МЕЖДУНАРОДНЫЙ

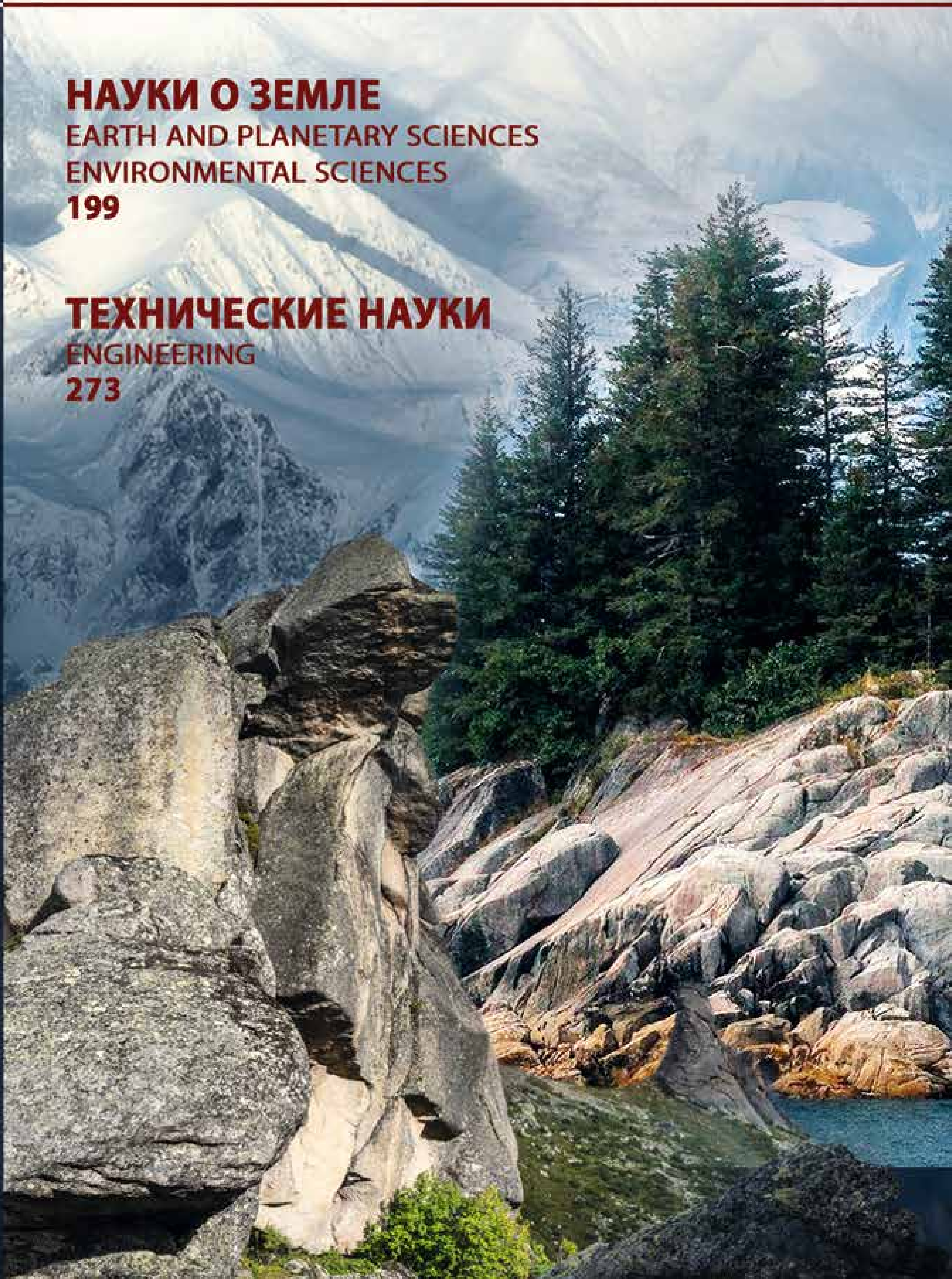
НАУЧНЫЙ ЖУРНАЛ

УСТОЙЧИВОЕ РАЗВИТИЕ ГОРНЫХ ТЕРРИТОРИЙ

Sustainable Development of Mountain Territories

ISSN 1998-4502
e-ISSN 2499-975X

"Земля - планета не простая".
А. де Сент-Экзюпери



Т.12
№2(44)
2020

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BLOCK BRICK PRODUCING METHOD BY MAKING USE OF DISPOSAL WASTE OF THONG NHAT COAL MINE, VIETNAM

УДК: 622
DOI: 10.21177/1998-4502-2020-12-2-265-272

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Utilizing the waste rock from mining activity to make block bricks is an effective solution to solve the environmental problems that they made. By theoretical basis and experiment, this research determined valid rates of waste rock (from wastes of disposal area of Thong Nhat coal mine), fly ash and cement conforming to standard block brick M100 to block brick M140 (according to TCVN 6477: 2011).

