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Highlights

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Discovering Thoughts, Inventing Future

VOLUME 16 ISSUE 3 VERSION 1.0

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# Analysis and Numerical Modelling of a Piled Foundation Reinforced Geosynthetics to Support for Full-Height Bridge Abutments Constructed through Soft Soil

By Pham Anh Tuan
*University of Science and Technology-The University of Danang*

*Abstract-* Increased traffic volume had made it necessary to rise transport capacities by construction of full-height bridge. Therefore, the scope of this paper is the analysis of full-height embankment behind abutment on geosynthetic reinforced pile supported (GRPS), with a commercially available finite element software. The analyses of fourteen cases of GRPS system supported under embankment and two untreated foundations are presented in this paper. The factors considered include the construction time, pile center to center spacing, supported region and length of piles DM (Deep-Mixing).

*Keywords: numerical analysis; piled bridge abutment; bending moment; settlement; distribution of stresses, strain.*

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ANALYSISANDNUMERICALMODELLINGOFAPILEDFOUNDATIONREINFORCEDGEOSYNTHETICSTOSUPPORTFORFULL-HEIGHTBRIDGEABUTMENTSCONSTRUCTEDTHROUGHSOFTSOIL

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# Analysis and Numerical Modelling of a Piled Foundation Reinforced Geosynthetics to Support for Full-Height Bridge Abutments Constructed through Soft Soil

Pham Anh Tuan

*Abstract-* Increased traffic volume had made it necessary to rise transport capacities by construction of full-height bridge. Therefore, the scope of this paper is the analysis of full-height embankment behind abutment on geosynthetic reinforced pile supported (GRPS), with a commercially available finite element software. The analyses of fourteen cases of GRPS system supported under embankment and two untreated foundations are presented in this paper. The factors considered include the construction time, pile center to center spacing, supported region and length of piles DM (Deep-Mixing). The result presented in this paper include the displacement and bending moment of abutment wall, the vertical and horizontal displacement, the deformation, the maximum and differential settlement, the longitudinal gradient change, and the distribution of stresses consist normal and shear stress in different zones, displacement contour and stress concentration factor for all cases, since they are the most critical parameters of observation and design. The results of this study are intended to provide some guidelines for designers, and to bring insight about the interacting mechanisms into the design process.

*Keywords: numerical analysis; piled bridge abutment; bending moment; settlement; distribution of stresses, strain.*

## I. Introduction

Increased traffic volume and infrastructural development has made it necessary to construct highways, motorways, or expanding roads. However, a lot of works that are built on soft soil with full-height embankment, and one of good examples for this mainly is construction of full-height bridge abutment. The design piled bridge abutments on soft soil is a topic challenging for geotechnical engineers due to the low strength, high compressibility, permeability of the soft clayer. The consolidation of of the soft clay due to the surcharge loads and accompanying of exstrution of soil between the piles, causes lateral pile deflections and bending moments. In some cases, serviceability limit states are exceeded and structural damaged is observed. Fig.1 show typical failures of bridge abutment.

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Besides, previous studies of piled bridge abutments on soft clays include centrifuge tests, analytical and numerical models, and field observation, mostly on the mobilisation of passive lateral loading in the soft clay like as Springman SM (1989), Ellis EA (1994), Tschebotarioff (1973), Stewartet.al(1993), Polous (1973) Oteo (1977), De Bear and Wallays(1972). Although, almost these study mainly focus on considering behaviour of abutment in low and unreinforced embankment cases as Fig.2. But, Kelesoglu and Cinicioglu (2010) calculated soil stiffness degradation using free-field instrumentation data and confirrmed that construction of an embankment prior to the pile installation would significantly reduce the lateral thrust exerted toward the piles.

Different techniques (Fig.3) have been used in practice to avoid, minimize, or remedy distresses to support for construction of full-height bridge abutment on soft soil, such as the use of lightweight backfill materials, geosynthetic reinforcement, over-excavation and replacement, installation of piles or foundation columns, pre-loading, and a combination of the above alternatives. Foundation columns include but are not limited to deep-mixed column, vibro concrete columns, stone columns, and aggregate piers, etc., which are the focus of this study. Forsman and Uotinen (1999) investigated the effect of geosynthetic reinforcement on the settlement and horizontal displacements of embankment. Han and Akins (1999) reported the use of vibro-concrete columns with geogrid layers above to support widening embankment. Geosynthetic reinforcement may not be needed if the spacing of the columns is close and/or the height of embankment is large. Syawal Satibi investigated the effect of supporting embankment by using stone columns.

Even though construction of full-height bridge abutment on soft soil has been commonly adopted in practical, so far, very limited guidance for design is available for bridge abutment projects. The objective of this study is to investigate the effects of installing Geosynthetic Reinforce Pile Support (GRPS) in the soil beneath embankment with using (Deep Mixing- DM) piles. A 2D finite difference method, incorporated in fast

Lagrangian analysis continue (PLAXIS) was adopted in this study through numerical analysis.


*Figure 1 :* Some failure modes of bridge abutment

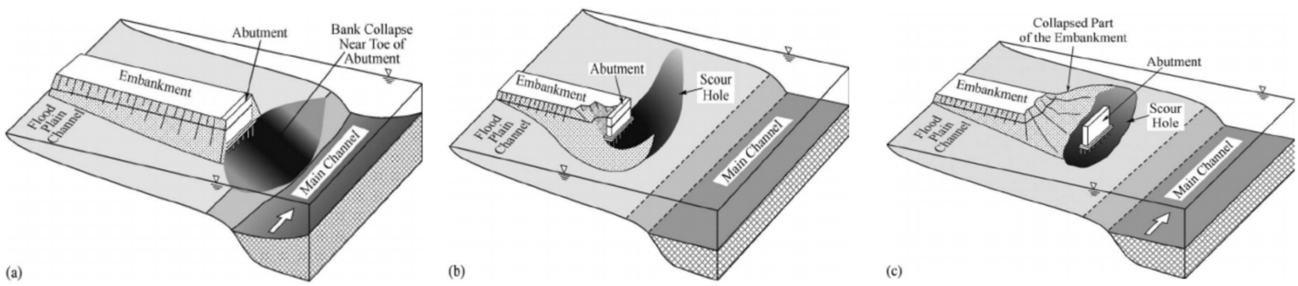


*Figure 2 :* Some Failure Modes of Bridge Abutment

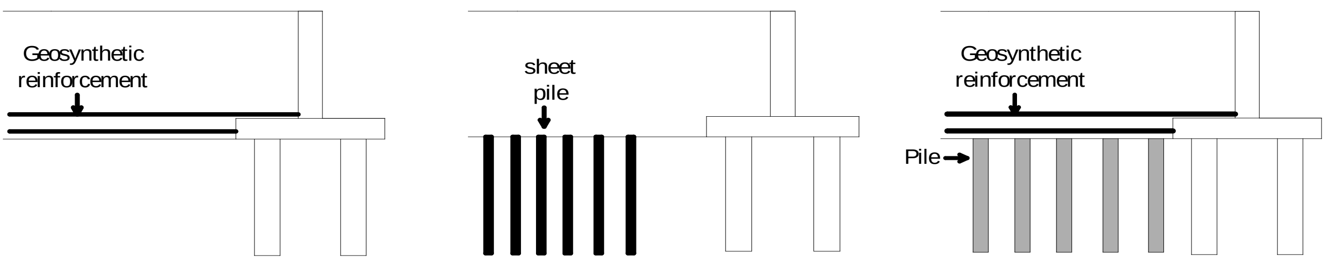


*Figure 3 :* Remedying techniques used in supporting full-height bridge abutment

## II. Project Description

### a) Analytical and Numerical modelling

*Finite element modelling:* A geotechnical software by finite element method, (PLAXIS) was adopted in this study for numerical analysis. The cross-section, boundary conditions, and dimensions for the numerical model used for this parametic study are presented in Figure 4.

