Study of Interlocking Brick Costing Based on The Result of Mixed Material Variation Design

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Abstract. Interlocking brick is a material that is used for wall filler with the method of installation interlocked with each other. This material can also be used as a substitute for reinforced concrete structures like sloof, columns and ringbalks, thus do not need to be plastered and painted because of its attractive appearance. The use of interlocking brick can save costs and time in the performance compared to using red bricks. The mixture of the forming material consists of cement, silt and river sand sourced from Aceh Besar District, Aceh Province, Indonesia. In general, industries that produce wall fill material do not differentiate their production for wall functions as structural or non-structural and tend to overall to one quality product classification quality. This research aims to analyze the costs for the requires interlocking brick in building houses that function as structural and non-structural walls. The interlocked brick function is distinguished against structural and non structural based on the compressive strength test at 28 days in the laboratory of the structure and building materials, Department of Civil Engineering, Faculty of Engineering, Syiah Kuala University. Mix design is carried out in the laboratory with a cement water factor (FAS) 0.3; 0.4; 0.5 and 18 mixed material variations with 15 specimen test for each mixture. Test objects used is 50 x 50 x 50 mm. FAS 0.4 and a mixture of material 1:2:2 and 1:2:4 are selected because meet the required workability and have a hollow concrete brick compressive strength, which are including quality levels 1 and III with an average compressive strength of 89.6 kg / m3 and 37.5 kg / m3 at the age of concrete reaching 28 days. Cost analysis is carried out by simulating the required need for interlocking brick in type 36 house buildings that can withstand structures and non-structures, then the costs of IRD 11,810,470,- is obtained. So the use of interlocking bricks can be considered as an alternative environmentally friendly building materials with low cost.

1. Introduction
Technological advances in the field of house construction continues to experience undergo huge development, one of which is the material technology that serves an environmentally friendly wall. Wall filler environment-friendly material consists of mixture of material that is not completely excavated from nature and do not need to use firewood for the manufacturing process such as red
bricks. Alternative materials that are eco friendly one is interlocking brick. Interlocking brick is a material used for wall filler with the method of installation locked together. The use of interlocking brick can save costs and time in its implementation as compared to using a brick red [1]. The use of this material may also be used as a substitute for reinforced concrete structures such as sloof, column and ringbalk and no need to be plastered and painted because it looks attractive, has the propensity to provide affordable, sustainable construction around the world and relatively low cost [2,3,4,5,6].

Interlocking brick is the development of hollow brick by adding Lisp on certain sides as the locker. The types and comparisons of mixed material forming interlocking brick are of various kinds depending on the availability of the material in the location being develop. Interlocking brick or also called with Interlocking Compressed Earth Block (ICEB) is a mixture of cement and soil that is compacted [7]. To provide the best durability, the desired con-stability, compressive strength testing of the work's most stable, then the mixture of materials consisting of soil, sand, cement, and water with a weight percentage of 74.3%, 10.0%, 6.2% and 9.5%, respectively, was adopted in the manufacture of interlocking brick [8]. The compressive strength of concrete is the magnitude of the load of a broad unity which causes the test specimen to break down when loaded with a certain compressive force produced by the press machine [9]. The factors that greatly affect the strength of concrete are water cement factor, density, age of the concrete, cement type, amount of cement, and aggregate properties. For the measurement of concrete brick compressive strength refers to the standard ASTM C-133-97.

Interlocking brick is included in the type of hollow concrete brick because its forming material is a mixture of cement, fine aggregate, water and other additives and the hardening is not burned. Concrete bricks can be divided into two types, namely hollow concrete bricks and solid concrete bricks. The quality of hollow concrete bricks is divided into four levels of quality, i.e. the quality level I and II that is used to load bearing construction, the quality of III and IV used for construction which does not bear the burden [10]. In general, industries that produce wall-filler material do not differentiate their production from wall functions as structural or non-structural and tends to only one quality classification. The quality of the interlocking brick product is influenced by many factors including the ratio of the mixture between the forming material.

