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Aims and Scope

Global Journal of Structural Design and Construction is a peer reviewed journal published by Original Papers. It is one of the pioneering starts up journal in Civil and Structural engineering which receives high quality research works from researchers across the globe. The journal publishes original research and review papers falling within the broad field of Civil Engineering.

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Emerging Construction Technology, in Anthropocene Epoch, India: The EPSC Panel

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ABSTRACT

Geotextiles, Geo-membranes and Geo-grids, the products ofGeo-synthetic materials are extensively used in 1980's have added Geo-EPS as a cost effective energy efficient new construction materials from 1990. The slogan of the nation, India is "Housing for all" on its 75th year of Independence, tentatively 20 million house by 2022. The herculean taskcannot be met by conventional method of constructing cast in situ houses with modern amenities under Indian climate and environment is a day dream. Innovative methods must be adopted in the construction practices such as prefabricated structures or precast slabs are essential. Structural concrete insulated panels like expanded polystyrene core (EPSC) arrangement, cladded with zinc coated welded fibers sprayed with shotcrete concreting are one of the best choices of early, easy, light weight, energy efficient and cost effective building construction even up to G+3 to G+22 and even more. High rise buildings can provide long lasting and green buildings for the burgeoning population of India at low cost if constructed using EPSC panels. A comparative study of the ongoing building materials have been investigated and the results were the EPSC walling with concrete columns and beams are the most effective in green and smart building age.

Keywords:EPS, AAC, Building materials, green buildings, energy efficient, economic.

INTRODUCTION (10PT)

The primitive building construction with traditional materials like cement, sand, brick and stone are no longer in use for last 1980 years i.e. the acceleration period of Anthropocene epoch Mishra S. P., 2017[1]. The in situ construction has been ceased and replaced by prefab construction technology. Like RCC hollow and solid beams, prefab stair cases, RCC precast slabs and ties, AAC precast slab or blocks. All these prefab structures are in use at present. The time consuming, solid waste producing and thermal inefficient AAC structures have been replaced by EPS buildings that provides required building comfort und green building concept.

Structural concrete insulated panels (SCIP) like expanded polystyrene core (EPSC) arrangement, cladded with zinc coated welded fibers sprayed with shotcrete concreting are one of the best choices for early, easy, light weight, energy efficient and cost effective building construction even up to G+3. High rise buildings with EPSC can provide long lasting dwelling shelters under green buildings for the burgeoning population of India at low cost. Expanded Polystyrene Core Panel's (EPSCP) Insulation products coupled with the construction industry from 1970 as a building materialof Anthropocene. It is a foam plastic materials manufactured from polystyrene expanded with butadiene, ethylene and butylene used as SCIP for insulation of buildings primarily. Further it is used as light weight building material having lifelong performance without thermal drift if properly constructed and maintained. The construction EPS materials have high compressive strength, great cushioning properties and water, acid/ alkali (at low conc.) resistant providing improved building comfort enhanced structural performance, fire retardant and cost effective. The novice innovative building materials are gaining popularity throughout the globe.

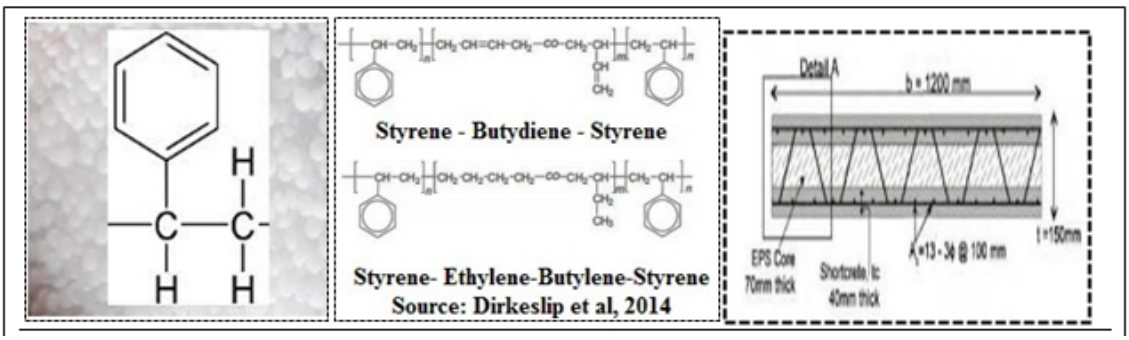

Fig 1: The chemical structure of SBS and SEBS, expanded polystyrene core as SCIP material

The Expanded Polystyrene:

As per Australian technical data of urethane and styrene, it is a polymerized lightweight close cell prepared from polystyrene (a polymer product of Benzene and Ethylene in form of beads) having five stages of manufacture i.e. Pre-expansion, property enhancement, ageing,moulding and finishing http://www.thermalps.com.au/ imagesDB/wysiwyg/TDS_Expanded_Polystyrene.pdfFig

1. The beads pre-expansion stage steamed under increased vapour pressure to have softening and volumetric expansion. To enhance the properties of the polystyrene, impact modifiers are added like SBS (Styrene butadiene styrene) or SEBS (Styrene Ethylene butylene styrene). For ageing the beads were stored in large silos on drying beds for fluidization. For drying, the beads are passed through ovens under a controlled temperature. Finishing is done by cutting the EPS to required shape and size for use.For property improvement the Polystyrene the EPS panels have the advantages like energy efficient, light weight, maintain buildings thermal comfort, low maintenance, reduces solid waste as recyclable and reusable, anti-vermin, rot protective, fast construction and reduced radiation, air leakage and infiltration rates.

REVIEW OF LITERATURE

Thermal comfort due to use of proper building materials was started from 19th century Rowley et all 1932[2], and 1937[3]. The geo expanded Polystyrene Core panels like geo-synthetics, geo- membranes and geo-g rids can be used under low or deteriorated soil conditions (Greenlay et al., 1997) [4]. During recovery of EPS beads during manufacture faces the problem of blowing agent so SBS or SEBS as impact modifier added to improve manufacturing problems. PS/SEBS exhibited higher tensile strength than PS/SEBS products (Direksilpa C., 2014) [5]. The EPS materials can be a low cost replacement for the wood doors and shutters (Asthana et al, 1996) [6]. Sailus et al 2006[7], have reported that stability and durability of polymeric foam used in building construction is associated generally with compressive strain. The Food and Drug Administration(FDA), Food Safety Modernization Act (FSMA), and the law by President Obama were provoked on January 4, 2011 in USA which protects public health by firming the food safety system https://www.fda.gov/Food/GuidanceRegulation /FSMA/ucm 253380.html.

Building materials & technology promotion council, Ministry of Housing and urban poverty alleviation, GOI has recommended the use of EPS materials for the fast and economic building construction. Bengaluru Police housing Board has adopted the EPS panel boards in their housing schemes. Karnataka State Police Housing Corporation (KSPHC) for Fire and Emergency Services has constructed anEPC panel structure within just 17days.CSIR – Central Building Research Institute Roorkee, June 2017 has prepared for Manual for Expanded Polystyrene (EPS) Core Panel System and its field Application sponsored by MoH&UpA, GOI [7] and Agrawal et. al 2014[9].Gitau N. S.,

2014[10], reported the EPC system of building saves 50% time and 30% cost through transport, labour and cost of construction machineries. DenizCarroll, 2017[11] has reported EPS panel boards with Aluminum foil, array of facers., polyethylene and Kraft paper increases performance and protect from abrasion, UV degradation and increase resistance to radiant heat absorption. Morgan D R R et al., 2008[12]and Qiao P et al. [13], have given guidelines for construction of shotcrete wall structures.Rohit Raj et al., 2014[14] mentioned that EPSC panels have thermal conductivity (0.032 - 0.038W/m•K) is less energy efficient hat of traditional concrete has much less values 0.4-0.7 W/(m•K).Mishra S. P., 2017[15] reported that the buildings should be constructed whose materials should be energy efficient, long lasting, better indoor air quality and low running and maintenance cost, low VOC and maximum thermal comfort as per norms of Indian green building council (IGBC) and LEED (Leadership in energy and environmental design) and GRIHA (Green rating for integrated habitat assessment.

REASONS FOR STUDY:

India is the 2nd largest populous country (1,344,569,353 on 11.11.2017) occupies 17.74% of the total globe with a density 450/sqkm with 32.8% living in urban http://www.worldometers.info /world - population/india-population/. Provision for roof to live in for each family is a titanic task for building Economically Weaker Section (EWS)/ Lower Income Group (LIG) houses. There are housing shortfall of 18.78 million (14.99 congested households inclusive) planned by the GOI by 2022 (Agrawal et al 2014) [9]. The urgent need for enormous housing projects to be started in both urban and rural segments with traditional limited building materials and funding, it is vital that green and proven construction skill to be adopted by taking care of structural, performance and fiscal allotment. Under-developed and evolving countries are fighting against housing deficit and forced to adopt RPC system of building construction to meet the requirement faster with local men, materials and less money. India is yet to standardize and prepare an IS code on the modern method of construction though the methods and the product is quite popular in many cities all over India and the world. Present work is to highlight the economic green concept of housing by EPC panels to the common people to meet their future need.

Clay/flyash bricks, AAC blocks/panels and EPC panels as materials building construction

The major man made conventional and modern brick blocks used as popular building materials are clay bricks, Flyash bricks, AAC and EPSC blocks or panels. The physical, mechanical and Usable properties of the four types of materials are given in Table 1, Table 2, and Table 3

Table 1: Comparison of Physical properties Clay/fly ash bricks, AAC panels and EPC panels

Parameters	Clay bricks	Flyash bricks	AAC bricks	EPC panels
Composition	Soil, Sand, Lime/ concrete materials and labour more	Mortar fly ash Less labour than clay bricks production	Mix of Sand, Cement, Coarse aggt gypsum. Lesslabour than EPC Constn..	Polystyrene, steel, shotcrete. Least labour in construction
Av size in mm (L x H x B)	230 x 75 x 115(±05to 15)	230x75x110mm (±5%)	600 x 200 x (100 to 300) mm(± 1.5)	Finished thick ness:155to235mm
Colour	Non-uniform (Red)	Uniform Cement grey	Uniform (grey)	Uniform/ Cement colour
Shape	Uneven	Even	Even	Even
Finish	May distort	Smooth finish	Smooth finish	Finished
Weight (av)	3.5Kg/brick	3.5kg/brick	lighter	lightest
Dry density	1600-1750	1850-1900	550 – 650	15 – 25 in kg/m3
Loading capacity	Yes	More than CB	> EPC blocks	Least

Earthquake (EQ) resistance	Less resistant	Less resistant	More than CB/fly ash brick	Resistant, used E.Q. retrofitting
Porosity	Porous(10%to 30%	Less porous	Porous	Least Porous
Cost/sqm	Higher than Flyash bricks	Less than clay bricks	Less than EPS panels	Higher than AAC blocks
Plastering	Needs and more mortar	lesser mortar than Clay bricks	Less mortar than fly ash bricks	Least mortar
Bonding	Strong	Less than CBB	Less	Less
Breakage on transportation	200 in 3000 bricks	30 no's in 3000 bricks	<25 in 3000 bricks	No breakage as shotcrete in situ
Construction	Local workers	Local workers	Local workers	Skilled worker

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http://www.dreamhomeguide.in/comparison-between-fly-ash-bricks-and-clay-bricks
https://www.materialtree.com/blog/cat/compare/post/redbricks-aacblocks/
http://santoshranjanblog.blogspot.in/
http://www.ecogreenproducts.in/technical_specification.php
http://www.leedsbeckett.ac.uk/teaching/vsite/low_carbon_housing/resources/thermal-conduc tivity-of-building-materials.pdf
http://www.iolitecube.com/AACBlockComparisonWithBricks.html

Physical properties

Clay brick: The properties of red clay brick have substantial influence on structural performance of the brick masonry are compressive strength. The materials of the puddle, % of water absorption and surface texture control the effect on masonry. The physical quality also depends upon the firing temperature (over or under) and duration of firing. Further compressive strengths of Clamp Burnt (CB) and Kiln burnt bricks differ.

Fly ash bricks: The local govt. is imposing royalty and cess on earth for brick manufacture and the cost of bricks have risen from 1990's. Considering the higher compressive strength of cement mortar bricks became popular but the harmful effect of fly ash, the pollution control board, India has imposed regulations. The rise in cost, low bonding, and least reusability is losing the popularity of fly ash cemented bricks gradually like plastic.

Table 2: Comparison of mechanical properties Clay/fly ash bricks, AAC panels and EPC panels

Parameters	Red clay bricks	Flyash bricks	AAC panels	EPC panels	Source
Weather/pest resistance	Not weather and pest resistant	Not weather and pest resistant	Resist adverse weather and pests	Resist adverse weather and pests	http://www.shimberg.ufl.edu/publications/hebelDoc.pdf http://epsa.org.au/about-ep s/eps-in-building/panel http://www.ecogreenproducts.in/technical_specification, http://www.gobrick.com/port
Plaster	Not possible	Possible	Possible	Possible	
Comp. strength	2.5 - 3 N/mm2	7-10 N/mm^2	3 – 4.5 (IS 2185	3-4 N/mm2,	
(N/mm^2)	30-35 kg/cm^2	90-100 kg/cm^2	part 3)		
Thermalcond.(	0. (W/m-K)	1.21(W/m-K)	0.16(W/m-K)	(W/m-K)	
K)					
Water	20-25%	06-12%	water and	High water	
absorption			vapour barrier	barrier	
R-Value	R 0.05 -0.07	R-0.5	R-30 insulation	R – 0.88	
insulation					
Sound reduction	50 for 230 mm		45 for 200 mm	poor insulation	
Index (Db.)	Thick Wall		Thick Wall	to sound	
Fire resistance (hrs.) 6"	2hours (EN ISO 11925-	4hours ((EN	2 to 6 (Depend on Thickness)	high and	als/25/docs/technical%20notes/tn16.pdf
thickness	2:2002)	ISO 11925-		medium thermal	
		2:2002)		resistant	
Effect on environment	Clay, Affect high CO2 emission	Uses wastes of TPP, save envt.	Eco friendly than EPCS	No solid waste, envt friendly	

Autoclaved aerated concrete blocks:

AAC blocks are about 80years old and gained popularity due to its low weight, fast construction, fire resistance, ecofriendly etc. But government restrictions, high cost, limited manufacturers, less strength making its use in construction is not alluring.

EPSC panels:

Expanded Polystyrene foam insulation with shotcrete surface board is not stable, asit has an expiry period. Though shrinkage cracks are developed, its versatility, cheapness, thermal high insulation, reusability and fast construction have made it popular in 21st century for the homes of burgeoning population

Table 3: Comparison of usable properties Clay/fly ash bricks, AAC panels and EPC panelsParametersRed clay bricksFlyash bricksAAC panelsEPC panelsSource

Parameters	Red clay bricks	Flyash bricks	AAC panels	EPC panels	Source
Advantages	Aesthetic, local, economical Hard& durable, Comp. strength acceptable low	Flexible/easy to construct, ideal for foundation,	Light Wt., Fire resistant, moderate comp strength, workable, economy, acoustic, easy/quick to install, durable, stable, ecofriendly, acoustic, energy saver,vent- elating, nontoxic, smooth, quick	Light wt., easy to install, fast constn. fire/E.Q./storm-resistant, Thermal insulation, lower cost. Airtight, flexible design, Long life, high strength, low upkeep, hygienic, economic, ,no	https://gharpedia.com/solid-concrete- blocks-vs-aac- blocks/ http://www.bmtpc.org/DataFiles/CMS/file
	upkeep, easy Demolishing ,reusable le & recyclable, fire resistant, less eco-pollution,	high strength, Ideal in cold &hot weather, durable, less up keep, less crack, crumbling, Eco friendly, acouostic, Less GHG	const, long lasting.	GHG Eco friendly, reusable	/PDF_Files/ http://www.ho use-energy.com/ Walls/AAC-Advantages.ht ml
Disadvantag es	Uneven shape, delay construction, not in high seismic zones, fluorescence cause, Less tensile strength	Low Bonding as smooth finish, corrected by using mortar of 1:4 & curing. poor quality brick harm the structure, high quality ash or affect health (EPA)	Cost high, limited manufacturers, less strength, may need Govt. permission, high water absorption and when dry may crack, less thermal insulation. Cost, wastage and availability,	Cost, wastage and availability, need to hang nets, complex construction, long constn time, toxic,, flammable, poor strength, cracking &spelling, use within maturity period,	http://www.styrofoamdensifier.org/the- advantages- and-disadvantages-of-poly styrene- foam-insulation- board/
	Moss growth, Color of low quality brick changes in sun. porous				
Cost benefit/ quality end product	Easily available in locally, hence economic for low rise structures. Least ecofriendly	High strength used in load bearing walls, need skill labour, need plaster	Skyscrapers re- duction in dead wt. leads to saving concrete &steel/ Exactor is good		
Whether IS code available	Available (IS 1077-1992)	Available IS:12894-2002)	No IS code	IS 4671:1984 (EPC),IS 9012: 1978 (shotcrete)	

Advantages of the EPS panels as building material: The multi advantageous EPCS panels are used for Load bearing wall panel, Non-load bearing wall panel, Shear Wall, Floor / roof slab. The advantages in embedding the housing walls , doors and windows with EPS panels are

1. Eco-friendly and green concept: The panels are reusable and recyclable. They generate little solid wastes in comparison to the conventional construction materials. EPS materials are stable, energy efficient, biologically non-degradable and nontoxic so produces less CO2 and CH4. Risk of pollution to air, surface and UG water is least and maintain green concept.

