2-Dimensional inline system for peppermint oil extraction

M Anas¹ and A Sharma²,*

¹,² Department of Mechanical Engineering, Integral University, Lucknow 226026, India
anas@iul.ac.in¹, anuragsharma186@gmail.com²

Abstract. Peppermint leaves have wide range of applications in medicines, toothpastes, soaps, mouth fresheners, chewing gums etc. However, in India, the traditional way of processing peppermint leaves for extraction of peppermint oil is slow, tedious, labour intensive, hazardous, and causes skin problem as well. This paper proposes a method of mechanizing the post harvesting process, with least modification in the current apparatus being used by the farmers in the Indian villages. It proposes a non-electric 2-dimensional Mechanized system for movement and compaction of the compact/hay. The mechanism will help to reduce the number of labourers per unit hay volume and the risk associated with the contact of in-process hay with their skin. Also, a lot of time is wasted in putting the leaves/hay in the boiler vessel, preparing the hay in a compact form and in removing the processed leaves. This paper is an attempt to get rid of most of the problems aforementioned and make the process safe, efficient, less labour intensive and more economical for farmers and workers. The mechanism proposed is sustainable and farmer friendly as it does not require any special training for its operation. It will increase the profit of small-scale industries with small capital investment for the setup.

Keywords. Extraction, Inline system, Manual, Mechanization, Menthol, Peppermint oil, Rural technology.

1. Introduction

Peppermint oil is extracted from Mentha piperita and has contents of menthol (45% approx.) and menthone (22%). Peppermint (i.e. Mentha Piperita) belongs to mint family (Lamiaceae), which is widely considered as a medical and aromatic plant and are produced extensively for the medicinal and as food product. It is believed that peppermint originated in the Mediterranean and Northern Africa. It was discovered through the Ebers papyrus, a medical text dating back to 1550 BC, that Egyptians have long known about its stomach calming effects. Its leaves containing essential oils consisting various aromatic chemicals compounds like menthol, menthone, isomenthone and menthofuran which are used in medicines, foods, flavourings, cosmetics and beverages. Tobacco industry is the leading consumer of mint essential oils and consumes about 40% of the total oil produced, followed by pharmaceutical and confectionary industries. Menthol, being the major substance, give the mints major characteristic aromas and flavours. It is used as a flavouring substance in toothpaste, mouthwash, chewing tobacco, mouth fresheners, analgesic balms, cough syrups, chewing gums, candies and tobacco industry. This is due to its fresh minty taste and fragrance and cooling effects due to presence of menthol.[1],[2]
The peppermint oil is reported to have anti-oxidant properties, antibacterial activity and due to this, it is a major constituent of some of the over the counter remedies available in Europe for the irritable bowel syndrome.[3]

There are four varieties of peppermint plants that are cultivated in India - Peppermint, Spearmint, Bergamot mint and Japanese mint. India produces about 75% of the total world mint oil supply by cultivation of Japanese mint on around 60,000 hectares of land. It produces about 12,000 tonnes of menthol mint oil annually. Japanese mint is cultivated in India in around 60,000 ha in tarai districts like Rudrapur, Bilaspur etc. of Uttaranchal and Central U.P. like Barabanki, Moradabad, Bareily, Badaun and Lucknow, besides smaller area in parts of Punjab (Ludhiana and Jallandhar). Along with Japanese mint, India produces Peppermint on an area of about 2,500 ha, Bergamont mint on 1,200 ha and Spearmint on 3,000 ha land which produces 200 tonnes, 150 tonnes and 300 tonnes of oils respectively. Other countries that grow these species and produce oil are China, Brazil, USA, former USSR and Thailand.[4]

Presently, India is one of the largest producer of Mentha oil in the world. As per, The HINDU Business Line report, dated February 21, 2019, India produces 80% of the world’s mint supply and exports 75% of its output.[5]

It is widely grown in temperature region of the world. In India it is grown between February to September (cultivated twice and hence extracted twice from single field). The crop gives high yield with regular irrigation and takes about 3.5 months to grow. Peppermint plants are about 30 to 90 cm high and have smooth stems with square cross section. Its leaves can be 4 to 9 cm in length and 1.5 to 4 cm in breadth and are of dark green colour with reddish veins, and they have an acute apex and coarsely toothed margins.