KEYWORDS:
Waste rock, Block bricks, Environment, Thong Nhat coal mine.

Article received 26.10.2019.

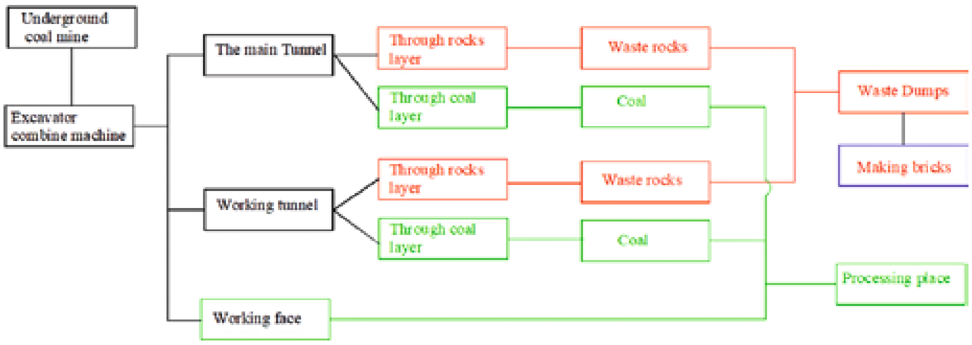
1. Introduction

The amount of waste rock in the coal mining process is very large and is concentrated in the disposal area [1–6]. Waste disposal not only wastes land but also pollutes the water and air environments (due to dust and solvents), jeopardizes for people (disposal area landslide in the flood season), increasing the cost of environmental protection. Wastes of disposal area of Thong Nhat coal mine have many kind of rock with different properties [7–11]. There is no specific research about using them as a recycled material. Therefore, researching in producing block brick from wastes of disposal area of Thong Nhat coal mine is necessary. Using waste rock to make Block brick helps to minimize the effects to environment and create surplus value and employment for the people [11–20].

2. Theoretical basis of producing block brick

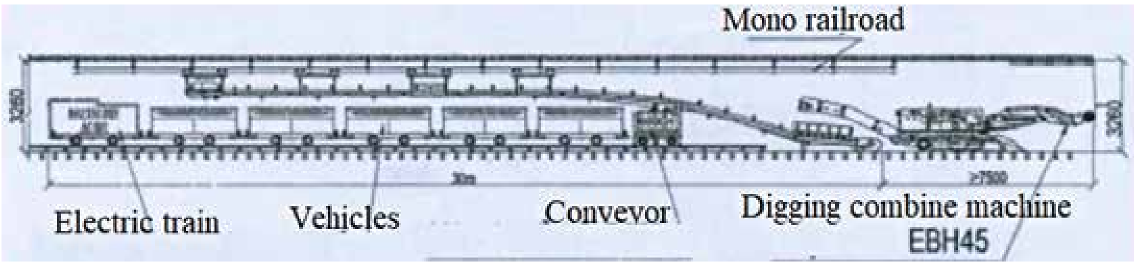
2.1. Additive component

Underground mining developments means that there is less ability to select sites based on preferential site for the environment, especial the waste rocks, Seriously affect the landscape and environment of water, air in a long term. Using waste rock from mining to make bricks is one of the good solutions to solve environmental problems. This is the same for thermal power plants. The main sources of materials to produce bricks here including mining waste rocks and ash from thermal power and cement bound.

