

AN OVERVIEW OF THE PRIMARY EXISTING LADDER TYPES FOR CONSOLIDATED BASIC INFORMATION

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Article Info

Keywords: Ladder types, Current information, Uses, Features, Overall significance, Safety issues, Needful practices, Research needs.

DOI

10.5281/zenodo.17338666

Abstract

Ladders are crucial for providing the elevation and stability needed to go up and get many jobs done, but they are characterized by safety and other usage issues. This paper presents an overview of the main ladders currently in use, covering their general relevance, material make, safety concerns, basic characteristics, selection, applications, and research needs. The paper shows that ladders have long been essential devices for various industrial, commercial, and domestic applications. These days, there are various types of ladders, each with unique characteristics and applications, so it is important to understand each type in order to choose and use it appropriately in terms of safety requirements, cost savings, height reachability, material composition, and avoiding the trouble of returning those that are inappropriate for different tasks in different environments. Engineering control measures, such as OSHA Standards 29 CFR 1910.2 and 29 CFR 1926.1053, have established guidelines for addressing safety issues in the design and development of ladders. Safety guidelines for ladder usage include ANSI A14.1 for wooden ladders, ANSI A14.2 for portable metal ladders, ANSI A14.3 for fixed ladders, and ANSI A14.5 for portable reinforced plastic ladders. The paper contributes to simplified current literature on ladders for understanding their relevance and safety requirements, relating any research on them with the literature information, identifying any research gaps on them, noting their potential future directions, and developing better ones for various needs.

1.0 INTRODUCTION

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A ladder is portable or mobile or a fixed structural device that consists of repeated bars or steps between two upright lengths of metal, wood, or rope, used to facilitate workers in going up a building or other structure to do tasks at elevated levels and then descending down when the tasks are done [1, 2, 3]. A ladder usually consists of two long, sufficiently strong pieces of wood, metal, or rope with steps attached between them. Ladders have a rich and colorful history spanning thousands of years. The biblical Book of Genesis, chapter 28, verses 12 and 13, made the earliest known mention of ladders. In that book, Jacob had a vision of a ladder that led all the way to heaven, with angels constantly climbing and descending it to perform God's work [3, 4, 5]. Before the invention of ladders, people would stack objects on top of one another to ascend to higher altitudes. This stacking of objects is exhausting, and it becomes more difficult when things must be carried up along. Using such pilings is also quite dangerous because there is a significant probability that the user will fall at the first sign of trembling. The first known ladders used by man were wooden and intended for tree climbing. In addition to climbing, the ancient Egyptians used them to access the pyramids. In siege warfare, the Romans frequently used metal ladders, called "scale," to scale fortifications. During the middle Ages, firefighters used rope ladders to ascend to the top of burning structures. The earliest known image of a ladder is from at least 10,000 years ago. It was discovered in a Mesolithic rock painting in the Spider Caves near Valencia, Spain, depicting two people climbing the ladder in the painting to get honey from a wild honeybee nest atop. The ladder appeared to be long and pliable and composed of some grass. For many years, ladders were mainly made of rigid wood. However, one of the major breakthroughs came in 1862, when an Ohio carpenter named John H. Balsley invented the first folding wooden stepladder. In 1867, the American inventor Henry Quackenbush obtained a patent for the first extension ladder. His company also created revolutionary new products, such as nutcrackers and air rifles. [4, 5, 6] In the 20th century, materials such as aluminum and fiberglass introduced lighter and safer models. The first aluminum ladder was made by the Aluminum Company of America when a Norwegian fire department asked them to create something that would be lightweight and easier to use. Various safety standards for assessing ladder safety were also introduced in the 20th century. Throughout the Industrial Revolution, workers needed ladders to reach the top floors of companies, and iron and steel ladders became widely used [7-12]. Today's manufacturing and industrial sectors still rely heavily on ladders because they provide employees with a safe, simple, cost-effective, and flexible way of accessing elevated areas for tasks such as inspection, maintenance, and repairs that do not require more complex equipment. However, several cases of ladder accidents, either in domestic settings or in the workplace, abound nowadays, indicating that the design and safety conditions of current ladders are not ideal [7-15]. Several research outputs on ladder development as a crucial area of technological development to address safety, material, and other issues associated with the improvements of existing ladders have been reported in the literature, such as the works of Hsiao et al. [8], Pliner et al. [9], Suparman Bin Samsuddin [10], Hire et al. [11], Hicks et al. [12], Pattewar et al. [13], Lonsdale [14], Hanipah inti Ghazali and Muhamad Danieal bin Shafie [15], Anjum et al. [16], Susanto et al. [17], Maejima et al. [18], Srivastava et al. [19], Pham and Vasilenko [20], Kubacki and Bialek [21], Mokyr [22], Erika Mae Pliner [23], Praneetha [24], Roberts et al. [25], Deshmukh et al. [26], Thiagarajan and Tajuddin [27], Frankovský et al. [28], Patil et al. [29], Cristina-Catalina Petica et al. [30], Kumar et al. [31], and Bouzid [32]. There are different types of ladders today, each with its own particular qualities and uses, making the ladder choice necessary for different needs. Choosing an ideal ladder for the job at hand is necessary to ensure our safety and save money and the trouble of returning ladders that are not suitable [25-36]. This paper aims to present consolidated basic information on the overall significance, basic features, specific uses, advantages and disadvantages, and encountered issues of the primary types of ladders to better

understand their limitations and the need for correctly choosing and safely using them or designing and developing better ladders for various unique requirements.

2.0 METHODOLOGY

Several relevant journal articles, books, university theses and dissertations, and dealership websites on the Internet were used to source the information presented in this overview report. The gathered information was summarized into a single resource that can be referenced to understand the significant role of ladders in human development, as well as the important issues or unanswered questions related to their usage safety, selections, improvements, and research progress that need to be addressed.

3.0 THE OVERVIEW REPORT

3.1 Significance of Ladders and Issues with them

Ladders [8-24]:

- i. Are suitable for various tasks, from reaching high shelves to accessing rooftops and other elevated areas.
- ii. Provide means to perform tasks safely and smartly at heights.
- iii. Offer height adjustability and configurations to meet different needs and environments.
- iv. Are ideal for home maintenance, painting, and do-it-yourself projects.
- v. Are ideal for use in offices, retail spaces, and warehouses for tasks requiring elevated access.
- vi. Are important in factories, warehouses, and construction sites for accessing high equipment and areas.

