RESEARCH ARTICLE OPEN ACCESS

Architectural Mechanism Developed By Cliff Swallow for Nest Construction

[1]Chaya H C, [2]E Santosh,[1]Mahesha G, and[3]Channaveerappa H
[1]Department of Zoology, Maharani Science College for Women, Mysore-570005, India
[2]Department of Computer Science and Engineering, Maharaja Institute of Technology, Mandya-571438, India
[3]Department of Zoology, Govt. Home Science College, Holenarasipura-573211, India

ABSTRACT
Indian cliff Swallow *Petrochelidonfluvicola* construct gourd shaped mud nest underneath the cliff against the gravitational pull. These birds do all basic works of construction such as blue print marking, platform construction and arrangement of pellets in brick like arrangement is a marvelous art and final form of an inverted dome. The top of the dome irrespective of the space remains uncovered as default space. This default space too originates in the nests of cliff swallow it is converted into entrance. The entrance, base attachment of the nest are aligned without disturbing the gravitation act on the nest, the same is discussed here.
KEYWORDS: Mud Nests, Inverted Gourd shape, Avian genius, default space, Center of Gravity.

I. INTRODUCTION

Cliff swallows are one of the favorite subjects for behavior ecology studies because of their nest construction behavior. Cliff swallows construct an inverted gourd shaped mud nest. The nest construction preferably takes place beneath the cliff, under surface of bridges, sloping edges of the man-made constructions.

Cliff swallows are good architects and builders in the nature; this act has been imprinted through the course of evolution. Cliff swallows use mud for construction slightly reinforcing the organic fibrous contents. Mud is a plastic material that can be molded when wet into required shape & structure on drying it hardens to give a durable shape. Nearly 5% of the bird species use mud as the vital material in nest construction (Rowley, 1970). Mud bear load in compression and in cliff swallows the nests built on rock overhanging are not supported from below. The addition of grass, feather & hair in to the mud probably provides the strength in tension (Hansell, 2000). Mud may vary in its contents. The mud is selected by swallows only when there is a consistency appropriate for building the nest (Chaya H C, 2012, Chaya H C etal, 2013).

This paper on cliff swallows nest is to understand the avian genius in planning, designing, building and architectural marvel of these birds.

II. MATERIALS AND METHODS

Stage by stage construction of the nest building activity by the bird were video -graphed using Sony Cyber shot which technical works at 25FPS (Frames per Second). All the measurements were done using Vernier Caliper. The images of modeled gravity act are created using JPEG (24 bits/pixel - 16 million colors) image "Arc.jpeg" which is showed in the Fig-01 is used to represent any dome shaped structure as well as any guard shaped nest structure too, as the basic component of the design in the canvas area, the area where the complete design takes place.

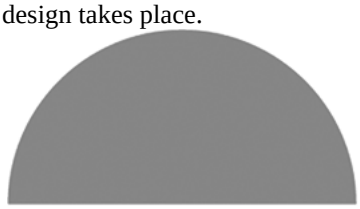

Fig-01: Arc.jpeg

The image was resized and tilted by selecting "Image Size" from the "Image" menu to almost 35%-40% and 30-40 degree inclination of the original. The Lines and Dots are even utilized to design the levels & to indicate the centers of the pass through with the arrow as the force representation.
The tool used to design and understand the act of gravitational force on the nest Adobe Photoshop 7.0 as this tool is very good at vector drawing as long as the image doesn't need to be scaled and one need not be specialized CAD drawing professional.

III. OBSERVATION

The architecture of the nest resembles the inverted dome or gourd. While construction of the bird marks a blue print later places a mud pellet at a point which determines the further proceedings of construction as shown in the Fig-02. The alignment of pellets follows on either side of this initial pellet which results in forming a base platform for the

construction of rest of the nest. This platform/base is the point through which gravitational pull passes. In Fig-03 it is represented the man made dome resembling roughly the shape of the nest of swallows. The measurements of the nest are noted in the Table-01.

Fig-02: Initial Marking on Cliff (Blue-Print) and the Base formation as Platform.

