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# Civil and Structural Engineering


Steel Wire Wrapped Bamboo

Flexural Behaviour of RC Beams

Highlights

Fly Ash-Slag based Concrete

Beams Reinforced with Basalt Rebars

**Discovering Thoughts, Inventing Future**

VOLUME 22 ISSUE 2 VERSION 1.0

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# Contents of the Issue

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# Steel Wire Wrapped Bamboo – As a Sustainable Reinforcement in Alkali Activated Fly Ash-Slag based Concrete

By Mahantesh N. B., Sowmya A. R. & Bharath Kumar K.
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*Abstract-* The cost ratio of steel to concrete exceeding 100 in most of the RCC structures, alternative materials for replacing steel are underway to develop a sustainable built environment. Bamboo has been in housing industry since time memorial as a standalone structural member for lighter loads of roofing and wall cladding units. It has been tested for its use as reinforcement in OPC based cement concrete structures replacing steel reinforcement with appreciable performance while requiring serious attention on serviceability and durational aspects. The alkali activated low calcium fly ash & slag-based concrete with steel reinforcement as structural components cured at ambient temperature (RGPC) are being popularized in the most consumed sector of concrete construction industry.

*Keywords: bamboo, geopolymer concrete, flexural behavior, fly ash, GGBS alkaline solution, crack width.*

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# Steel Wire Wrapped Bamboo – As a Sustainable Reinforcement in Alkali Activated Fly Ash-Slag based Concrete

Mahantesh N. B. [α], Sowmya A. R. [σ] & Bharath Kumar K. [ρ]

*Abstract-* The cost ratio of steel to concrete exceeding 100 in most of the RCC structures, alternative materials for replacing steel are underway to develop a sustainable built environment. Bamboo has been in housing industry since time memorial as a standalone structural member for lighter loads of roofing and wall cladding units. It has been tested for its use as reinforcement in OPC based cement concrete structures replacing steel reinforcement with appreciable performance while requiring serious attention on serviceability and durational aspects. The alkali activated low calcium fly ash & slag-based concrete with steel reinforcement as structural components cured at ambient temperature (RGPC) are being popularized in the most consumed sector of concrete construction industry.

The present research work outlines the efficacy of binding wire wrapped bamboo splints as reinforcement along with bamboo fibers in alkali activated geopolymer concrete (GPC). The flexural behavior of *Steel wire wrapped bamboo splints (SWBS)* as reinforcement in GPC beams provide valuable feedback on the use of bamboo as reinforcement and fiber.

*Keywords: bamboo, geopolymer concrete, flexural behavior, fly ash, GGBS alkaline solution, crack width.*

## I. Previous Research Work

From the early research groups of 21st century it was observed that low calcium fly ash based geopolymer concrete (GPC) develops strength in proportion to the amount of heat or steam supplied during its early stage of polymerization. Although fly ash-based GPC has appreciable structural skills, but heat/steam curing requirement had become the major limiting factor in further developing the in-situ applications of reinforced geopolymer concrete (RGPC) structural elements. Further research made it more suitable for ambient curing using fly ash - slag based GPC which develops significant early strength and very good structural skills superior to OPC based RCC applications [13][16][19]. This way the research entered into a broader area of in situ applications of Reinforced Geopolymer Concrete.

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The shortage of river sand was mitigated by using crushed granite stone powder known as manufactured sand (M-sand). Use of mixture of M- sand 80% and River sand 20% as fine aggregate in GPC & RGPC produced a more satisfying in situ concrete. [6][10]

Alkali activated fly ash-slag based geopolymer concrete cured at ambient temperature became more suitable and produced more satisfying steel reinforced structural application. These steel RGPC elements had inbuilt strength characters to produce attractive ductility compared to OPC based RCC structural components.[13]

The cost ratio of steel to concrete kept on increasing due to heavy urbanization and national economy. The research on development of alternate reinforcing elements started as early as 1970's with bamboo reinforced cement concrete. Bamboos belong to the class of Bambusoideae which are orthotropic materials with more strength along the fiber directions with variations in its density along thickness. Several researchers have produced valuable material feedback on Bamboo Reinforced Cement Concrete (BRCC) while still a major research work on development of Bamboo Reinforced Geopolymer Concrete (BRGPC) is yet to be seen. [12][2]

Structural parameters which have influence on the performance of Bamboo in OPC based cement concrete (CC) environment are studied and their mitigating solutions are proposed which are also applicable in case of alkali activated geopolymer concrete.

### a) *Biodegradability of Bamboo in Cement Concrete Environment*

Bamboo, like timber, is vulnerable to biodegradability due to insects and fungal attack. Bamboo like timber may also become weak when attacked by insects and fungus when improper conservation conditions prevail. Insect attack is mainly due to starch content with humidity more than 15 to 20% affecting physical and mechanical properties. Several preservatives are used to protect the properties like Modified Boucherie Method, Boucherie Method, leave transpiration, immersion, impregnation. [2] Preservative treated bamboo reinforced concrete have performed

well against aggressive environmental steel corrosions in RCC elements.

*b) Water Absorption*

Study on several species of bamboo on water absorption have resulted in increase in dimensions up to 7% within a span 7 days [2] This may also cause micro to macro cracks in cured concrete. But when bamboo is used inside the geopolymer concrete environment with the surface treatment using geopolymer paste, it has less chance of water absorption due to ambient curing i.e., no water curing. In addition to this the presence of sodium silicate in binder solution of geopolymer concrete, with which the splints were pretreated, also works as a better water proof coating on the surface of splint.[27] These reinforced concrete structural components, used for lighter to medium loads in housing industry, are always surface treated with waterproof plasters, have lesser chances of moisture absorption during their serviceability life.

*c) Bond Strength*

One of the primary factors of RCC design is perfect bond between reinforcement and concrete during the entire serviceability life of the structure. But in bamboo reinforced concrete elements the dimensional changes of bamboo due to moisture and temperature influence, swelling, shrinking and differential thermal expansion are seen at different stages of serviceability life. Various preservative treatments have resulted in different degrees of success. The impermeability conditions can be enhanced using coatings of geopolymer paste in steel wire wrapped bamboo reinforcements.

*d) Moisture Content*

Most of the concrete develop micro pores inside the concrete which is a greater source of moisture entry into concrete from surrounding environment and affect bamboo performance in flexural & bond. The voids inside the concrete can be minimized by using proper amount of binder solution and compaction by using prescribed vibrator which may reduce pores significantly. Geopolymer concrete manufactured with adequate workability will have excellent moisture resistance.

*e) Mechanical Properties*

Most of the species of bamboo improve their strength after a period of air dry with moisture content as major influencing variant. The density of bamboo varies from place-to-place ranging from 500 to 800 kg/m$^3$ while most of the Indian Bamboo have an average density around 614 kg/m$^3$.[15] The strength parameters of bamboo are comparable with mild steel, but it needs special treatment due to other issues. Few types of bamboo develop high tensile strength of 370 MPa while most of the Indian types develop tensile strength a round 250 MPa and compressive strength around 80 to 100Mpa without and with nodes respectively, Modulus of elasticity in the range of 20 GPa to 40 GPa. There are also few species of bamboo with modulus of elasticity around $2.5x10^6$ psi compared to steel $2.5x10^6$ Mpa.

*f) Pozzolanic Activity*

The pozzolanic activity of geopolymer concrete during its polymerization has more chances of developing bond with bamboo splints (vertically cut sections used as splints) apart from using mild steel-based binding wire wrapped on bamboo splints to be used as flexural reinforcement. The bamboo surface is to be treated with binder solution of geopolymer concrete to activate silica present in epidermis (in cellular level) of the bamboo splint to contribute to pozzolanic reaction. This will provide better bond with concrete and bamboo splint surfaces [2].

*g) Swelling & Shrinkage*

These are associated with change in moisture content of the bamboo reinforcement. The presence of binding wire controls the swelling while shrinkage will be under control if proper pretreatment chemicals are used.

*h) Ductility*

Geopolymer concrete has more ductility post cracking compared to OPC based steel reinforced cement concrete. Bamboo possesses ductility comparable with steel rebars and therefore when GPC with SWBS with prior chemical treatment will enhance ductility of composite.

*i) Deflections & Cracks*

Much depends on the structural forces acting and the design flexibility\safety factors used in BRGPC. Bamboo is known to deflect much and produce cracks in OPC based concrete environment. But use of binding wire wrapped bamboo splints in compression zone of a flexural element with appropriate safety factors for bamboo stresses, will be effective in controlling the deflection associated issues.

*j) Water Tightness*

With the increase in moisture content above 30% the bamboo splints show slight reduction in the mechanical properties while the bamboo relatively transits from brittle behavior to ductile behavior. Chemically treated bamboo splints show more water tightness during their service life.[2]

*k) Thermal Compatibility*

The thermal coefficients of bamboo are different in two directions because of which the dimensional changes occur in both directions affecting bond strength. The use of binding wire wrapped bamboo splints control the increase in dimensional changes and effective in transferring temperature stresses to binding wire.

*l) Durability*

The durability of BRGPC elements mainly depends on the continued bond over the years to come while the pure bamboo structures last for 15 to 20 years of life. Humberto C. Lima found 60 cycles of wetting and drying in solution of calcium hydroxide and tap water did not decrease the bamboo tensile strength neither the Young's Modulus [26]. However, the BRGPC structural elements may be sandwiched with small diameter steel rebar & wrapped with binding wire - for minimum serviceability conditions and duration to ensure continued service life. Further research is required in this regard.

*m) Creep*

Bamboo has the tendency to creep under sustained tensile loads, but creep resistance will increase if bamboo splints are used in compression zone also. Much depends on basic properties, design safety factors used and orientation of the bamboo splints/culms.

*n) Temperature Resistance*

Although steel and concrete have significant resistance to temperature\fire without degrading their properties, but the bamboo starts degrading its properties above 50 Degrees C. However prior thermal treatment helps to reduce biodegradability while partially reducing mechanical properties.

*o) Bamboo Reinforced GPC Joints in Frames*

For larger spans more than 6 meter or so and for lighter to medium structural loads the bamboo splint detailing inside the concrete, especially anchoragement length and development length, depends on the way boundary conditions are created/assumed. Steel reinforcements/flats sandwiched with bamboo reinforcements at the specific location can provide adequate joint strength. Further research is required in this regard.

## II. Material Properties and Mix Proportions

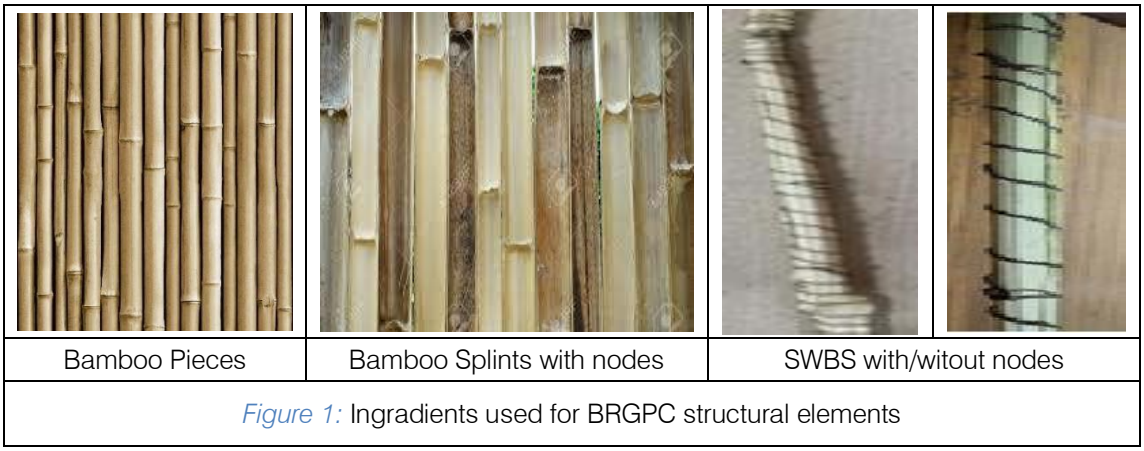




*Figure 1:* Ingradients used for BRGPC structural elements

*Manufactured Sand:* Angular & rough texture need more water. Moisture is not held. Develops more strength compared to river sand. Silt content is zero. Granite compressive strength 100 to 250 Mpa and E = 20 to 70 GPa. M-Sand, crushed from granite stone, having Sp.gr 2.45, Fineness Modulus (F.M) 2.70.

*River Sand:* Smoother texture needs less water. Moisture is trapper between particles. Develops less strength compared to manufactured sand. Silt may vary from 5 to 20%. Sandstone compressive strength 20 to170 Mpa. E =20 GPa River Sand of sandstone origin having F.M 2.62 confirming to Zone III of IS 383-1970 are used.

*Fly Ash:* used in this work collected from Raichur thermal power plant in Karnataka has sp.gr 2.15, Silicon dioxide ($SiO_2$) 61.98%, Aluminum oxide ($Al_2O_3$) 26.06%, Calcium oxide (Cao) 3.05%. *Slag:* is procured from Jindal Steel Plant Bellary, Karnataka has sp.gr 2.62, Silicon dioxide ($SiO_2$) 33.88%, Aluminum oxide ($Al_2O_3$) 18.02%, calcium oxide (Cao) 34.98%.

*Coarse Aggregates:* of granite origin of sizes 20mm, 12.5mm & 4.75mm having water absorption 0.5% by weight at room temperature (16 to 28 degree).

*Sodium Silicate (Na2 Sio3):* The sodium silicate solution used is of A53grade with $Si0_2$-to-$Na_20$ ratio by mass of 2, i.e., $Si0_2$ = 29.4%, $Na_zO$ = 14.7% & water = 55.9%.

*Sodium Hydroxide (NaoH):* of 97% purity and sodium silicates with $Na_2O$=14.7%, $SiO_2$=29.412%, water = 59.9% by mass are used to form Alkaline Activator Solution using ratio $Na_2Sio_3$/NaoH = 2.5.

*Alkaline Activator Solution (AAS):* is prepared 24 hours before mixing of concrete. To get 1liter of SHS of 8 Molarity, 255 Sodium Hydroxide pallets in gms are added with 745 gms of water. *Super Plasticizer:* Sulphonated Naphthalene based super plasticizer i.e Conplast SP430 DIS distributed by FOSROC- Bengaluru is used.

*Bamboo:* Locally available Bamboos used for general applications are selected for the present research work. These samples provide information that will help to further carry out research work from the same source as they are commonly available. The Bamboo logs with three successive knots are cut into slender. These slenders are further cut to form in to splints as shown in the figure 1.

*Binding Wire used for Bamboo Splints:* Locally available and used for normal RCC works of building construction binding wire from mild steel are used to prepare bamboo splints as shown in figure (1).

*Table 1:* Mix Proportions for Geopolymer Concrete

| S.N. | Materials | Wt kg | Specifications |
|---|---|---|---|
| 1 | Fly ash | 276 | 70% of total fly ash |
| 2 | GGBS (30%) | 120 | 30% of total fly ash |
| 3 | 20mm to 12mm size CA | 451 | 35% of total CA |
| 4 | 12mmto 4.75mm CA | 451 | 35% of total CA |
| 5 | 4.75mm & downsizes | 389 | 30% of total CA |
| 6 | River sand | 111 | 20% of total FA |
| 7 | M-sand | 444 | 80% of total FA |
| 8 | Sodium Hydroxide of 8M | 45 | 97% purity (26.20%) |
| 9 | Sodium Silicate ($Na_2sio_3$) | 113 | $Na_2O$14.7%, $SiO_2$29.4% |
| 10 | Super plasticizer | 3.6 | SP430DIS (1.5%) |
| 11 | Extra water | 4.0 | Potable water |
| | NOTATIONS; FA: Fine Aggregates, CA: Coarse Aggregates | | |

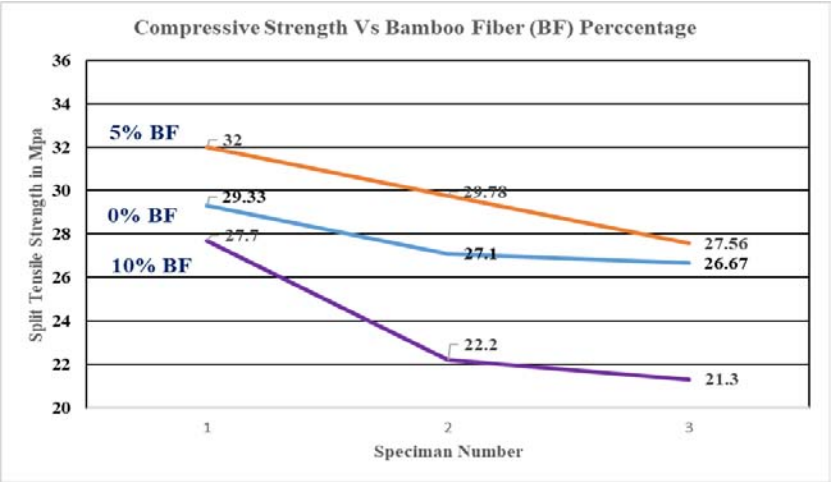
*A. Tests on GPC Cubes with Bamboo Fibers*

The mix design used for preparing geopolymer concrete cubes is detailed in the Table 1. Use of slag made the ambient curing develop early strength. Use of 80% and 20% combination of M-Sand and River sand provided good workable concrete along with strength.[6][10]

The aspect ratio of bamboo fibers and their diameter play a major role in influencing the mechanical properties of bamboo fiber reinforced geopolymer concrete. Bamboo fibers used in the GPC cubes and cylinders are tested for their compressive strength (CS) and tensile strength (TS). The bamboo cuts containing natural sizes from SAW mills were procured and seggregated from larger sized pieces and fibers and used in GPC cubes, cylinders and flexural beams. Most of the fibers were with aspect ratio ranging from 40 to 60 with diameter lesser than 1 mm.

*Table 2:* Compressive Strength of Bamboo Fiber (BF) – GPC cubes

| Specimen Number | %age of BF | Weight of cube (kg) | Average weight (kg) | Failure Load (kN) | Compressive Strength (Mpa) | Average Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|
| 1 | 0% | 8.028 | 7.96 | 660 | 29.33 | 27.7 |
| 2 | | 7.686 | | 600 | 26.67 | |
| 3 | | 8.156 | | 610 | 27.11 | |
| 1 | 5% | 7.52 | 7.63 | 670 | 29.78 | 29.78 |
| 2 | | 7.58 | | 620 | 27.56 | |
| 3 | | 7.79 | | 720 | 32 | |
| 1 | 10% | 7.72 | 7.51 | 500 | 22.2 | 23.73 |
| 2 | | 7.35 | | 480 | 21.3 | |
| 3 | | 7.46 | | 600 | 27.7 | |

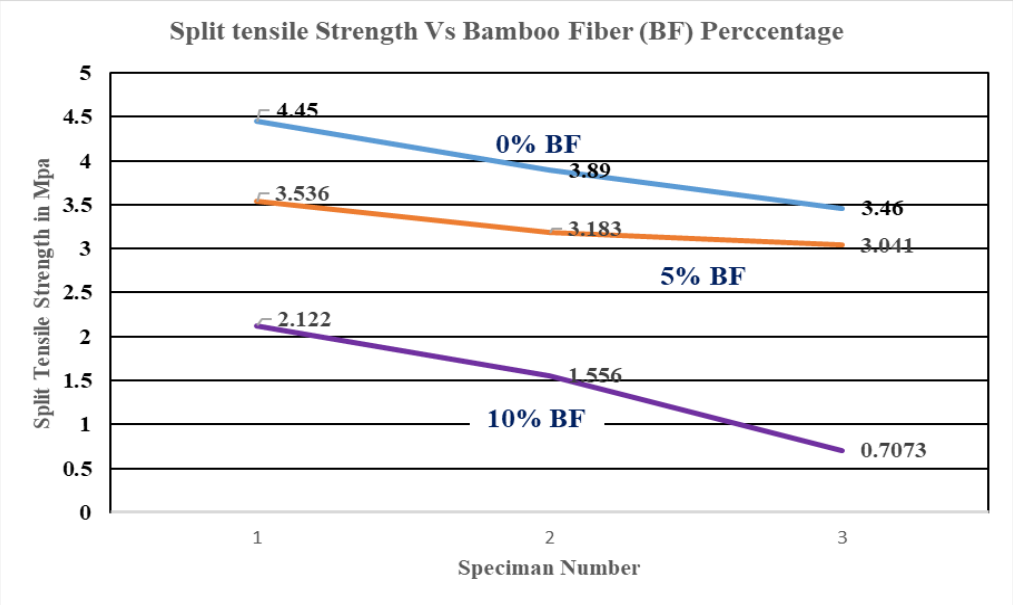



These fibers were air dried in open air inside the room before being used in GPC cubes. The compaction of cubes was achived using VB Vibrator which resulted in bamboo fibers being forced to interconnect the remaining voids inside the concrete. Two percentages of fibers were tried i.e 5% and 10% of the weight of the binder material i.e fly ash and slag. For the mix proportion (Table 1) the avearge compression strength (CS) of control cubes (0% fibers) after 7 days of room temperature curing was 27.7 Mpa but with bamboo fibers at 5% the average CS increased to 29.78 MPa which is increased by 7.5%. But with 10% fibers average CS dropped to a lower value of 23.73 Mpa resulting in reduction of CS by 14.3% indicating an optimum fiber dosage occuing well before 5%. The green weights of each cube before CS test indicate the possible reduction in CS because higher percentage of fibers reduce the content of binder solution/concrete. During the ambient curing period of GPC cubes for 7 days, the bamboo fibers did not undergo any degradation instead increased the CS.

The relation between CS and TS of control specimen of cubes and cylinders of GPC is nealry an etsablished theory[6][10] and follow BIS Code IS456-2000 obervations i.e for CS of 27.7 MPa the TS developed 3.93 Mpa following the relation $TS = 0.7\sqrt{CS}$. The split tensile strength of cylinders with BF at 5% and 10% show serious reduction in strength compared to control specimen. The reduction is nearly 17.2% for 5% fibers and 62.8% for 10% of fibers. These test results indicate that the optimum dosage of the selected fibers is at far lesser than 5%.

*Table 3:* Split Tensile Strength of BF- GPC Cylinders

| Specimen | %age of | W (kg) | Ave.wt | F Load | Split tensile | Avg split |
|---|---|---|---|---|---|---|
| 1 | 0% | 12.278 | 12.26 | 315 | 4.45 | 3.931 |
| 2 | | 12.234 | | 275 | 3.89 | |
| 3 | | 12.272 | | 245 | 3.46 | |
| 1 | 5% | 11.952 | 11.85 | 225 | 3.183 | 3.253 |
| 2 | | 11.782 | | 215 | 3.041 | |
| 3 | | 11.802 | | 250 | 3.536 | |
| 1 | 10% | 10.454 | 10.65 | 50 | 0.7073 | 1.46 |
| 2 | | 10.644 | | 150 | 2.122 | |
| 3 | | 10.862 | | 110 | 1.556 | |




Steel fibers up to 1.5% with aspect ratio around 60 provide excellent TS to geopolymer concrete [6][10][13]. But with bamboo fibers up to 10% the relation between CS & TS in GPC is seriously affected with the coefficient varying from 0.3 to 0.75. The alternate way to use BF is to partially use steel fibers along with BF so that the loss of TS is brought back into material by steel fibers. This needs further research on this.

### *B. Axial Tensile Test on Bamboo Splints*

Bamboo culms and splints help to provide tensile strength to concrete similar to steel reinforcements. The splints (longitudinally cut bamboo sections) have better bond strength than with the culms (small diameter full cross section bamboo specimen). The axial tensile strength of splints of 300 mm length with anchoring length of 150 mm on both ends are tested with one node and without any node in UTM.