The piles were used in solution GRPS is DM piles (Deep Mixing). They were modelled as wall in the plane condition. The properties of the soil, the DM piles, the geosynthetic layers are provided in Table 1. Most there figures were refereed and cited from geological data of Tran Thi Ly Bridge project in Danang city (Join-stock company CPU), and several data of Forsman et.al, Ellis and Springman (2011). To ensure the reasonabless of the numerical model to be used for the parametric study, two 3D cases study was modelled as described below for the calibration of this numerical model.

*Structural elements:* The embedded pile (reinforced concrete piles) model in Plaxis software, in which piles in considered as beam elements, is used to define the structural properties of the pile group (hình 4b). An equipvalent value of soil ground around the pile is assumed to behave elastically and plastically to exclude within that volume so that piles can be considered to be modelled by appróciate volume. The soil-pile interaction is modelled by interface elements both along the pile shaft and at the base. The definition of the interface elements is based on these nodes. Thus, the relative movements are considered in the analyses in the using the lateral displacements between the beam elements nodes and soil nodes.

Sinces the piles are installed using dispalcement technique in the numerical modelling. Skin friction and base resistance of the piles are calculated by the Coyle and Castelo method, which is based on large scale field load test of driven piles in sand. This is a potential source for calibration of numerical results. Account has been taken of this through the choice of stiffness parameters. Skin friction, base resistance and flexural resistance are the parameters required to define embedded pile properties. The moments of inertia for the pile, pile cap and abutment wall are 0.073, 0.0833,

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$0.0213\ m^4$, respectively. Using the young modulus of the structural materials as $61\ GN/m^2$. The flexiable stiffness is calculated as 5.02, 5.61, and 1.38 $GNm^2$ for the pile, pile cap and abutment wall.

*Soil layer:* A linear elastic perfectly plastic Morh-

*Geosynthetic reinforcement:* geotexitle is modelled as a linear elastic perfectly plastic material using the Von-Mises failure criteria.

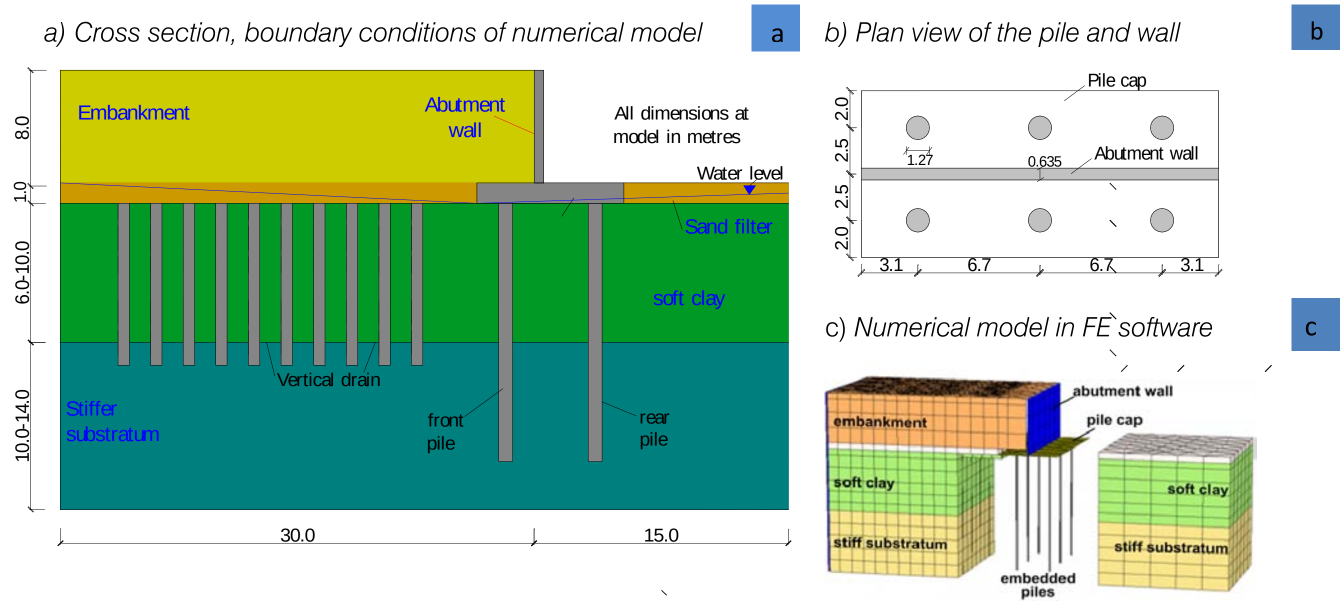



*Figure 4 :* Schematic presentation of geometry and boundary conditions in numerical modelling

*Table 1 :* Properties used for material in the numerical analysis after calibaration

| | γ(kN/m³) | $k_x$, $k_z$, $k_y$ (m/s) | $C_c$ | $C_s$ | $C_\alpha$ | $E_0$(Mpa) | $e_{init}$ | c' (kPa) | ϕ' (°) | ψ (°) | υ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soft Clay | 17.5 | $1.16\times10^{-5}$ | | | 0.006 | 2.85 | 0.82 | 4.3 | 5.26 | 0.0 | 0.4 |
| Substratum | 19.5 | $1.13\times10^{-6}$ | - | - | - | 22.23 | 0.67 | 32.2 | 26.3 | 5.0 | 0.3 |
| Embankment | 18.0 | $2.42\times10^{-5}$ | - | - | - | 32.0 | 0.50 | 25.0 | 26.8 | 5.0 | 0.3 |
| Sand filter | 20.0 | $1.63\times10^{-4}$ | - | - | - | 35.5 | 0.52 | 5.0 | 30.0 | 5.0 | 0.3 |
| DM pile | 22.3 | $9.93\times10^{-10}$ | - | - | - | 400 | - | 80 | 25 | 5.0 | 0.25 |
| Geosynthetic: EA=J.t ; J =1700kN/m; k=85000kN/m/m; $R_{inter}$ = 0.8; t=25mm, tensile strength = 400kN/m | | | | | | | | | | | |

*Note: $E_0$ - Strain modulus; E - Elastic modulus; υ - Poisson's ratio; γ - Unit weight; c' - effective cohesion; φ' - effective friction angle; ψ - dilatancy angle; J - tensile stiffness of geotextile; k - interface shear stiffness between sand and geotextile*

coulomb soil model was chosen for embankment fill, the sand filter, plarform fill as the stiff substratum, as proposed by Yapage et.al, Ellis and Springman. Drained behaviour was assigned for all layer, due to the high permeability of sandy material relative to clay

The soft clay layer were modelled using both Hardening Soil (HS) and the Soft Soil Creep. Ellis provided the parameters such as $C_\alpha$, Cc and ψ for both models as in table 1. A $C_\alpha/C_c$ ratio was defined as between 0.012 and 0.015, where $C_c$, $C_\alpha$ are the primary and secondary indices.

