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Zero-Threshold Ergonomics: Forensic Detailing of Flush Transitions for Fall Prevention in Indian Senior Housing

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Abstract- Geriatric slips, trips, and falls constitute the leading cause of accidental trauma and mortality among elderly populations globally, with heightened vulnerability observed within domestic residential environments. While the National Building Code (NBC 2016) of India outlines macro-level barrier-free guidelines, conventional construction practices frequently default to step-downs, raised door thresholds, and deep shower curbs to manage hydraulic drainage. This paper provides a forensic architectural analysis of zero-threshold (flush) ergonomic detailing as a primary architectural intervention for fall prevention. By evaluating the structural, material, and hydraulic intersection of flush-floor transitions, sliding track integrations, and concealed linear trench drainage systems, this study establishes a scalable technical framework. The findings demonstrate that removing micro-spatial steps directly optimizes wheelchair, walker, and assisted-locomotion kinematics while maintaining rigorous waterproof integrity in high-moisture tropical contexts.

Keywords— Zero-threshold ergonomics, Flush transitions, Fall prevention, Senior housing, Elderly safety

I. INTRODUCTION

The demographic profile of India is undergoing a structural transition. Projections indicate that by mid-century, the elderly population will constitute nearly 20% of the nation's total demographic matrix. This shift necessitates an immediate re-evaluation of residential architecture, transitioning from speculative developer paradigms to high-performance, senior-specific environments. In geriatric environmental design, the margin for architectural error is exceptionally narrow. A minor level variance that a healthy adult unconsciously navigates can function as a catastrophic barrier or a source of physical trauma for a senior citizen with altered gait dynamics, reduced visual acuity, or cognitive impairments.

Statistics from public health repositories in India consistently identify the home—specifically the bathroom-to-bedroom interface and the balcony threshold—as the primary zone of fall occurrences. Traditional Indian construction methodology heavily relies on physical drops (ranging from 25mm to

75mm) to act as a rudimentary barrier against water overflow and weather elements. However, from a mobility standpoint, these steps break the continuous, frictionless paths required for autonomous aging-in-place. This paper argues that universal accessibility cannot be achieved through retrofitted grab bars alone; it requires the absolute elimination of vertical level changes through zero-threshold ergonomics.

II. LITERATURE REVIEW AND REGULATORY FRAMEWORK

1. Mechanical and Kinematic Implications of Thresholds

Geriatric locomotion is structurally distinct from youth kinematics. Aging brings about a reduction in lift height during the swing phase of walking, a shortened stride length, and a forward-shifted center of gravity. When a user with a walker or a selfpropelled wheelchair encounters a standard 25mm door threshold or a raised marble strip, the mechanical force required to overcome the vertical resistance increases exponentially. For a wheelchair user, a sharp 20mm lip requires a sudden torque application that can cause the caster wheels to lock, tilting the center of mass forward and risking an abrupt forward tip. For a senior utilizing a rolling walker, lifting the device over an uneven threshold destabilizes their core posture, significantly increasing the probability of a balance loss.

Precedents of Geriatric Morphology: The De Hogeweyk Model

The global benchmark for salutogenic geriatric design, The De Hogeweyk Dementia Village in Weesp, Netherlands, provides vital empirical validation for zero-threshold ergonomics. De Hogeweyk's architectural philosophy transitions away from restrictive institutional layouts by utilizing a continuous, unhindered horizontal plane that seamlessly merges indoor living spaces with outdoor courtyards, public squares, and gardens.

To support safe, autonomous navigation for residents with severe cognitive and physical impairments, the village eliminates traditional architectural barriers:

- Frictionless Transitions: Dropped steps and vertical door sills are entirely absent between private residential rooms and public zones, completely removing tripping hazards for those with altered gait dynamics.
- Visual and Tactile Ergonomics: The flooring is purposefully devoid of highly contrasting or disruptive patterns, which can be misperceived by seniors as physical depth drops or structural holes.

2. Indian Code Compliance: NBC 2016 vs. Market Reality

The National Building Code of India (NBC 2016), specifically Volume 1, Section 13 (Requirements for Barrier-Free Environment for Persons with Disabilities and Elderly), dictates clear mandates regarding level changes. The code explicitly states that:

- Changes in level up to 6mm may be vertical without edge treatment.
- Changes in level between 6mm and 12mm must be beveled with a slope not steeper than 1:2.
- Any level change exceeding 12mm must be treated as a ramp with a maximum gradient of 1:12.

Despite these clear regulations, the prevailing real estate and construction landscape in Tier-1 and Tier-2 Indian cities regularly bypasses these parameters due to a lack of specialized construction detailing knowledge. Standard sliding door frames imported or manufactured locally feature lower tracks with profiles standing 35mm to 50mm above the finished floor line, presenting a persistent tripping hazard.

