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Design and Fabrication of a Retractable Bridge

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Abstract— **The objective of the project was to design and build a new type of bridge that would retract automatically to give way for ships to pass when movement in the river or canal is picked up by a sensor on the bridge. The idea of the retraction was to bring about an innovative design of bridge structure that couldn't be found easily at some part of the world. The mechanism of the retractable part would be design that would bale to support while maintaining balance and position the retractable part in correct order every time its retracted.**

The mechanism of the bridge would be designed by a mechanical engineer who would have knowledge of the mechanical part and detail the bridge movement accordingly. A civil engineer would later come into picture while structuring the bridge which would require a stable centred structure to maintain its stability and balance during the retraction process. The material used for the construction of the bridge and foundation should be strong enough and engineered to carefully nullify the vibration produced during retraction as the bridge would be easily affected by movement in the water and movement of air.

Index Terms— **Pneumatic Cylinders, Rolling Bridge, Retractable Bridge, Transportation System.**

I. INTRODUCTION

The Rolling bridge was first created in 2004 to provide a link for pedestrians to move across an inlet of the canal in Pedington. However, this bridge worked on the principal of hydraulic cylinders actuating when needed. The purpose of our bridge construction was to build the same bridge using the principal of pneumatic cylinders. The pneumatic design and initial planning was done in labs on Don Bosco College of Engineering, Goa. Fabrication was later carried out at the college campus while certain sections were fabricated in fabrication units outside the college campus due to unavailability of certain equipment's. The aim was to create a masterpiece of attraction that would standout for everyone who likes design, engineering and architecture, or someone who would appreciate the gentle artistry and even manoeuvring of watching this magnificent structure uncurl and curl itself as this type of bridge would remain horizontal when it's rolled as its not hinged on one side of its end. [1] [2].

II. WORKING MECHANISM

A. Pneumatics

Air cylinders which are sometimes known as pneumatic cylinders re mechanical devices which use the power of compressed air which is supplied from a pneumatic compressor. The compressed air in the pneumatic cylinder later reciprocates liner motion of the piston in the cylinder.

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The inner mechanism of the pneumatic cylinder forces the piston to move in the front and back position similar to a hydraulic cylinder. The piston s made up of a disc of cylindrical shape with a diameter, lower than the inner diameter of the pneumatic cylinder. The piston rod later transfers the force it develops to the mechanism/links its connected to at the other end.

The second reason of using pneumatics in the construction of this bridge is because they are much cleaner, quitter and don't require large amount of fluid storage as in the case of hydraulic cylinders used in the bridge which was constructed in Pedington. Thus, a bridge which would cost millions of pounds would be constructed with comparatively less expenditure using pneumatic mechanism.

Since the operating fluid would be compressed air, leakage from the pneumatic compressor or the pneumatic cylinder would not drip out and contaminate the surroundings. This also gets into picture another advantage of this kind of bridge wherein it could be desirable at locations where in cleanliness is not a requirement.

Further development of this pneumatic system with proper synchronization would lead to more improvement of the whole bridge and can be used for much more applications with more modifications. Figure 15 shows the double acting cylinder which was used in the construction of this bridge with its sketch shown in Figure 16. Simultaneously, Table 2 gives the specification of the cylinder used.

Figure 1: Pneumatic Cylinder with Rod Fork Mountings.

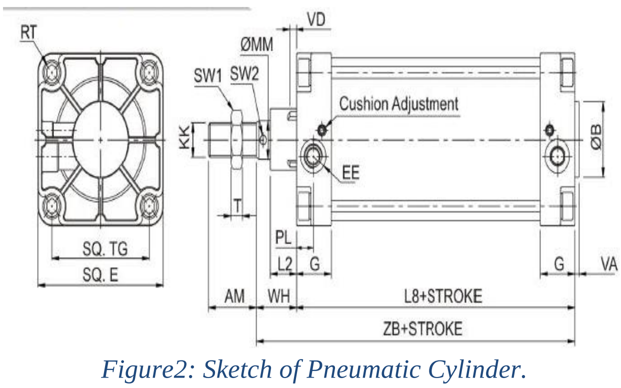

Figure2: Sketch of Pneumatic Cylinder.