*DM pile modelling:* An extended version of the Morh-Coulumb model is used to simulate the strain softening behavior of cement admixed soil (deep mixing). This material has been incorporated into the finite element code. The constitutive model is calibrated using triaxial compression test data found in the literature for cement admixed clay and sand. The parameters for the strain softening in the analysis are peak friction angle, $\varphi'=25^0$, peak cohesion c'=80kPa, peak dilation ψ =50, Elastic modulus E=400Mpa.

*Vertical drains and Groundwater:* The imposition of radial gravity field during the tests causes a curved groundwater level, which was maintained below the sand filter after initial consolidation, where the structural elements are located. This ground water level was assumed to be constant throughout FE sorftware.

The effects of soft clayer thickness and the rate of embankment construction on the soil-structure interaction, and on the resulting lateral structural loading and displacements.

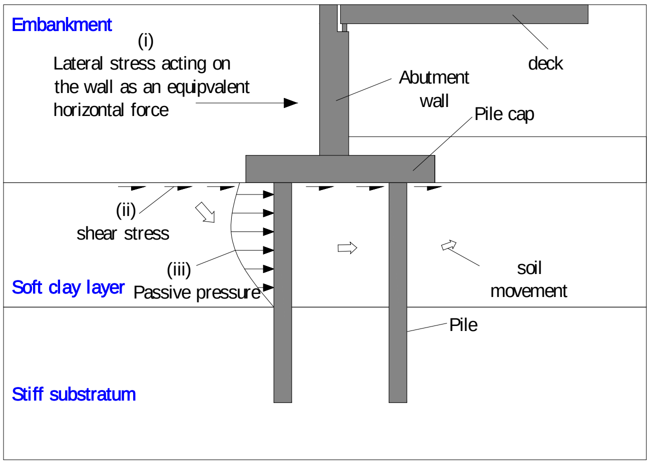



*Figure 5 :* Lateral loads acting on the piled abutment wall

The crucial importance for full-height abutment of (i) the shear stress transfer onto the pile cap at the embankment soft layer interface and (ii) the arching of the embankment loads to the retaining structure were identified and lateral loads that are acting on deforming piled bridge abutment were described (Figure 5).

*b) Study cases for practical project*

The selected project is a full-height embankment behind bridge abutment constructed on deep mixing (DM) piles and reinforced with geosynthetic beside Han River and Tran Thi Ly Bridge in Danang city, Vietnam. The soft foundation below embankment consists 6-10m of soft clay and 10-14m of stiffer substratum. The length of piles is 17m and the diameter of DM piles is 1m. The properties of materials are presented in table 1. The height of embankment behind bridge abutment is 7m and the longitudinal gradient along embankment is 2%. The determined Poisson's ratio under conditions is 0,3-0,4. The embankment has a 50mm thick asphalt layer, 200mm thick crushed stone base course and 1m thick sand working platform above the existing ground. The surchage load of vehicles is 16,7kN/m$^2$.

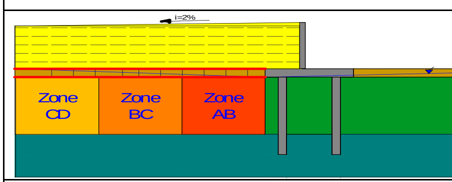
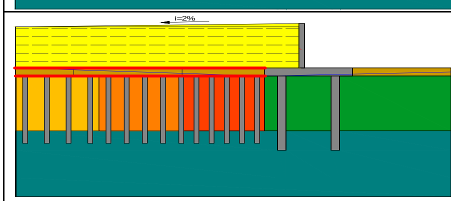
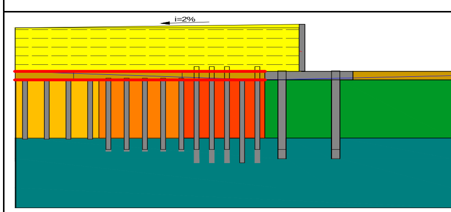
| Pattern | Case | Treatment | Pile spacing (m) | | | Pile length (m) | | |
|---|---|---|---|---|---|---|---|---|
| | | | AB, $s_1$ | BC, $s_2$ | CD, $s_3$ | AB, $L_1$ | BC, $L_2$ | CD, $L_3$ |
|  | 1a | No treatment | - | - | - | - | - | - |
| | 1b | Geotextile | - | - | - | - | - | - |
|  | 2a | Installing GRPS | 1.5D | 1.5D | 1.5D | 10m | 10m | 10m |
| | 2b | system | 2D | 2D | 2D | 10m | 10m | 10m |
| | 2c | beneath | 2.5D | 2.5D | 2.5D | 10m | 10m | 10m |
| | 2d | embankment, | 3D | 3D | 3D | 10m | 10m | 10m |
| | 2e | with same pile | 2D | 2.5D | 3D | 10m | 10m | 10m |
| | 2f | length | 2D | 3D | 3D | 10m | 10m | 10m |
| | 2g | | 2.5D | 3D | 3D | 10m | 10m | 10m |
|  | 3a | Installing GRPS | 1.5D | 1.5D | 1.5D | 12m | 10m | 8m |
| | 3b | system | 2D | 2D | 2D | 12m | 10m | 8m |
| | 3c | beneath | 2.5D | 2.5D | 2.5D | 12m | 10m | 8m |
| | 3d | embankment, | 3D | 3D | 3D | 12m | 10m | 8m |
| | 3e | with different | 2D | 2.5D | 3D | 12m | 10m | 8m |
| | 3f | pile length | 2D | 3D | 3D | 12m | 10m | 8m |
| | 3g | | 2.5D | 3D | 3D | 12m | 10m | 8m |

*Figure 6 :* Parameters used in all the analysed cases

The cross section, boundary conditions and dimensions for the numerical model used for this parametric study are presented in Fig.7. The piles were modeled as wall in the plane conditions. The diameter of the abutment walls used in this analysis is 0.635m.