2. Cost saving: Traditional standard construction cost of building in India varies from (Fly Ash Bricks, water supply/electricityfittings, etc.), then here's an approximate cost for construction on basis of Built-up Area: (https://www.quora.com/What-is-the-building-cost-per-sq-ft-in- India), For G+1 , G+7 , G+12 , G+22 buildings are tentatively INR 13000/sqm, INR 17000/sqm. INR 19000/sqm, INR 21000/sqm respectively. Whereas the traditional structural construction with insulated EPS buildings comes around INR 750 -1000/sqm. The Odisha State Housing Board has constructed by DSP MR ENERGY INFRA JV, Hyderabad, 42 low cost buildings with overall cost of Rs 14000/- INR/sqm. The traditional std. building cost is Rs 25000/sqm.

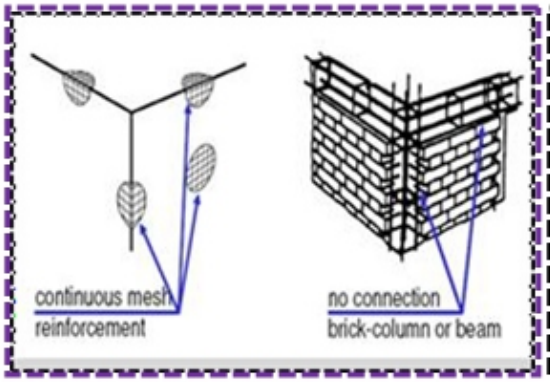

Fig2: Safe connection of nonstructural elements

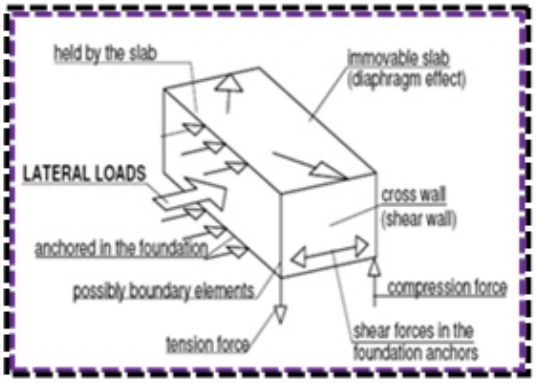

Fig 3.: Less damage during seismicity

3. Light in weight: The EPS panels are light in weight so easy to transport, handle and install which saves the cost of construction to a lot. The tentative weight of the panels varies from 3.5Kg to 5.0kg/sqm.

4. Seismicand storm resistance: The materials are best suited for earth quake retrofitting of walls and partitions as the panel is cladded with wiremesh which protect the building from tremors and gusty winds under erratic climatic changes in India Mishra S. P. 2017[13](Fig 3). The panels have strong protection against strong gusty winds and even during hurricanes.

5. Fast and safe installation: The panels are pre-fab structures. The installation need local minimal less-expert workers and handling no heavy materials which make the process of construction and fabrication easy smooth and quick. Once the foundation beams and columns are erected, all other items are much faster than traditional building construction(Fig 2).

6. High load bearing capacity: The EPS structures have high structural resistance. As light in weight, the less live load is fragmented and easily borne by the load bearing walls and part of the tension is taken by cladded wire mesh.

7. Thermal and acoustic insulation: OSHB buildings have standard 4cm thick EPS panel with density 15 kg/m3 against 1800 – 2100 kg/m3 and with a 3cm thick shotcrete on both faces by (thickness 10cm) is 0.78 W/sqm ºK which saves energy of about 40%. The concrete of 3.5cm thickness on both faces have average sound insulation of 43.50 db. The panels are fire resistant, self-extinguishing.

8. Thermal and energy efficient: the expanded Polystyrene core system with concrete and steel reinforcement (EPCSCSR) sheets are water-resistant, need long-term repair in areas of meteorological extreme (even wind up to 300Kmph and tolerate earthquakes of 0.4 g Ground Acceleration or more than7.5 on the R- scale (Zarnani et al., 2009)[14]

Men, machine and materials used:

The inner core of the panel is polystyrene with impact modifier (SBS or SBES) and conventional building materials used for shotcrete The EPC core is prefabricated as the Industry output (IS 4671:1984 and EN 13163:2013 EPS 80, splice mesh, Reinforcement bars (IS 1786:2008 and shortcrete ingradients (IS 456:2000,IS 2185 (Pt.3):1984 and IS 6073 : 2006) . The machineries and gadgets required are stapuling gun, shotcreting machine, and shuttering and scaffolding materials. Generally minimal semiskilled and unskilled labours are needed those who have hands on practice in the job.

Raw Materials

Steel Wire –2.5/3.0 mm φ and Zinc coated cold drawn galvanizing shall be of 60 gm/m2 ± 5 gm/m2 of mechanical properties Yield stress : > 600 N/mm2, Breaking load : > 680 N/mm2 , Elongation : > 8% and Chemical properties -- Weldability % C : < 0.24 % P : < 0.055 % S : < 0.055 % Ceq: < 0.52 Building Materials & Technology Promotion Council Ministry of Housing & Urban Poverty Alleviation, GOI, New Delhi.

EPC: Self-extinguishing type EPS 80 is in accordance to UNI EN 13163:2013 (IS 4671: 1984) having density not less than 15 kg/m3

Shotcrete materials: Portland cement, fly Ash, 6mm and downgraded coarse aggts,.admixers (IS : 9012 – 1978) or ASTM C33:Standard (Std.) Specification for Concrete Aggts. & ASTM C150: Std.Specification for Portland cement, Shotcrete, ASTM C1140& IS 9012-1978: Std. Practice for Preparing Testing Specimens from Shotcrete Test Panels, ASTM C1141.

Methodology of application

EPS panel after shotcrete has the following five components like, the outer layer of shotcrete, Welded reinforcing mesh of high wire, the core of expanded polystyrene sheet, Diagonal wire (stainless or galvanized wire), and the inner layer of shotcrete.http://www. Mortar sprayer.com/diy-shotcrete/

Methodology of application

EPS panel after shotcrete has the following five components like, the outer layer of shotcrete, Welded reinforcing mesh of high wire, the core of expanded polystyrene sheet, Diagonal wire (stainless or galvanized wire), and the inner layer of shotcrete.

The steps for construction are

1. Start erection from corners and initially connect to starter bars.
2. Fix splice mesh by using pliers and pneumatic tools like hog ring gun
3. Shoring is done by using adjustable props with tripods and bracing. Allow beams to support panels Prepare the slab panels is done by providing corner bars as additional reinforcement and straight bars for flexural reinforcement and for support the stirrups are used.
4. Place slab panels in position with maximum space between beams 1500mm.
5. Top concrete for roof is done by providing 6cm concrete on top of the slab.
6. In walls, shotcrete is done in one or two layers of 40 to 50mm thick on both sides.

7. For smooth finishing of walls and roof top, manual plastering is done in 2 to 3 layers by 40 to 50 mm thick cement mortar (Morgan et al.,2008).
8. Curing is done for minimum 21days to gain strength of shotcrete

Precautions during erection

1. The EPSC is sandwiched between two layers of 11-gauge 5cmx5cm welded-wire steel mesh connected by steel or plastic connectors through the polystyrene. Use plastic connectors to decrease thermal bridging Fig 4.
2. At corners only the strips of splicing mesh include a 90-degree bend are to be used.
3. Openings for doors and windows are to be cut on site. So necessity for bolt cutters or reciprocating saws are needed to cut the mesh and a handsaw to cut the foam. Pressure- treated lumber frames are to be fixed in the window openings before spraying shotcrete.
4. The water supply line, electrical conduits and boxes are inserted and fixed inside the mesh using propane torch prior to shotcrete.
5. The water supply line, electrical conduits and boxes are inserted and fixed inside the mesh using propane torch prior to shotcrete.
6. Shotcrete is pumped wet, gunite (water mixed at thenozzle) is pumped with a 2,500 psi concretegun. Where shotcrete is not possible hand plastering with cement concrete using bazri (6mm or less size chips) or done with stucco / mortar spraying tools
7. Casting roof panels are laid over surfaces supported by props, purlins and shoring till shotcrete is set.
8. During shotcrete by a jet wall blaster the procedures to be followed are:
   - Arrange complete process into steps and organize each one smoothly.
   - Frequently examine the material flow and quantity.
   - Mixing and pumping place should be close by shortening the hose length for easy pumping.
   - Stack sand, bajri, cement water and other ingredients close to the mixer and donot hoard more shotcrete concrete.
   - Regularly clean the gun and hose before pumping.

Characteristics of EPSCCSR panels:

The behaviors of the sandwiched panels are connected as fully composite, partially composite and non-composite materials. The fully composite panels are the Wythe's (concrete layers) are coupled so that both faces of the panels resist applied flexural loads as if monolithic and there is 100% transfer of longitudinal shear. In semi composite EPCS panels, the connectors transfers <100% longitudinal shear. The non-composite EPCS panels are those there is no transfer of longitudinal shear and both concrete faces have separate identity. The stress diagram for composite and non-composite panels are shown in Fig-5 Modular Ratio= E_{sc}/E_{EP} Where E_{sc} = The Young's modulus

Shotcrete

EEP = The Young's modulus of the EPC

Reinforcement and the steel diagonals areto be provided to make the materials fully composite

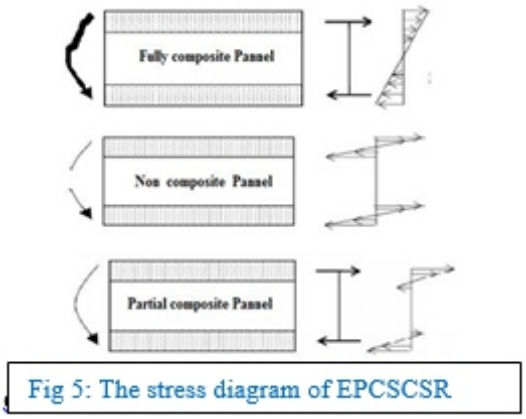

Fig 5: The stress diagram of EPCSCSR

Fig 4: The section of the EPSC core

Advantage of building characteristic with EPSC

1. Higher Value: Higher the Rvalue, more resistance to heat. Vacuum insulated panels have the highest R- value of 7.92 m2 K/W followed by that of aerogels as 1.76-5.28 m2 K/W. TheR-value of EPCS is 0.7 m2 K/W. so some producers offer an increased R-value by%https://www.bdcuniversity.com/sites/sgc-university/files/Fabcon%20- 20Precase%20Concrete%20Panels.pdf,

2. Indoor air quality: The precast shotcrete concretes needs less finishing and about zero plastering. The compatibility of water based paints with the shotcrete is good, the emission of VOC (volatile organic compounds) is least which maintains a good indoor air quality

3. Recyclabilityend-of-use: The panels, the steel can have reuse which is more than 50%

Sustainability of EPSC in long run:

Environmental Impact:
EPS of Ireland is composed of 98 whereas Expanded Polystyrene in Europe or EUMEPS from one liter of oil saves in its lifetime 150 liters in heating a building.

Toxicity, Non bio-degradable and no waste: The EPS is nontoxic, non-degradable during production in its lifetime use and generate 0.1% waste (in Europe) as all flawed materials are either reused or recycled.

Building benefits:
Prefabricated EPSCCSR panels are usually used as walls or roofs in India in framed RCC structures but not as foundations or columns and beams. The construction is not that much cost effective

Fig 6: Column concrete before and after concreting when casted with internal wiring and plumbing

Saving GHG emission: Building constructed or retrofitted with EPS saves 40% of GHG gas emission and zero CFC or HCFC.

EPSC in India:

In Indian scenario, pre-fabricated EPSC have multiple wide uses in walls and roofs but not in base /foundation, columns and beams. The new green building and smart city concept is facing the challenge of cost of construction. The methodology for construction by EPCSCSR is about 50-60 years old still not popular and acceptable. Till today no IS code have been prepared for EPSCCSR construction technology (Fig 6).

Since the materials are light in weight, durable and sustainable for strong gusty winds of storms and water logging for SWMonsoon/NEMonsoon, can prove to be the best choice for construction materials even in coastal structures. The durable, fast and simple construction can solve the problems of govt machinery to meet the demands of the exponentially rising population. Uses of less quantity of cement shotcrete enhance the environmental safety and accelerating saving in production of CO2 in cement industry.Non-adaptability to EPCS technology in India is due to its use as

a. EPCS are used for Filler walls but not for load bearing walls.
b. Not much cost effective than traditional building materials
c. Builder's non-acceptance of EPCS panel as the R-Value of composite is less.
d. Local construction industries are ignorant of the shotcrete and gunite equipment's which are expensive
e. Manufactured EPCS panels are to be jointed as exact size is not available in the market.
f. Errors in cutting and wastage of EPSC Panels may lead to financial loss

4. CONCLUSION (10PT)

Green house concept for the intensifying populations of the world the conventional building materials, labour and machines are rising abnormally. The sweet home concept middle income group of people in India is a day dream. The EPSC technology is 30 years old and still underutilized. EPSC a, sustainable ecofriendly, reusable, recyclable building material will not overexploit the natural resources stone, earth, wood, iron etc. Considering the escalating demography, fast erection, dwelling thermal comfort with rising solar radiation, EPSC panels as the building materials can be one of the unique construction methodology in the Anthropocene epoch.

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Flow in Sinusoidal Tube of Varying Cross Section with Permeable Wall

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ABSTRACT

In this paper, we study the low Reynolds number steady flow in Sinusoidal tube of varying cross section with permeable wall. The fluid is assumed to be incompressible and Newtonian. The wall assumed to be rigid and permeable. The wall permeability is assumed to be a function of axial distance and obeys Starling's Law. We are interested to analyze the effects of Reynolds number and permeability on flow characteristics when the initial flux in the tube is prescribed. The effect of variable permeability of the wall on various parameters on flow characteristics is discussed.

KEYWORDS: Numerical solution of differential equation, fluid m echanics, Reynolds number, Effect of wall permeability.

1. INTRODUCTION

Flow in tubes of varying cross-section is a good area for research work due to its importance in physiological and engineering flow problems. In particular, it plays a significant role in understanding the flow in blood vessels. Most of these studies have considered the tube walls to be impermeable. Flow through tube of uniform cross section with permeable wall has been investigated due to its application in engineering flow problem . Berman(1953) [2] worked on flow through ducts with permeable wall as suction/injection problem where normal velocity of the fluid at the wall is prescribed and these studies suction/injection velocity prescribed at the wall is constant. Macey(1965)[11] prescribed flux as an exponentially decreasing function of axial distance to account for the fluid absorption of the wall. Friealman and Gill(1967)[6] have studied flow though cylindrical tube with permeable walls with reference to flow in the proximal renal tubes.. Manton(1971)[12] have studied for pulsatile flow for tubes of slowly varying cross section. Apelblat,Karzin-katchesky and Silberbarg (1974)[1] presented Mathematical analysis for the fluid exchange across the capillary wall using Sterling law. Quaile and Levy (1975)[16] investigated flow through ducts with permeable wall as suction / injection problem in these studies constant suction /injection velocity prescribed at the wall. Varma and Sachati (1975)[20] investigated flow of a power law fluid through circular tube with porous material by property defining the non slip conditions.

