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# AN INDIGENOUS FOAMING AGENT FOR LOW DENSITY FOAMED CONCRETE

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FOAMED concrete is produced by incorporating a high proportion of air or gas bubbles in concrete. Although India uses foamed concrete, she has to depend on imported proprietary foaming agents for its production. Consequently the Central Building Research Institute at Roorkee, undertook research work with the idea of developing an indigenous foaming agent. This article describes the method of preparation of the foaming agent, its foam-forming characteristics as compared with proprietary products, and also its suitability in the making of foamed concrete.

## Preparation of the foaming agent

Of the various agents found suitable for mechanical foaming[2], those derived from wood resins were chosen for the purpose of investigation. Various grades of rosin, ranging from grade 'FF' to the paler grades were tried, and the 'N' grade rosin† was found suitable. 'N' grade rosin was saponified, and the soap was stabilized by emulsifying it in animal glue solution. Only glues having a particular jelly strength are effective. The product was prepared, packed in an air-tight container and stored in a cool place. The various foaming agents, namely A, B, C, D, E, F & H described herein, vary only in the ratio of rosin to stabilizer and in the concentrations of the latter.

The proportions of the materials, the condition of mixing, etc for preparing the indigenous foaming agent 'H' are covered under Indian patent No. 58909.

## Testing of foaming agent

The evaluation of the different foaming agents, A, B, C, D, E, F & H was carried out on the basis of their expansion, stability and effect on setting and hardening of cement.

The stability of foams was measured by using the apparatus based on the principle of Foulk and Miller.[3] A 0·5 per cent solution of pure saponin was used to calibrate the apparatus. Stability of different concentrations of the foaming agent was determined by noting the height of the foam at regular intervals on passing a steady current of air through the liquid at the recommended conditions of temperature and pressure.[4]

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† Manufactured by Indian Rosin and Turpentine Factory, Bareilly.

