CHALLENGES of stone depth, type of joint, locking mechanism on sustainability

Sameer Meghani (www.dankua.in)

B.E. Production, BVM Engg College, Vallabh Vidyangar

Self-employed, proprietor of Dankua (India), Vadodara, Gujarat.

Membership No. AFF-20076 (Affiliate member of IIID – Goa chapter)

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Author Note

Sameer Meghani (www.dankua.in)

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Correspondence concerning this article to should be addressed to Sameer Meghani,

(M) 9825167256 E-mail: dankuaintl@gmail.com

Abstract

This article examines the challenges of stone depth, type of joint, locking mechanism on sustainability. Despite an increase in cladding outdoors with natural stone sandstone or limestone having 3" depth, rock face, dry-stack joint, its ability associated with increasing sustainability at economical price has not been well published.

The present article aimed to identify, describe and define various stone variables for different elements of workplace that lead to attainment of sustainability, efficiency in energy use, resistance to weather and its contribution to climate change.

Using data from prototypes developed (N=2000 SqFt) and stones delivered (N=50,000 SqFt) to my clients, we conducted multivariate analyses of the depth of stone, type of joint and locking features to examine changes in durability, sustainability and resistance to weather.

The results illustrated that exterior cladding with 3" depth sandstone / limestone having rock face texture, tight-fit, dry-stack joint had positively affected the breathability, durability, and insulation of their house. They used it as a trigger for sustainability, self-efficacy and were more likely to have a peaceful healthy life. Thinner stones were both less resistant to water penetration and provided less insulation.

Common adverse effects of outdoor cladding with 1" thick stones was detachment, making it less sustainable. Our results underline the importance of taking wall stone 3" depth provides structural integrity, moisture exclusion and offers adequate insulation. This should be considered when scrutinizing stone cladding options for outdoor spaces. Harsh heat from west facing walls can be eliminated. This paper would have an impact on environmental protection; it would reduce both energy consumption, and pollution to create an environmentally friendly society

keywords: stone, depth, dry-stack joint, sustainable, energy use, insulation, structural integrity, locking features, detachment, breathability, resistance to water penetration, durability, climate change

Introduction

Façade stone cladding system is essential contributor to the sustainable performance of buildings. Sustainable materials reduce the use of resources and also minimizes the environmental impact which any building materials has on human health because of harmful chemicals were used in the production of these materials. In spite of an increase in stone cladding outdoors having 3" depth, dry-stack joint having locking mechanism its role associated with increasing sustainability has not been elegantly composed.

Objective

The purpose of study was to evaluate available stone cladding variable alternatives for a better sustainability. Identifying the criteria influencing the selection of stone depth, type of joinery and locking mechanism used in hot climate areas with respect to better water barrier, thermal insulation, energy consumption, maintainability, and sustainability. Limited research is available on the capacity of dry-stack joint with locking technique leads to accomplishment of *sustainability*.

Research Methodology

The adapted methodology is tested for the different cantons of Mumbai, Alibag, Karjat and Goa having harsh rainfall along. In-house prototypes (N = 80 variants) , models (N = 5,000 SqFt) , products delivered (N = 50,000 SqFt) were continuously observed for strength, stability, durability, water penetration resistance, buckling. The results are compared to the criticality of depth of stone, type of joint, locking technique. At the wall level, the life cycle assessment of various outdoor wall systems with stone cladding shows that the use of a thin cladding with mortar joint in the façade is not necessarily the sustainable solution.

The ultimate goal is to better understand the meaning of this concept and to provide tools and methodologies that will facilitate policy-makers and construction industry stakeholders define strategies and take decisions that will be in alignment with sustainable development.

Results / Findings / Discussion

1. Dry-stack joint

With dry-stack joint, the weight of stone is transferred to the footing via gravity. Each stone uses its self-weight, to lock the stone beneath it. This gives rise to self-locking – making it self-sustainable, which is witnessed in The Egyptian Pyramids. Rock face texture impart natural organic beauty to the buildings and offer an aesthetic that harmonizes with the surrounding environment.