Table 1: Specifications of Pneumatic cylinder used.

Parameters	Size mm	Parameters mm	Size mm
Bore Dia	32	PL	13
G	25.5	Va	4
øMM	12	L2	18.5
KK	M10 × 1.25	L9	5
Swl	17	ZB TOL	±0.7
TG	32.5	Stroke TOL	±2
øB	30	WH TOL	±1.3
E max	45	-	-
BG min	16	Sw2	4
EE	G1/8”	T	5
VD	6	WH	26
RT	M6	ZB	120
AM	22	L8	94

B. Instroke and Outstroke

Even though the force exerted by the cylinder and diameter of the piston are related, they are not directly proportional to each other. The typical mathematical relationship between the two is based on the assumption that air supply doesn’t become saturated. Thus, due to the effective cross sectional area is reduced of the piston rod. This makes the instroke force less than the outstroke force when both of them are powered pneumatically and by same supply of compressed air [3]. The relationship between pressure, force and radius is derived from the simple distributed load equation.

$Fr = \pi(PAe)$

Where in, Fr is the resultant force;

P is the pressure or distributed load on the surface, and

Ae is the effective cross sectional area the load is acting on.

1. Outstroke

Using the distributed load equation provided, Ae can be replaced with area of the piston surface where the pressure is acting on.

$Fr = P(\pi r^2)$

Where: Fr represents the resultant force;

r represents the radius of the piston

π is Pi, approximately equal to 3.14159.

2. Instroke

In case of instroke, the same relationship used in case of pressure, force and effective cross-sectional areal is applied as discussed above for outstroke. Nevertheless, since the piston area is more than the cross-sectional area, the relationship between pressure, force and radius is different. Hence calculations become easier, since the effective cross-sectional area that of the piston surface minus the cross-sectional area of the piston rod. For instroke, therefore, the relationship between force pressure, force exerted, radius of the piston and the radius of the piston rod is given as follows.

$Fr = P(\pi r1^2 - \pi r2^2) = P\pi(r1^2 - r2^2)$

Where: Frre presents the resultant force;

r1 represents the radius of the piston;

r2 represents the radius of the piston rod;

π is Pi, approximately equal to 3.14159.

A. Solenoid Valve

A solenoid valve can be coiled as an electromechanically operated valve which is controlled by flow of electric current through a solenoid valve. In the case of a two port valve as used in this project, the flow is switched off and on. While in case of a three port valves, the outflow is switched between two outflow ports.

In the case of this project, solenoid valves were used to control elements in fluidics. Shut off and release or distribution of air was the main application in this case. Solenoids offered quick and safe switching while providing high reliability, compatibility of the material and give long service life. The other advantage of using this is it consumes less power and has a compact design. The mechanism of a two-way valve is that when the valve opens, then the two ports are connected and fluid flows between the ports. While in case of the function of closed valve, the ports get isolated. If the valve is not energized and the valve is open, then its termed as normally open (N.O.). Similarly, if the solenoid is closed and the valve is closed, then the vale is termed normally closed, (N.C.) as shown in Figure 3 along with sketch in Figure 4 [4].

Figure 3: 3/2 Way Solenoid valve manifold G1/4".

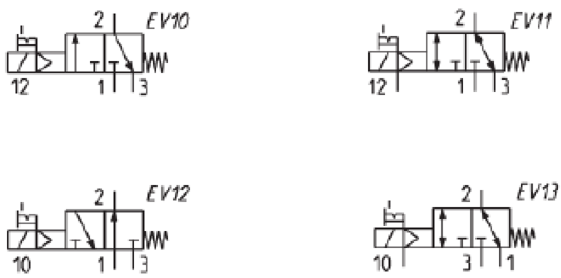

Figure 4: 3/2 Way Solenoid Valve diagram.