*Figure 2:* Bamboo Culms and Splints

The splint without node have taken load 24.65 kN with 131.2 Mpa as tensile strength (average) while that with node developed 127.8 Mpa as average tensile strength. As seen in the figure 3, the failure of splints followed linearity up to yield points. The splints with node show three different slopes while without node show two slopes exhibiting more deflections at same load than splint with node. The bamboo specimen with node has more ductility but has less tensile strength. The bamboo specimen without node has less ductility but carry more load compared to specimen with node.

*Table 4:* Tensile Test on Bamboo Splints – Specimen A

| Sl. N | PARAMETERS | Without Node | With Node |
|---|---|---|---|
| 1 | Length (mm) | 300 | 300 |
| 2 | Width (mm) | 10.8 | 10.9 |
| 3 | Thickness (mm) | 15.4 | 17.9 |
| 4 | Peak load (kN) | 21.3 | 25.8 |
| 5 | Tensile strength ($N/mm^2$) | 128.1 | 132.2 |
| 6 | Weight of bamboo (Kg) | 0.080 | 0.090 |
| 7 | Density ($Kg/m^3$) | 802 | 769 |

*Table 5:* Tensile Test on Bamboo Splints – Specimen B

| | | | |
|---|---|---|---|
| 1 | Length (mm) | 300 | 300 |
| 2 | Width (mm) | 10.5 | 10.8 |
| 3 | Thickness (mm) | 15.4 | 16.7 |
| 4 | Peak load (kN) | 20.6 | 23.47 |
| 5 | Tensile Strength ($N/mm^2$) | 127.4 | 130.1 |
| 6 | Weight of bamboo (Kg) | 0.076 | 0.080 |
| 7 | Density ($Kg/m^3$) | 783 | 740 |

*Table 6:* Tensile Test on Bamboo Culms – Specimen C

| Sl. N | PARAMETERS | Without Joint | With Joint |
|---|---|---|---|
| 1 | Length (mm) | 300 | 300 |
| 2 | Inner diameter (mm) | 22 | 13.5 |
| 3 | Outer diameter (mm) | 33.3 | 30.5 |
| 4 | Failure Load (kN) | 59.8 | 67.6 |
| 5 | Tensile strength ($N/mm^2$) | 121.8 | 115.0 |
| 6 | Weight of bamboo (Kg) | 0.22 | 0.25 |
| 7 | Density ($Kg/m^3$) | 747 | 709 |

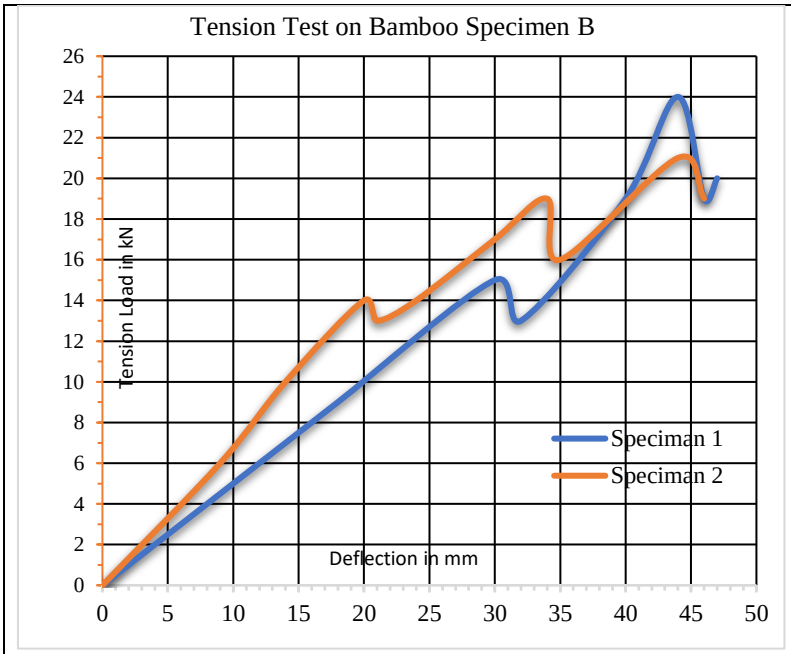



*Figure 3:* Load vs deflection of Bamboo splints

### C. *Load Tests on Bamboo Fiber (BF) Reinforced GPC Beams*

To assess the strength of bamboo fiber in plain GPC beams, specimens were cast of size 100mmx 100 mm x 500mm length with bamboo fibers at 0%, 5% and 10% of binder contents i.e., fly ash and GGBS. These plain GPC beams with bamboo fibers are ambient cured for 7 days and tested in UTM for single point central load. The details load testing and their failure loads are noted in Table 7. These failures are characterized by brittle failures under the load point at mid span with a crack widening gradually with no other cracks near supports. The failure loads increased from 7.5 kN at 0% to 9kN for 5% BF. But with the addition of 10% BF made the plain GPC beam fail at much lower load 6.45 kN as shown in table 7. These tests further confirm the pattern of split tensile strength and suggest the optimum dosage of bamboo fibers is around 5%.

*Table 7:* 7-Day Load Testing of Bamboo Fiber (BF) Reinforced GPC specimen

| Load Details | 0% BF | 5% BF | 10% BF |
|---|---|---|---|
| W(kg) | 11.9 | 11.3 | 10.9 |
| Breakage Load (kN) | 5.5 | 6.6 | 4.8 |
| Peak Load (kN) | 7.5 | 9 | 6.45 |

### D. *Load Tests on Plain Bamboo Splint Reinfoced GPC Beams*

Here GPC sections of size 100mm x 100 mm x 500 mm length with 3 plain bamboo splints as reinforcement were tested for a single point central load. The size of the splint used were of 15mm x 10mm. There was no reinforcement for shear. The beams were ambient cured for 7 days and tested. The test results as shown in Table 8, exhibit flexural behavior with appearance of first crack under the load and then gradual appearance of hair cracks near support. The peak load was marginally in line with yield load while the stresses in splints and concrete developed were around 50 to 65 Mpa and 10 to 15 Mpa respectively and the beam failed much before reaching their full capacity. The failure is mainly attributed to lack bond strength between bamboo and surrounding concrete. From flexural failure point of view the beams did not reach their full peak load but failed at an early load when the bond between bamboo and concrete lost.

### E. *Load Tests on Steel Wire Wrapped Bamboo Splint (SWBS) as Reinfocements in GPC Beams*

In these set of beams the splints were wrapped with the normal binding wire – normally used for RCC works, with adequate anchoragement at splints ends as shown in figure 4. The size of the test beams 100mm x 100 mm x 500mm length. The bottom cover for these splints provided was 20mm. The beams were ambient

cured for 7 days and load tested for mid span single point load. The test results are tabulated in the Table 8. The results show flexure failure of beams similar to plain splint reinforced GPC beams with an increased load carrying capacity. The deflections were more than the plain splint beam tests. The beams failed well before reaching their peak stresses in concrete and bamboo, due to loss of bond between splints and concrete. However, the increased failure load indicates enhanced bond strength due to binding wire.

Bamboo splints wrapped with binding wire

*Table 8:* 7-day Load Testing of Bamboo Splints as Reinforcements in GPC Beams

| Load -Deflection Details | FB1 | FB2 | FB3 | Average Value |
|---|---|---|---|---|
| W (Kg) | 10.9 | 11.2 | 11.8 | 11.50 kg |
| Breakage Load (kN) | 4.8 | 5.3 | 5.8 | 5.3 kN |
| Yield Load (kN) | 11.6 | 12.5 | 13.5 | 12.5 kN |
| Deflection at Yield Load (mm) | 3.2 | 2.4 | 4.1 | 3.2mm |
| Peak Load (kN) | 12.6 | 13.5 | 14.8 | 13.6 kN |
| Max. Deflection (mm) | 5.8 | 6.4 | 7.2 | 6.5 mm |

*Table 9:* Load Testing of steel wire wrapped bamboo splints as Reinforcement in GPC

| Load -Deflection Details | FB1 | FB2 | FB3 | Average Value |
|---|---|---|---|---|
| W (Kg) | 11.2 | 11.6 | 12.2 | 11.67 kg |
| Breakage Load (kN) | 5.4 | 6.20 | 6.8 | 6.13 kN |
| Yield Load (kN) | 13.1 | 14.4 | 15.8 | 14.43kN |
| Deflection at Yield Load (mm) | 3.8 | 3.1 | 4.8 | 3.9mm |
| Peak Load (kN) | 14.6 | 16.2 | 17.4 | 16.07 kN |
| Max. Deflection (mm) | 6.2 | 7.1 | 7.9 | 7.07 mm |

*Figure 4:* Single Point Load Testing on BFRGPC Specimen

| BRGPC specimen | Single Point Load Testing |
|---|---|

*Figure 5:* One point load testing of BRGPC sections

## III. Discussion and Conclusions

This work helps in minimizing the standalone issues of bamboo as reinforcement in geopolymer concrete. As there are nearly 2000 species of bamboo, the strength & other properties of bamboo vary vastly due to so many influencing parameters like moisture content, age, species type, size & location etc. To use bamboo from a particular location as reinforcement the properties needs to be studied frequently to arrive at most common and frequent values to be used in design with appropriate design safety factors and further develop design guidelines.

Some Species of Indian Bamboo are comparable with mild steel having tensile strength up to 250MPa with internode distance of 300 mm to 500 mm or so. Bamboo with nodes are the reinforcements required to be used in flexural elements of beams, slabs, and columns. Bamboo splints of sectional sizes 16 to 20 mm are best suited as reinforcements as they provide better bond with geopolymer concrete.

The use of bamboo fibers fill up the micro voids in the concrete and increase the direct crushing strength but excess fibers partially develop the bond with concrete and thus reduce the strength. This is also evident in bamboo fiber reinforced geopolymer concrete plain beams. The reduction in split tensile strength due to bamboo fibers is due to inadequate bond with geopolymer concrete when the splitting force is applied. Therefore, use of bamboo fibers in concrete needs careful consideration and attention on optimum percentage along with proper design parameters of aspect ratio and diameter.

Here in the present study the bamboo splints were wet coated with geopolymer slurry before placing inside the concrete to avoid water absorption from the surrounding environment. The geopolymer concrete needs water for workability purpose therefore absorption of water by bamboo has negligible effect on concrete strength development. The use of binding wire to bamboo splints helps in minimizing swelling, shrinkage, and creep related issues while increasing the bond strength significantly.

Two types of GPC beams were tested with bamboo splints, with and without binding wire, as flexural reinforcements but without any shear reinforcements. Addition of binding wire wrapped splints increased the load carrying capacity of the beams by 15 to 20% but the stresses in concrete and splints did not reach their peak values as the beams failed well before due to inadequate bond strength. From the load testing details it is observed that only 40 to 50% of the bond strength is developed at breakage point and around 60% at failure stage.

There are other inexpensive and effective methods to improve the bond strength to allow the bamboo to develop full bond with concrete like using higher yield strength binding wires, using sandwiched rebar of less diameter with bamboo splints, covering bamboo splint with light gage steel mesh, using staggered small cuts in bamboo at designed spacing and so on.

With the proper moisture content retention and protection, the biodegradability of bamboo may be prevented and the life of bamboo reinforced geopolymer concrete elements may have life of 15 to 20 years. More works on these are required to make bamboo a user-friendly reinforcement and formulate relevant design codes.

With this following conclusion can be drawn on use of bamboo products in alkali activated flay ash slag based geopolymer concretes.

1. From the present research work it can be concluded that the steel binding wires wrapped bamboo splints in alkali activated geopolymer concrete are the better solution to replace steel reinforcement. This has many structural, serviceability and economic benefits.
2. Bamboo splints with binding wires wrapped - provide better bond with geopolymer concrete than bamboo culms as reinforcement. And thus, they satisfy the long-term requirement of continued bond with concrete for flexural members.
3. The tested bamboo splints have a tensile strength of 130 Mpa at 18% moisture content. These type of bamboo species are suitable for lighter loads of housing industry.
4. Use of bamboo fibers have the same effect on geopolymer concrete as any other fiber with OPC based ordinary concrete Bamboo fibers increase the compressive strength of geopolymer concrete composite by 7.5 to 10%, but beyond 2.5 to 5% addition of fibers will affect the compressive strength.
5. Depending upon the species type, aspect ratio and diameter of bamboo fibers, the split tensile strength of GPC is influenced which have definite relations with compressive strength.
6. The plain bamboo splints wrapped with binding wire pre-treated with geopolymer paste can be used as reinforcements in geopolymer concrete environment without much water absorption related issue and develop enhanced bond strength due to polymerization.
7. Closely spaced binding wire wrapped splints increase the load carrying capacity of flexural elements by more than 15 to 20% because of the improved bond strength, compared to plain splints reinforced sections. This may be more for other species and types. Further research is required in this regard.
8. As plain bamboo culms and splints are vulnerable to biodegradability, treatment to preserve and protect the moisture contents needs top priority.
9. Bamboo provides the better opportunity to use as reinforcements in concrete. With proper care, treatment, and maintenance the life of bamboo reinforced sections can be more than 15 to 20 years. Further research is required in this regard.

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# The Environmental Dimensions of Iraqi Urban Legislation and Laws they Specialize in Environmental Protection Legislation

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*Abstract-* The legislation and laws related to protection against the natural environment aim to achieve a balance between what is taken from the natural environment and what can be achieved to protect it by the contemporary ideas of the international organizations of Earth Day and environmental protection organizations. That legislation has directed reflections on the protections against urban and architectural environments that are achieved by activating the role of the institutions under the names of environmental protection to adopt basic legislation for protecting the urban and architectural environment. The general problem of research is to determine the shortcomings of the environmental dimensions of Iraqi legislation, laws, and instructions, and the reality of the control system in the light of the renewable mechanisms in this area. The research aimed to assess the status of the local legislative system through a practical study to identify the category of specialists that are directly involved in the system (The planners, engineers, and designers).

*Keywords: environment, legislation, urban, architecture, Iraq.*

*GJRE-E Classification: DDC Code: 344.046 LCC Code: K3585*


*Strictly as per the compliance and regulations of:*

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*Abstract-* The legislation and laws related to protection against the natural environment aim to achieve a balance between what is taken from the natural environment and what can be achieved to protect it by the contemporary ideas of the international organizations of Earth Day and environmental protection organizations. That legislation has directed reflections on the protections against urban and architectural environments that are achieved by activating the role of the institutions under the names of environmental protection to adopt basic legislation for protecting the urban and architectural environment. The general problem of research is to determine the shortcomings of the environmental dimensions of Iraqi legislation, laws, and instructions, and the reality of the control system in the light of the renewable mechanisms in this area. The research aimed to assess the status of the local legislative system through a practical study to identify the category of specialists that are directly involved in the system (The planners, engineers, and designers). The research concluded to identify important indicators in the development and updating of the system of legislation to protect the urban and architectural environment, and the regulatory system following the principles of sustainable development, and investment of the characteristics of the environment and renewable energy, as well as activating the supervisory role and participation of the individuals themselves by raising awareness of the importance of environmental protection.

*Keywords: environment, legislation, urban, architecture, Iraq.*

## I. Introduction

The environment, both natural and man-made environments, represents all that surrounds man from the conditions and places that contain the various human activities. This activity reflects influences on the built and urban environment, and its components are the most important part of the human environment that he creates to organize his life from buildings, sectors, Institutions, and factories covering various aspects of civic life, social systems, and behavioral patterns.[1] The urban environment specification was included within the objectives of the national policy of regional planning and sustainable development to restore the natural and built environment balance as the surrounding environment of urban expansion and extensive construction works reflected in all its effects on the characteristics of the environment and human health.[2] It is noteworthy that many of the architectural problems facing the local community today in the field of the built environment are the result of the absence of legislation capable of simulating all the requirements of development, in addition, to the produced physical effects of surroundings and future implications. Because of the importance of laws, regulations, and legislation in human life, and due to the fact of the environmental dimension issue of legislation and laws is complex in detail, it used to be necessary to talk about the specialized part of these laws in the field of urban and architectural contexts.[3] Also, their mutual relationship with the environment from its impact, in the sense of negatives and positives that arise of the existence of the environment built within the natural environment, to achieve a harmonious with environmental factors and minimum environmental damage, as the legislation governing urbanization and local management control, is one of the mechanisms affecting the level of This is in line with the view that the level of social development is measured by the extent of its capability to build its civilization. Architecture is the mirror of civilization that reflects it to other societies. Therefore, urban areas should be subject to legislation and instructions that include various aspects of the environment, subject to the authority of regulatory institutions working to manage and enforce those laws.[4]

What is observed from the contents of the Iraqi legislation, laws, decisions, and regulations, even at the level of instructions for urban planning and housing was noticed a clear lack in the environmental dimensions of the most centers of attention on the issue of protecting the natural environment and the environment built on impact reduction. Additionally, neglecting the second part of the environment (built environments) is an as important step that can be taken to protect the environment itself, where deterioration in the natural environment, human health, and urban degradation environment built-in have a profound impact on humanity as part of life system[5]. *The general problem of research* is to determine the shortcomings of the environmental dimensions of Iraqi legislation, laws, and instructions, and the reality of control systems in the light of the renewable mechanisms in this area.

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## II. Environmental Dimensions of Urban Legislation

*a) The Environmental Dimension of Iraqi Urban Legislation*

Iraq in the past was called the blackness land for the intensity of its diversity of vegetation cover and the abundance of its water resources are mainly represented by the Tigris and Euphrates rivers, today is suffering from the expansion of the desert areas with the decline in natural plant cover in most it is provinces suffering from the problems of environmental change that caused by many factors. The uncontrolled consumption of petroleum products, the spread of generators and the expansion of their flats, toxic emissions from industrial sectors and water-contaminated chemicals, lack of sanitation planning, and wars that happened in the country in recent years are the main most factors that led to to this situation.[3] The urban planning projects of many local cities have been affected by the excessive increase in the random growth of urban areas causing a negative impact of these laws. The legislation has failed to comply with the contemporary requirements of society within the limits of successive developments. Given the growing environmental dangers represented by increasing air and water pollution problems, the Iraqi legislator's attention was aroused by the issuance of strict laws, regulations, procedures, and ways to implement them [6]. To reach the environmental dimensions of urban legislation to be organized and controlled in real laws and legislation, a comprehensive view must be taken of the various aspects of the environment that are based on the definition of the term environment law.

*b) Legal Definition of the Environment*

The environment is defined as the sum of the spatial and social resources available at some time and place to satisfy human needs and aspirations, the natural environment in which man and other organisms live, the set of natural, dynamic, and social conditions that interactive as balance that provides a stable environment for human life [1]. On the other hand, the environment can be defined by the adoption of two concepts that complement one another. First clarified by the biological environment that related to the human life itself from the growth and festivities, but also included the human relationship with other living creatures within one environment. Second is the surrounding environment. Each of the two environmental concepts contains natural resources, raw materials, and natural components of plants and animals, as well as habitat, weather factors, purity and pollution, and other characteristics of nature[2].

As for the legal definition of the environment, international legislation has defined the environment in the provisions of their laws as "the environment that includes living organisms and their contents, and the surrounding air, water, soil, and human habitation." The Iraqi legislator defined the environment as "surrounding with all its components living organisms and the effects of human economic, social and cultural activity).[2] The limited and absolute legal concept of the environment following the recent scientific and industrial development of the world has made the environment a new value within the values of a society that seeks to preserve and protect it from any act that harms it. In most legal systems, the legislator has taken a narrow approach to define the concepts of the environment by limiting them to the basic elements of the natural environment that enter human beings such as water, air, and soil [5].

## III. Concept of Urban Planning and Environmental Protection

Urban planning plays an important role in the sustainable development of the environment, which is highly dependent on the development and investment of the environment and within the advanced levels of urban planning, architecture, and even urban services, to help create a vibrant and sustainable urban environment. Enhancing the role of planners in creating and forming residential or service communities that are environmentally integrated and sustainable through various mechanisms, such as: bringing the sectors closer together, identifying their important role in construction, community development, social and health quality, building local economy alternatives preposition out of the universal economy, and finally the protection of the natural ecological balance and work to preserve the restoration of natural elements that have been physical and existential distortion[7].

Kibel defines urban planning as "an objective creative process of how to make human life and facilitate its tasks so that the greatest possible freedom is available to the individual and the community to ensure that they live in peace and security."[8] This approach illustrates urban planning. Minimize planning process is a mechanical process based on several requirements within the capacity and potential limitations because it has lacked flexibility in the movement possibilities, growth, and change in an unrealistic imaginary path, thus, the planner and designer for urban planning must be aware of a structure or model that can be developed or adopted [9][10]. Many theories have reappeared in urban planning procedures that aim to find ways and solutions through which the elements of city distribution are balanced and orderly, creating a flexible and smooth relation between the various elements to secure the rest of the population. The urban regulators have managed to overcome many problems, but with the complexity of the components of the cities and the spread of new industrial sectors, there have been other problems that are more complex, and most

important environmental pollution problems caused by industrial human activity production process that increase the industrial waste forms and like solid pollutants, visual pollutants, and water pollution. [8]

Urban planning as a concept is a logical and rational thinking methodology that is practiced by everyone at all levels, from the individual to the group, local, national, and regional management. This was related to the vision of the current and future life in the meaning of environmental conditions to achieve development and sustainability of the natural environment for both two time periods and then to develop the means and procedures to achieve them. There are many specifications of urban planning in multi-level and sectors, where we find strategic planning, local and regional planning, long-term, near-term, and the development and regulation of land allocation and use to achieve the best possible form through two important things. First, what is the allocation of land, or the extent of the relationship between such allocation and the environmental risks caused, and the other, what land is not occupied by human activity and industry and the extent to which it can be used to avoid risks and environmental problems? [9]

*a) Human Factors Affecting the Urban Environment*

The most important of these factors is the demographic explosion, as a result of increasing the growth rate of the population in a short period. This factor can be considered one of the pollution factors that have negative effects on natural resource consumption. The Cairo conference in 1994 discussed the development and population growth to establish reasonable controls for this phenomenon. Overpopulation leads to increased pressure on the urban environment by increasing the demand for energy and food. As well as many problems will appear successively related to overpopulation phenomena that can be listed as urban overcrowding, expansion at the expense of agricultural land, the emergence of transport problems, and insufficiency of services and infrastructure.[7]. The increasing of supply resources, service demands, failure of the economic system, and poverty lead to rural migration where this phenomenon is one of the most reasons that cause changes in the demography of cities and communities.[8] There are several aspects of environmental failure represented by different types of pollution resulting from humans and their connection with the surrounding environment. This pollution can be listed as audio pollution (which is the noise of various human activities, industry, traffic, and markets) visual pollution (It includes urbanization of distorted and disturbing urban scenes that show a lack of taste and beauty), air pollution (which has a strong impact on human health) and water pollution (resulting from overlapping sewage systems with water supply systems) [12].

## IV. Iraqi Laws and Regulations related to Urban Planning and Environmental Protection

The legislation and regulations of the Iraqi planning laws are almost identical to the rules and regulations for the planning of areas and sectors, especially the residential ones. These laws should protect the environment, so it is necessary to identify the laws, regulations, and decisions that determine the importance of urban planning between the pros and cons to come up with a comprehensive vision and specific recommendations. As they note many of the architectural problems faced by the Iraqi community today in the field of the built environment are the result of the lack of legislation capable of simulating all growth and expansion and development to meet the aspirations.[9] According to the research survey of the relevant Iraqi laws, these laws tend to adopt the narrow concept of the environment mentioned earlier in the protection of the environment (non-comprehensive protection of the environment built from the natural effects of the environment), so can be classified legislation and laws to the following:

1. Laws relating to urban planning for the protection of the environment
2. Decisions, regulations, and instructions for urban planning to environmental protection.
3. Local Building criteria (Urban Housing Standards).