Rayhouse, Alibag

Riparian house, Karjat

1.1. Benefits of dry-stack joint :

a) Weight is transferred vertically downwards by gravity

b) Tight-fit – ensures structural integrity of the wall

c) Stone locking features

d) Open breathable structure , does not hold water

e) Repair costs are less then mortared stonework

f) Greater lifespan than mortared stonework

g) Works of true dry stone craft ar

2. Transitional spaces: Bridging the gap between indoors and outdoors

Ray house, Alibag

It creates architectural harmony between outdoor and indoor. The concept of transitional spaces, which seamlessly connect the interior and exterior environments, facilitating integration of nature into living spaces. By understanding the principles of design continuity, homeowners can truly unlock the potential of transitional spaces. This trend not only enhances the aesthetics of interiors but also aligns with our innate human desire to reconnect with the outdoors. The paradigm is both inside and outside embodies the idea of singular in the plural.

3. Perforated stone screens:

Perforated screen - mockup

Perforated stone screens allow cooler air to gush inside. It can also be used as a shading wall for semi-open spaces and/or parapet wall.

4. Limitations of mortar joints:

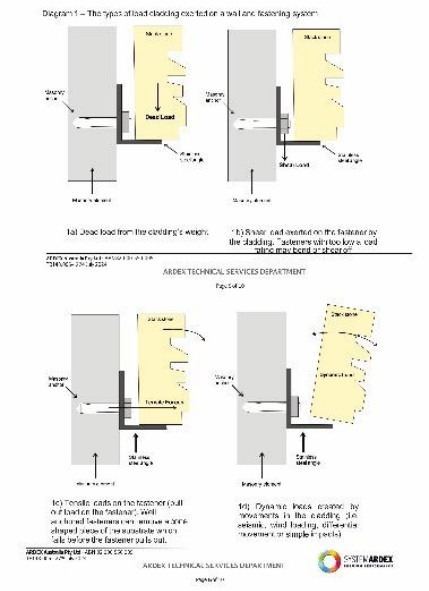
4.1. **Escalates project cost:** because of

a) Joints has to be maintained, filled and brushed off

b) Labour Intensive

c) Maintenance cost (less sustainable)

4.2. **Algae** / **Moss formation on the mortar joints:** In harsh rainfall, water penetrates the mortar joints, compromising on the strength and making the stones loose-fit, weakening the structural integrity of the wall. Weak mortar joints are not breathable. Cracks or damaged areas of stone or mortar hat require repointing. Hence, it is not self-sustainable.