Radha krishnamachrya (1978)[17] studied flow of a dusty fluid in constricted channel. Bestman (1981)[3] analyzed pulsatile flow of a Rivlin- Ericksen fluid at low Reynolds number non Newtonian flow in slowly varying cross section at asymmetrical tubes. Also Radhakrishnamachrya and Peeyush Chandra and Kaimel (1981)[18] the Hydrodynamical problem of flow in proximal renal tubule is investigated by considering axisymmetric flow of a viscous , incompressible fluid though long narrow tube of varying cross section with reabsorption at the wall. Chandra, Peeyush and Radhakrishnam achrya (1983)[4] worked on fluid exchange across converging/diverging tube walls. Colgan and Terril (1989)[5] presented first order solution for asymmetric flow through circular pipe of slowly varying cross section valid for arbitrary Reynolds number. Krishna Prasad and Peeyush Chandra (1990)[8] have worked on the low Reynolds number flow of a viscous incompressible fluid in channels of slowly

varying cross-section with permeable boundaries has been studied. The effect of various parameters on the flow characteristics like wall shear stress, pressure drop and volumetric flow rate has been discussed. Krishna Prasad and Peeyush Chandra (1992)[9] have studied low Reynolds number flow of viscous incompressible Newtonian fluid in cylindrical tube of varying cross section with absorbing walls. Krishna Prasad and Peeyush Chandra have(1992)[10]have studied Pulsatile flow in circular tubes varying cross section with permeable wall .Sarin(1997) [19] fully developed steady laminar flow of an idealized elastic-viscous liquid through a curve tube with elliptic cross section. M.Zakaria (2002)[13]worked on the equation of a polar fluid of hydromantic fluctuating through a porous medium. M.A.A.Mahmoud and M.A.E.Mohmoud (2005) [14] have studied the boundary layer flow of power-law non Newtonian fluid over continuously moving surface in presence of a magnetic field. H.Beirao da Veiga (2008) [7] have studied the motion of non Newtonian fluid with shear dependent viscosity between two cylinders. Mario, Dannis and Amaru Gonzalez (2017) [15] have worked on eleasto -viscoplastic fluid in tubes of varying cross section. The fluid exchange across the wall is accounted for prescribing the normal velocity of the fluid at the wall. A perturbation analysis has been carried out for flow Reynolds number flows and for small amplitude of oscillation.

We consider steady flow of an incompressible fluid in a rigid tube of slowly varying cross-section with absorbing wall. The effect of fluid absorption through permeable wall is accounted by prescribing flux as an arbitrary function of axial distance. The fluid exchange across the tube wall is accounted either by prescribing normal fluid velocity at the wall which is equivalent to prescribing flow flux at different cross-sections of the tube or through Starling's law which states that normal velocity of the fluid at the wall is proportional to the pressure difference across the vessel wall.

In this paper, we study low Reynolds number flow in Sinusoidal tubes of varying cross section with permeable wall. Further, we assume that wall permeability K is a function of axial distance. An initial value problem is formulated where flux and mean pressure at the initial cross section have been prescribed. We are interested to study the effects of Re and K on flow characteristics.

2. FORMULATION OF THE PROBLEM

Consider steady flow of a Newtonian incompressible fluid in an axisymmetric tube of varying cross-section with permeable wall. Using cylindrical polar coordinates (X, R, θ) where R = O is the axis of symmetry for the tube, the equations of motion and continuity are given as :

$$UU_X + V U_R = -\frac{1}{\rho} P_X + \nu [U_{XX} + (RU)_{RR} /R]$$

(1)

$$UU_X + V V_R = -\frac{1}{\rho} P_X + [V_{XX} + \frac{1}{R}(RV) - \frac{V}{R^2}]$$

(2)

$$U_x + (RV)/R = 0 \qquad (3)$$

Where (U, V) are the fluid velocity components in (X, R) directions respectively, P is the pressure, is the kinematic coefficient of viscosity and ρ is the constant fluid density.

We cons5ider tube of slowly varying cross-section, and hence, the radius of the tube R = a (X) is given as:

$$a(x) = S(\varepsilon X / a_0)$$
$$\varepsilon = a_0 / L << 1, \quad S(0)=1 \qquad (4)$$

Where ε is the wall variation parameter, a0 is the tube radius at the initial cross- section, L is the characteristic length and S(ε X/ a 0)is an arbitrary function of X.

The fluid exchange across the permeable wall is given by Starling's law and the net external pressure acting on the surface of the wall is assumed to be constant. This gives the normal fluid velocity at the tube wall as :

$$V - a_x U = K(P - P_{ext.}) \quad \text{at} \quad R = a(x) \qquad (5)$$

The tangential velocity of the fluid at the wall is zero, hence,

$$U + a_x V = 0 \quad \text{at} \quad R = a(x) \qquad (6)$$

The asymmetry of the flow implies

$$U_R = 0 \qquad V = 0 \quad \text{at} \quad R = 0. \qquad (7)$$

Further, we prescribe the mean pressure P_{mean} i. e. ,

$$P_{mean} = \frac{1}{\pi a^2(x)} \int_0^{(x)} 2\pi R\, P\, dR \qquad (8)$$

And the flux Q, $Q = \int_0^{(x)} 2\pi R\, U\, dR$ (9)

At the initial cross-section (X = 0) as P_{in} and Q_0 respectively, which gives

$$P_{mean} = P_{in}$$

$$Q = Q_0 \quad \text{at} \quad X = 0. \qquad (10)$$

The wall permeability is assumed to be a function of axial distance **K(X)=mk(1+nkX)**

where mk and nk are real constants less than 1. It may be noted that when n=0, our case reduces to constant permeability as given by [9] and [10].

3. ANALYSIS AND METHOD OF SOLUTION:

Using the non-dimensional quantities,

$$x = \varepsilon \tilde{X}/a \qquad r = \frac{\tilde{r}}{a_0}, \quad u = 2\pi a_0^2 U/Q$$

$$v = 2\pi a_0^2 V/\varepsilon Q_0, \quad (p, p_{ext}) = 2\pi a_0^2 \varepsilon (P, P_{ex})/\nu\rho Q_0,$$

$$k = \nu \rho K/\varepsilon^2 a_0, \quad q = Q/Q_0$$

and the perturbation technique in terms of parameter ε with

$$(u,v,p,q) = (u^{(0)}, v^{(0)}, P^{(0)}, q^{(0)}) + \varepsilon(u^{(1)}, v^{(1)}, P^{(1)}, q^{(1)}) + o(\varepsilon^2),$$

We get

Zeroth order velocity components as follows

$$u^{(0)} = \frac{1}{4} p_x^{(0)} (r^2 - s^2) \qquad (11)$$

$$v^{(0)} = -\frac{1}{16} r [p_{xx}^{(0)}(r^2 - 2s^2) - 4S S_{xx}^{(0)}] \qquad (12)$$

first order velocity components as follows

$$u^{(1)} = \frac{1}{4} p_x^{(1)} (r^2 - s^2)$$

$$+ \frac{R}{2304} r_x^{(0)} [p_{xx}^{(0)}(2r^6 - 9r^4 s^2 - 36 r^2 s^4 - 29 s^6) - 72 s^3 S_{xx}^{(0)} (r^2 - s^2) \qquad (13)$$

$$v^{(1)} = -\frac{1}{16} r [p_{xx_2}^{(1)}(r^2 - 2s^2) - 4S S_{xx}^{(1)}]$$

$$- \frac{R}{9216} r_x^{(0)} [p_{xx}^{(0)} + p_x^{(0)} p_{xxx}^{(0)} (r^6 - 6 r^4 s^2 + 36 r^2 s^4 - 58 s^6)$$

$$+ 12 S S_x^{(0)} p_{2x}^{(0)} (24 r^2 s^2 - r^4 - 41 s^4)$$

$$+ 72 (2) p_x^{(0)} \{S_{xx} (r^2 - 2 s^2) + S_x^2 (3r^2 - 10 s^2) \qquad (14)$$

Flow Rate and Wall Shear Stress :

The non-dimensional volumetric flow rate (q) Wall shear stress is given by :

$$q = \int_0^{(x)} ru\, dr$$

$$q = -\frac{S^4}{16}[{}^{(0)}_{x} + \varepsilon\{p^{(1)}_{x} + \frac{R^e}{16} S^{3(0)}_{x}(12k(p^{(0)}_{x} - p_{ext}) - S^{(0)}_{x\,x})\}] + o(\varepsilon^2)$$

(15)

The wall shear stress in non-dimensional form is given as :

$$T_w = 2\pi a_0^3 \tau_w / \rho \nu Q_0 \qquad (16)$$

$$T_w = \frac{S}{2} p^{(0)}_{x} + \frac{1}{x} + \frac{R_e}{24} S p_0 \; 16k\; p_0 - p_{ext} - S^2 S\; p^0_{x\,x} + o\,\varepsilon^2 .$$

(17)

CALCULATION OF PRESSURE :

Here, the expressions for various flow variables are given in terms of ${}^{(0)}$, $p^{(1)}$ and their derivatives. These flow variables can be determined once ${}^{(0)}$ *and* $p^{(1)}$are evaluated. The equation governing pressure is obtained through Starling's law.

Thus, using conditions expression for${}^{(0)}$ *and* $V^{(1)}$, we get the following differential equations for $p^{(0)}$ *and* $p^{(1)}$.

$${}^{(0)}_{xx} + 4\frac{S^x}{S} p^{(0)}_{x} - 16^{k}(\frac{p^{(0)}}{S^3} - p_{ext}) = 0 \qquad (18)$$

$${}^{(1)}_{xx} + 4\frac{S_x}{S} p^{(1)}_{x} - 16^{k} p^{(1)}_{S^3} = -\frac{R_e}{64} S^2 [3S^2 (p^{0\,2}_{x} + p^{0} p^{0}_{x})_{xxx} + 40S\, S_{xx}\, {}^{(0)}p^{(0)}_{xx} + 8p^{(0)^2}_{x}\, S_{xx} + 7S^2_{x})] \qquad (19)$$

$${}^{(0)} = p_{in} \quad , \quad {}^{(0)}_{x} = -16 \qquad (20)$$

$${}^{(1)} = 0 \, , p^{(1)}_{x} = 4\, R_e [3k\, {}^{(0)} - p_{ext} + 4]_x \qquad (21)$$

The differential eqns. (21) and (22) with initial conditions form two point initial value problems for${}^{(0)}$*and* $p^{(1)}$ for a given tube geometry, these equations can be solved and the mean pressure drop ΔP at a given cross-section

$$\Delta p = p^{(0)}_{mean} - p^{1}_{mean} = p_{in} - p^{0} x - \varepsilon p^{1}(x) + (\varepsilon^2) \qquad (22)$$

:can be calculated.

4. NUMERICAL SOLUTION AND DISCUSSION:

In general, analytical solutions of the equations (18), (19) are not feasible and equations have to be solved numerically for a given S(x), however, in a particular case of S(x)=1+0.2*sin(2*3.1415*x), Sinusoidal tube .It is possible to find analytic solution for p(0) analytically. But in this case also, it becomes very tedious to solve for p (0) analytically. In view of this, fourth order R-K Method is used to evaluate p(0) and p(1)numerically. Hence, we evaluate the expressions flow rate (Q) and wall shear stress T_w

We have taken ϵ =0.05 in fig.1, fig.3, fig.5 and fig.7 variation of flow rate Q has been shown. The effect of Re and permeability K on flow rate (Q)have been shown in constricted .The flow flux decreases for this tube .The effect of increase in permeability is to decrease the flux.

In fig.2, fig.4 fig.6, fig.8 Variation of wall shear stress ITWI has been shown. The maximum value of wall shear stress is observed around the point of constriction. When permeability increases the wall shear stress decreases.

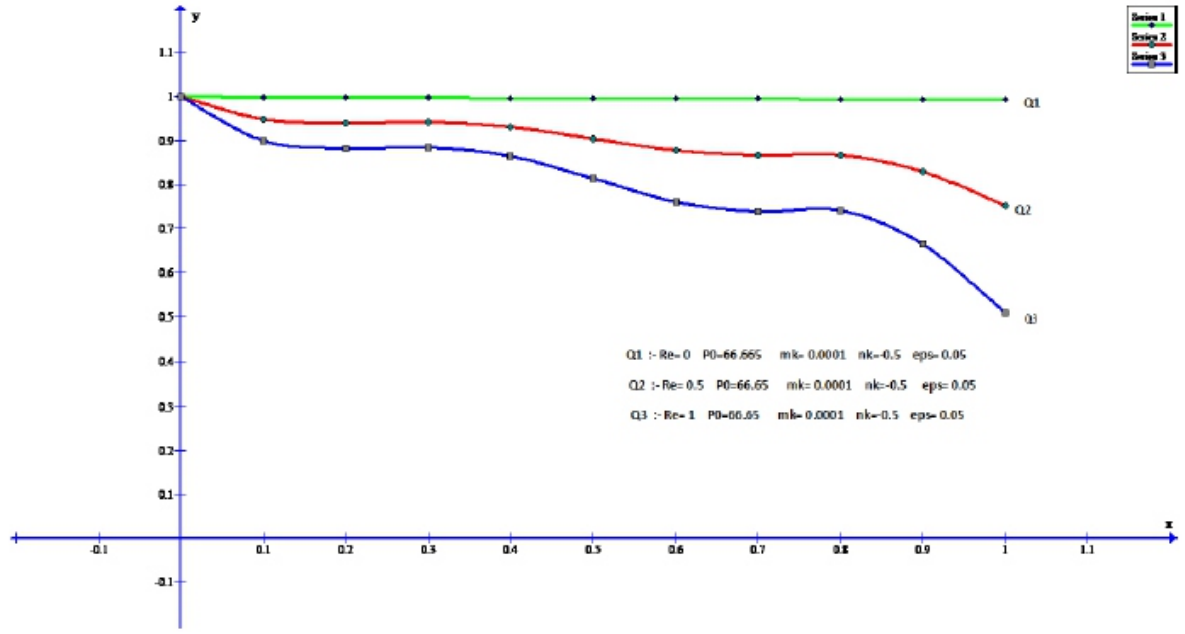

Fig.1) Flow rate Q vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1, mk=0.0001, nk=-0.5, eps=0.05

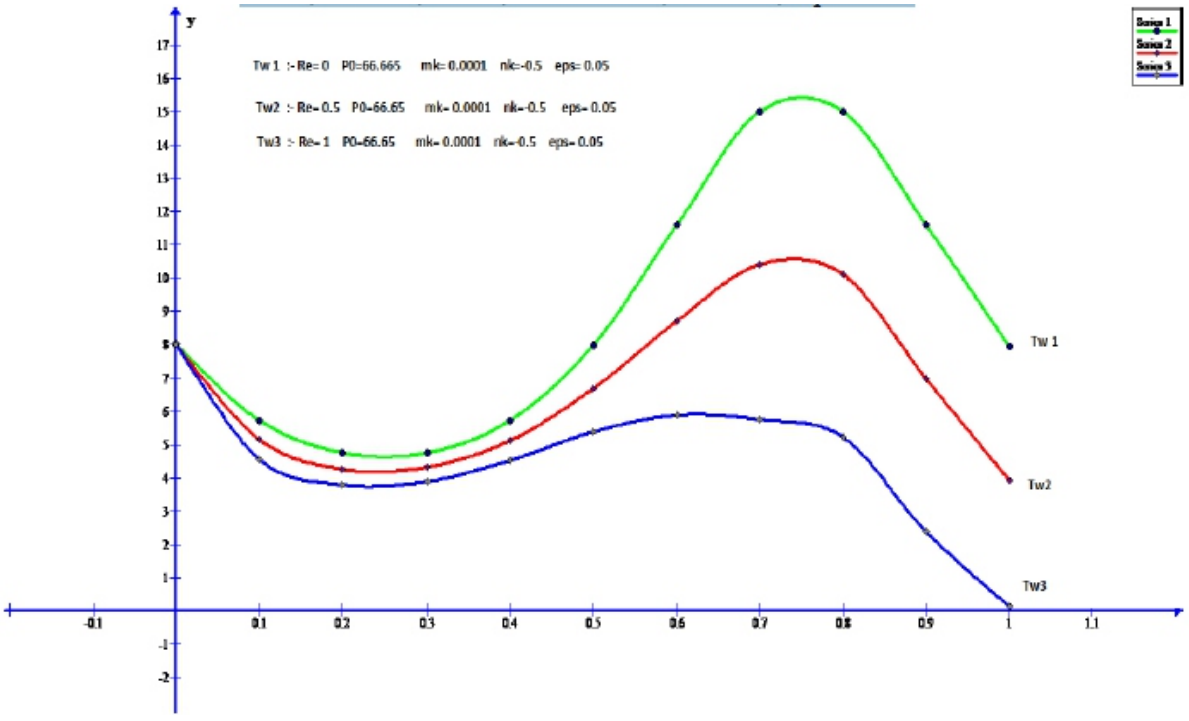

Fig.2) Wall shear stress Tw vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1, mk =0.0001, nk =-0.5, eps=0.05

