecting elements between walls and floors] must be mandatory and inspected — not optional.
- **Enforce Building Codes — Not Just Write Them:** Urban local bodies must legally link occupancy certificates [the government's permission to use a building] to independent structural safety clearances. No certificate without a genuine safety inspection. Treat building codes as a legal requirement, not a suggestion.
- **Fund Retrofitting of Lifeline Structures:** State governments must establish clear public-private funding models to prioritise retrofitting of critical lifeline structures — hospitals, schools, communication towers, bridges, and power stations — before the next earthquake, not after.
- **Micro-Zonation for Urban Planning:** Cities must complete high-resolution seismic micro-zonation [detailed local-level earthquake risk mapping] to prevent heavy construction on unstable fault

lines, loose river sediments [sand and silt deposited by rivers], or areas prone to soil liquefaction. Land-use rules must follow geology.

- **Early Warning System at Scale:** Scale up sub-surface sensor networks along the Himalayan arc for automated Earthquake Early Warning [EEW] systems that can instantly shut down gas pipelines, stop high-speed trains, and send mobile alerts in the seconds before destructive surface waves arrive.
- **Institutionalise School Drills:** The Ministry of Education and NIDM should mandate [make compulsory] routine Drop-Cover-Hold drills in all schools, twice a year. Children who practice respond correctly under stress. Children who have never practiced panic.
- **Nature-Based Solutions for Himalayan Slopes:** In the northeast and Western Ghats, standard concrete retaining walls [walls that hold back slopes] should be combined with deep-root bio-engineering [using plants with strong roots to stabilise slopes] and controlled slope drainage [channels that remove water from hillsides] to prevent earthquake-induced landslides.

The Examiner's Lens

The best Mains answers on this topic will argue that India's earthquake mortality is a governance problem, not a geology problem. The earth's behaviour cannot be controlled. Building behaviour can. Every answer should connect: IS 1893:2025 reforms → enforcement gap → 90% non-engineered stock → what must change. The Venezuela 2026 doublet is a fresh, specific example to open with. Bhuj 2001 remains the most powerful domestic evidence. Use both.

Mains Practice

Questions with model answers

Q "Earthquakes do not kill people — poorly built buildings do." Examine this statement in the context of India's seismic preparedness. (GS-III, 15 marks)

Model Answer

The statement, attributed to earthquake engineer Nicholas Ambraseys, encapsulates [captures perfectly] the central paradox of seismic risk management: while tectonic activity [movement of the Earth's plates] is a geological inevitability [something that cannot be avoided], the death toll from earthquakes is largely a product of human decisions — about construction, regulation, and enforcement. India, with 61% of its land area and 75% of its population in moderate-to-extreme seismic zones, provides both the strongest evidence for and the starkest violation of this principle.

Why Earthquakes Kill — The Real Chain

Weak buildings (no engineering) *90% non-engineered stock* → **No enforcement of building codes** *Municipal bodies under-staffed* → **Earthquake strikes** *Ground shakes — cannot be predicted* → **Mass structural collapse** *Buildings pancake, not the quake kills*

Evidence that Buildings, Not Earth, Kill

- **Bhuj 2001:** The Mw 7.7 Bhuj earthquake killed approximately 20,000 people. Post-disaster surveys found that over 90% of deaths occurred in non-engineered masonry buildings — structures built without any structural engineering input. Buildings designed to seismic code in the same region survived. The geological event was identical for both categories of building. The outcome was not.
- **Gorkha 2015 — India vs Nepal:** The Mw 7.8 Gorkha earthquake killed approximately 9,000 people in Nepal. The same event shook parts of northern India with similar intensity — yet Indian casualties were minimal. The difference: building stock quality and enforcement of codes in the affected Indian districts.
- **Venezuela 2026:** The June 2026 doublet earthquake damaged over 1.7 million structures in Caracas. Official post-event analysis confirmed the primary failure mode was unreinforced concrete frames [concrete buildings with no steel reinforcement] — a construction practice common across Latin America and South Asia.

India's Specific Governance Failure

India has strong policy on paper. IS 1893:2025 — the most comprehensive seismic design code update in decades — introduces Zone VI, geology-based mapping, PSHA methodology, and mandatory retrofitting of lifeline structures. The problem is the distance between the code and the construction site.

- **90% non-engineered stock:** The vast majority of India's buildings — residential and commercial — were built without any structural engineer's input. No code can protect a building that was never designed to any code.
- **Enforcement vacuum:** Municipal corporations routinely lack trained inspectors. Structural safety certificates are issued as administrative formalities. Unauthorised floor additions on weak foundations are commonplace in every Indian city.
- **Untrained masons:** India has no nationwide licensing system for construction workers. The mason who builds most of India's informal housing has never been trained in seismic bands, vertical ties, or any other earthquake-resistant technique.

