1 INTRODUCTION

Manufacturing Technology, Vol. 1, Foundry, Forming and Welding

3 METAL CASTING PROCESSES

Objectives

- Understand the history of metal casting process
- Design patterns and cores for metal casting process
- Understand the various moulding materials used in the making of moulds and cores

Casting

- It generally means pouring molten metal into a refractory mould with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the refractory mould either by breaking the mould or taking the mould apart.
- The solidified object is called casting.
- This process is also called founding.

History of Casting Process

- Discovery c 3500 B.C. in Mesopotamia
- Bronze age
- *cire perdue* process
- China
- Indus valley civilization
- Iron Pillar in Delhi

Advantages

- Any intricate shapes internal or external can be made with the casting process.
- It is possible to cast practically any material be it ferrous or non-ferrous.
- Tools required for casting are simple and inexpensive.
- Weight reduction in design can be achieved.
- Castings have no directional properties.
- Casting of any size and weight, even upto 200 tons can be made.

Limitations

- Dimensional accuracy and surface finish achieved by normal sand casting process would not be adequate for final application in many cases.
- Sand casting process is labour intensive to some extent and therefore many improvements are aimed at it such as machine moulding and foundry mechanisation.
- With some materials it is often difficult to remove defects arising out of the moisture present in sand castings.

Applications

- Typical applications of sand casting process are cylinder blocks, liners, machine tool beds, pistons, piston rings, mill rolls, wheels, housings, water supply pipes and specials, and bells.

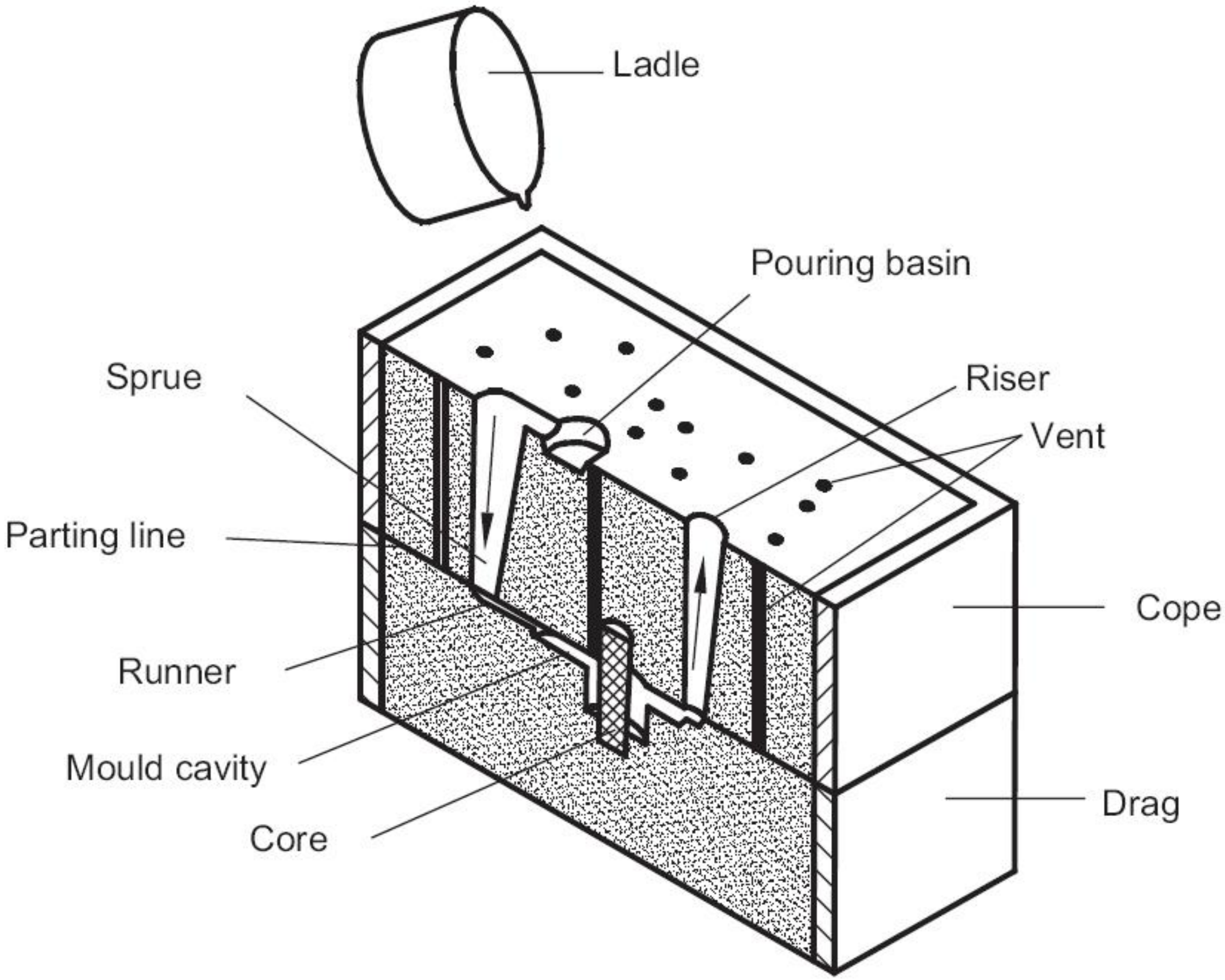

Fig. 3.1 *Cross section of a sand mould ready for pouring*

Casting Terms

- **Drag:** Lower moulding flask.
- **Cope:** Upper moulding flask.
- **Cheek:** Intermediate moulding flask used in three piece moulding.
- **Pattern:** Pattern is a replica of the final object to be made with some modifications. The mould cavity is made with the help of the pattern.

Casting Terms

- **Parting line:** This is the dividing line between the two moulding flasks that makes up the sand mould. In split pattern it is also the dividing line between the two halves of the pattern.
- **Bottom board:** This is a board normally made of wood, which is used at the start of the mould making. The pattern is first kept on the bottom board, sand is sprinkled on it and then the ramming is done in the drag.

Casting Terms

- **Facing sand:** The small amount of carbonaceous material sprinkled on the inner surface of the moulding cavity to give better surface finish to the castings.
- **Moulding sand:** It is the freshly prepared refractory material used for making the mould cavity.
- **Backing sand:** It is what constitutes most of the refractory material found in the mould. This is made up of used and burnt sand.

Casting Terms

- **Core:** It is used for making hollow cavities in castings.
- **Pouring basin:** A small funnel shaped cavity at the top of the mould into which the molten metal is poured.
- **Sprue:** The passage through which the molten metal from the pouring basin reaches the mould cavity. In many cases it controls the flow of metal into the mould.
- **Runner:** The passageways in the parting plane through which molten metal flow is regulated before they reach the mould cavity.
- **Gate:** The actual entry point through which molten metal enters mould cavity.

Casting Terms

- **Chaplet:** Chaplets are used to support cores inside the mould cavity to take care of its own weight and overcome the metallo-static forces.
- **Chill:** Chills are metallic objects which are placed in the mould to increase the cooling rate of castings to provide uniform or desired cooling rate.
- **Riser:** It is a reservoir of molten metal provided in the casting so that hot metal can flow back into the mould cavity when there is a reduction in volume of metal due to solidification.

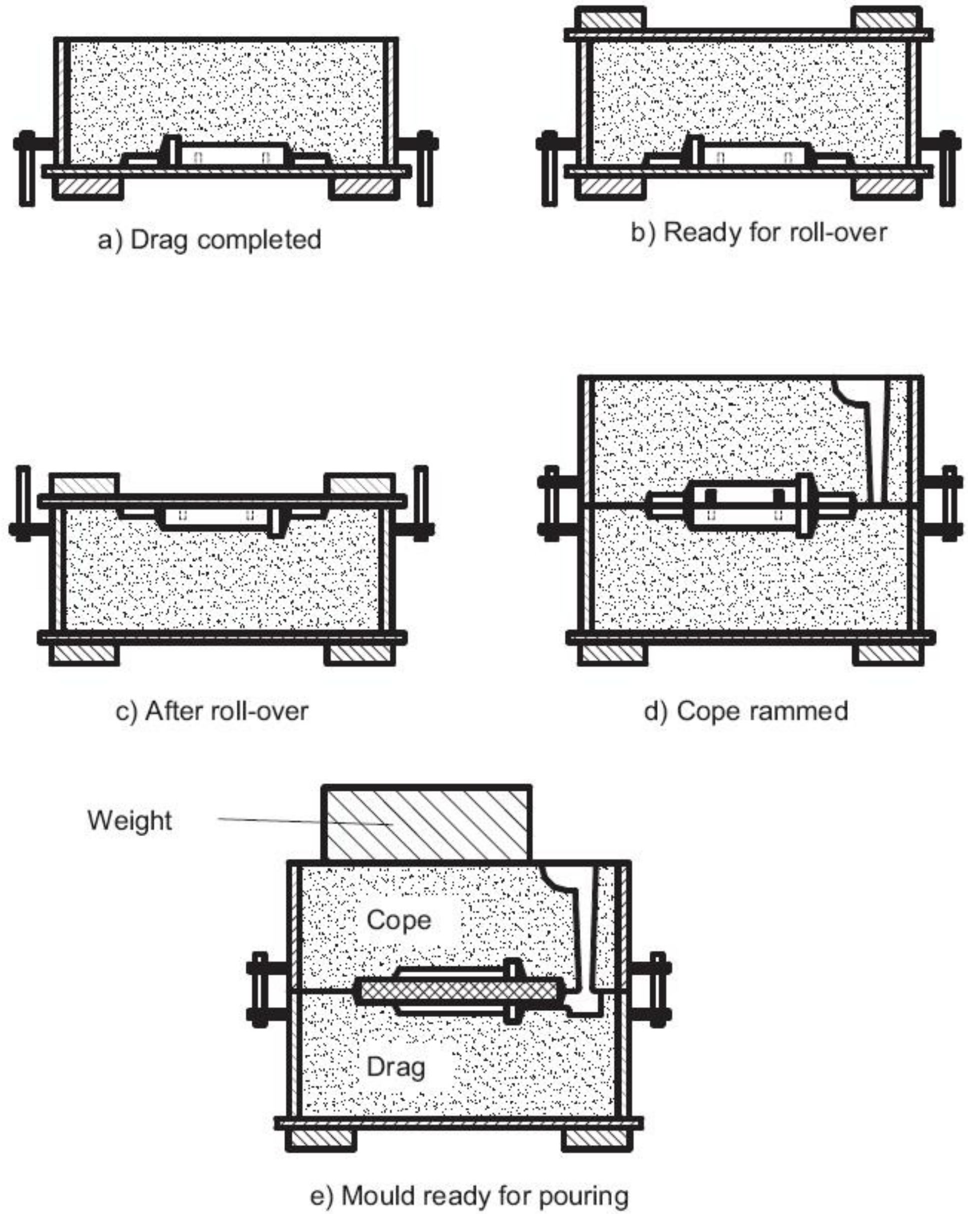

Fig. 3.2 *Sand mould making procedure*

Patterns

- Casting - Pattern
  - Addition of pattern allowances,
  - Provision of core prints, and
  - Elimination of fine details, which can not be obtained by casting and hence are to be obtained by further processing.

Pattern Allowances

- **Shrinkage**
- *Liquid shrinkage* refers to the reduction in volume when the metal changes from liquid to solid state at the solidus temperature. (Risers)
- *Solid shrinkage* is the reduction in volume caused, when metal loses temperature in solid state. (Shrinkage Allowance)

Table 3.1 *Shrinkage allowances for various metals*

Material	Pattern dimension, mm	Section thickness, mm	Shrinkage allowance, mm/m
Grey cast iron	upto 600	—	10.5
	600 to 1200	—	8.5
	over 1200	—	7.0
White cast iron	—	—	16.0 to 23.0
Ductile iron	—	—	8.3 to 10.4
Malleable iron	—	6	11.8
		9	10.5
		12	9.2
		15	7.9
		18	6.6
		22	4.0
		25	2.6
Plain carbon steel	upto 600	—	21.0
	600 to 1800	—	16.0
	over 1800	—	13.0

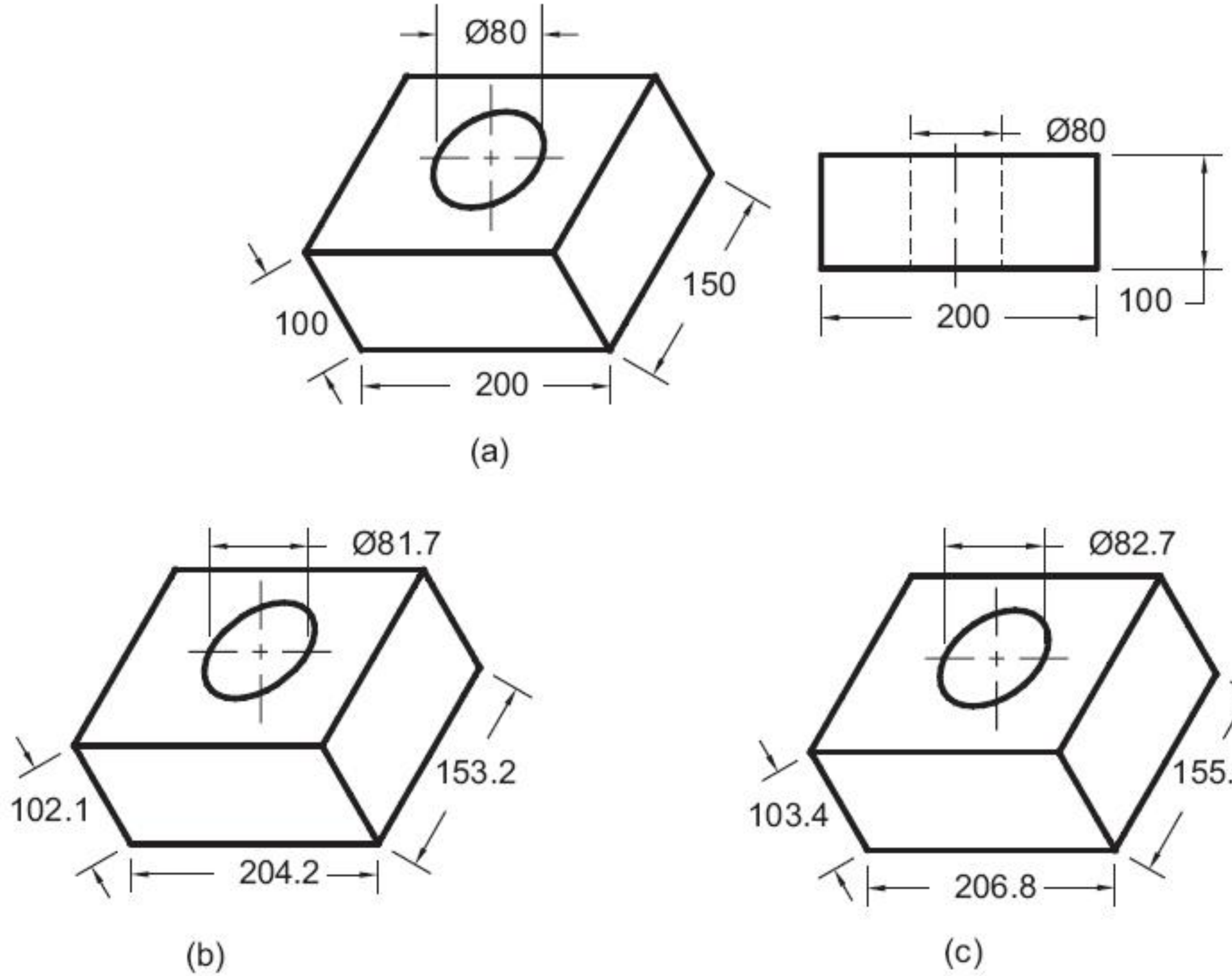

Fig. 3.3 *Provision of allowances for patterns in sand castings (All dimensions in mm)*

Pattern Allowances

- **Finish or machining allowance**
- Extra material is to be provided which is to be subsequently removed by machining or cleaning process.

Table 3.2 *Machining allowances on patterns for sand castings*

Dimension, mm	Allowance, mm		
	Bore	Surface	Cope side
Cast iron			
upto 300	3.0	3.0	5.5
301 to 500	5.0	4.0	6.0
501 to 900	6.0	5.0	6.0
Cast steel			
upto 150	3.0	3.0	6.0
151 to 500	6.0	5.5	7.0
501 to 900	7.0	6.0	9.0
Non ferrous			
upto 200	2.0	1.5	2.0
201 to 300	2.5	1.5	3.0
301 to 900	3.0	2.5	3.0

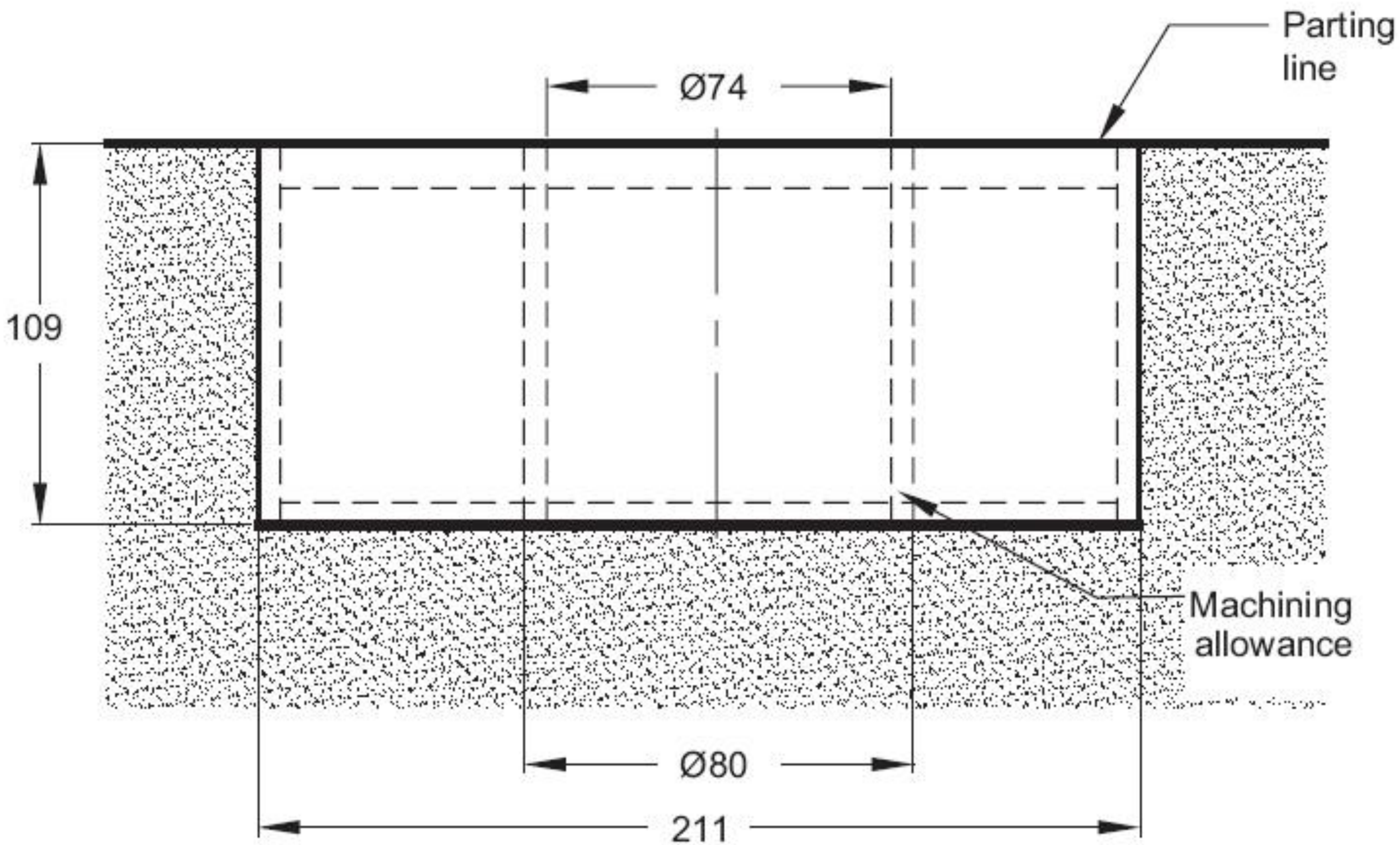

Fig. 3.4 *Pattern after providing machining allowance (All dimensions in mm)*

Pattern Allowances

- **Draft**
- At the time of withdrawing the pattern from the sand mould, the vertical faces of the pattern are in continual contact with the sand, which may damage the mould cavity, as shown in Fig 3-5 (a).
- To reduce the chances of this happening, the vertical faces of the pattern are always tapered from the parting line (Fig 3-5b). This provision is called draft allowance.