Peppermint can be cultivated both in tropical and sub-tropical regions of the world. A mean temperature of 20 to 40 C is required during major part of its growing period and a rainfall between 100 to 110 cm is ideal for its cultivation. Well drained loam or sandy loam soil rich in organic matter having pH between 6 and 8.2 are ideal for its cultivation. Both red and black soil can also be used. In case of acidic soil having pH less than 5.5 is recommended.

1.1. Need of mechanization
The small scale plants are very pathetic and so the old traditional method adopted is. The traditional method of oil production in Indian villages is based on steam distillation of peppermint leaves. The labours put the harvest directly in the boiling vessel and stomp it with their bare feet to compress and compact it for maximum utilization of vessel volume and make each process cycle more economical. But this manual process is hazardous as it makes the labourers come in direct contact with the in-process hay. They have to work inside a 5 ft deep vessel that may have gone through a process cycle before and may still be quite warm. Also, when they stomp the leaves with bare feet, the direct contact with it causes skin irritation. And at last they have to take all the processed hay out of the hot vessel by going inside it and manually throwing it out of the vessel walls with a poorly designed very rough tool, like big fork.
During the time when the distillation process is going on, the vessel is sealed and the workers have to wait for it to end. The farmers have to wait for 4-5 hours i.e. as long as distillation is carried on. Only when the vessel is cleared of the processed leaves, the next cycle can be started again with filling and compacting the leaves.

Most of the villages of Central U.P. like Barabanki, Mahmoodabad, Sitapur, Ramnagar, Bahraich, Gonda were visited. It was found that the whole process is slow and tedious and as mentioned above, hazardous. A lot of time is wasted in preparing the hay in a compact form and putting the leaves/hay in the boiler vessel. The time is again wasted in removing the processed leaves. This paper is an attempt to get rid of most of the problems aforementioned and make the process safe, efficient, less labour intensive and more economical for farmers and workers.

1.2. Literature survey

The old traditional method being adopted by farmers is least available in record. Anas & Abusad (2009) have surveyed and collected a series of problems associated with peppermint industry in rural India and about the many problems faced by the Indian farmers in processing of harvest for extraction of peppermint oil. The problems included unsafe material handling, direct contact of hay with skin, delay in process cycles, compact preparation inside hot vessel, removal of processed hay and many more. They have categorized problems as technical problems, ergonomics problem, economic and management related problems and so on. They also suggested various methods to solve these problems related with handling of the compact and making the whole process mechanized with and without electricity.[6]

Anas et. al. (2020) in their paper “Sustainable Model for Mechanization of Peppermint Oil Extraction Plants for Rural India” discussed about the feasibility of a 3-Dimensional model for movement and compaction of hay. Computerized model was made and motion study was done. They have attempted to reduce the time wasted in filling the drum with hay. They have also made the
technique/ process more safe for the farmers. It was found that the model could help the farmers to produce more oil in less time with large capital investment. However, it was a complex method and it required large area and large capital investment. [7] 

Braima & Andoh (2016) designed a mechanical system i.e. a prototype for extraction of lemon grass oil using direct steam distillation technique. Tests were conducted to measure the machine performance and quality of oil extracted. [8] Lucchesi et. al. (2004) developed Solvent-free microwave extraction (SFME). Solvent free microwave extraction is an original combination of microwave heating and dry distillation. It offers important advantages over traditional alternatives, namely: shorter extraction times (30 min for SFME method against 4.5 h for hydro-distillation), substantial savings of energy, and a reduced environmental burden (less CO2 rejected in the atmosphere). [9]

Gavahian et al. (2011) performed Ohmic-assisted hydrodistillation (OAHD) on Zataria multiflora Boiss (Shirazi thyme). OAHD is a combination of ohmic heating and distillation, and could be considered as a novel method for the extraction of essential oils. The method was compared with the quality and quantity of essential oil extracted from traditionally used Hydro-Distillation (HD) technique. In this study OAHD was presented as ‘environment friendly’ method for essential oil extraction. It was found that OAHD resulted in reduced extraction time as compared to traditional HD and extracted most of the oil from thyme in a time at which the HD method started giving out its first drops. Also the quality of oil extracted from both methods were similar. [10]

However, such methods are very expensive and require technical skills. Hence they are not suitable for Indian context. The mechanized models so far made are not accepted by our farmers because of complex mechanism of handling, high installation cost and lower profits. As a result we see the models h ave not replaced the old traditional methods of extraction of peppermint oil. The present mechanized model has very less installation cost, can be easily handled and besides that, increase in efficiency will be obtained when implemented. The mechanization of plant will not only make the process faster but also will be very safe to operate.