Critical Assessment

The statement holds with one qualification: it is not merely that buildings are poorly built — it is that the governance system that should ensure good construction has systematically failed. The path forward requires not just better building codes but a fundamentally different approach to enforcement: competency-based licensing for engineers and masons, mandatory independent structural clearances before occupancy certificates, and public-private funding models for retrofitting lifeline structures. India cannot predict when the Himalayan arc will rupture. It can decide whether its hospitals will still be standing when it does.

Q Discuss the significance of IS 1893:2025 in strengthening India's seismic safety framework. What challenges remain? (GS-III, 10 marks)

Model Answer

The revision of IS 1893 [India's primary earthquake design code] in 2025 represents the most significant update to India's seismic safety framework in over two decades. It moves the country from a largely historical and administrative approach to a science-driven, geology-based risk model — a foundational shift that has direct implications for planning, infrastructure, and lives.

Significance of IS 1893:2025

- **Zone VI — a new category for extreme risk:** The introduction of Zone VI — designed for earthquakes exceeding Magnitude 8.0 — finally acknowledges the true threat level of the Himalayan arc. Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh now have the highest design standards ever applied to any Indian region. This will require structural standards for new hospitals, schools, and government buildings to be fundamentally redesigned.
- **Geology over administration:** The old mapping system used district boundaries to define risk zones — boundaries that have nothing to do with underground fault lines or soil composition. The new system uses subsurface lithology, active fault mapping, and GPS-measured strain accumulation. This is how seismic mapping is done internationally.
- **PSHA adoption:** Probabilistic Seismic Hazard Assessment allows engineers to mathematically forecast future ground motion based on all known faults — including those that have not ruptured in recorded history. India previously relied almost entirely on historical records — missing the danger from silent but active faults.
- **Non-structural regulation:** For the first time, the code mandates anchoring of heavy non-structural elements exceeding 1% of building weight. Water tanks, false ceilings, and heavy facades cause enormous injuries and deaths during earthquakes even when the main structure survives.

Challenges That Remain

- **Implementation deficit:** Codes are updated at the national level but enforced — or not — at the municipal level. Most urban local bodies lack the trained staff, digital tools, or political will to enforce new standards.
- **Legacy stock:** IS 1893:2025 governs new construction. The vast majority of India's building stock — built over decades without any seismic code — remains exactly as vulnerable as before. Retrofitting at national scale requires dedicated funding that does not yet exist.
- **Awareness gap:** Most building owners, developers, and local contractors are unaware of the new code's requirements. Without mass awareness campaigns and accessible technical guidance, the code exists only on paper.

IS 1893:2025 is a necessary and significant step. But a code is only as strong as its enforcement. India's challenge now is to build the institutional and financial machinery to make the new code real — from the design table to the construction site.

Q Examine the role of community preparedness and institutional mechanisms in reducing earthquake casualties in India. (GS-III, 15 marks)

Model Answer

The central lesson from every major earthquake in the last two decades is that the first 72 hours — the 'golden window' for rescuing survivors from debris — cannot be managed by formal disaster response agencies alone. NDRF battalions require transit time. State machinery requires activation time. The community, in contrast, is already there. India's disaster management architecture increasingly recognises this — but the gap between policy and practice remains wide.

Community Preparedness — Why It Matters

- **The 72-hour reality:** Survival rates under earthquake debris fall sharply after 72 hours. Most NDRF teams arrive 6-12 hours after a major event in accessible areas — and much longer in the Himalayan arc. Community volunteers with basic search-and-rescue skills can begin work within minutes.
- **Drop, Cover, Hold:** The single most effective individual survival behaviour during an earthquake requires no equipment, no electricity, and no warning. Studies show that practised responses under stress require repeated, embodied [physically practised] drills — not just awareness. Schools that conduct regular drills produce students who respond correctly under real conditions.
- **Aapda Mitra Scheme:** India's community volunteer training programme has trained 1 lakh volunteers in earthquake-prone districts. Volunteers are trained in first aid, search and rescue basics, and emergency communication. This is the right model — but coverage remains limited relative to the at-risk population.

