International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Design of a Foam Generator in Manufacturing Foam Concrete

Sujiati Jepriani[1], Yudi Pranoto[2], Rido Ofona Zalukhu[3]
Study Program in Building Construction Engineering Technology, Department of Civil Engineering, Samarinda State Polytechnic, East Kalimantan, Indonesia, Corresponding Author Email: ridoofonazalukhu@gmail.com

Abstract— *Lightweight foamed concrete is an advanced construction material widely applied to reduce structural dead loads and prevent settlement on soft ground. However, the high capital cost of commercial foam generators presents a major obstacle for small and medium-scale construction enterprises. This study details the design, fabrication, and experimental performance evaluation of an economical pneumatic foam generator utilizing locally accessible components. The system incorporates a 1 HP air compressor, a modified 12 kg steel LPG cylinder as a pressurized mixing chamber, and a 1.5-inch diameter PVC nozzle packed with 12 pieces of stainless-steel wool as a turbulence media. The performance was evaluated across compressed air pressures ranging from 4 to 8 bar to assess foam density, physical stability over a 10-minute duration, and resulting lightweight concrete compressive strength in accordance with PUPR 2015 and SNI 03-3449-2002 standards. The results demonstrate that operating pressures between 4 and 7 bar produce compliant foam densities (0.082 t/m³ to 0.057 t/m³ initially, and 0.081 t/m³ to 0.056 t/m³ after 10 minutes). Pressure at 8 bar resulted in excessive expansion and instability (0.037 t/m³ density). Test cubes produced with 6-bar foam achieved a 28-day compressive strength of 5.42 MPa with a dry density of 978 kg/m³, fulfilling non-structural lightweight concrete requirements. The total fabrication cost was IDR 3,637,000 (~USD 230), representing a 34.6% cost reduction compared to commercial equivalents, proving its viability for local infrastructure projects.*

Keywords— *Foam generator design, lightweight foamed concrete, pneumatic system, foam stability, steel wool turbulence media, compressive strength.*

I. INTRODUCTION

Lightweight foamed concrete (LFC) has emerged as a versatile material in modern civil engineering due to its low self-weight, excellent thermal insulation, high flowability, and acoustic dampening characteristics [1]. LFC is synthesized by introducing a pre-formed aqueous foam into a cementitious mortar slurry, resulting in a cellular structure characterized by uniformly distributed micro-air voids [2]. In geotechnical and highway engineering, particularly under guidelines such as PUPR SE No. 44/SE/M/2015 in Indonesia, foamed concrete is increasingly specified for embankment fills over soft soils, bridge approach slabs (oprit), and void filling to prevent differential settlement and structural instability [3].

The macro and microstructural integrity of foamed concrete is fundamentally governed by the quality, bubble size distribution, and physical stability of the pre-formed foam [4]. Unstable foam collapses during mixing or curing, leading to segregation, density loss control, and severe strength deterioration [5]. Generating consistent micro-foam requires a dedicated foam generator that thoroughly mixes foaming agent solution with pressurized air through a porous medium or turbulence nozzle.

Despite its technical advantages, widespread adoption of LFC in regional and small-scale construction projects remains constrained by the prohibitively high procurement cost of imported or industrial-grade foam generators [6]. Existing commercial units often exceed IDR 5.5 million and rely on complex proprietary filter cartridges. Therefore, there is a critical need to engineer an accessible, low-cost pneumatic foam generator using standard market components without compromising foam quality or structural performance.

This study presents the complete engineering design, physical assembly, operational parameter optimization, and economic evaluation of a low-cost pneumatic foam generator. The research specifically investigates the effect of compressed air pressure variations (4 bar to 8 bar) on foam density, 10-minute volumetric stability, and the compressive strength of the synthesized lightweight concrete cubes.

II. METHODOLOGY

2. 1 Engineering Design and Component Specification

The foam generator was designed based on pneumatic fluid expansion principles. The system consists of three primary subsystems: the air supply unit, the pressurized mixing chamber, and the turbulence nozzle assembly.

A 1 HP electric air compressor served as the pressure source. A modified 12 kg steel gas cylinder was reengineered as a hermetic mixing chamber (capacity 12 kg / ~26 L) to store the diluted foaming agent solution under pressure. The turbulence nozzle was constructed from a 1.5- inch diameter PVC pipe with a length of 50 cm. Inside the nozzle, 12 pieces of commercial steel wool pads were tightly packed to act as a porous physical obstruction, forcing highshear turbulent mixing between compressed air and liquid solution.