III. METHODOLOGY

This study utilizes an applied, empirical architectural detailing methodology. It translates the spatial parameters established in the "Next Chapter Living" senior citizen housing unit catalog into high-performance construction junctions. The forensic analysis focuses on three critical spatial junctions within a standard 70 sq.m Premium 1.5 BHK independent living unit footprint:

- The Foyer-to-External Corridor Junction: Managing acoustic sealing, smoke seals, and dust control without a raised bottom sill.
- The Bedroom-to-Accessible Wet-Room (Bathroom) Junction: Resolving the conflict between high-volume open-discharge water management and a completely flush, step-free floor.
- The Living Room-to-Baramda (Balcony) Junction: Integrating weathering, monsoon wind-driven rain protection, and continuous sliding tracks into a zero-threshold slab drop.
- Forensic Detailing and Structural Junctions

1. The Bathroom Interface: Concealed Linear Trench Drainage

The wet-room interface is technically the most challenging aspect of zero-threshold design due to the strict necessity of controlling water migration without a physical curb or step. To achieve a perfectly flat, non-hazardous floor transition, the structural slab must be detailed with a recessed drop during the casting phase, paired with a multi-directional slope matrix pointing away from the dry zone.

Parameter	Standard Technical Specification	Ergonomic/Code Justification
Slab Recess (Raw)	100mm structural drop in the wet zone	Allows for thick screed slopes, waterproofing, and flush tile alignment.
Finished Slope	1:50 (2%) inward gradient from the door	Directs water away from the threshold autonomously via gravity.
Drainage Hardware	1200mm continuous linear stainless steel trench drain	Creates a full width hydraulic barrier across the door or shower entry.
Tile Alignment	100% flush, zero-lip matching at the brass transition strip	Eliminates micro-edges to prevent walker caster wheel snags.

The linear trench drain must feature an ultra-low profile stainless steel grade 304 or 316 grating that sits completely flush with the surrounding vitrified tiles. Water running off the user's body or chair is intercepted along the entire span of the threshold by a 50mm wide continuous slit before it can migrate outward into the bedroom dry zone.

2. The Balcony Interface: Flush Sliding Sub-Tracks

The transition from an internal living area to an outdoor Baramda (verandah) must withstand severe weather elements, particularly the high-velocity wind-driven rain common during the Indian monsoon season. Conventional design uses a 50mm stone sill to prevent water ingress. The zero-threshold alternative utilizes a specialized sub-floor drainage track configuration.

The bottom aluminum frame of the sliding door system is not mounted on top of the finished floor. Instead, it is embedded directly into a cast-in-place concrete channel. The top edge of the sliding track rail is perfectly aligned with both the interior living room floor tile and the exterior flamed-granite Baramda flooring. To manage rainfall, the bottom of the embedded aluminum profile is detailed with weep holes that discharge directly into an external subsurface slot drain running parallel to the track. This dual-layer system guarantees that even if water pools within the track mechanism during a heavy downpour, it discharges safely beneath the floor finish level, leaving the walking plane completely level and dry.

IV. MATERIALITY, FRICTION COEFFICIENTS, AND SAFETY

To learn how this forensic detailing connects directly to material science, we must evaluate the tactile interaction between the senior user and the surface flooring. Universal design is compromised if a flush floor becomes a slippery hazard when wet.The paper must establish strict Material Performance Specifications based on the Pendulum Test Value (PTV) and Slip Resistance Classifications (R-ratings):

- Internal Dry Areas (Foyer, Living, Bedroom): Flooring must maintain a minimum value of R10, utilizing anti-skid matte-finished vitrified tiles with a Light Reflectance Value (LRV) difference of at least 30 points between the floor plane and the vertical wall skirtings to ensure spatial depth clarity for low-vision residents.
- Wet Zones & External Semi-Open Zones (Bathrooms, Baramdas): Materials are restricted to high-texture, unpolished finishes such as flamed granite, locally sourced non-porous laterite stone tiles, or customized Class C tactile anti-slip ceramic modules possessing a minimum wet PTV of 36. This material constraint ensures that even under soap-water film conditions, the kinetic grip remains stable during wheelchair braking or unassisted human steps.

V. STRUCTURAL INTEGRATION CHALLENGES IN THE INDIAN CONTEXT

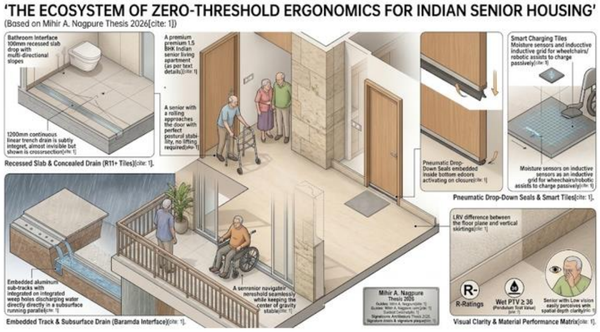
Transitioning standard construction layouts to zero-threshold ergonomics requires strict quality control on the active construction site. The primary architectural challenges are not conceptual; they are execution-dependent and require rigid oversight during three distinct phases of construction:

Civil Casting and Structural Formwork: Structural engineers must specify a mandatory 100mm slab drop for all wet-room zones during the initial shuttering phase. If the structural slab is poured flat across the entire layout, retrofitting a zero-threshold system later requires chipping away cured concrete, which compromises the structural integrity of the building.