Improper choice and/or use of ladders can make them unsafe in industrial and commercial environments by causing accidents such as falls that can cause loss of life or severe injuries such as broken bones and head damage. Falls from ladders are one of the leading causes of occupational injuries and fatalities. Over 500,000 individuals are injured, and approximately 400 people are killed annually from ladder falls. Employers and employees are gravely concerned because most fatality-related falls from ladders involve falls of less than three meters. Ladder fall accidents, including lost wages, medical and legal expenses, liabilities, and pain and suffering awards, are projected to cost \$24 billion annually [7-24]. Ladder falls are common in all professions and are one of the most serious safety concerns in the building industry. According to the Bureau of Labor Statistics, of the 645 fatal falls around the world in 2009, over one-third involved falls from roofs or ladders [8-24, 33-37]. According to OSHA figures, falls account for nearly 40% of construction deaths. According to the Centers for Disease Control and Prevention, ladders are involved in 81% of fall injuries by construction workers treated in U.S. emergency rooms, with a substantial number of ladder accidents occurring at a height of 182.88 cm (6 feet) or less [7-24, 32-37]. In the US, more than 500,000 people are reportedly treated for ladder-related injuries annually, and that number does not include people who suffered injuries but did not go to a medical care provider for them. The impact of sprains and strains, broken bones, and other more serious disabling conditions resulting from ladder falls extends far beyond the suffering of the injured worker. Ladder incidents plague the construction sector despite the significant resources and effort devoted to preventing falls. Ladder slide (top or bottom), overreaching, slipping on rungs/steps, malfunctioning equipment, and poor ladder selection for a given operation all contribute to ladder falls [7-24]. Using a worn or damaged ladder, throwing tools to a worker on the ladder, using metal ladders in areas where they may be in contact with electrical wires, and exceeding the ladder's weight limit all contribute to a ladder-related hazard. Choosing the right ladder is essential, and ensuring that it is in sound condition is important [7-24, 25-37].

3.2. Safety Standards and Requirements for Ladders

To prevent issues with ladders, reputable organizations like the Occupational Safety and Health Administration (OSHA) have set standards for ladder design and development, safe use, and maintenance. OSHA safety standards

CFR 1910.2 and 29 CFR 1926.1053 cover all ladder types, including mobile, permanent, and portable ladders [33–38]. According to the safety standard, precautions must always be taken when using a ladder, including ensuring that the ladder is stable before climbing, avoiding standing on the top rung, and never leaning too much to either side.

Caution should be used when carrying tools or materials up a ladder, as one may lose their balance if they are not careful. If one falls from a ladder, they should try to land on their feet and roll to absorb the impact. If possible, they should avoid landing on their heads or backs, as these can lead to serious injuries. Lastly, if someone is hurt or in pain after falling from a ladder, they should immediately seek medical help. Other safety standards, such as ANSI A14.1 for wooden ladders, ANSI A14.2 for portable metal ladders, ANSI A14.3 for fixed ladders, and ANSI A14.5 for portable reinforced plastic ladders, cover specifications for the number of steps, step depth, climbing angle, tread slip resistance, storage or containment or tray for tools and materials, and the duty rating of the ladder. Ladders are made under five categories of duty rating: Type IAA for extra heavy duty, with a maximum load of up to 170.25 kg (375 pounds); Type IA for extra heavy duty, with a maximum load of up to 136.2 kg (300 pounds); Type I for heavy duty, with a maximum load of up to 113.5 kg (250 pounds); Type II for medium duty, with a maximum load of up to 102.15 kg (225 pounds); and Type III for light duty, with a maximum load of up to 90.8 kg (200 pounds). The intended use of a ladder must be considered while choosing it. Although broad information about ladders is available, it is necessary to concentrate on product-specific information when choosing the ideal ladder for a given activity [32-37]. Duty rating which shows the maximum weight capacity a ladder can safely support, material type by conductivity or non-conductivity for handling electrical sources such as changing lightbulbs, etc., and other aspects that directly affect how and when one uses their new ladder are often considered. There are many available options for both design and material composition regarding selecting the ideal ladders for specific requirements. In addition to supporting the user's weight and any tools or items they may be carrying, ladders should be free from flaws and serviced regularly. Ladders must also be used, stored, and set up according to the appropriate protocols. Before use, the ladder must be inspected to ensure that the side rails are undamaged and the rungs are in satisfactory condition without being broken or loose, having rot or decay, cracks or splints, corrosion or oxidation of metal ladders, and warping. Other safety measures entail positioning the ladder on firm, level ground before climbing; facing the ladder when climbing; gripping both side rails with one's hands; not standing on the top rung of the ladder since this is unsafe and can cause the ladder to tip over; using one hand to hold onto the side rail while reaching with the other hand if something high on the ladder needs to be reached; and never leaning too far to one side while on a ladder, as this can also cause it to tip over [7-25, 33-38].

3.3. Types of Ladders

Different types of ladders are designed and produced according to their sizes, capabilities, functional requirements, shapes, technological sophistication, and costs. The main types of ladders are as follows [7-38]:

3.3.1 Step stool ladder

The step stool ladder is possibly the most common ladder type. It has rungs only on one side, and the other side is for support. It is only used to climb from one side. These ladders are used for less intensive tasks. They are the shortest ladder types. They typically have one or two sturdy steps on one side, with a second side for extra support. Their design makes them foldable, easy to set up, relocate, and store. They are designed in an upside-down V shape, are foldable with a handle on top, have four legs with a bottom support, and have a height of less than 81.28 cm or 32 inches per step. They are used for indoor projects, such as painting, changing light bulbs, using the pantry, and reaching high shelves and cupboards in the room. The ladder is relatively lightweight and highly portable, making it easy to move and store; safe for low-height tasks, such as reaching shelves, cabinets, or

changing light bulbs; and stable with non-slip steps, offering a secure standing surface for quick tasks. However, it has limited height, usually between 30.48 and 121.92 cm or 1 and 4 feet, making it unstable for higher-reach tasks; it has a low weight capacity compared to larger ladders, limiting its use for heavy-duty applications; and it is less versatile, as it is designed primarily for indoor, low-level risks [33-44]. Fig. 1 shows a view of the step stool ladder.



Fig. 1: Step stool ladder [39]

3.3.2-Step ladder

A stepladder is a self-supporting, portable frame ladder with flat steps that can be used without leaning against a wall. It is hinged at the top, and when fully opened, the hinged construction provides two sloping parts that form a solid, independent structure with wide climbing stairs and occasionally a top platform for tools or comfortable standing [33-44]. The most widely used type of stepladder is the twin ladder. Because it contains rungs on both sides, it is more adaptable and fully comfortable for two people to climb on. A stepladder is an essential tool for enterprises and warehouses because of its many applications. The ladder is versatile and can be used anywhere in a space where it can be kept stable away from walls. Some stepladders have two sides with rungs, whereas others have rungs only on one side. Most of the ladders have anti-skid material on the bottom to keep them stable. Because stepladders tend to be shorter, they are typically used for indoor and small outdoor projects. These ladders are designed in a shape that looks like an A-frame with four legs and a support bar that folds to store. The ladder is lightweight, simple to set up, often with a locking mechanism for stability, perfect for interior operations requiring moderate heights, and usually has a platform at the top where tools or materials can be placed. Their height is usually 121.92–600.96 cm, or 4–20 feet, and they are used for painting, decorating, changing light bulbs, and simple maintenance. [33-44] Stepladders are among the most versatile types of ladders that are commonly used in homes. This ladder type is usually not too large, portable, and convenient to transport. With its balancing system, it can be set up anywhere the ground is level and solid without the fear of tipping over or shifting. Because step ladders are compact, they can be used in most situations, even in areas with limited space. Owing to their small size and portability, they are suitable for indoor work such as painting the upper ends of walls or fixing things such as lights or other high-up fixtures or accessing high shelves. A stepladder can also be used in commercial settings, such as in retail stores for restocking a shelf or reaching a higher area, and in gardens that require elevation and have level ground. Stepladders that are less than 121.92 cm, or 4 feet, in length are called

stepstools. The highest standing level on the stepladder is slightly more than 60.96 cm, or 2 feet, from its top [33-44]. A diagram of a stepladder with its parts is shown in Fig. 2 cm.