For 1 m² of wall filler work requires 33,333 pieces of interlocking brick [1]. The study does not distinguish between the walls that function as a structure and non-structure. When using interlocked brick then sloof, column and ringbalk work can use interlocked brick component material by adding an iron in vertical and horizontal direction. While the price of each piece of interlocking brick was heavily influenced by the prices of material, costs of labor and its function as a structural or non-structural wall.

This research aims to analyze the costs for the requires needs of interlocking brick in building houses that serve as structural and non structural walls. The interlocking brick function is distinguished between structural and non structural based on the compressive strength test at 28 days at the Laboratory of Building Structure and Materials, Department of Civil Engineering, Faculty of Engineering, Syiah Kuala University.

2. Methodology
This research was conducted with several stages of work that started from the material preparation, materials inspection, mix design, making the test items, testing of the test objects, analysis of the test results, then choose the mix design results to the most optimum compressive strength to be used as a structural and non-structural wall material. The results of the mix design selection are then used in estimating the cost of selling interlocking brick per piece and analyzing the needs of interlocked bricks used as structural and non-structural walls. The study of the cost of interlocked brick needs for structural and non-structural walls for building houses type-36 was also analyzed.

This research was conducted in the laboratory of the structure and building materials at Faculty of Engineering, Syiah Kuala University to test the compressive strength of interlocking brick that can be used as wall material that can function as a structure and non-structure. Test object preparation is
carried out at the interlocking brick production industry located in Miruk Lamreudeup Village, Baitussalam sub-District, Aceh Besar regency. This industry produces interlocking bricks using a manual brick machine, called Soeng Thai BP-6 Model compactor that produces interlock bricks with the measurement of 100 x 150 x 300 mm in 9 types of interlocking bricks, but in this review only applied for 6 types.

Building materials-forming interlocking brick came from Aceh Besar District which consists of cement, silt soil and river sand which is used by the industry in producing it. Mix design is carried out in a laboratory with water cement factor (FAS) 0.3; 0.4; 0.5 and 18 materials of mixture variations and 15 specimens for each mixture. The Table 1 describes mix designs made for interlocking brick that can withstand structures. The specimen used is 50 x 50 x 50 mm. Maintenance of the test object was carried out for 28 days and after that the compressive strength testing was carried out in the Laboratory.

Table 1. Mix design and loading given

| Campuran FAS | No Benda Uji | Berat (g) | Berat Volume (kg/m³) | Beban (kg) |
|--------------|--------------|-----------|----------------------|------------|
| 0.3          | 1:1:2 A      | 283,7     | 1856,7               | 3584       |
|              | 1:1:1 B      | 271,4     | 1831,9               | 4176       |
|              | 1:2:1 C      | 273,1     | 1788,9               | 3520       |
| 0.4          | 1:2:2 D      | 262,2     | 1786,6               | 2456       |
|              | 2:1:1 E      | 268,6     | 1863,4               | 5760       |
|              | 2:1:2 F      | 263,4     | 1816,3               | 5236       |
|              | 2:2:1 G      | 287,4     | 1882,7               | 4824       |
|              | 1:1:2 H      | 274,9     | 1867,8               | 4388       |
|              | 1:1:1 I      | 264,5     | 1843,0               | 3632       |
|              | 1:2:1 J      | 261,8     | 1811,6               | 3020       |
|              | 1:2:2 K      | 262,3     | 1751,8               | 2528       |
|              | 2:1:1 L      | 286,9     | 1884,1               | 5316       |
|              | 2:1:2 M      | 279,7     | 1841,1               | 4752       |
|              | 2:2:1 N      | 2853      | 1878,0               | 4244       |
| 0.5          | 1:1:2 O      | 285,1     | 1892,2               | 4524       |
|              | 1:1:1 P      | 268,6     | 1751,5               | 2936       |
|              | 1:2:1 Q      | 266,8     | 1771,9               | 1924       |
|              | 2:2:1 R      | 264,4     | 1800,8               | 2292       |

Whereas the interlocking brick which functions as a non-structure is carried out by a mixture ratio of 1: 2: 4 with water cement factor (FAS) 0.4. Tests carried out on concrete with age reached 28 days against 12 specimens with a size of 50 x 50 x 50 mm. The Table 2 describes the mixture and loading comparisons given, in testing the compressive strength of concrete.