The plunger or core in the valve is the magnetic component that moves when the solenoid is energized while the core is coaxial along with the solenoid. The core is held in normal position by the springs when the coil is not energized. Since the plug nut is also coaxial, the core tube guides and contains the core and helps it retain the plug nut which may seal the air movement. To optimize the movement of the core, the core tube needs to be non-magnetic.

If the core tubes had to be magnetic, the nut would offer as hunt path for the field lines. In few designs, the core tube is in an enclosed metal shell produced by deep metal engraving. Such a design simplifies the sealing problems because the air cannot escape from the enclosed area, but the design also increases the magnetic path as the magnetic path should traverse the thickness of the core tube twice, once near the core and once near the plug nut. While in some designs, the core tube isn't enclosed and provides an open tube that slips over one end of the plug nut. To hold the plug nut, the tube may be fitted to the plug nut. An O-ring sealing between the plug nut and the tube will keep the fluid from keeping away. The solenoid curl comprises of many turns of copper wire that encompass the centre tube and initiate the development of the core. The coil is regularly coated in epoxy. The coil additionally has an iron casing that gives a less magnetic path resistance.

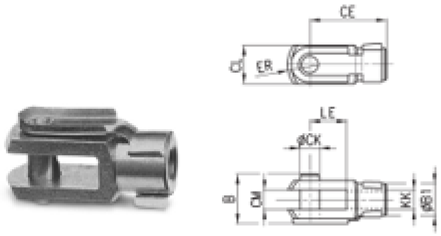

Figure 5: Upper Mounting and Sketch.

Table 2: Specifications of upper mounting.

Mod	ø	CL	ER	CE	B	CM	Øck	Le	Kk	øB 1
G 12-16	12-16	12	7	24	16	6	6	12	M6×1	10

C. Flow Control Valve

Flow control valve was used to regulate the flow and pressure of the compressed air. Since temperature gauges and flow meters generally respond to signals from control valves, they are preferred in such conditions where they are useful. Control valves are normally fitted with positioners and actuators. Certain control valves also work with hydraulic actuators also knows as Automated Control Valves (ACV's). ACV's don't require an external power source which leads to the fluid pressure to open and close the valve. Figure 6 shows the Flow control valve which was used in this project.

Figure 6: Flow control valve.

D. Filter, Regulator and Lubrication Unit (FRL)

A filtration unit is required to filter the air coming out from the pneumatic cylinders which is later recirculated into the cylinders. The compressed air is hot, dirty and wet which can damage and shorten the life of downstream equipment. Thus this air has to be filtered, lubricated and regulated through an equipment called the FRL unit. The airline in FRL strains the air while trapping solid particles such as dirt, dust and rust and separates liquid such as water and oil incoming from the compressor. Filters are installed in the air line upstream of regulators, for directional control valves, lubrication and air driven devices such as air motors and cylinders. The removal of this foreign particles help in preventing contamination in the pneumatic system thus preventing it from a major blockage and going into a breakdown maintenance. It also helps in reducing production losses [5].

The selection of the proper size of filter for this application was done by determining the maximum allowable pressure drop, which could be caused by the filter. The pressure drop was determined by the manufacturer which control fluid pressure and regulate the compressed air in the system. Often, regulators are referred as pressure Reducing Valves (PRV's). the primary function of a regulator is to maintain constant pressure regardless of input pressure variations, the downstream pressure requirement should be supplied the same at all time. The regulator has a control spring which acts as a diaphragm thus regulating air pressure. The adjustment of this pressure adjustment range in the regulator depends on the rating of the spring. Desired quantities of lubrication oil are added by a lubricator present in the moving component [6].

Figure 7: FRL Unit.