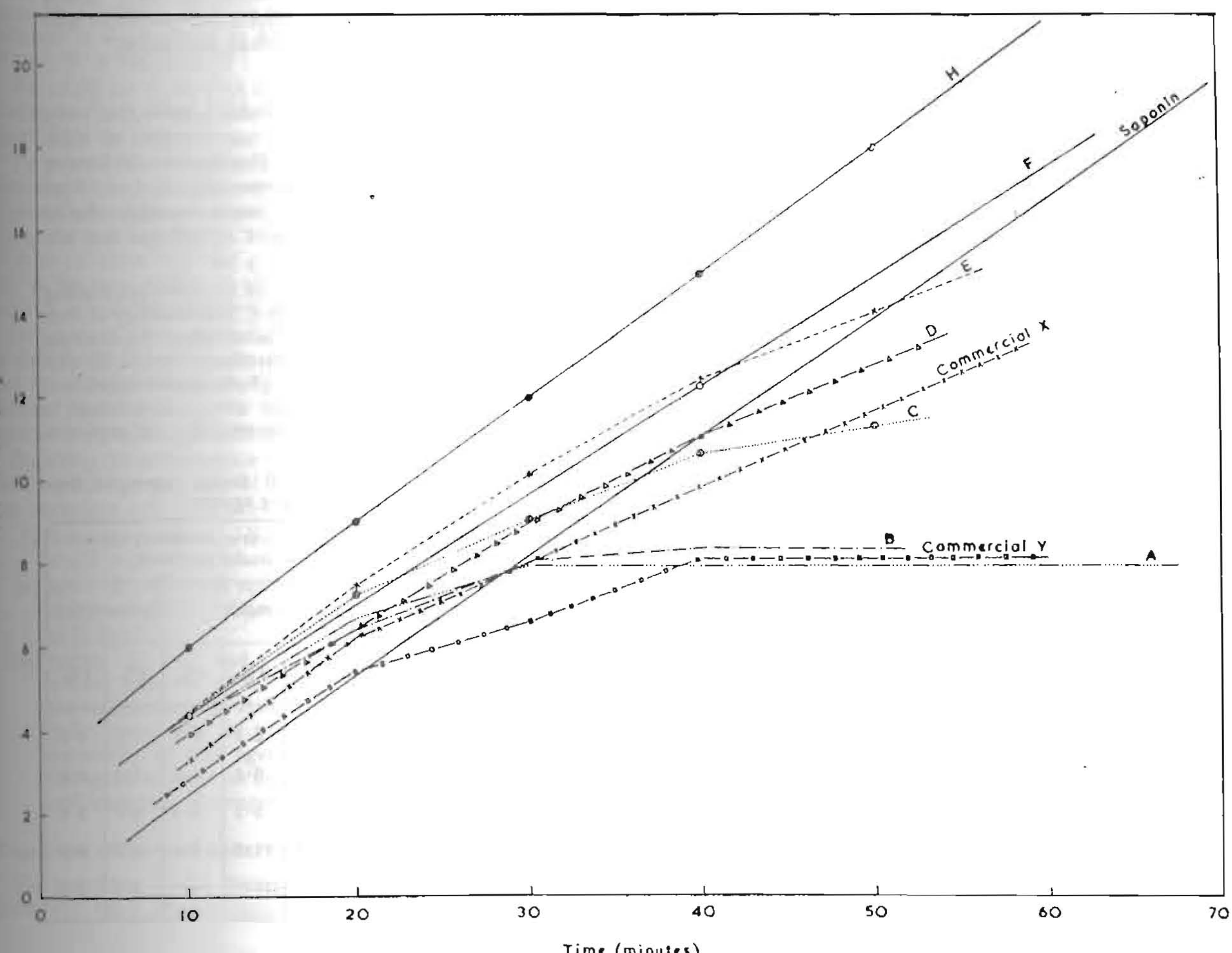


Fig 1 Stability of foams.

**TABLE 1. Relationship between expansion factor and concentration of the foaming solutions**

| Concentration of the solution (per cent) | Foaming Agents | | | | | | | Commercial X | Saponin | Commercial Y |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | H | | | |
| 1·0 | 4·00 | 3·61 | — | — | — | 1·36 | 1·64 | 3·72 | 3·50 | — |
| 2·0 | 4·41 | 4·62 | 2·72 | 3·00 | 2·69 | 2·52 | 2·90 | 3·80 | 3·60 | 3·22 |
| 3·0 | 4·46 | 4·72 | 3·82 | 3·74 | 3·76 | 3·08 | 3·76 | 4·36 | 3·44 | 4·08 |
| 4·0 | 4·45 | 4·80 | 4·22 | 4·36 | 3·88 | 4·30 | 4·20 | 5·16 | — | 3·72 |
| 5·0 | 4·48 | 4·72 | 4·32 | 4·12 | 3·56 | 4·24 | 4·04 | 4·64 | — | — |

**TABLE 2. Comparative stability of foams generated from various foaming agents**

| Time (minutes) | Height of Foam (cm) for various Foaming Agents with different Strengths of Solution | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | | B | | C | | D | | E | | F | | H | |
| | 3% | 4% | 3% | 4% | 3% | 4% | 3% | 4% | 3% | 4% | 3% | 4% | 3% | 4% |
| 10 | 5·8 | 4·3 | 4·0 | 4·3 | 5·8 | 4·5 | 4·0 | 4·0 | 4·5 | 4·5 | 4·5 | 4·5 | 5·9 | 6·0 |
| 20 | 6·2 | 6·8 | 6·0 | 6·5 | 8·4 | 7·3 | 6·1 | 6·5 | 7·4 | 7·5 | 7·5 | 7·0 | 8·6 | 9·0 |
| 30 | 6·0 | 8·0 | 6·5 | 8·1 | 10·0 | 9·1 | 8·5 | 9·0 | 9·5 | 10·2 | 10·0 | 9·6 | 11·0 | 12·0 |
| 40 | 6·0 | 8·0 | 6·5 | 8·4 | 11·4 | 10·7 | 11·3 | 11·0 | 11·5 | 12·5 | 12·3 | 12·5 | 14·0 | 15·0 |
| 50 | 6·0 | 8·0 | 6·5 | 8·4 | 12·4 | 11·3 | 13·3 | 12·8 | 13·1 | 14·1 | 14·7 | 15·0 | 17·0 | 18·0 |

## Laboratory preparation of foamed concrete

The efficacy of the foaming agents was further tested by using the foams generated from their solutions in making foamed concrete of low densities (14 to 20 $lb/ft^3$).

The raw materials used in the making of foamed concrete were :

(*i*) Portland cement or rapid hardening cement, and

(*ii*) Jumna or Solani sand (ground to pass 170 mesh BS sieve with a maximum residue of 10 per cent).

Foamed concrete of various densities was prepared by a judicious selection and proportioning of the above materials in a 2 ft diameter Winget mixer.