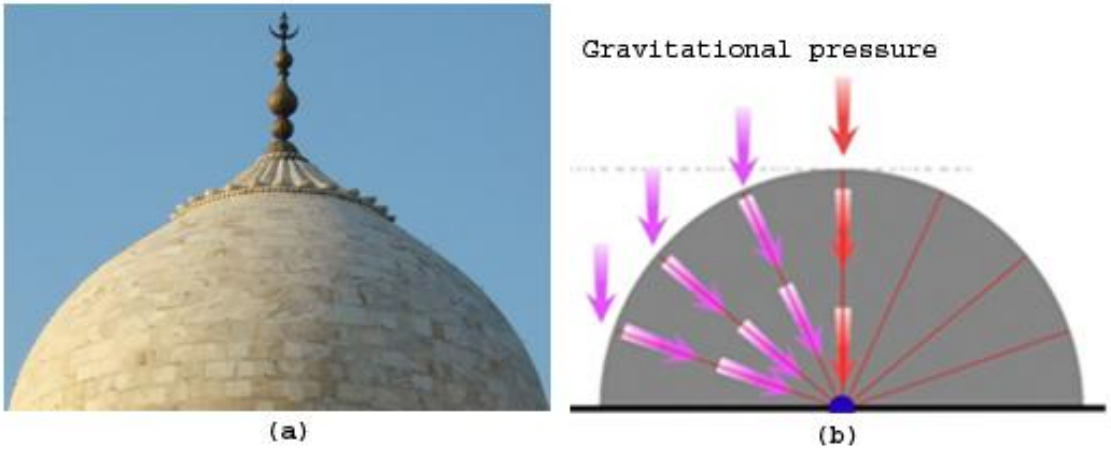

Fig-03: Comparison of (a) Man-Made dome and (b) Flow & Convergence of Gravitational force on Dome.

Factors	**Value (cms)**	
Depth	2.2 – 2.4	
Height	6.4 – 10.8	
Width	7.5 – 11.3	
Thickness	1.7 – 2.2	
Circumference at	Base layer	5 - 5.8
	Between base & middle	3.5 – 4.2
	Middle layer	2 – 2.4
	Between middle & Entrance	1.4 – 1.6
	Entrance	1 – 1.1

Tabe-01: Physical Structure Measurement of Cliff Swallow Nest.

The placement of initial pellet describes the future course of construction including the positioning of nest entrance or base platform. After initiation the construction process continues by subsequent arrangement of pellets till an arch on the lower part of circle is produced. Pellet by pellet arrangement is done as mason workers do by the bird, involved in Construction. The attainment of shape of the nest is represented as in the form shown in Fig-04.