*Table (1):* The most important Iraqi legislation and laws according to their level

| Legislation | Number | Issues |
|---|---|---|
| Laws | The fundamental urban planning No. (156) for the year 1971 for the city of Baghdad | It is not permissible to use the land or construction or change the condensation except by a license from the Municipality of the capital provided that the use is identical to the design basis |
| | Law for the Regulation of West Landfill Areas No. (67) of 1986 | The allocation of fenced-off sites to temporarily collect wastes and then transfer the waste by the municipality to the landfill areas. |
| | Industrial Investment Law for the Private and Mixed Sectors No. (20) for the year 1998 | To grant the state departments the allocation of what the industrial project needs of state-owned land within the basic design. |

| | | |
|---|---|---|
| | Law of forests and quarries No. (30) for the year 2009 | Planting of river banks, irrigation tables, and highways - Trees are brought only for technical necessity if the forests protect the lands from flooding, keeping the springs, or affecting public health. |
| | Noise Control Law No. 41 of 2015 | Take into consideration the noise problems when planning the public streets within the cities and the establishment of a multi-story mooring and attended the establishment of crafts workshops within residential areas. |
| Decrees | Decree No. (297) of 1987 for the dissolved Revolutionary Command Council | Owners of agricultural land and orchards inside and outside cities, the construction of residential houses for them (which changed the decision to use the land) |
| | Decree No. (154) for the year 2001 the Revolution Command Council dissolved | Determining the urban fabric of a city by type of land uses, building heights, area, and density of use. |
| | Decree No. (165) of 2001 for the dissolved Revolutionary Command Council | The people who were created without housing on state-owned land have their owners |
| System | Road and Building System No. (44) for the year 1935 amended | Determining the specifications of roads, maps, straightness, spikes, and road signs. Where we find the absence of the nature of urban fabric in the city. |
| Instructions | Poultry Projects Instructions under the Book (4338) for the year 1988 | The project is located outside the basic design of the cities with a distance of (1) km and the residential communities (20) km |
| | Instructions for the prevention of non-ionizing radiation for mobile number (1) for the year 2010 | Central switchboards attended in residential neighborhoods and hospitals |
| | Instructions of radio station No. (2) for the year 2011 | Construction of stations outside the basic design of the cities and not allowed built in residential areas and above the roofs of buildings |
| | Instructions for environmental determinants for the establishment of projects No. (3) for the year 2011 | Determining the distance of industrial projects according to their jurisdiction on the municipal boundaries of the city from 3-15 km (animal protein factories - production of industrial yarns - petrochemicals - cement - food) |
| | Instructions for emission factors for activities and business No. (3) for the year 2012 | The non-recyclable solid materials or the use resulting from the various activities are identified as wastes that constitute damage to health - sanitary building waste. |
| Standards | Urban Housing Standards (Ministry of Housing and Construction) | |
| | Local Building Controls for Building Legislation for Baghdad Municipality (Structural Density and Repetition) | |

*Source: researcher[11]*

It is clear from the table of the Iraqi legislative laws, old or new, that it is very weak in dealing with environmental problems in all their forms. Most of these laws are not flexible and effective in addressing environmental problems. Most of these laws are not sufficiently flexible and effective in the face of environmental problems as they need to be re-evaluated and designed with different mechanisms to deal with these problems related to human health, investing natural resources, funding, and employment problems.

## V. Environmental Requirements of Legislation and Urban Laws

To construct the urban model and preserve the national heritage of any city, build social and economic structures aimed at the budget and equality between the components of civil society in all its components and different activities of life, the application of the principle of protecting the natural environment in all its components and elements, possibilities of investing in the development and sustainability of the urban environment new laws must be enacted. Therefore, in the formation of regulatory and legal systems, or the sense of legislation, regulations, such legislation should emerge from the basic environmental requirements that are effective in protecting the constructed urban environment, which must take its identity and its authority in legislation, as follow:

1. Characteristics of Climate: The city's climate is characterized by the amount of solar radiation and the direction of the wind and the level of humidity and temperature of the surface of the earth and reflects the differences in architectural and urban

details, as well as the heat of the ground, which steadily thinking of building under the surface of the earth.

2. Energy Sources: The sun is one of the most important and must be invested effectively as alternative energy from the available sources being cleaner, wind energy and its uses in the purification of streams of penetrating air to urban communities, the morphology of the land, the slanted areas towards the sun acquire more energy, directing buildings and its impact on the acquisition of heat (The cubic and central shape acquire heat from the four sides while the mass proximity reduces the thermal and optical acquisition), as well as the balance in the ratio of construction to green areas.
3. The use of Building Materials (raw): One of the most important requirements and most effective in dealing with the previous natural factors, in terms of retaining heat and sustainable construction and the characteristics of thermal insulation and voice and everything that would improve the health requirements of the details of the daily life of man.[12]

## VI. Principles of the Applications the Environmental Legislation to Protect the Urban Environment

Given the close relationship between man and his environment represented by the physical and vital environment, including the living organisms, compositions of surrounding materials such as air, soil, and water, and indirect characteristics of the natural environment, appropriate laws should be enacted that could address many positive points. To ensure environmental protection in both natural and built the following principles must be adopted in the formulation, development, and application of legislation and laws:

1. The principle of sustainable development.
2. The principle of media and participation
3. The principle of integration and substitution of preventive activity.

*a) The Principle of Sustainable Development*

One of the most important requirements of the process of community and economic development is the increase in the demand for natural resources, especially in the field of urban growth. Needs for raw materials in the construction process is the increasing demand for land uses, natural and agricultural characteristics changes, overcome the edges of rivers, which in turn reflects the increasing all pollution forms. Therefore, for the deterioration of the environmental system and the general situation of the natural environment, it is necessary to remain the legislative institution in the dialectic of a trade-off between increasing development and the increase in social and civil needs on the one hand and environmental degradation on the other.

Since the Stockholm Conference in 1972, studies have begun to focus on clarifying the links between the environment and development to adopt each other, and that development is in line with the achievement and improvement of living standards and the management of economic systems while preserving environmental resources so that future generations can live a decent life.[9] The European Union at its 1992 conference stated that sustainable development is a method of organization and a strategy aimed at ensuring continuity over time in the framework of respecting the environment without threatening the natural resources necessary for human activity. Therefore, sustainable development is an attempt to reduce the conflict that leads to environmental degradation by finding a way to integrate the environment and the economy by meeting the needs of the present without destroying the ability of future generations to meet their life needs. [12]. It is clear from the above that the protection of the urban environment based on the principle of sustainable development is linked to sustainable urbanization through the intelligent adaptation of urban areas and the provision of the living framework of the population without prejudice to the ability of natural systems to long-term production.[10]. This is done in terms of the concept of dividing the environment for protection into two main systems:

1. Natural environment system with all its elements and natural resources of air, water, soil, and its natural production of raw materials and sources of energy, as well as their living interactions of climate, wind, and natural systems.
2. The built or artificial environment system is the physical environment and the social and civil system and all that man created to organize his life in all aspects of housing, education, industry, entertainment, economy, and others.

*b) Media and Participation Principle*

Many laws deal with the urban aspect and regulate and protect it in international legal legislation. This was done to enhance the role of individuals in environmental protection, which is done only by guaranteeing the right to information on environmental data. Protecting and preserving the environment ".[18] The declaration at the Earth Summit in Rio de Janeiro in 1992 stipulates that "everyone should have access to environmental information held by the public authorities and related to the environment." The principle of the media has multiple images, including that the state provides the environmental information to the citizen, especially that has a direct or indirect impact, To encourage the participation of citizens through publicity and media to activate a broad partnership in the development of perceptions and proposals for

appropriate environmental measures and procedures, as well as inviting citizens to study the environmental impacts expected on the environment resulting from the total human and urban activities[12].

i. *Principle of Participation in the Protection of the Urban Environment*

The protection of the urban environment requires legal mechanisms and effective management of legislation, as well as the costs of operating and processing budgets of the regulatory system as well as the need for media cooperation in the consolidation of the principles of protection.[13] The participation of individuals in the protection of the urban environment is an effective means of protecting and preserving them by contributing to the preparation and implementation of protection policies. The environment from the perspective of complementarity between the interests of individuals and the public interest, a practical principle that shifted from a rigid and interactive character of law that guaranteed the promotion of citizenship by respect for human rights as long as man was the essential element of the environment[14].

Principle 10 of the Conference of the Earth Summit Declaration in Rio de Janeiro 1992 recognizes that "education and public awareness are the best way to address environmental issues and the population involved in environmental decision-making". The adoption of the principle of information and participation and adoption as a goal in the national legislation to protect the urban environment is reflected in three forms of human rights: the right to access environmental information, the right to participate in environmental decision-making, and the right to resort to justice[12].

c) *Principle of Integration, Substitution, and Preventive Activity*

The principle of integration is one of the fundamental principles in the protection of the environment and is related to the public interest. It enshrines the human right to a healthy and healthy environment and the right of future generations in this environment. The Declaration of the Earth Summit states: "Peace, development, and environmental protection are intertwined and inseparable."[17] The integration of organizations related to the protection of the environment, the sustainable development in the preparation of urban plans and programs and their applications, the important role of the urban environment in preventing the spread of environmental degradation in both natural and constructed nests or imbalances of their nests, Sustainable development to improve the living conditions of the citizen on the one hand and the conservation of resources and rationalization of consumption on the other are all the aspect's that must take into account when adjusting new laws.[11]

The use of the principle of integration in the protection of the urban environment leads to the combination of the goals of social and economic development and social welfare to provide adequate housing for the elimination of fragile construction, not only by the adoption of the quantitative side but must be adopted quality that respects environmental factors as a right for future generations. [12].

i. *Principle of Substitution and Preventive Activity*

The principle of substitution plays an essential role in protecting the urban environment through the replacement of harmful work to the environment with other work that is less harmful and dangerous to it.[18] This latter activity, even if its cost is high, is as long as it is appropriate for the values of environmental protection. By adopting this principle and activating it in the field of the urban environment, contaminated energy can be replaced with a clean card such as solar heating. The multi-facades of buildings can be replaced by facades inspired by their environment and their cultural heritage, and the replacement of roofed materials with environmental raw materials such as wood, stone, and local materials. Waste recycling, replace the discharge of sewage work by recycling, filtering, and exploiting for agricultural purposes[14].

## VII. The Case Study

The objective of this article is to get the spotlight on the environmental dimensions of Iraqi urban legislation and laws and the specialization of environmental protection legislation. To increase knowledge about a conceptual understanding of the nature of legislation with environmental exclusion from the protection of the natural or constructed environment, or for the exploitation of natural resources from climate factors and clean energy, the study was carried out to evaluate the environmental legislation system by the employees in the field of planning, design, and implementation.[12] Control systems and their role in controlling the effective application of such legislation and regulations according to the community segments working at the level of control were taken into account in this study. The evaluation was conducted through a questionnaire form for a sample composed of architectural staff of the Department of Architecture and civil engineering at the University of Mosul (30), considering that it is the community system closest to all the engineering specialties of planning, design, and implementation through the technical and professional team of engineering offices, As well as dealing directly with the regulatory bodies that govern the controls and engineering laws. The questions were addressed according to five main axes according to the following:

1. The focus of the evaluation of local legislation, laws, and regulations for the protection of the environment.
2. The natural and urban environment.
3. The axis of proposing legislation supplementing the current laws to reduce environmental degradation.
4. The focus of the proposal of renewed principles for the application of legislation and laws to protect the urban environment.
5. The focus of the legislation is to invest in natural environmental factors.

*Statistical Processing:* The questionnaire application supported by Google Forms for questionnaire evaluation was adopted through a descriptive approach for the study variables and the SPSS-10 correlation method, V1, V2, V3, V4, V5, V6 variables for the first axis, V7, V8, V9, V10, V11, V12, for second axis, V13, V14, V15, V16, V17, V18 for the third axis, V19, V20, V21, V22, V23, V24, for fourth axis, V25, V26, V27, V28, V29) for the fifth axis.

## VIII. Results

The SPSS program referred to the statistical processing of the data obtained in the questionnaire for the study. Several indicators of importance in determining the level of awareness of the specialized sector (planners, engineers, and designers) in dealing with the legislation and laws related to urban and architectural planning and design, which are designed to protect the natural and urban environment Both as follows:

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| VAR00001 | 12 | 1.00 | 3.00 | 2.3333 | .77850 | .606 |
| VAR00002 | 12 | 1.00 | 3.00 | 2.5000 | .79772 | .636 |
| VAR00003 | 12 | 1.00 | 2.00 | 1.5833 | .51493 | .265 |
| VAR00004 | 12 | 1.00 | 3.00 | 2.5000 | .79772 | .636 |
| VAR00005 | 12 | 1.00 | 3.00 | 2.1667 | .71774 | .515 |
| VAR00006 | 12 | 1.00 | 3.00 | 2.7500 | .62158 | .386 |
| Valid N (listwise) | 12 | | | | | |

*Source: SPSS*

The results of the evaluation of local legislation, laws, and regulations for the protection of the environment: The highest level of non-agreement with the value of (2.75), although the system of legislation of waste collection areas and standards of industrial sectors and radio and mobile broadcasting stations achieved its goal in protecting the natural and urban environment. (2.5) With the comprehensive laws and legislation protecting the environment, all aspects and elements of the urban environment and the system of legislation planning the basis of cities and the urban environment requires the use of land and limit abuses, while the rest of the variables confined to a convention to some extent.

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| VAR00007 | 12 | 2.00 | 3.00 | 2.8333 | .38925 | .152 |
| VAR00008 | 12 | 2.00 | 3.00 | 2.5000 | .52223 | .273 |
| VAR00009 | 12 | 2.00 | 3.00 | 2.4167 | .51493 | .265 |
| VAR00010 | 12 | 2.00 | 3.00 | 2.3333 | .49237 | .242 |
| VAR00011 | 12 | 1.00 | 2.00 | 1.1667 | .38925 | .152 |
| VAR00012 | 12 | 1.00 | 3.00 | 1.8333 | .93744 | .879 |
| Valid N (listwise) | 12 | | | | | |

*Source: SPSS*

The results of the evaluation of the mechanism of implementing local legislation and laws in the protection of the natural and urban environment: The highest level of non-agreement (2.83) referred to the effectiveness of the existing legislation in applying and controlling the legal violations and penalties imposed in reducing environmental degradation and transgression. (2.55.2.34) comprehensively implement legislation on the application and control of all stakeholders in the deterioration of the natural and urban environment and the effectiveness of the regulatory groups in reducing the excesses and change in the pattern of land use and thus reducing the environmental degradation, the value (1.6) with the need for the regulatory agencies responsible for the application of legislation to re-examine the structure and their representative groups, and the values of the limited Convention for the rest of the variable.

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| VAR00013 | 12 | 1.00 | 2.00 | 1.1667 | .38925 | .152 |
| VAR00014 | 12 | 1.00 | 3.00 | 1.3333 | .77850 | .606 |
| VAR00015 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00016 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00017 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00018 | 12 | 1.00 | 2.00 | 1.2500 | .45227 | .205 |
| Valid N (listwise) | 12 | | | | | |

*Source: SPSS*

The results of the proposed legislation to complement the existing laws to reduce environmental degradation: The highest level of the convention (1.16) with the coordination of national efforts aimed at protecting the environment, including the development of a strategy for integration and coordination with global legislation for the protection of the environment. Its components were follow-up through the research centers to ensure the global standards and with the adoption of systems to monitor and measure the degradation levels of both the natural and urban environment. Using periodic surveying and research studies on environmental protection laws involve engineering planning and professional work teams, while I noted with limited results in agreement with the rest of the values of variables.

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| VAR00019 | 12 | 1.00 | 2.00 | 1.2500 | .45227 | .205 |
| VAR00020 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00021 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00022 | 12 | 1.00 | 2.00 | 1.1667 | .38925 | .152 |
| VAR00023 | 12 | 1.00 | 2.00 | 1.3333 | .49237 | .242 |
| VAR00024 | 12 | 1.00 | 2.00 | 1.4167 | .51493 | .265 |
| Valid N (listwise) | 12 | | | | | |

*Source: SPSS*

The results of the proposal of renewed principles for the implementation of legislation and laws for the protection of the urban environment: the highest level of the Convention (1.16, 1.2) with the legislation of the principle of sustainable development to balance the increase in societal needs and between environmental degradation and urbanization. Intelligent adaptation of urban legislation was adopted to provide the framework of the population without compromising the ability of natural ecosystems for long-term production as well as raising public awareness to improve the vision of individuals. Communities and institutions in their responsibilities to protect the environment. Although everyone has the right to know the environmental information. The gained results indicated limited values in agreement with the rest of the variables.

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|
| VAR00025 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| VAR00026 | 12 | 1.00 | 2.00 | 1.1667 | .38925 | .152 |
| VAR00027 | 12 | 1.00 | 2.00 | 1.6667 | .49237 | .242 |
| VAR00028 | 12 | 1.00 | 2.00 | 1.1667 | .38925 | .152 |
| VAR00029 | 12 | 1.00 | 3.00 | 1.1667 | .57735 | .333 |
| Valid N (listwise) | 12 | | | | | |

*Source: SPSS*

The results of the legislation focus on the investment of natural environment factors: the highest level of the agreement (1.16) with the legislation, which invests nature factors (heat, wind, sun, and underground heat) in supporting and attributing the characteristics of the physical environment to reduce the speed of degradation. Renewable resources in enhancing the characteristics of the urban environment and prepare an environmental emergency plan to absorb the environmental conditions that are emerging to reduce the speed of environmental degradation, especially the infrastructure and services, and the inclusion the principle of protecting human health (physical and psychological).

## IX. Conclusions

1. The system of local legislation, laws, and decisions for the protection of the environment lacks comprehensiveness of all environmental aspects and is limited to the general aspects of land use and urban planning of the street system and the signing of industrial facilities and broadcasting stations and mobile, and neglect of the detailed aspects of the natural environment first and the urban environment II, through planning standards and specifications Urbanism is the most important in environmental conservation and based on activating the characteristics of the environment and investing in improving the urban and urban environment.
2. The local regulatory system adopts the principle of violation and the fine to oblige individuals to implement environmental legislation (which is always exceeded by exceptions and temporary improvisation decisions). This is a narrow perspective of control and does not give the individual the leading role in censorship by developing an awareness of the importance of preserving the environment and adopting the principle of Participation and integration in the activation of such legislation, and this is what States aspire to in their current vision to protect the urban environment.
3. The environmental dimensions of urban legislation are based on two main axes: first, is the protection of the urban environment, and this is what most local legislations agree with. Second is the sustainability of the urban environment. This is required by the complementary legislation of the local system. The protection of the environment is insufficient without sustaining its natural resources and urbanism.

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## Appendix (1)

*Questionnaire Form-Environmental Dimensions of Urban Laws and Legislation*

The process of assessing the environmental dimensions of legislation, laws, and regulations relating to the protection of the natural environment and the urban environment requires a comprehensive view of the local legislation and laws, and possible complementary and supportive legislations of what exists, and the study of the mechanism of application and control of the regulatory bodies by adopting principles of application arising from public and institutional awareness Legislation and contribution to application and control. Please specify the level of agreement with the terms of the main points of the questionnaire through your vision and interaction in the field of professional engineering and consulting work, as follows:

1. *General questions:*

| | | | | |
|---|---|---|---|---|
| 1. | a) Functional affiliation | Architect | Civil Engineer | Planner |
| 2. | b) Education: | B.SC | M.SC | PH.D |
| 3. | c) Professional experience: | 5 years | 10 years | 20 years |
| | d) Work Field: | | | |

2. *Evaluation of local legislation, laws, and regulations for environmental protection:*

| | Questions | Agree | Agree somewhere | Not Agree |
|---|---|---|---|---|
| V1 | Inclusion of environmental protection laws and regulations All aspects and elements of the natural environment. | | | |
| V2 | Inclusive environmental protection laws and regulations All aspects and elements of the urban environment. | | | |
| V3 | The system of environmental protection legislation lacks flexibility, transparency, and clarity. | | | |
| V4 | System of legislation The basic planning of cities and the urban environment necessitates the use of land and limit abuses. | | | |
| V5 | The system of local building control legislation helps to improve the performance of planning and design work with the competent authorities. | | | |
| V6 | The system of legislation of waste collection areas and standards of industrial sectors and radio and mobile broadcasting stations is aimed at protecting the natural and urban environment. | | | |

3. *Mechanism for the application of local legislation and laws in the protection of the natural and urban environment:*

| | Questions | Agree | Agree somewhere | Not Agree |
|---|---|---|---|---|
| V7 | Effectiveness of existing legislation on the application and control of legal violations and mandatory penalties in reducing environmental degradation and transgression. | | | |
| V8 | Inclusion of legislation based on the application and control of all stakeholders in the degradation of the natural and urban environment. | | | |
| V9 | Effectiveness of SAIs in reducing excesses and changes in the pattern of land use and thus reducing environmental degradation. | | | |
| V10 | The role of legislative exceptions in the binding procedures for the application of environmental protection legislation and laws. | | | |
| V11 | The need for SAIs responsible for implementing legislation to reconsider their structure and their representative bodies. | | | |
| V12 | Keep pace with regulatory bodies responsible for enforcing environmental protection laws for technological and technological advances in regulatory means. | | | |

4. *The proposed legislation complementary to the current laws to reduce environmental degradation:*

| | Questions | Agree | Agree somewhere | Not Agree |
|---|---|---|---|---|
| V13 | Coordinate national efforts to protect the environment, including a strategy for integration and coordination with global environmental protection legislation. | | | |
| V14 | Develop a general policy for the protection of the environment from the preparation of plans and programs necessary for sustainable development. | | | |
| V15 | Approving the systems of monitoring and measuring elements of the environment and its components and follow-up through the research center to ensure global standards. | | | |
| V16 | Approval of systems for monitoring and measuring the level of degradation and degradation of both the natural and urban environment and the use of periodic surveying devices. | | | |
| V17 | Conduct research studies related to environmental protection laws by involving planning, engineering, and vocational teams. | | | |
| V18 | The legislation of supplementary laws that are based on the causes leading to the excess and the disappearance of the environment more than the limit only. | | | |

5. *The proposed principles for the renewed application of legislation and laws to protect the urban environment:*

| | Question | Agree | Agree somewhere | Not Agree |
|---|---|---|---|---|
| V19 | To legislate the principle of sustainable development to achieve a balance between increasing societal needs and between environmental and urban degradation. | | | |
| V20 | Intelligent adaptation of urban legislation to provide the living framework of the population without compromising the ability of natural ecosystems for long-term production. | | | |
| V21 | Raise public awareness by improving the vision of individuals, communities, and institutions in their responsibilities to protect the environment. | | | |
| V22 | Everyone should have the right to access the environmental information held by the legislative institution for awareness of its role in protecting the environment. | | | |
| V23 | The right of individuals to participate in environmental decision-making and the right to seek justice when they violate their rights to live with dignity. | | | |
| V24 | To legislate the principle of substitution and precautionary measures by replacing harmful work to the environment with less harmful damage, even at a higher cost. | | | |

6. *Legislation by investing factors of the natural environment:*

| | Questions | Agree | Agree somewhere | Not Agree |
|---|---|---|---|---|
| V25 | Legislation to invest factors of nature (heat, wind, sunlight, and heat underground) in supporting and attributing the characteristics of the physical environment to reduce the speed of degradation. | | | |
| V26 | Legislation using clean energy alternatives and renewable resources in enhancing the characteristics of the urban environment. | | | |
| V27 | Legislation using local building materials is the most adapted to its natural producing environment. | | | |
| V28 | Preparation of an environmental emergency plan to accommodate the emerging environmental conditions to reduce the speed of environmental deterioration, especially the infrastructure and service. | | | |
| V29 | Incorporate the principle of protecting human health (physical and psychological) in defining environmental pollution control controls. | | | |

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# Experimental Studies on Flexural Behaviour of RC Beams Reinforced with Basalt Rebars

By R. Ashutosh V. Kulkarni, Santosh Rathod, Praveen Talwar, John Wesley, Sujeet Patil & Dr. Aravindkumar B. Harwalkar

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*Abstract-* The Paper covers utilization of Basalt rebar for concrete reinforcing, its comparatively new element, which seems a potential material for infrastructural reinforcing. Superior temperature endurance and low weight are only some of the advantages it offers above other composites and steel. Because it is non-corrosive, basalt rebar is an excellent option for reinforcing concrete constructions that are located near sea. The work describes several experimental studies, like a tensile strength testing of basalt rebar with standard steel as well as flexure strength test of beams reinforced both by basalt rebar and traditional steel, also work is being done for identifying material qualities, mixture ratio of M20 grade concrete as well as standard cubes were tested in compression as well as prisms are examined for flexural strength. There are 12 samples of 1500×150/230mm×1500 mm that have been cast and monitored under a 1000kN capacity load frame. Six of the specimens have standard steel reinforcement, while the other six have basalt reinforcement. Rebar with diameters of 10mm and 12mm is often utilized.