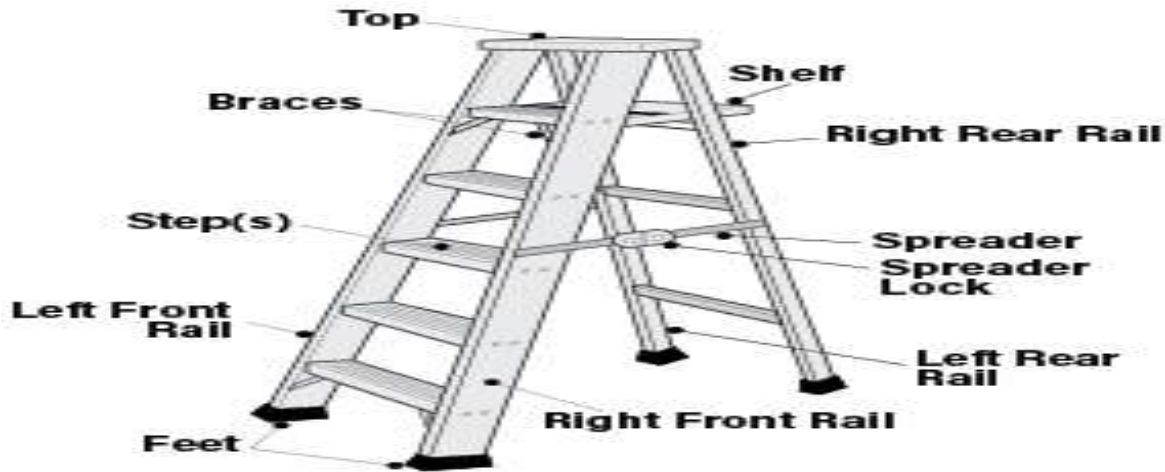


Fig. 2: Step ladder [39, 40]

3.3.3 Extension ladder

An extension ladder is the tallest ladder known. The ladder features multiple sections to create an adjustable length. As a result, these types of ladders can reach heights of 213.36–2194.56 cm, or 7–72 feet, for accessing rooftops or fixing high ceilings. However, extension ladders do not have support; therefore, they need to lean against a wall shelf for stability. For extra stability, a person is required to hold its base steady while another person uses it. The ladder has two legs with no additional support, two side rails with evenly spaced rungs, and two or three extendable sections. It is used for outdoor projects and industrial settings, such as exterior repairs, gutter cleaning, tree trimming, and painting. It is also used in construction to reach elevated areas in roofing and maintenance [32-43]. These ladders have wide treads that reduce slippage and promote friction, giving users a sense of security. The ladder can be retracted to a small size for transport, and it is also portable. The ladder type has a tool-holding device. It is frequently used to access rooftops, enabling do-it-yourselfers to accomplish tasks more efficiently. The ladder type is necessary for painting, building repair, construction, and other tasks on towering walls, rooftops, large structures, and tree branches. It is perfect for tasks requiring more elevation than that provided by a typical step ladder. Certain trees, such as those that reach a high-hanging basket, can be pruned using extension ladders. Most window cleaners use extension ladders to reach second-story windows, often with their equipment. Extension ladders are compact for storage because their sections slide into each other. The disadvantages of this ladder type are that it requires a stable structure to lean against, can be challenging to handle and set up at full extension, and has a higher risk of tipping if not properly angled at a 4:1 ratio as stipulated for the safety requirements for construction, performance, use, and care of extension ladders by ANSI A14.1 for portable wood ladders, ANSI A14.2 for portable metal ladders, and ANSI A14.5 for portable reinforced plastic ladder standards [33-44]. Fig. 3 is a schematic of the extension ladder.

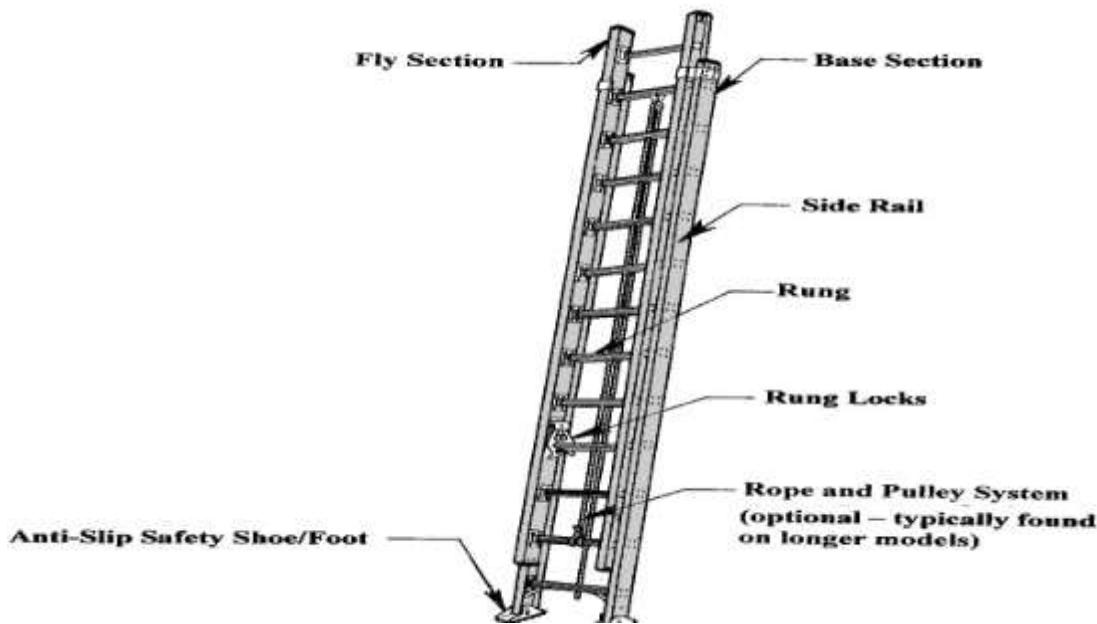


Fig 3: Schematic of the extension ladder [39, 40]