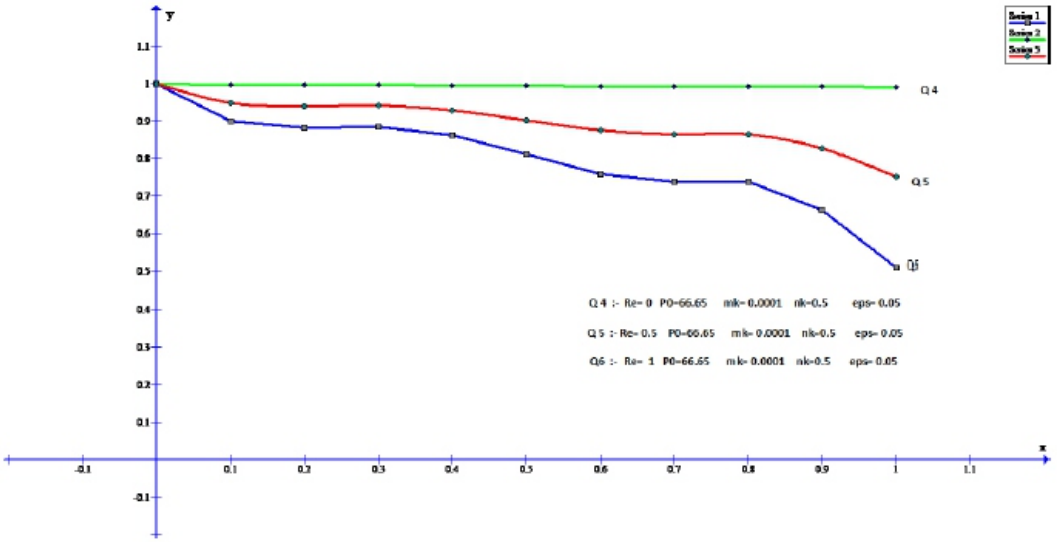

Fig.3) Flow rate Q vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1,mk=0.0001, nk=0.5, eps=0.05

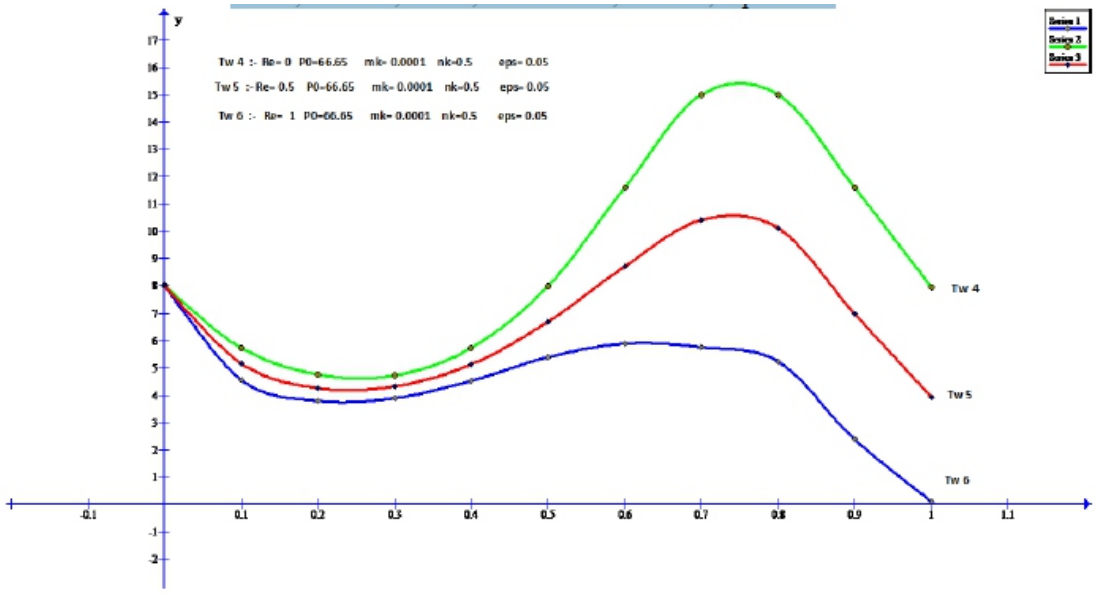

Fig.4) Wall shear stress Tw vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1, mk=0.0001, nk=0.5, eps=0.05

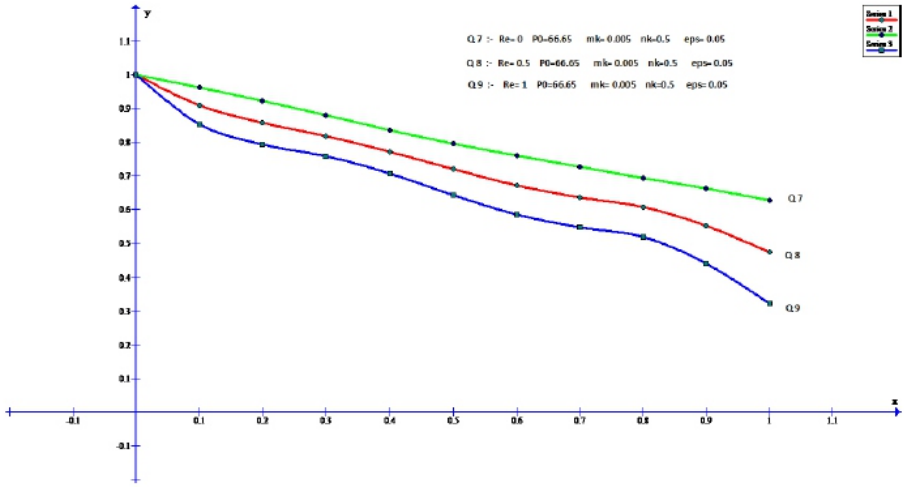

Fig.5) Flow rate Q vs axial distance X for Sinusoidal tube Re=0, Re=0.5, Re=1,mk=0.005, nk=-0.5, eps=0.05

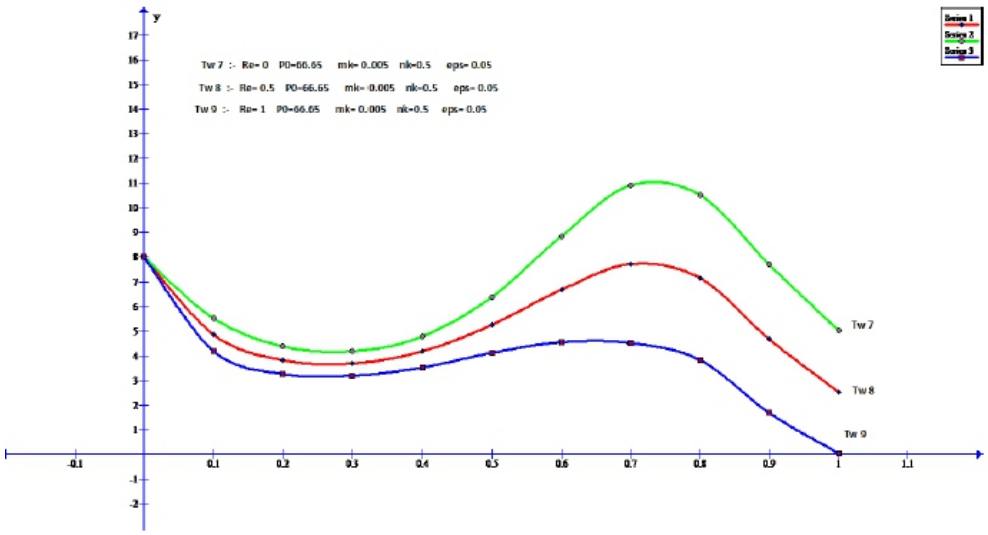

Fig.6) Wall shear stress Tw vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1,mk=0.005, nk=-0.5, eps=0.05

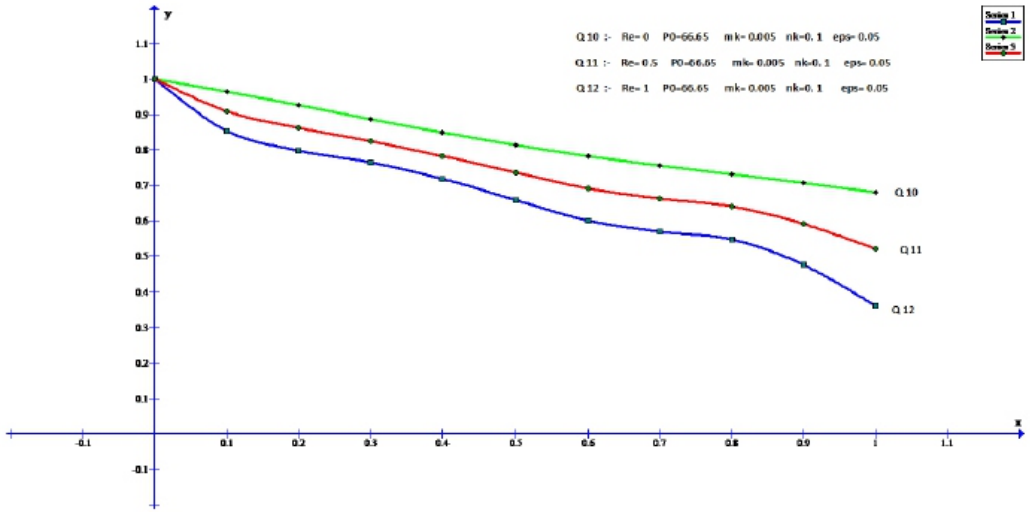

Fig.7) Flow rate Q vs axial distance X for Sinusoidal tube for Re=0, Re=0.5, Re=1, mk=0.005 nk=0.5 eps=0.05

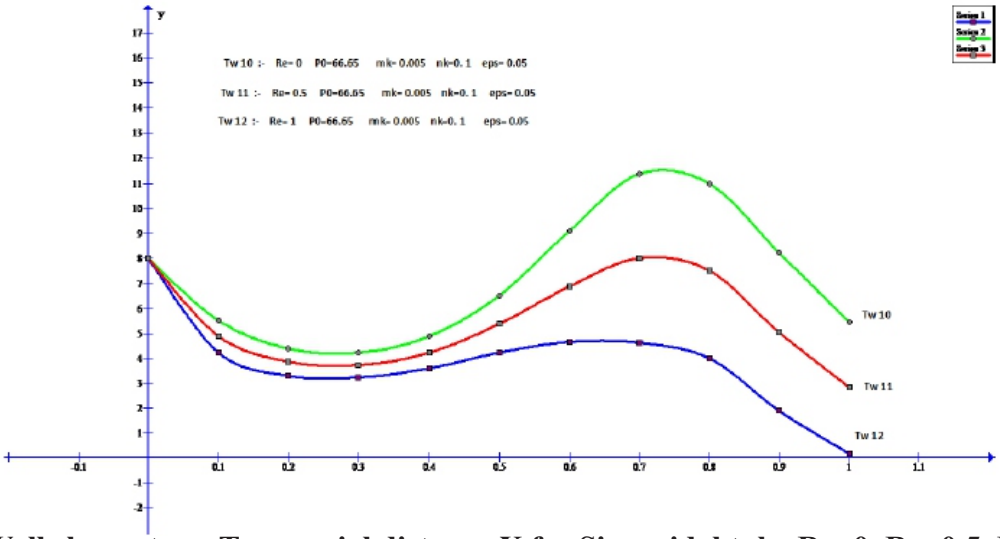

Fig.8) Wall shear stress Tw vs axial distance X for Sinusoidal tube Re=0, Re=0.5, Re=1, mk=0.005, nk=0.5, eps=0.05

4. CONCLUSION

Using numerical values of P(0) and P(1) and their derivatives ,value of flow rate (Q) and wall shear stress (W) are calculated .We have taken $\epsilon = 0.05$ for numerical calculation. The numerical solution obtains by fourth order using R-k method.

In this paper, we have considered effect of wall permeability (Kp) and Reynolds number Re on wall shear stress , pressure and flow flux for Sinusoidal tube. It is observed all these flow value of flow rate decreases as the wall permeability increases. In this tube maximum value of wall shear stress (I Tw I) is observed around the point of contraction. Also as Re increases wall shear stress increases in the constricted region of the tube then decreases in diverging region of tube.

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Spatial Distribution of Red- Swamp Crayfish Procambarus Clarkii (Girard, 1852) in Wetland Ramsar Sites in Morocco

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ABSTRACT

RAMSAR sites are a wetlands that have specific criteria, internationally recognized, and very important not only in the countries where they are located but for all humanity.

Recently, the introduction of a species of crayfish classified as invasive in Morocco: Procambarus clarkii has created a debate among the local population, wetland conservators, wetland conservation NGOs, farmers and fishermen at regional and even national level, this study was essential to answer some questions and to enrich scientifically this discussion.

The notion of presence/absence of Procambarus clarkii and its dispersal has been monitored in Ramsar wetland sites in Morocco for 4 years.

The main objectives of this present study are to understand how this species was introduced in the wetlands Ramsar site of Morocco, identify the points of presence and absence of this species, and establish a presence map.

The study showed that everywhere it appear Procambarus clarkii in Morocco is resistant to different living conditions, and easily colonizes various habitats. The results support the hypothesis of illegal intentional introduction, and a rapid colonization upstream and downstream with high speed.

KEYWORDS: Procambarus clarkii; Alien species; Spacial distribution; Wetland Ramsar; Morocco.

1. INTRODUCTION

Wetlands are considered to be the most biodiverse and fragile ecosystems as well [1].

They face many threats whose invasive species exist in the first degree.

Anthropogenic activities facilitate the transport of non-native species [2], [3], such as the red swamp crayfish (Procambarus clarkii (Girard, 1852)), which has been introduced in several countries, usually for gastronomic or commercial reasons[4], [5], [6], [7].

As a result, this species, which is native to north-eastern Mexico and south-central USA, is nowadays the most cosmopolitan freshwater crayfish species in the world [8], [9], [10].

The red swamp crayfish (Procambarus clarkii (Girard, 1852)), was first introduced in Africa, Kenya around 1960, and then into Portugal in the late 1970's [11], [12] and their numbers increased without control, invading most of the rice fields and wetland areas [13]. Then, a few years later the species was observed in Spain [14]. Thanks to massive imports of live crayfish from these countries [15], the species was introduced into France in 1976 [16] where it is freely sold to consumers.

In Morocco, Procambarus clarkii it occurs on the Atlantic border of the northwestern part of the country, and was first detected in the Sebou River [17].

The success of Procambarus clarkii invasion may be the result of its r-selected strategy, its ecological plasticity as well as its high dispersal ability [6], [8], [18], [19]. Indeed, movements ofthis species can exceed several kilometers per day in rice fields during wandering periods [20].

This article presents the results of the surveys and summarizes in the form of a distribution map all the data collected on the different areas of the national territory.

The main objectives of this study were to confirm the presence of this invasive species in the wetland Ramsar sites in Morocco, investigate the origin of it introduction, and establish a coherent mapping of the spread of the species in these sites.

The natural importance of Ramsar wetlands in Morocco and their need for protection make this study very important.