Institutional Mechanisms

- **Three-tier NDMA structure:** The Disaster Management Act 2005 created a coordinated structure from national to district level. The 2024 amendment strengthened this by adding Urban Disaster Management Authorities for metros — recognising that dense urban settings require specialised institutional capacity.
- **NDRF rapid response:** 16 battalions provide India's specialised rescue capacity. Deployment protocols have improved significantly since Bhuj 2001. Operation Dost — deploying NDRF to earthquake-hit Turkey in 2023 — served both a humanitarian purpose and a capacity-building one, giving teams experience in complex urban search-and-rescue.
- **BhooKamp App and early warning:** Real-time tremor notifications help communities initiate emergency protocols faster. Scaling earthquake early warning systems along the Himalayan arc — to provide automated shutdown signals to gas pipelines, trains, and elevators — remains a priority gap.

Remaining Gaps

Three gaps stand out. First, drill frequency: most communities conduct disaster drills once in several years — far too infrequent for practised response to become instinctive. Second, geographic coverage: Aapda Mitra and similar programmes are concentrated in identified high-risk districts, but India's seismic risk is now confirmed across 61% of its territory. Third, inter-agency coordination: communication between NDRF, state disaster response forces, military units, and civil administration during the first hours of a major earthquake still requires improvement.

The evidence from Turkey 2023, Nepal 2015, and Japan 2011 is consistent: countries with high community preparedness and practised institutional coordination suffer far fewer deaths per unit of seismic energy released. India has the policy architecture. The investment must now go into activation — making preparedness a living habit, not a document.

Q Critically examine India's vulnerability to earthquake-induced tsunamis and the adequacy of its early warning systems. (GS-III, 10 marks)

Model Answer

The 2004 Indian Ocean earthquake demonstrated with devastating clarity that India's coastal vulnerability extends far beyond its seismically active land borders. With 7,516 km of coastline and a significant portion of its 1.4 billion people living in coastal districts, India's exposure to earthquake-induced tsunamis represents a distinct and deadly dimension of seismic risk.

Nature of India's Tsunami Vulnerability

- **Andaman-Sumatra Subduction Zone:** The eastern Indian Ocean contains one of the world's most active subduction zones — where the Indian Plate dives under the Eurasian and Burma plates along the Sunda trench. This zone produced the 2004 earthquake and can generate tsunamis that reach India's eastern coast in 90-120 minutes.

- **Exposed coastlines:** The eastern coast — Tamil Nadu, Andhra Pradesh, Odisha — and the Andaman & Nicobar Islands face the highest tsunami risk. Low-lying coastal plains with high population density amplify the danger. The 2004 tsunami killed over 10,000 people in Tamil Nadu alone.
- **2004 — the evidence:** India had no tsunami early warning system in 2004. The waves arrived with no alert. Over 10,000 Indians died — the vast majority in the first wave, before any evacuation was possible. This event was the direct catalyst for building India's current warning architecture.

India's Current Early Warning Architecture

- **INCOIS — Indian National Centre for Ocean Information Services:** The nodal agency for India's Tsunami Early Warning System (TEWS), based in Hyderabad. Integrates data from seismic sensors, deep-ocean DART buoys, and tide gauge networks to issue warnings within 7-10 minutes of a triggering earthquake.
- **DART Buoys:** Deep-ocean Assessment and Reporting of Tsunamis buoys are placed in the Indian Ocean to detect pressure changes from tsunami waves. They provide confirmation data that distinguishes tsunami-generating earthquakes from non-tsunamigenic ones — reducing false alarms.
- **Multi-modal warning dissemination:** Warnings are transmitted through the Emergency Alert System on mobile phones, All India Radio, Doordarshan, and direct hotlines to coastal district administrations. Sirens have been installed in high-risk coastal areas.

Remaining Adequacy Gaps

- **Last-mile reach:** Technical warning systems are functional. The gap is in last-mile communication — reaching fishing communities at sea, elderly populations without smartphones, and tourists unfamiliar with local evacuation routes.
- **Evacuation infrastructure:** Many high-risk coastal areas still lack clearly marked and rehearsed evacuation routes, vertical evacuation structures, and community wardens trained to direct movement under panic conditions.
- **Warning time for near-field events:** For earthquakes close to India's coast, the warning window may be as short as 15-20 minutes — insufficient for full coastal evacuation. Natural warning signs — sudden sea withdrawal, strong shaking — must be recognised instinctively by coastal populations, requiring sustained community education.

India's tsunami warning architecture has improved dramatically since 2004 — the investment in INCOIS, DART buoys, and multi-channel dissemination reflects serious institutional commitment. The remaining challenge is the human link in the chain: warning systems save lives only when coastal communities know what to do within the minutes they have. That requires not technology, but sustained, repeated community preparedness — exactly what remains underdone.