For the preparation of foamed concrete of low density (20 $lb/ft^3$) in the Winget mixer, the materials required and the proportion to be adopted are given below :

| | |
|---|---|
| Portland cement .. | 25 lb |
| ground sand .. | 25 lb |
| Foaming solution (4 per cent solution of foaming agent in water). | 4 litres (to be added in three lots). |

As a result of a number of trials the following sequence of operations was found efficient :

(*i*) the mixer was started and 23 lb of water poured in its mixing pan ;

(*ii*) 25 lb of portland cement was gradually added to the water in the pan of the running mixer so as to give a cement wash ;

(*iii*) 25 lb of ground sand was then added gradually to the cement wash and the contents of the pan thoroughly mixed to give a homogeneous slurry ;

(*iv*) 1·25 litres of the foaming solution were then charged into the top pre-foamer which generated foam from the solution ;

(*v*) when the pre-foamer was full with foam to its capacity, the foam was delivered into the pan underneath ;

(*vi*) while the foam was getting mixed with the cement-sand slurry in the pan, the pre-foamer was charged again with another lot of foaming solution (1·25 litre), and when the pre-foamer was again full of foam, the latter was delivered into the pan ;

(*vii*) the addition of 1·5 litres of foaming solution to the pre-foamer and the foam to the material in the pan was repeated once more to make the final mix of the desired density ;

(*viii*) as soon as the final charge of foam was well mixed and the product of desired density was obtained, the foamed concrete slurry was discharged into buckets and poured into the moulds for casting purposes ;

(*ix*) the moulds were removed after 24 hours and the cast specimens were cured in an auto-clave at a pressure of 140 to 150 $lb/in^2$ for 6 hours ; and

(*x*) the autoclaved specimens were allowed to cool, and stored at room temperature till tested.

## Testing of foamed concrete

The properties of foamed concrete such as bulk density, moisture absorption, compressive strength under various conditions, dimensional changes, and other properties were determined according to the established procedures.[5]

## Results

The results, which are given in *Table* 1, show that every foaming solution has an optimum concentration at which the expansion factor is maximum. For commercial foaming agents *X* and *Y* this optimum concentration is 4 and 3 per cent respectively. Saponin shows maximum expansion at 2 per cent whilst for agents *A* and *C* it is 5 per cent and for the remainder it is 4 per cent.

The values of stability of foams of the different foaming agents are reported in *Tables* 2 and 3. The stability of foam is related to the concentration of the solution. For example, the stability of the various concentrations tried in the case of commercial foaming agent '*X*' (*Table* 3) the stability is maximum for a solution of 0·5 per cent concentration. In the case of commercial agent '*Y*' the stability and expansion

**TABLE 3. Comparative stability of foams generated from commercial foaming agents**

| Time (minutes) | Height of foam (cm) with different agents and strengths of solution | | | | | | |
|---|---|---|---|---|---|---|---|
| | Saponin | Commercial X | | | | Commercial Y | |
| | 0·5% | 0·5% | 2% | 3% | 4% | 3% | 4% |
| 10 | 2·8 | 4·5 | 3·3 | 3·4 | 3·3 | 4·8 | 2·9 |
| 20 | 5·4 | 7·6 | 6·0 | 6·4 | 6·3 | 7·4 | 5·5 |
| 30 | 8·2 | 10·5 | 8·8 | 9·2 | 8·1 | 9·4 | 6·7 |
| 40 | 11·1 | 13·6 | 11·2 | 11·7 | 9·9 | 9·5 | 8·2 |
| 50 | 14·0 | 16·3 | 14·7 | 14·3 | 11·7 | 9·5 | 8·2 |

**TABLE 4. Values of dy/dx**

| Foaming Agent | Solution (per cent) | Relation between foam height and time, where x and y denote time and height respectively. | Value of dy/dx |
|---|---|---|---|
| Saponin | 0·5 | 10y = 28·5 x − 3 | 2·85 |
| A | 4·0 | y = 8·0 | 0·0 |
| | 5·0 | y = 7·3 | 0·0 |
| B | 3·0 | y = 6·5 | 0·0 |
| | 4·0 | y = 8·4 | 0·0 |
| C | 4·0 | y = 1·2 x + 5 | 1·2 |
| | 5·0 | y = 1·85 x + 3·8 | 1·85 |
| D | 3·0 | y = 2·5 x + 1·25 | 2·5 |
| | 4·0 | y = 2·25 x + 2 | 2·25 |
| E | 3·0 | y = 2·2 x + 3 | 2·2 |
| | 4·0 | y = 2·32 x + 3·0 | 2·32 |
| F | 3·0 | y = 2·6 x + 2·1 | 2·6 |
| | 4·0 | y = 2·6 x + 1·9 | 2·6 |
| H | 3·0 | y = 3·33 x − 11·63 | 3·33 |
| | 4·0 | y = 3·33 x − 10 | 3·33 |
| Commercial X | 0·5 | y = 3 x + 1·5 | 3·0 |
| | 4·0 | 10y = 18·0 x + 2·7 | 1·8 |
| Commercial Y | 3·0 | y = 0 | |
| | 4·0 | 10y = 18 x + 12·0 | 1·8 |

of a 3 per cent solution is better than that of the 4 per cent solution. For the foaming agent 'E' the expansion and stability values of the 4 per cent solution are better than those for a solution of 3 per cent. There is hardly any difference in the stability of 3 and 4 per cent solutions of 'F' and 'H' is similar to 'F'.