It is therefore important to understand how Procambarus clarkii uses the artificial and natural water bodies to spread. Such knowledge will provide a better understanding of the ecology of the species and important information on how nature of the biotope may be linked to the spread of Procambarus clarkii.

2. MATERIALS AND RESEARCH METHOD

2.1. Study area

The Kingdom of Morocco, located in the extreme northwest of Africa, is bordered to the north by the Mediterranean, to the west by the Atlantic, and to the south and east by the Sahara.Morocco includes twelve regions; it supports habitats ranging from high-altitude moorland through cork-oak forests to wetlands, deltas, arid steppes and deserts [21].

The present study was conducted in 38 wetlands of international conservation importance, with a total area of 316'086 hectares (Figure 1).

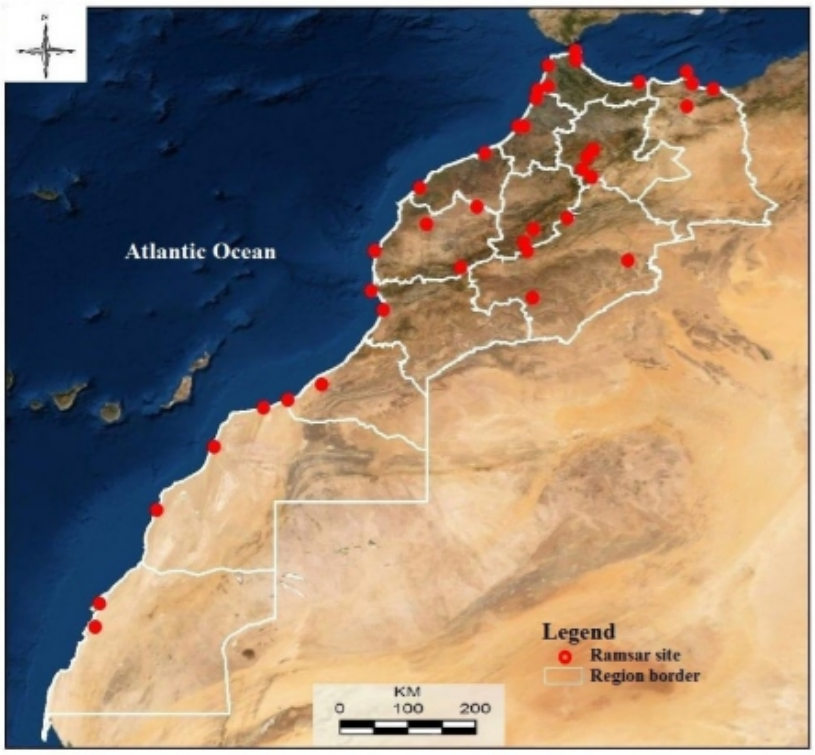

Figure 1. Location of the 38 Ramsar site wetlands in Morocco, 2019

2.2. Sampling methods

To collect the first information on the presence of the species, and the date of first observation an anonymous survey approved by the Regional Department of Water and Forests and the Fight against Desertification North West Kenitra Moroccoin collaboration with the University Abdelmaled Essaadi Faculty of Science Tetouan Moroccowas used.

A survey was distributed to the local population, fishermen, farmers, NGOs, and the administrations concerned at a national level. Forty-threeNGOs active at the national level in the field of environment, education and awareness replied to the survey. 1531 people were interviewed in Morocco, including 927 farmers, 386 local people and 218 fishermen between April 2015 and December 2018 (one field trip per month).

To verify the responses of survey respondents who confirmed the presence of Procambarus clarkii in their areas, it was necessary to take samples of the crayfish and then confirm it in the laboratory using the freshwater invertebrates determination key [22].

The red swamp crayfish populations were caught per unit of effort (p.u.e.), we used the manual fishing technique to catch crayfish. It was necessary to wait for crayfish to start moving on the surface of the land or water to catch it. In water, two methods were used depending on depth. For rivers, lakes, shallow streams (less than 0.30 m), it is possible to catch crayfish by hand. Conversely, in rivers, lakes, dams, water sources (more than 0.30m deep), it is therefore necessary to use another fishing technique, using a landing net and a trap that remains submerged for 24 hours to catch crayfish.

An initial verification of the data collected was carried out at the level of each Directorate of Water and Forestry and the Fight against Desertification, and the Regional Offices for Agricultural Development,

this stage gave rise to many exchanges between the Scientific Committee, NGOs and the administ ration.

The map presented in this article summarize information regarding the notion of presence/absence (Figure 2).

2.3. Statistical analysis :
The data collected by the questionnaire concerning the presence/absence of Procambarus clarkii, the date of first observation and the origin of it introduction in Morocco required a qualitative analysis using XLStat and Nvivo software.

2.4. Cartographic analysis :
The data collected on the concept of the Presence/absence of Procambarus clarkii in Ramsar sites in Morocco are analysed and organised in map form using the ArcGis software.

2.5. Difficulties encountered
Establishing a national distribution map of red swamp crayfish at Ramsar sites is an ambitious project that faces various challenges. The general level of knowledge of this species varies greatly from one region to another. Information on the location of the species is often scattered, no database currently exists at the national level.

3. RESULTS AND DISCUSSION
Surveys on the distribution of red swamp crayfish in Morocco conducted in 2015, 2016, 2017 and 2018 revealed that the spread of red swamp crayfish populations was rapid resulting by its natural characteristic and helped by two identified trends: displacement of the species by uninformed people and the presence of rivers.

The last survey conducted in 2018 therefore covers the period from 2008 to 2018. It should make it possible to verify these trends and acquire new knowledge about the geographical situation of the species.

In the twelve regions of Morocco, the crayfish is absent in ten regions and present in two regions depending on the people surveyed and the field work by our research team to confirm the absence or presence (Figure 2).

In the area where the red swamp crayfish is present, the question on the origin of its introduction has been crucial, a survey was conducted among the local population, farmers, fishermen, NGOs and the administration.
54% of the people surveyed answered that the introduction of this species was by people, 42% they do not know, and 3.3% think that the crayfish was introduced in other areas and it followed the watercourses to arrive in their areas.

Communicate the result of this question with Regional Directorate of Water and Forests and the Fight Against Desertification North West – Kenitra was important to test the credibility of the survey respondents' replies. So, Regional Directorate replied; that Between 2005 and 2010, it has received request for temporary occupation of a State land given to the Waters and Forests called Laachachba, which was under the jurisdiction of the rural commune of Morgane province of Kenitra for the purpose of breeding Tilapia fish and red swamp crayfish. However, the administration refused this request.

The hypothesis put forward by the Provincial Directorate of Water and Forests and the Fight against Desertification of Kenitra, after these requests, is that the presence of the red swamp crayfish in the Sidi Allal Tazi area could only be a clandestine introduction made, in all probability, by one of the candidates. The administration's response confirms and explains the response of 54% of the people surveyed.

The presence of Procambarus clarkii in Morocco could be due to a clandestine introduction to test the degree of acclimatization. The area was chosen given its ecological conditions and, as expected, the acclimatization was very successful.

The species has rapidly spread into the tributaries of the Sebou River, the Gharb rice fields, and the wetlands that lie downstream. With the exception of isolated areas, particularly in the northern and central region, Currently, Procambarus clarkii is present in most river systems in northwestern Morocco and in the four wetlands Ramsar site considered in the study, confirming the high plasticity of the species[10] (Figure 2).

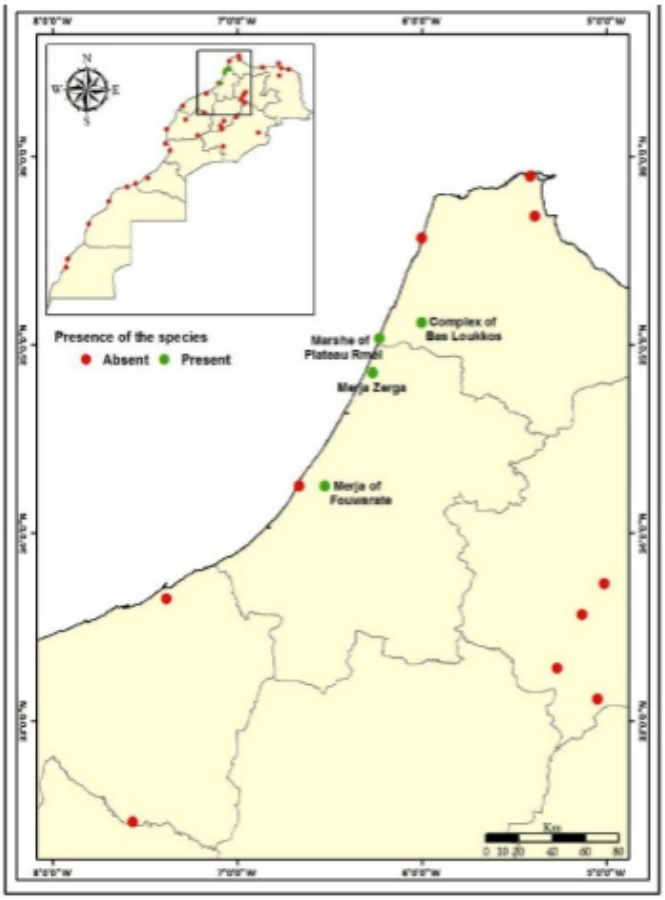

Figure 2. Presence map of the red swamp crayfish (Procambarus clarkii) in the Ramsar site, 2019, Morocco.

The question on the date of first appearance was essential to understand the rate of spread of red swamp crayfish in the study area. 91% of respondents in the regions where Procambarus clarkii is present replied to this questionand only 8% of them replied that they don't know.

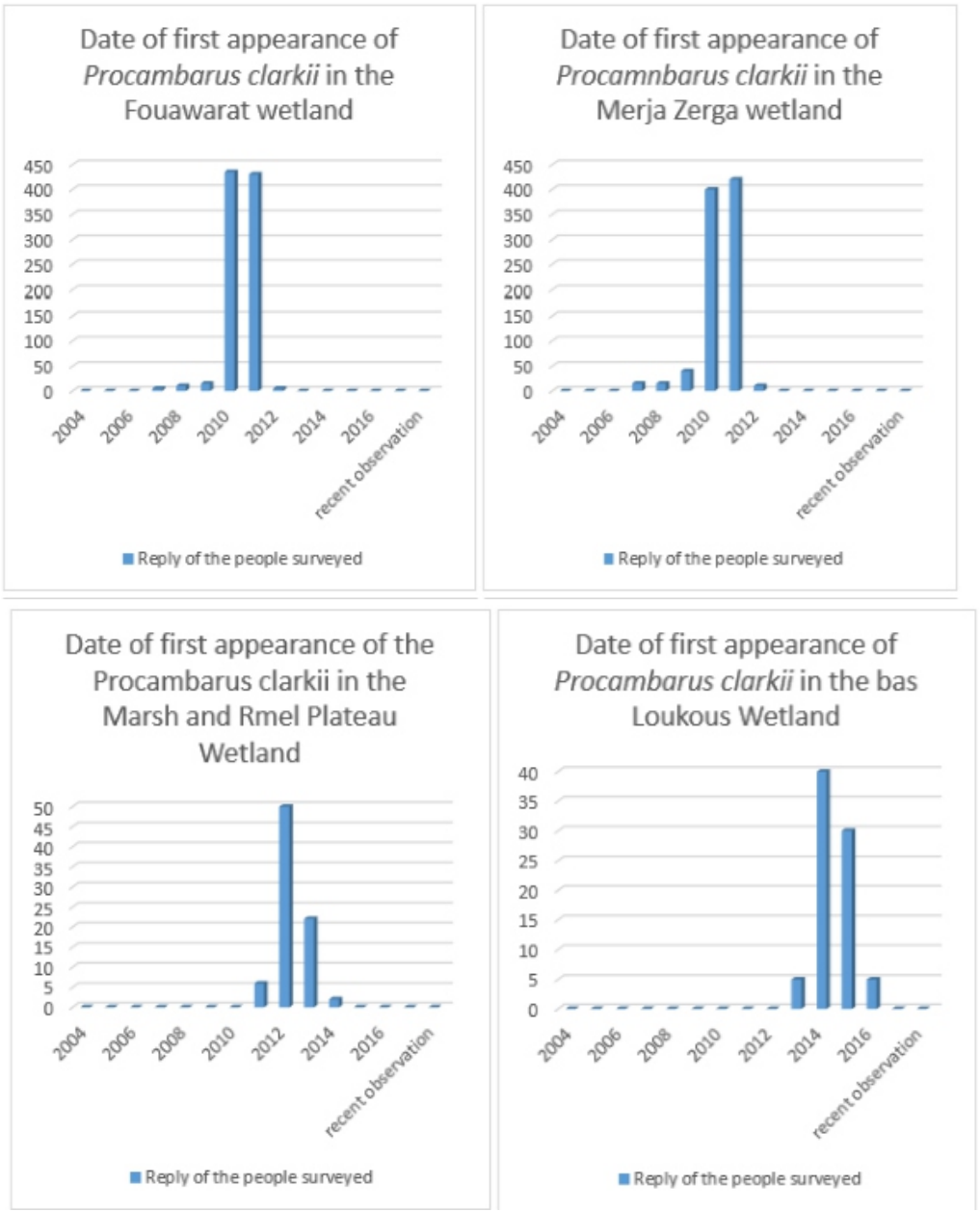

Figure 3. The distribution of responses from survey respondents on the date of first appearance of Procambarus clarkii in their wetlands, Survey 2015, 2016, 2017, 2018, Morocco.

The Red swamp crayfish was observed in the Merja Fouwarate site, a wetland area located at the southwestern end of the Gharb coastal plain. The population of Fouwarate and some researchers from Ibn Tofail University Faculty of Science Kenitra have confirmed that the presence of this species dates back to 2010/2011, it was during the flooding of Oued Sebou in 2010 that it was widespread (Figure 3).

Figure 4. Location of Ramsar sites in northwestern of Morocco and distribution expansion of Procambarus clarkii (black lines). Red mark in the map is the point of the first introduction of Procambarus Clarkii in the area.

According to the local inhabitants, the first indicators of the presence of the species was detected in 2008/2009 in the Sidi Allal Tazi area [17]. This means the crayfish took two years to travel 43.8 km from the site of introduction to site 2 at a distance of 21.9 km per year (Figure 4).

Several studies reported crayfish were more likely to spread downstream at higher rates [23], [24], [25], [26], which is consistent with the results of this study.

The high speed of the crayfish downstream can be linked to the high flow of the Sebou river, which reaches an average flow rate of 137 m3/s. Nevertheless, an anterior study, high flows appear to have no effect on downstream displacement of adult crayfish [27]. The effect of high flows may depend on the current velocity and on the presence of larger substrate fractions which provide shelter for crayfish, decreasing the probability of being washed downstream. But small crayfish may be more easily transported downstream over long distances thus promoting downstream colonization [28].

From then on, the upstream expansion gradually progressed. In 2010/2011 and with a distance of 44.6 km between site 1 and site 3, the red crayfish arrived in the Merja Zerga wetland with an average rate of 22.3 km per year (Figure 4). The discovery of crayfish in wells and water sources between the commune of Sidi Allal Tazi and the commune of Moulay bouslham, the local community and fishermen of the rural commune of Moulay Bousselham, supports the idea that the presence of Louisiana crayfish in Merja Zarga and the Canal Nador is directly linked to its underground spread from Oued Sebou.

The high speed of crayfish from site 1 to site 3 is difficult to understand, but considering its high ecological plasticity, high resistance to extreme conditions of drought and oxygen, high speed outside water [29], this act seems compressible and acceptable. Procambarus clarkii is able to survive

fluctuating hydroperiods, retreating into self-constructed burrows during the dry periods [8], [18]. Then it exits the water searching for new areas during the first rains [30].

The Ramsar Marais site and the Rmel plateau site 4 are a complex of three freshwater coastal lakes, the adjacent sandy beach and coastline, inter-dunal marshes, and irrigated areas. It colonized by the red swamp crayfish in 2012/2013 (Figure 3) which is far from site 3 by 35.5 km. So the average rate is 17.7 km per year (Figure 4).

In 2014/2015, the red swamp crayfish arrived at the Rmsar Bas Loukous site (site 5)(Figure 3), including estuarine waters, shallow marine waters, salt steppes, freshwater swamps and floodplains, in addition to rice paddies in drained areas and a number of abandoned salines. Which is far from site 4 by 40.3 km, this means that the crayfish has travelled at a rate of 21.9 km per year (Figure 4).