*Keywords:* *basalt rebar, steel, flexural behavior, reinforced concrete beams.*

*GJRE-E Classification:* *FOR Code: 090599*


*Strictly as per the compliance and regulations of:*

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*Abstract-* The Paper covers utilization of Basalt rebar for concrete reinforcing, its comparatively new element, which seems a potential material for infrastructural reinforcing. Superior temperature endurance and low weight are only some of the advantages it offers above other composites and steel. Because it is non-corrosive, basalt rebar is an excellent option for reinforcing concrete constructions that are located near sea. The work describes several experimental studies, like a tensile strength testing of basalt rebar with standard steel as well as flexure strength test of beams reinforced both by basalt rebar and traditional steel, also work is being done for identifying material qualities, mixture ratio of M20 grade concrete as well as standard cubes were tested in compression as well as prisms are examined for flexural strength. There are 12 samples of 1500×150/230mm×1500 mm that have been cast and monitored under a 1000kN capacity load frame. Six of the specimens have standard steel reinforcement, while the other six have basalt reinforcement. Rebar with diameters of 10mm and 12mm is often utilized. The patterns of crack development with load deflection are being studied in this research project. Tensile strength of basalt rebar is double that of standard steel, according to results of experiments. When comparing basalt-reinforced beams with steel-reinforced beams, the load–deflection curve, the first crack load, the maximal load, as well as deflections are all taken into consideration. Conventional beams with basalt-reinforced beams have similar ultimate load-carrying capability. Deflection in basalt reinforced beams is 66.66 percent lower than in normal beams, according to the research. Failure of conventional RC beams was determined to be based on flexure criteria, but the failure of basalt reinforced RC beams was based on the expansion of shear crack.

*Keywords: basalt rebar, steel, flexural behavior, reinforced concrete beams.*

## I. Introduction

New and better materials are being sought for by construction industry in an effort to develop product which is both lucrative to business as well as useful to building projects. These days, many new composite materials are being created upon large scale in industry and are being employed in routine building projects all over world. New, environmentally friendly materials must be used in lieu of older ones that are no longer sustainable or worthy of use because of their weakness, corrosion risk, or environmental effect.

Basalt is a common rock found all over world, and it's used to make basalt fibre. Concrete may be reinforced using Basalt Rebar, which is a great product. The tensile strength is three times greater and it is four times lighter over steel rebar. Basalt fibres are pultruded into rebar using pultrusion technology. Massive volumes of basalt rebar can be mass-produced. When exposed to heat, basalt rebar does not emit hazardous fumes or combust, and it does not cause an explosion. They will not generate a product that is toxic or detrimental to the environment when they are in close touch with chemicals. Corrosion damage to reinforced structures does have negative effect upon its endurance and ultimate strength. Basalt bars used as reinforcing in concrete projects are non-corrosive, according to Saravanan S and Rohith N S [1]. Flexural behavior and load bearing capacity were both improved by 23% and 11%, respectively, when M30 grade beam specimens were reinforced with Basalt bars, according to the findings of the experiments. Because to its lower density, basalt bar weighs less than steel bar. Basalt bar has the benefit of being resistant to chemical assaults like alkali, rust, as well as acids in its natural state. A volcanic igneous rock, basalt is created with cooling of molten lava hundreds of kilometers below surface. Researchers led by Marek Urbanski et al. [2] investigated the stress-strain behavior of material that turned out as linear besides quite dissimilar compared with steel. Jibin.c bright and Preetha Prabhakaran [3] studied the effects of prolonged stress and exposed with alkaline solution at extreme heat on concrete deformation and compared findings to acceptable standard levels defined by codal criteria. As in comparison with steel bars, Basalt rebar's creep rupture strength is much lower than steel bars' tensile strength. Rebars made of basalt are characterized by their intrinsic qualities, resin as well as adhesion with one another, all of which influence their creep properties.

## II. Objectives

1. Studying ductility as well as mechanical characteristics of Basalt Rebar with Conventional steel Rebar.

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2. Regarding RC beams having basalt reinforcement, to establish preliminary cracking load, ultimate load, and load-deflection pattern; and to compare findings with conventional RC beams.
3. In order to determine how RC beams having basalt reinforcement and standard RC beams behave when subjected to flexure.

## III. Methodology

*a) Material used*

In the experiment, materials included are cement, river sand, coarse aggregates, Basalt rebar, regular steel, and water.

A single batch of OPC53 graded cement, manufactured with compliance to specifications of IS 12269-1987, is utilized throughout the project. The project uses river sand from zone II of IS 383-1970, which is occurs naturally as well as locally accessible. According to IS 383-1970, crushed basalt stones are a depth of 20 mm. Basalt rebar is a cutting-edge composite material that has ardent proponents across the world. Rebar produced from basalt roving is known as basalt rebar. Spiral-ribbing carrier rods are made from twisted basalt strip, oiled on exterior, and enclosed in very durable polymeric compound. Corrosive conditions are no match for basalt rebar. In contrast, steel is vulnerable to regular corrosion. Alkalis, rust, and acids can't penetrate basalt rebar since it is inherently resistant. There's no need for a particular finish on this piece. Cutting basalt rebar to length is simple and may be done using standard tools. The basalt rebars are shown in Figure 1.

Fe 500 grade steel should be used for typical RC beams that meet IS 1786-1985 standards. Reinforcement is provided by 12mm as well as 10mm diameter bars.

In compliance with IS 456-2000, water that is fit for human consumption is used for both the casting as well as curing of concrete in this study.

*Fig. 1:* Basalt Rebars

*b) Mix Proportion*

M20 graded concrete had ben utilized for casting RC beams. Utilizing code requirements of IS-10262- In 2009, a concrete mix design for M20 grade was completed. The accelerated curing technique was used to assess concrete's compressive strength in order to determine the mix percentage for future investigation. 3 trial mix proportions are used in total. Table I shows the mix ratios.

*Table I:* Sample mixtures of M20 grade concrete

| Sl.No. | Material | MIX1 | MIX2 | MIX3 |
|---|---|---|---|---|
| I. | 1Cement | 380kg/m3 | 370kg/m3 | 360kg/m3 |
| II. | Fine2 Aggregate | 667.05kg/m3 | 676.01kg/m3 | 677kg/m3 |
| III. | Coarse 3 Aggregate | 1163.12kg/m3 | 1178.74kg/m3 | 1180.48kg/m3 |
| IV. | 4 Water | 209kg/m3 | 199.8kg/m3 | 194.4kg/m3 |

Concrete mix 3 was chosen for casting RC beams based upon preceding findings of compressive strength, and selected mix's compressive strength were determined after 28 days of traditional curing.

*c) Specimen Details*

All these conventional as well as basalt-reinforced beams are included in Table III, which details specimens utilised in investigation and specifications for reinforcements.

*Table II:* Details on the test specimen

| Specimen kind | Specimen dimension (mm) | Tests | Specimens quantity |
|---|---|---|---|
| Cube | 150×150×150 | Testing of compressive strength for typical concrete. | 09 (3 trials) |
| Plain concrete Beam (prism) | 100×100×500 | Flexural strength of traditional concrete. | 03 |
| RC Beam | 1500×150×230 | Two-point loading flexural strength test.<br>1. Traditional beam/ reference beam.<br>2. Beam strengthened with basalt rebars. | 06<br>06 |

*Fig. 2:* Basalt Reinforcing

*Fig. 3:* Laying Reinforcement into wooden mould

*Table III:* Reinforcement specifics of beam specimen

| Series | Beam identification | Whole length | Clear span | Beam dimension in mm | Reinforcing particulars |
|---|---|---|---|---|---|
| Traditional beam | CB11 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | CB12 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | CB13 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| Traditional beam | CB21 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | CB22 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | CB23 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |

| Series | Beam identification | Whole length | Clear span | Beam dimension in mm | Reinforcement particulars |
|---|---|---|---|---|---|
| Basalt reinforce Beam | BB11 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | BB12 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | BB13 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 10mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| Basalt reinforce Beam | BB21 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | BB22 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |
| | BB23 | 1500 | 1300 | 1500×150×230 | 2 of 8mm at top and 2 of 12mm at bottom, 2 Legged Vertical Stirrups of 6mm at 125 c/c |

*d) Determining Mechanical Characteristics*

i. *Tensile strength testing for rebar's*

Tensile strength testing is often used steel tests. An attempt is made to break the sample until it cracks in order to measure its tensile strength, yield strength, plasticity, and decrease in surface area using a bending test. For testing, this has been put into its paces using 500-kN digital servo-driven universal equipment.

ii. *Compressive Strength*

Compressive strength may be determined experimentally in accordance with codal criteria. Compressive strength of cube may be calculated using below equation.

Cube Compressive strength=load at failure/ cross sectional area in N/mm$^2$.

iii. *Bending Strength*

According to codal criteria, bending strength of a normal concrete prism is deliberated. Equation is used to determine bending strength is as shown below:

Bending strength=PL/bd2 in N/mm$^2$.

iv. *Analysis of RC Beams*

After 28 days of curing, reinforced concrete beams were prepared to be tested. For making it easy for mounting upon testing machines and reinforced concrete beams are capable for testing. Marking lines were used to indicate placement of point loads, supports, as well as beam's mid-span on the testing machine. In order to conduct the test, the specimen was placed horizontally in a loading setup. In such 1000KN capacity loading frame, the beams are put to the test. The beams are held in place by circular steel supports on each of their two sides. There was only one-third point loading on all of the beams since they were designed to break in flexure instead of shear. During this test, the beam was equipped with an LVDT to measure deflection at the mid-span. The beam's mid-span point was fitted with a load cell. Repetition of the jacking process until beam's maximum load capacity was attained was necessary for applying load. The two-point loading system was chosen. The pace of loading remained constant throughout. The data gathering technology automatically acquired information. Figure 4 depicts testing apparatus.

*Fig. 4:* Flexural Failure of beam

## IV. Results and Discussions

*a) Rebars Characteristics*

i. *Weight / Meter Rebar Length*

As shown in Table IV, conventional as well as basalt reinforcing bars have an average weight per meter.

*Table IV:* Average weight/meter length of rebars

| Rebar type | Diameter | Average weight / meter length in kg |
|---|---|---|
| Traditional Rebar | 12 | 0.86 |
| | 10 | 0.58 |
| | 8 | 0.38 |
| Basalt rebar | 12 | 0.23 |
| | 10 | 0.16 |
| | 8 | 0.10 |

When compared to standard steel, basalt rebars are 72.5 percent lighter in weight.

*b) Tensile Strength Test for Conventional and Basalt Rebars*

A 500 kN digital universal servo-controlled tensile strength testing equipment was used to perform test in accordance with requirements of IS 1608, as indicated in Figures 5 and 6. Figures 7 and 8 illustrate results of tests.

*Fig. 5:* Marking upon Conventional rebars



*Fig. 6:* Marking upon Basalt rebars while testing while testing

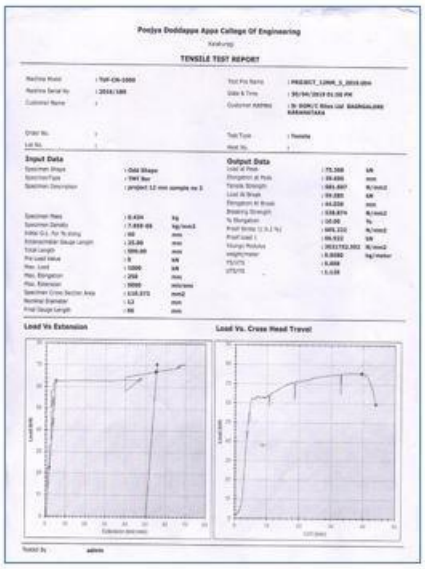

*Fig. 6:* Tensile testing report for Conventional

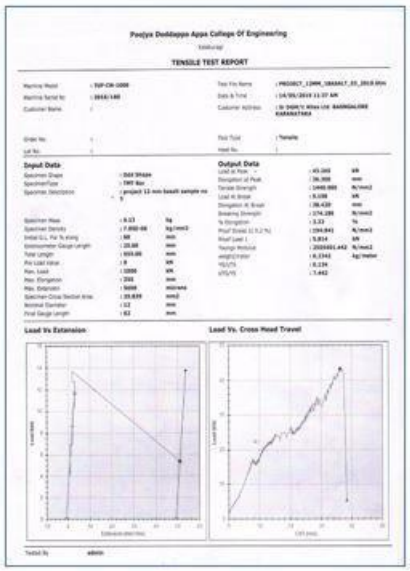

*Fig. 7:* Tensile testing report for Basalt Steel Rebar

c) *Ductility Testing upon Rebars*

In addition to elongation value, Bend and Re-bend test was utilized to determine ductility, and test was carried out in accordance with IS1786-2008. basalt rebar failed bend and rebend test, but standard steel did, demonstrating that basalt rebar has a lower ductility value than steel. The basalt rebar's biggest drawback is this.

d) *Compressive Strength Test*

Using the accelerated curing technique, compressive strength test results are shown in Table IV. After testing trial mixes utilising an accelerated curing technique, it was determined that Trial MIX3 was strong enough for use in casting of RC beams. Table V shows results of compressive strength testing after 28 days. Trial MIX3 is used to make three cubes, which are then kept for conventional curing. Traditional curing yields compressive strength that is almost comparable to predicted strength attained with accelerated curing. Fig. 8 shows a cube specimen that has failed.

*Table IV:* Compressive strength testing result (Accelerated curing technique)

| Mix identity | Specimen Name | Load (kN) | Compressive strength in N/mm² (accelerated curing test) | Compressive strength +12.65 N/mm² | Average compressive strength N/mm² |
|---|---|---|---|---|---|
| MIX.1 | Cube 11 | 405.8 | 18.03 | 30.68 | 33.59 |
| | Cube 12 | 458 | 20.35 | 33 | |
| | Cube 13 | 550.4 | 24.46 | 37.11 | |
| MIX.2 | Cube 21 | 342.6 | 15.22 | 27.87 | 29.77 |
| | Cube 22 | 481.9 | 21.41 | 34.06 | |
| | Cube 23 | 331.9 | 14.75 | 27.40 | |
| MIX.3 | Cube 31 | 337.6 | 15.0 | 27.65 | 29.08 |
| | Cube 32 | 451.2 | 20.05 | 32.70 | |
| | Cube 33 | 320.4 | 14.24 | 26.89 | |

*Table V:* Compressive strength testing result at 28 days with M20 grade mix

| Mix identity | Specimen Name | Load (KN) | Compressive strength N/mm² | Average compressive strength N/mm² |
|---|---|---|---|---|
| MIX.3 | Cube 11 | 742 | 33 | 29.6 |
| | Cube 12 | 659 | 29 | |
| | Cube 13 | 602 | 26 | |

*Fig. 8:* Compressive Strength Test Failure Pattern on a Cube

*Fig. 9:* For M20 grade concrete, prism failure patterns during flexural strength testing

*e) Flexural Strength Test upon Concrete*

Table VI shows outcomes of flexural strength testing, and Fig 9 shows the prism's failure pattern. The prism fails slowly, with first sign of failure being development of flexural crack.

*Table VI:* Results of flexural strength testing with M20 grade mix at 28 days

| Mix identity | Specimen Name | Load (kN) | Flexural strength N/mm² | Average flexural strength N/mm² |
|---|---|---|---|---|
| MIX.1 | Prism 11 | 11.76 | 4.704 | 3.78 |
| | Prism 12 | 8.82 | 3.52 | |
| | Prism 13 | 7.84 | 3.13 | |

After steady stress, prism fails gradually, with creation of flexural crack as precursor.

*f) Behavior of RC Beams under Flexure*

Every beam is attributed to 2kN/sec escalation in load, and resulting deflection is recorded.

i. *Conventional RC Beams*

a. *Conventional RC Beams (CB1 SEREIS)*

Figure 10 depicts usual crack pattern and load-deflection graphs depicting CB11, CB12, and CB13 beams.

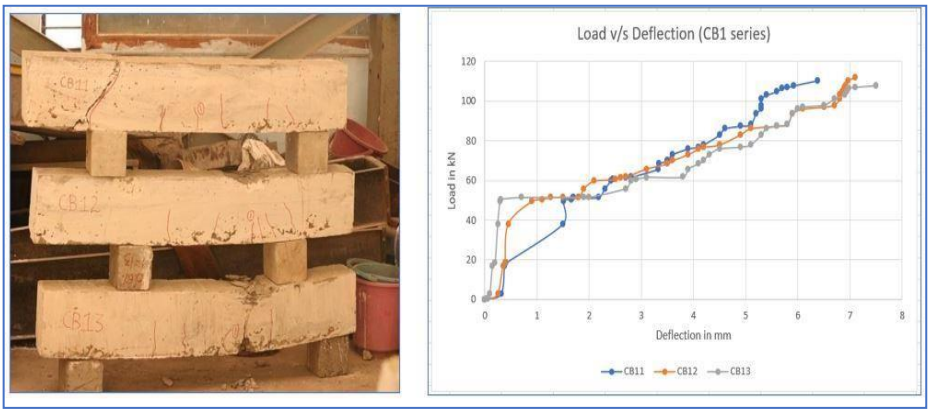


*Fig. 10:* For conventional beams of CB1 series, crack patterns with load deflection graph CB11, CB12, and CB13

There are 110.4 kN for CB11, 111.2 kN for CB12, and 107.6 kN for CB13 in terms of first crack loads. The final loads are 135.7 kN, 127.2 kN, also 124.6 kN, respectively. These are equivalent deflections: 6.38mm, 7.07mm, and 7.54mm, respectively. Flexural failure was seen in CB12 and CB13. On the other side, CB11 indicated compression face extension of shear crack. Regardless of fact that first crack is flexural.

b. *Conventional RC Beams (CB2 Series)*

Fig. 11 depicts usual crack pattern for CB21, CB22, and CB23 beams, as well as a load vs. deflection graph for these three beams.

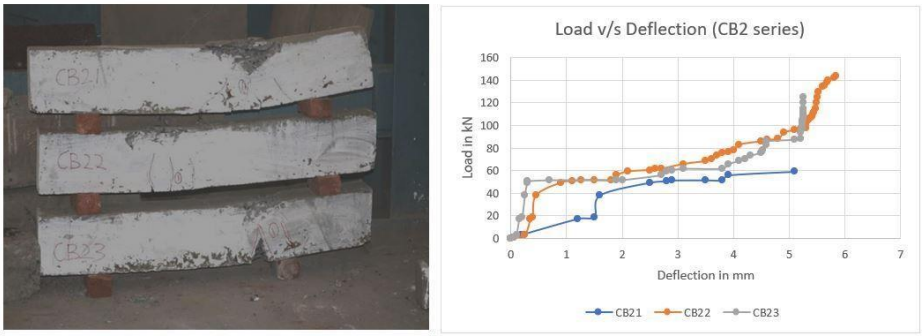


*Fig. 11:* Crack pattern along with typical beam load vs. deflection graph

Primary crack loading are determined as 59.2kN, 143.3kN as well as 124.2kN for CB21, CB22 also CB23 correspondingly. Equivalent ultimate load values were 121.7kN, 155.6kN and 157.5kN, as well as deflection readings are 5.21mm, 5.84mm, and 5.6mm, respectively. Flexural collapse was seen in all CB2 series specimens.

ii. *Beams with Basalt Reinforcement*

a. *Basalt Strengthened Beams (BB1 Series)*

Load-vs-deflection graphs for load-bearing beams illustrated in Figure 12 demonstrate typical crack patterns of BB11, BB12, and BB13.

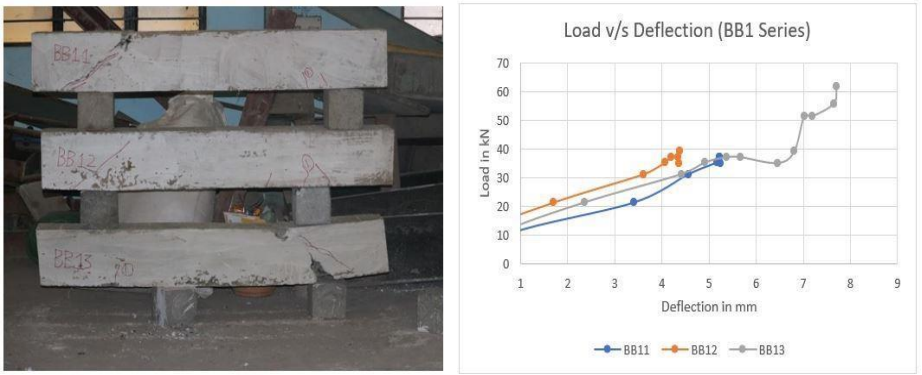


*Fig. 12:* Crack shape as well as Basalt-reinforced beams load-deflection graph

There are three primary crack loading for BB11, BB12, and BB13, respectively: 61.7kN, 37.2kN, and 35.1kN, correspondingly. Ultimate load values were 120.7kN, 124kN, as well as 121kN respectively. Also, deflection value was 5.24mm, 4.38mm, 7.7mm respectively. Every one of specimen exhibited shear crack which went all way through to compression face. The initial crack had been flexural crack.

b. *Basalt Reinforced Beams (BB2 Series)*

As shown in Figure 13, typical cracking formation of beam BB21, BB22, and BB23 and load vs. deflection graph is displayed.

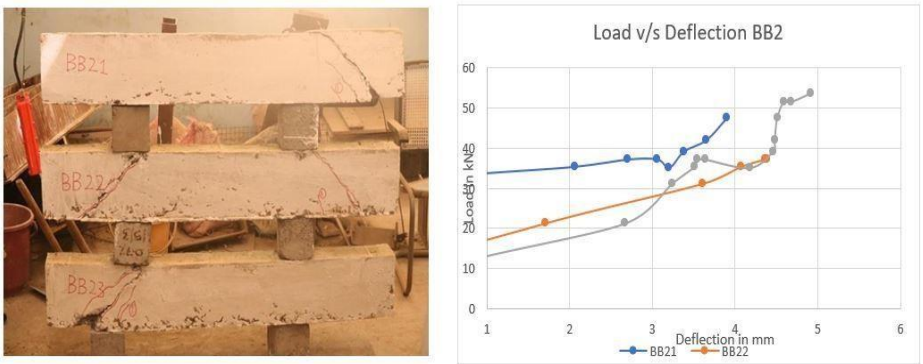


*Fig. 13:* Crack pattern as well as Basalt reinforced beam load-deflection graph

For BB21, BB22, and BB23, first crack loads are 53.5kN, 37.2kN, and 47.5kN, correspondingly. There is a 107.5kN, 120.7kN, and 116.2kN ultimate load. That's 4.91mm, 4.38mm, and 3.63 millimetres of deflection in each case.

Every one of the specimens exhibited shear crack which went all way through to compression face. The initial crack had been flexural crack, in spite of fact that.

ii. *Assessment of First Crack as well as Ultimate Load of Several RC Beam*

Figures 14 and 15 show comparing with first crack as well as ultimate weight for standard RC beams with basalt strengthened beam (CB1&BB1) besides (CB2&BB2).