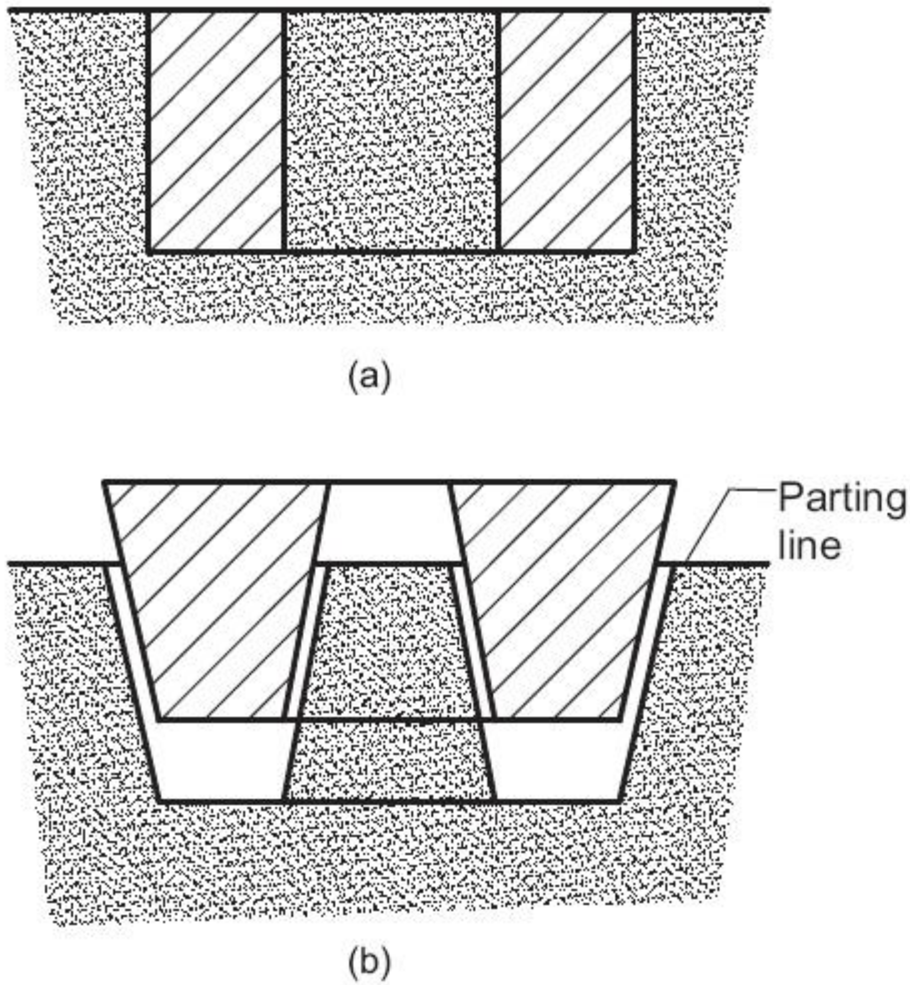

Fig. 3.5 *Effect of draft on pattern withdrawing*

Table 3.3 *Suggested draft values for patterns*

Pattern material	Height of the given surface, mm	Draft Angle of surfaces, degrees	
		External surface	Internal surface
Wood	20	3.00	3.00
	21 to 50	1.50	2.50
	51 to 100	1.00	1.50
	101 to 200	0.75	1.00
	201 to 300	0.50	1.00
	301 to 800	0.50	0.75
	801 to 2000	0.35	0.50
	over 2000	—	0.25
Metal and plastic	20	1.50	3.00
	21 to 50	1.00	2.00
	51 to 100	0.75	1.00
	101 to 200	0.50	0.75
	201 to 300	0.50	0.75
	301 to 800	0.35	0.50

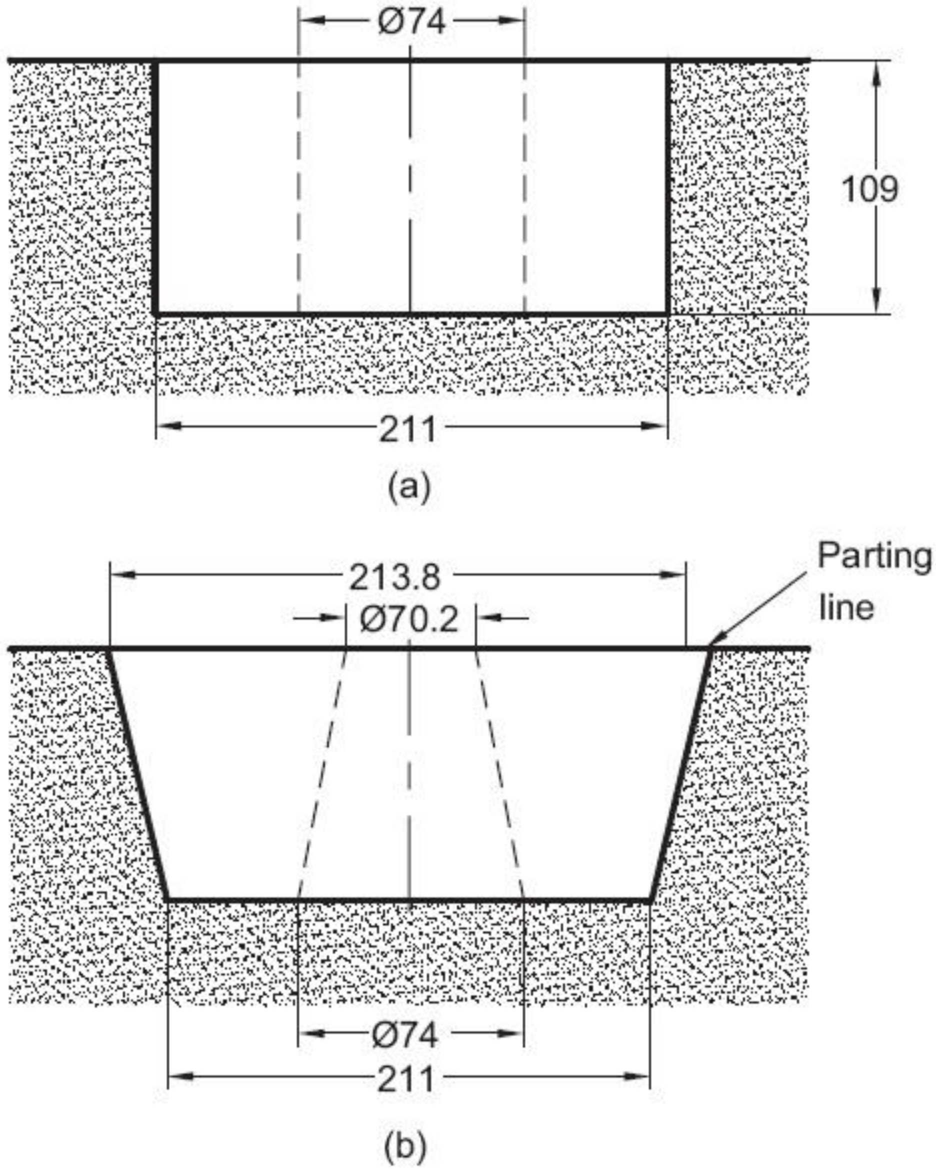

Fig. 3.6 *Example showing the application of draft (All dimensions in mm)*

Pattern Allowances

- **Shake allowance**
- Before withdrawal from the sand mould, the pattern is rapped all around the vertical faces to enlarge the mould cavity slightly, which facilitates its removal. Since it enlarges the final casting made, it is desirable that the original pattern dimensions should be reduced to account for this increase.

Pattern Allowances

- **Distortion allowance**
- A metal when it has just solidified is very weak and therefore is likely to be distortion prone. This is particularly so for weaker sections such as long flat portions, V, U sections or in a complicated casting which may have thin and long sections which are connected to thick sections. The foundry practice should be to make extra material provision for reducing the distortion.

Core Prints

- For all those castings where coring is required, provision should be made to support the core inside the mould cavity. Core prints are provided for this purpose.

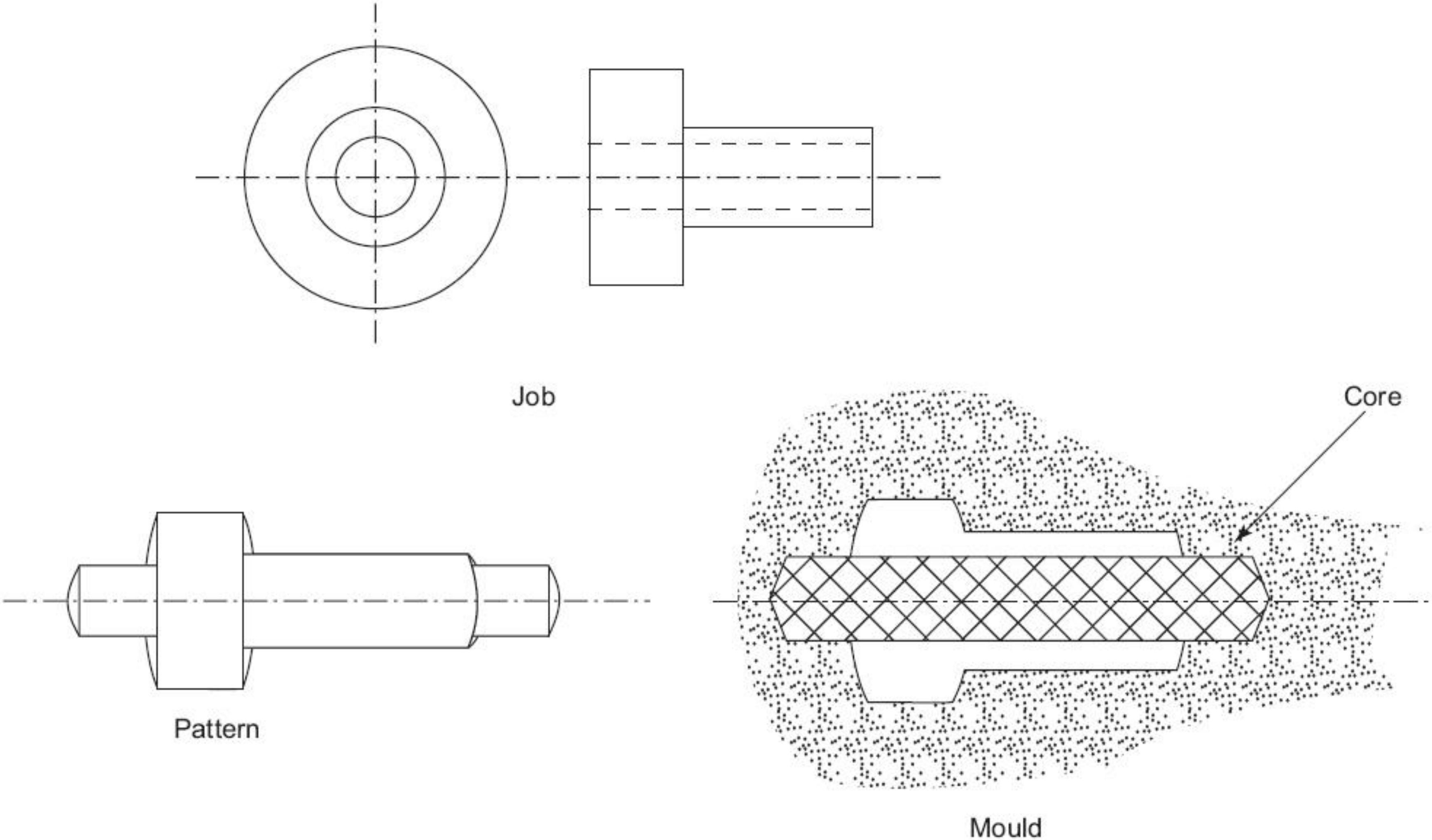

Fig. 3.7 *Typical job, its pattern and the mould cavity*

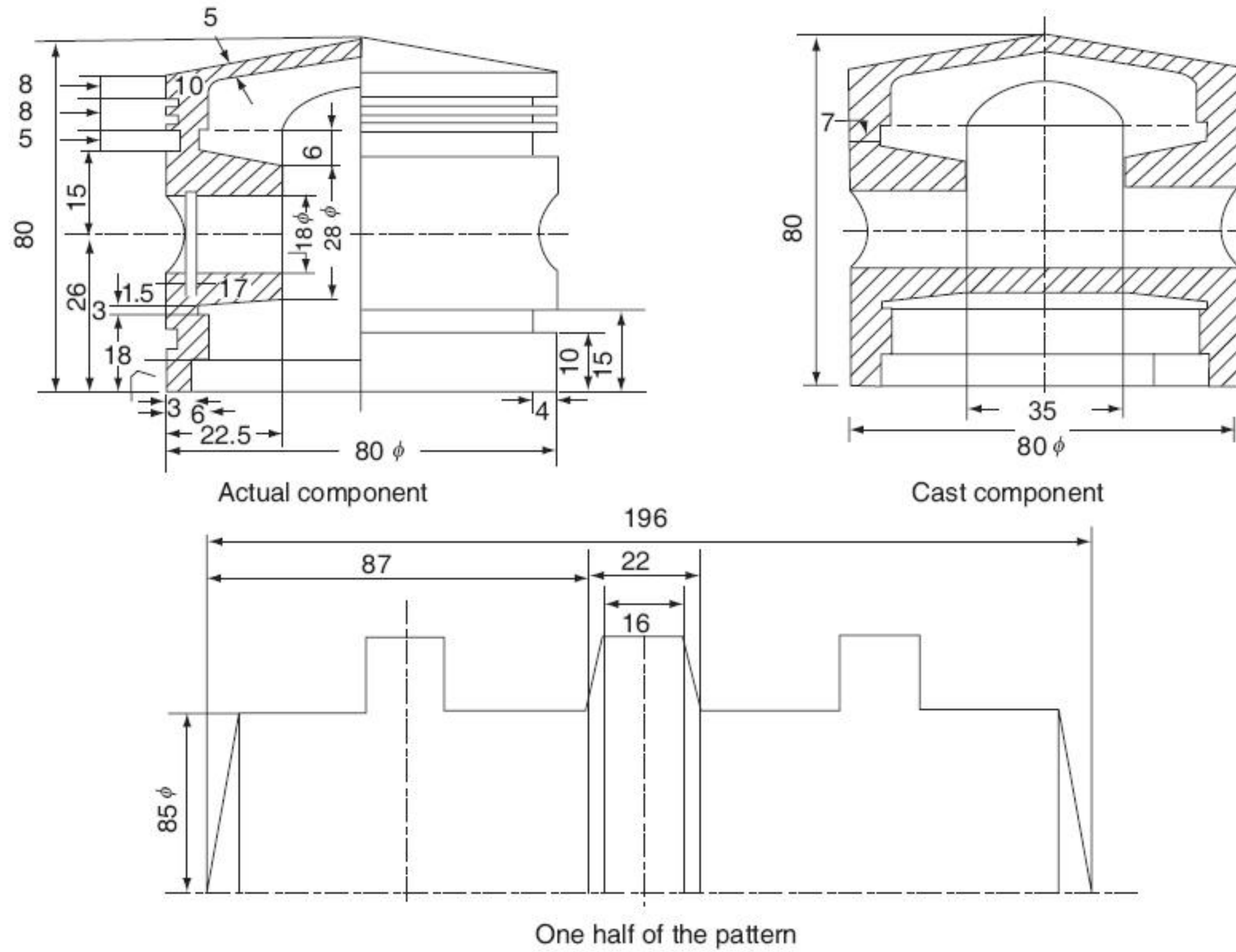

Fig. 3.8 *Elimination of details on a casting to simplify moulding*

Pattern Materials

- The usual pattern materials are wood, metal and plastics.

Table 3.4 *Comparative characteristics of metallic pattern materials*

Pattern metal	Advantages	Disadvantages
Aluminium alloys	Good machinability High corrosion resistance Low density Good surface finish	Low strength High cost
Grey cast iron	Good machinability High strength Low cost	Corrosion prone High density
Steel	Good surface finish High strength	Corrosion prone High density
Brass and bronze	Good surface finish High strength High corrosion resistance	High cost High density
Lead alloys	Good machinability	High cost High density Low strength

Table 3.5 *Pattern materia ls based on expected life*

Number of castings produced before pattern equipment repair		
Pattern	Core	Pattern Material
Small castings (under 600 mm)		
2 000	2 000	Hard wood
6 000	6 000	Aluminium, Plastic
100 000	100 000	Cast iron
Medium castings (600–1800 mm)		
1 000	750	Hard wood
3 000	3 000	Aluminium, Plastic
Large castings (above 1800 mm)		
200	150	Soft wood
500	500	Hard wood metal reinforced