3.3.4 Telescoping ladder

A telescoping ladder is an extension ladder that is either collapsible or extendable to a given length. The ladder becomes compact and convenient to store by collapsing all the telescoping beams. Most telescoping ladders are straight, but some can be bent into twin-step ladders for self-support [38-44]. A telescoping ladder is highly versatile and space-saving, making it suitable for various tasks, especially for on-the-go professionals. It combines the adjustable height of an extension ladder with the stepladder's easy storage design. To change the ladder height, its legs must be extended to the appropriate length and retracted when finished. Telescoping ladders are versatile and can replace a step stool or a two-section extension ladder. Unlike stepladders, a telescoping ladder does not have 8 extra supports and must be leaned against a wall or sturdy frame. It is a straight ladder with an extendable section at the bottom, two side rails, and evenly spaced rungs with an adjustable height ranging from 60.96 to 487.68 cm, or 2 to 16 feet. It is used for heavy-duty indoor and outdoor projects, such as painting walls, cleaning gutters, and general maintenance [38-44]. The weight of the telescoping ladders is proportional to their height. The cumbersomeness of keeping many other types of ladders at home or in the workplace can be reduced or eliminated by using telescoping ladders because of their compact size, which allows them to be conveniently stored even in narrow spaces. It is very convenient to store, carry around, and fetch the ladder from place to place because of its collapsing nature. The ladder can be extended to the required heights at each rung and locked before use, making it very customizable for a range of projects. It is also important to always use, store, and transport these ladders carefully and cleanly. It is necessary to adhere to the user instructions for opening and closing the ladders. The overall benefits of these ladders include being incredibly lightweight, portable, and compact; being ideal for tiny vehicles or storage locations with limited space; and having an adjustable height that makes them suitable for various applications. However, it has a restricted load capacity that makes it unsuitable for heavy-duty jobs; it may not be constructed with high-quality materials, which could lead to durability difficulties; its configuration may be less intuitive; and its misuse may result in pinch spots that could injure fingers [38-44]. Fig. 4. shows a view of telescoping ladder.



Fig. 4: Telescoping ladder [39-44]

3.3.5 The rolling ladder

The term "rolling ladder" or "sliding ladder" is commonly used to describe ladders fixed to a rolling or sliding mechanism, for example, on a wall or shelving system. These ladders are only mobile in two directions, rolling or sliding along a shelving system. These ladders are usually fixed-frame structures; they may be made of metal with supports, handrails, and wheels and used, for example, for stage work or access to shelving in large industrial warehouses. They may be found as part of a warehouse shelving system or traditionally constructed of timber and installed in libraries. They are convenient for accessing high shelves or inventory, stable and easy to move, often with lockable wheels for secure use, and provide a larger, often platformed top step for safe standing. On the other hand, they are suitable for indoor, flat surfaces; heavier and bulkier, making it harder to maneuver in tight spaces; and generally limited in height compared to extension ladders [38-44].

3.3.6 Folding ladder

A folding ladder is similar to a stepladder. A folding ladder unfolds to rest on four legs for extra stability or extends for extra height. It is ideal for projects on uneven surfaces because of its stable build and wide rungs. Additionally, a folding ladder is easy to compact for storage and transportation. It is designed to have an upside-down V shape with broad rungs and hinges that extend them as well as additional side safety railings for some models. The ladder has an adjustable height that can reach up to 640.08 cm, or 21 feet, and is used on even or uneven ground for indoor or outdoor projects [36-44]. Fig. 5 is an image of a folding ladder.



Fig. 5: Image of the folding ladder [39]

3.3.7 The platform ladder

A platform ladder provides a stable surface for the worker and their equipment. Although it has a broad, flat-top platform similar to the stepladder, it differs from the stepladder in appearance [38-44]. No other ladder supports the platform ladder to enable the user to stand on it or place things at its top. It is self-supporting and features a single climbable side with hinges for convenient folding, similar to stepladders. Industrial platform ladders with safety railings and steps are available in the market. It is an A-frame with hinges, its platform on top of the frame is sturdy, and it is adjustable in components depending on the model. These ladders are ideal for tasks that require extended periods of height, such as electrical work, carpentry, or maintenance. They are used for long-lasting indoor or outdoor projects, such as painting, landscaping, installation, construction, or decorating at heights ranging from 60.96 to 548.64 cm, or 2 to 18 feet [35-44]. Longer-duration jobs are safer when performed on a platform ladder, which also offers a firm area for standing on and frequently has guardrails and tool trays to increase convenience and safety. The shortcomings of the ladder include being heavier and more unwieldy than typical step ladders, having a limited height range of only 487.68 cm or 16 feet, not being self-supporting, and requiring a level surface for its stable stand. Platform ladders are frequently used in construction projects, maintenance tasks, and warehouses. They are ideal for jobs that require the worker to remain up for extended periods without stepping up and down all the time. They provide a safe and sturdy place to stand when working at heights because they are often big and level. Platform ladders are the most stable compared to the other ladder types. Most of these ladders have a rail on which to lean and grasp. Both the steps and the platform are non-slip. The ladder type is also employed for large-scale house remodeling tasks, such as painting an entire outside wall. Platform ladders provide comfort and safety and are high enough to be used in place of an extension ladder. A platform ladder also makes it convenient for workers to free up both hands to perform more difficult tasks that require both hands, such as fixing fixtures or changing light bulbs [32-44]. A platform ladder is schematically shown in Fig. 6 cm.



Fig 6: A platform ladder [38,44]

3.3.8 Straight ladders

A straight ladder is also known as a single ladder. A straight ladder is the simplest of the ladder types. It has a single frame without extensions or hinges, with only rung-bridged side rails. A straight ladder is not self-supporting; therefore, it requires an anchor at the top for safe usage. To reposition and transport it, workers must first descend it. The ladder takes up more storage space compared to many other ladder types, such as step ladders, which fold into an A-frame, and extension ladders or telescoping ladders, which are collapsible into more compact forms. For some models, it has two side rails with evenly spaced rungs and anchor hooks at the top. Its height ranges from 121.92 to 914.4 cm, or 4 to 30 feet. The straight ladder is used for leaning against surfaces to reach high places, ideal for exterior home maintenance like gutter cleaning, painting, and roof repairs, as well as for construction, commercial tasks, and window washing. It allows for close-to-wall access because of its simple design, and its length is suited for this specific scenario because of its rigidity. Straight ladders are commonly made from aluminum, fiberglass, or wood. They are lightweight and easy to maneuver because of their straightforward design [36-44]. Fig. 7 depicts a straight ladder with its parts.

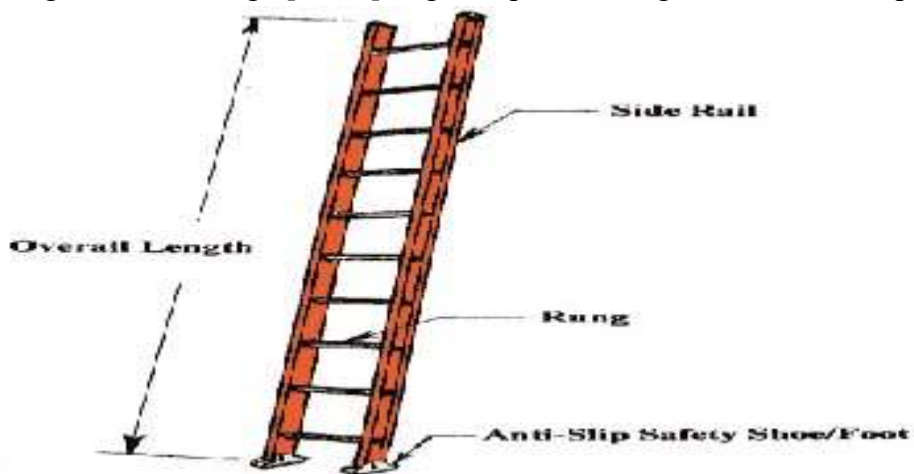


Fig 7: Straight ladder and its components [39]