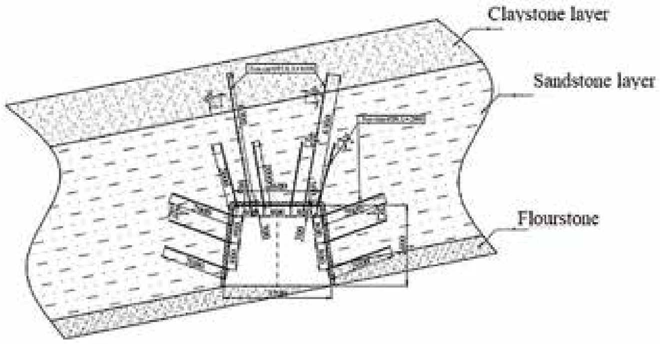


a. Diagram of exploitation in the underground coal mine

b. Excavators in the working face



d. Diagram of construction area which generating waste rocks



e. Example about the geological structure of the construction area which generating waste rocks

Fig. 1. *Mining technology process generates waste rock in coal mines*

The recommended additive component is fly ash with the purpose:

Improving surface and increasing waterproofing: Small particle size helps the fly ash fill the voids of the brick's voids; make the bricks' surface smoother, more waterproof. In addition, the color of the fly ash may change the color of the brick;

Increasing durability of bricks: Fly ash combined with Portland cement will give CaO to SiO_3 residue to become a non-calcined SiO_3, much better than CaO alone in calcined SiO_3 dust (also known as clinker). As a result, bricks are more durable and loads are better.

Increasing Acid Resistance: When calcining Portland cement with limestone and clay, there is always a free CaO content of about 6% in cement. This lime meets brackish water or sulphate-based saline water, which combine with lime to form gypsum salt of mechanical properties, especially water-absorbing and swelling. The swelling makes bricks break with time, and finally, breaks the brick's structure.

For brick against that crack, called as against sulfate or sulfate resistance, it needs to mix fly ash of lean lime with very low rate.

The product is abundant supply, cheap: Cam Pha thermal power plant annually exhausts to 300,000 tons of fly ash.

2.2. Determination of the process of brick making technology

Based on the references and actuality, the technological process of manufacturing Block brick from waste rock will be similar to the conventional Block brick technology. Specifically as follows:

Step 1 – Preliminary screening or washing: The aggregates used to make unbaked bricks need to be solid and durable so it is necessary to premilitarily screen and wash to remove clay, quaternary soil, and organic impurities;

Step 2 – Crush the rock to a suitable particle size: The solidify, mechanical durability of the unbaked brick depends on the hydration reaction of the cement to bond the aggregate particles. The more exposed the contact, the closer the grains are associated, but at the same time the amount of cement will increase;

Step 3 – Mix aggregate, cement and fly ash in a reasonable ratio: The appropriate mix ratio ensures the bricks achieve TCVN 6477:2011 and economic efficiency, while ensuring uniform distribution of materials;

Step 4 – Brick molding: This is a step to create a brick while at the same time ensuring to cancel ou the the pores between the grains, helping the bricks achieve durability as required;

Step 5 – Maintenance: The hydraulic reaction requires sufficient time and regular humidity to complete the reaction.

2.3. Determination of the ratio boundary of the aggregate component (objective function)

Number The objective function is the optimal balance function between economic and technical indicators. For unbaked bricks, the objective function determines the smallest cement ratio while maintaining the brick grade of M15-M20 (TCVN 6407:2011). To find the equilibrium point, the researcher determines the upper chord based on the economic indicator and technical theory. The lower chord is 0% and then gradually increased and based on the test results to conclude.

Temporarily set:

- Unbaked limestone brickis *A*; Unbaked waste rocky brick is *B*;
- C_A, C_B respectively, is the cost of 1 brick, type *A* and *B*;
- m_A, m_B respectively, is the weight of a brick, type *A* and *B*;
- *V* is the volume of a brick;
- x_A, y_A respectively, is the ratio of cement and limestone in brick *A*;
- x_B, y_B, z_B respectively, is the unit price of cement, waste rock, fly ash and limestone.

Table 1

Testing result of heavy metal in the surface water around waste rocks dump of Thong Nhat Coal Company

