1.1 BACKGROUND

Marble is a metamorphic rock originating from limestone or calcium carbonate (CaCO₃). Agglomerated marble, also known as reconstituted or compressed marble, is produced by binding selected marble chips (93 to 95%) with specially formulated resin (7 to 5%). It is one of alternative choices to natural marble, as a large part of agglomerated marble consists of natural marble chips and therefore possess similar characteristics of marble.

In natural marble production, large rocks are acquired from quarries. After cutting the selected rocks, the remaining boulders are classified as residue. In the past, the excess material was treated as waste or used as substrate for roads. This is not an efficient use of limited natural resources and does not contribute positively to environmental sustainability. The need to make full use of the natural stone substance to produce a product similar to natural marble led to agglomerated marble as a natural stone substitute.
1.2 AN OVERVIEW OF A TYPICAL PRODUCTION CYCLE

1. Selected marble boulders are crushed and sieved into various sizes.

2. Marble granules are mixed with specially formulated polyester resin and compacted under vacuum by vibro-compression technology.

3. Large marble blocks are produced and cured for few days.

4. Cured agglomerated marble blocks are sawn into slabs.

5. Unpolished slabs are calibrated using digital automatic machine to ensure uniform size and thickness.

6. Different stages of polishing are carried by automatic machines, the transformation process is closely similar to natural marble production.

7. Cutting into required sizes by a laser machine to ensure dimensional accuracy.

8. Final sorting, packing in cardboard boxes and stacking on wooden pallets before dispatch.

Fig. 1.4 – Overview of a production cycle.
1.3 QUALITY FEATURES IN AGGLOMERATED MARBLE

a. Homogeneous body and re-polishable

Agglomerated marble is made of the same materials and the whole body is homogeneous. Gentle grinding and polishing after installation make the floor surface smooth and shiny. This same quality finish can still be achieved years after installation by re-grinding and re-polishing. The measurement of hardness (MOH) scale for agglomerated marble is just slightly higher than natural marble. Thus, the tools and equipment used for polishing natural marble can be employed for agglomerated marble.

Fig. 1.5 – A schematic outline of production cycle.

Fig. 1.6 – Homogeneous body can be repeatedly polished and renewed.

Fig. 1.7 – Polishing tools are similar to those for natural marble.
b. Less effort required on dry lay

Most end users especially in residential developments prefer to have a consistent colour tone in the finishing work. Dry lay or pre-selection is not an uncommon practice when using natural stones. This is to minimize tonality and other issues inherent in the natural material. Dry lay is often a meticulous, time consuming and labour intensive process, especially in large scale residential projects. Sufficient space is also required to carry out this process. Separate dry lay shop drawings based on layouts need to be prepared and the selected marble must be installed according to the numbered sequence to ensure consistent results.

Fig. 1.8 – Dry lay requires additional manpower and sufficient space for segregation and storage.

Fig. 1.9 – Direct installation (without dry lay) saves time and cost in construction.

The addition of resin and inorganic pigments in agglomerated marble production process helps to minimize tone variations in the same batch of production. However there may be variations between different batches of production. It is therefore advisable that orders be placed for the total requirement for a project, so that the manufacturer can blend the raw materials in one batch and minimize the risk of tonality differences.
Fig. 1.10 – Sorting stones by production “batch code” to minimize tone variation.

Fig. 1.11 – Tonality consistency is a key feature in agglomerated marble finish.
c. Less inherent imperfections in the surface

The inherent imperfections like open veins, tone variations and pinholes are common in natural stones. These imperfections are sometimes classified as "defects" by end users. In most situations, it is not easy to rectify these flaws, especially after installation. Much time and cost need to be expended to address such "imperfections", apart from the inconvenience to end users. For this reason, dry laying is often necessary in natural stone works. A well controlled mechanism in the manufacturing process for agglomerated marble, together with the compressed vacuum technology will reduce concerns like pin holes and open veins in flooring.

1.4 QUALITY CONSIDERATIONS AND PREVENTIVE MEASURES IN AGGLOMERATED MARBLE

a. Stain ingress and etching

**Stains:** All natural stones are porous to a certain extent with micro interconnected capillaries through which liquids and gases can move. Agglomerated marble, although considered a dense material, have similar porosity characteristics like natural marble as they are made substantially from the same material. Given sufficient time, liquid and moisture can penetrate the material and cause staining. Porosity is also affected by its finish – a highly polished marble is a little harder to penetrate than marble with a honed (matt) finish. Due to presence of iron in the stone, prolonged exposed to water may develop stain marks. The other common sources of stains are spillage and ingress of liquids like juice, coffee, etc.