3.3.9 Trestle ladders

A trestle ladder's distinctive feature is its ability to hold two people simultaneously [37-44]. It has a trestle ladder at the base, similar to a regular stepladder, and an extension ladder that can be adjusted vertically. Its length can be changed, and various components can be locked in and modified based on needs. It safely accommodates two persons simultaneously on opposite sides, making the accomplishment of any task considerably faster than

ladders that can accommodate only one person. As long as users maintain three points of contact at all times and use the ladder with all its four side rails, it offers reliable support because its design also provides a very robust base. Trestle ladders are utilized for both residential and commercial projects, where they can make some jobs better for two people to do simultaneously at the same height with enhanced safety measures instead of requiring two individual ladders. Commercial decorators, painters, and cleaners frequently use trestle ladders. Trestle ladders can be conveniently stored in little storage spaces such as in vans and other vehicles. The length of a trestle ladder measured along the side rail can reach up to 600.96 cm, or 20 feet. The highest standing level on a trestle ladder is a bit over 60,96 cm, or two feet above the ladder's summit. The product's side rail's specifications label must indicate the highest standing level. This ladder offers exceptional stability and is ideal for electrical or painting tasks when equipment and supplies are required on both sides. The drawbacks of trestle ladders include being heavier than single-sided step ladders which limits their portability and reduces their versatility compared to multi-position ladders for different purposes as well as having the capability of only reaching lesser heights of usually 121.92–365.76 cm, or 4–12 feet, [35-44]. Fig. 8 depicts a trestle ladder with its main parts.

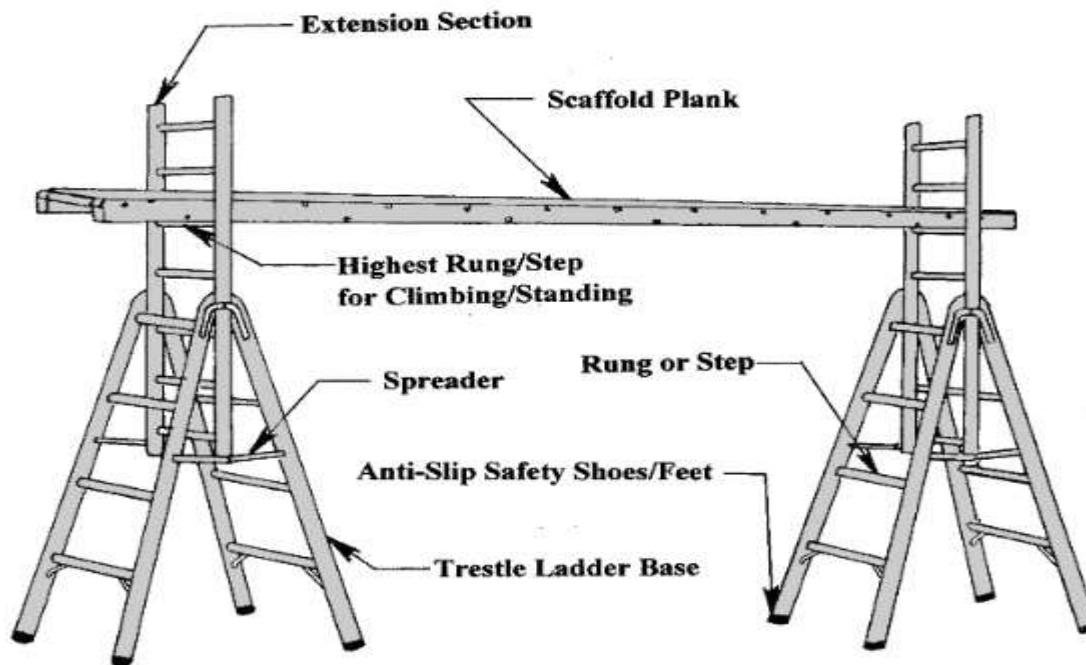


Fig. 8: Extension trestle ladder and its main parts [39]

3.3.4 Multipurpose ladders

The other names for multipurpose ladders are combination ladders, folding ladders, and multi-position ladders [40-46]. Multipurpose ladders can be changed into three distinct structural shape types, namely, stepladders, extension ladders, and scaffolds, making them incredibly adaptable. The multipurpose ladder has advantages in terms of adjustability, lightness, cost-effectiveness, home improvement, and commercial applications. This type of ladder can be extended to reach even very high areas. The ladder is portable even if it contains a large amount of material. A one-time purchase of this type of ladder will count as multiple purchases because of its many uses and high degree of customization. Because of their numerous configurations, these ladders can be used for home improvement projects such as painting, adding new equipment, or decorating, enabling tasks to be completed in a variety of ways. For instance, the horizontal freedom provided by the scaffold mode makes it perfect for painting. Workers, including engineers, painters, and maintenance personnel, frequently use multipurpose ladders to avoid the need for an arsenal of ladders. The multipurpose ladder enables them to have all their tools in one

location and travel light up it. Multipurpose ladders are designed to support heavy weights, making them suitable for heavy-duty tasks. They are ideal for contractors, technicians, and anyone who needs to adjust the shape of the ladder according to the job's requirements. Multi-purpose ladders are invaluable whether you are a technician doing electrical work or a construction worker managing multiple tasks [36-46]. Fig. 9 shows an image of a multipurpose ladder.



Fig. 9: Image of the multipurpose ladder [38, 45]

3.3.11 Combination of ladders

Combination ladders are a suitable option for homeowners who require a ladder that can be used for different jobs because they are multipurpose ladder types [38-45]. In contrast to conventional ladders made for certain purposes, combination ladders can be set up in different ways, such as an A-frame, extension, or staircase. These ladders are typically employed for various indoor and outdoor jobs, such as tree trimming and wall painting. They are also well-liked by do-it-yourselfers due to their adaptability and simplicity of usage. The adaptability of combination ladders is one of their main advantages. Because of their multipurpose design, homeowners may use them for various jobs without having to buy different ladders. They can also be used on uneven areas, such as hillsides or stairs, by adjusting their legs. Usually composed of lightweight materials like fiberglass or aluminum, they are portable throughout the house. Additionally, they have non-slip treads and locking mechanisms, which increase safety when working at various heights and angles. For homeowners who require a ladder that can be used for various chores, combination ladders are a great option. A combination ladder is a great purchase for any homeowner, regardless of whether you are a do-it-yourselfer or require a sturdy ladder for domestic duties. It is simple to select the ideal combination ladder for one's requirements because of the abundance of excellent possibilities. Numerous excellent choices exist for combination ladders. Due to their strength and adaptability, homeowners favor them. Owing to their folding portions, combination ladders are incredibly versatile for various operations, portable for storage, and perfect for anyone who requires a ladder with multiple configurations on the job site. They can be secured into an A-frame to be used as a freestanding ladder or as trestle or platform ladders. They can also be set up as an extension ladder with a long single run that leans on a wall. The vertical uprights are single pieces rather than joined, which distinguishes them from articulated ladders. In addition to being more

expensive initially than single-purpose ladders, they can be heavier and more difficult to assemble, and they need trained personnel to operate them securely in various configurations [37-46]. Fig. 10 shows a sketch of a combination ladder.