No	Symbol	Season	TSS	COD	As	Cd	Fe	Hg
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	N1	dry season	73	33.3	0.0021	0.0018	1.12	<0.0001
		rainy season	48	21	<0.001	<0.0005	0.75	<0.0001
2	N2	dry season	324	158	0.0017	0.0088	6.77	<0.0001
		rainy season	160	60	0.0032	0.0011	5.51	<0.0001
3	N3	dry season	92	33	0.0155	0.0009	0.59	<0.0001
		rainy season	71	93	0.0076	0.0008	4.45	<0.0001
4	N4	dry season	134	16.6	0.0058	0.0013	1.62	<0.0001
		rainy season	41	66.8	0.0069	0.0011	5.21	<0.0001
5	N5	dry season	127	120.2	0.0028	0.0009	3.81	<0.0001
		rainy season	38	29.8	0.0088	0.0095	0.99	<0.0001
6	N6	dry season	98	36.5	0.0035	0.0004	2.25	<0.0001
		rainy season	122	55.5	0.0125	0.0006	6.66	<0.0001
7	N7	dry season	166	45	0.0089	0.0008	1.07	<0.0001
		rainy season	52	52	0.0065	0.0093	3.6	<0.0001
8	N8	dry season	11	14	0.0112	0.0011	1.11	<0.0001
		rainy season	37	36	0.0066	0.0089	1.45	<0.0001
9	N9	dry season	59	60	0.0079	0.0068	3.22	<0.0001
		rainy season	45	48	0.0068	0.0005	1.15	<0.0001
Vietnam Standard: 08-MT/BTNMT (GH b1)			50	30	0.05	0.01	1.5	0.001

Note: *N1 – N9:* The local to take sample; *TSS:* Turbidity & suspendid solids; *COD:* Chemical Oxygen Demand*; As:* Arsenic content; *Cd:* Cadmium content; *Fe:* Iron content; *Hg:* Mercury content.

2.3.1 Determination of upper chord by economic index

The cost of a brick covers administration costs, production costs, raw material costs, and other costs with the same processing technology, which can be considered administrationcosts, production costs, and other costs as the same, is the price of bricks will compete with the input material, as in (1):

$$C_B < C_A \Leftrightarrow x_B \cdot t_1 + y_B \cdot t_2 + z_B \cdot t_3 < x_A \cdot t_1 + y_A \cdot t_1 \quad (1)$$

$$x_B < \frac{x_A \cdot t_1 + y_A \cdot t_{11} - y_B \cdot t_2 - z_B \cdot t_3}{t_1}$$

$$t_1 > t_{11} > t_3 > t_2; \forall x_B \in [0, x_A]$$

$$\Rightarrow y_B \cdot t_2 + z_B \cdot t_3 < t_2(y_B + z_B) < y_A \cdot t_{11} \Rightarrow C_B < C_A$$

For tigher bouding of chord, as in (2):

$$x_B < \frac{x_A \cdot t_1 + y_A \cdot t_{11} - y_B \cdot t_3 - z_B \cdot t_3}{t_1} = \frac{x_A \cdot t_1 + y_A \cdot t_{11} - t_3(100 - x_B)}{t_1} \quad (2)$$

$$\Leftrightarrow x_B < \frac{x_A \cdot t_1 + y_A \cdot t_{11} - y_B \cdot t_2 - z_B \cdot t_3}{t_1} = \frac{x_A \cdot t_1 + y_A \cdot t_{11} - 100 \cdot t_3}{t_1 + t_3}$$

Change the unit price: t_1; $t_{11;}$ t_3; t_2 price of cement, waste rock, fly ash and limestone, t_1 = 1480 VND/kg; t_{11} = 90 VND/kg; t_2 =30 VND/kg; t_3 = 50 VND/kg and combined with the actuality, *xA* often is in the 8–10 % range. We have the limitation of cement ratio of: x_B< 9.88 %

2.3.2. Determination of aggregate of water rate

Water plays a role in the hydration reaction of cement. However, the compressive strength of bricks is only ultimate varied flow function for variable "water rate". That is, not enough water, bricks will not achieve high compressive strength, however, maintenance process (watering) provides enough water for hydration process. At the same time, much water does not mean that bricks will increase compressive strength. Therefore, the amount of water used here is relative. The mixing process will spray the mist until the mixture is moist enough. (This is also easier for the research process, since the sample size is small, hard to accurately identify the amount of water).

2.3.3. Determination of the vibration compressive force

Under laboratory conditions, there is no hydraulic brick compressor. To determine the vibration compressive force for each brick, the researcher, based on the factor of brick from waste rock with light weight or equal to the weight of common brick", is the volume of material in the brick cage must be equal with the volume of a typical unbaked brick (multiplication of hydrated coefficient). The press force is sufficient to allow the volume to be compressed by the volume of brick to be made.