The presence of this crayfish in the merja zerga, Marais and the Rmel plateau, bas Loukous wetlands confirms its adaptation to estuarine ecosystems since the species is able to breed in brackish water [31], [32].

In Northeast Portugal, The mean spread rate of signal crayfish was faster for the downstream expansion, 2.8 km per year, while the upstream rate was 1.7 km per year. Exceptionally, in one period, the rate of spread reached 6.7 km per year [28].

Higher downstream expansion rates were reported for Austria, up to 7 km per year [33] and for Croatia, 18−24.4 km per year [34].

The mean spread of Procambarus clarkii is higher than the observed in other studies in other countries, which may also be related to linked to the richness of Morocco's northwestern region in groundwater and surface water, its temperate climate, high rainfall, abundant agricultural land, abundant dikes and irrigation channels. these factors provides favourable conditions for a fast upstream and downstream colonisation.

The survey conducted in 2018 confirms the continued spread of this species, which is now a topic of discussion in all regions of Morocco. In about ten years, the species has been able to colonize a large area in the Rabat-Salé-Kenitra region called Gharb, which is one of the largest regions in the country, confirming its extraordinary capacity for expansion. Between 2008 and 2018, the crayfish was able to colonize four wetlands designated as Ramsar sites in Morocco, in addition to other rivers, wells, and springs.

4. CONCLUSION

Overall, the 2016 survey shows two trends: An increase in the colonized area is reflected in a continuous progression of the species towards the north and center of the country and the high rate of dispersion.

The expansion of this recently introduced species in Morocco encourages specific ecological monitoring at the national level.

Looking for the origin and circumstances under which this species arrived in Morocco is no more important than the future status of our wetlands with the presence of this invasive species. For this

reason an awareness and enforcement of the law prohibiting the import of this species in its living state is strongly recommended.

5. ACKNOWLEDGEMENTS

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Planning, Scheduling and Earned Value Management Analysis of Green Construction

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ABSTRACT

Indian construction industry is the second largest sector after agriculture. Construction Industry these days are going under reformation, where paradigm is shifting towards Green Construction. This type construction is eco-friendly and sustainable. In light to any type of construction, the heart and soul of any project is it proper planning and project management, where we can keep record of duration, resources, cost and other parameters.In the current paper, an existing conventional building is transformed into green building by replacement of some of its element with green ones, so as to call it as Green project. Detail Estimate and BOQ is extracted so as to plan and schedule the building in Primavera P6. EVM analysis is performed on it to get EVM indicators such as EV, PV, SPI, SV, CV and CPI.Apart from the green project, existing/conventional project is also scheduled in Primavera P6 and EVM analysis is performed on it. So that results of both Projects can be compared and concluded..

KEYWORDS: Earned Value Management; Planning; Scheduling; Primavera P6; Green Building.

1. INTRODUCTION

A „green“ building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.[1]

Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

Planning, scheduling is an important part of the construction management. Planning and scheduling of construction activities helps engineers to complete the project in time and within the budget. The term „Construction“ does not only denote physical activities involving men, materials and machinery but also covers the entire gamut of activities from conception to realization of a construction project. Thus, management of resources such as men, materials, machinery requires effective planning and scheduling of each activity.

Earned Value Management (EVM) is a method that allows the project manager to measure the amount of work actually performed on a project beyond the basic review of cost and schedule reports[3].EVM

provides a method that permits the project to be measured by progress achieved. The project manager is then able, using the progress measured, to forecast a project‟s total cost and date of completion, based on trend analysis or application of the project‟s “burn rate”. This method relies on a key measure known as the project‟s earned value.

EVM indicators are in table 1:

NAME	FORMULA	INTERPRETATION
Planned Value (PV) or Budgeted Cost for Work Scheduled (BCWS)		
Earned Value (EV) or Budgeted Cost for Work Performed		
Cost Variance (CV)	CV=EV-AC	-ve = Over Budget,
		+ve = Under Budget
Schedule Variance (SV)	SV=EV-PV	-ve = Behind Schedule,
		+ve = Ahead Schedule
Schedule Performance Index (SPI)	SPI=EV/PV	SPI=1 means Project is on schedule
		SPI<1 means Project is Behind schedule
		SPI>1 means Project is Ahead schedule
Estimate AtCompletion (EAC)	EAC=AC+(BAC-BCWP)/CPI	As of now how much do we expect total project cost
Estimate to Completion (ETC)	ETC=EAC-AC	How more to finish
Variance at Completion (VAC)	VAC=BAC-EAC	How much over/under we expect to be

Table 1. EVM Indicator[2]

2. METHODOLOGY

2.1. Selection of Green Project:

Green Project is design by considering a conventional building and replacing it elements to green ones, so as to consider the building green.

Following are changes made in green building:

Element of Conventional building (which are replaced)	Green Elements
Concrete blocks	Flys ash block
Normal paint	Low VOC Paint
Normal Lighting Fixtures	LED lighting Fixtures
Normal Faucets	Low water Faucets

Table 2. Green elements replaced

Following are site statistics:

Sl.no	Particular	Specification
1	Site area	**3117.9 m^2**
2	Area/flat	**117.308 m^2**
3	No. of floor	**LB+UB+G+20**
4	Coverage	**2752 m^2**

Table 3. Site Statistics

Further in design of Green Buildin, it includes Open to Slab(OTS) so as to increase ventellation and natural lighting in the building.

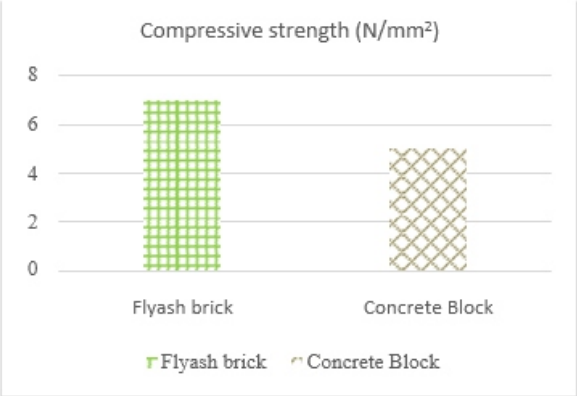

Figure 1. Comparison between Flyash brick and Concrete block [7]

2.2. Estimation and bill of Quantities:

Before planning of any project, we must BOQ prepared for the project so as to know the cost of the project. So, estimation of Quantities are extracted on MS Excel using design plan of the building. In this scenario Drawing plan will be same for both project so quantities the projects extracted will be same. Since we are changing the elemets of the projects the BOQ build using the estimate quantities will differ from each other.

Project Type	Budgeted Cost	Duration (days)
Green Building	Rs. 36,36,80,492	856
Conventional Building	Rs. 36,40,79,548	856

Table 4. Cost of prjects

2.3. Prepare Plan and schedule using Primavera:

Primavera P6 is used as planning software here, where it uses to perform schedule and attain EVM parameters.

The following are step to schedule a project[3]:

i. Create Project: New project is created in the Primavera P6 , by defining EPS and OBS. And start date is defining

ii. Define WBS: WBS for the project is created, by providing sequential work of the project, in the main categories. While defining WBS it should be kept in mind that hierarchy of the WBS should relate with BOQ.

iii. Calendar

Calendar is set as according to the standard of work of the company, usually includes regional work schedule and holidays

iv. Defining Activities: In Primavera Activities are created according to BOQ items extracted,. These activities are distributed through Whole WBS in some logical sequence. Activities are logical relationship, duration and lags.

v. Performing Scheduling: Basically, in primavera Schedule is done on the principles of CPM , where schedule is done base on activity links , which in part create a critical part.

Schedule can be done for any required date.

vi. Resource allocation: Resource list is created according to BOQs , and resources are distributed are distributed according among the activities.

Resources plays important role while scheduling; the cost of the project depends on resources.Cost of resources are extracted from the BOQ. In BOQ each item cost is distributed among its Activity ID, so it would be helpful during resource allocation [9].

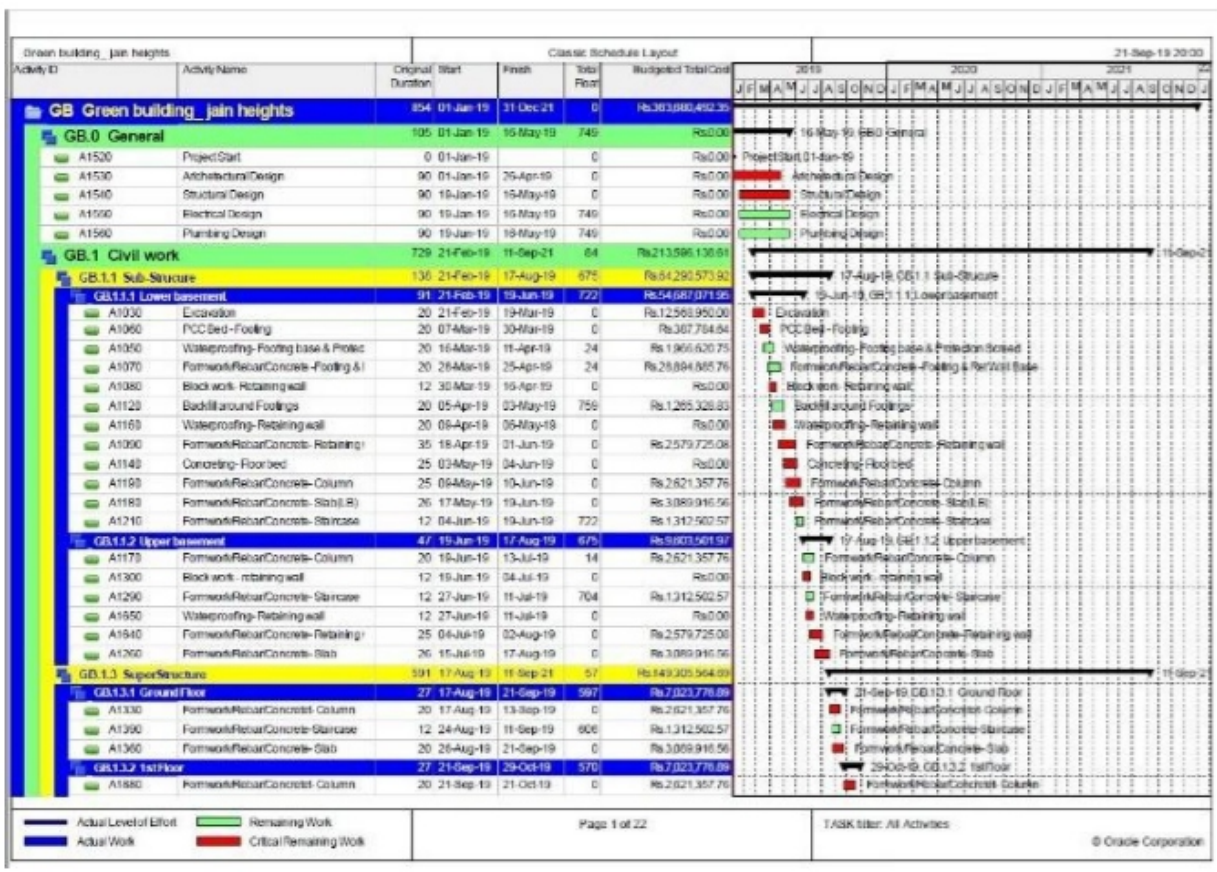

Figure 2. Sample fo scheduling in Primavera P6

2.4. EVM Analysis:

The steps involve after scheduling leads to performance of earned value analysis as follows [10]:

i. Creating basline of the project by selecting same project or different project as base line.

ii. Updating/tracking the project by giving inputs of its progress.

Creating the baseline is the crucial step to perform EVM analysis, to that baseline is assign to the project. And the project is track by updating the activity progress, start date and finish date. After the updation of project we arrive at EVM parameter.

2.5. EVM parameters comparison:

EVM parameters for both project at the date of completion are:

Project	Earn value	Planned Value	SPI	SV
Green building	Rs. 10,71,21,217	Rs. 12,93,32,939	0.83	Rs. 2,22,11,722
Conventional Building	Rs. 10,71,78,225	Rs. 12,94,21,083	0.82	Rs. 2,22,42,857

Table 5. EVM parameters

Earned value and Planned value for updated dates of Conventional Building are shown in table 6 and S-curve for it is shown in figure 3.

NO	Date	PV	EV
1	Jan-19	☐ 0.00	☐ 0.00
2	Feb-19	☐ 38,96,374.50	☐ 38,96,374.50
3	Mar-19	☐ 1,73,34,810.73	☐ 1,65,46,175.88
4	Apr-19	☐ 4,57,76,285.13	☐ 4,33,93,094.34
5	May-19	☐ 5,10,22,161.56	☐ 4,95,79,479.08
6	Jun-19	☐ 5,61,46,719.96	☐ 5,49,32,824.24
7	Jul-19	☐ 6,26,58,080.58	☐ 6,26,34,378.64
8	Aug-19	☐ 6,75,88,346.04	☐ 6,62,37,202.89
9	Sep-19	☐ 7,54,96,752.24	☐ 7,14,49,472.34
10	Oct-19	☐ 8,51,45,206.48	☐ 7,81,01,760.29
11	Nov-19	☐ 9,31,81,978.21	☐ 8,45,68,234.19
12	Dec-19	☐ 10,36,10,078.61	☐ 9,08,12,626.26
13	Jan-20	☐ 11,48,21,963.92	☐ 9,83,96,392.16
14	Feb-20	☐ 12,49,86,006.64	☐ 10,51,44,271.57
15	Mar-20	☐ 13,62,97,291.05	☐ 10,71,78,225.02

Table 6. EV and PV for conventional building

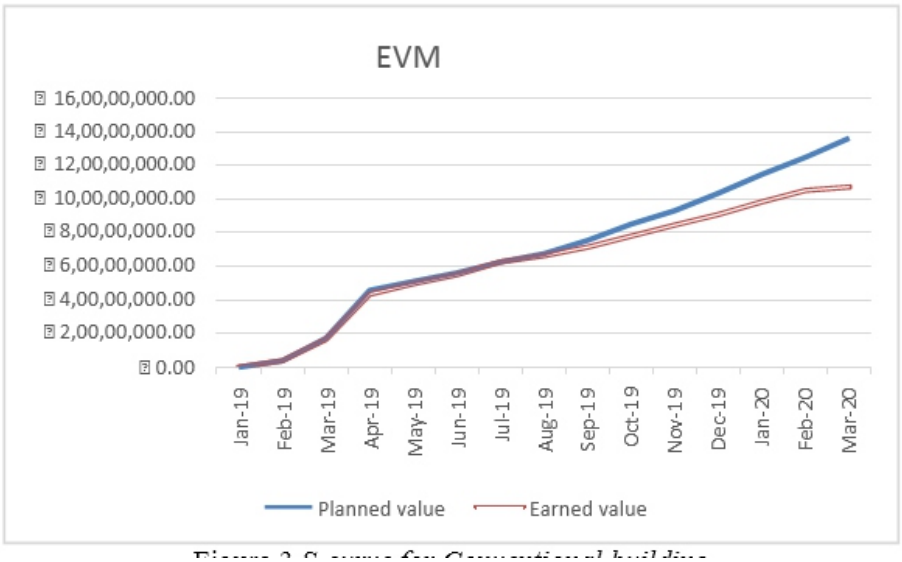

Figure 3.S-curve for Conventional building

Earned value and Planned value for updated dates of Green Building are shown in table 7and S-curve for it is shown in figure 4.