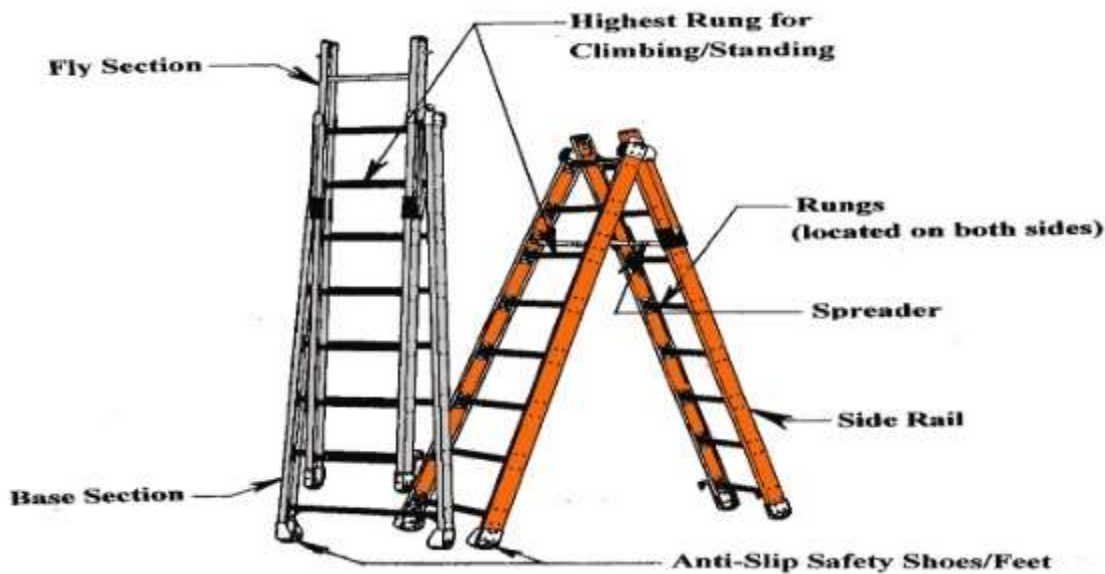


Fig 10: A sketch of a combination ladder with an extension ladder on the left and a trestle ladder on the right [38, 39]

3.3.12. The attic ladder

An attic ladder is a retractable, space-saving staircase that neatly tucks away when not in use and folds from the ceiling to offer good, secure access to an attic or loft area for maintenance or storage. Attic ladders are used to reach the top from the ground floor. They are set based on hinges and conveniently reach the top floor, allowing the loft to be obtained at an angle. These types of ladders are ideal for use on loft floors. The ladders are steep but strong enough to withstand loads. They are a suitable choice for reaching attics, narrow storage spaces, or hallways. An attic ladder is articulated on hinges, making an angle to the floor. This type of ladder makes climbing up and down easier, safer, and faster. Attic ladders are sturdy and easy to use, with built-in support and a non-slip design. On the other hand, the fixed location of the ladder limits specific access points, its installation may be challenging and require structural adjustments, and it usually has a lower weight capacity. Attic ladders are used to store seasonal items in the attic, perform maintenance tasks on heating, ventilation, and air-conditioning systems or plumbing, and access crawl spaces for wiring or insulation work. They are essential for homeowners with an attic, providing easy and safe access to this often-underutilized space. Unlike traditional ladders, attic ladders are specifically designed to fit into small openings and can be conveniently installed in homes. They typically fold into the ceiling, occupying minimal space and allowing the attic to be used as a storage or living space. Additionally, they are designed with safety features such as handrails and non-slip treads, making them safe and simple to use. These ladders are also easy to install, with many models coming with simple-to-follow instructions and all necessary hardware included. The simple-to-follow installation instructions mean that homeowners can install the ladder themselves, saving on professional installation costs. An attic ladder is an excellent investment for any homeowner, either for storage or living space. With a range of high-quality options, it is easy to obtain the right attic ladder for one's needs. Fig. 11 shows a sketch of an attic ladder [37-46].



Fig. 11: Sketch of an attic ladder [37-40]

3.3.13 Podium ladder

Among the different ladder types and their uses, podium ladders have ample standing space and are well locked. The ladder frame is also robust and safe for use. If one is looking for ladders to install the running cable and paint high walls, they can buy podium ladders [37-46]. Fig. 12 illustrates the podium ladder



Fig. 12: Sketch of the podium ladder [38-40]

3.3.14 Folding/articulated ladders

Folding ladders have pairs of locking hinges midway through the upright supports, allowing them to be locked and fixed into a variety of positions and configured as a standard step ladder, smaller trestle, and larger platform. The headlining feature of this type of ladder is its ability to fold quickly and require minimal storage space. This type of ladder is preferred for small tasks that are encountered in our day-to-day life due to its ability to change its height to fit job requirements, such as changing bulbs and cleaning fans and windows. A folding ladder occupies less space, and it is lightweight. It is a unique ladder type that offers a compact and easy-to-store solution for various tasks. Unlike traditional ladders, which can be bulky and difficult to store, folding ladders can be conveniently folded and stored in small spaces such as closets or under beds. They have pairs of locking hinges midway through the upright supports, allowing them to be locked and fixed into a variety of positions and configured as a standard step ladder or smaller trestle, larger platform, etc. They are typically used for indoor tasks such as reaching high shelves or changing light bulbs. They are also popular among do-it-yourself

enthusiasts because of their versatility and ease of use. Folding ladders are typically made of lightweight materials such as aluminum or steel, making them convenient to move around the house. They are also convenient to use and typically come with safety features such as non-slip treads and locking mechanisms. Additionally, many ladders are designed with features such as trays for holding tools or paint cans, making them an excellent choice for do-it-yourself enthusiasts. Many high-quality options for various tasks exist in the market for a folding ladder. Folding ladders are an excellent choice for homeowners who require a compact and easy-to-store ladder for indoor tasks. Whether one is a do-it-yourself enthusiast or needs a reliable ladder for household tasks, a folding ladder is an excellent investment for any homeowner [38-46]. Fig. 13 shows the outlook of the folding ladder.



Fig. 13: An outlook of the folding ladder [38]

3.3.10 Flexible/Rope ladders

A flexible/rope ladder, also called Jacob's ladder, is used where storage space is extremely limited and weight must be kept to a minimum, or when the thing to be climbed is too curved for a rigid ladder. A rope ladder has rigid or flexible rungs, and climbing it requires more skill than climbing a rigid ladder because it tends to swing like a pendulum. Flexible/rope ladders are suitable for emergency purposes, such as the need to escape from a high building window to a safe place. They are also used for recreational purposes, such as caving. The rope ladder is a special kind of ladder that enables homeowners to ascend and descend in unusual areas. Rope ladders are ideal for climbing in confined or difficult-to-reach areas because they can be adjusted to different lengths, unlike regular ladders that have a set length. Usually, they are employed for outdoor activities such as scaling trees or reaching roofs. Homeowners who wish to design distinctive play areas for children like these ladders. These ladders' main advantage is being able to be used in unusual places. They are a suitable option for getting to difficult places because they can be fastened to various objects, such as poles and trees. They are a flexible ladder option because they are lightweight and portable. They are also user-friendly. They are safe and simple to use because they usually have safety measures such as strong rungs and ropes. When not in use, they are easy to roll up and store, saving important storage space. Many high-quality rope ladder options are in existence and popular among homeowners due to their durability and versatility. Rope ladders are an excellent choice for those who require a ladder that can adapt to unconventional spaces. With a range of high-quality options, finding the right rope ladder for one's needs is easy. The advantages of these ladders are their portability, lightness, compactness, the ability to be used in spaces where fixed ladders are not feasible, and usability in emergency kits or for temporary access. However, they have limited stability due to flexibility, require careful balance, generally have a lower weight-carrying capacity, and are not suitable for long-term or heavy-duty use [36-46]. Fig. 14 shows the appearance of a rope ladder.