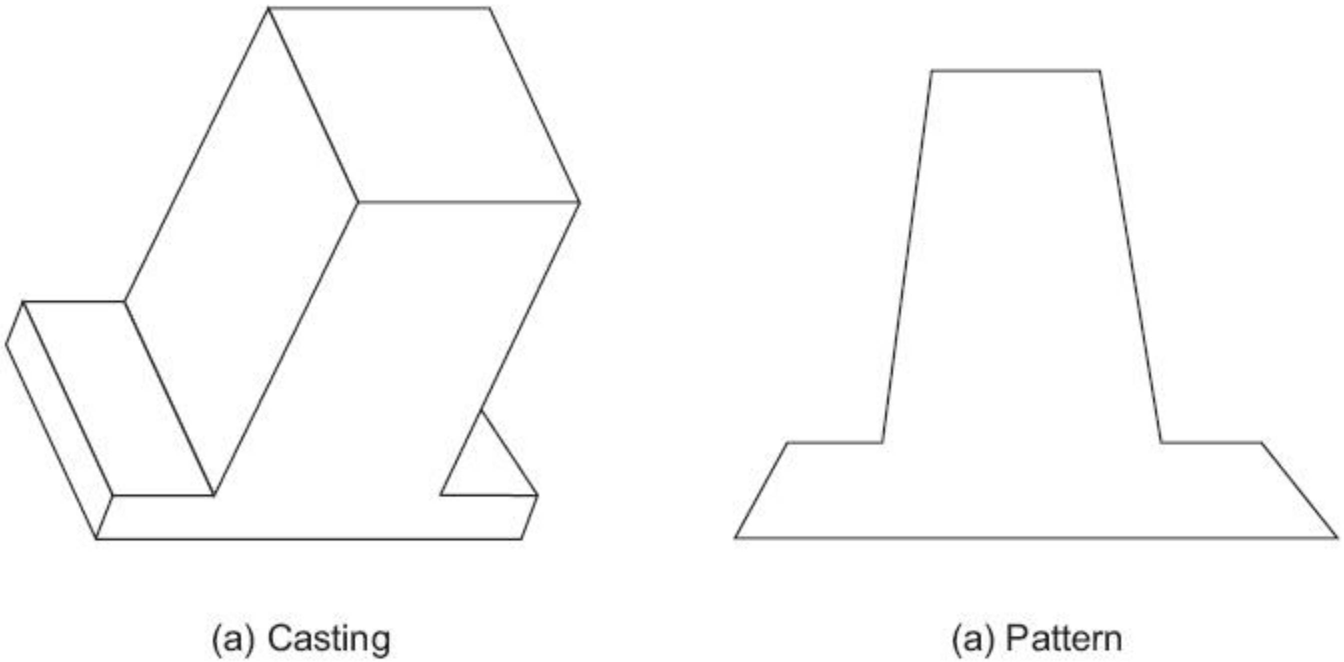

Fig. 3.9 *Single piece pattern*

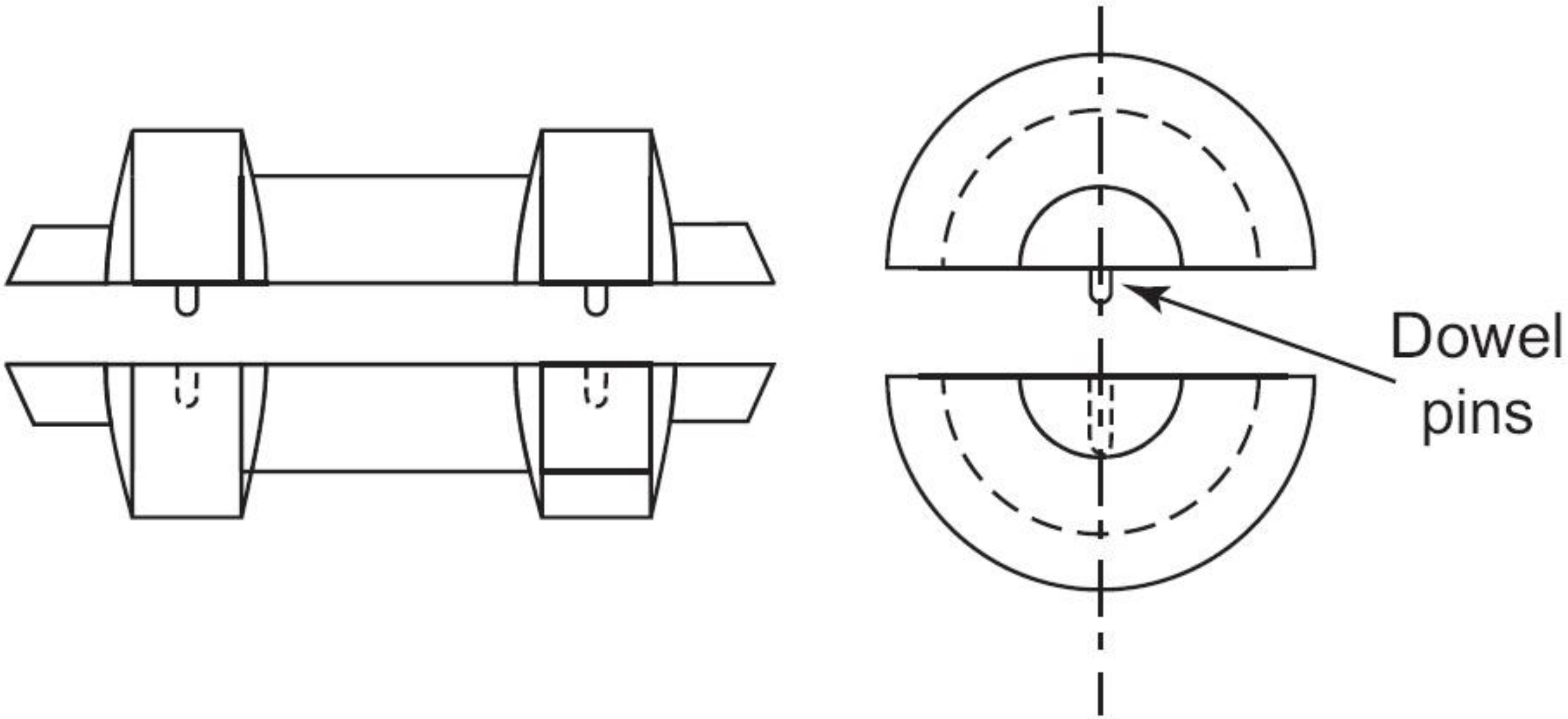

Fig. 3.10 *Split pattern*

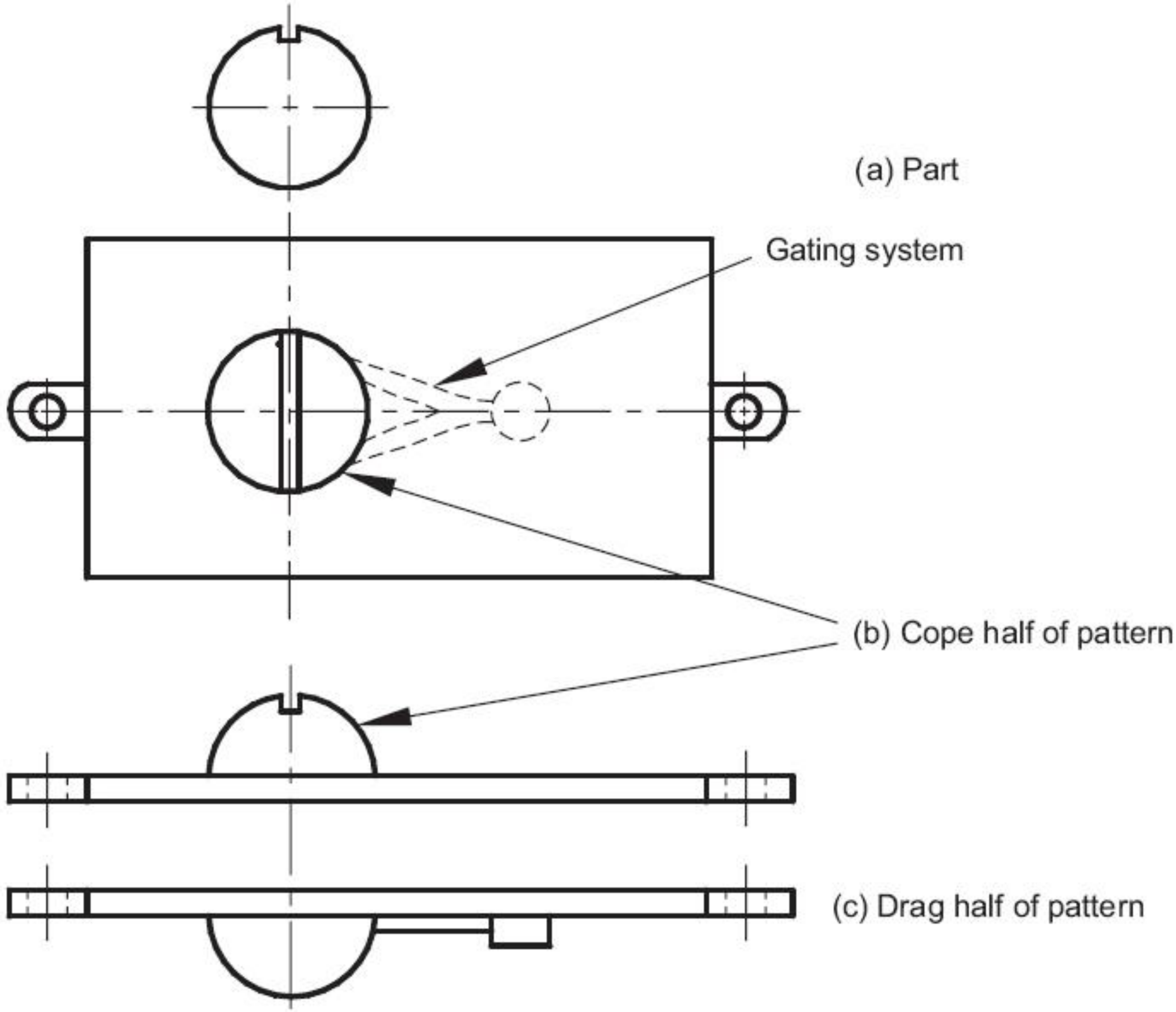

Fig. 3.11 *Cope and drag pattern*

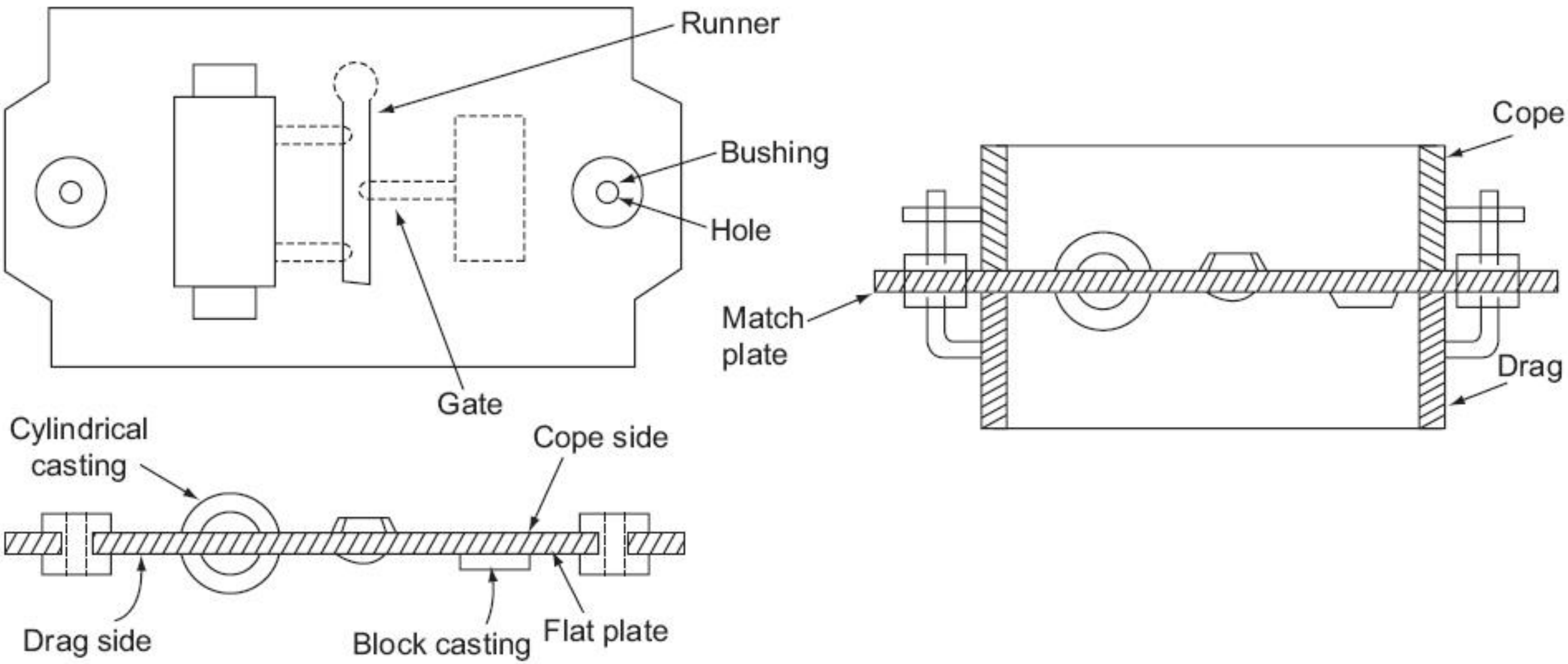

Fig. 3.12 *Match plate pattern (courtesy JS Campbell: Principles of Manufacturing Materials and Processes, p 153, McGraw Hill, New York)*

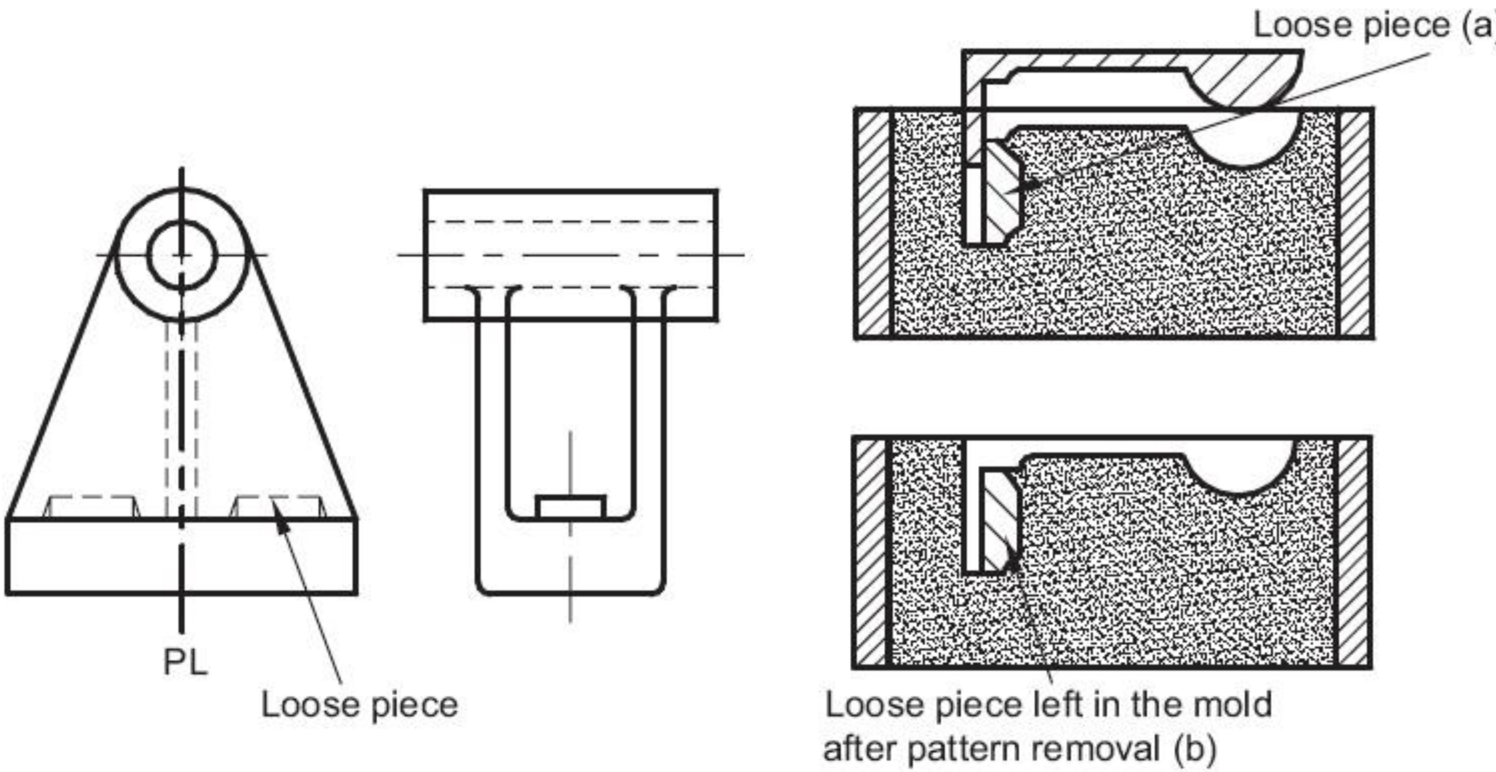

Fig. 3.13 *Loose piece pattern*

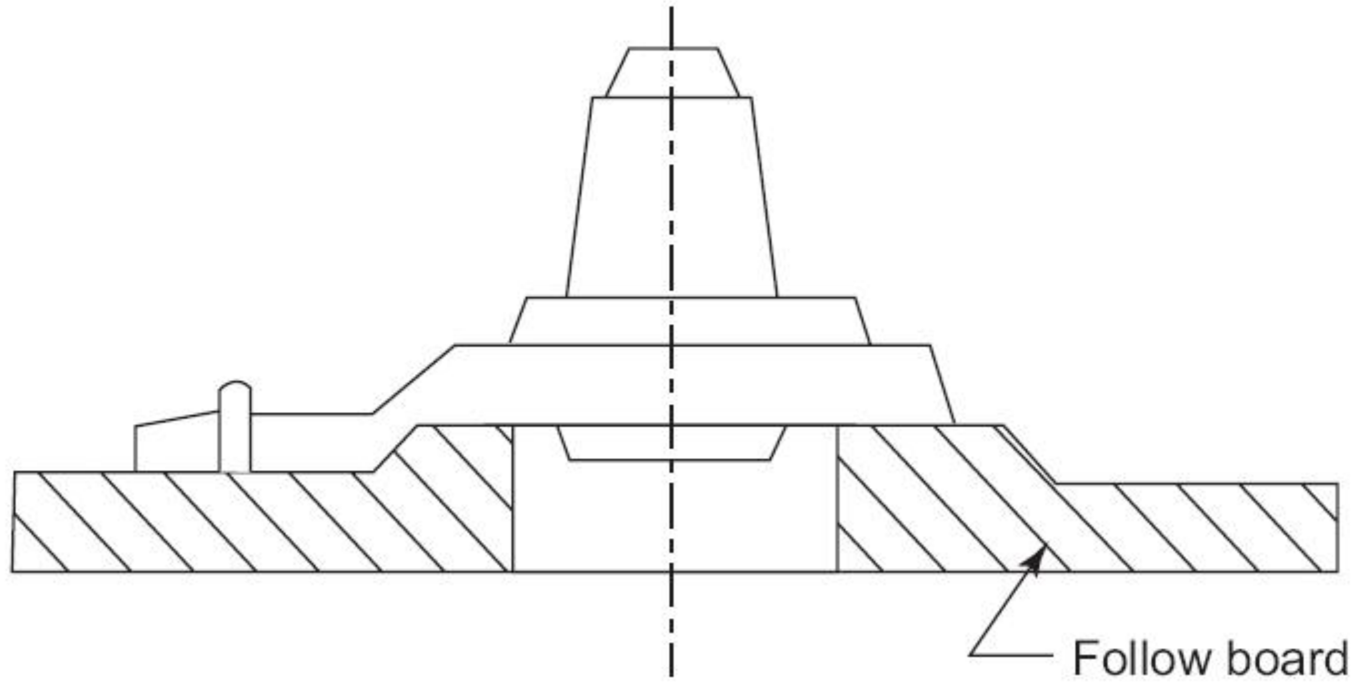

Fig. 3.14 *Follow board pattern*

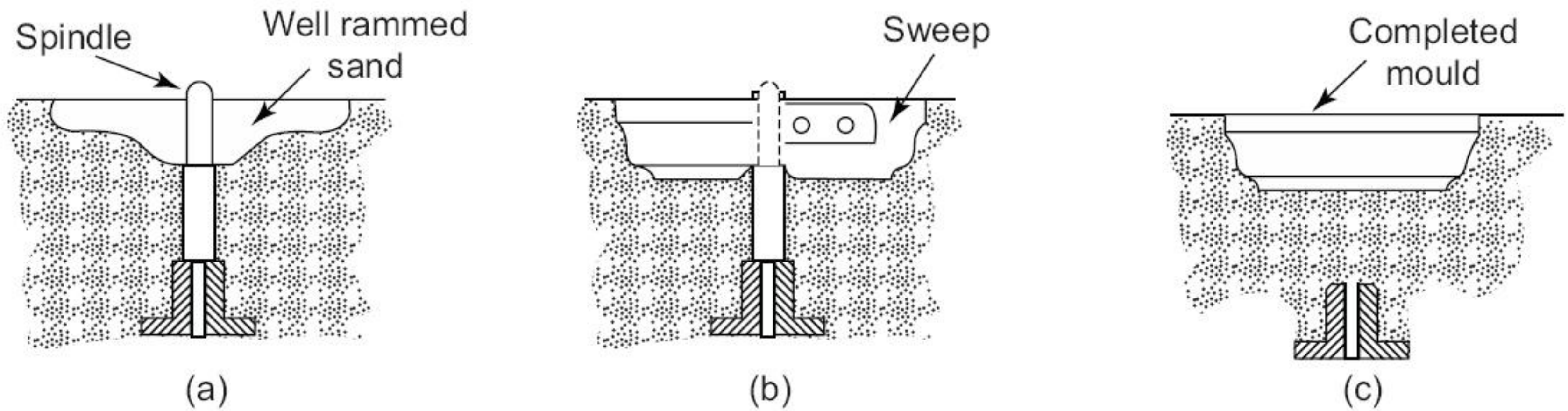

Fig. 3.15 *Sweep pattern*

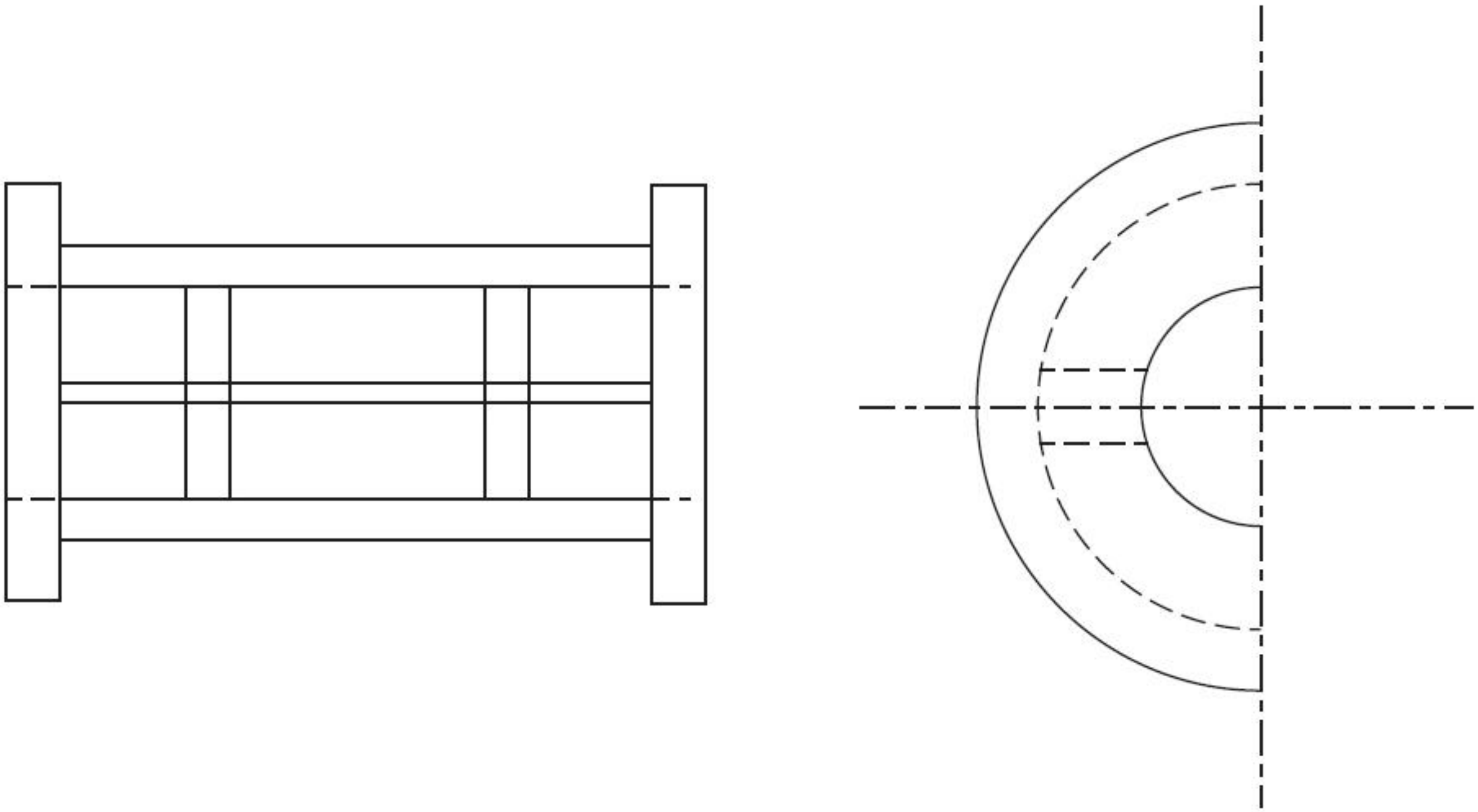

Fig. 3.16 *Skeleton pattern*

Pattern Colour Code

- Red or orange on surfaces not to be finished and left as cast
- Yellow on surfaces to be machined
- Black on core prints for unmachined openings
- Yellow stripes on black on core prints for machined openings
- Green on seats of and for loose pieces and loose core prints
- Diagonal black stripes with clear varnish on to strengthen the weak patterns or to shorten a casting

Rapid Prototyping (RP)

- In this method a 3D model of the object as CAD file is sliced into equidistant layers with parallel horizontal planes.
- The system then generates trajectories for the material to be added in each layer by the RP machine.
- The sacrificial supporting layers are also simultaneously generated to keep the unconnected layers in proper position.
- The resultant separate cross-sectional layers of very small thickness when assembled (glued) together will form the final object.