2.3.4. Test method and test results

Due to limited conditions, instead of making complete brick samples and testing, the researcher will produce cylindrical "specimens" of 25mm and 35mm high diameter. These samples are manufactured according to the same process and rate as the complete sample.

Among the criteria of compression strength, cutting resistance, waterproofing, aesthetics, weight, the compressive strength is a priority. Therefore, the test specimens will be tested for roughness of compressive strength. The rates for "test specimens" with the best test results will be developed to make complete brick samples and test methods based on TCVN. 6477:2011.

3. Experiments and some result

3.1. Fabrication of unbaked brick samples

3.1.1 Equipment, tools

- Mesh sieve 3 mm, 5 mm;
- PVC Φ25 pipe being cut into sections of 4.5–5 cm;
- Error balance ± 0.05 g;
- Wood mold, stamp, bearing, material basin…

3.1.2 Sample preparation

Step 1: Preparation of raw material. The rock and soil will be washed through the grinding equipment to remove unstable soils. The crushed product is then fed to a 25 mm sieve and collected on the mesh. Products on the mesh are crushed and screened to a size of 3–5 mm.

Step 2: Aggregate. Rate of cement: waste rock: fly ash is *a: b: c.* of which, a runs from 1 to 9 %, the jump is 1 %. For each fixed rate of a, let b run from (100-*a*) % to 55–60 % jump is 5 %. The fly ash ratio is the rest. Each kind of rate makes 4 samples.

Step 3: Create shape. For each aggregate, the researcher mixes with sufficiently water, then weighs the weight of material and then puts into the 25 mm PVC mold and presses with the compression level with the hammer and pestle and codes the symbol accordingly with mixing ratio (eg 1.6.3 is 10 % cement, 60 % waste rock and 30 % fly ash).

Step 4: Maintenance. After 2 days of compression, the samples are removed from the plastic molds and maintained for further 28 days.

Step 5: Filter the results. Test by immersion for 120 minutes to determine the degree of separation in water. Distortion is measured on a score scale. (These submersion samples are not used in subsequent destruction tests.)

1. Very easy to lose. The sample is self loosen in water.
2. Easy to lose. The sample is easy to loose with external force (light hold).
3. May be relatively loose. The sample is loosen with large external force (strong hold).
4. Difficult to lose. The sample is loosen with large external force (strong bend).
5. Do not loose. The sample cannot be loosen when using normal external force (manual).

The remaining samples are tested for roughness by a 0.5 kgpincer freely felt from height of 1m (for pincer in Φ25PVC pipes for straight falling).

The large-sized lump in lumps after a broken sample are considered as initial sample, and smaller lumps are considered to be destroyed part.

Removal of test specimens with a breakdown mass > 10 % of the test specimen and samples with a loose grading scale of less than 3. Proportions of at least 2 satisfactory samples are taken as scaling for bricks production and tests.

3.1.3. Results determining optimal ratio

Through visualization and roughness testing, the researcher determines:

- Brick samples with less than 6% cement are easily broken, chipped;
- Brick samples with 0 ÷ 10% fly ash easy to chip, easy to peel, loose when immersed in water for 120 minutes. Brick is dark gray.
- Brick samples with 6–10 % cement and 15–35 %, fly ash hard to chip, macerating in water within 30–60 minutes without swelling phenomenon, smooth surface, hard to chip. Brick color from dark brown to ash light brown.

3.2. Brick making and testing result

The brick making process is similar to the sample fabrication process. Brick made with the proportion of standard raw samples.

The determination of compressive strength and water absorption is carried out at the AGC Quality Assurance and Testing Enterprise. The results are shown in Annex 4 and graphed in Table 1 and Fig.4.

3.3. Result

- Determine the calculated field of aggregate ratio

Fig. 2. *Sample result*

Table 2

Results of brick testing

Ratio			Compressive strength, daN/cm^2	Water absorption, %	Equivalent brick grade standard
a%	b%	c%			
6	79	15	79.20	8.04	M75
6	74	20	83.48	7.97	M75
6	69	25	87.04	7.79	M75
6	64	30	93.22	7.59	M75
7	83	10	87.40	7.82	M75
7	78	15	91.90	7.58	M75
7	73	20	91.77	7.50	M75
7	68	25	95.55	7.29	M75
7	63	30	102.19	7.11	M100
8	82	10	96.40	6.92	M100
8	77	15	102.81	6.80	M100
8	72	20	111.11	6.80	M100
8	67	25	120.46	6.67	M100
8	62	30	123.16	6.52	M100
9	86	5	113.87	7.08	M100
9	81	10	117.8	6.99	M100
9	76	15	125.87	6.73	M100
9	71	20	129.53	6.76	M100
9	66	25	127.64	6.60	M100
9	61	30	129.38	6.66	M100
10	85	5	118.61	7.01	M100
10	80	10	127.77	6.90	M100
10	75	15	130.35	6.91	M100
10	70	20	136.09	6.58	M100
10	65	25	138.86	6.46	M100
10	60	30	139.42	6.62	M100