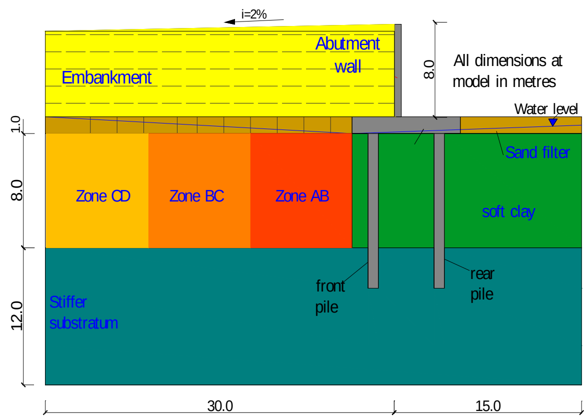



*Figure 7 :* Model for the numerical analysis of project

Embankment behind bridge abutment is divided into three zones (AB, BC and CD) as in Fig.7. The width of zones is 10m along embanlment. The length and pile spacing of each zone depend on loads condition and the interaction between embankment and abutment. Zone AB will be installed with pile spacing $s_1$ and pile length $L_1$; Zone BC will be installed with pile spacing $s_2$ and pile length $L_2$; Zone CD will be installed with pile spacing $s_3$ and pile length $L_3$.

All cases that is widen to study and analyse overall for full-height bridge abutment by using GRPS solution are presented in Fig.6.

The options of treatment for the foundation soil include no treatment, installing system GRPS under embankment with only a DM pile length but the pile spacing is changed from 1.5D to 3D and installing system GRPS under embankment that have shifted DM pile length in three different zones (8m in zone CD, 10m in zone BC and 12m in zone AB) and the pile spacing is changed from 1.5D to 3D. In the case 3, pile spacing and length of pile that will altered together for the different zones. The result presented in this paper include the vertical and horizontal displacement, the maximum and differential settlement, the longitudinal gradient change, and the distribution of stresses.

## III. Analysis of Results

### *a) Displacement and strain contour*

Strain contour for embankment are given in Fig.8. Vertical and horizontal displacement contour for the embankment are presented in Fig.9 and Fig.10 for four typical cases. It is shown that the maximum settlement develops on the crest of the embankment due to the traffic loading, the compression of the embankment fill.

Fig.9 shows that the differential and maximum settlements have decreased from case 1b (no DM pile) by 78% in case 2c, 54% in case 3c and 65% in case 3e. In addition to, the location of maximum displacement and strain contour is shifted toward installing models of DM piles. In case 1b, the location of maximum settlement has established away from abutment ≈ 12m $(\cong h_s\sqrt{2})$. In case 2c, this location moved toward abutment with smaller value, whereas this was toward away abutment in case 3c and case 3e.