2. Materials and Methods
As mentioned above, the plants surveyed in rural areas of India run without electricity. The mechanized model hence proposed here is also developed while keeping that in mind and also that very technologically advanced system would be inoperable by the farmers due to lack of technical knowledge. The model proposed is a 2-dimensional inline mechanized system. The details of the Plant is given in Table 1 and Fig. 6.

**Table 1: List of components.**

| Sl. no. | Component name             | Material                        | Specification/ Capacity            |
|--------|----------------------------|---------------------------------|-----------------------------------|
| 1      | I-beam                     | Structural Steel                | SC 140 (140mm x 140mm x 33.3Kg/in) |
| 2      | I-beam trolley             | -                               | 0.5 Ton                           |
| 3      | Chain block                | -                               | 0.5 Ton                           |
| 4      | Wire rope                  | Stainless Steel                 | 3/16 in                           |
| 5      | Hand winch                 | -                               | 362 Kg                            |
| 6      | Boiling vessel             | Alloy Steel                     | Diameter = 72 in Height = 60 in   |
| 7      | Lower compacting container| Mild Steel Frame, Galvanized Steel mesh | Diameter = 71in Height = 36 in |
| 8      | Upper compacting container| Mild Steel Frame, Galvanized Steel mesh | Diameter = 72in Height = 36 in |
| 9      | Prepared hay compact       | Peppermint hay                  | Diameter = 70in Height = 30 in    |
| 10     | Base net                   | Mild Steel Frame, Galvanized Steel mesh | Diameter = 71in Height = 1 in   |
| 11     | Chain Sling                | Alloy Steel                     | 3 Legs, 2m                        |
| 12     | Processed hay              | Peppermint hay                  | Diameter = 70in Height = 30 in    |
The trolley moves on an I-beam held at a height of 12 ft. The trolley is connected to the wire ropes of two hand winches present on both columns supporting the I-beam. Hence when a person winds one hand winch and other unwinds the other one, the trolley moves in either directions. The chain block is suspended from the trolley and is used to move the load (compact) in and out of preparation drum and boiling vessel.

The average elbow height of male workers in northern regions of India is 1102mm.[11] Best ergonomic height of crank should be 0.9 times of the elbow height for maximum torque transmission and least discomfort of the worker.[12] Hence the suitable height chosen for hand winch placement on the pillar becomes 992 mm from the ground.

The main stages of working mechanisms are as follows:

1. Leave collection 1: The hay is collected in a net of wire in compaction container that is about the size of boiling vessel.
2. Leaves compaction 1: The workers compact the hay by walking on it. They can’t be bare feet. They have to wear long rubber boots to avoid contact of skin with the hay, otherwise it results in skin irritation (Fig 8a).
3. Compaction Drum Expansion: The Compaction drum is telescopic and can be pulled upward when half of it gets filled and compacted. This creates space for preparation second compact (Fig 8b).
4. Leave collection 2: More hay is collected and filled inside the new space generated after the expansion of compaction container.

5. Leaves compaction 2: Similarly, more hay is compacted to form a second compact.

6. Transport of compact 1 & 2: The chain block is used to lift the net that is now filled with compacted hay (Fig 8c). The hand winches on both columns are used to move and align the compact hovering above the boiling vessel (Fig 8d). And again the chain block lowers the compact into the boiler drum. Both the compacts from compaction drum are transported to boiling drum one by one in the same way. Then the vessel lid is fixed over the boiling vessel by chain block and then it is fastened by nut bolts. It is heated at the base, containing water up to 300 mm. The steam so produced extracts the oil from the peppermint leaves. The oil is separated from steam when it is condensed in the condenser and the oil is collected in a container.

7. Removal of the processed compact: The cover is unfastened and lifted by chain block. The chain block further removes the compacts of processed hay one by one, loaded on a rickshaw-trolley, which can be kept beside the boiler drum, and transported over to smoke emission chamber (drier unit) the hay is scattered in the field for faster cooling and drying.

