

*Research Article*

## Semi-automatic Bar Storage and Retrieval System

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### Abstract

*In all types of industries, selection of material handling methods play an important role with various factors such as production rate, efficiency, accuracy and cost, depending on that. This paper provides information regarding different material handling methods and storage systems. According to factors such as objective of industry, floor space and required cost etc various systems can be selected. Mainly for storage, different racking systems can be used e.g. structural racking, narrow pallet racking, double deep racking etc. The details of all these systems with prime focus on structural racking are given. An optimum material handling solution for industries with medium production, lesser floor space and minimum human intervention is discussed by combining structural racking, AS/RS and scissor lift. The concept of this combined mechanism is explained theoretically. The structural pallet rack is used for storage of material with retrieval mechanism containing rollers. Scissor lift enables separate access to the pallets with little human intervention. The conceptual study of mechanism proves it to be an optimum solution of material handling for industries with less floor space available and low investment cost.*

**Keywords:** Material handling, Structural rack, AS/RS, Scissor lift, Semi-automated bar storage and retrieval

### 1. Introduction

Material handling is the unavoidable part of any production or assembly industry. Previously, material handling was done manually or using man power. Even today, in many small scale industries, the same system of manpower is used for material handling. But, as the industries flourished, they felt the need of proper system for handling these materials. This material can be raw material of the factory, intermediate goods or final products that company keeps in stock. Although the quality of final product does not directly depend upon these material handling systems, the time required for storage and pulling of material, work environment, safety of workers are some factors which contribute to the need of material handling system. As the industrial revolution took place, the demand for the products increased. Hence industries started with the concept of mass production. And with this increased demand, the requirement of raw material also increased, due to which it became necessary to keep this raw material in proper racks rather than on floor. Various material handling methods have a positive effect on company profit as it helps increase the productivity. Material handling methods also help to reduce labour cost, storage and handling cost, as well as they reduce the wastage of raw material as maximum amount of raw material is protected from

environmental factors, preventing the components from rusting. With proper selection of material handling method maximum floor space can be utilized.

Industries such as process industries, heavy manufacturing industries, construction industries, mining industries, shipbuilding or aircraft industries deal with huge components easily affected by external factors. Hence material handling and storage system plays a vital role in such companies.

Material handling equipments encompasses various tools, storage systems, vehicles, etc for transporting, storing, sorting and protecting the components. These material handling equipments are classified in four types, namely

- Storage
- Engineered systems
- Industrial trucks
- Bulk material handling

#### 1.1 These types are further discussed in this paper

- **Storage:** Storage systems are basically non – automated systems. These storage systems are used to hold and buffer the material during the processes and downtime of the company. These non – automated storage systems are used to build up the stock. Also, many companies have marked improvement in efficiency of products and decrease in lead time of the products. Pallet racks,

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drive through and drive in rack, sliding racks, etc. are the various types of racks used for storing of material. Stacking frames, shelves, bins are also for storing material.

- *Engineered system*: Engineered system consists of various parts working together to form a system. These engineered systems are usually automated. The best example of this system is AS/RS i.e. Automatic Storage and Retrieval System.
- *Industrial truck*: Industrial trucks refer to various transportation items and vehicles to move the material in the company. Hand trucks, pallet jacks, pallet trucks, order picker, etc are the various vehicles used to move the material inside the company.
- *Bulk Material Handling*- It refers to storing and transportation and control of various materials in loose bulk form. Conveyer belts, stackers, bucket elevators, etc are various methods for material handling.
- There are various racking systems selected according to the need, usage and design of warehouse. The most common racking systems are selective racking system, Double deep racking, Narrow pallet racking, Drive-in racking, Push back system, Pallet flow racking, Mobile pallet racking, Carton racking etc. Out of these systems the most widely used are explained in this paper.