Waterproofing Continuity: Eliminating the physical door sill removes a safety buffer against poor waterproofing. The elastomeric membrane must be continuously applied from the wet-zone floor, dropped down into the recessed linear trench channel, and extended up at least 300mm onto the dry-zone wall skirtings. Any pinhole failure in the membrane layer will cause sub-floor water migration into the adjacent bedroom.

Tile-Lipping Tolerances: Traditional Indian masonry often permits a 1.5mm to 3mm height variance (lipping) between adjacent tiles. In a senior living community, a 2mm tile edge can snare a walker's caster wheel. Zero-threshold execution demands the absolute mandate of mechanical tile-leveling clips during installation to achieve a precision-engineered, uniform plane.

'THE ECOSYSTEM OF ZERO-THRESHOLD ERGONOMICS FOR INDIAN SENIOR HOUSING'
(Based on Mihir A. Nagpure Thesis 2026[cite: 1])



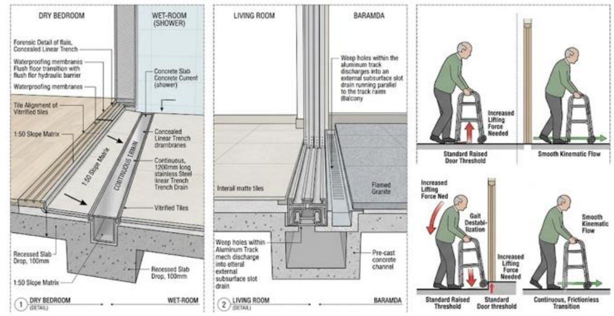


Figure 1: Bathroom Interface - Concealed Linear Trench Drainage Figure 2: Balcony Interface - Flush Sliding Sub-Tracks Figure 3: Kinematic Comparison - Traditional vs. Zero-Threshold

VI. CONCLUSION & FUTURE SCOPE

1. Conclusion

Geriatric fall prevention cannot be treated as a decorative or superficial afterthought in senior housing design. It is a fundamental structural obligation that must be coded directly into the building's physical details. This paper proves that the traditional practice of using raised marble sills and step-downs to manage water is an outdated paradigm that actively endangers elderly residents.

Through the implementation of zero-threshold ergonomics—specifically recessed structural slabs, concealed linear trench drains, and sub-floor sliding door sub-tracks—architecture can eliminate these physical hazards. The technical specifications detailed herein prove that a continuous horizontal plane can be executed safely in high-moisture tropical environments, fully complying with both the National Building Code (NBC 2016) and the operational standards of the MahaRERA senior housing directives.

2. Future Scope for Indian Smart-Cities

As India continues to develop its urban infrastructure, the future scope of zero-threshold ergonomics lies in the integration of material science and smart-home technology:

- Pneumatic Drop-Down Seals: Future research should evaluate the integration of automatic mechanical drop-seals embedded inside the bottom edge of flush wooden doors. These seals drop down to form an acoustic and smoke barrier only when the door is completely closed, keeping the floor smooth and unhindered when open.
- Smart Linear Sensors: Integrating moisture-sensing capacitive alerts inside the concealed

linear trench drain can warn nursing stations of any sub-floor blockages before water can overflow into dry living areas.

- Inductive Charging Floors: Exploring how flush vitrified tile planes can incorporate low-frequency inductive charging grids beneath the screed will allow electric wheelchairs and robotic mobility assists to charge passively as they navigate the home.

REFERENCES

1. National Building Code of India (NBC 2016), Volume 1, Section 13: Requirements for Barrier-Free Environment for Persons with Disabilities and Elderly. Bureau of Indian Standards (BIS), New Delhi.
2. MahaRERA Order No. 55/2024: Housing for Senior Citizens, Model Guidelines for Barrier-Free Infrastructure in Senior Living Communities, Maharashtra Real Estate Regulatory Authority.
3. World Health Organization (WHO), Global Report on Falls Prevention in Older Age, Lifecourse and Ageing Cluster.
4. Precedents of Geriatric Morphology: The De Hogeweyk Dementia Village Model, Weesp, Netherlands.
5. Field Studies and On-Site Audits: Athashri Senior Living Community, Pashan, Pune.