**Etching:** Calcite-based stone such as marble, limestone and travertine reacts with acidic substances on contact, leaving dull marks or even deep furrows over time. This is known as acid etching. The use of inappropriate materials for maintenance like acidic or alkalis products can cause such etching. Even mild household acids, including cola, wine, vinegar, lemon juice and milk, can damage these types of stone. The milder the acid, the longer it takes to etch; stronger acids can damage the stone in seconds.
To prevent stain ingress, it is suggested that a compatible impregnator be applied on the surfaces of agglomerated marbles. Impregnator is a subsurface treatment, formulated to penetrate the stone which enhances resistance to stains. The impregnator will resist stain ingress from top and block entry of salts from bottom. Further information on impregnators and its application can be found in Chapter 7.

Fig. 1.14 – Application of suitable impregnator enhances stain resistance.

b. Scratch and damage

The Measurement Of Hardness (MOH) scale value for agglomerated marble is about 3.5 to 4.5. This is slightly higher than natural marble (see MOH scale range). The MOH scale measures material resistance to hardness. A material lower on the MOH scale will not scratch or cause damage to a material higher on the MOH scale. For example, a piece of hard plastic (MOH #2) will not scratch calcite (marble) (MOH #3). However, a grain of sand (MOH #6) will scratch calcite (marble) but not quartz (granite) (MOH #7). The major composition of agglomerated marble is calcite, hence it tends to get scratched or damaged if it is exposed in heavy traffic areas. Furthermore during construction, many activities take place concurrently. Proper protection is therefore necessary to prevent damage to agglomerated stone by other trades.

Fig. 1.15 – Scratches and damage by other trades during construction.

MOH SCALE RANGE:

<table>
<thead>
<tr>
<th>MOH</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Diamond</td>
</tr>
<tr>
<td>9</td>
<td>Corundum</td>
</tr>
<tr>
<td>8</td>
<td>Topaz</td>
</tr>
<tr>
<td>7</td>
<td>Quartz (Granite)</td>
</tr>
<tr>
<td>6</td>
<td>Feldspar (Granite)</td>
</tr>
<tr>
<td>5</td>
<td>Apatite</td>
</tr>
<tr>
<td>4</td>
<td>Fluorite</td>
</tr>
<tr>
<td>3</td>
<td>Calcite (Most Marbles)</td>
</tr>
<tr>
<td>2</td>
<td>Gypsum</td>
</tr>
<tr>
<td>1</td>
<td>Talc</td>
</tr>
</tbody>
</table>

Agglomerated marble MOH value: 3.5 to 4.5

Fig. 1.16 – Protection is necessary during construction stage.
c. De-bonding and grouting discoloration

Use of incompatible adhesive is one of the root causes for agglomerated marble de-bonding. Unsuitable grouting (pointing) material can cause staining when it reacts with water. The presence of iron oxide in the stone can discolour the edges. At times, the incompatible grouting may not form a sound bond with the marble, so it may surface at the joints during polishing or over a period time. The use of polymer based adhesive system and epoxy based grouting materials can potentially reduce these issues. More information on such adhesives and grouts can be found in Chapters 5 & 6.

![Fig. 1.17 - Use of compatible adhesive and grout enhances the performance of agglomerated marble.](image)

Fig. 1.17 – Use of compatible adhesive and grout enhances the performance of agglomerated marble.

d. Maintenance

Agglomerated marble can react with acids and alkalis. Thus it is advisable to apply compatible impregnator to prevent or minimize stain ingress and other reactions. Also, it should be cleaned only with pH neutral detergents. Some other tips to maintain the original surface finish are:

- Protect during construction
- Remove spillage immediately
- Avoid using cleaning agents containing soluble salts like sulphate or chloride
- Use neutral cleaner or plain water for regular maintenance

1.5 TESTS FOR AGGLOMERATED MARBLE

The following key tests are adopted broadly by industry to ensure the quality of agglomerated marble. Although the tests are carried out by sampling, it is advisable that the selection of samples should be taken from different production batches to ensure reliability and consistency of results.

<table>
<thead>
<tr>
<th>S NO</th>
<th>TEST STANDARDS</th>
<th>PURPOSE OF TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BS EN 14617-12: 2005</td>
<td>Determination of dimensional stability (Manufacturing tolerance)</td>
</tr>
<tr>
<td>2</td>
<td>BS EN 14617-15: 2005</td>
<td>Determination of compressive strength</td>
</tr>
<tr>
<td>4</td>
<td>BS EN 14617-10: 2005</td>
<td>Determination of chemical resistance</td>
</tr>
<tr>
<td>5</td>
<td>BS EN 14617-1:2005</td>
<td>Determination of apparent density and water absorption</td>
</tr>
<tr>
<td>6</td>
<td>BS EN 14617-4:2005</td>
<td>Determination of abrasion resistance</td>
</tr>
<tr>
<td>7</td>
<td>EN 101:1991</td>
<td>Determination of scratch resistance</td>
</tr>
</tbody>
</table>

As each site presents its own particular requirements, it is important to understand the characteristics of the materials and match it to the conditions for its intended use. For example, the stone used for internal flooring of a house should be more resistant to stains and scratches. To achieve the desired results, the selection of stones, adhesives and other supplementary products should be chosen according to the specialist recommendation, specific type of application and the environment.