III. CAD MODEL

The following 3D CAD model was designed by using Solid works software. It's a solid modelling Computer Aided Design (CAD) software used for computer Aided Engineering (CAE). The main function of Solid Works is extrusion of the model in 3D after its been designed in 2D. Cut-Extrude and Boss-Extrude. The shell tool of the software to hollow out parts, leave open the selected face and create thin walled features on the selected faces. A closed hollow model was created by not selecting a face on the model [7].

The whole bridge was first designed in Solid Works taking into consideration the actual dimensions in which the bridge would be created. Each section of the bridge was later fabricated taking the dimensions of these individual parts which are shown in Figure 8 to Figure 16 below. For publication purpose, the dimensions of these parts/sections are not listed below, while only the design is shown [8] [9].

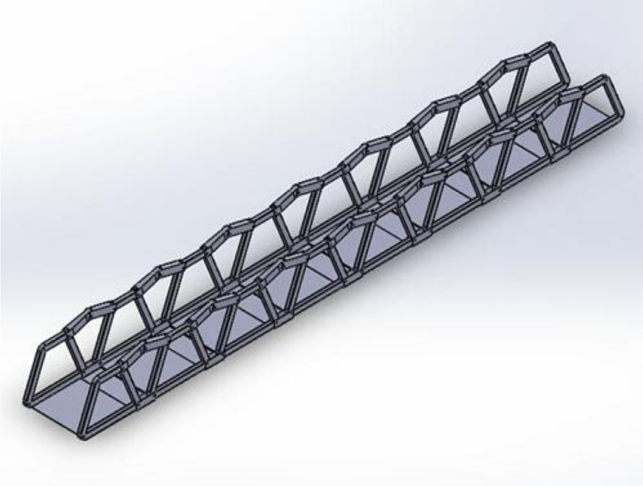

Figure 8: Assembled Bridge.

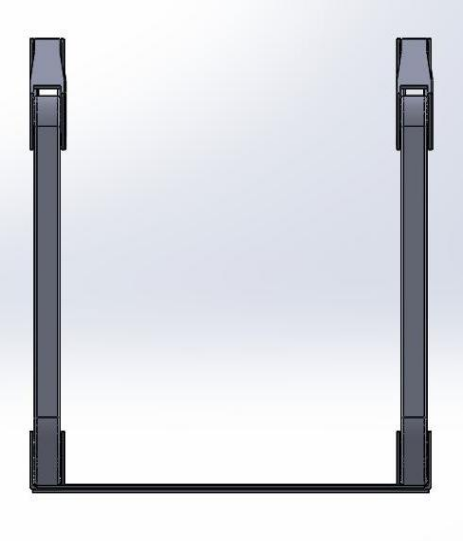

Figure 9: Front View.

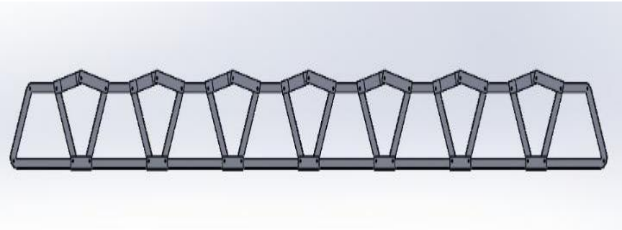

Figure 10: Side View.

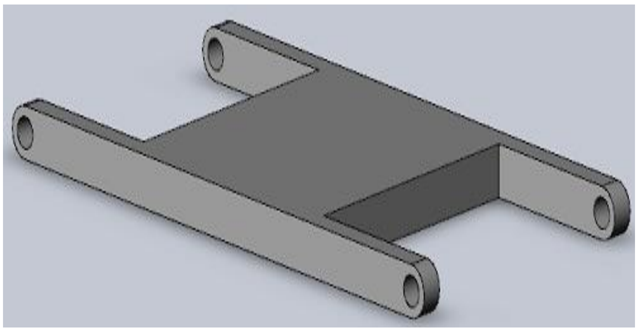

Figure 11: Top Link which was used to mount the cylinder base.