With the addition of a compaction container, the labourers can prepare another round of compacts while two compacts are already in the boiler being distilled. As soon as the first two compacts are removed from the boiling vessel after processing, the pair of prepared compacts can be put inside the vessel for the next round. This would save the otherwise waiting time while the vessel was full and distillation was going on.

3. Results and Discussion
The traditional method adopted in various places is surveyed and it is found that farmers use various sizes of drum (Boiling vessel). However, the preferred size of drum and other details related to plant are as follows:

The working area for entire plant is 7.5 x 3 m².
The plant has following major elements

Boiling vessel is of diameter= 6Ft (1.82m) and height= 5Ft (1.52m)
Compaction container of diameter= 6Ft (1.82m) and height= 3Ft (0.92m) (collapsed)
The items required are listed in Table 2 along with their costs and suitable capacities.

Other items that need to be fabricated are:

a) Base net (4 Units)
b) Telescopic Compaction container (with wire mesh walls)

| Sl.No | Item                        | Capacity | No.(s) | Avg. Cost          |
|-------|-----------------------------|----------|--------|--------------------|
| 1.    | I-beam SC 140 (23Ft)        | -        | 1      | Rs.11672@ Rs.50/Kg |
| 2.    | I-beam trolley              | 0.5 ton  | 1      | Rs. 3000           |
| 3.    | Chain block                 | 0.5 ton  | 1      | Rs. 4000           |
| 4.    | Hand winch                  | Min.     | 2      | Rs. 2000x2         |
| 5.    | Pulley (with mount)         | -        | 2      | Rs. 700 x2         |
|       | Total cost                  |          |        | Rs. 24072          |

3.1 Time Calculations

3.1.1 Time taken for lifting and lowering of compacted compact with chain block:
Travel ratio of 0.5 ton chain block = 41:1 (assumed as available in market)
Let’s assume that worker moves the hand chain at a constant velocity \( V_H = 1 \text{ m/s} \)
Load chain velocity \( V_L = 1/41 \text{ m/s} = 0.002439 \text{ m/s} \)
Total time to lift or lower load chain by 6 feet = \( (6 \times 12 \text{ in})/(0.96024 \text{ in/s}) \)
= 74.98 s ~ 75 s approx.
Total time to lift or lower load chain by 3.5 feet = (3.5x12 in)/(0.96024 in/s) 
= 43.74s ~ 44s approx.

3.1.2  Time taken to move the trolley in one direction:
Gear ratio of hand winch = 2.9:1 (assumed as available in market)
The trolley travel per revolution of winch handle =75.87 mm/rev (assumed to be const. with each rev.)
Hence, 1 rps on handle = 1/2.9 = 0.3448 rps on drum
The trolley velocity \( V_T = 0.3447 \times 75.87 \text{ mm/s} = 26.16 \text{ mm/s} \)
Time to move 3.81m (centre distance of drums) = 145.6s ~ 146 s

3.1.3  Total time taken in removal of two processed compacts:
Total time for removal = Time taken to (move from beam centre to vessel centre + lift first compact + move back to beam centre + lower the first compact + move back to vessel + lift second compact + move back to centre + lower second compact)
= 146/2 + 44 + 146/2 + 75 + 146/2 + 75 + 146/2 + 75
= 561s = 9m21s

3.1.4  Total time taken in transport of two compacted compacts:
Total time to fill vessel = Time taken to (move from beam centre to container centre + lift first compact + move back to vessel centre + lower the first compact + move back to container centre + lift second compact + move back to vessel centre + lower second compact)
= 146/2 + 44 + 146 + 75 + 146 + 75 + 146 + 44
= 749s = 12m 29s

3.2  Load determination for hand winch capacity:
Trolley wheel diameter = 4in = 71 mm
No. of wheels = 4
Mass of Compact = 200kg
Total mass to be hung = Mass of Compact + (Base Net + Chains + Chain Block) = 200 + 50(assumed)
= 250kg
Load per wheel \( W = (250 \times 9.81) / 4 = 613.125 \text{ N} \)
Coefficient of rolling friction for steel on steel \( C_r = 0.001 \)

\[ F = C_r W / R \] [14]

where, \( F = \) Frictional force
\( C_r = \) Coefficient of rolling friction
\( W = \) Load per wheel (N)
\( R = \) Radius of wheel (m)

\( F = 17.27 \text{ N} \)
Total rolling friction on 4 wheels = 17.27x4 = 69.08N
Starting force (2 to 2.5 times of rolling friction) = 69.08x2.5 = 172.71N = 17.55 KgF