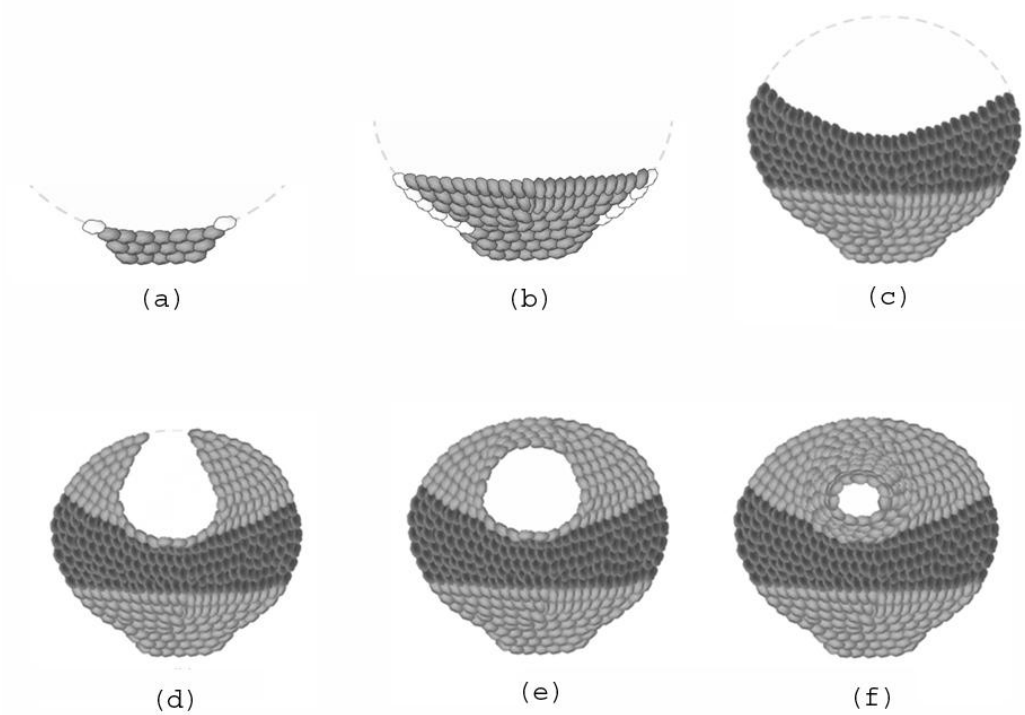

Fig-04: Graphics (a- f) showing different stages of pellet arrangements.

The dome has a radial coordinate r inscribed on its surface and is rotationally symmetric about the origin r=0, which is also the highest point of the dome. The shape of the dome is given by specifying h, how far the dome surface lies below this highest point, as a function of the radial coordinate in the surface, r. For simplicity of the mathematics, we shall set $h = (2/3g)r^{3/2}$.The gravitational force can only accelerate the mass along the surface. At any point, the magnitude of the gravitational force tangential to the surface is $F = d(gh)/dr = r^{1/2}$ and is directed radically outward. There is no tangential force at r = 0. That is, on the surface the mass experiences a net outward directed force field of magnitude $r^{1/2}$ (John D. Norton, 2005). These concepts gives a clear idea about how the dome upholds the gravitational force with the equal radius all around the surface and center of circle acting as Center of Gravity in dome's.

IV. DISCUSSION

Indian cliff swallows are good animal builders. Often the animal builders are cited as ecosystem engineers because of their ability to modify the biodiversity around by their presence. Many of the builders are considered to be model species for analyses of the niche construction and ecological variations. The mud nest building birds belonging to the family *Hirundinae* are interesting among the animal builders. The cliff swallows mud nests are inverted retort like or gourd shaped that represent the model of inverted domes on earth inverted dome construction by human is not yet possible but these birds even before the emergence of human beings have practiced such a type of nest building.

The cliff swallows are good designers, architects and builders for the reason these birds apply their behavior to materials to bring out the structures. These birds mark the blue print by using their beak to initiate the work. These birds have no specialized structures to build but use only the beak. On the mark first pellet laid decides the course of constructions as shown in Fig-02 which have been dealt in detail (Chaya H C 2012).Dome is a type of shell structure which is hemispherical in shape mainly used as roof structure where its technique is based upon transmitting load more than 2 directions to support all types of force without bending or twisting. Dome is constructed of stones, concrete & brick usually supported on circular or regular polygon shaped walls. Every dome should have certain height & diameter ratio and can be constructed with or without lanterns.

In the construction of domes it has been well known that, it is the construction strategy where the dome is made to be upheld without the use of centering during construction or beam to with hold the pressure as design of construction. In dome all the force or pressure is resolved into compressive stresses. Usually while discussing about the dome and its types, all the domes types has a base structure of semi-circle. Hence the study will be focused on the

load share of dome due to gravitationally force which results in non-collapse. In Domes and Arcs construction uses the technique called center of gravity to nullify the effect of pressure on the surface of domes & arcs as shown in Fig-03.

As shown in the Fig-03 we have a building with the dome constructed with the opening at top but covered using addition key stone structure as an alternative to the keystone. The Fig-03also reveals how the gravitational force acts on the dome and the convergence of gravitational force to nullify the gravity effect.