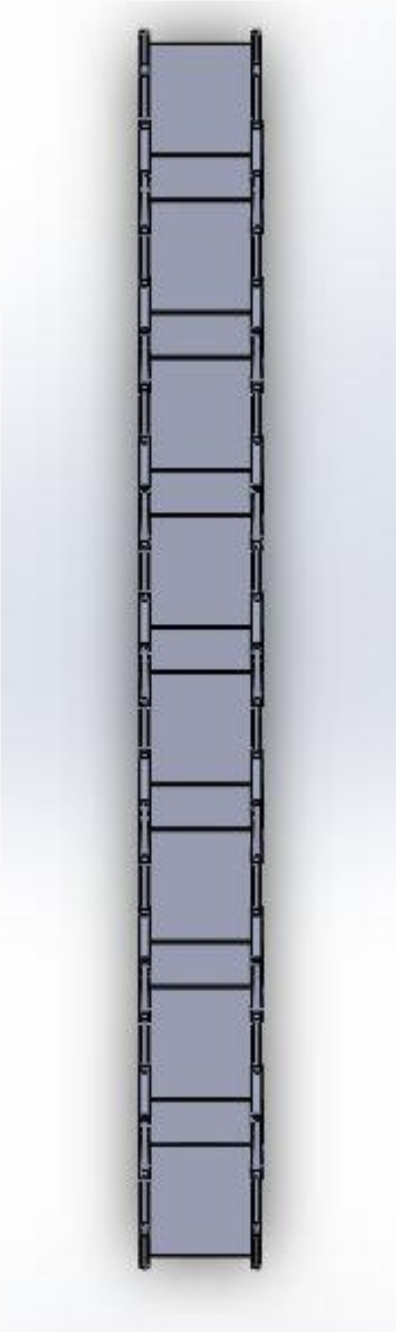

Figure 12: Top View

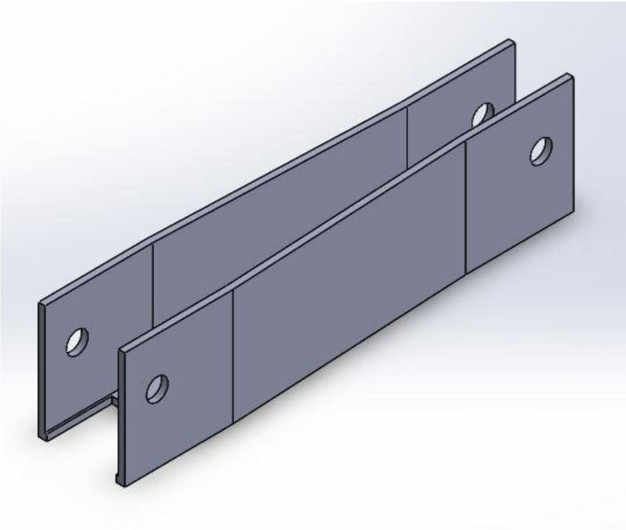

Figure 13: Upper Link 1.

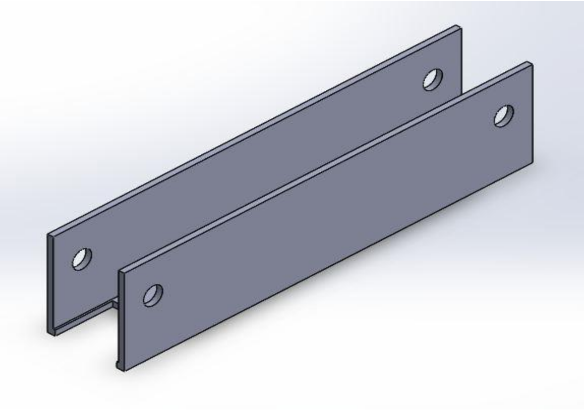

Figure 14: Upper Link 2.