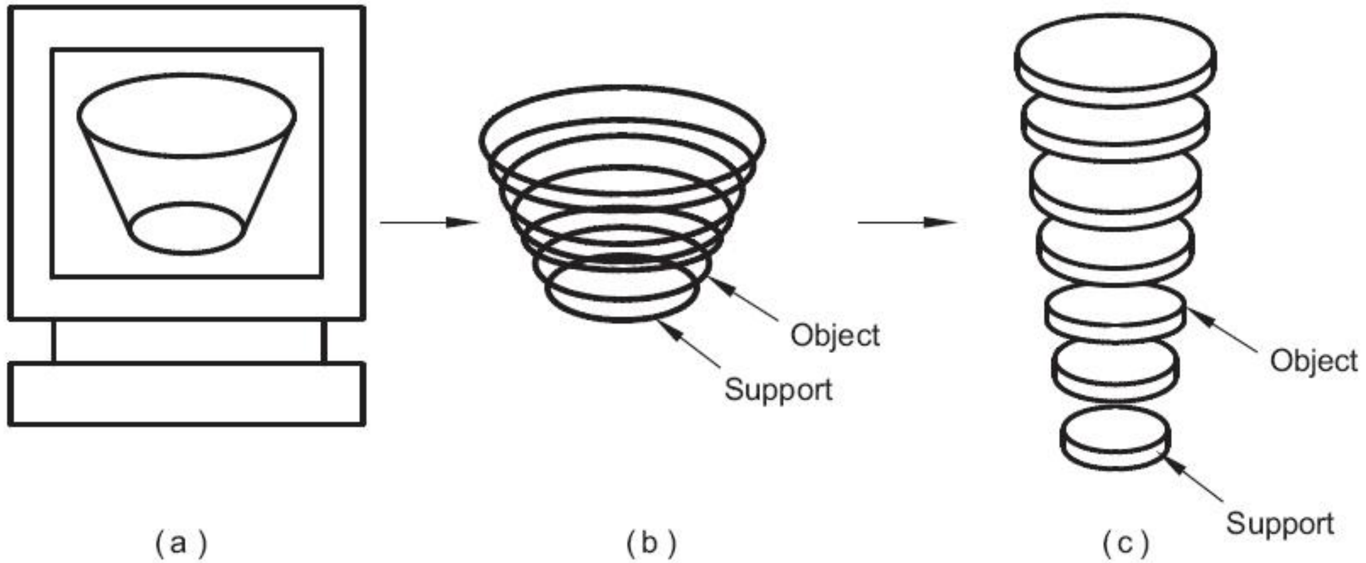

Figure 3.17 *Concept of layer manufacturing; a- shape data as input in the CAD system, b- CAD model is sliced into layers, c) each of the layer is then deposited starting from the bottom until the model is completed.*

Rapid Prototyping (RP)

- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Laminated Object Manufacturing (LOM)
- Fused Deposition Modeling (FDM)
- 3D Printing (3DP)
- Laser Engineering Net Shaping (LENS)

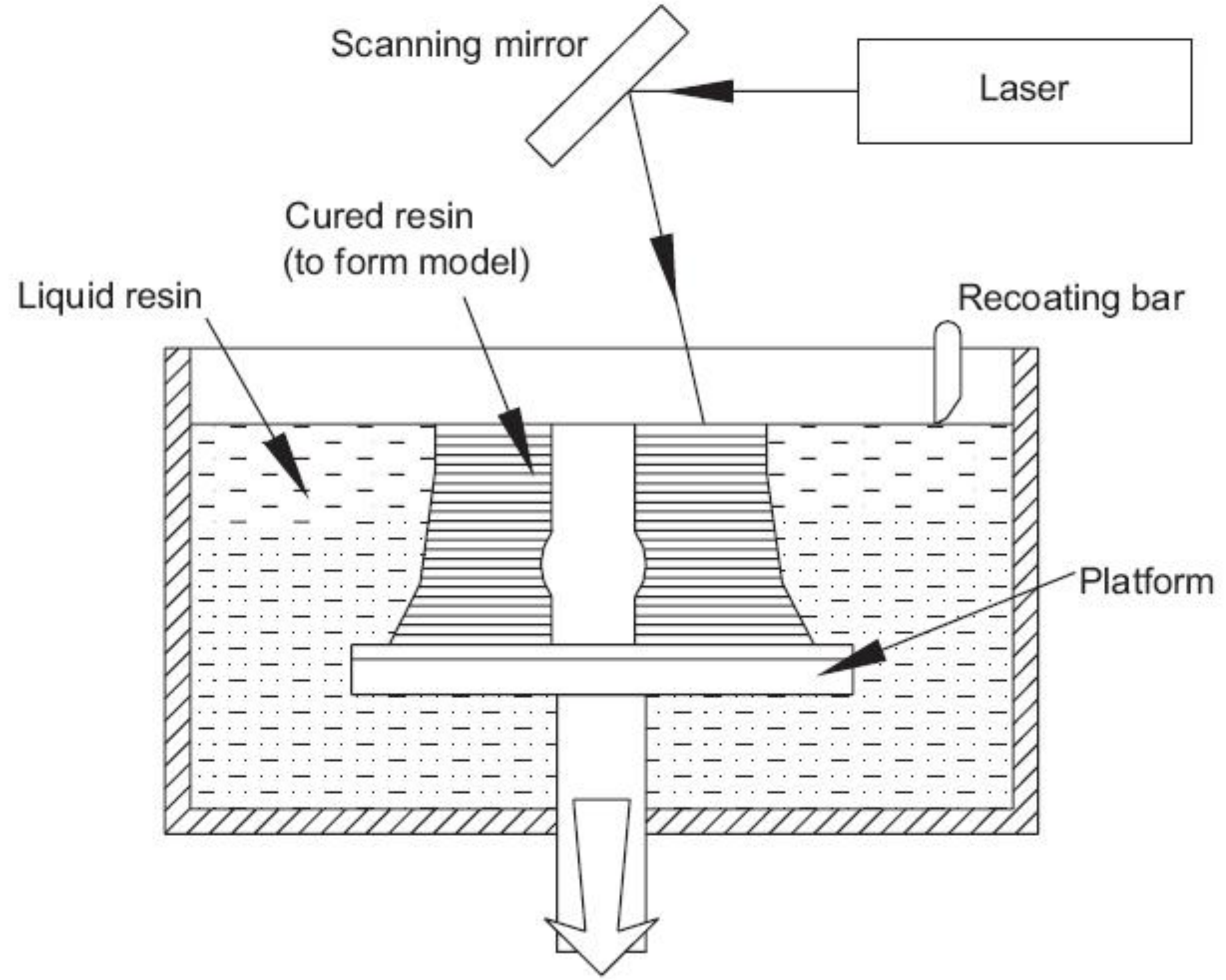

Fig. 3.18 *Schematic of Stereolithography device*

Table 3.6 *Summary of some rapid prototyping technologies*

System	Max. build size (mm)	Dimensional Accuracy (mm)	Materials	Advantages	Disadvantages
Stereo-lithog-raphy	(500 × 400 × 200)	(0.1–0.2)	Liquid photosensitive resins	High accuracy, medium range of materials, large build size	High cost process, sup-port structures needed, post cure required
Selective Laser Sintering	(550 × 550 × 750)	(0.1–0.2)	Nylon based materials, elastomer, rapid steel, cast form, sand form	Large range of materials, good accuracy, large build size	High cost process, poor surface finish
Fused Deposition Modeling	(600 × 500 × 600)	(0.1–0.2)	ABS, elastomer and wax	Good accuracy, functional materi-als, medium range of materials	Support structures needed
Laminated Object Mod-eling	(815 × 560 × 508)	(0.1–0.2)	Paper	Good accuracy, large build size	Limited range of materials, sup-port removal necessary, poor material properties

Moulding Materials

- **Refractoriness:** It is the ability of the moulding material to withstand the high temperatures of the molten metal so that it does not cause fusion.
- **Green strength:** The moulding sand that contains moisture is termed as green sand. The green sand should have enough strength so that the constructed mould retains its shape.

Moulding Materials

- **Dry strength:** When the moisture in the moulding sand is complete-ly expelled, it is called dry sand.
- **Hot strength:** The strength of the sand that is required to hold the shape of the mould cavity then, called hot strength.
- **Permeability:** This gas evolution capability of the moulding sand is termed as permeability.

Moulding Sand Composition

- Silica grains (SiO_2),
- Clay as binder, and
- Moisture to activate the clay and provide plasticity.
- The amount of water used should be properly controlled. This is because a part of the water absorbed by clay helps in bonding while the remainder upto a limit helps in improving the plasticity but more than that would decrease the strength and formability. The normal percentages of water used are from 2 to 8.

Table 3.8 *Comparison of foundry base sand properties*

	Silica	Olivine	Chromite	Zircon
Colour	White–light brown	Greenish grey	Black	White–brown
Hardness	6.0–7.0	6.5–7.0	5.5–7.0	7.0–7.5
Dry bulk density (lb/ft^3)	85–100	100–125	155–165	160–185
Specific gravity	2.2–2.6	3.2–3.6	4.3–4.5	4.4–4.7
Grain shape	Angular/ Rounded	Angular	Angular	Rounded/ Angular
Thermal expansion (mm/ mm/°C)	0.018	0.0083	0.005	0.003
Apparent heat transfer	Average	Low	Very high	High
Fusion point, °C	1427–1760	1538–1760	1760–1982	2038–2204
High temperature reaction	Acid	Basic	Basic	Acid
Wettability with molten metal	Easily	Not generally	Resistant	Resistant
Grain distribution	2–5 screens	3–4 screens	4–5 screens	2–3 screens
AFS Grain fineness number	25–180	40–160	50–90	95–160

Testing Sand Properties

- **Sample preparation:** The moulding sand should be prepared exactly as is done in the shop on the standard equipment and then carefully enclosed in a closed container to safeguard its moisture content.
- **Moisture content**
- **Clay content**

Testing Sand Properties

- **Sand grain size:** The dried clay-free sand grains are placed on the top sieve of a sieve shaker, which contains a series of sieves one upon the other with gradually decreasing mesh sizes.

Table 3.10 *AFS Sieve numbers and their Indian equivalents with sizes*

US Series equivalent no. (ASTM)	Mesh opening (mm)	IS Sieve no. microns	Multiplying factor
6	3.327	3.35	3
12	1.651	1.70	5
20	0.833	850	10
30	0.589	600	20
40	0.414	425	30
50	0.295	300	40
70	0.208	212	50
100	0.147	150	70
140	0.104	106	100
200	0.074	75	145
270	0.053	53	200
Pan	—	—	300

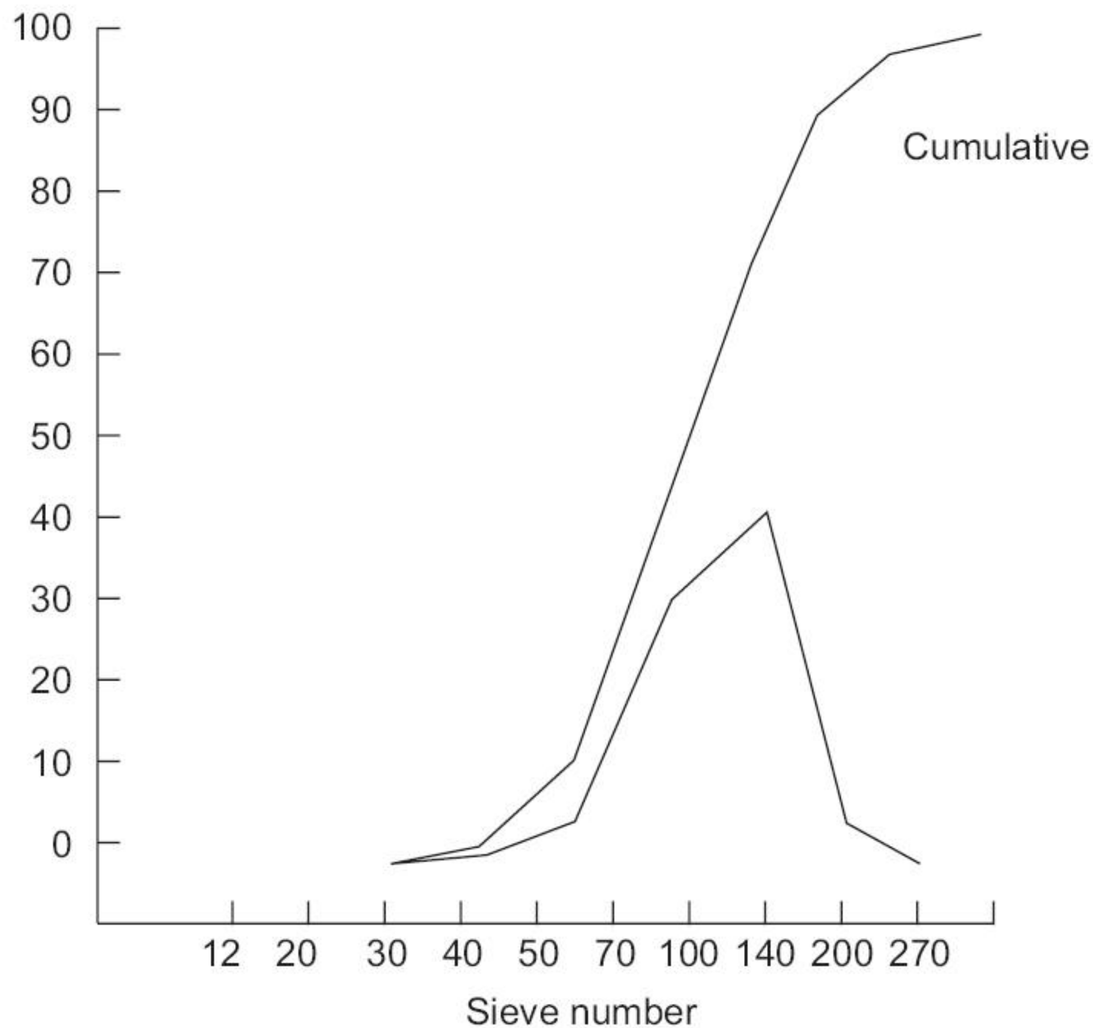

Fig. 3.19 *Sand grain size distribution*

Table 3.11 *Sieve analysis*

Sieve number	Multiplying factor, M_i	Retained sample f_i (g)	Retained percentage P_i	$M_i \times P_i$	$M_i \times f_i$
40	30	2.495	5	150	74.85
50	40	13.972	28	1120	558.88
70	50	23.952	48	2400	1197.60
100	70	6.986	14	980	489.02
140	100	2.495	5	500	249.50
		49.900	100	5150	2569.85

$$\text{GFN} = \frac{5150}{100} = 51.501$$

$$\text{GFN} = \frac{2569.85}{49.90} = 51.502$$

Permeability

- The rate of flow of air passing through a standard specimen under a standard pressure is termed as permeability number.
- The standard permeability test is to measure time taken by a 2000 cm^3 of air at a pressure typically of 980 Pa (10 g/cm^2), to pass through a standard sand specimen confined in a specimen tube (Fig 3-20). The standard specimen size is 50.8 mm in diameter and a length of 50.8 mm. Then, the permeability number, P is obtained by

Permeability

- The permeability number, P is obtained by

$$P = \frac{V \cdot H}{p \cdot A \cdot T}$$

FIG 3-20
Permeability meter for measuring the permeability of green sand

Specimen Preparation

- Since the permeability of sand is dependent to a great extent, on the degree of ramming, it is necessary that the specimen be prepared under standard conditions. To get reproducible ramming conditions, a laboratory sand rammer is used along with a specimen tube. The measured amount of sand is filled in the specimen tube, and a fixed weight of 6.35 to 7.25 kg is allowed to fall on the sand three times from a height of 50.8 + 0.125 mm. The specimen thus produced should have a height of 50.8 + 0.8 mm. To produce this size of specimen usually sand of 145 to 175 g would be required.

Strength

- Green compression strength
- Green shear strength
- Dry strength
- Mould hardness

Sand Preparation

- During the mixing process any lump present in sand is broken up and clay is uniformly enveloped around the sand grains and moisture is uniformly distributed.
- Besides manual mixing, equipment called mueller is normally used in foundries to mix the sands. These are essentially of two types, batch type and continuous

FIG 3-21 Batch Mueller

Moulding Sand Properties

- The properties of moulding sand are dependent to a great extent on a number of variables.
  - Sand grain shape and size,
  - Clay type and amount,
  - Moisture content,
  - Method of preparing sand mould.