The results for 4 per cent solutions (*Tables* 2 and 3) are plotted in *Fig* 1, from which it is obvious that foaming agent '*H*' is the best.

The criterion for a stable foam is the linear relationship between the foam height with time. The gradient *dy/dx* represents the degree of stability ; the greater the value of the gradient, the greater is the stability. Calculated values of *dy/dx* are given in *Table* 4. From these, it is found that '*H*' is the most stable of all the foaming agents, and is superior to both the commercial samples.

On the basis of the values for expansion factor and degree of stability (*dy/dx*), it is seen that foaming agents *D*, *E*, *F*, and *H* are superior in performance in the ascending order. Besides, the solutions of '*H*' can be stored in darkness for a period of 15 to 30 days without deterioration.

Regarding the performance of the various foaming agents for the actual preparation of low density foamed concrete the conclusions arrived at are :

(*i*) foaming agents '*A*', '*B*', and '*C*' were not sufficiently stable to give a satisfactory foamed concrete ;

(*ii*) agent '*D*', although sufficiently stable, was not found stable enough to yield a low density product, namely of 20 lb/ft$^3$ ;

(*iii*) agents '*E*', '*F*' and '*H*' are suitable for making foamed concrete of 20 lb/ft$^3$. With the agent '*H*' foamed concrete of still lower density, *i.e.* 14 to 15 lb/ft$^3$, could also be prepared showing thereby the superiority of this agent over the others ; besides, the agents showed no deleterious effect on the setting and hardening of cement.

## Properties of foamed concrete

The properties of the foamed concrete prepared in the laboratory using the indigenous foaming agent '*H*' are

**TABLE 5. Properties of foamed concrete**

| Bulk Density (lb/ft$^3$) | Water absorption by volume (per cent) | Compressive Strength (lb/in$^2$) | | | | Dimensional change in saturation with water (per cent) |
|---|---|---|---|---|---|---|
| | | After 28 days curing in 90 per cent humidity | After autoclaving at 145 lb/in$^2$ | Autoclaving followed by drying at 105°C | Autoclaving followed by saturation in water | |
| 13·9 | 25·17 | — | 77·0 | 92·4 | 64·4 | + 0·106 |
| 14·5 | 24·5 | — | 81·2 | 98·0 | 62·0 | + 0·106 |
| 20·0 | 27·87 | 22·4 | 86·8 | 119·0 | 92·4 | + 0·068 |
| 24·1 | 29·74 | 39·2 | 210·0 | 190·0 | 185·0 | + 0·08 |
| 42·1 | 28·02 | 77·0 | 165·0 | 264·0 | 214·0 | + 0·078 |
| 59·3 | 25·77 | 218·0 | 408·0 | 442·0 | 390·0 | + 0·058 |
| 64·3 | 22·65 | 215·0 | 568·0 | 732·0 | 554·0 | + 0·066 |
| 78·2 | 27·90 | 378·0 | 1771·0 | 1916·0 | 1554·0 | + 0·055 |
| 81·5 | 22·47 | 700·0 | 1750·0 | 2240·0 | 1582·0 | — |
| 108·8 | 25·64 | 1540·0 | 4074·0 | 4139·0 | 3584·0 | — |

reported in *Table* 5. The bulk density of the foamed concrete may be taken as an index of the efficacy of the foaming agent.

The values of the bulk density and the compressive strengths in *Table* 5 show that an increase in density results in an increase in strength and the general trend of the relationship between the two is in agreement with the previous findings.[6]

The results of the compressive strengths reported in columns 3, 4, 5 and 6 of *Table* 5 show the influence of the curing conditions on the strength of the final product.

On comparing the strength results amongst themselves, it is evident that drying of the foamed concrete, after autoclaving, results in the highest strengths. That normal curing conditions are not proper and that the saturation of foam concrete with water after autoclaving lowers the ultimate strength are also borne out by the strength results in *Table* 5.

The values in the last column show that compared to dense concrete, foamed concrete, in general, is prone to greater dimensional changes.

The results of the present investigation show that the new indigenous foaming agent developed at the Central Building Research Institute, Roorkee, is suitable for making foamed concrete even of low density (20 lb/ft$^3$). This has also been confirmed by successful full-scale trials conducted at the Hindustan Housing Factory, Delhi.

The coefficients of thermal conductivity of two samples of foamed concrete having densities of 20.0 and 42.1 lb/ft$^3$ were found to be 0.305 and 0.529 BTU/hr/ft$^2$/°F/in respectively (vide Report No. CT-58-36 of the Government Test House, Alipore). The corresponding values of the coefficient of sound absorption were 0.25 and 0.23 at a frequency of 500 cycles/sec and 0.32 and 0.26 at 1000 cycles/sec.


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