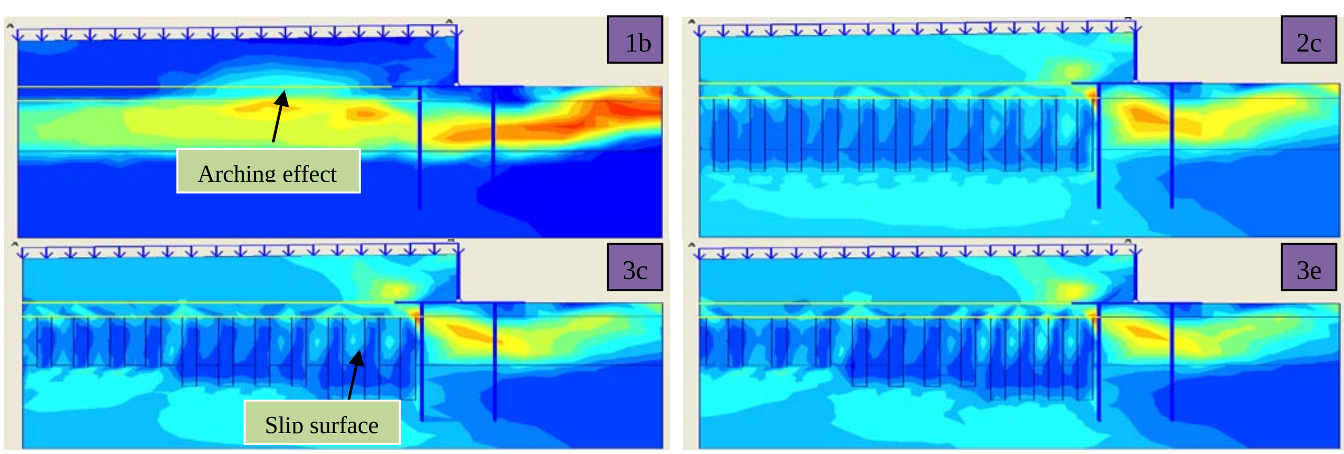



*Figure 8a :* Volume strain shading contour of four typical cases

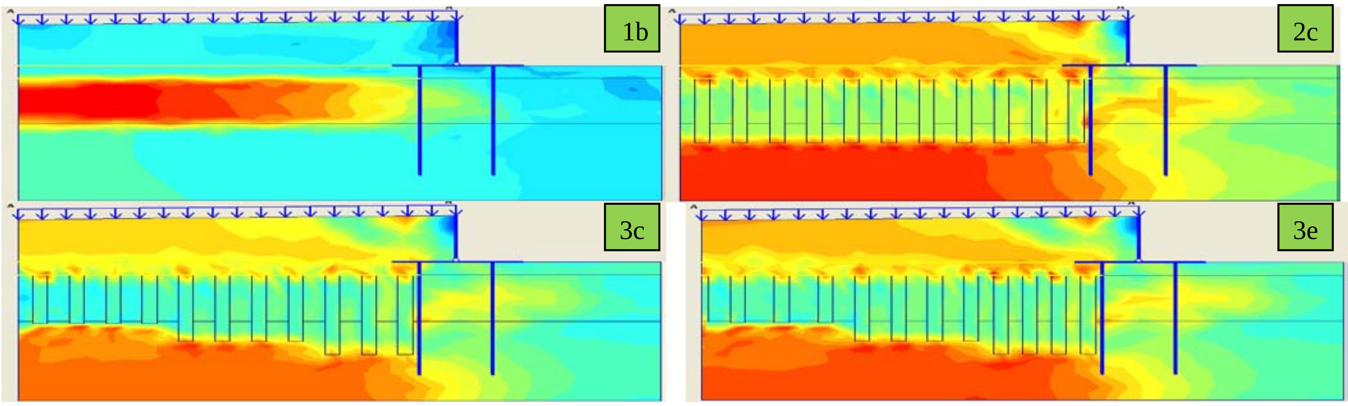



*Figure 8b :* Volume strain shading contour of four typical cases

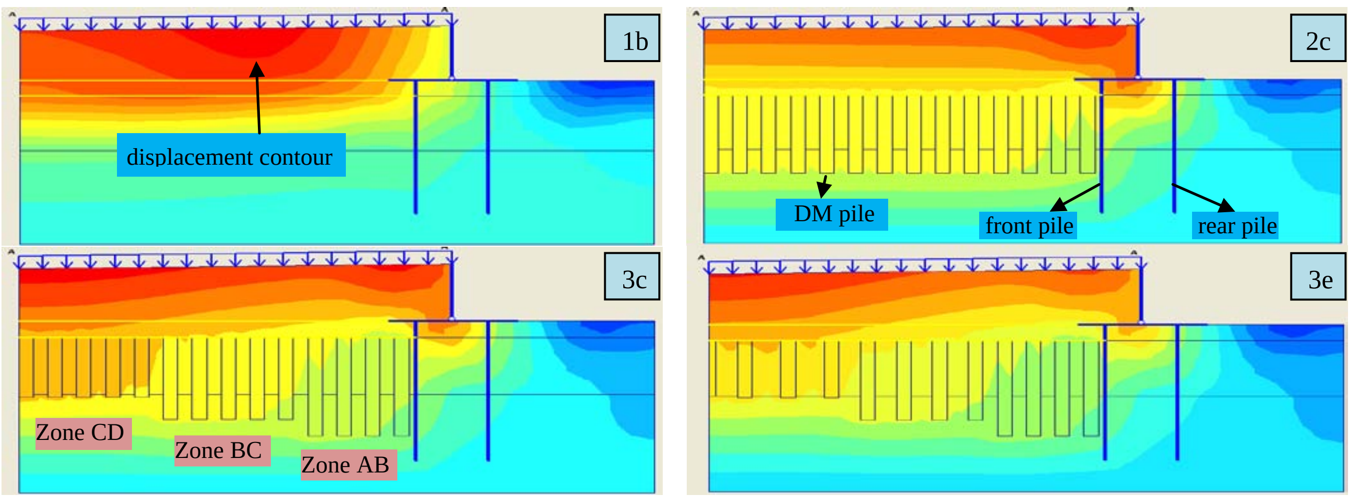



*Figure 9 :* Vertical displacement contour of four typical cases

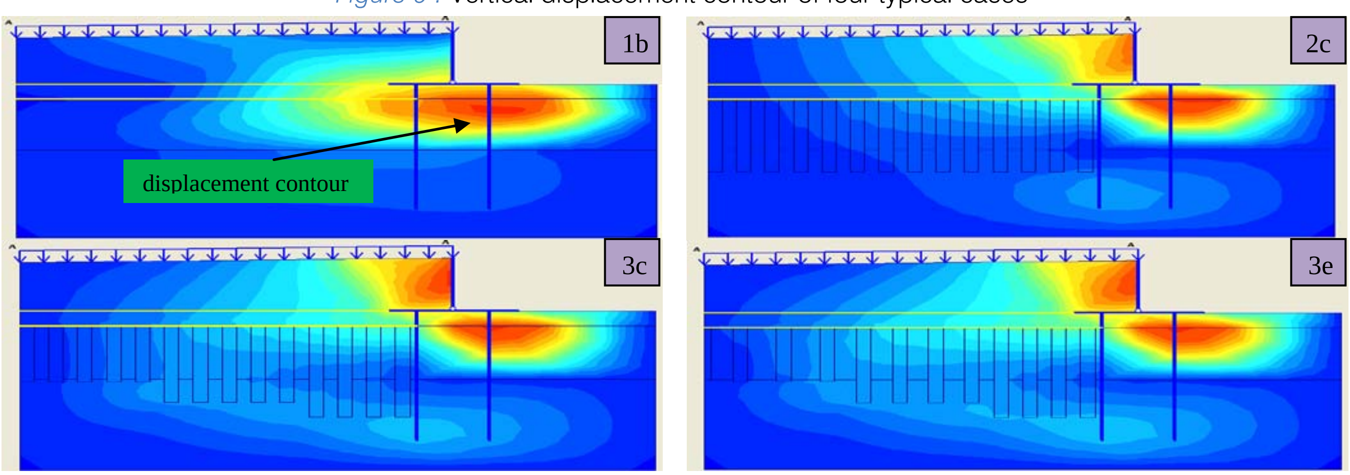



*Figure 10 :* Horizontal displacement contour of four typical cases

Fig.10 shows horizontal displacement contour, and is is shown that the location of mobilisation appeared at the edge of pile cap and real pile. Therefore, the real pile endured a greater lateral pressure from embankment than front pile). So it is necessarily to consider to design of real pile that has higher strength than front pile to avoid shear and bending failures. As can be seen in Fig. 10 that in the cases has installing of DM piles (2c,3c,3e), the horizontal displacement contour was narrower approximately 63% on both area and value than case 1b( no DM pile). However, the difference between these cases include (2c,3c,3e) is insignificantly with only ≤15%. Clearly, the use of the DM piles not only reduces the maximum settlement but also pushes the location of the maximum settlement towards away abutment. In other words, the soft soil under the embankment plays an important role in the maximum settlement, but the length of DM piles less influence to the location of the maximum settlement.

The magnitude of the arching effect become more dominant in the long term, as consolidation settlement advances and causing reduction horizontal stress.

The reason for this is because stiffness of soft soil impact to arching effect. It is obviously that lateral loading due to arching must be considered, in order to perform a realistic design for this problem.

*b) Displacement and bending moment of wall*

The abutment wall is a critical element of superstructure. The variations of displacement of abutment wall for different cases are given in Fig.11. As case 1a is compared with case 1b and case 2a in Fig.11a, the use of DM piles not only decreases the displacement of wall to approximately 67% (120mm and 40mm). With case without piles DM(case1a, 1b), horizontal displacement of wall was greatly at pile cap and might be cause of failure of abutment wall.

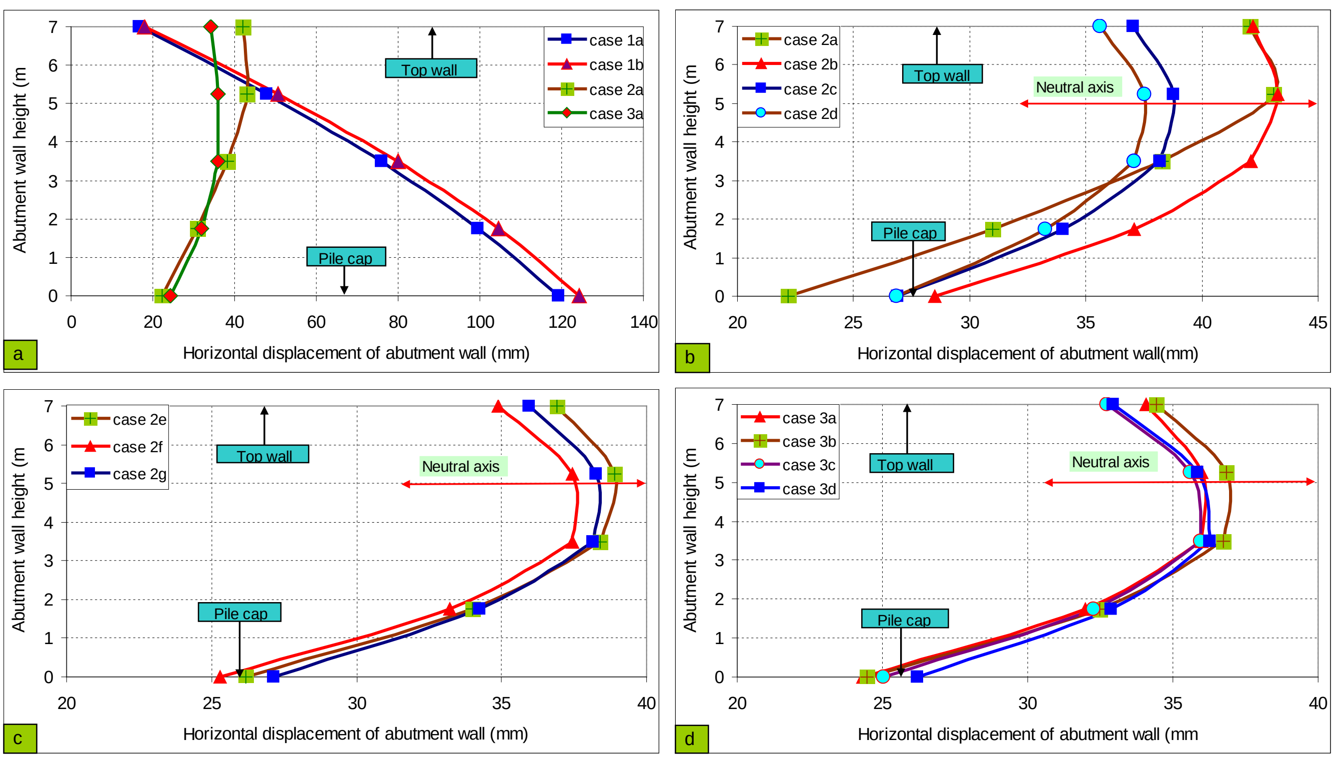
Fig.11b shows the effect of DM pile spacing. Case 2c and case 2d with spacing is 2D and 2.5D respectively have horizontal movement less than case 2a(1.5D) and case 2b(2D) about 16.5%, but the magnitude of differences between case 2c and case 2d is not significantly, the range of 2-4%.