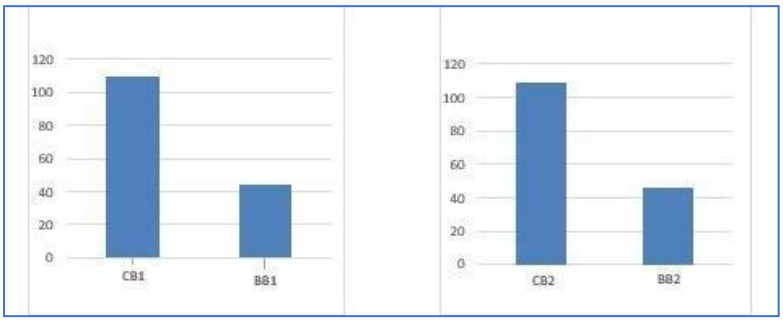


*Fig. 14:* Comparing first crack of (CB1 & BB1) and (CB2 & BB2)

Matched to ordinary RC beams of CB1 series, first crack weight of BB1 series' Basalt strengthened beams was reduced by 59.2 percent. As a result, ultimate loading for Basalt-reinforced BB1 series beams fell by 57.66 percent in comparison to standard RC beam of CB1 series.

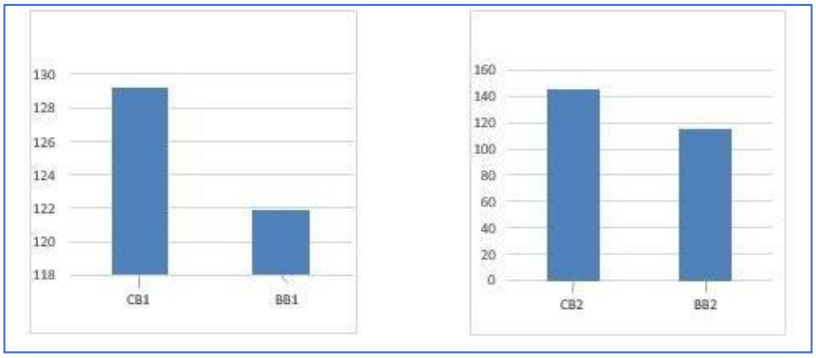


*Fig. 15:* Comparing ultimate load of (CB1 & BB1) and (CB2 & BB2)

When equated with conventional reinforced concrete (RC) beam of CB2 series, first crack load of Basalt reinforced BB2 series beam fell with 5.62 percent. In comparison to ordinary RC beam of CB2 series, maximum load for BB2 series' Basalt reinforced beam was reduced by 20.78 percent.

## V. Conclusions and Further Scope

*a) Conclusion*

Established upon findings of an experimental investigation, the relevant conclusions are drawn:

1. Basalt rebar has a tensile strength double that of conventional steel.
2. This means that basalt rebar is 71.5 percent lighter per meter of length when compared to ordinary steel.
3. The basalt rebar's lack of ductility is a serious drawback. In contrast to slow collapse of ordinary rebar, failure of basalt rebars was instantaneous.
4. The failure of conventional RC beams occurred immediately after first crack formed, but failure of basalt-reinforced beams occurred after first crack formed.
5. Deflecting value for basalt reinforced beam is extraordinarily reduced by 66.66% in comparison with normal beam, basalt reinforced RC beams have a greater rigidity.
6. Conventional RC beam failure was flexural, but the failure of basalt reinforced beams was due to expansion of shear cracks, which may be linked to basalt reinforcing bars' increased tensile strength.
7. Basalt reinforced beams including a tension steel percentage of 0.5 percent had lower first crack load as well as ultimate load than conventionally reinforced beams, reducing by 59% and 5.62 percent, respectively.
8. For 0.73 percent tension steel reinforced Basalt beams, ultimate load as well as first crack load were reduced by 57.66 percent and 20.78%

correspondingly as compared to normal beams of the same size.

*b) Scope for Further Study*

1. Basalt rebars may be made more ductile by research on this topic.
2. RC beams having basalt reinforcement may be examined in terms of their shear behavior.
3. Studying RC beams having basalt reinforcement at impact as well as fatigue loads is possible.

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# Superpave System Calculation

By Eng. Adeeb Khalil Adeeb Khalil
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*Abstract-* A superpave system is a way to specify the components in asphalt pavements that perform better than average.

A new approach has been created for specifying the asphalt ingredients in asphalt concrete as part of the Strategic Highway Research Program (SHRP). The shorthand name for this technology is superpave, which stands for high performance asphalt pavements.

The research that resulted in the creation of this new system was started because, prior to the invention of superpave, it was challenging to connect the dots between the performance of the pavement and the findings from laboratory analysis in the previous systems.

*Keywords: superpave system, binder, asphalt mixture, asphalt mix design, superpave calculation.*

*GJRE-E Classification: DDC Code: 738.52095694 LCC Code: NA3760*


*Strictly as per the compliance and regulations of:*

# Superpave System Calculation

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## Introduction

The Superpave mix design approach primarily uses performance-based and performance-related features as the selection criteria for the mix design, which is a significant distinction from other design methods like the Marshal and Hveem methods.

Here, we'll take a smooth and accurate look at how to use superpave method to create an asphalt mix and compare it to the minimum criteria using procedures including employing equations, displaying the results, modifying, and comparing.

The objective of this mix design is to obtain a mixture of asphalt and aggregates that has the following characteristics:

1. Sufficient asphalt binder.
2. Sufficient voids in the mineral aggregates (VMA) and air voids.
3. Sufficient workability.
4. Performance characteristics over the service life of the pavement.

*Enter:*

*Superpave system consists of the following parts:*

- Selection of Materials
- Volumetric Trial Mixture Design
- Selection of Final Mixture Design

## I. Selection of Materials

*a) Selection of Asphalt Binder*

The selection can be made in one of three ways:

1. The designer may select a binder based on the geographic location of the pavement.
2. The designer may determine the design pavement temperatures.
3. The designer may determine the design air temperatures which are then converted to design pavement temperatures.

* Superpave system specifies asphalt on the basis of the climate and pavement temperatures is expected to serve.
* Physical properties requirements remain the same, but the temperature of asphalt must attain the properties changes.

*Performance grade (PG) binders are graded such as PG 64-22.*

*The first number 64*, is often called the "*high temperature grade*".
This means that the binder would possess adequate physical properties at least up to 64C.

This would be the high pavement temperature corresponding to the climate in which the binder is actually expected to serve.

*The second number -22,* is often called the "*low temperature grade*" and means that the binder would possess adequate physical properties in pavements at least down to -22C.

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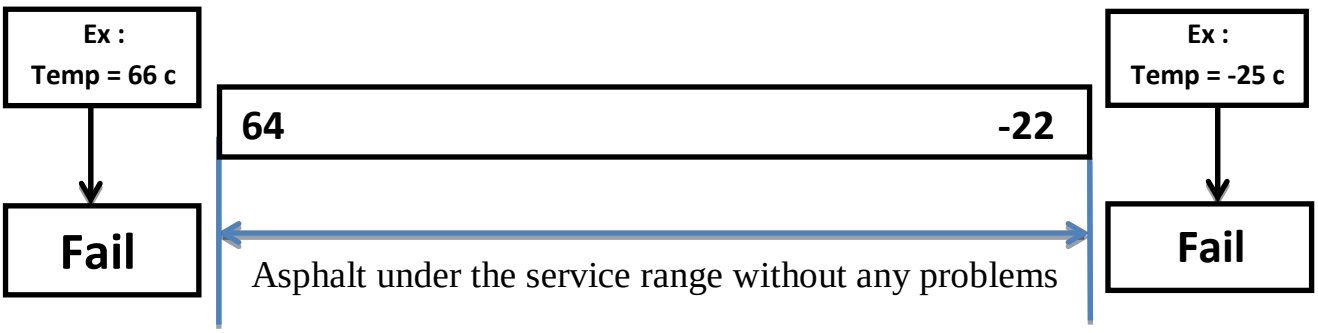



*Performance grade (PG) evaluation*

The Superpave system didn't consider the air temperature should be used as the design temperature; the system therefore uses this equation to convert the maximum air temperature to the maximum design pavement temperature.

*The low-pavement design temperature can be selected using this equation:*

$$T_{20mm} = (T_{air} - 0.00618Lat^2 + 0.2289Lat + 42.2)(0.9545) - 17.78$$

Where:

$T_{20mm}$ = high-pavement design temperature at a depth of 20 mm
$T_{air}$ = seven day average high air temperature (C)
*Lat*= the geographical latitude of the project location (degrees)

*The low-pavement design temperature can be selected using this equation:*

$$T_{pav} = 1.56 + 0.72T_{air} - 0.004Lat^2 + 6.26log_{10}(H+25) - Z(4.4 + 0.52\sigma_{air}^2)^{0.5}$$

Where:

$T_{pav}$ = low AC-pavement temperature below surface (C)
$T_{air}$ = low air temperature (C)
*Lat*= latitude of the project location (degrees)
$H$ = depth of pavement surface mm
$\sigma_{air}$ = standard deviation of the mean low air temperature (C)
$Z$ = 2.055 for 98 percent reliability

*Ex:*

Determining a Suitable Binder Grade Using High and Low Air Temperatures.

The latitude at a location where a high-speed rural road is to be located is $41^o$. The seven-day average high air temperature is $50^o$C and the low air temperature is $-20^o$C. The standard deviation for both the high and low temperatures is $\pm 1^o$C.

Determine a suitable binder that could be used for the pavement of this highway if the depth of the pavement surface is *155 mm* and the expected ESAL is $9 \times 10^6$.

1. *Determine the high-pavement temperature at a depth of 20 mm*

$$T_{20mm} = (T_{air} - 0.00618Lat^2 + 0.2289Lat + 42.2)(0.9545) - 17.78$$

$$T_{20mm} = (50 - 0.00618*41^2 + 0.2289*41 + 42.2)(0.9545) - 17.78$$

$$T_{20mm} = 69.27^o \text{ C}$$

2. *Determine low-AC-pavement temperature*

$$T_{pav} = 1.56 + 0.72T_{air} - 0.004Lat^2 + 6.26log_{10}(H+25) - Z(4.4 + 0.52\sigma_{air}^2)^{0.5}$$

$$T_{pav} = 1.56 + 0.72(-20) - 0.004*41^2 + 6.26log_{10}(155+25) - 2.055(4.4 + 0.52*1^2)^{0.5}$$

$$T_{pav} = -10^o\text{C}$$

PG (–10, 69)

*Tests on Binder Asphalt (Physical Properties)*

Physical properties are also measured on binders that have been aged in

1. Rolling thin film oven (RTFO) (Long Term Aging)

to simulate oxidative hardening that occurs during hot mixing and placing.

2. Pressure aging vessel (PAV) (Short Term Aging)

to simulate the severe aging that occurs after the binder has served many years in a pavement.

*Binder physical properties are measured using four devices*

1. Dynamic Shear Rheometer (DSR)

is used to measures the complex shear modulus and phase rotational angle.

* to control asphalt stiffness
* prevent Fatigue cracking

2. The Rotational Viscometer (RV)

to characterizes the stiffness of the asphalt at 135 C , where it acts entirely as a viscous fluid.

* To know that asphalt have a viscosity of less than 3 Pa-s. This ensures that the asphalt can be pumped and otherwise handled during HMA manufacturing.

3. The Bending Beam Rheometer (BBR)

to characterize the low temperature stiffness properties of binders.

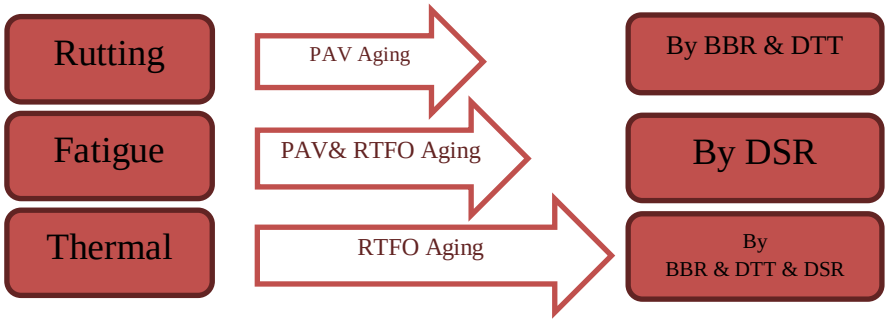
* To minimize low temperature cracking due to load.

4. Direct Tension Test (DTT)

to Know binders (Asphalt) are sufficiently ductile at low temperatures

* Resistance low temperature cracking due to Climate.

** These are examples of problems and how they are tested to prevent them from occurring.*




*b) Selection of Mineral Aggregate*

The aggregate characteristics that generally were accepted by the experts for good performance of the hot mix asphalt include:

1. Coarse Aggregates Angularity (CAA)
2. Fine Aggregates Angularity (FAA)
3. A flat and elongated particle
4. The clay content

1. *Coarse Aggregates Angularity (CAA)*

The percent of coarse aggregates larger than 4.75 mm with one or more fractured faces.

*Table 18.14:* Coarse Aggregate Angularity Criteria

**Minimum Value** **Given**

| *Traffic, Million ESALs* | *Depth from Surface* | |
|---|---|---|
| | *< 100 mm* | *> 100 mm* |
| < 0.3 | 55/– | –/– |
| < 1 | 65/– | –/– |
| < 3 | 75/– | 50/– |
| < 10 | 85/80 | 60/– |
| < 30 | 95/90 | 80/75 |
| < 100 | 100/100 | 95/90 |
| > 100 | 100/100 | 100/100 |

*Note:* "85/80" indicates that 85% of the coarse aggregate has one or more fractured faces and 80% two or more fractured faces.

**When CAA Increase , Performance Increase**

Ex : ESAL = 40*10^6 and depth from surface = 12 cm
are 82% acceptable ?

SOL: Depth from surface = 12 cm = 120 mm

ESAL = 40 < 100

82% < 95/90% → Not Acceptable

2. *Fine Aggregates Angularity (FAA)*

The percent of air voids in loosely compacted aggregates smaller than 2.36 mm.

*Table 18.15:* Fine Aggregate Angularity Criteria

**Minimum Value** **Given**

| *Traffic, Million ESALs* | *Percent Air Voids in Loosely Compacted Fine Aggregates Smaller than 2.36 mm* | |
|---|---|---|
| | *Depth from Surface* | |
| | *< 100 mm* | *> 100 mm* |
| < 0.3 | — | — |
| < 1 | 40 | — |
| < 3 | 40 | 40 |
| < 10 | 45 | 40 |
| < 30 | 45 | 40 |
| < 100 | 45 | 45 |
| ≥ 100 | 45 | 45 |

**When FAA Increase , Performance Increase**

Ex : ESAL = 20*10^6 and depth from surface = 7 cm
percent of air voids in fine aggregates = 40%
the FAA acceptable ?

SOL: Depth from surface = 7 cm = 70 mm
ESAL = 20 < 30

40% < 45% → Not Acceptable

3. *The Clay Content*

Is the percentage of clayey material in the portion of aggregate passing through the 4.75 mm sieve.

*Table 18.17:* Clay Content Criteria

**Minimum Value** **Given**

| *Traffic, Million ESALs* | *Sand Equivalent Minimum, Percent* |
|---|---|
| < 0.3 | 40 |
| < 1 | 40 |
| < 3 | 40 |
| < 10 | 45 |
| < 30 | 45 |
| < 100 | 50 |
| ≥ 100 | 50 |

**Blend which has lowest sand Equivalent , has a highest clay content**

**When sand Equivalent increase , performance increase**
**When clay content increase , performance decrease**

Ex : ESAL = 18*10^6 , sand equivalent = 45%
is the caly content Acceptable ?

SOL:

ESAL = 18 < 30
45% = 45% → Acceptable

4. *A Flat and Elongated Particle*

Maximum dimension five times greater than its minimum dimension.

*Table 18.16:* Thin and Elongated Particles Criteria

**Maximum Value** **Given**

| *Traffic, Million ESALs* | *Maximum, Percent* |
|---|---|
| < 0.3 | — |
| < 1 | — |
| < 3 | 10 |
| < 10 | 10 |
| < 30 | 10 |
| < 100 | 10 |
| ≥ 100 | 10 |

**When ElongatedIncrease , Performance Decrease**

Ex : ESAL = 4*10^6 , elongated particles = 11%

Acceptable or Not ?

SOL:

ESAL = 4 < 10

11% > 10% → Not Acceptable

Summary

- Seeking to achieve HMA with a high degree of internal friction and thus, high shear strength for rutting resistance.
- Limiting elongated pieces ensures that the HMA will not be as susceptible to aggregate breakage during handling and construction and under traffic.
- Limiting the amount of clay in aggregate, the adhesive bond between asphalt binder and aggregate.

*c) Gradation*

The distribution particle sizes for a given blend of aggregate mixture is known as the design aggregate structure.

The advantage of granular grading of aggregates is to obtain the highest density of aggregates and the lowest voids

## 1-The nominal maximum size

Is one sieve larger than the first sieve that retains more than 10 percent of the aggregate.

## 2- Maximum size

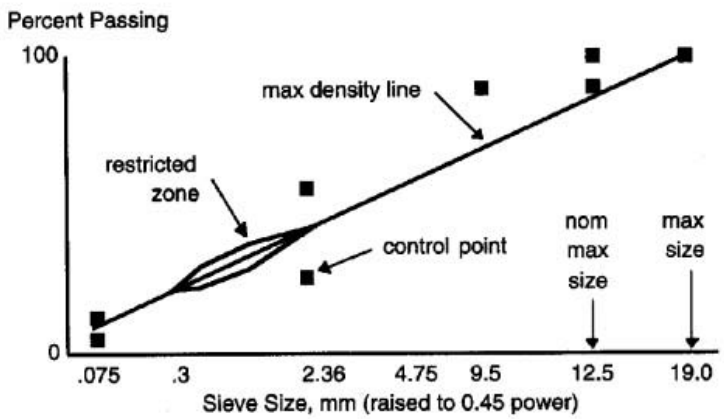
Is defined as one sieve larger than the nominal maximum size.

EX : Find Maximum nominal size & Maximum Size for These Sieve

| Sieve ( mm ) | Passing ( + ) | Retain ( - ) |
|---|---|---|
| 50 | 100% | 0% |
| 37.5 | 100% | 0% |
| 25 | 95% | 5% |
| 19 | 92% | 8% |
| 12.5 | 89% | 11% |
| 9.5 | 85% | 15% |
| 4.75 | 70% | 30% |

Maximum Nominal Size

Maximum Size




**Control point :**
upper and lower limits where superpave gradation must pass through them

**Restricted Zone :**
Control Fine Minerals

**Max density Line :**
to Know density Of Mix

## II. Volumetric Trial Mixture Design

*a) Determining Trial Percentage of Asphalt Binder*

**Step 1**

Compute the **bulk** and **apparent** specific gravities of the total aggregates in the trial aggregate mix using

$$G_{sb} = \frac{P_{ca} + P_{fa} + P_{mf}}{\frac{P_{ca}}{G_{bca}} + \frac{P_{fa}}{G_{bfa}} + \frac{P_{mf}}{G_{bmf}}}$$

$$G_{asb} = \frac{P_{ca} + P_{fa} + P_{mf}}{\frac{P_{ca}}{G_{aca}} + \frac{P_{fa}}{G_{afa}} + \frac{P_{mf}}{G_{amf}}}$$

**Step 2**

Compute the **effective** specific gravity of the total aggregate in the trialgradation

$$G_{se} = G_{sb} + 0.8(G_{asb} - G_{sb})$$

**Step 3**

The amount of **asphalt binder absorbed** by the aggregates

$$V_{ba} = \frac{P_s(1 - V_a)}{\frac{P_b}{G_b} + \frac{P_s}{G_{se}}}\left[\frac{1}{G_{sb}} - \frac{1}{G_{se}}\right]$$

**Where:**
**Vba** : volume of absorbed binder of mix

**Pb**:percent of binder = 0.05
**Ps**: percent of aggregate = 0.95
**Gb**:specific gravity of binder =1.02
**Va**= **Pa** = volume of air voids = 0.04

**Step 4**

The percent of effective asphalt binder by volume

$$V_{be} = 0.176 - (0.0675)\log(S_n)$$

**Where:**

Vbe : the volume of effective binder content

Sn : the nominal maximum sieve size (mm)

**Step 5**

A trial percentage of asphalt binder

$$P_{bi} = \frac{G_b(V_{be} + V_{ba})}{(G_b(V_{be} + V_{ba})) + W_s} \times 100$$

$$W_s = \frac{P_s(1 - V_a)}{\frac{P_b}{G_b} + \frac{P_s}{G_{se}}}$$

**Where**:

Pbi: initial trial percent of binder by mass of mix

Gb :specific gravity of binder assumed = 1.02

Ws:mass of aggregate

*Ex:*

The table below shows properties of three trial aggregate blends that are to be evaluated so as to determine their suitability for use in a Superpave mix. If the nominal maximum sieve of each aggregate blend is 19 mm, determine the initial trial asphalt content for each of the blends.

| Property | Trial blend 1 | Trial blend 2 | Trial blend 3 |
|---|---|---|---|
| $G_{sb}$ | 2.698 | 2.696 | 2.711 |
| $G_{se}$ | 2.765 | 2.766 | 2.764 |

Since $G_{sb}$ and $G_{se}$ are given, the trial percentage of asphalt binder can be found using Equations 18.17, 18.18, and 18.19 and the assumed values as indicated in the textbook:

$P_b = 0.05$
$P_s = 0.95$
$G_b = 1.02$
$V_a = 0.04$

*For trial blend 1:*

Use Equation 18.17,

$$V_{ba} = \frac{P_s(1-V_a)}{(\frac{P_b}{G_b}+\frac{P_s}{G_{se}})}[\frac{1}{G_{sb}}-\frac{1}{G_{se}}] = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.765})}[\frac{1}{2.698}-\frac{1}{2.765}] = 0.0209$$

Use Equation 18.18,

$V_{be} = 0.176\text{-}0.0675 \log S_n = 0.176\text{-}0.067 \log (19) = 0.0903$

Use Equation 18.20,

$$W_s = \frac{P_s(1-V_a)}{\frac{P_b}{G_b}+\frac{P_s}{G_{se}}} = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.765})} = 2.323$$

Use Equation 18.19,

$$P_{bi} = 100\frac{G_b(V_{be}+V_{ba})}{(G_b(V_{be}+V_{ba}))+W_s} = 100\frac{1.02(0.090+0.021)}{1.02(0.090+0.021)+2.323} = 0.0466$$

*For trial blend 2:*

Use Equation 18.17,

$$V_{ba} = \frac{P_s(1-V_a)}{(\frac{P_b}{G_b}+\frac{P_s}{G_{se}})}[\frac{1}{G_{sb}}-\frac{1}{G_{se}}] = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.766})}[\frac{1}{2.696}-\frac{1}{2.766}] = 0.0218$$

Use Equation 18.18,

$V_{be}$ = 0.176-0.0675 log $S_n$ = 0.176-0.067 log (19) = 0.0903

Use Equation 18.20,

$$W_s = \frac{P_s(1-V_a)}{\frac{P_b}{G_b}+\frac{P_s}{G_{se}}} = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.766})} = 2.324$$

Use Equation 18.19,

$$P_{bi} = 100\frac{G_b(V_{be}+V_{ba})}{(G_b(V_{be}+V_{ba}))+W_s} = 100\frac{1.02(0.090+0.022)}{1.02(0.090+0.022)+2.324} = 0.0469$$

*For trial blend 3:*

Use Equation 18.17,

$$V_{ba} = \frac{P_s(1-V_a)}{(\frac{P_b}{G_b}+\frac{P_s}{G_{se}})}[\frac{1}{G_{sb}}-\frac{1}{G_{se}}] = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.764})}[\frac{1}{2.711}-\frac{1}{2.764}] = 0.0164$$

Use Equation 18.18,

$V_{be}$ = 0.176-0.0675 log $S_n$ = 0.176-0.067 log (19) = 0.0903

Use Equation 18.20,

$$W_s = \frac{P_s(1-V_a)}{\frac{P_b}{G_b}+\frac{P_s}{G_{se}}} = \frac{0.95(1-0.04)}{(\frac{0.05}{1.02}+\frac{0.95}{2.764})} = 2.322$$

Use Equation 18.19,

$$P_{bi} = 100\frac{G_b(V_{be}+V_{ba})}{(G_b(V_{be}+V_{ba}))+W_s} = 100\frac{1.02(0.090+0.016)}{1.02(0.090+0.016)+2.322} = 0.0634$$

*b) Evaluating Trial Mix Design*

To know if the percentage of asphalt that we got is suitable after the compaction

* By Using Superpave Gyratory Compactor (SGC)

1. Number of gyrations ($N_{design}$) to compute level of compaction.
   The $N_{design}$ depends on the average design high air temperature and the design ESAL.
2. Maximum number of gyrations, $N_{max}$, is used to compact the test specimens.
3. Initial number of gyrations, $N_{ini}$, is used to estimate the compactibility of the mixture.