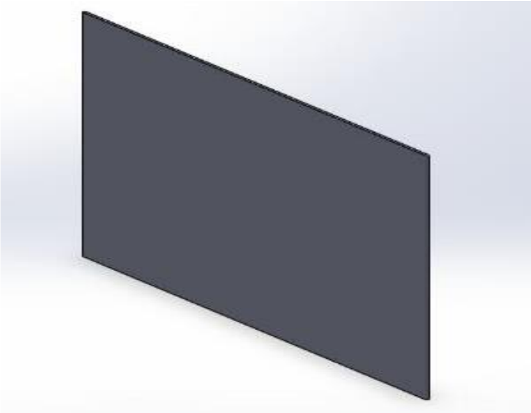

Figure 15: Base which was made of Fibre Reinforced Plastic to reduce the weight of the bridge.

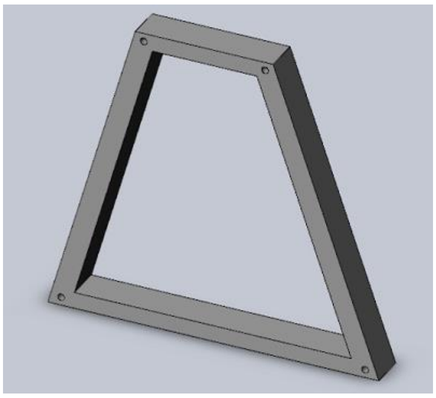

Figure 16: Trapezoidal Frame.

IV. FABRICATED BRIDGE AND DESIGN CALCULATIONS

A. Specifications

Following are the dimensions of 3D trapezoidal frame [10].

Table 3: Frame Dimensions.

Dimensions	Size
Length	384
Width	40
Height	354

Following are the specifications of compressor.

Table 4: Compressor Specifications.

Parameters	Ratings
Current	3A
Voltage	3phase 415V
Frequency	50Hz

B. Calculations

To calculate total cylinder length

Area of Octagon $= 2(1+\sqrt{2})a^2$

$A = 2(1+\sqrt{2}) \times 384^2$

$A = 711980.55$ mm^2

Area of Circle $A = \pi R^2$

$A = \pi R^2 = 711980.55$

Total Cylinder length = cylinder length + stroke

$R = 476.057$ mm

$R \approx 477$ mm

To find the weight of the bridge

Weight $W = 2 \times 16 + 0.5 \times 14 + 37 = 76$kg.

Taking weight ≈ 80kg

To find pressure per cylinder

Force $F = 800$N

Since there are 14 cylinders taking the weight of the bridge while lifting it,

Force per cylinder $= \frac{800}{14} = 57.14N \approx 60$N

Pressure required per cylinder $= \frac{60}{\pi \times b^2} = \frac{60}{\pi \times 16^2}$

Pressure required per cylinder = 0.0746N/mm^2 = 0.746bar.

V. FABRICATED MODEL

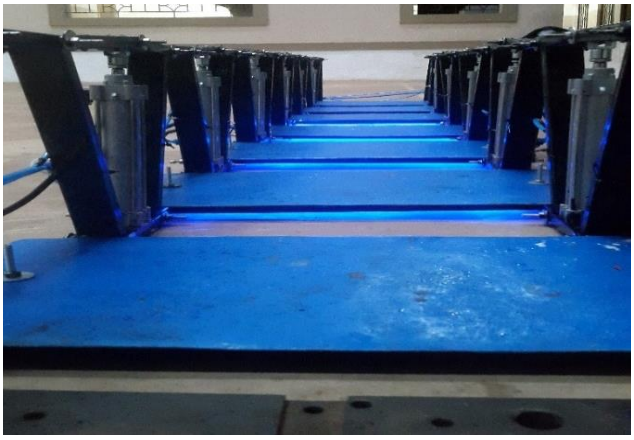

Figure 17: Completed Bridge when not folded and base lit up.