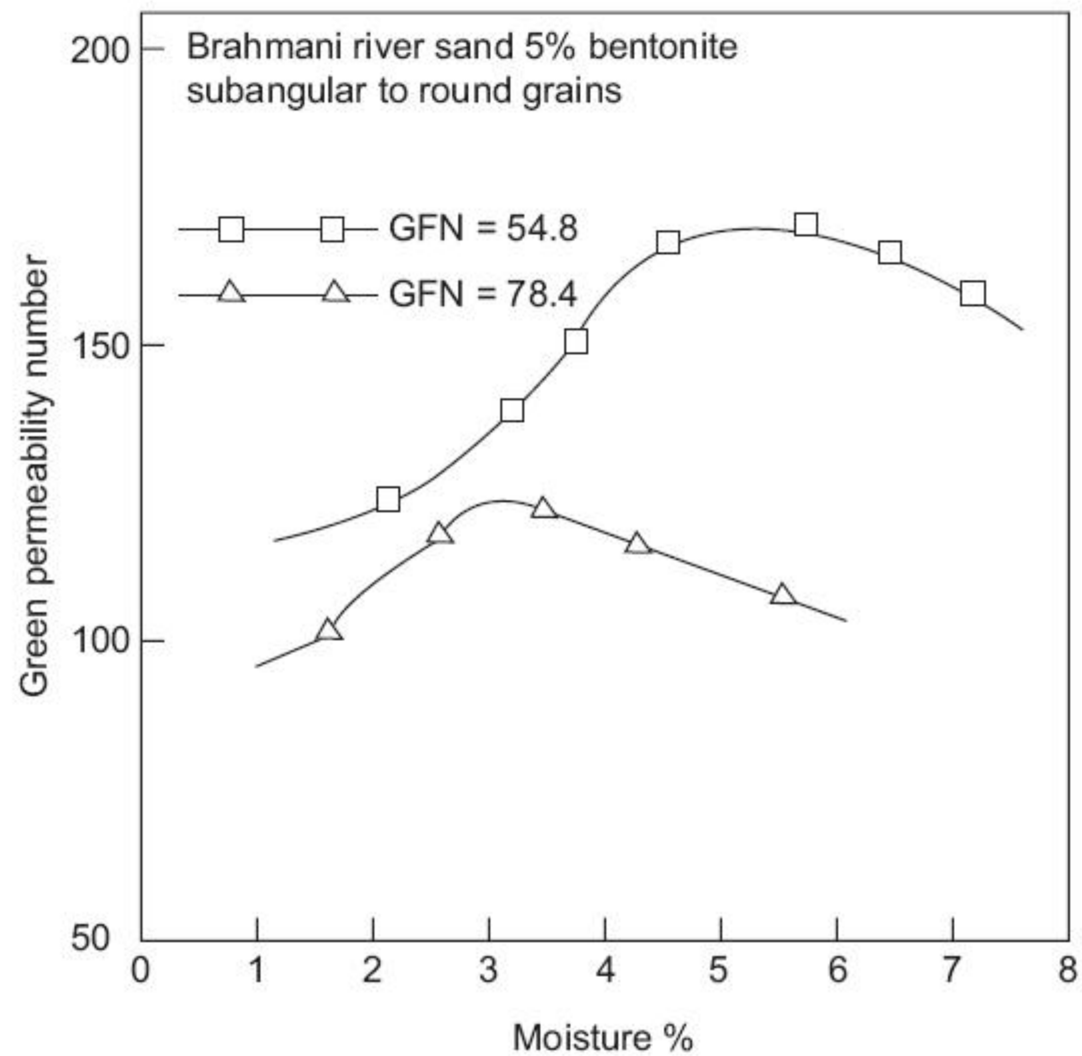

Fig. 3.22 *Variation of permeability with grain size*

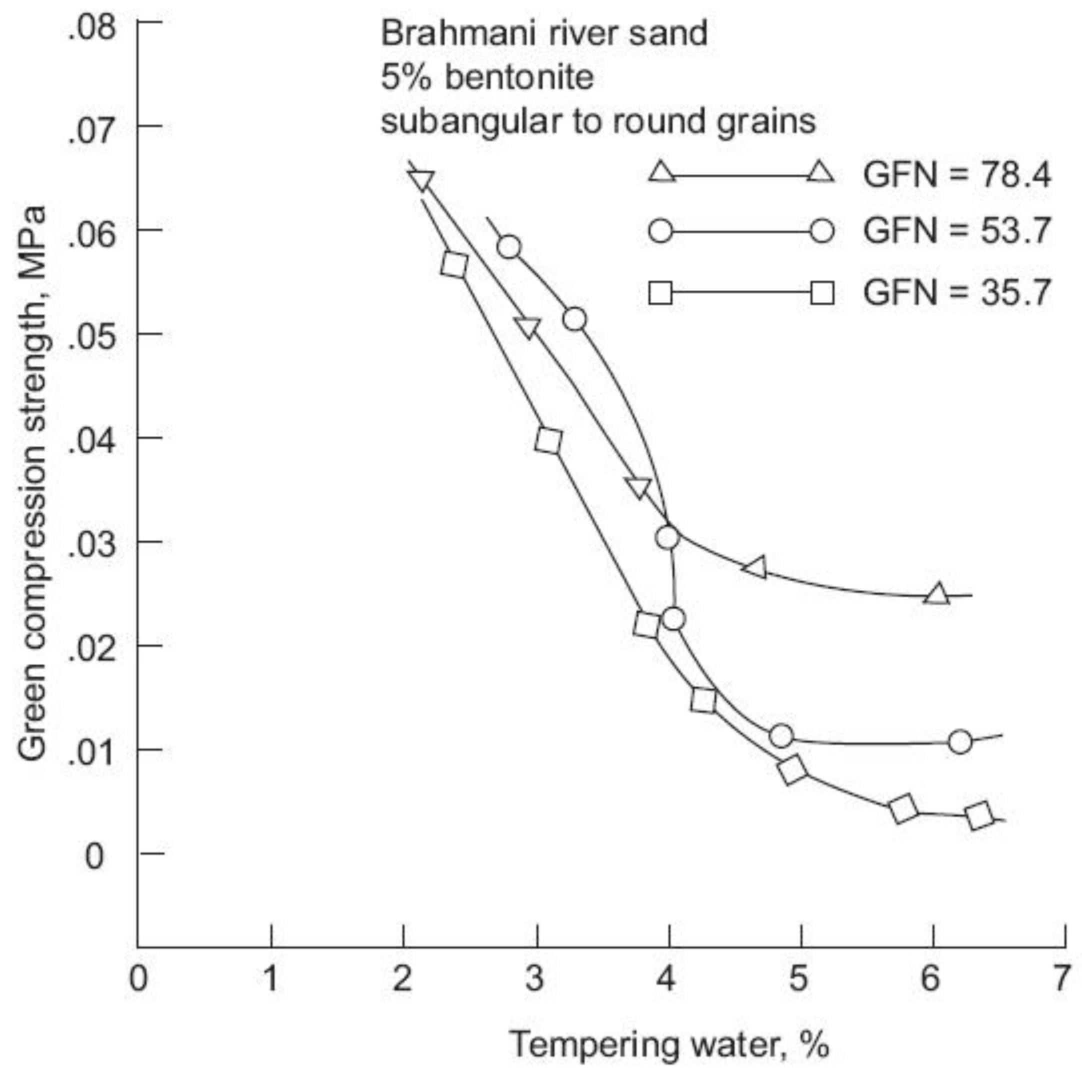

Fig. 3.23 *Variation of green compression strength with sand grain size*

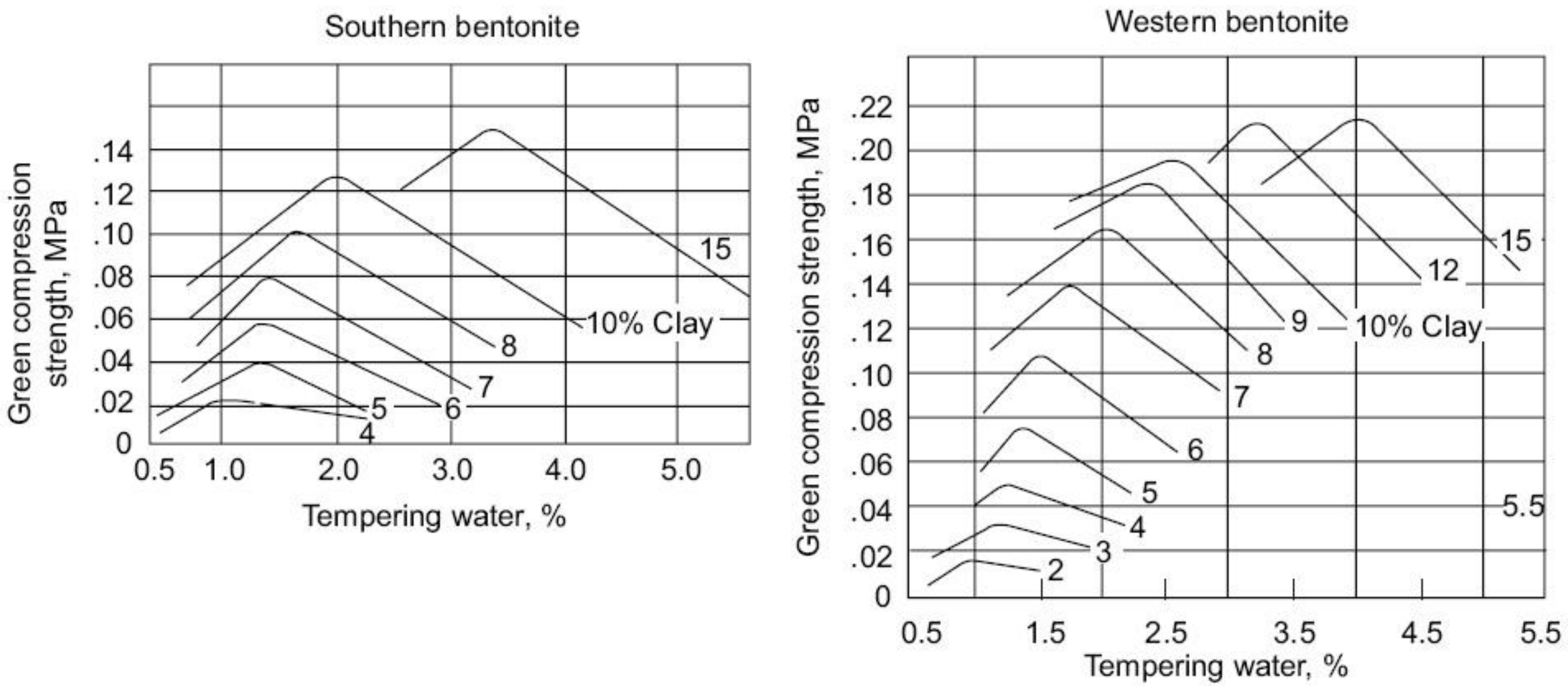

Fig. 3.24 *Variation of green compression strength with clay and water*

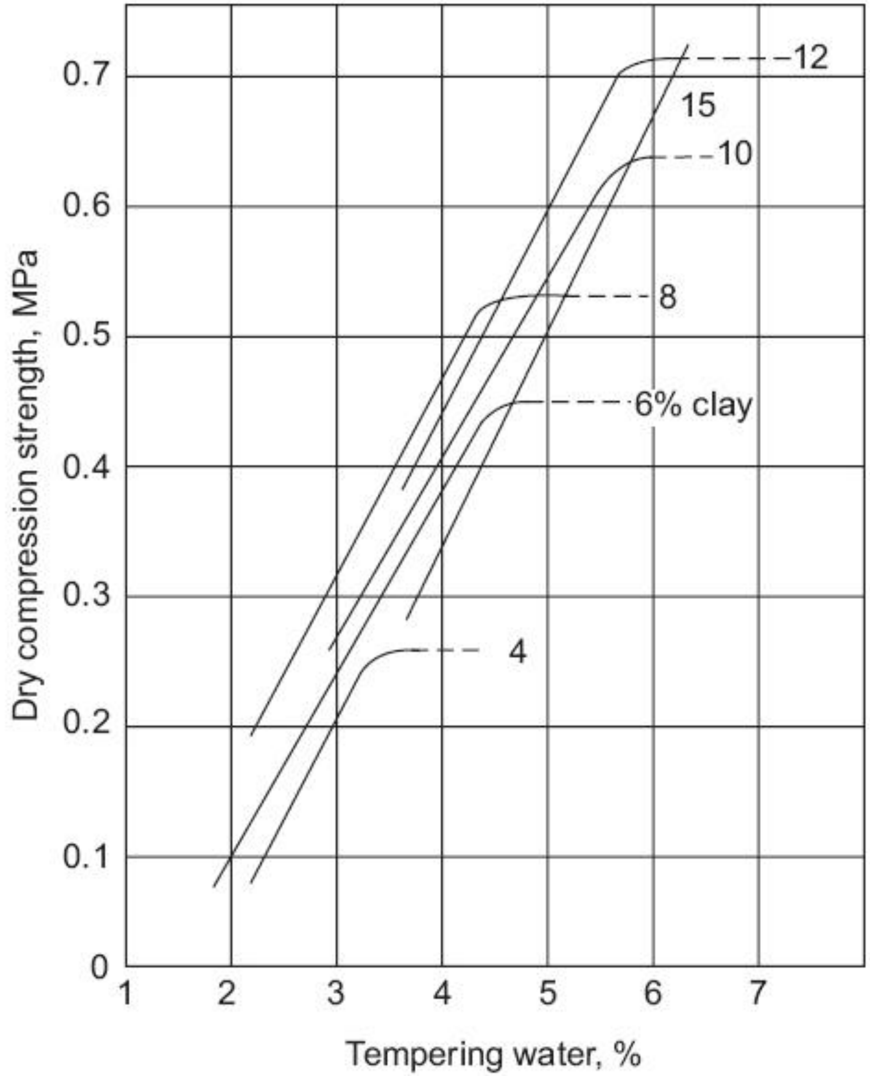

Fig. 3.25 *Variation of dry compression strength with water content*

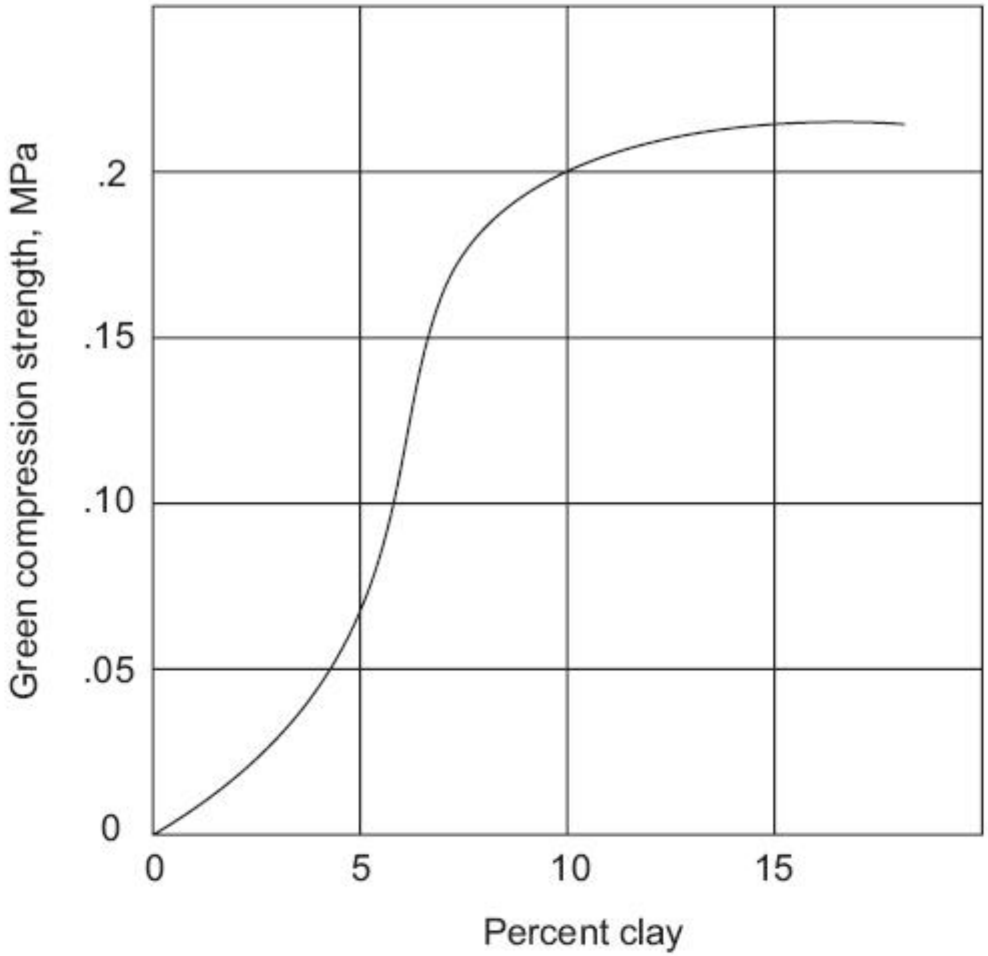

Fig. 3.26 *Maximum green compression strength obtainable with clay*

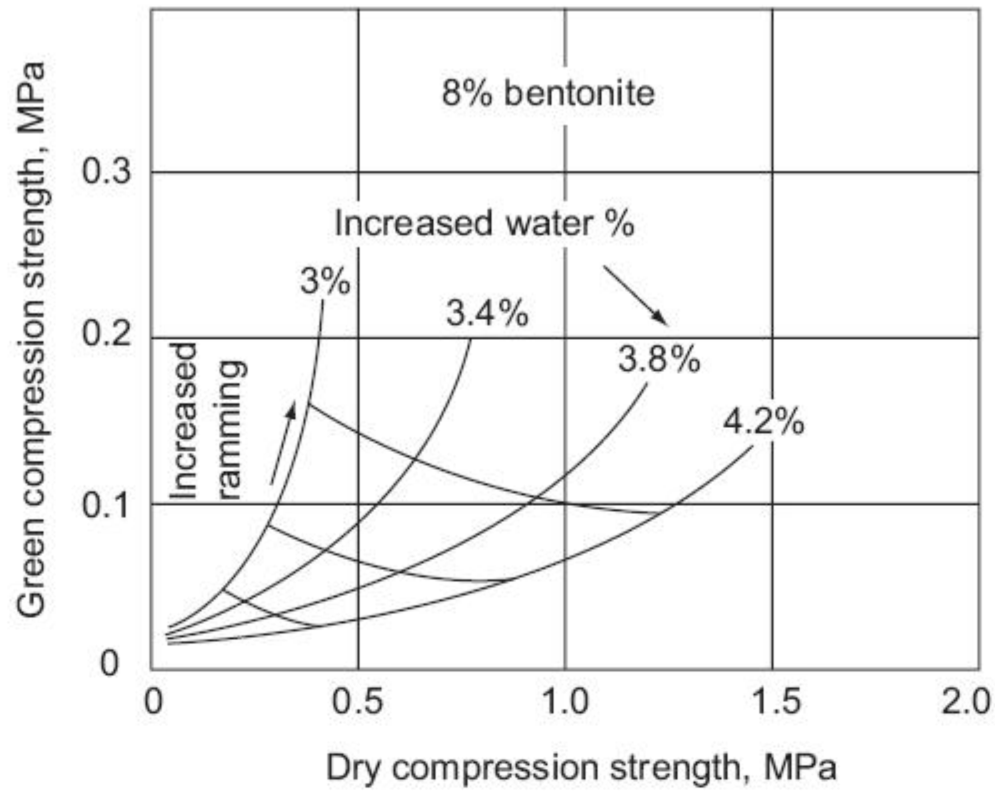

Fig. 3.27 *Interrelation between sand properties with various constituents*

Indian Sands

- The normal practice of Indian foundries is to use the locally available river sand.
- For example, the foundries in Jamshedpur use the local Swarnarekha river sand.
- The river sands normally are of medium to fine grain and sub-angular in shape.
- They contain about 80 to 85 % silica and the rest are alumina and other impurities.

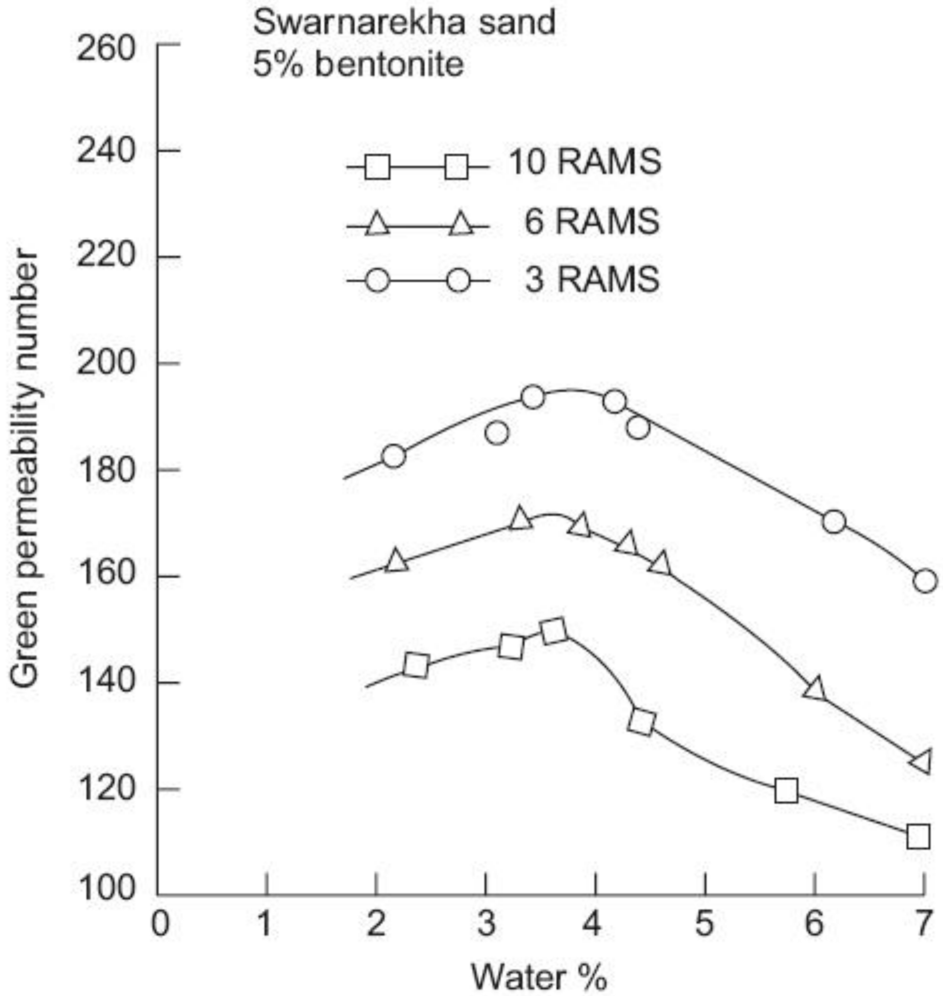

Fig. 3.28 *Change in the permeability of moulding sand with the degree of ramming*

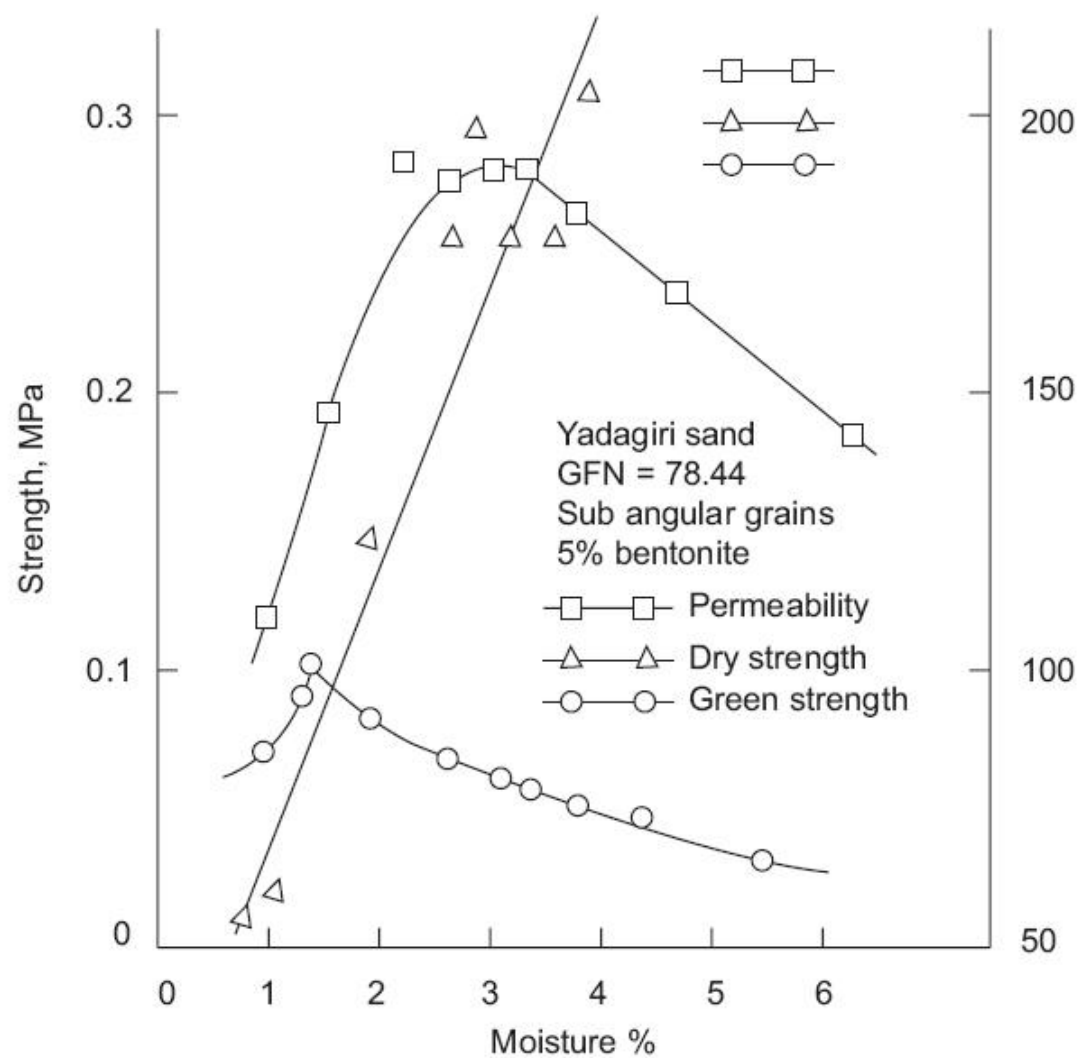

Fig. 3.29 *Properties of Yadgiri sand*

Additives

- A number of materials are added to moulding sand such as coal dust, saw dust or wood flour, starch and dextrin, iron oxide and silica flour to improve their moulding properties.