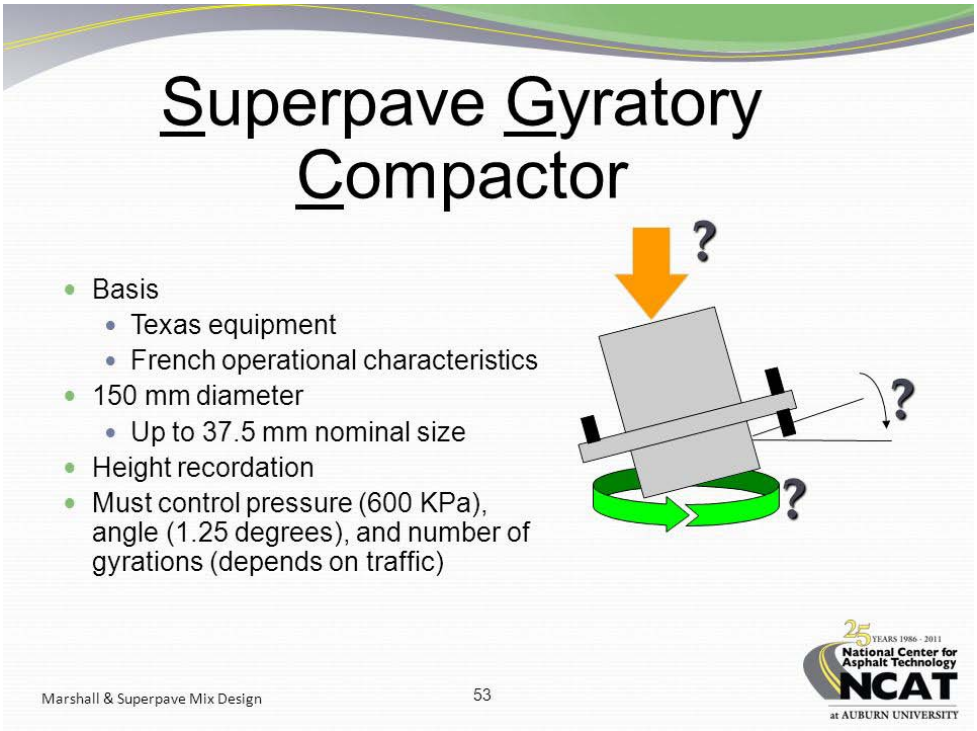
$$\text{Log } N_{max} = 1.10 \text{Log } N_{des}$$

$$\text{Log } N_{ini} = 0.45 \text{Log } N_{des}$$

**Ndesign**
**To know compaction level**

**Nmax**
**To compact the specimen**

**Ninitial**
**To know specimen's bearing capacity**



Ex : When Design ESALs = 10 – 30 (millions) and the Average design high air temperature = 41 to 42 C given $N_{design}$= 124

Find $N_{max}$&Compactibility ?

Log $N_{max}$ = 1.1 Log $N_{design}$ or $N_{max}$ = ( $N_{design}$) ^ 1.1

$N_{max}$ = ( 128 ) ^ 1.1 = 208

$N_{initial}$ = ( $N_{design}$ ) ^ 0.45

$N_{initial}$ = ( 128 ) ^ 0.45 = 9

## - Volumetric Calculation at the $N_{design}$gyration

Know the characteristics of the sampleafter compaction.

1- percent air voids at $N_{design}$ (Pa or Va)

$$P_a = 100\left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) = 100 - \%Gmm\ @\ N_{design}$$

Pa :air voids at Ndes percent of total volume
Gmm: maximum theoretical specific gravity at Ndes
Gmb : bulk specific gravity of the compacted mixture

2- voids in mineral aggregate (VMA)

**Gmb=%Gmm @ Ndes *Gmm**

$$VMA = 100 - \left(\frac{G_{mb}P_s}{G_{sb}}\right)$$

VMA : voids in mineral aggregate, percent in bulk volume
Gmb: bulk specific gravity of the compacted mixture
Ps : aggregate content cm3/cm3, by total mass of mixture
Gsb: bulk specific gravity of aggregates in the paving mixture

3- Void filled Asphalt (VFA)

$$VFA = 100\left(\frac{VMA - P_a}{VMA}\right)$$

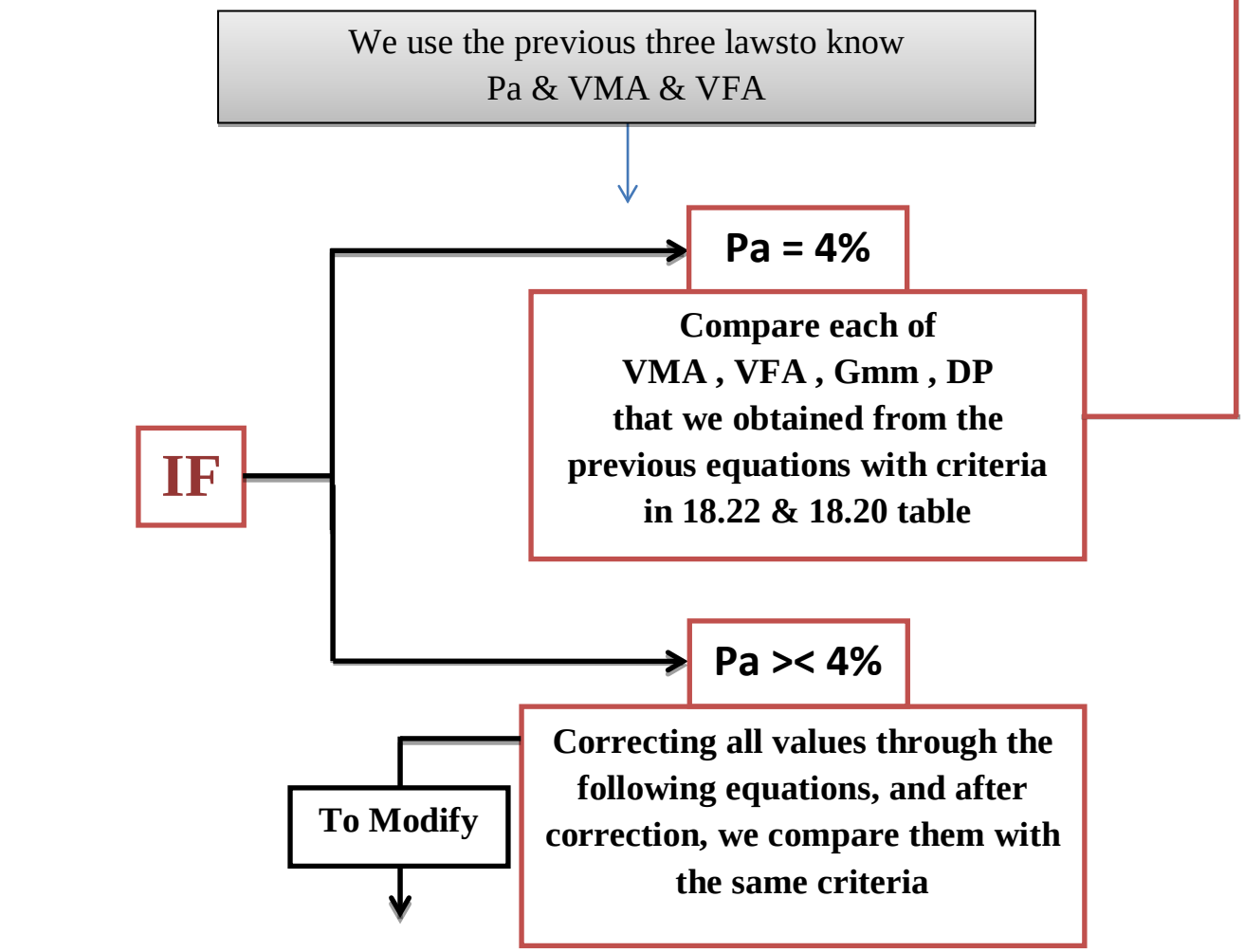
VMA equation in the past paper

4- %Gmm = ( Gmb / Gmm ) * 100%

5-$P_{ba} = 100 * \frac{G_{se} - G_{sb}}{G_{se}\ G_{sb}} * G_b$

6- $P_{be} = P_b - \frac{P_{ba}}{100} * P_s$

7- Dust % = P0.75 / Pbe



## ***Correction Equation***

1) $P_b$,estimated= $P_{bi}$ - 0.4 (4 – Pa )

Pb,estimated: estimated asphalt content.
Pbi: initial (trial) asphalt content, percent by mass of mixture.
Pa : percent air voids at Ndes (trial)≠**4%**

2) VMAestimated = VMAinitial + C (4 – Pa )

C = 0.1 if Pa < 4%
C = 0.2 if Pa > 4%

3)

$$VFA_{\text{estimated}} = 100\,\frac{VMA_{\text{estimated}} - 4.0}{VMA_{\text{estimated}}}$$

4) The effective binder content after correction ($P_{be}$)

$$P_{ba} = 100 * \frac{G_{se} - G_{sb}}{G_{se}\,G_{sb}} * G_b$$

$$P_{be} = P_{b,estimated} - \frac{P_{ba}}{100} * P_s$$

5) Dust Percetage

$$DP = \frac{P_{0.75}}{P_{\text{be}}}$$

**Percent of aggregate content passing the 0.075-mm sieve**

6) Gmm,estimatedat Nmax= Gmm,trialat Nmax– (4 – Pa)

7) Gmm,estimatedat Nini = Gmm,trialat Nini – (4 – Pa)

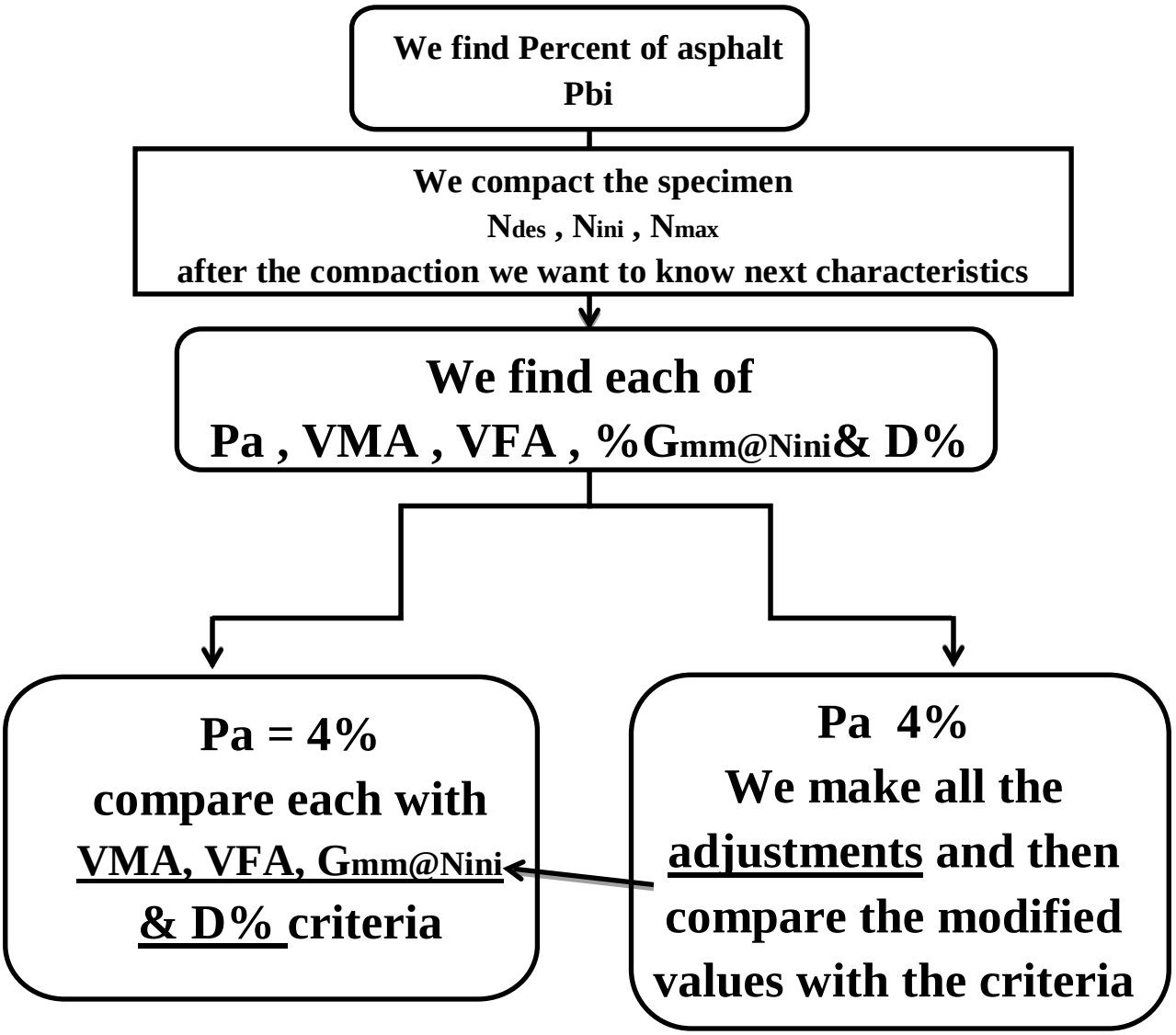


*Table 18.20:* Voids in Mineral Aggregate Criteria

| *Nominal Maximum Size (mm)* | *Minimum Voids in Mineral Aggregate (%)* |
|---|---|
| 9.5 | 15.0 |
| 12.5 | 14.0 |
| 19.0 | 13.0 |
| 25.0 | 12.0 |
| 37.5 | 11.0 |
| 50.0 | 10.5 |

*Table 18.22:* VFA Criteria

| *Traffic, Million ESALs* | *Design VFA, Percent* |
|---|---|
| < 0.3 | 70–80 |
| < 1 | 65–78 |
| < 3 | 65–78 |
| < 10 | 65–75 |
| < 30 | 65–75 |
| < 100 | 65–75 |

$$0.6\% < \text{Dust}\% < 1.2\%$$

$$\text{Gmm at } N_{initial} \leq 89\%$$

$$\text{Gmm at } N_{Max} \leq 98\%$$

## Ex:

Find which blend satisfy to criteria for volumetric properties in trial mix, use result in this table to choose.

| blend | 1 | 2 | 3 |
|---|---|---|---|
| Trial binder | 4.4% | 4.4% | 4.4% |
| % $G_{mm}$ at $N_{des}$ | 96.2% | 95.7% | 95.2% |
| % $G_{mm}$ at $N_{ini}$ | 87.1% | 85.6% | 86.3% |
| % Pa | 3.8% | 4.3% | 4.8% |
| %VMA | 12.7% | 13% | 13.5% |
| %VFA | 68.5% | 69.2% | 70.1% |
| %Dust | 0.9% | 0.8% | 0.9% |

First, we look at the percentage of air voids **Pa**for each mixture. We note that each mixture needs to adjustthe values to obtain percentage of air void 4%, after that we compare the specifications for each ratio.

Blend 1:

1- $P_{b,estimated} = P_{bi} - 0.4(4 - P_a) = 4.4 - 0.4(4 - 3.8) = 4.32\%$

Old Pa% not modified

2- $VMA_{estimated} = VMA_{ini} + C(4 - P_a) = 12.7 + 0.1(4 - 3.8) = 12.72\%$

C = 0.1 because $P_a < 4\%$

3- $VFA_{estimated} = 100 * \frac{VMA_{estimated} - 4}{VMA_{estimated}} = \frac{12.72 - 4}{12.72} = 68.55\%$

4- $G_{mm,estimated}$ at $N_{ini} = G_{mm} - (4 - P_a) = 87.1 - (4 - 3.8) = 86.9$

Blend 2:

1- $P_{b,estimated} = P_{bi} - 0.4(4 - P_a) = 4.4 - 0.4(4 - 4.8) = 4.72\%$

2- $VMA_{estimated} = VMA_{ini} + C(4 - P_a) = 13.5 + 0.2(4 - 4.8) = 13.34\%$

C = 0.2 because $P_a > 4\%$

3- $VFA_{estimated} = 100 * \frac{VMA_{estimated} - 4}{VMA_{estimated}} = \frac{13.34 - 4}{13.34} = 70\%$

4- $G_{mm,estimated}$ at $N_{ini} = G_{mm} - (4 - P_a) = 86.4 - (4 - 4.8) = 87.2$

Blend 3:

1- $P_{b,estimated} = P_{bi} - 0.4(4 - P_a) = 4.4 - 0.4(4 - 4.3) = 4.52\%$

2- $VMA_{estimated} = VMA_{ini} + C(4 - P_a) = 13 + 0.2(4 - 4.3) = 12.94\%$

3- $VFA_{estimated} = 100 * \frac{VMA_{estimated} - 4}{VMA_{estimated}} = \frac{12.94 - 4}{12.94} = 69.1\%$

4- $G_{mm,estimated}$ at $N_{ini} = G_{mm} - (4 - P_a) = 85.6 - (4 - 4.3) = 85.9$

| Criteria to compare>>> Given | | | | |
|---|---|---|---|---|
| $G_{mm}$ at $N_{ini}$ < 89% | $P_a$ = 4% | VMA ≥ 13% | 65% <VFA <75% | 0.6%<Dust<1.2% |

1- All Blend $P_a$ = 4%

2-

Blend 1 VMA = 12.72% < 13% ×

Blend 2 VMA = 12.94% < 13% ×

Blend 3 VMA = 13.34% > 13% ✓

3- All Blend VFA between 65–75%

4- All Blend $G_{mm}$ less than 89%

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# Analytical Study & Design of Flexible Pavement

By Mousa Ayesh Hussein Al-Asakereh

*Abstract-* Flexible pavement usually constructed of bituminous materials such that they remain in contact with the underlying material even when minor Distortions occur. Flexible pavement usually consists of a bituminous surface underlaid with a layer of granular material and a layer of a suitable mixture of coarse and fine materials.

Flexible pavement is the pavement that remains adjacent to the surface soil road, even if the surface is rutting.

Provides sufficient thickness for load distribution through a multilayer structure so that the stresses and strains in the Subgrade soil layers are within required limits.

The strength of subgrade soil would have a direct bearing on the total thickness of the flexible pavement.

*Keywords:* *flexible design, pavement, asphalt design.*

*GJRE-E Classification:* *DDC Code: 738.52095694 LCC Code: NA3760*


*Strictly as per the compliance and regulations of:*

# Analytical Study & Design of Flexible Pavement

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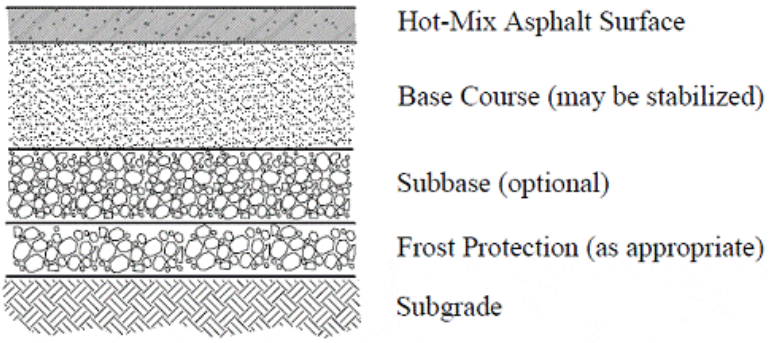
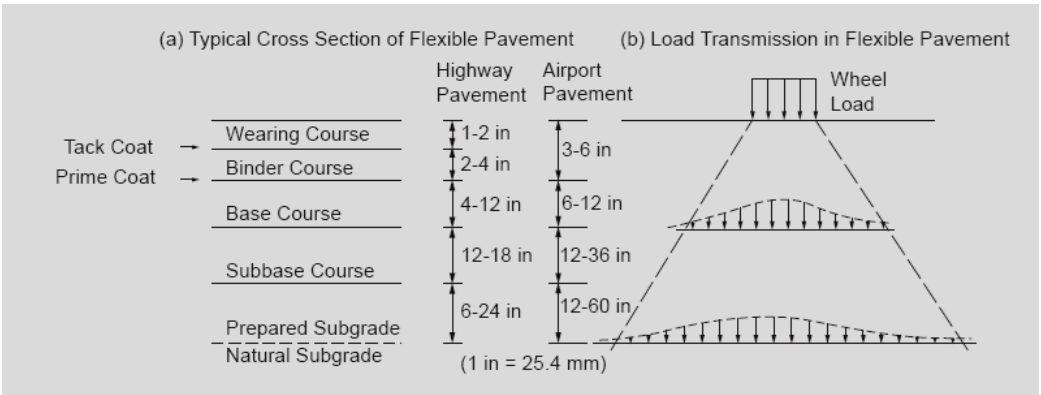
The strength of subgrade soil would have a direct bearing on the total thickness of the flexible pavement.
*Keywords: flexible design, pavement, asphalt design.*

*Enter:*

*Structural Components of a Flexible Pavement*




1. *Subgrade (Road Bed)*

The subgrade is usually the natural material located along the horizontal alignment of the road and serves as the foundation of the pavement structure.

2. *Subbase Course*

Located immediately above the subgrade, the subbase component consists of material of a superior quality to that which is generally used for subgrade construction.

3. *Base Course*

Located immediately above the subbase, if a subbase course is not used. This course usually consists of granular materials such as crushed stone, crushed or uncrushed slag, crushed or uncrushed gravel, and sand.

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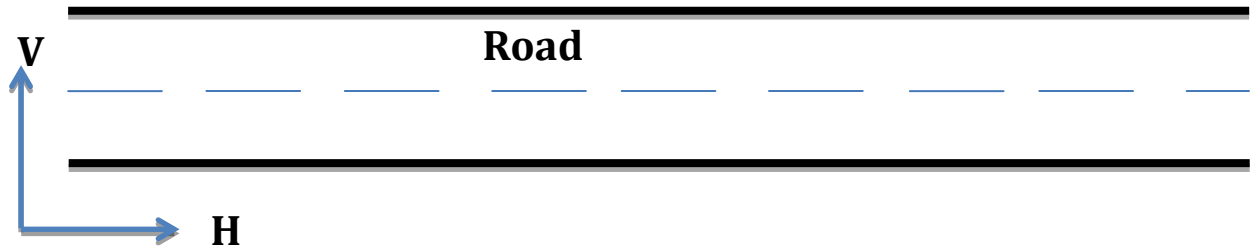
4. *Surface Course*

Constructed immediately above the base course, usually consists a mixture of aggregates and asphalt. It should be capable of withstanding high tire pressures, resisting abrasive forces due to traffic, providing a skid-resistant driving surface, and preventing the penetration of surface water into the underlying layers.