NO	Date	PV	EV
1	Jan-19	₹ 0.00	₹ 0.00
2	Feb-19	₹ 38,96,374.50	₹ 38,96,374.50
3	Mar-19	₹ 1,73,34,810.73	₹ 1,65,46,175.88
4	Apr-19	₹ 4,57,76,285.13	₹ 4,33,64,801.84
5	May-19	₹ 5,10,22,161.56	₹ 4,95,79,479.08
6	Jun-19	₹ 5,61,46,719.96	₹ 5,49,22,994.15
7	Jul-19	₹ 6,26,58,080.58	₹ 6,26,34,378.64
8	Aug-19	₹ 6,75,88,346.04	₹ 6,60,97,903.37
9	Sep-19	₹ 7,54,96,752.24	₹ 7,14,49,472.34
10	Oct-19	₹ 8,51,32,343.14	₹ 7,80,85,365.84
11	Nov-19	₹ 9,31,53,035.70	₹ 8,45,36,563.09
12	Dec-19	₹ 10,35,64,179.87	₹ 9,08,00,778.62
13	Jan-20	₹ 11,47,58,378.10	₹ 9,83,39,384.18
14	Feb-20	₹ 12,49,06,341.64	₹ 10,58,76,667.31
15	Mar-20	₹ 13,61,99,938.96	₹ 10,71,21,217.04

Table 7. EV and PV for Green building

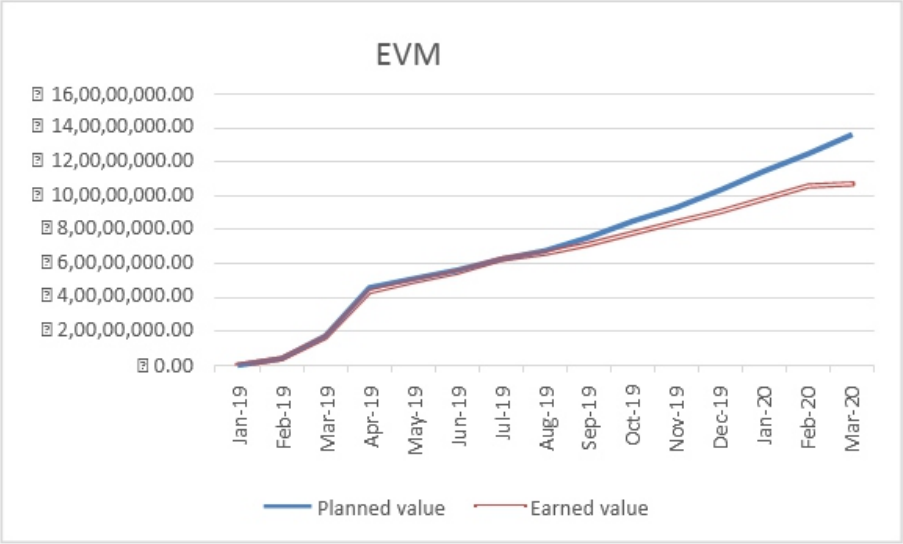

Figure 4.S-curve for Green building

3. RESULTS AND DISCUSSION

- Since analysis SPI of green project is 0.83 and conventional project is 0.82
- Schedule variance of both project are in negative value
- By comparing the cost of the projects there is difference of around 4 lakh rupees which is not a major difference in case of 36 crore projects

Project Type	Budgeted Cost	Duration (days)
Green Building	Rs. 36,36,80,492	856
Conventional Building	Rs. 36,40,79,548	856

Table8: Cost and duration comparison of both project

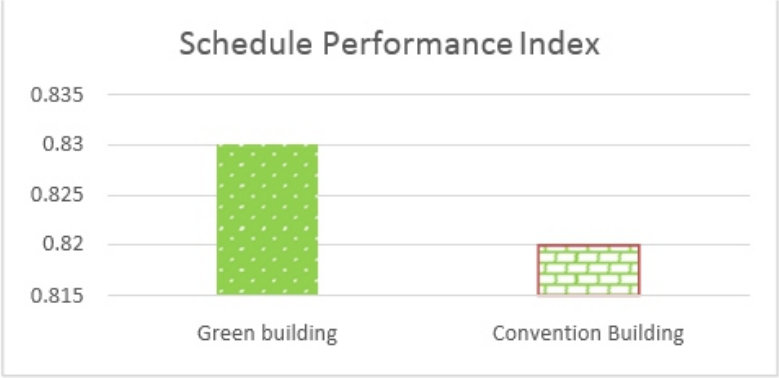

Figure 5. Schedule Performance Index

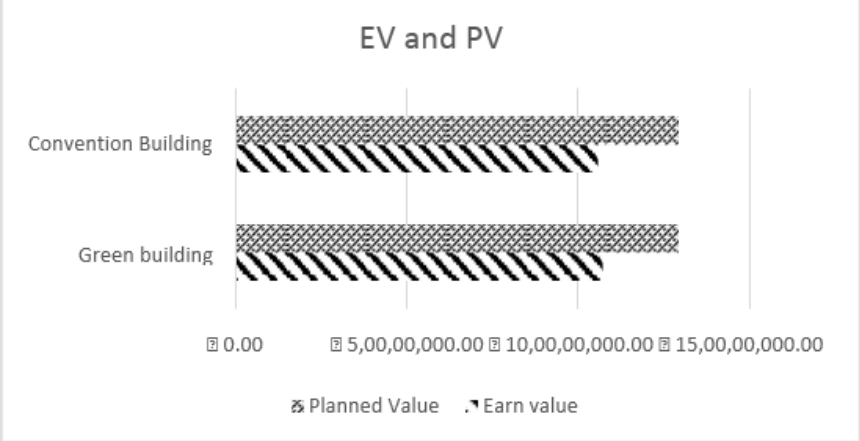

Figure 6. Earned value and Planned Value

4. CONCLUSION

Green project with above mention features can cost only around 4 lakh Indian rupees less. Moreover, green materials make the building more sustainable and economical in their life time. EVM indicators analysed shows that green project is 17% behind the schedule as compare to conventional project that is 18% behind the schedule. And cost run out faster in case of conventional project.

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Detailed Study on Roads in Tamilnadu

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ABSTRACT

Transportation is the movement of people or goods from one place to another. Transport is important since it enables trade between people, which in turn augment economic growth and foster civilizations. The transport system comprises of highways or roadways, Railways, water ways and air ways.

Road ways include highways, city roads, village roads, feeder roads and Ghat roads. Roadways provide maximum service to one and all. It is possible to provide door to door services only by road.

INTRODUCTION ABOUT ROADS AND HIGHWAYS DEVELOPMENT OF ROADS IN INDIA

Transportation is one of the infrastructures of a country. Transportation helps in economic, industrial, social and cultural development of a country. Transportation is very important for the economic development of any region since commodities produced, like food, clothing, industrial products, medicine need transport at all stages from production to distribution. It is also essential for strategic movement in emergency for defense of the country and to maintain better law and order. Transportation also helps in tourism development.

Road transport is one of the most common modes of transport. Roads in the form of track ways, human pathways etc. were used even from the pre-historic times. Since then many experiments were going on to make the riding safe and comfort. Thus road construction became an inseparable part of many civilizations and empires.

The history of highway engineering gives us an idea about the roads of ancient times.

Roads in Rome were constructed in a large scale and it radiated in many directions helping them in military operations. Thus they are considered to be pioneers in road construction.

In India the Mauryan dynasty rulers and Harsha Vardhana took much interest in the development of road system as they were able to appreciate the importance of road in terms of strategic and economical development of country. In the later period the Mughal emperors paid much importance in counstrucion of roads. Patna-Kabul, Delhi-Surat, Delhi-Golconda, Golconda-Bijapur, Bijapur-Ujjain and Surat-Maulipatanam are some of the notable highways developed by them.

BRITISH ROAD

The British government also gave importance to road construction. The British engineer John Macadam introduced what can be considered as the first scientific road construction method. Stone size is an important element of Macadam surface formation. By empirical observation of many roads, he came to realize that 250 mm layers of well compacted broken angular stone would provide the same strength and stiffness and a better running surface than an expensive pavement made on large stone blocks. Thus he introduced an economical method of road construction.

The mechanical interlock between the individual stone pieces provides strength and stiffness to the course. But the inter particle friction abraded the sharp interlocking faces and partly destroy the effectiveness of the course. This effect was overcome by introducing good quality interstitial finer material to produce a well-graded mix. Such mixes also proved less permeable and easier to compact. A typical cross section of British roads is given in Figure 1.

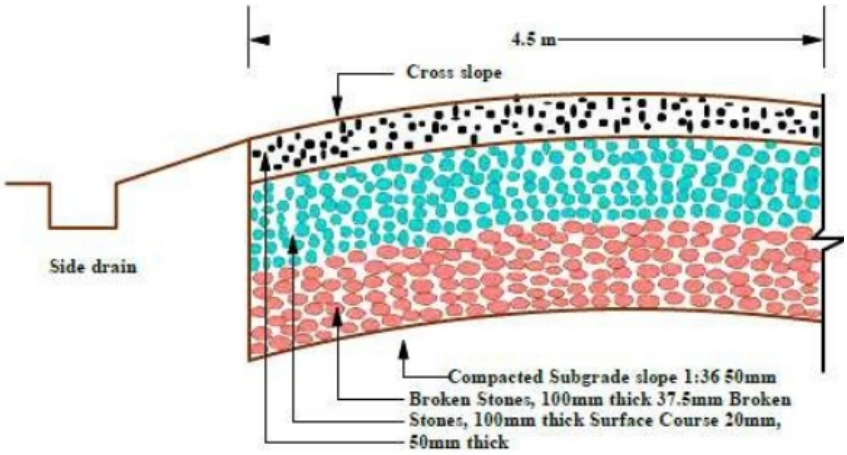


Fig.1 Typical cross section of British Road

MODERN ROADS

The modern roads by and large follow Macadam's construction method. Use of bituminous concrete and cement concrete are the later developments. Various advanced and cost-effective construction technologies are used. Development of new equipments helps in the faster construction of roads. Many easily and locally available materials are tested in the laboratories for their suitability and then used on roads for making economical and durable pavements.

CLASSIFICATION OF ROADS

Roads are also classified based on the following criteria. They are given in detail below.

1. BASED ON USAGE

This classification is based on whether the roads can be used during different seasons of the year.

i) All-weather roads: Those roads which are negotiable during all weathers, except at major river crossings where interruption of traffic is permissible up to a certain extent are called all weather roads.

ii) Fair-weather roads: Roads which are negotiable only during fair weather are called fair weather roads.

2. BASED ON CARRIAGE WAY

This classification is based on the type of the carriage way or the road pavement.

i) Paved roads with hard surface: If they are provided with a hard pavement course such roads are called as paved roads.(eg: stones, Water bound macadam (WBM), Bituminous macadam (BM), concrete roads.

ii) Unpaved roads: Roads which are not provided with a hard course of at least a WBM layer are called as unpaved roads. The earth and gravel roads come under this category.

3. CLASSIFICATION OF ROADS AS PER I.R.C (INDIAN ROAD CONGRESS)

Based on location and function, the Nagpur plan classifies the roads as

a) National Highways (NH)
b) State Highways (SH)
c) Major district Roads (MDR)
d) Other district roads (ODR) and
e) Village Roads

National Highways (NH)

The road network connecting State capitals, Major Cities, Major Ports, large industrial areas and important tourist centers are classified as the National Highways by Ministry of Road Transport and Highways (MORTH), Government of India (GOI). National Highways form the economic backbone to the country enhancing quick movement of men and materials to the requisite destinations in right time and facilitate rapid development along their routes.

Totally 4994 km length of National Highways runs through Tamil Nadu State. Out of this 1985 km are maintained by State National Highways Wing and balance 3009 km are maintained by the National Highways Authority of India (NHAI). National Highways are being developed by widening to two lane / four lane / six lane with paved shoulders and strengthening the existing riding surface with the funds from the MORTH, GoI and some of them are also taken up under Public Private Partnership mode.

State Highways (SH)

The State Highways connect District headquarters with National Highways and neighbouring States. These stretches get maximum importance owing to heavy traffic intensity. The total length of State Highways in Tamil Nadu is 12095 km.

Major District Roads (MDR)

The Major District Roads connect towns and municipal areas with District headquarters. These roads connect the production and marketing centres with National Highways and State Highways. In Tamil Nadu, the total length of Major District Roads is 11628 km.

Other District Roads (ODR)

The Other District Roads (ODR) are the backbone of the rural economy and day to day activities of general public which connect villages with marketing, educational and health care centers and Taluk headquarters and other nearby important roads. Based on the traffic intensity, the Other District Roads are maintained as Single Lane or Intermediate Lane.

Sugarcane Development Roads are also under the ODR category, which are connecting the sugarcane cultivating areas with Sugar mills and in turn with nearby marketing centres. There was 33751 km of Other District Roads including 1676 km of Sugarcane Development roads in the State of Tamil Nadu.

MODIFIED CLASSIFICATION OF ROAD SYSTEM BY THIRD ROAD DEVELOPMENT PLAN (1981 – 2001)

The roads in the country are now classified into three classes

1. Primary system
2. Secondary system
3. Tertiary system

1. Primary system consists of two categories of roads

- Expressways and
- National Highways (NH)

Express ways are separated class of highways with superior facilities and design standards meant for very high volume traffic. These permit only fast moving vehicles.

2. The secondary system consists

- State highways (SH) and
- Major District Roads

3. Tertiary system consists of

- Other District Roads (ODR) and
- Village Roads

CLASSIFICATION OF URBAN ROADS

The urban roads are classified as

- Arterial Roads
- Sub-arterial roads
- Collector streets and
- Local streets

Arterial and sub arterial roads are the streets primarily for through traffic.

FLEXIBLE ROAD PAVEMENTS AND RIGID ROAD PAVEMENTS FLEXIBLE ROAD PAVEMENT

Flexible pavements will transmit wheel load stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure (see Figure 2). The wheel load acting on the pavement will be distributed to a wider area, and the stress decreases with the depth. Taking advantage of this stress distribution characteristic, flexible pavement normally has many layers. Hence, the design of flexible pavement uses the concept of layered system. Based on this, flexible pavement may be constructed in a number of layers and the top layer has to be of best quality to sustain maximum compressive stress, in addition to wear and tear. The lower layers will experience lesser magnitude of stress and low quality material can be used. Flexible pavements are constructed using bituminous materials. These can be either in the form of surface treatments (such as bituminous surface treatments generally found on low volume roads) or, asphalt concrete surface courses (generally used on high volume roads such as national highways). Flexible pavement layers reflect the deformation of the lower layers on to the surface layer (e.g., if there is any undulation in sub-grade then it will be transferred to the surface layer). In the case of flexible pavement, the design is based on overall performance of flexible pavement, and the stresses produced should be kept well below the allowable stresses of each pavement layer.

Pavement structure consists of the prepared sub-grade and the pavement component layers such as sub-base, base and surface course. The stability or the structural capacity of the pavement depends upon the pavement layer system including the sub-grade. However, the road users are concerned about the riding quality, safety and other performance aspects of the road pavement rather than the pavement structure,

design life etc. Hence, it is important to ensure the above requirements also while designing a pavement. The flexible pavements are constructed as a multi-layer system consisting of typical component layers, namely sub-base, base course, and surface course.

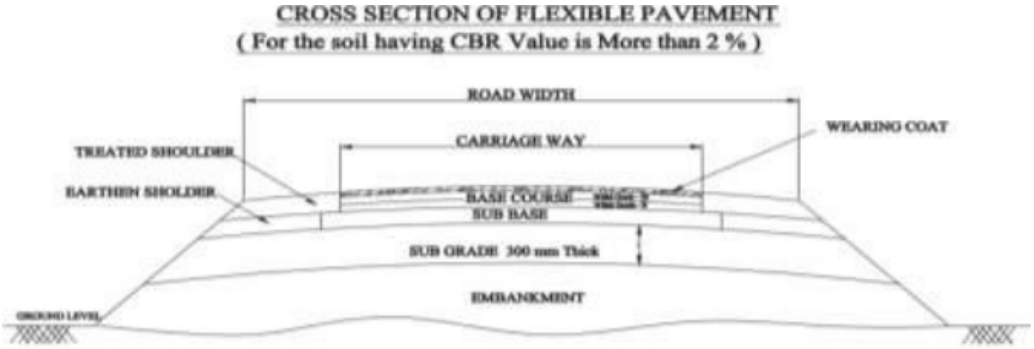


Fig. 2 Flexible pavements consist of a number of layers

RIGID PAVEMENTS

Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. A typical cross section of the rigid pavement is shown in Figure 3. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub- base course.