## 2. Selective pallet racking

This type of racking system is most widely used having the lowest cost among all the material handling solutions. It usually comes in two different configurations viz. Roll formed and structural bolt together configuration. In roll formed selective pallet racking system the holes on the upright column are having 'teardrop' shape. These are mainly used when there are varying load sizes. On the other hand, structural bolt configuration has beams attached to the upright by bolts. The basic components of selective pallet racking are frame, footplate, shim, beam, post protector, skid support, row spacer and pallet support.

Selective racking allows access to a large range of stock keeping units with FIFO (First In First Out) type handling. It needs minimum floor space and provides good product protection and order picking. As this system is mainly used for low pallet storage capacity, for medium and high storage requirement large initial cost investment and large warehouse space is needed. It is not suitable for frequent loading and unloading.

## 3. Double deep racking

This racking system is similar to selective racking system. It has two rows one after the other allowing deep storage of pallets. This is one of the best methods for increasing the warehouse capacity when other racking systems are not suitable. In double deep racking 50% pallets are accessible at a time and it

requires specialised trucks or alternative mechanism for accessing all the pallets. Double deep racking also has roll formed and structural bolt beam configurations similar to selective pallet racking. To be precised, it provides 30% more storage capacity than selective pallet racking.

## 4. Narrow pallet racking

This type of racking system is mainly used for larger vertical storage capacity up to 17 meters. In narrow pallet racking the pallets are marginally larger in size than the material to be stored. As the height of this system is very large, it requires higher rigidity with accurate manufacturing tolerances. The storage capacity of narrow pallet racking is 40% more than the conventional selective pallet racking. It is suitable for warehouses having super flat floors and provides good stock rotation, order picking and product protection. [3]

## 5. Drive in racking

Drive in or Drive through racking are often interchangeable terminologies. Typically drive-in Racking system has single entry and exit point following LIFO (Last In First Out) inventory management. In this system pallets are stored back to back without aisles and are used for extremely dense storage. They are mostly used for products that are fast moving or products that are unaffected by long term storage. For accessing the pallets stored deep inside forklift or other suitable mechanism is used. This racking system requires 75% less space than standard selective pallet racking system. This system is suitable for warehouses where products are produced in batches and there are high stock and low stock keeping units (skus').

## 6. Structural rack

For long, complex shaped or heavy loads, cost and manual efforts are increased resulting into less productivity. In this situation, structural rack serves the major purpose of reducing manual efforts and cost. This Structural rack system is specially designed for materials like beams, bars, pipes, sheets, etc with different weight ranges, varying in length. The choice of the suitable system depends upon the material to be stored, its height, weight and overall size. Structural rack is used for light duty, medium duty and heavy duty materials. For light duty materials, loads can be handled manually. For medium duty and heavy duty materials, appropriate lifting mechanisms or vehicles like forklift and overhead cranes can be used.

Structural racks can be distinguished in two different types, viz single sided and double sided racks. In a warehouse, single sided racks are placed against the walls allowing access from only one side. Double sided racks provide the access from both sides contributing to better storage capacity.

### 6.1 The detailed description of the structural rack is as follows

1. *Columns*- Column is the fundamental component of structural rack which supports the whole assembly. It consists of slots at specific intervals for positioning of the arms. The core has attachment points for joints and cross bracing. At the bottom of the columns are support plates, reinforcements and holes for anchoring the bases. Single I beams are generally used but two beams can be joined together to further increase the load bearing capacity. Size of I beams can be selected from standard charts.

2. *Base*- The base consists of base plates that provide support and enable the column to be easily levelled and anchored to the floor. The front of the bases includes supports for stoppers, if required. In some cantilever rack designs base and column are considered as a single unit known as 'upright'.

3. *Arms*- structural arms are the heart of the rack system as proper selection can make or break a successful storage plan. Generally for cylindrical objects and bars, arms inclined towards the column are used to avoid slipping of the bars. For heavy duty cantilever racks hooked arms or bolted arms are used. Hooked arms are attached to the column by hooks and the slope is maintained by an accessory to avoid accidental damage. Bolted arms are generally used with very heavy loads or in situations where minimal movement of the arms is required.