Key Design Specifications:

- Compressor: 1 HP (750 W), Max pressure 8 bar
- Mixing Chamber: Modified 12 kg Steel Tank
- Nozzle: PVC Pipe Ø 1.5" × 50 cm
- Turbulence Filter: 12 units Steel Wool
- Valves/Fittings: 1/4" Brass Y & T-connectors

2. 2 Material Selection and Solution Preparation

A synthetic surfactant-based foaming agent (CBM Foam Agent) was utilized. The agent was diluted with clean potable tap water at a volumetric ratio of 1:25 (foaming agent to water), adhering to PUPR 2015 recommendations. For concrete sample

Sujiati Jepriani, Yudi Pranoto, and Rido Ofona Zalukhu, "Design of a Foam Generator in Manufacturing Foam Concrete," *International Research Journal of Advanced Engineering and Science*, Volume 11, Issue 3, pp. 133-135, 2026.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

preparation, Ordinary Portland Cement (OPC), fine Palu sand, and clean water were combined to form the base slurry.

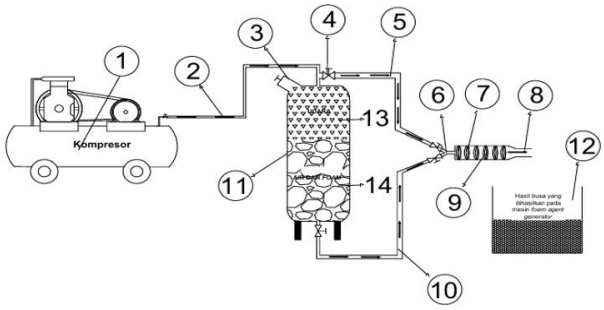

Figure 1. Foam Generator Design

2. 3 Experimental Testing Protocols

The experimental testing was conducted in two primary phases at the Civil Engineering Laboratory, Samarinda State Polytechnic:

1. Foam Characterization: The generator was operated across five air pressure levels: 4, 5, 6, 7, and 8 bar. Initial foam density (***ρ***) was measured by filling a calibrated 1-liter container and weighing on a digital balance (accuracy ±0.1 g) using Equation 1:

$$\rho = (m2 - m1) / V \quad (1)$$

where m_1 is container mass (g), m_2 is mass of container with foam (g), and ***V*** is volume (m^3). Stability was determined by measuring mass and volume loss after leaving the foam undisturbed for 10 minutes.

2. Lightweight Concrete Testing: Utilizing the optimal foam density generated at 6 bar, concrete test cubes (15 × 15 × 15 cm) were cast with a cement-sand-water-foam mixture. Cubes were demolded after 24 hours, cured in water, and tested at 28 days for dry density and compressive strength (f'c) per SNI 03-3449-2002 using Equation 2:

$$f'c = P / A \quad (2)$$

where ***P*** is maximum ultimate load (N) and ***A*** is crosssectional area (mm^2).

III. Results and Discussion

3. 1. Effect of Air Pressure on Intial Foam Density

Table 1 summarizes the initial foam density measurements across varying compressor air pressures (4 to 8 bar). Each data point represents the average of three independent sample trials.

TABLE 1. Initial Foam Density at Air Pressures 4–8 bar

Pressure (bar)	Sample 1 (g/L)	Sample 2 (g/L)	Sample 3 (g/L)	Avg Density (t/m^3)	PUPR 2015 Status
4	88.5	80.0	77.0	0.082	Compliant
5	69.0	72.0	70.0	0.070	Compliant
6	60.5	66.0	65.0	0.065	Compliant
7	53.0	62.5	56.5	0.057	Compliant
8	32.5	42.0	37.0	0.037	Non ompliant

The data reveals an inverse non-linear relationship between pressure and foam density. Increasing air pressure from 4 bar to 8 bar increased the volumetric gas-to-liquid ratio, reducing average foam density from 0.082 t/m^3 to 0.037 t/m^3. Under PUPR 2015 guidelines (standard range: 0.055 to 0.085 t/m^3), pressures between 4 bar and 7 bar successfully met technical requirements. At 8 bar, the excessive air velocity damaged bubble wall integrity, yielding an overly light foam below the minimum threshold.

3. 2. Foam Volumetric Stability Analysis

Foam drainage and bubble collapse were monitored over a 10-minute rest period. Table 2 presents the post-10-minute stability evaluation.

TABLE 2. Foam Density after 10-Minute Stability Duration

Pressure (bar)	Initial Avg (g/L)	10-min Avg (g/L)	Density Drop (g/L)	Final Density (t/m^3)
4	82	81	1.0	0.081
5	70	69	1.0	0.069
6	65	69	1.0	0.064
7	57	56	1.0	0.056
8	42	36	6.0	0.036

For pressures between 4 and 7 bar, the foam exhibited exceptional physical stability with a minimal density reduction of only 1.0 g/L (1.2% to 1.7% drop). This high stability is attributed to the high shear action of the 12 steel wool pads in the nozzle, which produced uniform microbubbles with strong lamella wall resistance. Conversely, foam produced at 8 bar suffered a substantial drop of 6.0 g/L (14.3% loss), confirming bubble wall rupture and liquid drainage.