The estimated cost of one interlocking brick based on the price list of cement, soil and sand material that originated in the Aceh Besar District market in 2018. Estimated cost of interlocking brick requires by using house design type-36 as a simulation calculation. that will distinguish between interlocking brick requirements for structural walls and non-structural walls. In this research for the columns, sloof, and ringbalk works is using Interlocking brick that is included in the quality of level I,
while for work that does not hold the wall structure of the entry is in the quality level III. In this study all the work is done by using the Indonesian National Standard (SNI).

| No Benda Uji | Weight (g) | Volume Weight (kg/m³) | Load (kg) |
|--------------|------------|-----------------------|-----------|
| Q1 A         | 245        | 1800.81               | 760       |
| Q1 B         | 233        | 1759.54               | 740       |
| Q2 A         | 241        | 1740.50               | 860       |
| Q2 B         | 235        | 1681.64               | 820       |
| Q3 A         | 233        | 1721.88               | 1200      |
| Q3 B         | 235        | 1769.12               | 1120      |
| Q4 A         | 244        | 1707.43               | 1160      |
| Q4 B         | 232        | 1657.01               | 1140      |
| Q5 A         | 242        | 1732.61               | 900       |
| Q5 B         | 243        | 1864.22               | 870       |
| Q6 A         | 232        | 1666.90               | 890       |
| Q6 B         | 239        | 1859.18               | 830       |

3. Results and Discussion

3.1 The compressive strength test results
The results of the compressive strength analysis explain that a large amount of cement will result in high compressive strength and excess water in the mixture will increase the ability of the work but reduce strength. 1:2:2 mixture with 0.4 cement water factor was chosen to be used as a wall material that can hold the structure and can replace sloof, column and ringbalk. The average value of compressive strength is 89.6 kg / m³ at the age of concrete reaching 28 days and fulfill the workability requirements and consider as quality of level I for hollow concrete brick. The compressive strength test results can be seen in the Figure 1.

![Figure 1](image-url)

Figure 1. Graph of the relationship of compressive strength to 28 days concrete age mixture

Interlocked brick that functions as a non-structure has also been tested for compressive strength. Mixture of 1:2:4 with FAS 0.4 is selected as wall material that function as a non structure. The results of the analysis showed that the compressive strength reaches 35.4 kg / m³ and meets the workability requirements and categorized as quality of level-III as a construction that does not carry the load.
The type of material used on the mix design is only based on the type of material used by industry that produces interlocking brick. Based on earlier research, [2, 3, 4, 5, 6] that a mixture of interlocking brick is various, where one of which is a mixture compose of cement and clay.

4.2 The required Interlocking Brick and cost analysis
Interlocked brick requirements for structural walls such as Sloof, columns and ringballs and non structural walls are estimated based on the analysis of type 36 house design. The house designed consists of 2 bedrooms, 1 bathroom, 1 living room, 1 kitchen and 3 terraces (3 of the terraces do not count for interlocking brick requirements and cost analysis). Figure 2 until 5 describe the design of the House type 36 and the required number of interlocking brick. The house design is designed by considering the method of building implementation based on a concept that has been developed by previous researchers, namely the use of interlocking brick types in layers 1 through 6 using interlocking brick building blocks, Corner building blocks and half building blocks, while every 7th layer uses a type of channel building block, channel angle block and half channel block angle so on repeated until it reaches the planned building height.

Structure work consists of sloof, column and ringbalk. Sloof is located on a foundation by using interlocking brick material in the channel building block, channel angle and half channel angle. In this channel block, Ø 12 threaded iron reinforcement with a total of 2 pieces along the sloof. Ringbalk is located on the top of the column and the type of block used similar as sloof and will also be given the
The column consists of the main and practical columns, where the main column amounts to 15 pieces and practical columns as much 27 pieces. The main column is located on the corner of the building while the practical column is located on each edge of the door and window frames. In the column using 6 types of interlocked brick where in layers 1 through layer 6 use building blocks, corner building blocks and half building blocks and in the 7th layer using channel building blocks, channel angles and half channels. The main and practical column treatment is the same, that is in the vertical direction in the column placed Ø 12 thread reinforcement iron as much as 2 pieces at the column height.