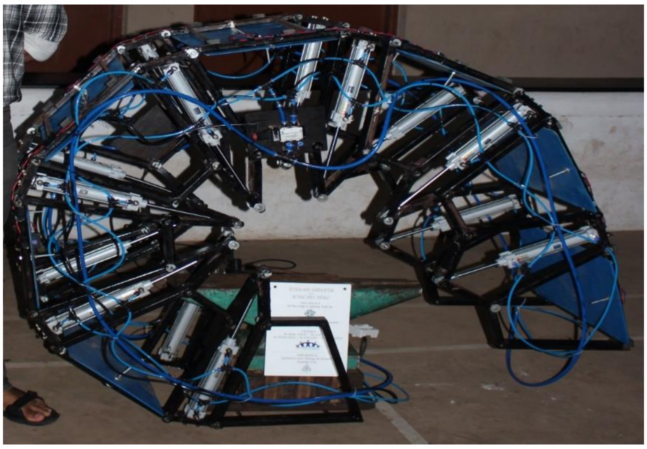

Figure 18: Bridge when curled.

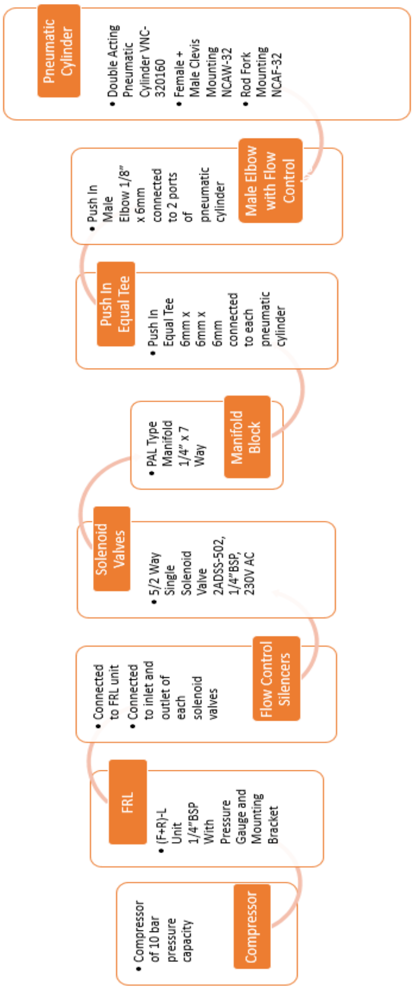

Figure 19: Working flow chart of the cylinders.

Table 5: List of Items Required.

Sr No.	Items	Quantity
1	Double Acting Pneumatic Cylinder VNC-320160	14 cylinders
2	Female + Male Clevis Mounting NCAW-32	14 mountings
3	Rod Fork Mounting NCAF-32	14 mountings
4	3/2 Way Single Solenoid Valve 2ADSS-502, 1/4"BSP, 230V AC	2 solenoid valves
5	PAL Type Manifold 1/4" x 7 Way	1 manifold
6	Fiber Reinforced Plastics base	8
7	Push In Equal Tee 6mm x 6mm x 6mm	30
8	Steel 18 x 4mm	8
9	PU Tubing 4mm x 6mm	20 meters
10	Flow Control Silencers	4
11	(F+R)-L Unit 1/4"BSP With Pressure Gauge and mounting bracket	1 FRL unit
12	Push In Male Connector 1/4" x 10mm	8

VI. APPLICATIONS

The bridge could be used for the following purpose.
1. Linking cruise liners to ports.
2. Providing a pathway to link canals, creeks, and canyon.
3. Providing a link for pedestrian to travel distance of 10 to 12 meters across river banks or canals.
4. Providing a link between two buildings in mid-air as a tourist attraction.

VII. CONCLUSION

Based on the project carried out, it could be proved that a rolling bridge could be constructed by using the mechanism of pneumatics system such a compressor and pneumatic cylinders. The bridge could later be used at locations wherein laying foundation on both the sides of the canal or river would be difficult under relatively less budget as compared to conventional bridges.

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