Fig.11c shows comparison among case 2e, case 2f and case 2g. As can be seen that case 2f has smallest displacement, following is case 2g and 2e but three cases are closely.

Fig. 11d and Fig.11e show the influence of changing DM pile length based on support region (case 3). Generally, all cases have the good match, the maximum displacement value averaged out at about 36.2mm.

With an identical pile spacing, abutment wall dispalcement value of case 3a and case 3b are lesser ≈18% compared to case 2a and case 2b as in Fig.11f.

Case 3(c,d,e,g) with varying pile length from 12m in zone AB to 10m in zone BC and 8m in zone CD. Additionally, varying spacing from 2D in zone AB to 2,5D in zone BC and 3D in zone CD reduces maximum displacement of abutment wall as compared with case2(a,d,e,g). Case 3c and 3e had the least movement among all the cases as presented in Fig.11(g,h).



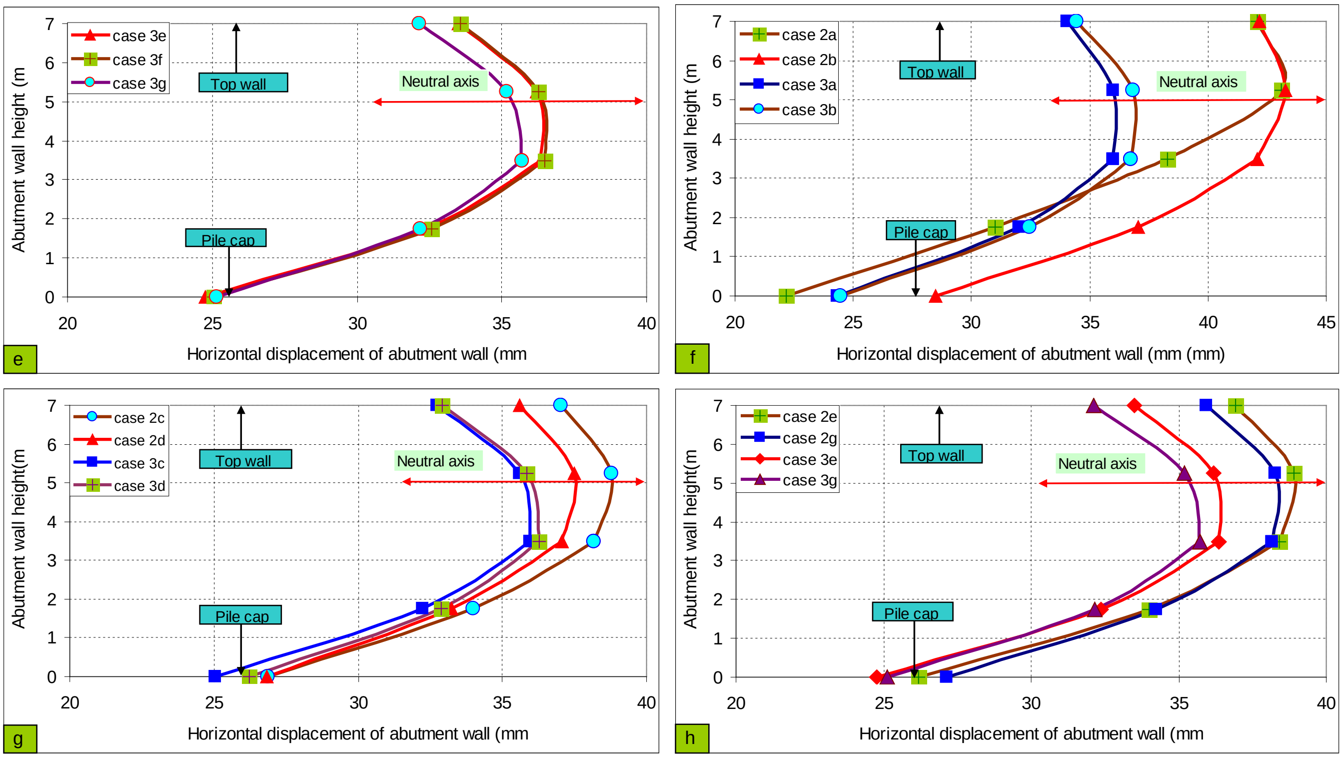



*Figure 11 :* Horizontal displacement of abutment wall

The bending moment of abutment wall is presented in Figure 12. Abutment wall deformations as a funtion of the global the rotation of pile group and the pile cap translation. However, the rotational deformation of the pile group in the numerical analysis, was almost zero and only translational movement of the abutment wall was observed.

Fig.12a shows displacement between case1(a,b) with case2a and case 3a. It is clearly that almost the gap of cases is quite narrow. However, The location of maximum bending moment moved up above in case 2 and case 3 which have support of GRPS system.

The results for bending moment of abutment wall in cases 2 are given in Fig.12(b,c). It is particularly to see that the position of maximum bending moment in all cases were at 2m away from pile cap(tip wall), except case 2a(at 3.5m). The absence of bending moment mobilised in the upper part of the abutment wall reveals the influence of the aforementioned arching onto the pile cap, due to the settlement and shear stress transfer.

Fig.12(c,d) show the comparision bending moment of wall among cases when have change length and spacing of piles DM. It is obviously that bending moment value in case 3 is smaller a little than case 2 (≈2-3%). It also quite similar to the results in cases 2. Case 3c and case 3d have the smallest value among all the cases. Aslo, all the cases 2 were compared to cases 3 as in Fig.12(e,f,g,h). It is evidently to confirm that all cases 2 and cases 3 were similarly, the differences is insignificantly with only range of 1-4%.