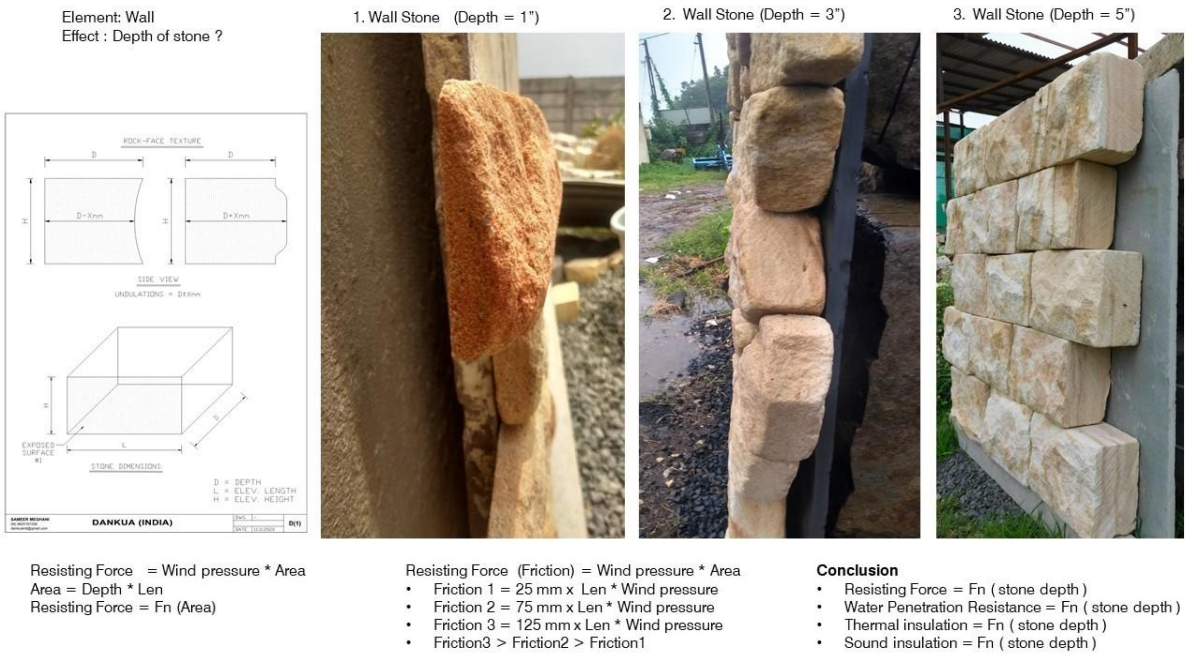


Modes of failure: Mortar interface

Two basic failure modes can occur at the level of the unit–mortar interface: tensile failure (mode I) associated to stresses acting normal to joints and leading to the separation of the interface, and shear failure (mode II) corresponding to a sliding mechanism of the units or shear failure of the mortar joint.

4.3. **Freeze and thaw situation**: Resistance to water penetration is minimal. In extreme cold countries, water is absorbed by the mortars and converts into ice. Ice created leads to crack formation onto the stones. Over time, the freeze-thaw process weakens the mortar, leading to crumbling and gaps between stones. This damage not only affects the appearance of the masonry but can also compromise the structure's stability.

5. Effect of stone depth on sustainability:



Effect: stone depth

5.1. **Frictional resistance:** The depth of stone creates an intrinsic frictional resistance between adjoining stone pieces – eliminating the probability of detachment arising out of wind pressure forces. This makes it self-sustainable. This characteristic is lacking in thin cladding stones.

Frictional resistance force = Fn (Depth of stone). This mathematical modeling has been extended to both Riparian house, Karjat and Ray house, Alibag

5.2. **Water penetration barrier:** More the depth of stone, more is the resistance to water penetration has been observed in my mock-ups.

Resistance to water penetration = Fn (Depth of stone).

(Ref: Riparian house, Karjat and Ray house, Alibag)

5.3. **Thermal insulation:** The stone-finished exterior insulation system is commonly used in green remodelling projects to reinforce the insulation of concrete exterior walls. Use of stone materials with high thermal mass and density is of paramount importance. Because of the density, heat seeps through the wall very slowly so that by the time the sunsets, heat is just starting to reach the home's cool interior.

Mass = Fn (Depth of stone) (Ref: Riparian house, Karjat and Ray house, Alibag)

5.4. **Acoustic properties**: ((Ref: Riparian house, Karjat and Ray house, Alibag)):

5.4.1. More the depth of stones implies higher mass per unit area and structural discontinuity between the elements, increases its ability to attenuate the transmission of sound and vibrations. It constitutes a considerable obstacle to the free propagation of vibrations reducing the field of bending waves.

5.4.2. The sound waves are absorbed rather than reflected, reducing noise levels within a room. The dense composition of 3" stones, helps minimize sound reverberation, preventing echoes, absorbing and dampening sound waves more effectively.

5.4.3. When used as a flooring application (white marble) , it minimize the transfer of airborne and impact noise, contributing to a quieter and creates a more acoustically comfortable environment.

6. **Stone Weight:** Weight being the primary area of concern when building with stone.

6.1. **Total stone weight** = Stone Kg/SqFt * coverage area SqFt

6.2. **High Rise building:** The depth of stone can be reduced to 1.5" and weight is transferred to each slab floor / column via angle. Both ceiling and slab floor facilitates locking of the stone. This assist in equal weight distribution of the stone weight onto the respective floor.

6.3. **Weekend house:** Footing details as below

Weekend house footing: Weight of stone is transferred to footing

On the envelop, the weight of stone has to be transferred to a footing base created on the borderline of the house. A proper design would not transfer the weight onto the slab floor of the house. This minimises load transferred to the superstructure or dead load.