3.3  Load determination for I beam size:
Beam length \( L = 23ft = 7.0104m \)
Total Load \( P = (\text{Trolley mass} + \text{Hung mass}) \times 9.81 \)
\( = (18 + 250) \times 9.81 = 2629.08 \text{ N} \)

\[ \delta_a = L/500 \] [16]

where \( \delta_a = \) Allowable deflection (m)
This gives \( \delta_a = 0.0140208 \text{ m} = 14.02 \text{ mm} \)
Assuming simply supported beam with concentrated load, maximum deflection will occur when trolley is mid span
Hence by beam equation,
\[ \delta_{\text{max}} = \frac{PL^2}{48EI} \] (3)

where, \( P \) = Load on beam centre (N)
\( L \) = Beam length (m)
\( E \) = Young’s Modulus (N/m²)
\( I \) = Moment of inertia (m⁴)

For steel Young’s Modulus \( E = 200\text{GPa} \)

Solving for \( I \),
\[ I = 6.27 \times 10^{-6} \text{ m}^4 = 627 \times 10^4 \text{ mm}^4 \]

SC 140 H-Beam (BIS) has an \( I \) value equal to 1470x10⁴ mm⁴.[15]

Mass of SC 140 is 33.3Kg/m

Max deflection with self weight included,
\[ \delta_{\text{max}} = \frac{(PL^2)}{48EI} + \frac{(5wL^4)}{384EI} \] (4)

where, \( w \) = Self weight (N)

This gives \( \delta_{\text{max}} = 0.00991\text{m} = 9.91\text{mm} \)

This value is less than Allowable deflection, hence this beam is selected.

The comparison of traditional plant and mechanized plant is presented in Table 3.

| S No | Description                        | Existing plant | Mechanized plant |
|------|------------------------------------|----------------|------------------|
| 1    | Installation cost                  | Rs 2,20,000    | Rs 3,20,000      |
| 2    | Modification cost only             | -              | Rs 1,00,000      |
| 3    | Working area covered               | 5.5 x 5.5 m²   | 7.5 x 3.0 m²     |
| 4    | Preparation time of compact (hay)  | 2 hours in main boiler drum | 1.5 hour in compaction container |
| 5    | Time required for removal of processed hay | 3 hours | 10 min |
| 6    | Distillation time                  | 4.5 hrs        | 4.5 hrs          |
| 7    | Cycle time                         | 9.5 hrs        | 5 hrs            |
| 8    | Peppermint hay weight in 1 tank    | 400Kg          | 400Kg            |
| 9    | No. of labourers                   | 4              | 2                |
| 10   | Labour cost                        | Rs 1600/ day   | Rs 800/ day      |
| 11   | No. of boilers used in one day     | 02             | 05               |
| 12   | Earning per day of the plant@Rs1000/ cycle | Rs 2000/day | Rs 5000/day |

Table 3: Comparison of mechanized model with existing model.

Referring Table 3, it is clear that the earning per day is increased by Rs 3000 per day and labour cost is halved compared to traditional approach. The time required for removal of used leave is highly decreased. The chain pulley arrangement utilizes 9-10 minutes for removal of used/ processed hay.

It is depicted from above discussion that the incurred cost of setting up this can soon be covered with increased profit of the plant. It is also depicted that hand winch can be used ergonomically for moving the compact from compaction container to the vessel and vice versa.

However, this study is theoretical and assumptions are made at various stages. These assumptions may give very ideal results and more accurate results can only be obtained after successful trial in the real world. Uncertainties are involved, especially the time taken by various operations, may divert from these ideal values obtained here but not by much. But the reduction in effort that the mechanism offers is for sure.

4. Conclusion

Indian farmers largely depend on cultivation of crops. Cultivation of peppermint plant is common in northern part of India. The traditional methods being adopted in rural India is not at all safe and has several other problems as discussed in section 1.

The 2 dimensional mechanized system, presented in this paper, can easily replace the already existing traditional setup, with very little changes and modification of the existing system.

For Indian context, the traditionally used hydro-distillation technique for oil extraction from
peppermint plant is found suitable due to its low cost, easier operation and high yield. There is no need of electricity. The drawbacks present in the currently used methods in Indian farms and the problems that arose are discussed and solved. The presented model eradicates the problems related to the material handling, long cycle times and will reduce the waiting time to greater extent. The proposed 2 dimensional model satisfies the need of farmers.