On wall work using 6 types of interlocked brick is the same as in column work. The position of each interlocked brick type is the same as in column work, that is every 7 layer using block channels and will be given thread reinforcement iron Ø 12 as much as 2 pieces in horizontal direction.

Based on the picture above, the analysis of interlocking brick requirements for structural systems, namely sloof, columns, ringballs and non-structural walls can be explained in the Table 3.

**Table 3.** The requires amount and cost of interlocking brick material for type-36 house

| Work Structural - Sloof                  | Types of Interlocking Brick | Figure | Price (Rp) | Function                  | The Required Interlocked Brick (Piece) | Total (IDR) |
|-----------------------------------------|----------------------------|--------|------------|---------------------------|---------------------------------------|-------------|
| Channel Building Blocks                 | 6.000                      |        |            | Included iron in channel block | 125                                   | 750.000     |
| Channel Angle Block                     | 6.000                      |        |            |                           | 17                                    | 102.000     |
| Half Channel Angle Block                | 3.000                      |        |            |                           | 6                                     | 18.000      |
| **Total**                               |                            |        |            |                           | **148**                               | **870.000** |
| The number of interlocked brick requirements for Sloof and Ringbalk is the same so for Ringbalk the total are |                            |        |            |                           | 148                                   | 870.000     |

| Work structure - main column             | Types of Interlocking Brick | Figure | Price (Rp) | Function                  | The Required Interlocked Brick (Piece) | Total (IDR) |
|-----------------------------------------|----------------------------|--------|------------|---------------------------|---------------------------------------|-------------|
| Channel Building Blocks                 | 6.000                      |        |            | At wall layer 7           | 34                                    | 204.000     |
| Channel Angle Block                     | 6.000                      |        |            | Included iron in channel block | 26                                    | 156.000     |
| Half Channel Angle Block                | 3.000                      |        |            |                           | 30                                    | 90.000      |
| Building Blocks                         | 6.000                      |        |            | At Wall layer 1-6         | 155                                   | 930.000     |
| Corner building blocks                  | 6.000                      |        |            |                           | 156                                   | 936.000     |
| Work Structure | Amount | Value |
|----------------|--------|-------|
| Half angle block | 3.000 | 154 | 462.000 |
| Amount | 555 | 2.778.000 |

### Work Structure - Practical Column

| Work Structure | Amount | Value |
|----------------|--------|-------|
| Channel Blocks | 6.000 | 113 | 678.000 |
| Channel Angle Block | 6.000 | 29 | 174.000 |
| Half Channel Angle Block | 3.000 | 29 | 87.000 |
| Building Blocks | 6.000 | 540 | 3.240.000 |
| Corner building blocks | 6.000 | 158 | 948.000 |
| Half angle block | 3.000 | 166 | 498.000 |
| Amount | 1.035 | 5.625.000 |

### Work Wall

| Work Structure | Amount | Value |
|----------------|--------|-------|
| Channel Blocks | 4.500 | 434 | 1.953.000 |
| Channel Angle Block | 4.500 | 72 | 324.000 |
| Half Channel Angle Block | 2.250 | 76 | 171.000 |
| Building Blocks | 4.500 | 2517 | 11.326.500 |
| Corner building blocks | 4.500 | 410 | 1.845.000 |
| Half angle block | 2.250 | 469 | 1.055.250 |
| Amount | 3.978 | 16.674.750 |
| Total Amount | 5864 | 11.810.470 |
The price of each piece of interlocking brick that serves as structural is Rp. 6,000 / piece, and non structural Rp. 4,500 / piece. The required number of interlocking brick that functions as sloop, column and ringbalk as many as 1,886 pieces and for 3,978 pieces for non-structural walls. So that the interlocked brick cost to build a type-36 house is IDR. 11,810,470.

4. Conclusion
The results of an analysis of interlocking brick costs have addressed the problems faced by industry that interlocked brick products can be differentiated into two quality classifications based on their compressive strength test. Interlocking brick that functions as a wall construction that holds the load classified to quality I and it cost per piece is greater than the interlocked brick that functions as a non-structural wall. This research is an initial analysis in obtaining the quality of interlocking brick material. This research needs to be developed further by using other types of material in the mix design so that an effective and efficient mixture is obtained.

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