4. *Arm stops*-Arm stops are considered as an optional component and is generally used for heavy duty applications. The stops consist of a round tube and a plastic protection plug which are inserted in the top hole on the supports and fit into the lower tab, thereby preventing loose goods from falling.

5. *Safety pins*-They are used to prevent the arms from accidentally slipping out of place.

6. *Braces*- They are mainly used to provide lateral stability to the system. They are structural channel members that are bolted between pairs of uprights. Brace lengths are measured from centre line of upright to centre line next upright. X-bracing is generally used to increase the stability of taller uprights.

### 6.2 Advantages

- Long, short or complex shaped items can be easily stored
- Easy front loading without any obstruction
- Structural steel components provide superior strength and durability
- Highly efficient use of floor space with maximum storage capacity
- Suitable for high density storage capacity
- Braces and uprights ensure better stability
- Punched holes run the full height of each column for excellent adaptability and versatility.
- Cantilever racks are easy to install and reconfigure. Such flexibility allows a wide variety of materials to be stored.

- Cantilever racks improve the handling of material and reduce the time, ultimately increasing the productivity of warehouse.
- It ensures better safety than manual handling.

### 6.3 Disadvantages

- As compared to floor stacking cantilever rack system requires a much more financial investment.
- Manual handling and efforts cannot be completely avoided as for loading and unloading human efforts are required.
- Although double-sided can utilize same number of columns as single-sided, it requires multiple wide aisles to access.

### 6.4 Safety measures

- Load should not exceed the maximum capacity
- Nuts and bolts should be checked to verify they are tightened and that safety locks are functioning. Inspections racking should involve checking the hardware to ensure it is tightened, looking for missing pieces in hardware, and a visible assessment to check whether racks are level, square, and plumb.

## 7. Automated Storage/ Racking system (AS/RS system)

The racking systems discussed so far under material handling, have human intervention in some or the other way. Some systems need human efforts for loading and unloading whereas others require human efforts for material classification, sorting and picking. In industries having large production rates huge amount of material needs to be handled at a time. If traditional material handling and storage systems are used in such big industries it will lead to a lot of difficulties including huge labour cost investment, manual errors, low handling rate resulting in low production and other safety issues.

In these situations AS/RS system is the most suitable method to be adopted. AS/RS system provides better inventory control, less utilization of floor space with improved production rate and efficiency.

As the name suggests Automatic Storage and Retrieval System is a material handling method comprising of components and parts that can be automatically handled and retrieved with material storage facility. ASRS system allows storage of any nonstandard parts, complex materials or odd shaped components with no difficulty in loading and unloading. Mainly, the functions of ASRS system include removal of a specific item from storage system automatically, placing the same on desired machine or location and again returning to the initial point.

The heart of ASRS system is its Storage and Retrieval system (S/R). The primary function of Retrieval System is to locate the correct object and retrieve it within a given time span. For this purpose,

material classification techniques such as colour coding, barcode system etc are used. Scanners or sensors are located at the transfer location to scan the identification code and the appropriate material is identified and transferred. Specifically for retrieval, rollers with actuated retainers or shuttle system can be used.

7.1 Detailed components and constructional details of ASRS system are as follows:

- **Storage structure-** It involves the basic framework that supports the storage of material. Storage system can be selected according to the warehouse design, capacity and production rate. The racking systems discussed so far can be used based on their characteristics. The three-dimensional space used in terms of pallets is known as storage space.
- **Storage and Retrieval machine-** It mainly consists of the mechanisms used to load or retrieve the pallet for example rollers with retaining actuators or shuttle system. S/R system is capable of moving in all three directions. The systems that are not completely automated or when human intervention is necessary forklift or overhead cranes are used to load and unload the material.
- **Pick up and Deposit Station (P/D)-** When the material is not required to be directly transferred to a machine, it is stored in the pickup and deposit station for easy access.
- **Control unit-** As ASRS is a completely automated system, all the movements of S/R system are controlled by a computerised control unit. By using control panel any pallet can be easily and safely accessed without human intervention. The major requirement of ASRS system is avoiding the failure of control unit.