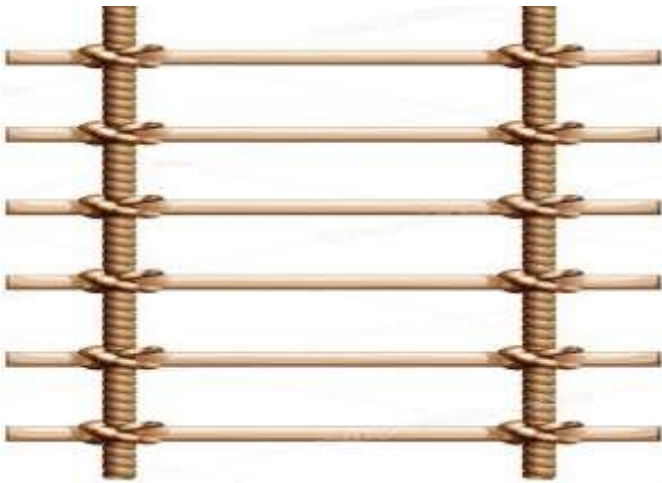


Fig. 14: The appearance of a rope ladder [38-44].

3.3.15 Boarding and pool ladders

Boarding and pool ladders, sometimes known as swim or diving ladders, are frequently used on the sides or sterns of boats to allow people to climb into and out of the water, as well as in swimming pools. Most of the ladders are constructed from plastic, wood, or metal steps with a rough upper surface for grip and metal rails at the sides to support the steps and serve as user handrails. Boat boarding ladders can be fixed; however, they are typically moveable and fold up when not in use to reduce drag when moving underwater. Boarding ladders can also be used on other types of vehicles or boarding steps that are directly supported by the vehicle structure [35-44].

3.3.16 Hook ladders

A hook ladder is designed with hooks at its top to hook onto a structure. It is typically used in firefighting and rescue work. A hook ladder allows secure placement over ledges or windowsills, is highly specialized for rescue operations where fixed ladders are not feasible, and is ideal for rapid deployment because it is lightweight and portable. Hook ladders are limited to specific rescue or firefighting tasks, require training for safe use, and are not suitable for everyday tasks due to their specialized design. Hook ladders are particularly advantageous for tall buildings, enabling firefighters to quickly traverse between floors and access different parts of a building without needing to reach the ground floor or a larger ladder lorry. The lengths of the hook ladders vary from 300 to 500 cm, or 10 to 16 feet [35-46]. Fig. 15 shows the appearance of a hook ladder.



Fig. 15: The appearance of a hook ladder [38-45]

3.3. 17 Library ladder (track ladder)

A library ladder is a specialized ladder that typically features a sliding or rolling mechanism that allows it to move smoothly along a fixed rail or track installed on shelving units, a loft, or high walls, providing convenient and safe vertical access without being cumbersome or requiring frequent repositioning. Library ladders are commonly used in libraries or high-storage areas for convenient movement to access high bookshelves. A library ladder is stable and secure on a fixed track, reducing tipping risks; convenient to slide across the track, providing efficient access to a wide area; durable; and often integrated into library or store designs. The ladder type has fixed installation, which limits its mobility and requires significant setup and customization, and it is not practicable for non-fixed shelving or outdoor use [38, 46]. Fig. 16 shows an image of a library ladder.



Fig. 16: Image of a library ladder [38-45]

3.3.18 Sectional ladder

Sectional ladders consist of interchangeable interlocking components that make them customizable in height based on the component combinations constructed by addition or reduction. Although they cannot be substituted for all-purpose extension ladders, they are ideal for tasks requiring a specific range of heights or access. The main benefit of these ladders is their portability and ease of transportation, enabling them to be assembled and stored in confined spaces. Firefighters and other specialist rescue workers frequently use these ladders. The other merit of these ladders is that their customizability in height based on additional components makes them very versatile. They are also stable, space-saving, portable, and easy to transport. The demerits of ladders are; they are time-consuming to set up due to the assembly of components and the need for the components to be carefully aligned for stability, they are less commonly used outside of emergency services, they are costly, and they have a specialized nature [35-47]. Fig. 17 shows an image of a sectional ladder.



Fig. 17: Image of sectional ladder [48].

3.3. 19. Fixed ladders

A fixed ladder is one that is permanently affixed to a structure. It is commonly found on commercial buildings, warehouses, and industrial sites. Examples of fixed ladders are fixed access ladders, fire escape ladders, loading dock ladders, and ship ladders. These ladders provide constant access to elevated areas, thereby reducing the setup time. They usually incorporate a safety cage or rail to prevent falls and are highly durable and suitable for frequent use. However, they are limited to a single access point, are not portable, require routine inspections and maintenance to ensure safety, and are generally challenging to retrofit with additional safety features [37-47].

3.3.20 Hydraulic ladders

A hydraulic ladder is a ladder type whose height position or platform is hydraulically operated to smoothly lift and lower worker(s) and tools with reduced manual effort and provide stable and safe access for performing various tasks in residential, industrial, and construction settings [26-32]. Hydraulic ladders are classified into two categories: scissor and vehicle-mounted hydraulic ladders. Hydraulic-operated ladders have outstanding advantages that include accident prevention, remote control, and automated moving mechanisms compared to other ladder types. Hydraulic ladders are used in facilities such as warehouses, factories, street light repair, and many other related applications [25-32]. The hydraulic scissor ladder, also called a scissor lift, has a platform and provides vertical movement in a crisscross pattern using linked, folding supports. The base of the scissor ladder can be either fixed or movable with sliding wheels, and one end of the scissor is attached to the base. The other end of the scissor ladder is connected to the flat platform that can conveniently raise the load to any desired height and lock it to prevent falling. The crisscross hydraulic scissor arm is placed between the base and platform, and it can be extended to cylinders connected in between with the applied hydraulic power. The ladder starts lifting when the pump pressurizes the fluid and transfers it to the hydraulic cylinder. The maximum load capacity and reach of the crisscross hydraulic ladder depend on the number of its cylinders and their retracted lengths. A compatible fluid column supports the lifted scissor ladder. The raised ladder can be lowered by opening the down valve and returning the oil to the cylinder. The scissor ladder is most suitable for warehouses and factories with indoor work [26-32]. The vehicle-mounted hydraulic ladder is usually attached to trucks or vans, and it provides greater convenience for field workers to work safely at heights. Firefighting vehicles used for rescue operations often include hydraulic ladders. The cylinder is the major component used for ladder lifting. When not in use, the ladder rests on the truck deck and is raised when hydraulics are used. The hydraulic ladder mounted on trucks or

vans provides better flexibility, mobility, and reach. A hydraulic ladder can be used to simplify the high-altitude work of street light maintenance. The operation of this ladder is effectuated by the control panel located inside the cabin. Vehicle-mounted ladders are mostly used for on-site work [26-32]. The inclination angle of the ladder attached to a vehicle is adjustable by 360° rotation to provide easy access. Hydraulic ladders are transportable. They have the following pros [25-32].