Table 3.14 *Different types of moulding sand additives used*

Additives	Purpose served
Molasses Cereals Ethylene glycol	Enhancement of bench life and resistance to drying out
Iron oxide Silica flour	Hot strength development
Coal dust Silica flour	Surface finish and resistance to metal penetration
Cereals Saw dust	Collapsibility and resistance to expansion defects

OTHER SANDS

- **Facing sand**
- **Mould wash**
  - to prevent metal penetration into the sand grains and thus ensure a good casting finish
  - to avoid mould-metal interaction and prevent sand fusion.
- **Backing sand**
- **Parting sand**

Fluidity

- The term fluidity is normally used in a foundry, to designate the casting material's ability to fill the mould cavity.

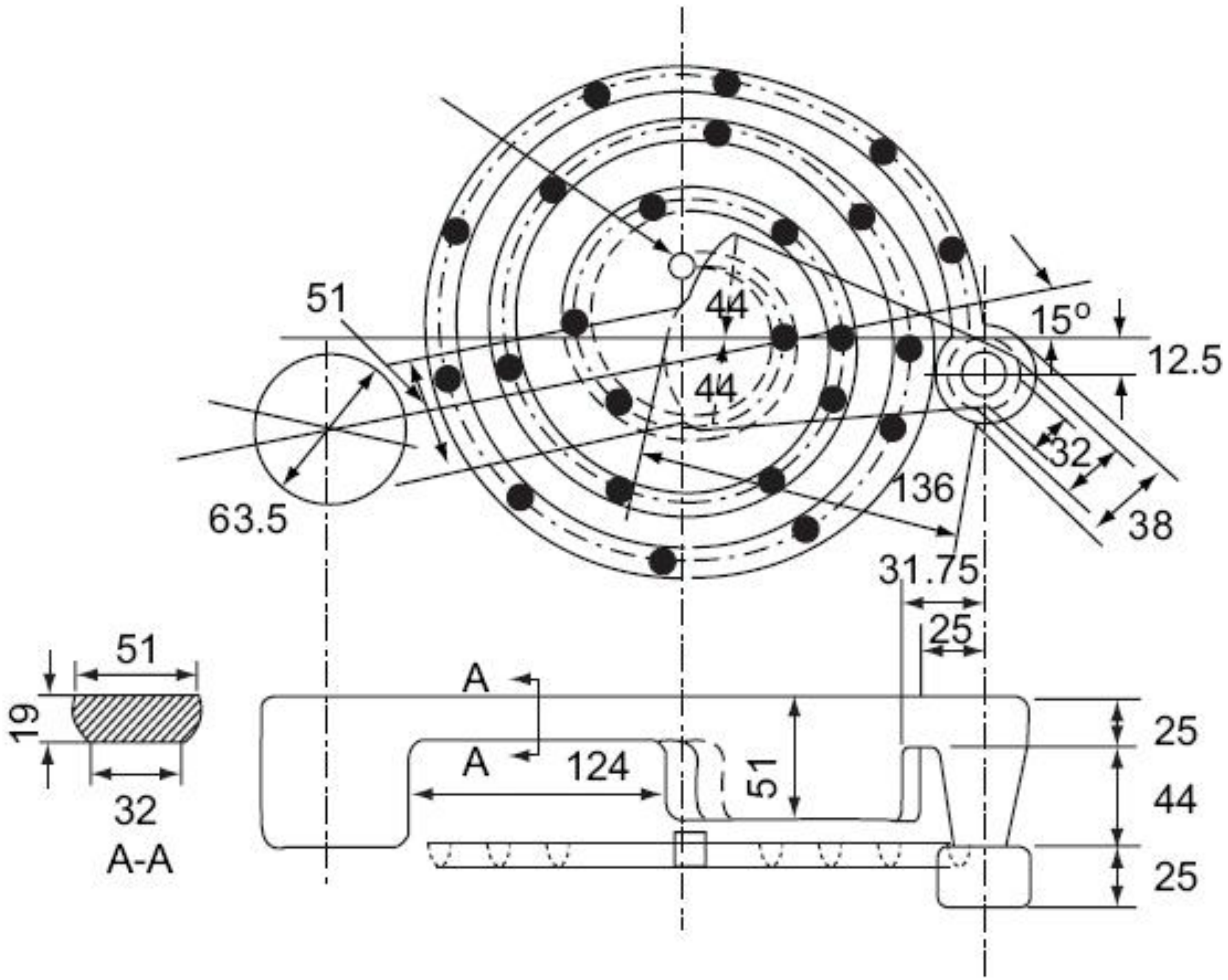

Fig. 3.33 *Fluidity spiral design*

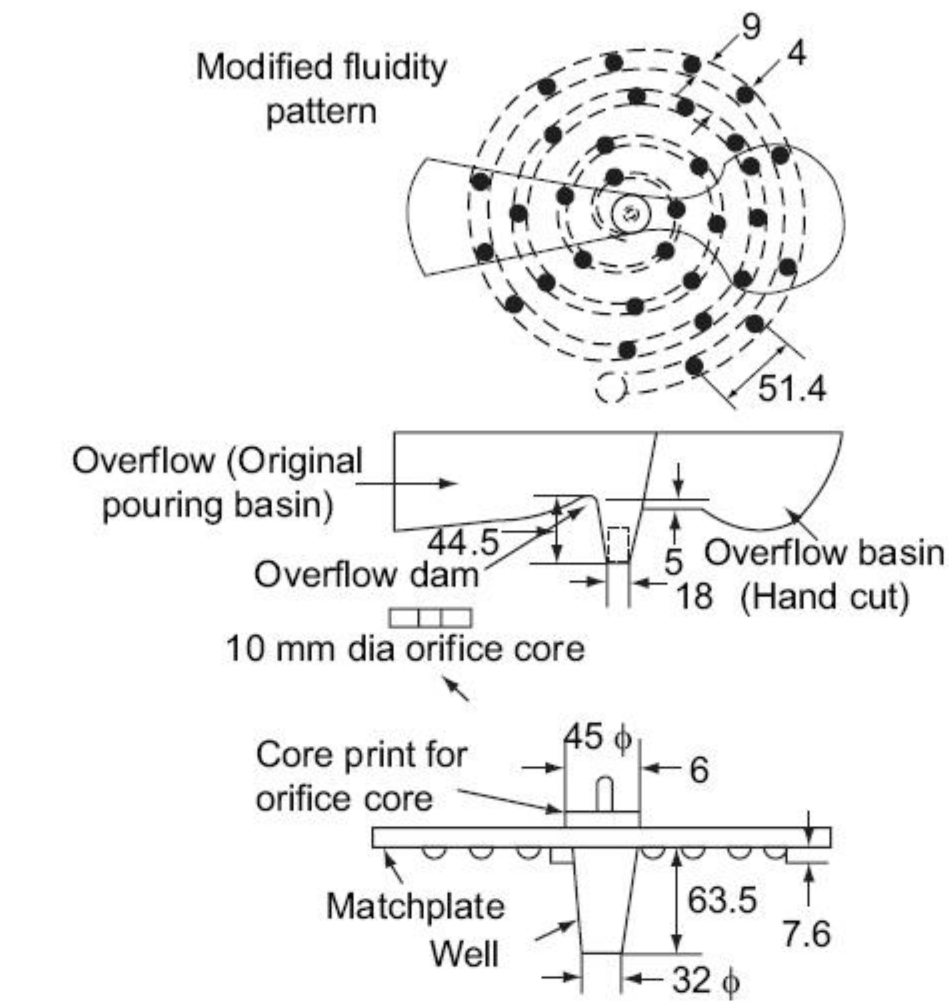

Fig. 3.34 *Fluidity spiral for grey cast iron*

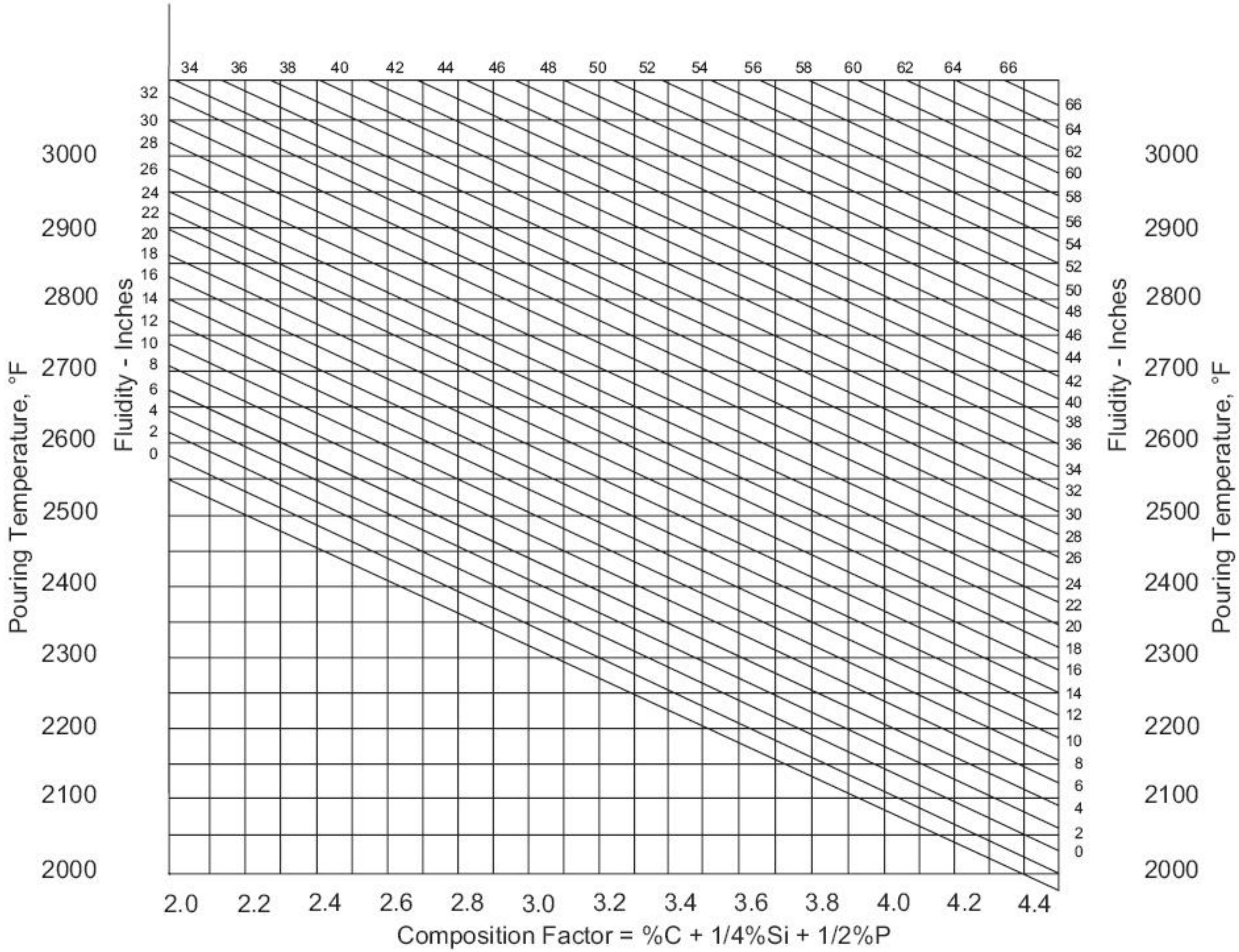

Fig. 3.35 *Fluidity of grey cast iron*

Types of Sand Moulds

- It must be strong enough to withstand the temperature and weight of the molten metal.
- It must resist the erosive action of the flowing hot metal.
- It should generate minimum amount of gases as a result of the temperature of the molten metal.
- It should have good venting capacity to allow the generated gases to completely escape from it.

Types of Sand Moulds

- Green sand moulds
- Dry sand moulds
- Skin dried moulds

Moulding Machines

- For production work involving large batches of the same type of casting is to be produced, machine moulding is a necessity.
- Jolting
- Squeezing, and
- Sand slinging

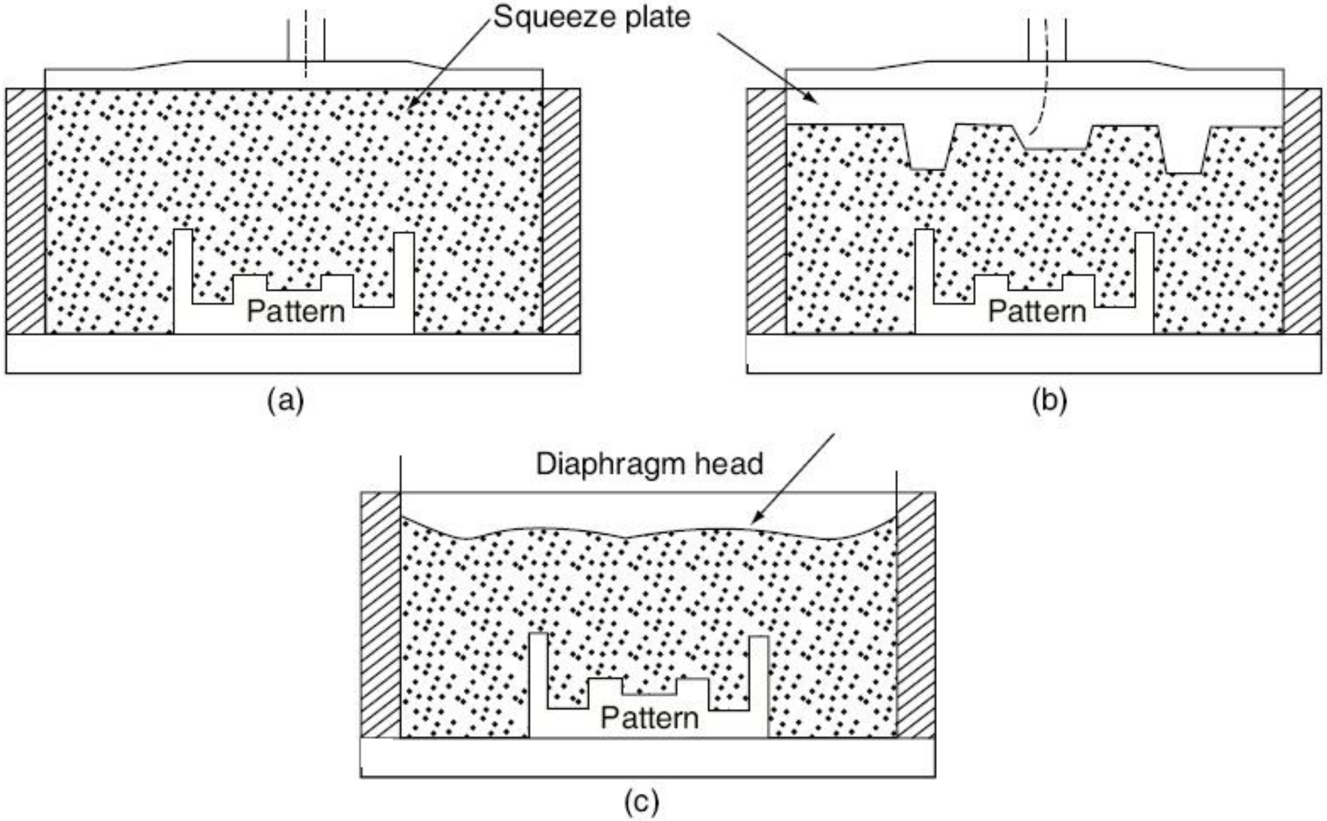

Fig. 3.36 *Types of squeeze heads used for machine moulding, (a) conventional squeeze, (b) profile squeeze head and (c) diaphragm squeeze*

Cores

- Green strength: A core made of green sand should be strong enough to retain the shape till it goes for baking.
- Dry strength: It should have adequate dry strength so that when the core is placed in the mould, it should be able to resist the metal pressure acting on it.
- Refractoriness: Since in most cases, the core is surrounded all around it is desirable that the core material should have higher refractoriness.

Cores

- Permeability: Some of the gases evolving from the molten metal and generated from the mould may have to go through the core to escape out of the mould. Hence cores are required to have higher permeability.
- Collapsibility: As the casting cools, it shrinks, and unless the core has good collapsibility (ability to decrease in size) it is likely to provide resistance against shrinkage and thus can cause hot tears.

Cores

- Friability: After the casting is completely cooled, the core should be removed from the casting before it is processed further. Hence the friability (the ability to crumble) should also be a very important consideration.
- Smoothness: The surface of the core should be smooth so as to provide a good finish to the casting.
- Low gas emission: Because of the high temperatures to which a core is subjected to, it should allow only a minimal amount of gases to be evolved such that voids in the castings can be eliminated.

Core Sands

- Binders: Core sands need to be stronger than the moulding sand and therefore the clay binder used in moulding sands is not enough but somewhat better binders need to be used.
- The normal binders are organic in nature, because these would be burnt away by the heat of the molten metal and thus make the core collapsible during the cooling of the casting.
- The amount of binder required depends to a great extent on the fineness of the sand grains.

Core Sands

- The binders generally used are, linseed oil, core oil, resins, dextrin, molasses, etc.
- Core oils are mixtures of lin-seed, soy, fish and petroleum oils and coal tar.