7.2 The advantages of AS/RS are as follows

- 1) AS/RS is the most suitable material handling and storage system for warehouses and industries where a large volume of material is to be stored.
- 2) It consists of computerized programs and subroutines to transfer a particular component from one location to another desired location. As a result it can be used for all types of standard or non-standard components irrespective of their size, weight and shape and with the same accuracy and efficiency in the work.
- 3) AS/RS requires minimum floor space with optimum storage capacity. Horizontal as well as vertical movement ensure better accessibility with faster rate of operation.
- 4) This system helps in inventory control to a large extent. Companies can keep the record of production and demand and accordingly can manage the storage of material with utmost safety. For the industries that need to fulfill Just In Time demands, AS/RS is the best option to opt for.
- 5) The labour required for conventional material

handling and storage systems is completely avoided in AS/RS resulting in less time required for loading and unloading, better accuracy, and maximum safety.

- 6) The cost required for labour and other handling tools is reduced making it a more economical solution of storage and material handling.
- 7) AS/RS makes use of the most effective technology providing more comfortable and convenient work environment.

7.3 Some limitations of AS/RS are

- 1) AS/RS handling requires technical knowledge and skills.
- 2) The initial investment cost of AS/RS is very high hence it is suitable for companies with large storage and production need only.
- 3) As no human intervention is there, if the control unit fails the whole system is interrupted and production is stopped till the problem is solved or till the whole unit is changed.

## 8. Semi-automatic bar storage and retrieval

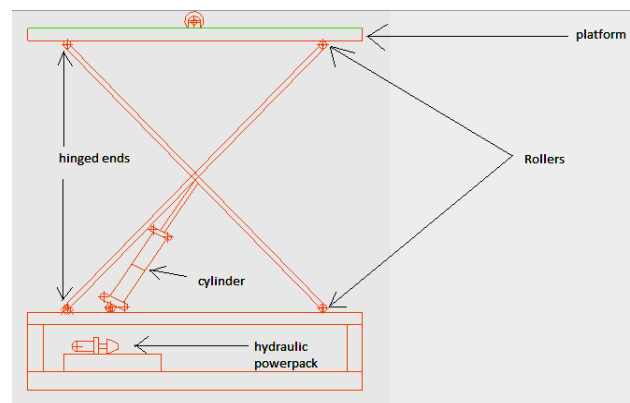


Fig 1 Semi-automated bar storage and retrieval

As discussed above, AS/RS is used in large scale industries, where the storage required is quite large. But in small scale industries, where material to be stored is less, AS/RS cannot be used. Also, the cost of AS/RS is too much for small scale industries. Space is another factor due to which use of AS/RS is restricted in small scale industries. Although, in such cases storage systems like Cantilever rack and other systems that are discussed above can be used, but these systems being non-automated have limited usage. Hence to avoid this problem, we are going to discuss the solution that is semi-automatic and can be applied in industries having constraints like space and cost.

In this system, we will use the Structural rack with rollers between the structural pallets of the rack. Bearings will be inserted in the structural pallets that are at the end of the rack. Outer diameter being same for rollers and bearings, a pallet will be mounted on these rollers, upon which the bars or the components will be placed. The load of the bars that will come on

rollers from pallet, will transfer from arms to the columns and then to the base of the rack. From base, the load will be transmitted to the ground. Braces will be used for the stability of the rack, as in case of cantilever rack.

The pallet that is being used to put the entire load on, will be pulled out on the platform of scissor lift. This pulling mechanism will be done by the man on board on the platform of the scissor lift. The person will pull the pallet like a drawer. Force required to pull this pallet will be very low due to rollers and bearings used in the rack. As the person pulls the drawer out, it will be easier for him to choose the material and hook it to the crane. As the component required is hooked to crane, the scissor lift will come down and person can safely come down to continue his work. The lifting mechanism i.e. scissor lift is mainly classified into 3 types viz., hydraulic lift, pneumatic lift and mechanical lift. In this mechanism, hydraulic lift are taken into consideration to avoid the maintenance required in mechanical lift. Hydraulic lifts are more powerful that can sustain the weight which is distributed uniformly.