- i. They can be used even with no support.
- ii. They are very safe to lift people up to any height above the ground.
- iii. They can be easily moved to the required locations.

The main disadvantage of hydraulic ladders is their generally slow operation in conveying people to the required work height and their higher costs than most other types of ladders. Fig. 18 shows a sketch of a hydraulic ladder.



Fig. 18: Sketch of a hydraulic ladder [26-27]

3.3.21 Types ladders by material makes

Fiberglass ladder

The fiberglass ladder is one of the newest choices for applications requiring a strong and reliable ladder for industrial spaces [48]. Fiberglass is a plastic that has been reinforced using glass fiber. During the manufacturing process, glass fiber is flattened and reformed to create a strong fabric that can be used for ladders. These ladders have been designed to combine the best of other commonly used ladder materials, such as timber and aluminum. They are highly durable and resistant to dampness and rotting, giving them a wider range of possible uses. Unlike timber, fiberglass is not prone to splintering and does not require daily maintenance. Fiberglass ladders are also non-conductive to both hot temperatures and electricity. Fiberglass is extremely strong and, in some cases, beats aluminum in this area. Aesthetically, many other materials have a broader choice of colors than fiberglass. Due to its high cost and weight, a fiberglass ladder is not usually a suitable choice for domestic use. Fiberglass can be used to create single-section, platform, or extension ladders to suit many requirements. Fiberglass ladders are a suitable choice for electrical tasks or high-heat environments. They are also suitable and safe for damp or wet environments because of their water resistance. Although they are a flexible solution for industrial work, they have some disadvantages. They generally cost more than other ladders but have a long lifespan and are weatherproof in wind, rain, or heat. Their sturdy construction also makes them heavier and more challenging to move than aluminum ladders, and they are not always the optimal choice for heavy-duty needs or small business settings. They are corrosion-resistant and electrically non-conductive, making them ideal for outdoor and electrical applications. They offer excellent safety in potentially hazardous environments. They are generally stronger, more weather resistant, more flame resistant, and more resistant to electricity and electric shocks

compared to aluminum ladders, depending on the grade of the material used. The cost of a 731.52 to 1097.28 cm, or 24 to 36 feet, fiberglass ladder varies from N450, 000 to N495, 000 [48-55].

Wooden ladders

Wooden ladders are made of wood [48]. These ladders have high strength and aesthetic appeal, but they are becoming less popular because of their weight and splintering risk. They are suitable for certain specialist jobs or for people who prefer a more conventional appearance. Wooden ladders are an excellent option for use in commercial, industrial, and residential contexts. Douglas fir is one of the most widely used wood species for ladders. It is far less expensive than oak wood, which is also widely used. It is more stable and can support more weight than other wood types. These ladders are made of firm and durable wood, and they are not expensive, allowing for ownership to suit several different needs. They are a cheaper and lighter option for easier transportation than fiberglass ladders. They are non-conductive and suitable for both indoor and outdoor applications, making them safe for use around electrical items. A wooden ladder can be the right material for those seeking a ladder with a long lifespan at a cheap rate. These ladders have remained popular due to their many benefits, but they have some drawbacks. These ladders are notably heavier than other ladder types of comparable sizes; therefore, the larger ladders may need to be moved by more than one person. They also need to be maintained appropriately, regularly checking for cracks and damage to keep them in the best possible condition. While they are resistant to heat, they also easily catch fire, which can be a safety issue. These ladders are also unsuitable for regular outdoor work in poor weather. Although they are resistant to adverse weather conditions, they are prone to dampness, rot, and pests such as woodworms. They need to be kept indoors when storing them to help maintain their condition, though this can be inconvenient if there is limited storage space available for them [48-55].

Aluminum ladders

Aluminum metal has many benefits as a construction material, including the creation of sturdy and reliable ladders [48-55]. Aluminum ladders are often more affordable than many other options and are lightweight enough for a single person to lift. They are also extremely strong, durable, and corrosion-resistant. An aluminum ladder can be used outdoors, as it will not deteriorate easily in challenging weather conditions. In addition, the ladder type is nonflammable and nonmagnetic, so it can be used in various industrial settings where heavy or light work is required. While aluminum ladders are widely used and have several benefits, they are not suitable for every industrial space because aluminum is conductive, causing electric shocks. High-heat situations are also not recommended for aluminum ladders; therefore, it is important to consider these when selecting the correct ladder. Aluminum ladders are popular for general use and are easily transportable. They are suitable for a wide range of indoor and outdoor tasks, such as painting and maintenance. They are lightweight, cheaper, and less likely to crack than fiberglass ladders [48-55].

Steel ladders

Steel ladders are a dependable option for heavy-duty industrial tasks because of their remarkable strength, stability, and longevity [48-55]. They are perfect for jobs requiring long-lasting performance and support under frequent intense use because of their sturdy design, which enables them to withstand the rigors of factories, warehouses, and construction sites. Steel ladders offer a safe platform for professionals working in demanding conditions because steel ladders have better duty ratings than ladders made of most other materials. Steel ladders have certain drawbacks. It is difficult for them to move around while doing repetitive or high-altitude jobs because of their relatively greater weight. They are dangerous for any electrical work because steel conducts electricity. Steel ladders are susceptible to rusting, corrosion, and dampness as well as heat and electrical conduction if left

in humid circumstances or exposed to moisture. To avoid or minimize their corrosion, it is necessary to properly store them and periodically maintain them. These ladders are used in rugged settings, such as industrial buildings and warehouses. To comply with standard norms, these ladders are made of stainless steel, painted, or galvanized to prevent corrosion. They are less expensive than fiberglass and aluminum ladders, rot-resistant, and appropriate for heavy-duty tasks. They are also heavier than aluminum and fiberglass ladders and require regular maintenance [8-55].

4.0 CONCLUSION

An overview of the principal ladders currently in use has been provided with basic information on their overall importance, material composition, safety issues, primary types, key characteristics, research and development, selection needs, applications, and upkeep. All ladder types are used to simplify work or solve the problem of accessing unreachable elevated heights to accomplish various tasks, according to the review report. Several factors, such as portability, ease of use, storability, cost-effectiveness, compactness, safety, height reachability, adjustability, stability on the surface base, and material make, must be considered when designing or selecting a ladder for a specific job. To avoid ladder accidents such as falls that cause loss of life or severe injuries, all the safety factors, such as the duty rating, stability, and material make, must be considered in designing or selecting ladders. The overview also shows that the area of ladder design and development, selection and use, and maintenance is very significant in mechanical engineering and has intense research and development and manufacturing and commercial activities involving cutting-edge technologies. The overview provides consolidated current information on ladders that can be consulted for understanding their basics with respect to safety issues, selection and uses, design improvements, and appreciation of any research and development gaps for the way forward.

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