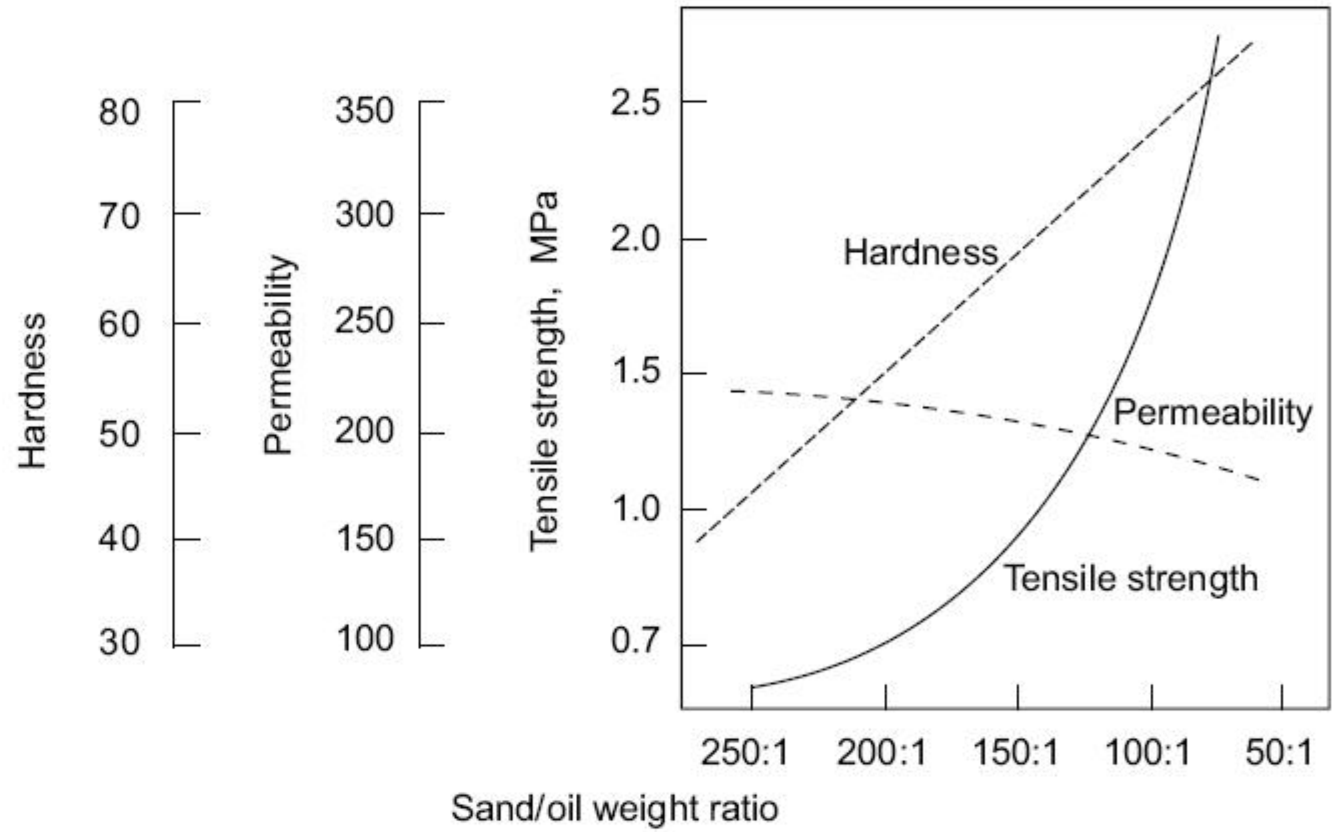

Fig. 3.37 *Core sand properties varied by composition*

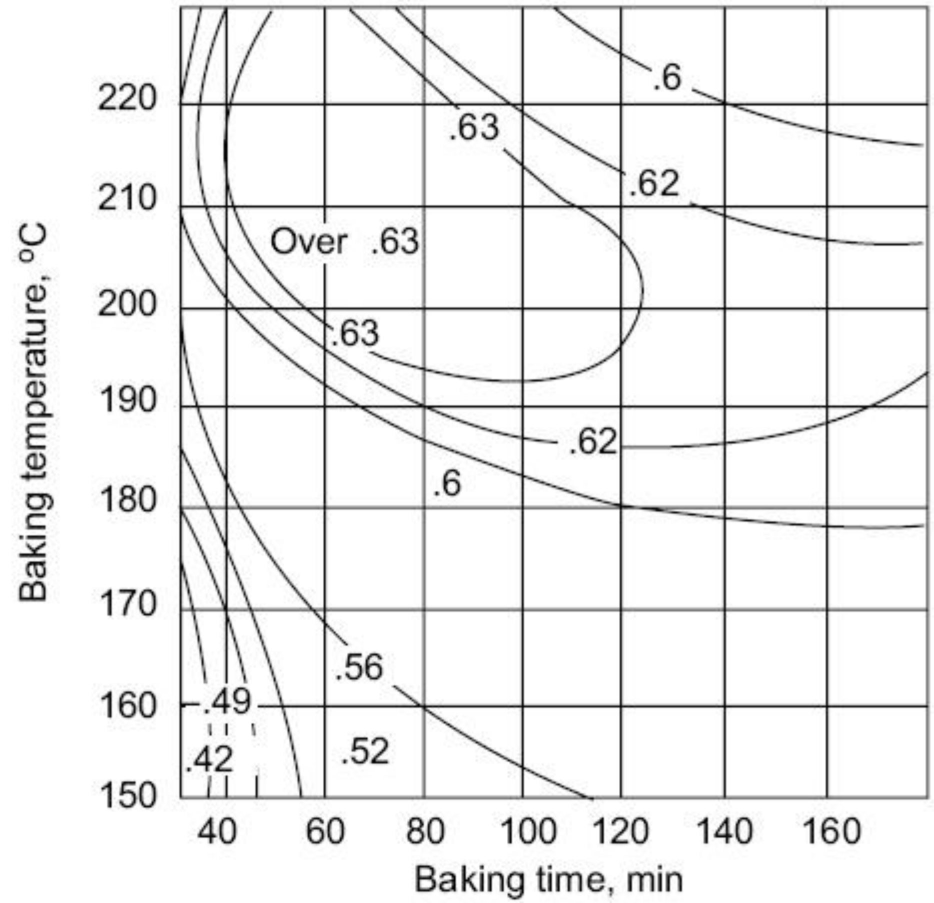

Fig. 3.38 *Core properties as affected by baking time and temperature*

Carbon Dioxide Moulding

- The other method which is widely used in making cores and occasionally for moulds is to use sodium silicate (water glass, $SiO_2:Na_2O$) as a binder.
- The mould is prepared with a mixture of sodium silicate and sand and then treated with carbon dioxide for two to three minutes such that a dry compressive strength of over 1.4 MPa is arrived at.

Types of Cores

- Green sand cores are those, which are obtained by the pattern itself during moulding.

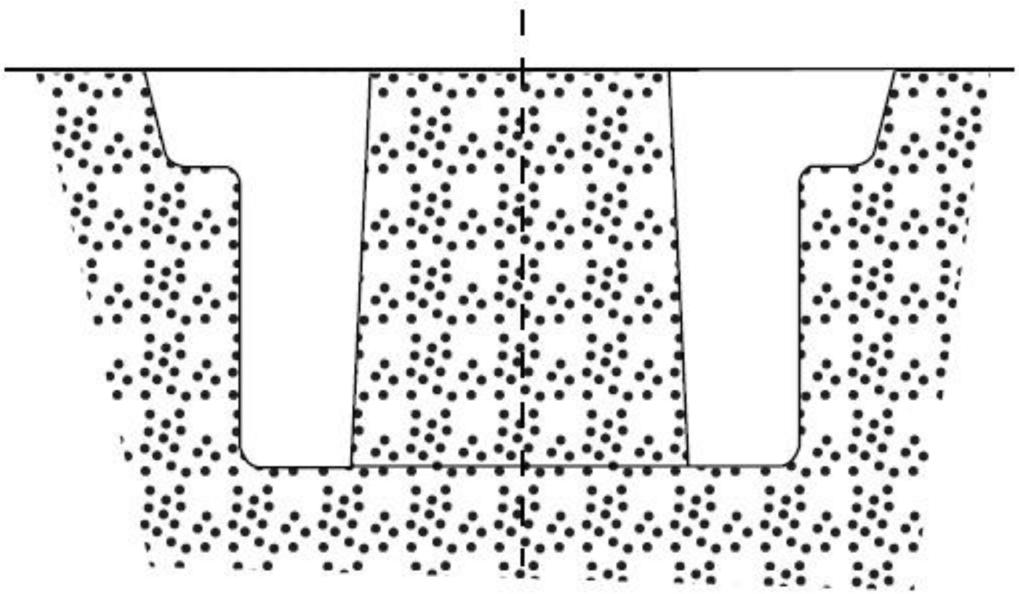

Fig. 3.39 *Green sand core*

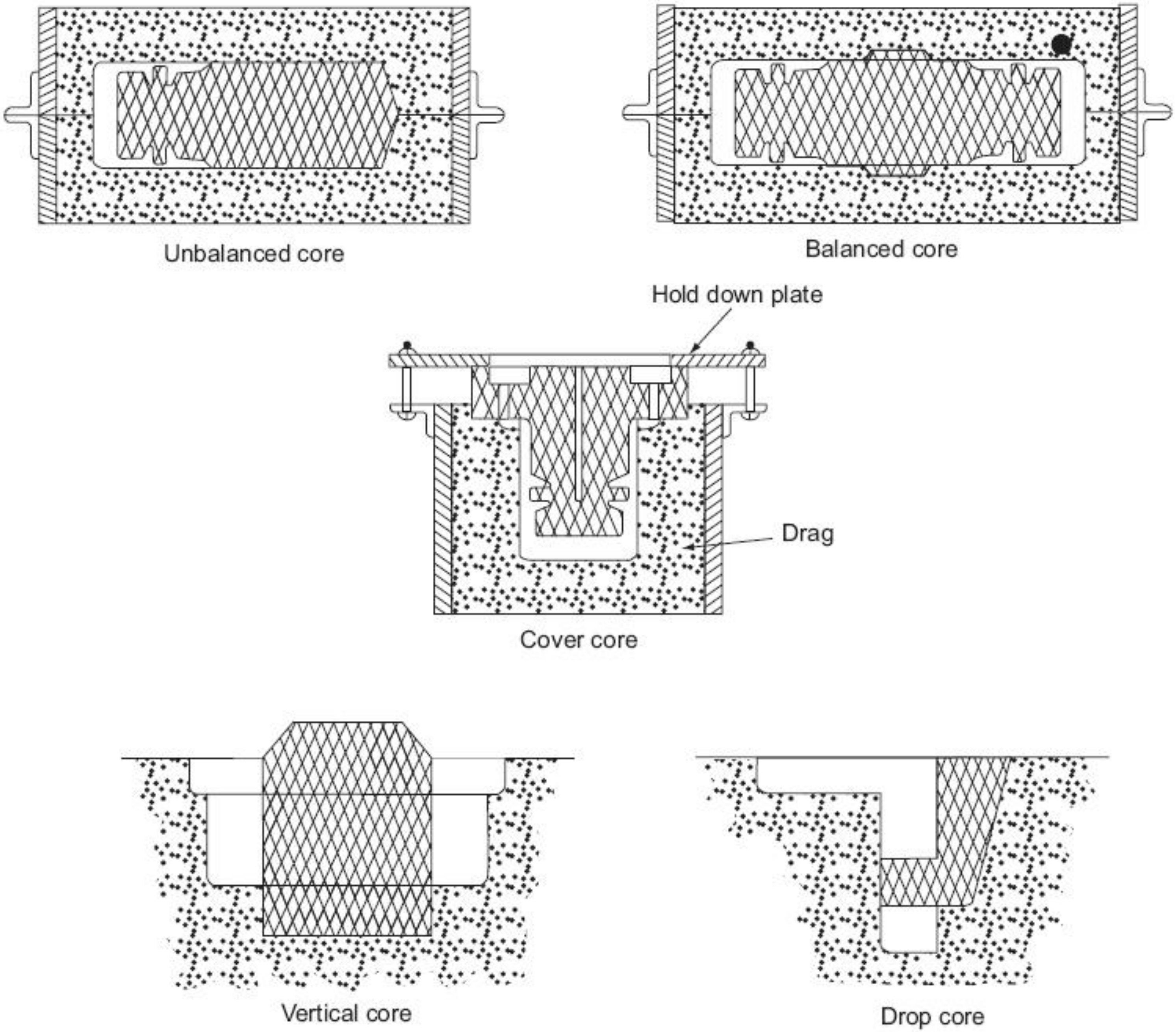

Fig. 3.40 *Dry sand core types*

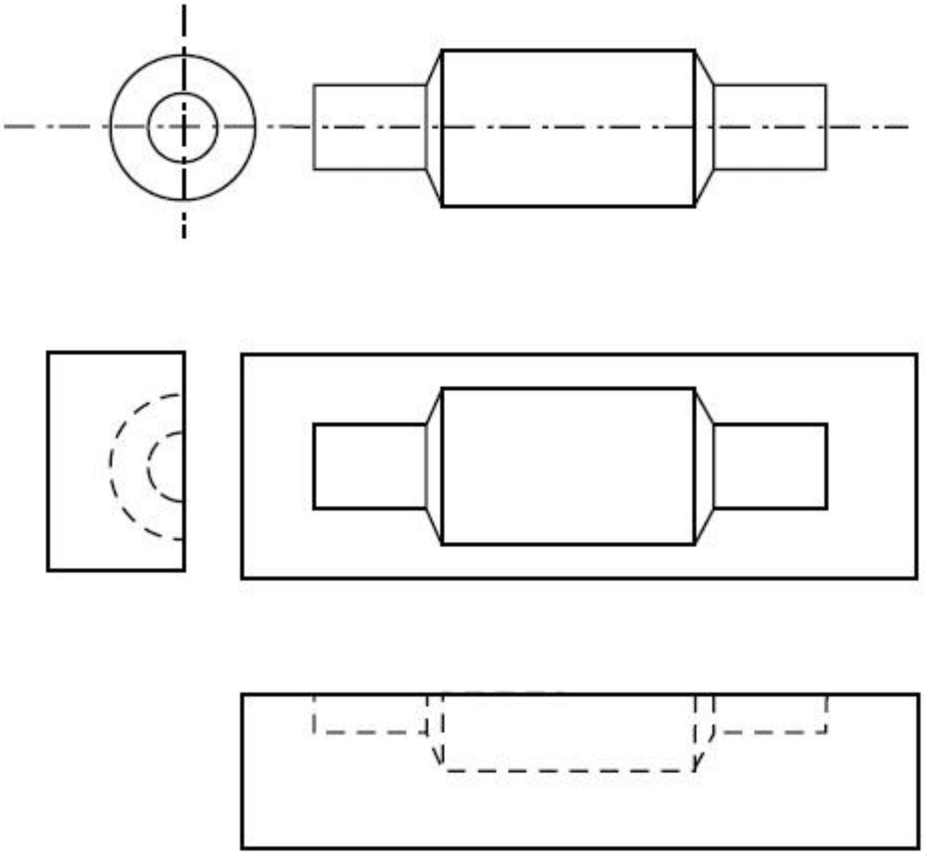

Fig. 3.41 *A typical core box*

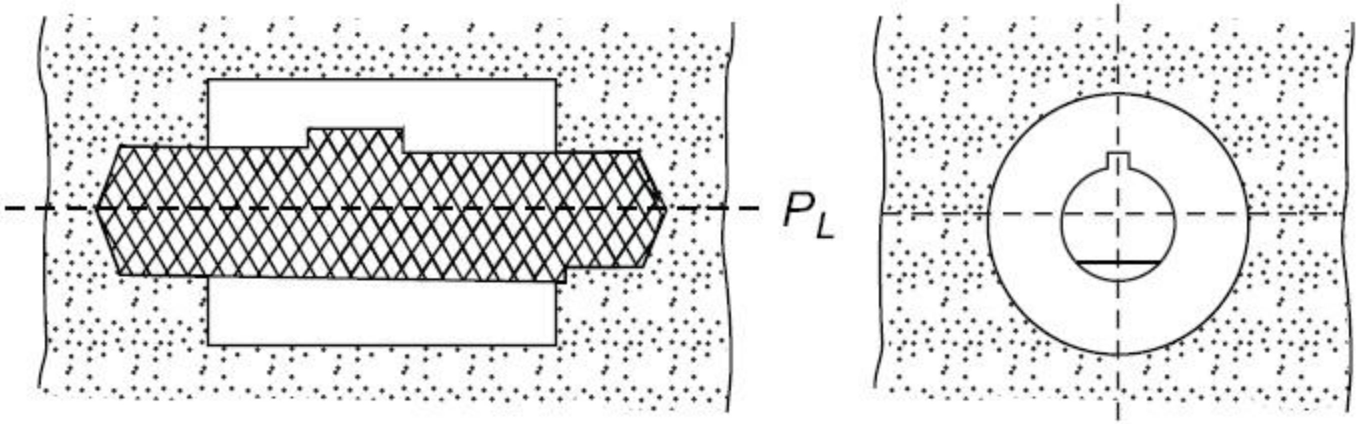

Fig. 3.42 *Unsymmetrical core location*

Core Prints

- The main force acting on the core when metal is poured into the mould cavity, is due to buoyancy.
- It can be written as, $P = V (\rho - d)$
  - P = buoyant force, N
  - V = volume of the core in the mould cavity, cm^3
  - ρ = weight density of the liquid metal, N/cm^3
  - d = weight density of the core material = $0.0165\ N/cm^3$