The results about displacement and bending moment of abutment wall showed that the arching mechanism has a significant effect in the long-term, when the lateral loading due is more dominant than that due to the shear sress transfer along the soft soil-embankment interface. Initially, the lateral stresses form an arch onto the front face of the pile cap and increase rapidly near the pile cap, still with considerable vertical load transfer onto the top pf soft clay layer below. The magnitude of the arching effect become more dominant in the long term, as consolidation settlement advances and causing reduction horizontal stress. The results also confirm that the thick of soft clayer, strength pameters of clayer impact strongly to the arching effect.

As the results were analysed that using geosynthetic reinforced pile supported system reduced lateral loading affect onto abutment wall. Especially, cases (3c,3d,3g) have smallest displecement value of abutment wall. Changing the length of piles DM based on different regions gave a better effect. In the distance away from wall should be examined to install longer length of pile DM and decrease gradually as toward away abutment

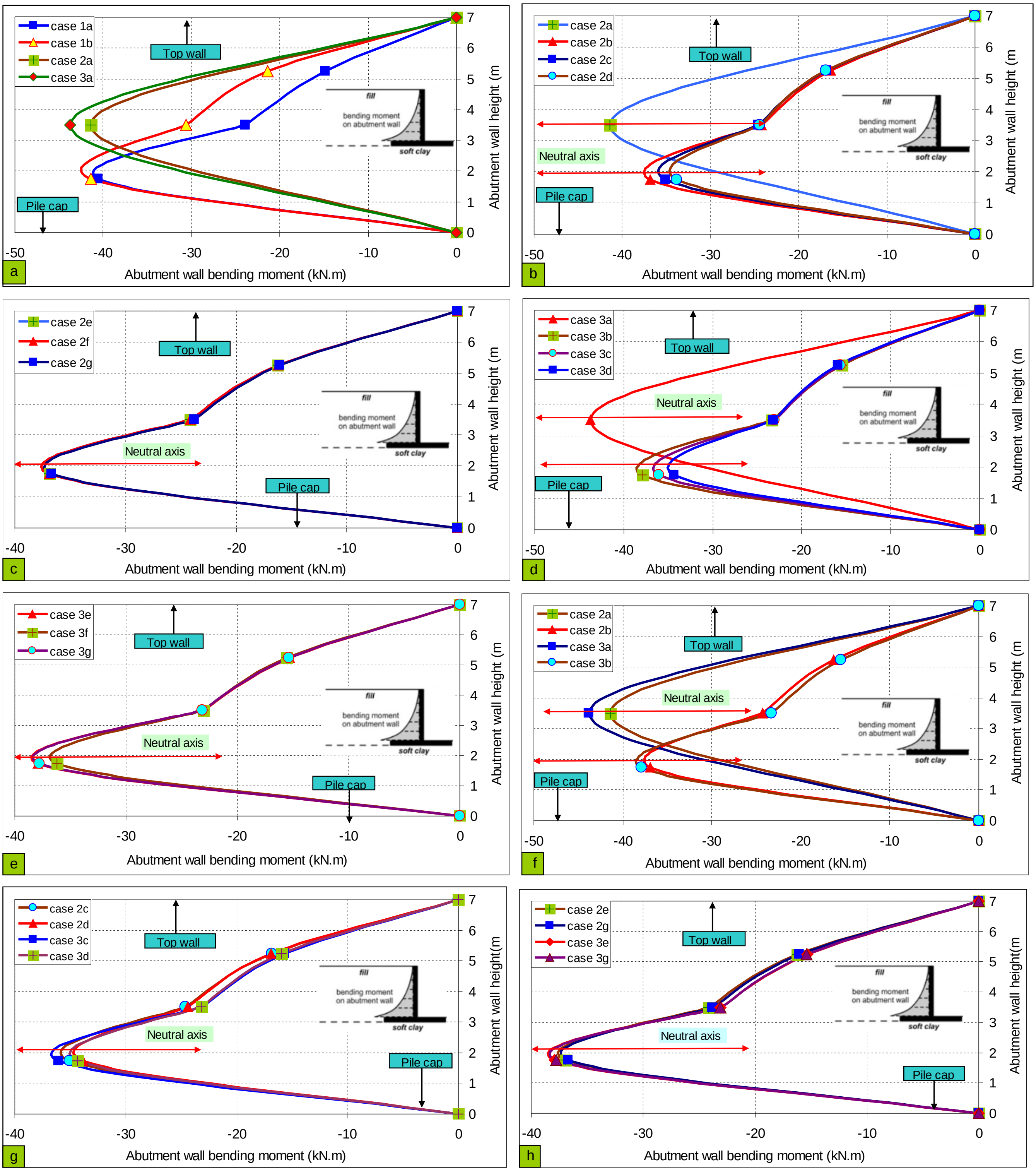



*Figure 12 :* The bending moment on abutment wall

c) *Strain of embankment*

Fig.13 presents normal and shear strain of some typical cases for embankment behind bridge abutment. The results show that the strain area and the degree of strain in case 1a is higher significantly(≈61%) than cases where use GRPS solution. Additionally, the maximum strain location is at nearly with the position $\sqrt{2}$ $h_s$ from away abutment wall. As can be seen in Fig.13b, the degree of strain in case 3c is much smaller (≈49%) than case 2c, this has confirmed that the length of DM pile has strongly influenced to the increase of strain of embankment. For the shear strain, Fig.13f shows that shear strain in case 2c is significant smaller than case 3c. A similar comparison also was taken beween case 2a with case 3a and case 3b as in Fig.13(e,g,h). Evidently, the length of DM piles has strongly impacted to the stranfer of shear stress from embankment on pile cap.

It is also particularly to notice that all cases 2 as compared to cases 3 nearly give to a similar result, which show the shear strain in cases 3 are much higher than cases 2. Similarly. The shear strain differences at position of pile cap and at the ground between pile is significantly among all the cases 3. Such as in Fig.13e, the shear strain of case 3c is approximately 2.5 times highe than case 1 and case 2a. It also can see case 3c and case 3e have shear strain larger 73% than case 2c, case 2e. However, all cases 3 have a goot match in shear strain result. Evidently, changing the length of pile DM contributed greatly to this differences.