The gravitational force is always downwards towards the earth which results in fall of objects towards earth until it rests on a base or a surface to nullify the effect of gravitational pressure. Hence center of gravity plays a major role to sustain the gravitational force. In an arc or dome construction the center of gravity is at the point of radius from any point on the surface of the arc or dome. Hence engineers need to maintain a common or constant radius from an imaginary or referential center point to any point on the surface. As the gravitational force flows downwards it is always true in the case of dome that all the gravitational force and pressure converges at center of gravity which results in nullifying the gravity and sustain of the dome or arc at its place without subjecting itself to bend or break.
Construction mechanism of Cliff Swallow Nests, also heavily resembles the arc-shaped dome which overhangs to the surface of cliff. In the construction of nest the arc is placed in a tilted manner so that the base of arc is inclined to the surface of cliff as show in the Fig-05.

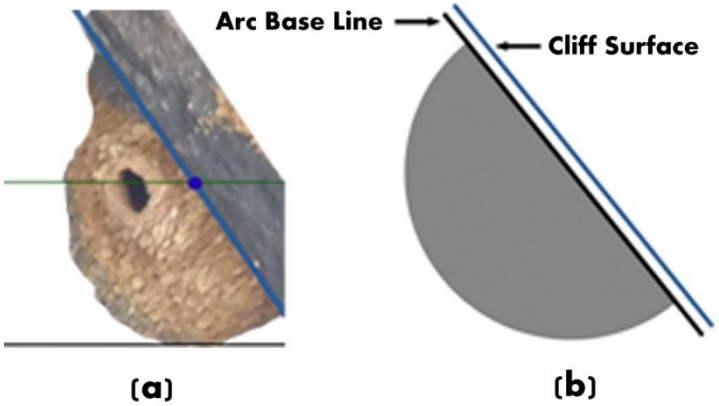

Fig-05: Comparison of (a) Cliff Swallow Nest and (b) Tilted arc like Dome.

Here the arc is made to be hanged to the cliff surface in Fig-05 as to replicate the construction of cliff swallow nests. In the dome usually the keystone space (default opening) appears to be at the top-most tip of the arc as it is impossible to cover the arc completely with use of constant sized bricks or pellets. The default opening also exists in the Cliff Swallow arc-like dome nest construction almost at the top of the nest which it is used as an opening for entrance. The entrance is constructed like a tube structure to complete the construction of nest. The representation of this default opening dome and the conical-tube like entrance structure at the default opening in the nest can be seen in the Fig-06

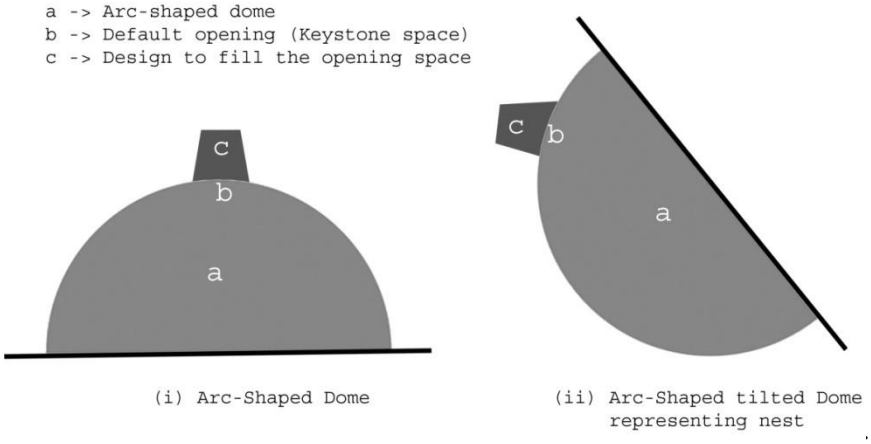

Fig-06: Default openings in Arc-shaped dome and cliff swallow nest.

When the concept of base or base line is in discussion it is a known fact that the base of an object should be always be parallel to the ground surface, in turn a base surface which is the major platform for any object or even to the nest to nullify the gravitational pull. So as to continue the discussion we need to shift the arc base line in such a way that it needs to be parallel to the ground level and the bottom most tip of the arc or nest as shown in the Fig-07.