3. 3. Mechanical Propeties of Lightweight Concrete

Concrete test cubes prepared using foam generated at 6 bar were subjected to compressive strength testing at 28 days. Results for five test specimens are detailed in Table 3.

TABLE 3. 28-Day Compressive Strength and Density of Concrete Cubes

Specimen	Weight (kg)	Failure Load (kN)	Compressive Strength (MPa
Specimen 1	2.9	122.0	5.42
Specimen 2	3.7	120.0	5.33
Specimen 3	3.7	110.0	4.89
Specimen 4	3.2	130.0	5.78
Specimen 5	3.0	123.0	5.47
Average	**3.3**	**122.0**	**5.42**

The average specimen weight of 3.3 kg over a 0.003375 m^3 volume corresponds to a dry unit weight (density) of 978 kg/m^3. The average 28-day compressive strength was 5.42 MPa. According to SNI 03-3449-2002, this performance classifies the material as non-structural lightweight concrete, perfectly suited for partition walls, sub-base insulation layers, and lightweight fill applications.

3. 4. Economic Fabrication Analysis

A detailed bill of materials was compiled to evaluate economic feasibility. The total cost to fabricate the prototype was IDR 3,637,000, as itemized in Table 4.

Compared to standard industrial foam generators marketed at approximately IDR 5,560,000, the engineered prototype delivers a direct cost saving of 34.6% (IDR 1,923,000), offering an accessible solution for contractors in developing regions.

Sujiati Jepriani, Yudi Pranoto, and Rido Ofona Zalukhu, "Design of a Foam Generator in Manufacturing Foam Concrete," *International Research Journal of Advanced Engineering and Science*, Volume 11, Issue 3, pp. 133-135, 2026.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

TABLE 4. Foam Density after 10-Minute Stability Duration

Component Item	Specification	Qty	Cost (IDR)
Air Compressor	1 HP Electric	1 unit	2,000,000
Steel Gas Tank	12 kg Capacity	1 unit	500,000
PVC Pipe & Fittings	Ø 1.5" & 1" Accessories	1 set	104,000
Brass Valves & Tees	1/4" Y, T, Stopcock	1 set	182,000
Filter Steel Wool	Stainless Mesh	12 pcs	30,000
Assembly & Welding	Tank Modifications	Service	700,000
Miscellaneous	Clamps, Tape, Glue	1 set	31,000
Total Fabrication Cost		**3,637,000**	

IV. CONCLUSION

This study successfully designed, built, and evaluated an economical pneumatic foam generator for lightweight concrete production. The key findings are summarized below:

1. The prototype constructed from a 1 HP compressor, a 12 kg steel gas cylinder, and a 1.5-inch PVC nozzle filled with 12 steel wool pads reliably produces homogeneous micro-foam.
2. Operating air pressure significantly governs foam density. Pressures between 4 bar and 7 bar yielded compliant initial foam densities ranging from 0.082 t/m³ to 0.057 t/m³, fulfilling PUPR 2015 criteria. Pressure at 8 bar resulted in non-compliant foam (0.037 t/m³).
3. Foam produced at 4–7 bar exhibited high volumetric stability with only a 1.0 g/L density drop after 10 minutes.
4. Concrete test cubes achieved an average 28-day compressive strength of 5.42 MPa with a dry density of 978 kg/m³, conforming to SNI 03-3449-2002 for non-structural lightweight concrete applications.
5. The total fabrication cost of IDR 3,637,000 offers a 34.6% savings compared to commercial alternatives, demonstrating strong potential for local industry adoption.

REFERENCES

[1] A. F. Aulia and U. Rio, "Application of Water Sample Testing Identification According to Indonesian National Standards (SNI)," J. Sci. Inf. Technol., vol. 1, no. 1, pp. 55–62, 2015.
[2] D. S. Afrilian, "Effect of Maxx 102 CLC Foam Agent Addition on Permeability of Lightweight Concrete," Proc. FTSP Ser., pp. 332–337, 2024.
[3] Ministry of Public Works and Housing (PUPR), "Guidelines for Mix Design of Lightweight Mortar Foam for Road Cons
[4] M. Sinlae and M. Astryana, "Performance Analysis of Foam Generator in Lightweight Concrete Mixture," J. Civil Eng. Res., vol. 4, no. 2, pp. 45–52, 2016.
[5] S. Putranto, "Operational Optimization of High-Pressure Air Compressor for Foam Concrete Synthesis," J. Build. Technol., vol. 8, no. 1, pp. 12– 19, 2017.
[6] F. K. A. Ferly and C. A. Ferly, "Comparative Study of Filter Media in Low-Cost Foam Generator Systems," Int. J. Infrastructure Dev., vol. 12, no. 3, pp. 88–96, 2024.
[7] National Standardization Agency of Indonesia (BSN), "Specifications for Lightweight Aggregate for Structural Concrete," SNI 03-3449-2002, Jakarta, 2002.