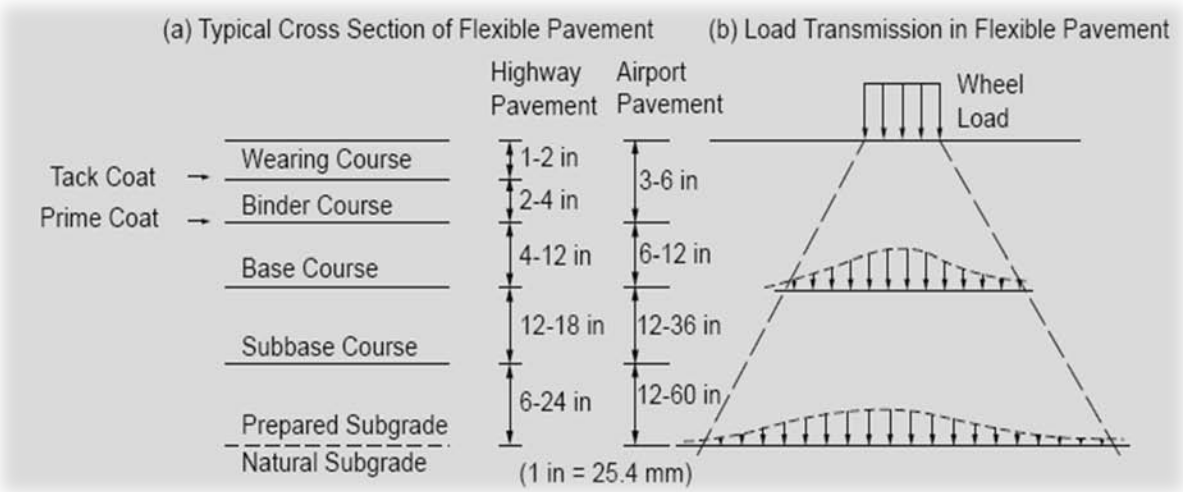
## I. General Principles of Flexible Pavement Design

Assumed initially that the subgrade layer is infinite in both the horizontal and vertical directions, whereas the other layers are finite in the vertical direction and infinite in the horizontal direction.




In the design of flexible pavements, the pavement structure usually is considered as a multilayered elastic system, with the material that may include the modulus of elasticity (E), the resilient modulus (R), and the Poisson ratio ( $\nu$ ).

Applying of a wheel load causes a stress distribution; the maximum vertical stresses are compressive and occur directly under the wheel load. These decrease with an increase in depth from the surface.




## II. AASHTO Design Method Considerations

*a) Pavement Performance*

- Structural performance is related to the physical condition of the pavement with respect to factors that hurt the capability of the pavement to carry the traffic load.
- These factors include cracking, faulting, unraveling, and so forth.

Functional performance is an indication of how effectively the pavement serves the user.

- The main factor considered under functional performance is riding comfort.
- *To quantify pavement functional performance,* a concept known as the serviceability performance was developed.

And Under this concept, a procedure was developed to determine the present serviceability index (PSI) of the pavement, based on its roughness and distress, which were measured in terms of the extent of cracking, patching, and rut depth for flexible pavements.

- *Two serviceability indices are used in the design procedure:*

1. *The initial serviceability index (pi)* is the serviceability index immediately after the Construction of the pavement.
2. *The terminal serviceability index (pt)* is the minimum acceptable value before reconstruction is necessary.

*b) Traffic Load*

In the AASHTO design method, the traffic load is determined in Terms of the number of repetitions of an 18,000-lb (80 KN) the Single-axle load applied to the pavement.

This is usually referred to as: *The Equivalent Single-Axle Load (ESAL).*

➢ A general equation for the accumulated ESAL for each category of axle load is

$$ESAL = AADT \times N \times F_{Ei} \times G_{rn} \times 365 \times f_d$$

Where:

ESAL = Equivalent Accumulated 18,000-lb (80 KN) single-axle load.

AADT = First year annual average daily traffic.

N = Number of axles on each vehicle.

$F_{Ei}$ = load equivalency factor for Single and Tandem axle.

$G_{rn}$ = Growth factor for a given growth rate r and design period n.

365 = Convert from day to year.

$f_d$ = Design lane factor.

| Name | Equation |
|---|---|
| ESAL Design lane | AADT × N × $F_{Ei}$ × $G_{rn}$ × 365 × $f_d$ |
| Total ESAL | AADT × N × $F_{Ei}$ × $G_{rn}$ × 365 |
| First Year ESAL Design lane | AADT × N × $F_{Ei}$ × 365 × $f_d$ |
| Total ESAL First Year | AADT × N × $F_{Ei}$ × 365 |
| Daily ESAL Design Lane | AADT × N × $F_{Ei}$ × $f_d$ |
| Total Daily ESAL | AADT × N × $F_{Ei}$ |

*Table 19.4:* Growth Factors

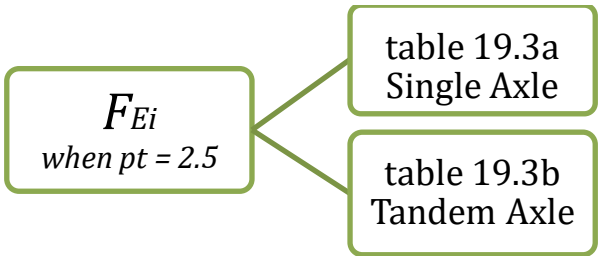
| Design Period, Years (n) | Annual Growth Rate, Percent (r) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No Growth | 2 | 4 | 5 | 6 | 7 | 8 | 10 |
| 1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2 | 2.0 | 2.02 | 2.04 | 2.05 | 2.06 | 2.07 | 2.08 | 2.10 |
| 3 | 3.0 | 3.06 | 3.12 | 3.15 | 3.18 | 3.21 | 3.25 | 3.31 |
| 4 | 4.0 | 4.12 | 4.25 | 4.31 | 4.37 | 4.44 | 4.51 | 4.64 |
| 5 | 5.0 | 5.20 | 5.42 | 5.53 | 5.64 | 5.75 | 5.87 | 6.11 |
| 6 | 6.0 | 6.31 | 6.63 | 6.80 | 6.98 | 7.15 | 7.34 | 7.72 |
| 7 | 7.0 | 7.43 | 7.90 | 8.14 | 8.39 | 8.65 | 8.92 | 9.49 |
| 8 | 8.0 | 8.58 | 9.21 | 9.55 | 9.90 | 10.26 | 10.64 | 11.44 |
| 9 | 9.0 | 9.75 | 10.58 | 11.03 | 11.49 | 11.98 | 12.49 | 13.58 |
| 10 | 10.0 | 10.95 | 12.01 | 12.58 | 13.18 | 13.82 | 14.49 | 15.94 |
| 11 | 11.0 | 12.17 | 13.49 | 14.21 | 14.97 | 15.78 | 16.65 | 18.53 |
| 12 | 12.0 | 13.41 | 15.03 | 15.92 | 16.87 | 17.89 | 18.98 | 21.38 |
| 13 | 13.0 | 14.68 | 16.63 | 17.71 | 18.88 | 20.14 | 21.50 | 24.52 |
| 14 | 14.0 | 15.97 | 18.29 | 19.16 | 21.01 | 22.55 | 24.21 | 27.97 |
| 15 | 15.0 | 17.29 | 20.02 | 21.58 | 23.28 | 25.13 | 27.15 | 31.77 |
| 16 | 16.0 | 18.64 | 21.82 | 23.66 | 25.67 | 27.89 | 30.32 | 35.95 |
| 17 | 17.0 | 20.01 | 23.70 | 25.84 | 28.21 | 30.84 | 33.75 | 40.55 |
| 18 | 18.0 | 21.41 | 25.65 | 28.13 | 30.91 | 34.00 | 37.45 | 45.60 |
| 19 | 19.0 | 22.84 | 27.67 | 30.54 | 33.76 | 37.38 | 41.45 | 51.16 |
| 20 | 20.0 | 24.30 | 29.78 | 33.06 | 36.79 | 41.00 | 45.76 | 57.28 |
| 25 | 25.0 | 32.03 | 41.65 | 47.73 | 54.86 | 63.25 | 73.11 | 98.35 |
| 30 | 30.0 | 40.57 | 56.08 | 66.44 | 79.06 | 94.46 | 113.28 | 164.49 |
| 35 | 35.0 | 49.99 | 73.65 | 90.32 | 111.43 | 138.24 | 172.32 | 271.02 |

EX: If the value of design period years n =9, and annual growth rate r = 5%, Find $G_{rn}$ ?

* From above table → $G_{rn}$ = **11.03**

* From Equation → $G_{rn} = \frac{(1+r)^{n}-1}{r} = \frac{(1+0.05)^{9}-1}{0.05} = 11.03$

**-$F_{Ei}$ From table 19.3a & 19.3b**



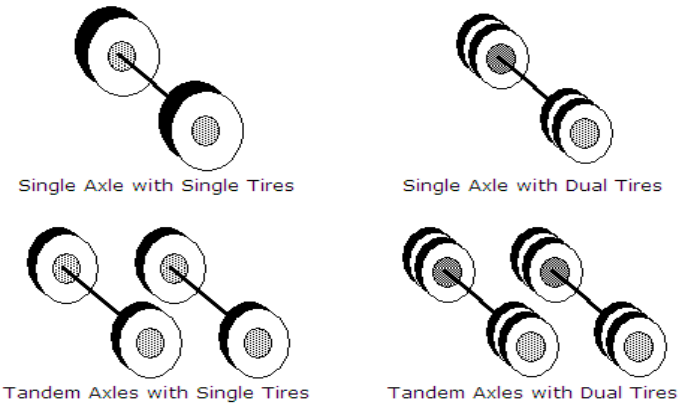




*Table 19.3a:* Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and $p_t$ of 2.5

| Axle Load (kips) | Pavement Structural Number (SN) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | .0004 | .0004 | .0003 | .0002 | .0002 | .0002 |
| 4 | .003 | .004 | .004 | .003 | .002 | .002 |
| 6 | .011 | .017 | .017 | .013 | .010 | .009 |
| 8 | .032 | .047 | .051 | .041 | .034 | .031 |
| 10 | .078 | .102 | .118 | .102 | .088 | .080 |
| 12 | .168 | .198 | .229 | .213 | .189 | .176 |
| 14 | .328 | .358 | .399 | .388 | .360 | .342 |
| 16 | .591 | .613 | .646 | .645 | .623 | .606 |
| 18 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 20 | 1.61 | 1.57 | 1.49 | 1.47 | 1.51 | 1.55 |
| 22 | 2.48 | 2.38 | 2.17 | 2.09 | 2.18 | 2.30 |
| 24 | 3.69 | 3.49 | 3.09 | 2.89 | 3.03 | 3.27 |
| 26 | 5.33 | 4.99 | 4.31 | 3.91 | 4.09 | 4.48 |
| 28 | 7.49 | 6.98 | 5.90 | 5.21 | 5.39 | 5.98 |
| 30 | 10.3 | 9.5 | 7.9 | 6.8 | 7.0 | 7.8 |
| 32 | 13.9 | 12.8 | 10.5 | 8.8 | 8.9 | 10.0 |
| 34 | 18.4 | 16.9 | 13.7 | 11.3 | 11.2 | 12.5 |
| 36 | 24.0 | 22.0 | 17.7 | 14.4 | 13.9 | 15.5 |
| 38 | 30.9 | 28.3 | 22.6 | 18.1 | 17.2 | 19.0 |
| 40 | 39.3 | 35.9 | 28.5 | 22.5 | 21.1 | 23.0 |
| 42 | 49.3 | 45.0 | 35.6 | 27.8 | 25.6 | 27.7 |
| 44 | 61.3 | 55.9 | 44.0 | 34.0 | 31.0 | 33.1 |
| 46 | 75.5 | 68.8 | 54.0 | 41.4 | 37.2 | 39.3 |
| 48 | 92.2 | 83.9 | 65.7 | 50.1 | 44.5 | 46.5 |
| 50 | 112.0 | 102.0 | 79.0 | 60.0 | 53.0 | 55.0 |

Ex 1 :

Traffic (AADT) in both directions on the Highway during the first year of operation will be 12,000 with the following vehicle mix and axle loads.

**2**-axle **single-unit** trucks (2000 lb/axle) = 50%
**2**-axle **single-unit** trucks (6000 lb/axle) = 33%
**3**-axle **single-unit** trucks (10,000 lb/axle) = 17%
And the traffic growth rate is 4% for all vehicles, design period of 20 years, assume **SN = 5**, and the percent of the traffic on the design lane is 45%; **determine the design & Total ESAL?**

Find $\boldsymbol{F_{Ei}}$ from table 19.3a → **Single unit trucks**

1- 2000 lb/axle = 2 kips/axle → $F_{Ei1} = 0.0002$
6000 lb/axle = 6 kips/axle → $F_{Ei2} = 0.01$
10000 lb/axle = 10 kips/axle → $F_{Ei3} = 0.088$

2- AADT 1 = 50% * 12000 = 6000
AADT 2 = 33% * 12000 = 3960
AADT 3 = 17% * 12000 = 2040

3- n = 20 years
r = 4% → from table 19.4, $G_{rn} = 29.78$

AADT1 N1 $F_{Ei1}$ AADT2 N2 $F_{Ei2}$ AADT3 N3 $F_{Ei3}$

Design ESAL = $[(6000 \times 2 \times 0.0002) + (3960 \times 2 \times 0.01) + (2040 \times 3 \times 0.088)] \times 29.78 \times 365 \times 0.45 = 3033429 = 3.03 \times 10^6$

Total ESAL = $\frac{3033429}{0.45} = 6740953 = 6.74 \times 10^6$

Ex 2:

The present AADT (in both directions) of 6000 vehicles is expected to grow at 5% per annum. Assume SN =4 and the percent of the traffic on the design lane is 55%, the design life is 20 years.

If the vehicle mix is:

(3-axle tandem, 4-single axle) trucks (10000 lb/axle) = 60%

2-axle single-unit trucks (5000 lb/axle) = 30%

(3-axle single-unit, 2-axle tandem) trucks (7000 lb/axle) = 10%

Determine :

a- Daily Design ESAL

b- Total ESAL for the First year

c- Total ESAL

d- Design ESAL for (10000 lb/axle)

e- Daily Total ESAL for (7000 lb/axle)

Solution :

1- 10000 lb/axle = 10 kips/axle → Table 19.3a → $F_{Ei1}$ single = 0.102

$F_{Ei1}$ tandem = 0.009 → Table 19.3b

5000 lb/axle = 5 kips/axle → $F_{Ei2}$ single = $\frac{0.003+0.013}{2}$ = 0.008

7000 lb/axle = 7 kips/axle → $F_{Ei2}$ single = $\frac{0.013+0.041}{2}$ = 0.027

→ $F_{Ei2}$ tandem = $\frac{0.001+0.004}{2}$ = 0.0025

2- AADT1 = 60% × 6000 = 3600

AADT2 = 30% × 6000 = 1800

AADT3 = 10% × 6000 = 600

3- n = 20 years

r = 5% → $G_{rn}$ = 33.06

**a- Daily Design ESAL**

Daily Design ESAL = AADT × N × $F_{Ei}$ × $f_d$

DDESAL = [ 3600(3× 0.009 + 4 × 0.102) + 1800(2 × 0.008)

+ 600(3×0.027+2× 0.0025) ] * 0.45 = 741

**b- Total ESAL for First year**

Total ESAL the First Year = AADT × N × $F_{Ei}$ × 365

= [ 3600(3× 0.009 + 4 × 0.102) + 1800(2 × 0.008)

+ 600(3×0.027+2× 0.0025) ] * 36 = 600936

**c- Total ESAL**

Total ESAL = AADT × N × $F_{Ei}$ × $G_{rn}$ × 365

= [ 3600(3× 0.009 + 4 × 0.102) + 1800(2 × 0.008)

+ 600(3×0.027+2× 0.0025) ] * 365 * 33.06

= 19866944 = 19.9 × $10^6$

## d- Design ESAL for (10000 lb/axle)

10000 lb/axle = 10 kips/axle → $F_{Ei1}$ single = 0.102
→ $F_{Ei1}$ tandem = 0.009

$$DESAL = AADT_{10} \times N \times F_{Ei} \times G_{rn} \times 365 \times f_d$$
$$= 3600(3\times 0.009 + 4 \times 0.102) \times 33.06 \times 365 \times 0.45$$
$$= 8503544 = 8.5\times 10^6$$

## e- Daily Total ESAL for (7000 lb/axle)

$$Total\ ESAL = AADT_7 \times N \times F_{Ei} \times G_{rn} \times 365$$
$$= 600(3\times 0.027 + 2\times 0.0025) \times 33.06 \times 365$$
$$= 622652 = 0.62\times 10^6$$

*c) Roadbed Soils (Subgrade Material)*

AASHTO Code uses the *Resilient Modulus (Mr)* of the soil to define its property and convert the CBR value of the soil to an equivalent Mr value using the following conversion factor Mr (lb/in$^2$) = 1500 CBR (for CBR of 10 or less).

*d) Materials of Construction*

The materials used for the construction of pavement can be classified under three general groups:

i. *Subbase Construction Materials*

The quality of the material used is determined in terms of the layer coefficient (a3), which is used to convert the actual thickness of the subbase to an equivalent Structure Number (SN).

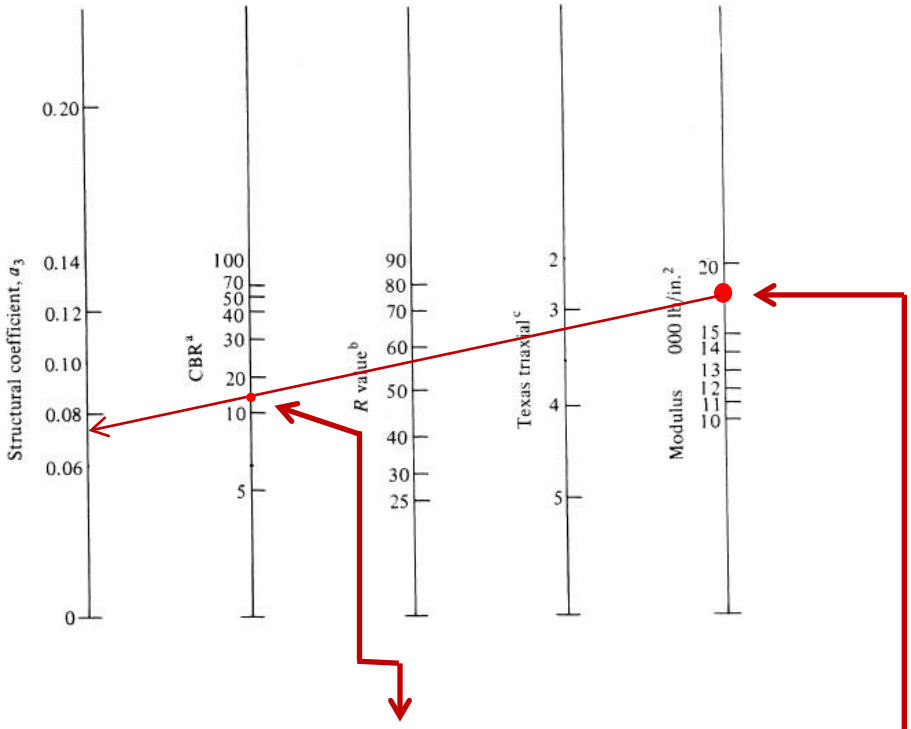


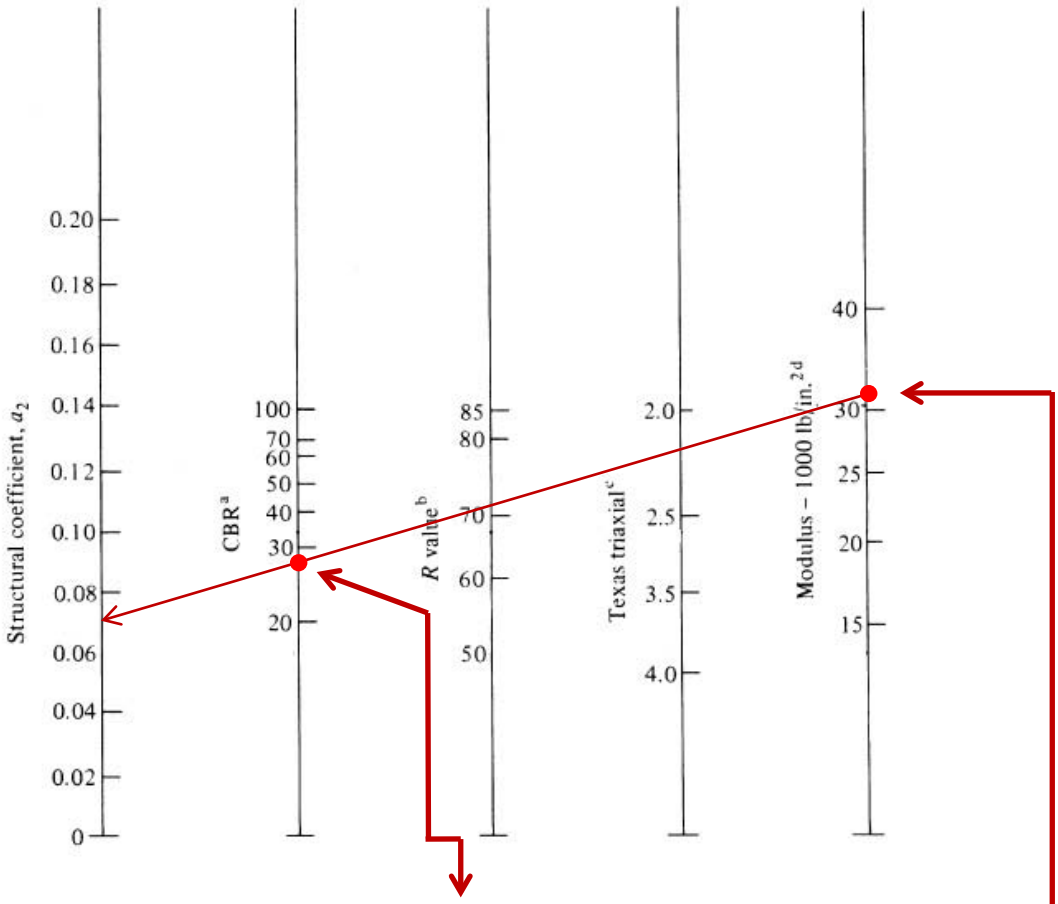

Figure 19.3

EX: CBR value of subbase course material =15
Mr = 17,500 lb/in$^2$
Find Subbase layer Coefficient $a_3$? → $a_3$= 0.077

ii. *Base Course Construction Materials*

Materials selected should satisfy the general requirements for base course materials, A structural layer coefficient, *a*2, for the material used also should be determined.

**Figure 19.4**




EX: CBR value of subbase course material =28

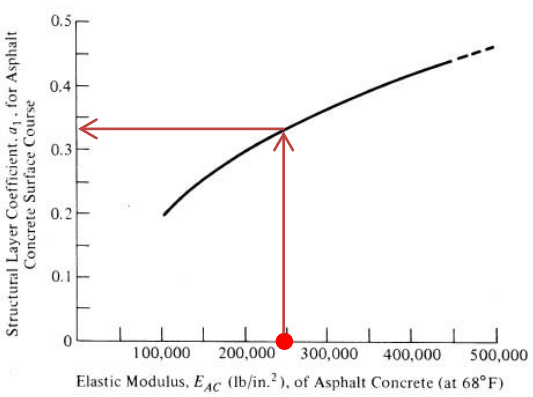
Mr = 31,000 lb/in$^2$

Find Subbase layer Coefficient $a_2$? $\boldsymbol{a_2}$**=0.075**

iii. *Surface Course Construction Materials*

The structural layer coefficient (a1) relates to a dense graded asphalt concrete surface with its resilient modulus at 68°F.