(Ref: Riparian house, Karjat and Ray house, Alibag)

7. **Stone Locking mechanism**: It provides significant benefits in terms of safety and stability.

7.1. Attributes of stone locking mechanism

a) Cater to both horizontal (buckling) and vertical loads

b) Resistant capacity – shear and tensile forces

c) Reliable

d) Restricts stone movement

e) Alignment of stones

f) Concealed

g) Corrosion proof (Fibre glass)

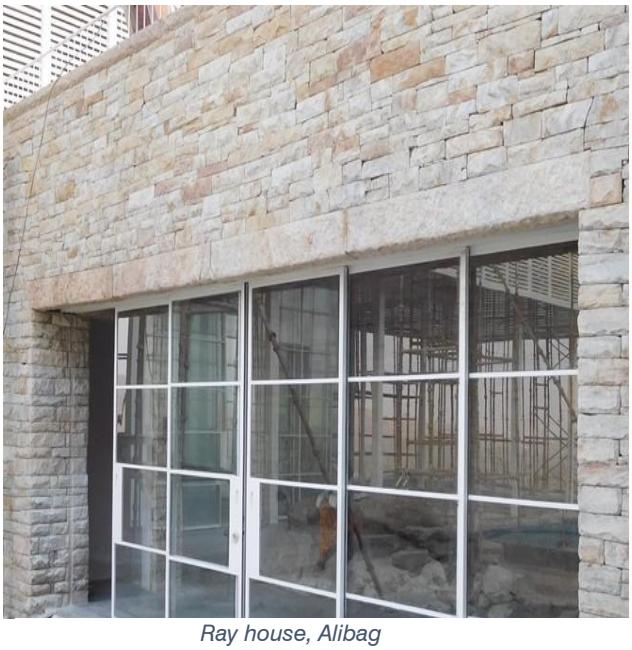
7.2. **Effect of depth of stone on locking stability:** For 3" depth of stone, the depth itself facilitates machinability or ability to incorporate robust self-locking and/ or locking features into it. It is easy to lock the stones against vertical loads and/or buckling. Thin cladding stones, have minimal depth and is challenging to create locking features onto it, as it will tend to crack. It is more or less at the behest of chemical adhesive for bonding with substrate. Chemical adhesives are not breathable, which has a detrimental effect on indoor air quality, defeating the purpose of sustainability. Thin cladding stones will tend to buckle and detach easily reiterating its unsustainable characteristic.

8. **Elements**: Stone elements, used in conjunction, to accomplish sustainability

8.1. Wall stones unification with wall caps

Wall caps, use self-weight to lock the wall stones beneath – making them self-sustainable. *Riparian house, Karjat*

8.2. Lintels



Ray house, Alibag

Riparian house, Karjat

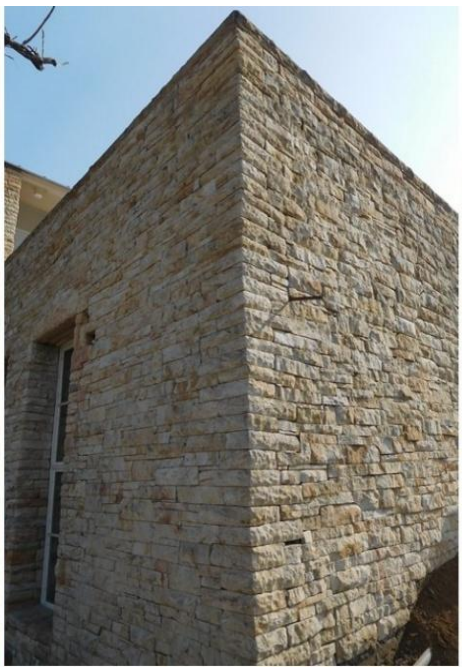
Lintels integrate into the wall stones, which ensures stability and strong connection. It supports the wall stones above.