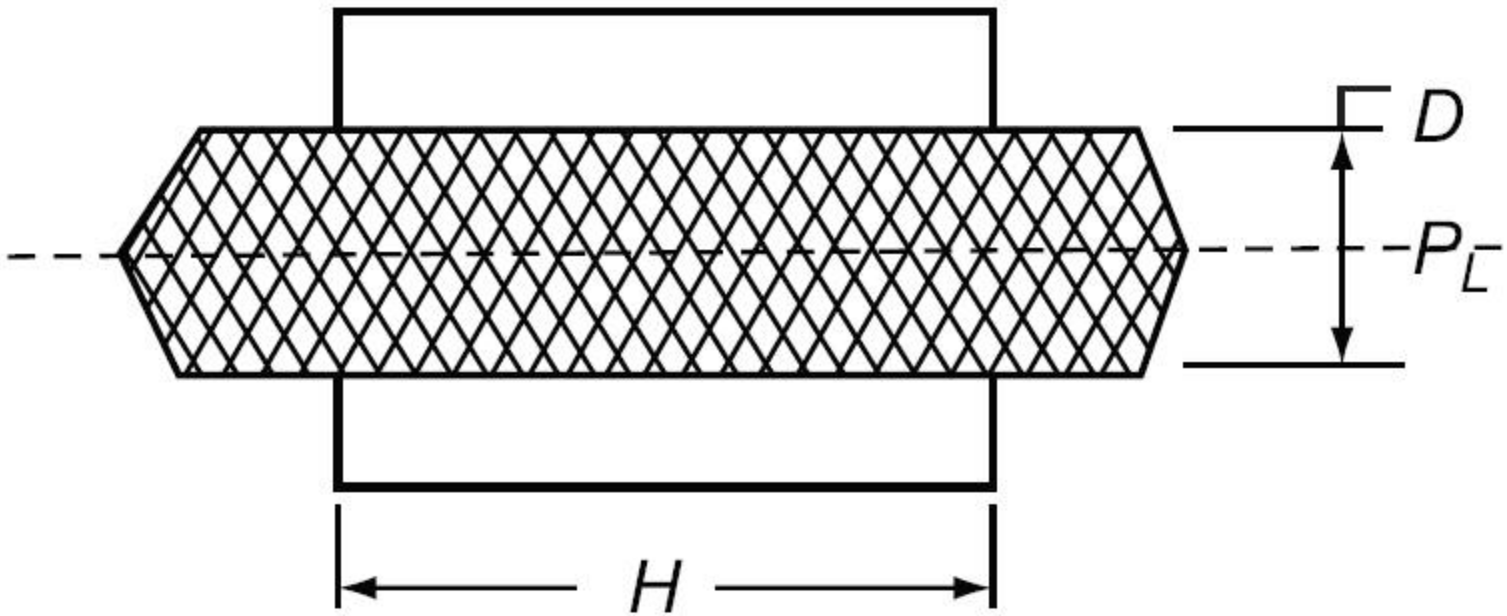

Fig. 3.43 *Horizontal core position*

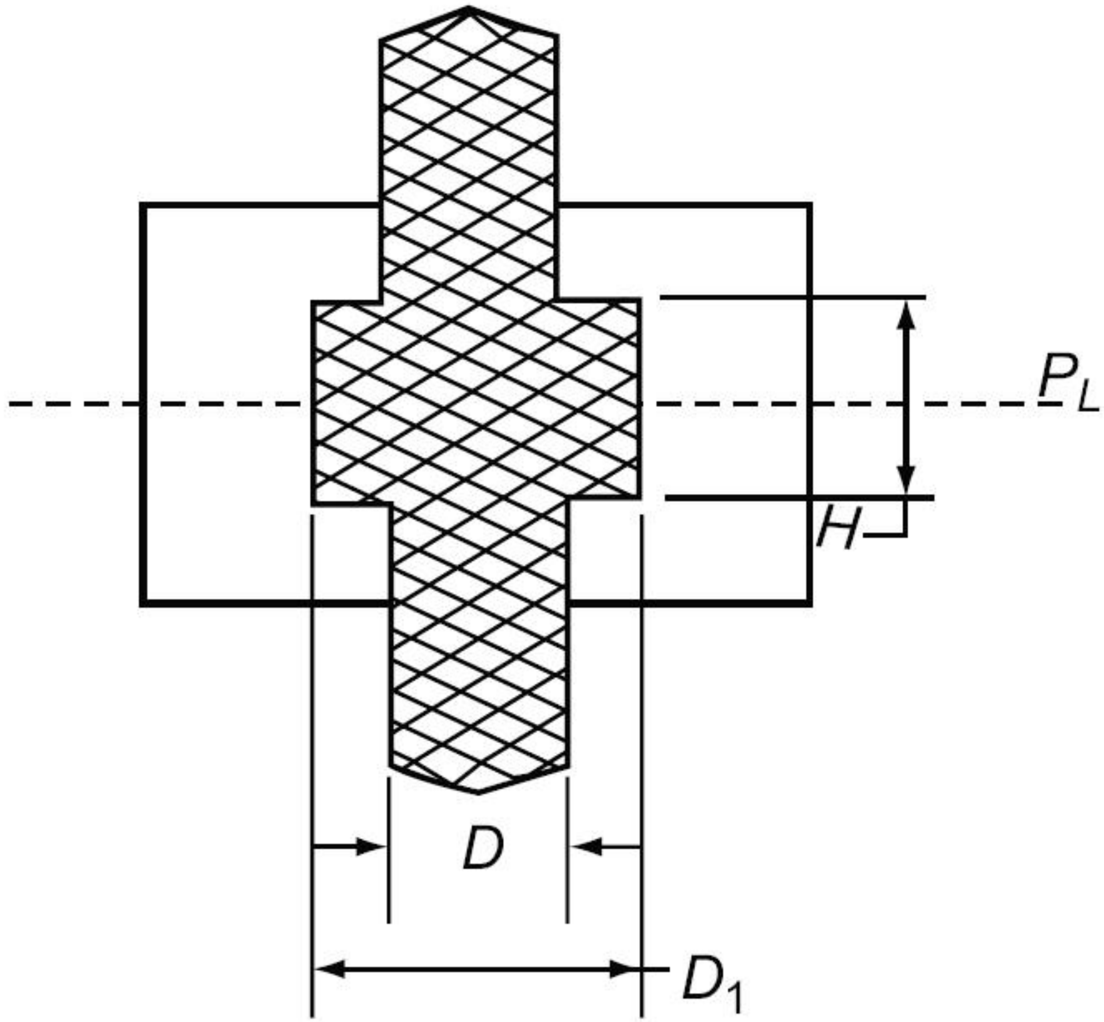

Fig. 3.44 *Vertical core*

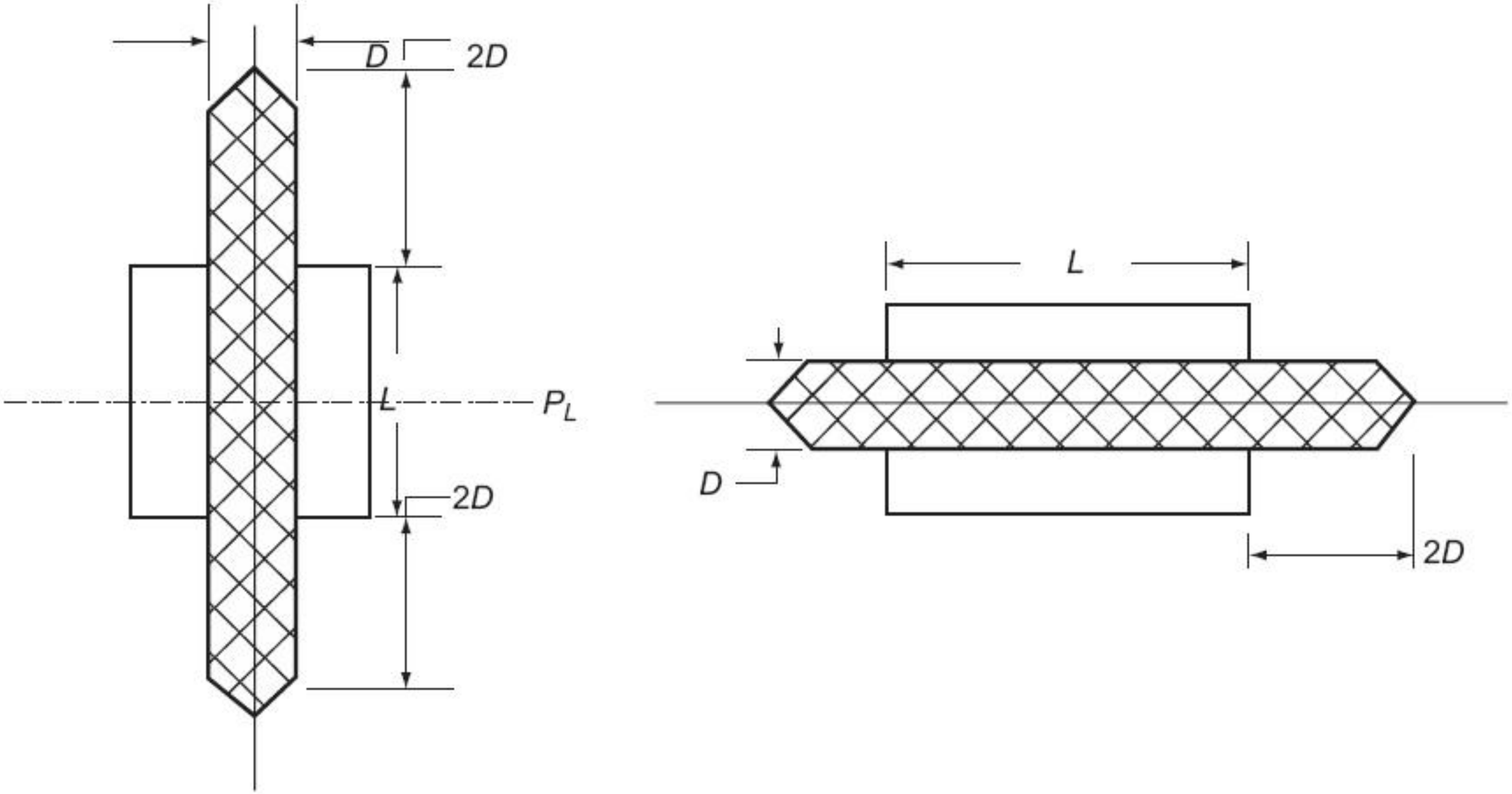

Fig. 3.45 *Core print proportions*

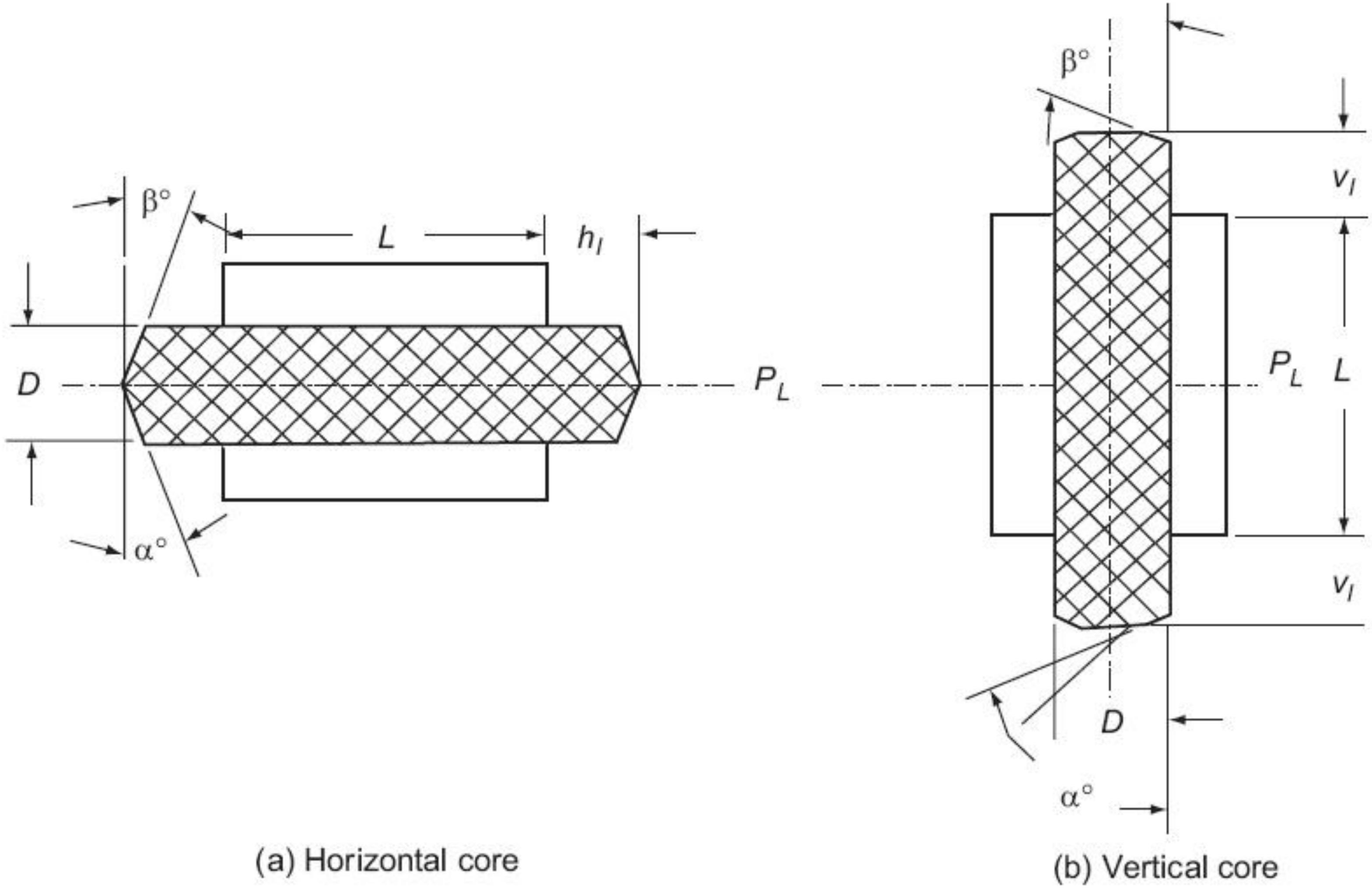

Fig. 3.46 *Core print sizes*

Table 3.19 *Core print dimensions*

Core diameter D, mm	Core length L, mm									
	<50		51– 150		151 – 300		310 – 500		500-750	
	vl	hl	vl	hl	vl	hl	vl	hl	vl	hl
up to 25	20	15	25	25	—	40	—	—	—	—
26–50	20	20	40	35	60	45	70	60	—	—
51–100	25	25	35	40	50	50	70	70	100	90
101–200	30	30	30	50	40	55	60	80	90	100
201–300	35	—	35	—	40	60	50	90	80	110
301–400	40	—	40	—	40	80	50	100	70	120
401–500	40	—	40	—	40	110	50	120	60	130

Table 3.20 *Draftangles for core prints*

Core print, h_l or v_l, mm	Vertical, degrees		Horizontal, degrees	
	α	β	α	β
< 20	10	15	10	15
21 to 50	7	10	7	10
51 to 100	6	8	6	8
101 to 200	5	6	5	

Chaplets

- Chaplets are metallic supports often kept inside the mould cavity to support the cores.
- Unsupported load = P - 3.5 Ac
- Ac = chaplet area

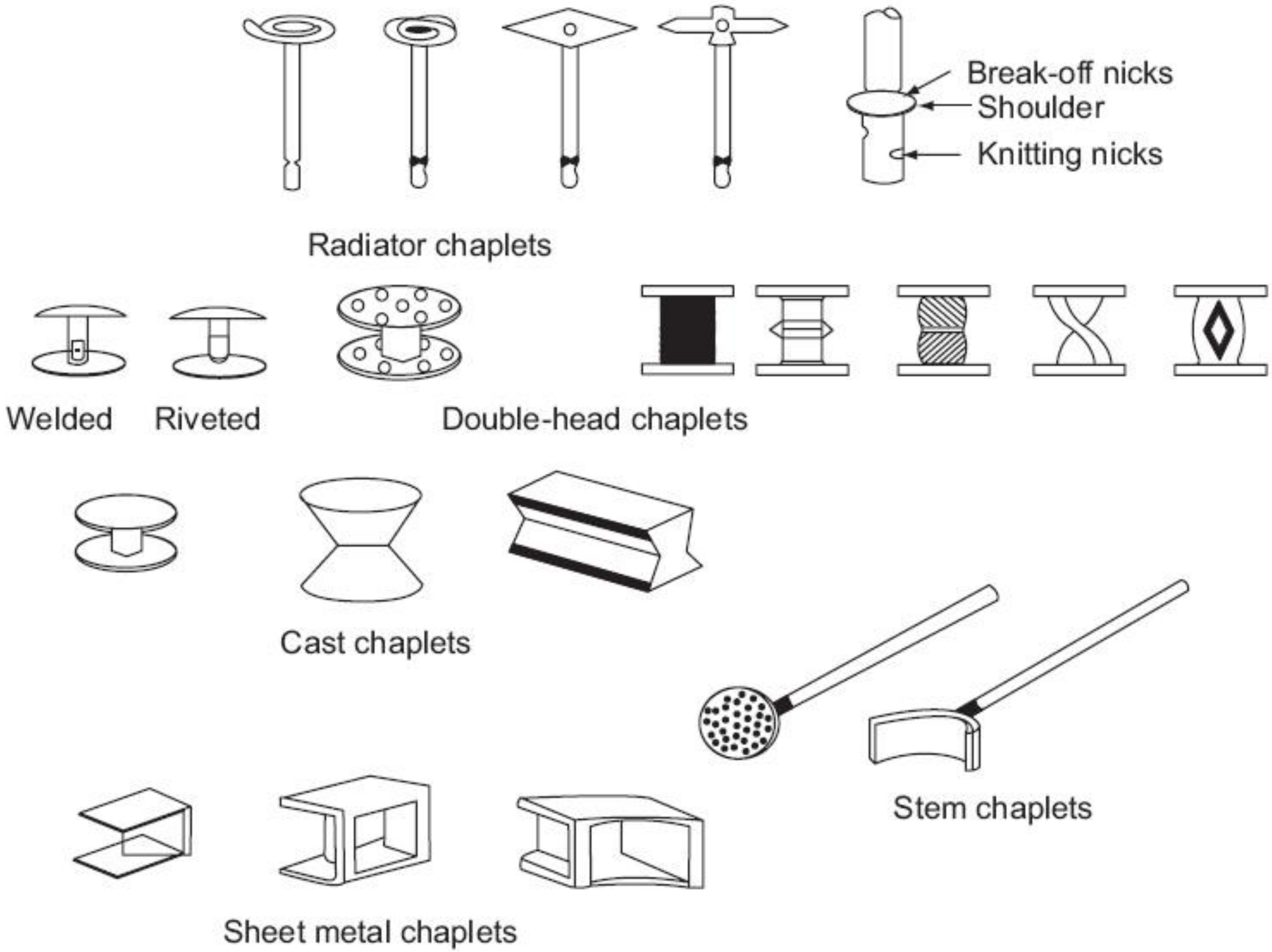

Fig. 3.47 *Types of chaplets*

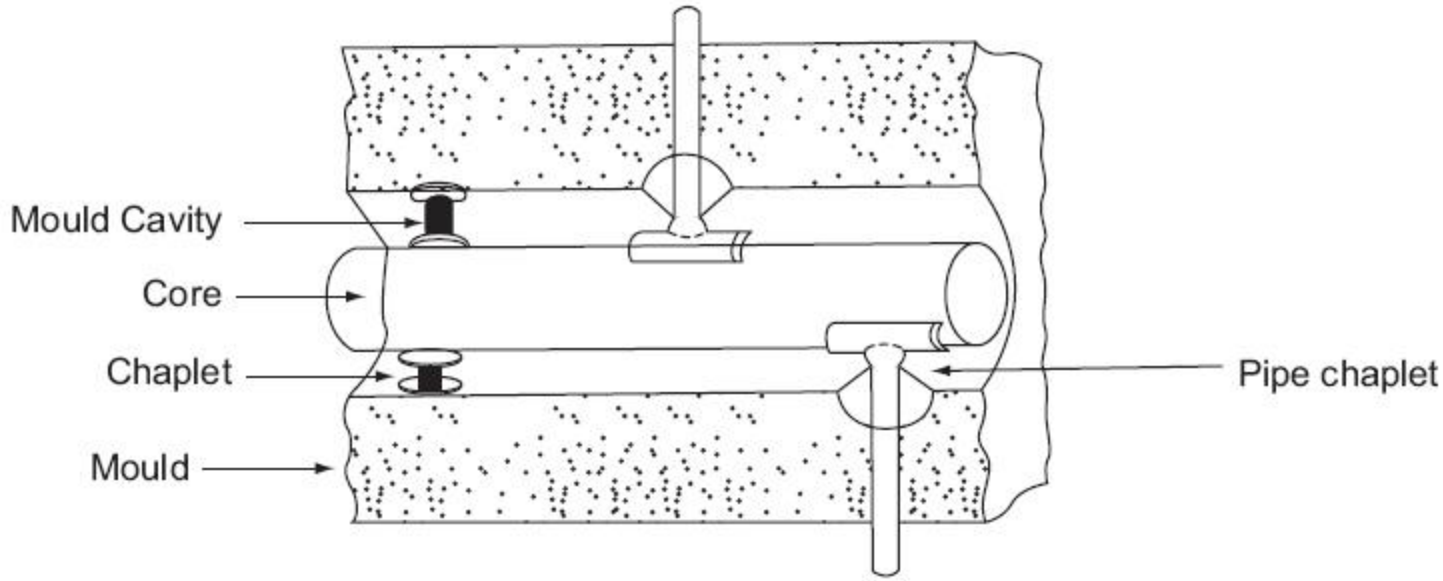

Fig. 3.48 *Core supported by chaplet*

Forces Acting on the Moulding Flasks

- Buoyancy force is transmitted by the core to the cope and would tend to lift the cope away from the drag.
- 'Metallostatic' force is exerted by the molten metal in all the directions of the cavity.
- $F_m = A_p \rho (h - c)$

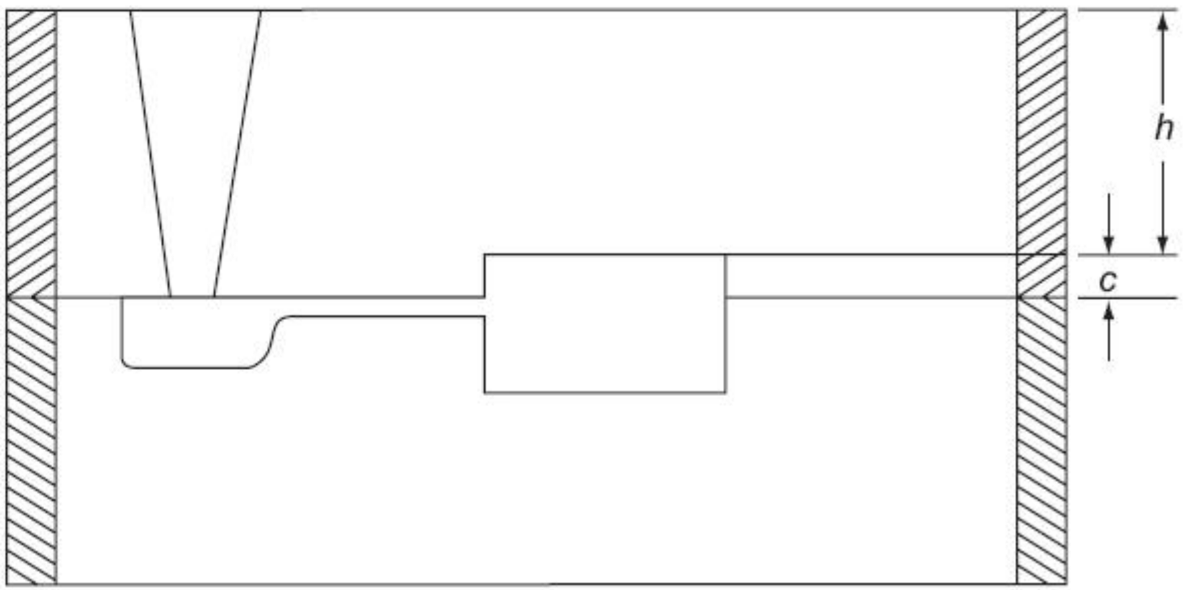

Fig. 3.49 *Head of the metal in sand casting*

Summary

- Metal casting processes are the primary manufacturing processes that are used to make complex parts utilising liquid metal.
- Metal casting is one of the oldest manufacturing processes invented and practiced over the last 5000 years.
- However the major developments have taken place in the last 100 years in adopting it as a major primary manufacturing process.

Summary

- A pattern is different from the final casting because of the pattern allowances to be added.
- Most patterns are made from wood though it is also made using plastics and metals.
- There are a number of types of patterns depending upon the geometry of the part and the production volumes required.
- A variety of moulding materials are used in preparing the refractory mould for casting.
- Sand is the primary moulding material with clay and water.
- In addition a number of additives to sand improve its properties for specific requirements.

Summary

- Cores are required to make holes and hollow portions of a casting.
- Sand for cores requires better properties and for this purpose, special binders are used.
- There are a number of types of cores used in casting based on the geometry of the part.