**Figure 19.5**




EX:

Elastic Modulus of Asphalt Concrete $E_{AC}$ = 250,000 lb/in$^2$

Find Asphalt layer Coefficient $a_1$ ?

$\boldsymbol{a_1}$ **= 0.33**

*e) Environment*

Temperature and rainfall are the two main environmental factors used in evaluating pavement performance in the AASHTO method.

The effects of temperature on asphalt pavements include stresses induced by thermal action and the impact of freezing and thawing water in the subgrade.

The effect of temperature, particularly about to the weakening of the underlying material during the thaw period, is considered a significant factor in determining the strength of the underlying materials used in the design. The effect of rainfall is due mainly to the penetration of the surface water into the underlying material, if penetration occurs, the properties of the underlying materials may be altered significantly.

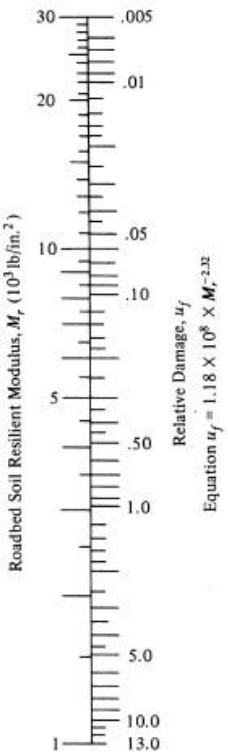
The resilient modulus of materials susceptible to frost action can reduce by 50 percent to 80 percent during the thaw period, and it is likely that the strength of the material will be affected during the periods of heavy rains.

The AASHTO guide suggests a method for determining the effective, resilient modulus. In this method, a relationship is then used to determine the resilient modulus for each season based on the estimated in situ moisture content and Relative damage during the period of time.

*The relative damage* $u_f$ for each period is determined from the following chart, using the vertical scale or the equation given in the chart. *The mean comparable damage* $u_f$ then computed, and the effective subgrade resilient modulus is determined using the Chart and value of $u_f$.

**Figure 19.6**

| Month | Roadbed Soil Modulus $M_r$ (lb/in.$^2$) | Relative Damage $u_f$ |
|---|---|---|
| Jan. | 22000 | 0.01 |
| Feb. | 22000 | 0.01 |
| Mar. | 5500 | 0.25 |
| Apr. | 5000 | 0.30 |
| May | 5000 | 0.30 |
| June | 8000 | 0.11 |
| July | 8000 | 0.11 |
| Aug. | 8000 | 0.11 |
| Sept. | 8500 | 0.09 |
| Oct. | 8500 | 0.09 |
| Nov. | 6000 | 0.20 |
| Dec. | 22000 | 0.01 |
| Summation: $\Sigma u_f$ = | | 1.59 |




Average $\bar{u}_f = \frac{\Sigma u_f}{n} = \frac{1.59}{12} = 0.133$

Effective Roadbed Soil Resilient Modulus, $M_r$ (lb/in.$^2$) = 7250 (corresponds to $\bar{u}_f$)

Ex:

1- Find Roadbed Resilient Modulus $\mathbf{M_r}$ When Relative Damage $u_f$ 7.23?

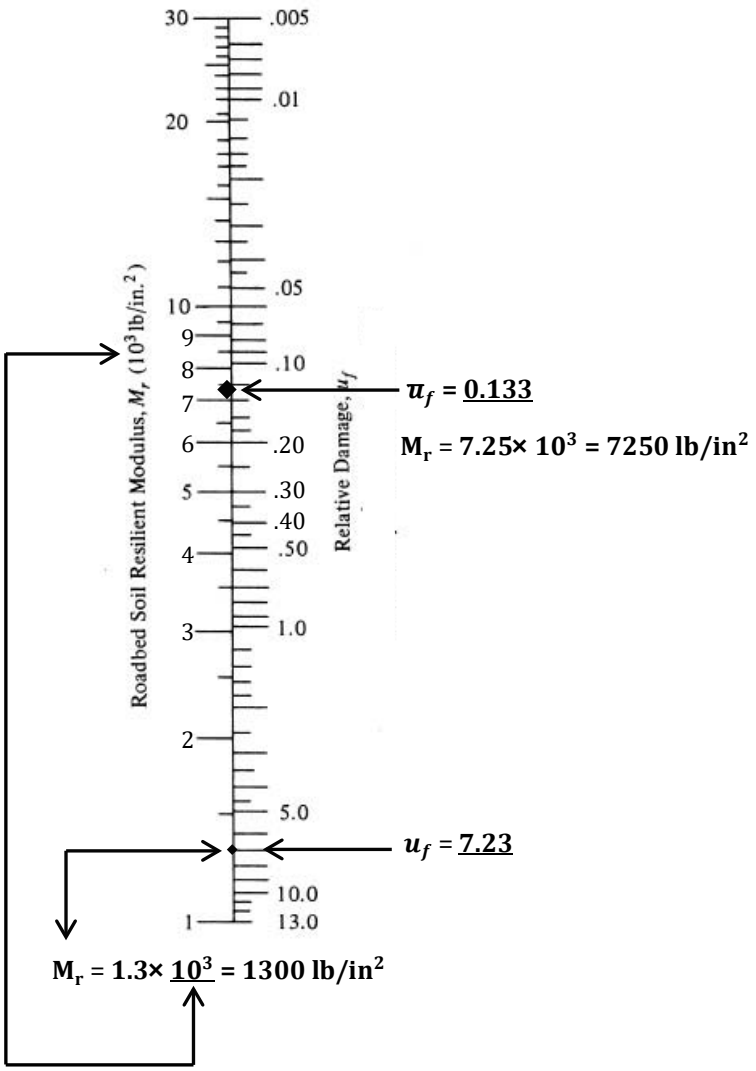
2- Find Roadbed Resilient Modulus $\mathbf{M_r}$ For mean Relative damage $u_f$?

**- Using the Equation:** $u_f = 1.18 \times 10^8 \times M_r^{-2.32}$

1- $0.723 = 1.18 \times 10^8 \times M_r^{-2.32}$ **Solving** → $\mathbf{M_r = 1285\ lb/in^2}$

2- Mean $u_f = \underline{\mathbf{0.133}} = 1.18 \times 10^8 \times M_r^{-2.32}$ → $\mathbf{M_r = 7193\ lb/in^2}$

**-Using vertical scale:**



*f) Drainage. ( $m_i$)*

The effect of drainage on the performance of flexible pavement is considered to the effect water has on the strength of the base material and roadbed soil, and The approach used is to provide for the rapid drainage of the water from the pavement structure by providing a suitable drainage layer and by modifying the structural layer coefficient.

The modification is carried out by adding a factor $\boldsymbol{m_i}$ for the base and subbase layer coefficients ($\boldsymbol{a_2}$ and $\boldsymbol{a_3}$). The $\boldsymbol{m_i}$ factors are based both on the percentage of time during which the pavement structure will be nearly saturated, and on the quality of drainage, which is dependent on the time it takes to drain the base layer to 50 percent of saturation.

Ex1:

A flexible pavement takes **one day** for water to be drained from within it and the pavement structure will be exposed to moisture levels approaching saturation for 7% of the time. Find the pavement drainage coefficient?

*Table 19.5:* Definition of Drainage Quality

| *Quality of Drainage* | *Water Removed Within** |
|---|---|
| Excellent | 2 hours |
| Good | 1 day |
| Fair | 1 week |
| Poor | 1 month |
| Very poor | (water will not drain) |

**Time required to drain the base layer to 7% saturation.**

*Table 19.6:* Recommended $m_i$ Values

| *Quality of Drainage* | *Percent of Time Pavement Structure Is Exposed to Moisture Levels Approaching Saturation* | | | |
|---|---|---|---|---|
| | *Less Than 1%* | *1 to 5%* | *5 to 25%* | *Greater Than 25%* |
| Excellent | 1.40–1.35 | 1.35–1.30 | 1.30–1.20 | 1.20 |
| Good | 1.35–1.25 | 1.25–1.15 | 1.15–1.00 | 1.00 |
| Fair | 1.25–1.15 | 1.15–1.05 | 1.00–0.80 | 0.80 |
| Poor | 1.15–1.05 | 1.05–0.80 | 0.80–0.60 | 0.60 |
| Very poor | 1.05–0.95 | 0.95–0.75 | 0.75–0.40 | 0.40 |

**Pavement drainage coefficient m = (1.15 – 1)**

*g) Reliability. R%*

The cumulative ESAL is an essential input to any pavement design method. However, the determination of this input is usually based on assumed growth rates which may not be accurate.

AASHTO guide proposes the use of a reliability factor that considers the possible uncertainties in traffic prediction and pavement performance prediction.

For example, a 50% reliability design level implies 50% chance for successful pavement performance.

Table 19.7 shows suggested reliability levels based on the AASHTO guide.

*Table 19.7:* Suggested Levels of Reliability for Various Functional Classifications

| *Recommended Level of Reliability* | | |
|---|---|---|
| *Functional Classification* | *Urban* | *Rural* |
| Interstate and other freeways | 85–99.9 | 80–99.9 |
| Other principal arterials | 80–99 | 75–95 |
| Collectors | 80–95 | 75–95 |
| Local | 50–80 | 50–80 |

## III. Flexible Pavement Structural Design

$$\mathbf{SN = a_1 \times D_1 + a_2 \times D_2 \times m_2 + a_3 \times D_3 \times m_3}$$

$m_{2,3}$= drainage coefficient for the base, subbase layer
$a_{1,2,3}$= layer coefficient of surface, base, and subbase Course
$D_{1,2,3}$= actual thickness **in inches** of the surface, base, and subbase courses

***1- By Equation***

$$log_{10}(W_{18}) = Z_R S_o + 9.36\, log_{10}(SN+1) - 0.2 + \frac{log_{10}\left(\frac{\Delta PSI}{2.7}\right)}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 log_{10}(M_R) - 8.07$$

Where:

$W18$ = predicted number of 18,000-lb (80 KN) single-axle load applications
$\Delta PSI = p_i - p_t$
SN = structural number indicative of the total pavement thickness
$Z_R$ = standard normal deviation for a given reliability
$S_o$ = overall standard deviation

| | *Standard Deviation, $S_o$* |
|---|---|
| Flexible pavements | 0.40–0.50 |
| Rigid pavements | 0.30–0.40 |

*Table 19.8:* Standard Normal Deviation ($Z_R$) Values Corresponding to Selected Levels of Reliability

**R% given** → 1

| *Reliability (R%)* | *Standard Normal Deviation, $Z_R$* |
|---|---|
| 50 | −0.000 |
| 60 | −0.253 |
| 70 | −0.524 |
| 75 | −0.674 |
| 80 | −0.841 |
| 85 | −1.037 |
| 90 | −1.282 |
| 91 | −1.340 |
| 92 | −1.405 |
| 93 | −1.476 |
| 94 | −1.555 |
| 95 | −1.645 |
| 96 | −1.751 |
| 97 | −1.881 |
| 98 | −2.054 |
| 99 | −2.327 |
| 99.9 | −3.090 |
| 99.99 | −3.750 |

2

***2- By Figure 19.8***

Ex: Designing a Flexible Pavement Using the AASHTO Method

A flexible pavement for an urban interstate highway R =95%, and Standard deviation $S_o$=0.45 is to be designed to carry **a design ESAL of $2\times10^6$**. It is estimated that it takes about **a week** for the water to be drained from within the pavement, and **the pavement structure will be exposed to moisture levels approaching saturation for 30% of the time**. The following additional information is available:
Initial serviceability index $p_i$=4.5
Final serviceability index $p_t$=2.5
Resilient modulus of asphalt concrete at 68°F = 450,000 lb/in$^2$
CBR value of base course material = 100, $M_r$ = 31,000 lb/in$^2$
CBR value of subbase course material = 22, $M_r$ = 13,500 lb/in$^2$
CBR value of subgrade material = 5

$M_r = 1500 * CBR = 1500*5 = 7500$ lb/in$^2$

Solution:

1- Find Drainage Coefficient $m_i$ from table 19.5, 19.6

*Table 19.5:* Definition of Drainage Quality

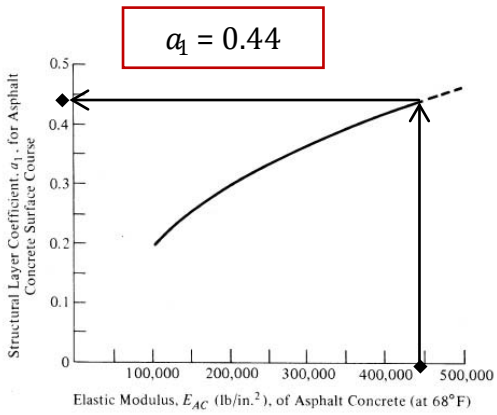
| *Quality of Drainage* | *Water Removed Within** |
|---|---|
| Excellent | 2 hours |
| Good | 1 day |
| Fair | 1 week |
| Poor | 1 month |
| Very poor | (water will not drain) |

*Table 19.6:* Recommended $m_i$ Values

| *Quality of Drainage* | *Percent of Time Pavement Structure Is Exposed to Moisture Levels Approaching Saturation* | | | |
|---|---|---|---|---|
| | *Less Than 1%* | *1 to 5%* | *5 to 25%* | *Greater Than 25%* |
| Excellent | 1.40–1.35 | 1.35–1.30 | 1.30–1.20 | 1.20 |
| Good | 1.35–1.25 | 1.25–1.15 | 1.15–1.00 | 1.00 |
| Fair | 1.25–1.15 | 1.15–1.05 | 1.00–0.80 | 0.80 |
| Poor | 1.15–1.05 | 1.05–0.80 | 0.80–0.60 | 0.60 |
| Very poor | 1.05–0.95 | 0.95–0.75 | 0.75–0.40 | 0.40 |

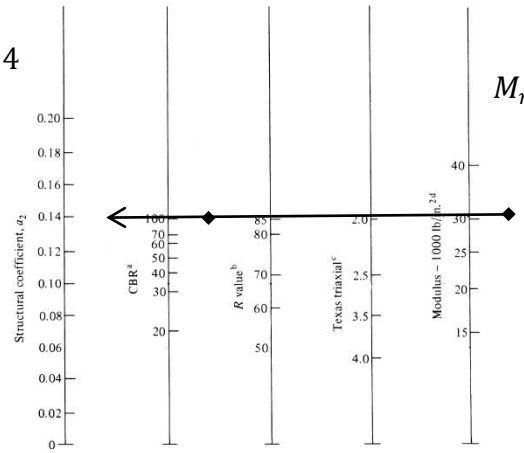
**Drainage Coefficient $m_i$ for base and subbase layer = 0.8**

2- Find Layer Coefficient $a_1$, $a_2$, $a_3$ from figure 19.3, 19.4,19.5




$a_1$ = 0.44

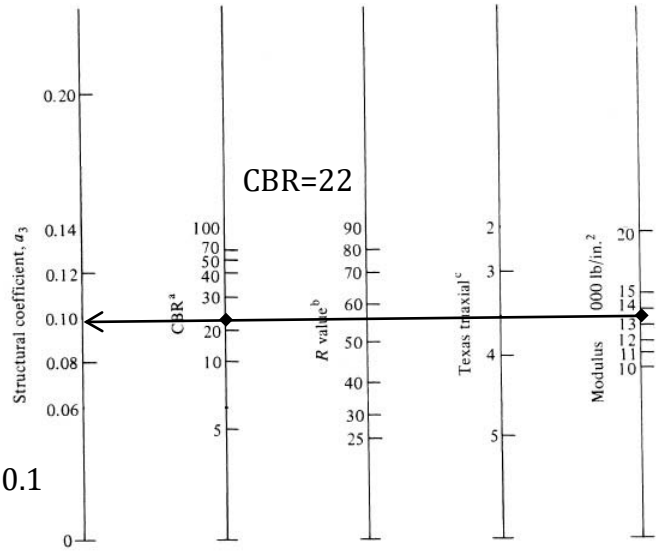
$a_2$= 0.14




$M_r$=31,000 lb/$in^2$

$E_{AC}$= 450,000 lb/$in^2$

CBR=100



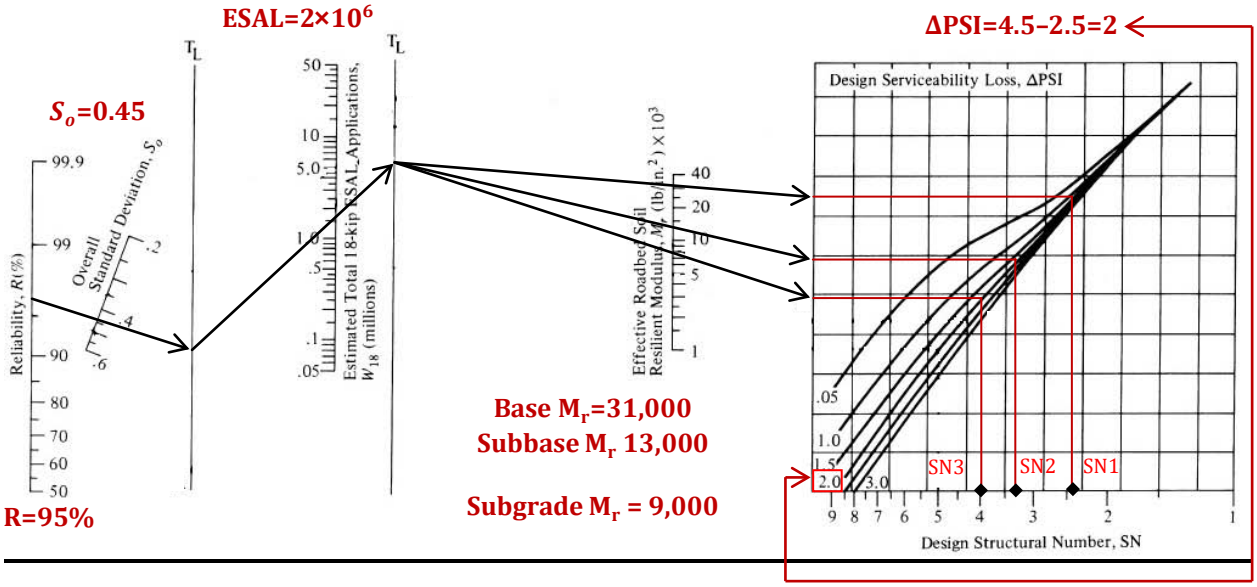

CBR=22

$M_r$=13,500 lb/$in^2$

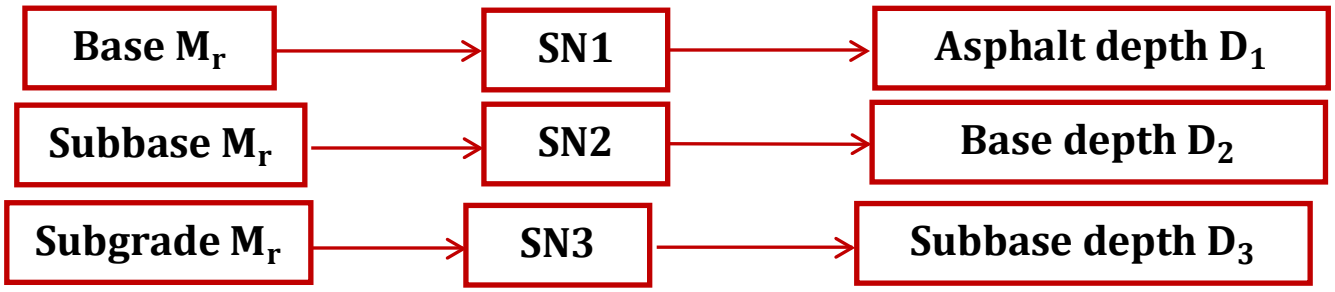
$a_3$= 0.1

**Layer Coefficient: $a_1 = 0.44$ , $a_2 = 0.14$ , $a_3 = 0.1$**

3- Find the Structure Number for each layer from figure 19.8




SN1=2.45 SN2=3.4 SN3=4




**SN1 = $a_1$× $D_1$**
2.45 = 0.44 × $D_1$
$D_1$= 5.57 = 6 in
SN1=0.44×6=2.64

**SN2 = SN1 +$a_2$× $D_2$× $m_2$**
3.4 = 2.64 + 0.14 ×$D_2$ × 0.8
$D_2$= 6.79 = 8 in
SN2 = 2.64 + 0.14 × 8 × 0.8 = 3.54

**SN3 = SN2 + $a_3$× $D_3$× $m_3$**
4 = 3.54 + 0.1 × $D_2$ × 0.8
$D_2$ = 5.75 = 6 in
SN3 = 3.54 + 0.1 × 6 × 0.8 = 4.02

## References Références Referencias

1. Principles of Pavement Design Yoder Ej (ch1,2,3).
2. Highway and Traffic Engineering N. Garber (ch19,20).

# Global Journals Guidelines Handbook 2022

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# Memberships

## Fellows/Associates of Engineering Research Council

### FERC/AERC Memberships

## Introduction

FERC/AERC is the most prestigious membership of Global Journals accredited by Open Association of Research Society, U.S.A (OARS). The credentials of Fellow and Associate designations signify that the researcher has gained the knowledge of the fundamental and high-level concepts, and is a subject matter expert, proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice. The credentials are designated only to the researchers, scientists, and professionals that have been selected by a rigorous process by our Editorial Board and Management Board.

Associates of FERC/AERC are scientists and researchers from around the world are working on projects/researches that have huge potentials. Members support Global Journals' mission to advance technology for humanity and the profession.

## FERC

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FELLOW OF ENGINEERING RESEARCH COUNCIL is the most prestigious membership of Global Journals. It is an award and membership granted to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Fellows are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Fellow Members.

# Benefit

## To the institution

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### Get access to a closed network

A FERC member gets access to a closed network of Tier 1 researchers and scientists with direct communication channel through our website. Fellows can reach out to other members or researchers directly. They should also be open to reaching out by other.

Career | Credibility | Exclusive | Reputation


## Certificate

### Certificate, LoR and Laser-Momento

Fellows receive a printed copy of a certificate signed by our Chief Author that may be used for academic purposes and a personal recommendation letter to the dean of member's university.

Career | Credibility | Exclusive | Reputation


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Career | Credibility | Exclusive | Reputation

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Career | Credibility | Reputation

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Career | Financial

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Career | Credibility | Reputation

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# AERC

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ASSOCIATE OF ENGINEERING RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.

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Career | Credibility | Financial

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Exclusive


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### Earn 30-40% of sales proceeds

Associates can publish articles (limited) without any fees. Also, they can earn up to 30-40% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.

Exclusive | Financial

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Financial

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| Associate | Fellow | Research Group | Basic |
|---|---|---|---|
| $4800<br>**lifetime designation** | $6800<br>**lifetime designation** | $12500.00<br>**organizational** | APC<br>**per article** |
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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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**Acknowledgments**

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

***Manuscript Style Instruction (Optional)***

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

***Structure and Format of Manuscript***

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

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***It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.***

All manuscripts submitted to Global Journals should include:

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The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

**Author details**

The full postal address of any related author(s) must be specified.

**Abstract**

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

**Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

**Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

**Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

**Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

**Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

**Figures**

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

***3. Ask your guides:*** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

***4. Use of computer is recommended:*** As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

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***7. Revise what you wrote:*** When you write anything, always read it, summarize it, and then finalize it.

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

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***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

***14. Arrangement of information:*** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

***16. Multitasking in research is not good:*** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

***18. Go to seminars:*** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

***20. Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

***21. Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

***22. Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

***23. Upon conclusion:*** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.

*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

## Criterion for Grading a Research Paper (Compilation) by Global Journals

**Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.**

| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

# INDEX

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