#### 8.1. The major components used for this semi-automatic bar storage and retrieval rack will be

- **Base:** Base will provide the required support to the rack and is mainly used to anchor the rack to the floor.
- **Columns:** Columns being the fundamental component of any rack, it is mainly used to hold the beams of the rack and the cross braces.
- **Braces:** Braces will be used to support the rack and improve the stability of the rack.
- **Beams:** Beams will be used to support the structural pallets that will be bolted to the beams.
- **Structural pallets:** These structural pallets will be used to transmit the load from rollers to columns.
- **Rollers:** Rollers will be attached to the structural pallets that are used for load transmission. Rollers will hold the plate for smooth operation of pulling the plate out and pushing it inside.
- **Bearings:** Bearings are used for the same purpose as rollers, i.e. to pull and push the plate smoothly. Bearings will be used only at the two ends of the plate. It will ensure the smooth performance of pulling and pushing the plate on the platform.
- **Plate/Pallet:** Pallet will be placed upon the rollers and bearings and the bars or the material to be stored in the rack will be stored on this pallet. This pallet will come on the platform of scissor lift so as to allow the worker to choose and hook the correct material in the overhead crane. The man on board on scissor lift will pull the plate out and hook the selected material in the overhead crane or will be given for further processing.

#### 8.2. The major components used in scissor lift will be



**Fig 2.** Scissor lift

- **Platform:** It is the most essential component of scissor lift that carries the entire load on the scissor lift. This platform is designed to withstand high stresses.
- **Scissor arm:** Scissor arm is used to lift the platform to the desired height. These arms bears the load of the platform and the components placed on the platform. If the height of the platform desired is more, then more number of arms are used. In some journals, scissor arms are also referred as legs of the lift
- **Coupler:** Coupler is a supporting element that supports the hydraulic cylinder to lift the weight of the platform along with the pallet weight and man on board.
- **Hydraulic cylinder:** Hydraulic cylinder is the key element of the scissor lift. Hydraulic cylinder is used to raise the platform. the whole assembly is extended upwards when the pressure is applied at the lower parts. Double acting cylinder is preferably used in scissor lift mechanism.
- **Base Plate:** Base plates are provided to anchor the mechanism to the floor. Arms are bolted to these base plates. Base plates are provided at the bottom to support to the mechanism.

#### 8.3. Advantages of combination

- Space required for this mechanism is far less than AS/RS
- Cost required for this mechanism is less than AS/RS
- Maintenance required for this mechanism is less than AS/RS
- Material handling becomes easy in small industries due to this mechanism where space and cost are major constraints
- Hydraulic system makes the use of system easier and independent of single computer system.
- Use of scissor lift makes it safer to use than cantilever rack with still having some human intervention.
- It is easy for a worker to choose the component from the pallet and then hook the desired component to the crane or keep it near P&D.

## 9. Future Scope

The mechanism is not robust due to use of hydraulic cylinders and actuators in it. Also, cost of the mechanism will be reduced if used for light duty application, as the pressure required will be very low in light duty applications. Although the mechanism is semi-automated, use of overhead crane or forklift is not completely avoided to load or unload the material. The analysis of the entire mechanism is yet to be completed which will show the real time problems that will be faced by company while using the system. Also, all the possible failures will be shown on software after completion of analysis.

## 10. Conclusion:

Cantilever rack is preferable when only storage system is required without any automation. It is mostly used for storage of items whose one dimension is much larger than other two dimensions. AS/RS is used for components that are mainly kept in cartons. These cartons are pulled out of rack with the help of shuttle system as discussed above. Although AS/RS is most automated system till date, it requires lot of space and money. Hence it is used in large scale industries, where material handling is major concern where these constraints does not act as an important factor. Since it becomes difficult for small scale industries where automation is required but have the constraints of cost and space, combination system can be used effectively to lift heavy objects within less space and which is cheaper with human intervention. This system can be modified by anyone according to their own requirement of space and weight.

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