The 2 dimensional mechanized system has overall effective suitability for Indian villages. It will be easy to install as it a modification of the existing one. The setup cost required is moderate. This new model will increase the profit of the plant. No power supply is needed. No special technical knowledge is required for operation.

The major conclusions are:
1. Provides safety to workers.
2. Makes it easier for removal of processed hay. The time required for removal of used hay is largely decreased. The chain pulley arrangement takes about 9-10 minutes for removal of processed hay.
3. Compacts can be prepared while distillation is going on, hence saving large amount of time.
4. More distillation cycles can be completed in same time
5. Works without electricity and special technical knowledge.
6. The earning per day is increased by Rs 3000 per day and labour cost is halved compared to traditional approach.

A real world working setup will give more accurate results as the study presented in this paper is theoretical. Assumptions have been made at various stages for calculations and the results may be more on the idealistic side.

The 2 dimensional mechanized techniques for easy, safe and fast material handling, can bring a drastic change in the field of agriculture. The efficient method and highly economical setup will increase the productivity of the plant.

References

[1] Gavahian M, Farhoosh R, Farahnaky A, Javidnia K and Shahidi F 2015 Comparison of extraction parameters and extracted essential oils from Mentha piperita L. using hydrodistillation and steam distillation Int Food Res J 22(1) pp. 283-8.
[2] Sugiura T, Uchida S and Namiki N 2012 Taste-Masking Effect of Physical and Organoleptic Methods on Peppermint-scented Orally Disintegrating Tablet of Famotidine Based on Suspension Spray-coating Method. Chem. Pharm. Bull. 60(3) pp. 315–324.
[3] Pittler MH, Ernst E 1998 Peppermint oil for irritable bowel syndrome: a critical review and metaanalysis Am J Gastroenterol. Jul 93(7) pp. 1131-5.
[4] http://www.nhb.gov.in/Horticulture%20Crops/Mint/Mint1.htm [02 March 2021].
[5] https://www.thehindubusinessline.com/economy/agri-business/high-prices-boost-mint-cultivation/article26332498.ece [02 March 2021].
[6] Anas M and Abusad 2019 Mechanization of Peppermint Oil Extraction Plant of Rural India Proc. iNaCoMM2019 (IIT Mandi, Mandi) paper 195.
[7] Anas M, Mujeeb A and Sharma A 2020 Sustainable Model for Mechanization of Peppermint Oil Extraction Plants for Rural India IPROMM-2020 (BITS-Pilani, Hyderabad) paper 132.
[8] Braimah S R, Andoh P Y and Tawiah P O 2016 Designing a Mechanical System That Will Be Used To Extract and Separate Lemon Grass Oil Int j sci eng 5(3) pp. 01-11.
[9] Lucchesi M E, Chemat F, and Smadja J 2004 Solvent-free microwave extraction of essential oil from aromatic herbs: comparison with conventional hydro-distillation J Chromatogr A 1043(2) pp. 323–7.
[10] Gavahian M, Farahnaky A, Majzoobi M, Javidnia K, Saharkhiz M J and Meshahi G 2011 Ohmic-assisted hydrodistillation of essential oils from Zataria multiflora Boiss (Shirazi thyme) Int J Food Sci Technol 46(12) pp. 2619–2627.
[11] Chandra P, Deswal S and Chandra A 2010 An anthropometric survey of industrial workers of the northern region of India Int J Ind Syst Eng 6(1) pp. 110-128.
[12] Kharade H, Deshmukh M, Tiwari P and Gite L 2010 Optimum crankshaft height and crank length for hand operated rotary maize sheller PKV Res J 34 (2010) pp. 177-180.
[13] https://www.indiamart.com [14 June 2021].
[14] Lippert D and Spektor J Calculating proper rolling resistance: A safer move for material handling, (2012). https://www.plantengineering.com/articles/calculating-proper-rolling-resistance-a-safer-move-for-material-handling/ [22 February 2021].

[15] Gorenc E B 2003 *Crane Runway Girders - Limit States Design* (Australian Institute of Steel Construction) pp. 43-44.

[16] Dimensions For Hot Rolled Steel Beam, Column, Channel And Angle Sections (Third Revision ), IS 808:1989