8.3. Arches

Arches are curved vertical cladding, spanning an open space beneath. It supports the stones above. Ray house, Alibag

8.4. L-shape corner stones

FLute mockup, Aditya Birla group



Ray house, Alibag

Riparian house, Karjat

8.4.1 **Benefits of L-shape corner stones**

a) Used for windows and door surrounds –*conceals the frame giving a sleek look*

b) Enhances insulation of the building – *both at corner and by insulating frames of windows and/or door surrounds.*

c) Built into the corners of building, as a part of the structure, integrating with wall.

d) Joints at corners will not be seen (seamless) , accomplishing a solid-stone-wall look

e) Provides insulation and strength to the corners

f) Protects the corners from all kinds of weather

g) Enhances artistic refinement of the building and gives a monumental impression

9. Stone cavity wall:

9.1. It is a solution to the harsh heat that penetrates via the west facing walls including apartment. Both the exterior and interiors of the west facing wall and/or balcony can have a cavity wall in conjunction with traditional lime plaster on the substrate – leading to energy savings, reduced environmental impacts, thermal insulation and reduction of wind pressure effects.

Cavity wall

9.1. Stone cavity wall benefits:

a. Moisture cannot enter from outside leaf to the inner leaf

b. Provides good insulation against sound, thermal insulation

c. Application: West facing walls including balcony of apartment

d. The problem of efflorescence is very much reduced

e. Rock face texture, dry-stack joint benefits can be extended

f. Interior or exterior application

g. Construction is economical and can be used in conjunction with L-shape corners

10. Effect of climate change:

Typhoon in Xiamen, China Oct'15

10.1. Flash floods in Saudi Arabia Jan ’25, torrential rains in Kuwait, Jan ’22 - indicate that rising temperature will intensify the earth’s water cycle, increasing evaporation. Increased evaporation will result in more frequent and intense storms, which will likely to increase in precipitation and increased risk of flooding, while areas far away from storm will have increased risk of drought.

10.2. With the typhoon and torrential rains, the thin stone cladding layout, in which its section is considerably reduced, significantly increases the stresses both on stone tiles and on anchoring elements used. They are subjected: effects of concentration of stresses in the anchorage area, bending effect by dead load and pressure and/or wind suction.

Conclusion:

The inherent limitations of outdoor cladding with 1" thick stones noted were – buckling, detachment, less durable, reduced strength, minimal insulation, less sustainable. Our results underline the importance of taking wall stone 3" depth in conjunction with L-shape corners, lintels, wall caps, tight-fit, dry-stack joint, locking mechanism provides structural integrity, offers moisture protection, minimises carbon footprint. This should be taken into account when researching stone cladding options for outdoor spaces.

While used as a material for cavity wall, it minimizes consumption of energy resources. By incorporating stone cavity walls, harsh heat from west facing walls can be eliminated, improve energy efficiency and indoor air quality. Regardless of depth of stone, a robust customised locking technique has to be designed to ensure that its functionality remains uncompromised. It both lowers the project cost and makes them an excellent array of not only sustainable design choice but also adaptable and durable for years to come!

Attachments

Data Analysis: Source of data identified

1. **Projects** - identified for data analysis:
    - Project 1: Riparian house, Karjat, Maharashtra (Harsh rainfall)
        - Architect: Ar. Robert Verrijt, Architecture Brio, Rotterdam / Mumbai
        - Testimonial letter: Ar. Robert Verrijt , Matthews Spacie
    - Project 2: Ray house, Alibag, Maharashtra. (Harsh rainfall)
        - Architect: Ar. Robert Verrijt, Architecture Brio, Rotterdam / Mumbai
    - Project 3: Outdoor shower panels – Equninox developers, Goa (Harsh rainfall)
        - Architects:
            - Ar. Mustafa Eisa, Mustafa Eisa Design, Mumbai
            - Ar. Yadavendra Naik, Intarch, Goa
        - Testimonial letter: Ar. Yadavendra Naik
    - Project 4: Japanese stone lanterns - Puranik developers, Thane (Harsh rainfall)
        - Architect: Ar. James Chamberlain, Waho, Pune
        - Testimonial letter: Puranik developers
    - Project 5: Stone post - Dushyant Patel's house, Baroda
        - Architect: Ar. Karmavir Ghatge, Baroda
    - Project 6: Forthcoming Projects
    - Project 7: Exported world-class quality stone to USA
        - Testimonial Letter: Tim Hovey