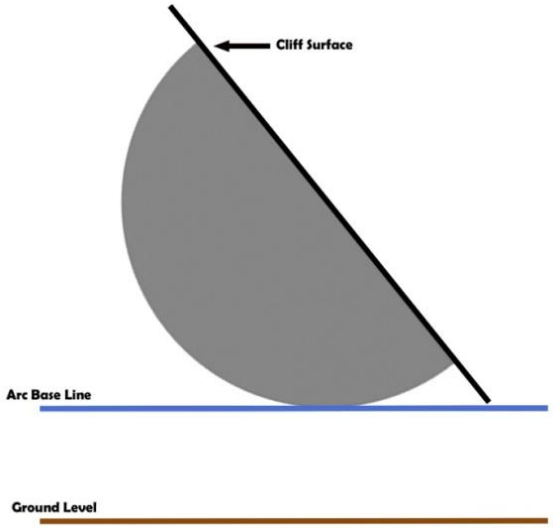

Fig-07: Shift of Arc Base Line to be in parallel with the Ground Level.

By this interpretation of observation and the gravitational facts the study reveals that a dome has one center of gravity where as the Cliff Swallow's nest or tilted arc has two points of distributed gravity one at the center of the arc (COG1) and other at the contact point of arc bottom-most tip, the base line and the vertical line from the center of arc (COG2) as shown in the Fig-08.

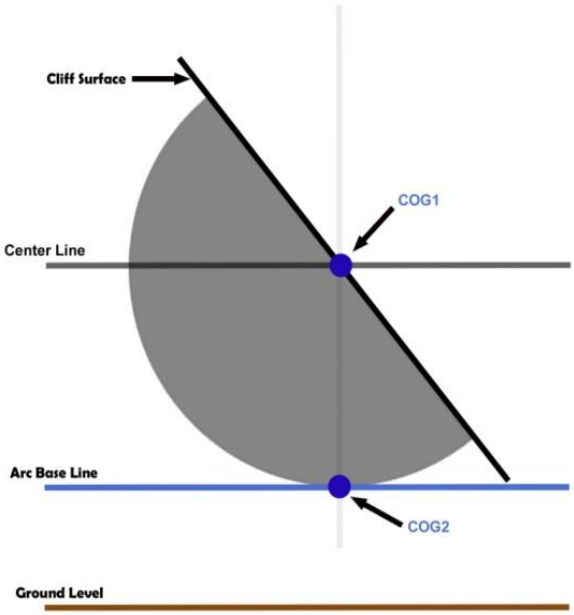

Fig-08: Showing Positions of Center of Gravities which is observed in nests.

This key technique of distributing the gravitational pull over two points has made the Nest to be hanged over the Cliff area without down fall or collapse. The pull pressure on the surface of nest above the Center line converges at COG1 and the pull pressure on the surface of nest below the Center Line and as well as the pressure of COG1 converges at COG2 as shown in the Fig-09.