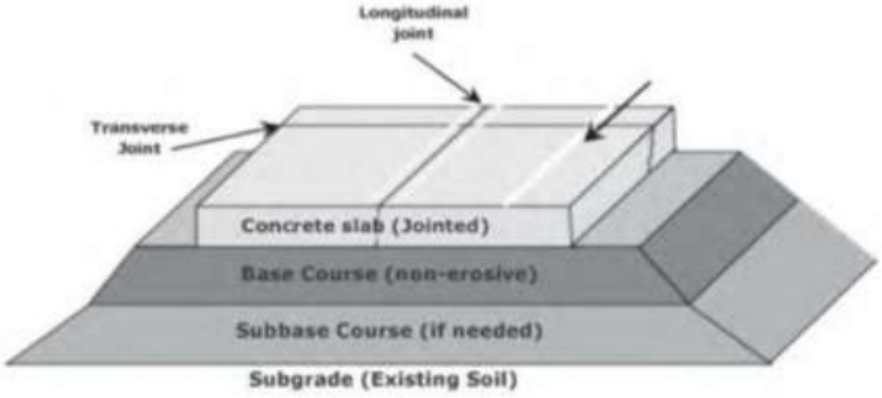


Fig. 3 Rigid pavements

In rigid pavement, load is distributed by the slab action, and the pavement behaves like an elastic plate resting on a viscous medium. Rigid pavements are constructed by Portland cement concrete (PCC) and should be analyzed by plate theory instead of layer theory, assuming an elastic plate resting on viscous foundation. Plate theory is a simplified version of layer theory that assumes the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading.

SPECIFICATIONS OF ROAD ROAD STRUCTURE

Road structure consists of the following components as shown in the following figure 4.

i. Sub soil
ii. Sub grade
iii. Base course
iv. Wearing course or Surface course
v. Berm

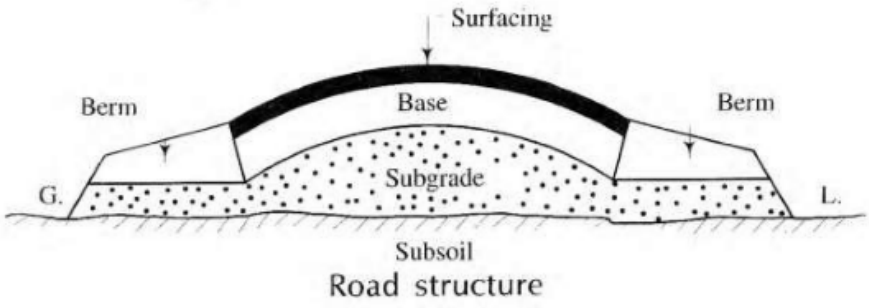


Fig. 4 Cross sections of road structures

i) SUB SOIL:

This is the natural or prepared soil on which a road has to be formed which should be strong and stable to carry the road traffic and weight of road construction.

ii) SUB GRADE:

The sub grade functions as a support to road surface and serves as a foundation. The life of road primarily depends on the stability and dryness of sub grade. Therefore considerable attention should be paid in the preparation of the sub grade.

iii) BASE COURSE:

Base course is a layer made of granular material such as broken granite stone, natural gravel, and boulder stone. It is a layer immediately under the weaning course. It is an important structural part of the road. It should be strong enough to bear the loads of the traffic. The material in a base course must be of extremely high quality. It must be well compacted.

iv) WEARING COURSE OR SURFACE COURSE:

Wearing course is the top most layer of a road which is in direct contact with the traffic. The purpose of the weaning course is to give a dense smooth riding surface with flexibility. It resists the pressure exerted by tyres and withstands wear and tear due to the traffic. It acts as a water tight layer and prevents percolation of water.

RIGHT OF WAY

Right of way is the area of land acquired and reserved along its alignment for construction and development of a highway is known as right of way.

LAND WIDTH

A minimum land width is prescribed for different categories of road. The below table 1 gives the minimum width of right of way for different categories of road.

Table 1 Requirement of right of way

NO.	Type of road	Plain and rolling terrain				Mountainous and steep terrain	
		Open areas		Built- up areas		Open areas	Built- up areas
		Normal m	Range m	Normal m	Range m	Normal m	Normal m
1	NH and SH	45	30-60	30	30-60	24	20
2	MDR	25	25-30	20	15-25	18	15
3	ODR	15	15-25	15	15-20	15	12
4	VR	12	Dec-18	10	Oct-15	9	9

There are chances of developments along its route and when it becomes necessary to have the widening of road in future; it proves to be difficult and costly to acquire such developed lands along the boundary of road. Hence the appropriate width of land has to be acquired in the initial stage so that the road can be widened without serious difficulties when the occasion demands in future. The rights of ownership of road land are vested with the highway authority.

As a further precaution, restrictions are put up on the construction activities along the road and for this purpose, building lines and control lines are decided at suitable distance from the road boundary.

The owner of land along highway route has to leave a certain set back or margin from road boundary and he can construct the building up to that line only in his plot. This line is known as building line.

A further set back in the form of control line has to be maintained by the private land owners along the highway route and the development between the portion covered by the building line and control line is restricted by the concerned highway authority.

The right of way mainly depends on the importance of road and it is decided in such a way that the following components of road are suitably accommodated:

(i) Availability of funds;
(ii) Cost of acquisition of lands;
(iii) Drainage systems;
(iv) Height of embankment or depth of cutting;
(v) Side slopes of embankment or cutting;
(vi) Visibility considerations on curves;
(vii) Width of formation;
(viii) Width of land required for future development;

WIDTH OF FORMATION:

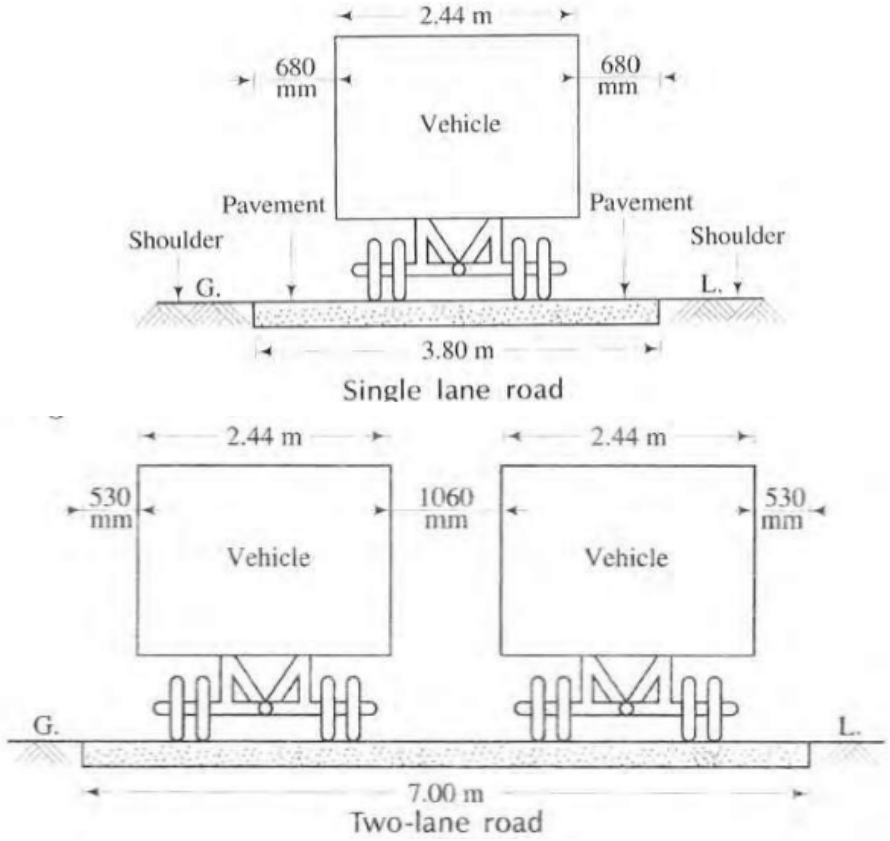
The width of pavement or carriage way depends on the width of traffic lane and number of lanes. The carriage way intended for one line of traffic movement may be called as a traffic lane. The lane width is determined on the basis of the width of vehicle and the minimum side clearance provided for the safety. When the side clearance is increased there is an increase in speed of the vehicles and hence in increase in the capacity of the pavement. A width of 3.75 m is considered desirable for a road having single lane for vehicles of maximum width 2.44 m. For pavement having two or more lanes, width of 3.5 m per lane is sufficient.

		Formation width in m	
No.	**Type of roadway**	**Plain and rolling terrain**	**Mountainous and steep terrain**
1	National and State Highways		
	Single lane	12	6.25
	Two lanes	12	8.8
	Major district roads		
2	Single lane	9	4.75
	Two lanes	9	-
3	Other district roads		
	Single lane	7.5	4.75
	Two lanes	9	-
4	Village roads		
	Single lane	7.5	4

Table 2 Road Classification and dimensions

WIDTHS OF FORMATION

Class of Road		Width of the Carriage way
(i)	Single lane	3.75m
(ii)	Two lanes, without raised kerbs	7.0m
(iii)	Two lanes, with raised kerbs	7.5m
(iv)	Intermediate carriage way	5.5m
(v)	Multi lane pavement	3.5m per lane



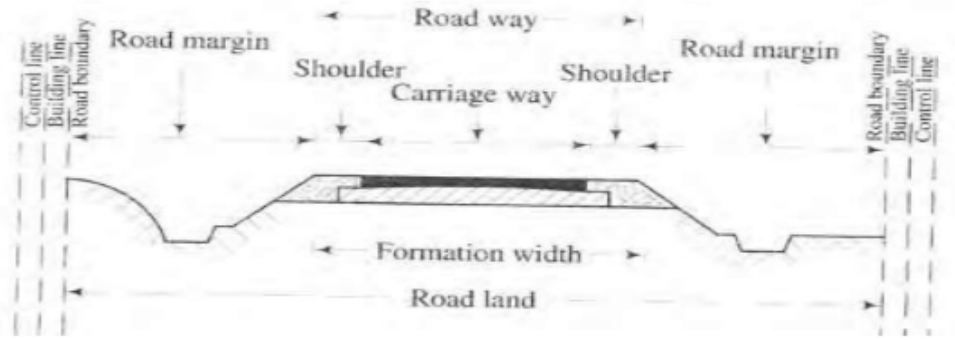
Single and double lane Roadway

SHOULDERS:

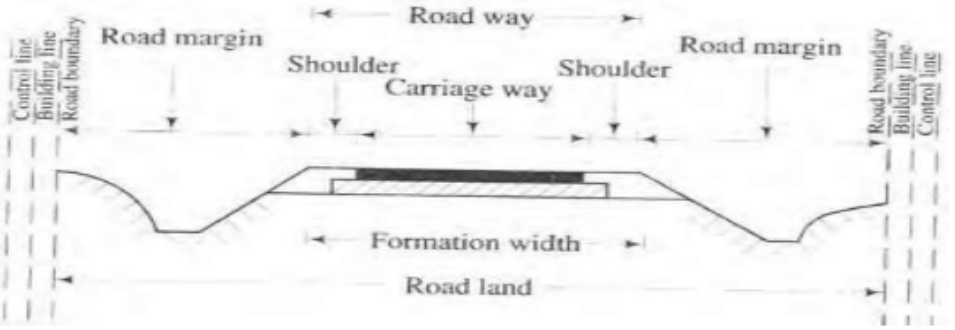
Shoulders are provided along the road edge to serve as an emergency lane for vehicles to be taken out of the pavement. These also act as service lanes for vehicles that have broken down. The minimum shoulder width recommended by the IRC is 2.5 m. The shoulders should have sufficient strength to support loaded even in wet weather. The surface of the shoulder should be rougher than the traffic lanes so that the vehicles are discouraged to use the shoulder as a regular traffic lane.

CROSS SECTIONS OF ROADS:

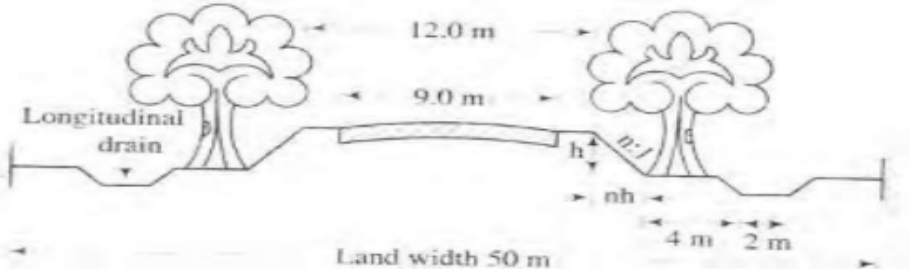
The following figures shows the cross-section of road in embankment, cross-section of road in cutting, the typical cross-section of two-lane NH or SH in rural area , the typical cross-section of two-lane city road in Built up area



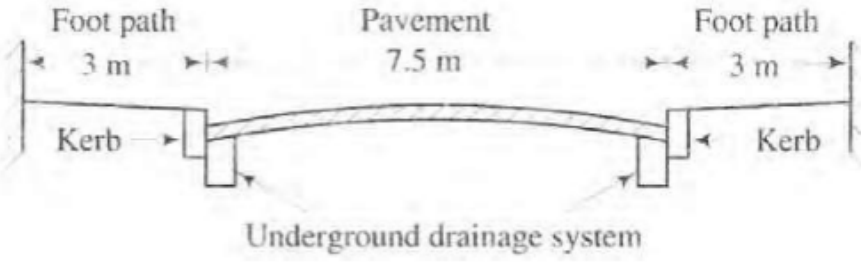
Cross section of road in cutting



Cross section of road in embankment



Cross section of two lane national highway



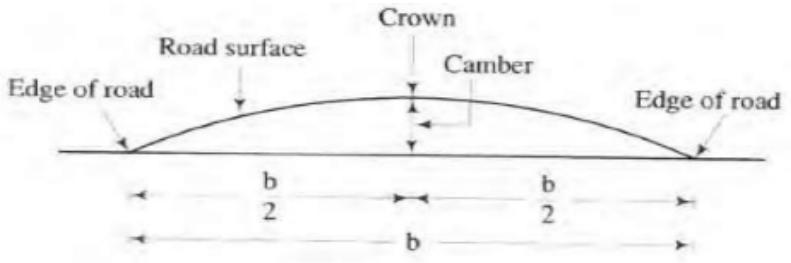
Cross sections of two lane road in built-up area

The carriage way intended for one line of traffic movement may be called a traffic lane.

The pavement may be of single lane, two-lane or multi-lane.

ROAD CAMBER:

Camber is the cross slope provided across the road to raise middle of the road surface to drain off rain water from road surface. The camber given is either a parabolic, elliptic or straight line shape in the cross section.



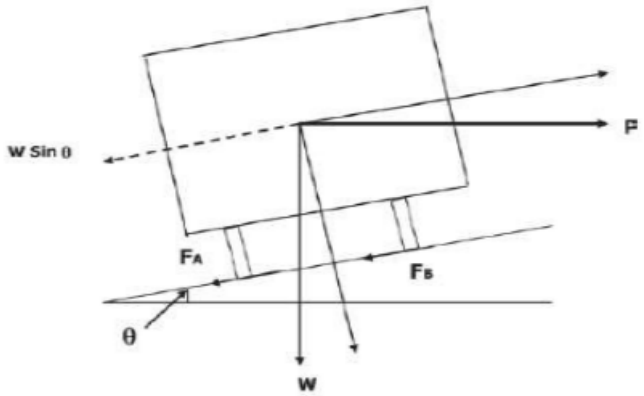
Camber or cross fall of road surface

Camber is measured in 1 in n or n % (e.g. 1 in 50 or 2%) and the value depends on the type of the pavement and the amount of rainfall.

Surface type	Heavy rain	Light rain
Concrete/Bituminous	2%	1.70%
Gravel / WBM	3%	2.50%
Earthen	4%	3.00%

SUPER ELEVATION

In order to counter act the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to inner edge, by providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is known as super elevation or cant or banking. The super elevation "e" is expressed as the ratio of the height of outer edge with respect to the horizontal width.



Super elevation is provided to counteract centrifugal force on moving vehicles at horizontal curves. Super elevation obtained from the above expression should, however be kept within limit mentioned below:

Plain terrain - 7 %

Snow bound area - 7 %

Hilly area but not snow bound - 10 %

REFERENCES:

1. Indian Roads Congress (IRC) SPECIFICATIONS, STANDARDS, DESIGN CODES

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