2. **Models** developed and/or delivered to clients **-** identified for data analysis:
    - Model 1: Planter retaining wall - Godrej, Mumbai. (Harsh rainfall)
        - Architects:
            - LA James Corner, Field operations, NY
            - P G Patki Architects, Mumbai
    - Model 2: Mock-up of Setts - Flora Fountain, Mumbai. (Harsh rainfall)
        - Architect: Ar. Vikas Dilawari specifications
    - Model 3: Rock face flute panels - Aditya Birla group, Mumbai. (Harsh rainfall)
        - Architect: P G Patki Architects, Mumbai
    - Model 4: Cobbles - Mrs. Tina Ambani & Mr. Anil Ambani @ Mumbai (Harsh rainfall)
        - Architect: Ar. Pallavi Jitkar, Edifice Consultants Pvt Ltd, Mumbai
    - Model 5: Steps - Banganga, Mumbai (Harsh rainfall)
        - Architects:
            - Ar. Vikas Dilawari, Mumbai
            - Ar. Shashi Prabhu, Mumbai

3. **Prototypes** - identified for data analysis:
    - Outdoor wall
        - Random rubble, coursed ashlar
        - Bricks, 3-D bricks
        - Temple architecture
        - Partition wall
        - Flute panels
        - Planks
        - Inverted pyramid wall
        - Spot light holder
    - Outdoor floor
        - Deck
        - Pencil line texture
        - Random rubble
        - Cobbles, strips, pavers
        - Steps
        - Kerbstones
    - Interior
        - 7 mm thin biscuits
        - 25 mm thick stone
        - Random rubble, coursed ashlar
        - L-shape corner
        - Shiplap joints
        - Balcony parapet walls
        - Arches
        - Partition walls

4. **Stone elements** - identified for data analysis
    - Wall stones
    - L-shape corner stones
    - Lintels
    - Arches
    - Ceiling stones
    - Wall caps
    - Cavity walls
    - Stone screens
    - Partition planks
    - Spout
    - Drainage
    - Gazebo
    - Patio

Analysis

Effect of the following variables on sustainability

5. Depth of stone
6. Type of joint
7. Locking mechanism

Acknowledgement

1. Ar. Robert Verrijt , Ar. Shefali Balwani: By being a stone vendor in both Riparian house and Ray house projects, I mastered the skills and know- how to make wall stones, l-shape corners, l-shape lintels, wall caps, ceiling stones. When these elements are used in conjunction with dry-stack joint, I relished how it leads to attainment of sustainability. Their projects have pushed me out of my comfort zone, enhancing my self-confidence. Ar. Robert Verrijt has been a key person in my journey.

2. Ar. Gurdev Singh: Through our brain storming sessions, I acquired the expertise of stone locking design principles and was successful in developing prototypes. His emphasis was on buckling, which I had been ignoring. I must say – he has been very warm, patient and kind-hearted to share his plethora of knowledge. I have been very fortunate to learn valuable stone locking skills from the right person!

3. Ar. Vikas Dilawari: By developing basalt sett mockups for Flora Fountain, Mumbai, I gathered the production expertise required for accomplishing undulations within +/- 2mm tolerance. I had developed a customized machine to accomplish this international quality standard. I would like to express my deepest appreciation to Ar. Vikas Dilawari, for giving me an opportunity to broaden my horizons.

4. Ar. Parool Tiwari: She assisted me to understand technical drawings more confidently and refined design for my mock-ups.

5. Ar. Karan Patil , Ar. Vrushali Jadhav: They gave me insights on what it takes and how to extend my stones to interiors. They assisted me in designing installation templates, which enhanced the speed of installation and reduce project cost.

6. Dr. Jwalin Patel: He has always been giving me the much-needed push, guidance and mentorship all the time. His wealth of knowledge, which he generously shares, stems from both his education and experience. He being a research scholar, his core competency lies in analytical reasoning.

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8. Parth Ingreji: He has been instrumental in repositioning my brand – by designing graphics, which are in line with my business needs.

References

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- Freeze-Thaw cycle
- Climate Change
- Masonry institute of British Columbia
- Bridging the gap between indoors and outdoors