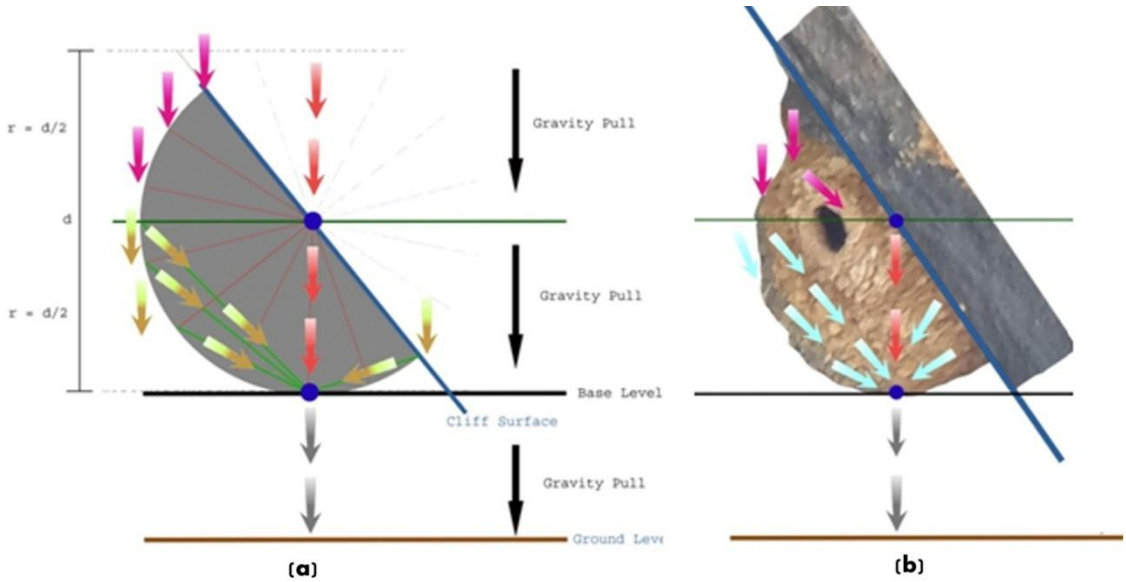

Fig-09: Flow and Pull of gravitational force on (a) Tilted Dome and (b) Nest through COG's.

All these shows that the COG2 is the at most main Center of Gravity Point to with stand the gravity pull, hence the Cliff Swallow birds at initial stage constructs the base platform strong enough to withhold the complete weight of nest and in turn which acts as COG2 as shown in Fig-10 and even the construction of complete nest on this base is shown in Fig-10.

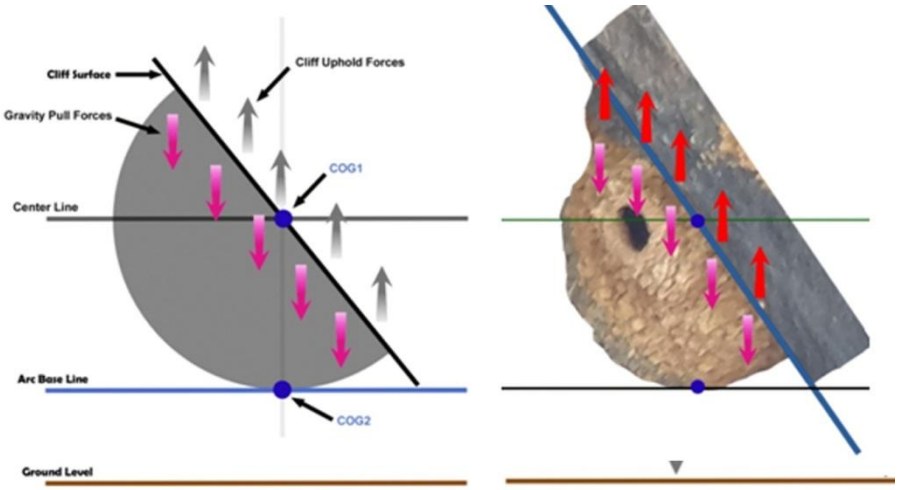

Fig-10: Act of Cliff surface Upload Force as to defend the Gravity pull force.

The nest may rest all of its weight for upholding at COG2 but COG2 alone is not sufficient to guard the nest against the downward gravitational pull that may lead to collapse of the nest by detaching from the cliff. But this is safe guarded by creating equal and opposite pressure built by the cliff on the attached nest, which nullifies the effect of gravity to pull down the nest.

REFERENCES

[1] Chaya H C, 2012, A Study on The Nest Construction in Indian Cliff Swallows – *Petrocheledonfluvicola*, 1st M.Sc Dissertation, Submitted to University of Mysore.

[2] Chaya H C, Mahesha G and Channaveerappa H, 2013, Composition analysis of two Swallows Nests – Petrochelidonfluvicola and Hirudorustica, International Journal of Current research, Vol-5, Issue 11:3335-3338.

[3] Hansell M H, 2000, Bird Nests & Construction behavior, Cambridge university press, Cambridge London.

[4] John D. Norton, 2005, Acausality in Classical Physics of Causation as Folk Science, Philosophers Imprint Vol. 3, No. 4, Causation and the Constitution of Reality, Oxford University Press.

[5] Rowley I, 1970, The Use of Mud in Nest-Building in Ostrich, CSIRO Sustainable Ecosystems; Birds/Bird nests, suppl. 8, pp. 139-148.