Fig. 3. *Preliminary experiments (demolition and maceration)*

Fig. 4. *Block brick by from wastes of disposal area*

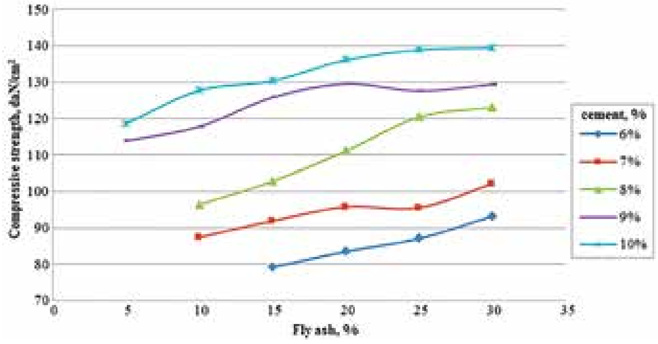


Fig. 5. *The relationship between compressive strength and brick aggregate ratio*

with cement content ≥7 %, fly ash content ≥ 15 % or cement content ≥ 6 %, fly ash content ≥ 28 % fly ash for the result of brick with compression resistance strength of ≥ 90 daN/cm^2.

- Brick with water absorption satisfies TCVN 6477:2011.

- The small compression force cannot press all the volume of material needed for a brick (3kg) so the average brick weight is 2.5kg smaller than common cement aggregate brick. At the same time, the maximum compressive strength is 139 daN/cm^2, lower than the initial target of the Grade 150 brick.

- It is necessary to expand the scale of experiments, use hydraulic compressor to make bricks and increase the number of samples for more accurate results.

- It is predicted that the aggregate rate for bricks in laboratory with a compressive strength of ≥ 90 daN/cm^2 will be compressed by vibration hydraulic compressor of up to 150 daN/cm^2 – meeting grade 150 or higher.

- In terms of funding for the topic, the researcher used aggregate 3–5mm. It is necessary to separate these two aggregates for better economic evaluation (crushing and cement costs).

4. Conclusions

This study determined the mixing ratio of waste rock, fly ash and cement, the process of producing block brick in the laboratory. It proved the economic efficiency and applicability to reality. However, these mixing ratio and process just are right when use waste rock from wastes of disposal area of Thong Nhat coal mine because their own attributes.

Thong Nhat mine should build a factory which used waste rock to make Block brick for helping to minimize the effects to environment and create surplus value and employment for the people.

ACKNOWLEDGEMENT

The authors would like to acknowledge Vietnam Institute of Mining Science and Technology (IMSAT), Thong Nhat coal mine company, and student researcher group in Hanoi University of mining and geolygy for their approvals of using data; and special this work was financially supported partly by “Quality Control Consulting, AGC” Hanoi, Vietnam.

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СПОСОБ ПРОИЗВОДСТВА БЛОЧНОГО КИРПИЧА ПУТЕМ ИСПОЛЬЗОВАНИЯ ОТХОДОВ УТИЛИЗАЦИИ УГОЛЬНОЙ ШАХТЫ ТХОНГ НХАТ, ВЬЕТНАМ

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DOI: 10.21177/1998-4502-2020-12-2-265-272

Использование пустой породы от горнодобывающей деятельности для изготовления блочных кирпичей является эффективным для решения экологических проблем. На теоретической основе и экспериментально в ходе нашего исследования были определены допустимые нормы для пустой породы (из отходов зоны захоронения угольной шахты Тхонг Нхат), летучей золы и цемента, соответствующие стандарту блочного кирпича M100, M140 (согласно TCVN 6477: 2011).

Ключевые слова: пустая порода, блочный кирпич, окружающая среда, угольная шахта Тхонг Нхат.

Статья поступила в редакцию 26.10.2019