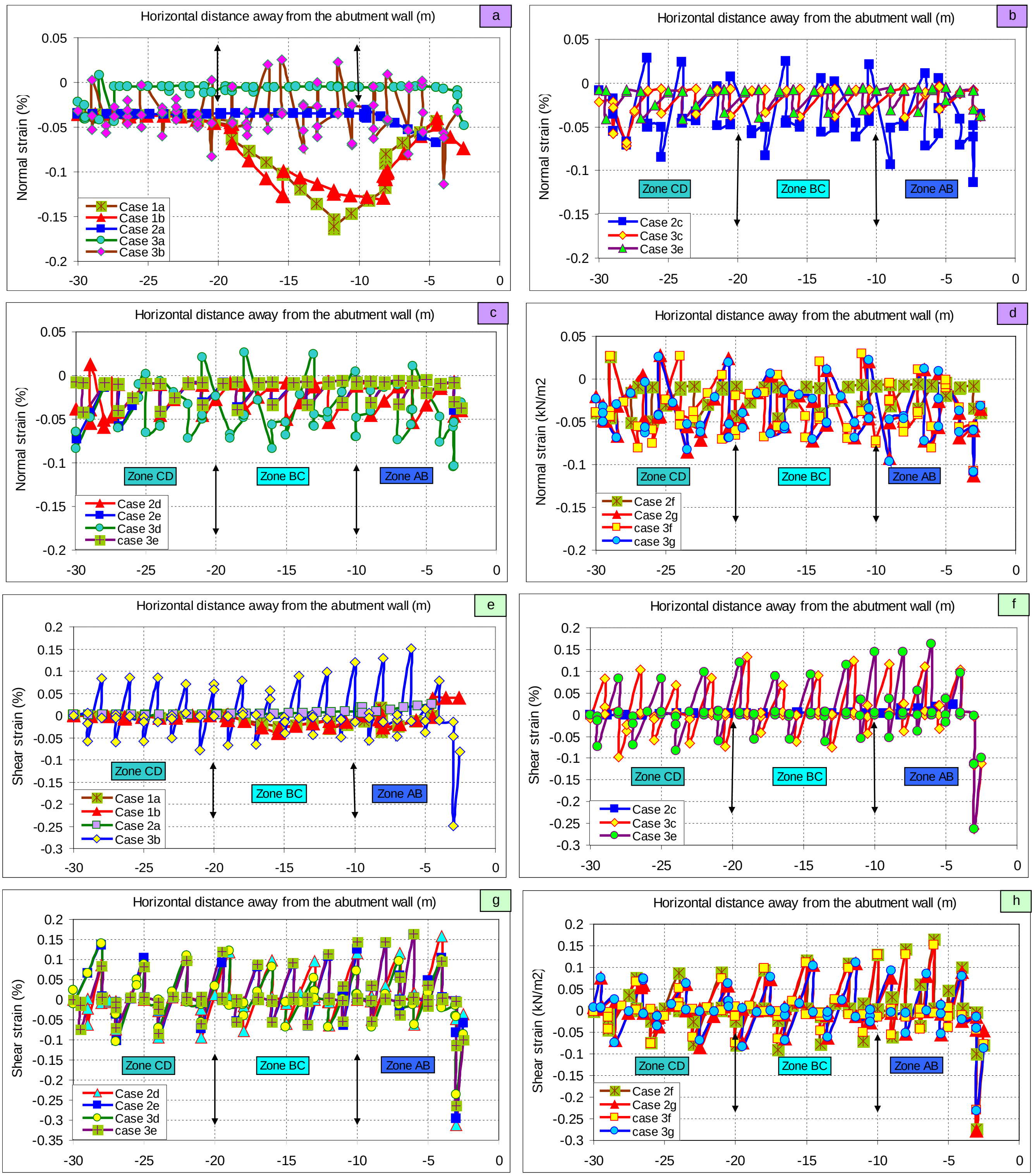



*Figure 13 :* Normal and shear strain at the base of embankment behind bridge abutment

*d) Settlement profile*

The settlement at the base of embakment is presented in Fig.14. As case 1a is compared with case 1b and case 2a in Fig.14a, the use of DM piles not only reduces the maximum settlement from 20cm (Case 1a) to 5cm (Case 2a-decreasingly 80%), but also help the settlement of embankment is less difference along all embankment ($\approx 5cm$ ).

Fig.14b shows the impact of pile spacing when all zones (AB, BC, CD) are installed by the identical pile length. The avarage settlement of embankment in case 2b is approximately 5.45cm compared to case 2a ($\approx$5.18cm), case 2c($\approx$4.9cm), and case 2d($\approx$5.5cm). Differential settlement in case 2(a,b,c) is also smaller than case 2d as comparison in table 2. Hence, the settlement in Case 2c (s=2,5D) is lowest and distribution settlement is relatively equal as case 2(a,b). This is result of arching effects and group pile effect.

Fig.14c shows the influence of DM pile spacing when all zones AB, BC, CD are supported by various spacing. The avarage settlement of embankment in cases 2e, 2f, 2g is similarly with approximately 4.7cm for zone AB and approximately 5.0cm for zones BC, CD. However, the differential settlement in case 2f and case 2g is higher significantly ($\approx$10%) than case 2e for area of zone BC and CD. In addition to, the use of DM piles shifted the location of maximum settlement toward away abutment than case 1a and case 1b.

Another analysis was performed for case 2 by changing the length of pile for zones (AB, BC, CD) likely in Fig.14d and Fig.14e. The avarage settlement and differential settlement in case 3d is clearly higher greatly ($\approx$19%) than case 3(a,b,c). The settlement results also has trend decreasingly at position nealy abutment, the difference of settlement between zone AB with BC and CD is aprroximately 30% .

Due to the influence of the strength and length of soft soil under the embankment to various zones(AB, BC, and CD) is differently as discussed above. So, the piles installed under the embankment is shifted pile spacing and length of piles for each zone that was compared and analysed in Fig.14f, Fig.14g, Fig.14h. As case 2(a,b) is compared with case 3(a,b) shown that the settlement in zone AB and CD of case 2(a,b) largely reduce (21.2%) than case 3(a,b).

Fig.14g shows results for comparison of cases have changing pile spacing from 2,5D to 3D and the length of piles has decreased gradually follow supporting zones. With case 3c (s=2,5D), distribution of settlement only slightly increase than case 2c and 2d. The results of comparision also presented similarly for case 2(e,f,g) with case 3(e,f,g) in Fig.14h. And the longitudinal gradient change is defined as distortion (i.e., differnetial settlement/distance) of pavement is relatively small with 0,22%, at in safety limitation ($\leq$ 1.5%)(Ling. et.al ).

Differential settlement ratio $S_d$ (%), that is defined as ratio between settlement on DM pile and settlement of soft ground, as well as longitudinal gradient change, $g_e$, for all cases presented in bảng 2. As can be seen that GRPS solution has significantly reduced settlement of embankment (5,5cm-treatment and 25,1cm-untreatment). Also, GRPS solution help decreasing longtitudoinal gradient change by settlement of embankment, as case 1a with ge =1,89% over limited value (1.5%), but avarage value ge in other cases only 0,11%. Case 2c and case 3c show the best suitable results include all factors such as displacement, differential settlement, longitudial gradient change.

It is obvously to see that the cause of this is because of the wall displacement is often significantly affected by the stiffness and displacement of the embankment behind the abutment by arching effects and pile group effects. Arching effect increases the stress on the pile DM concentration leads to lower displacement of soft ground, arching effects will decrease as the pile sapcing is the greater. The pile group effect occurs because phenomena ovelap stress lead to increased displacement of the soft ground, pile group effects also decrease as the distance increases piles. With case 3c, the case of the impact of arching effects tend to be greater than the impact of the pile group effect as the cause of the smallest value of the wall displacement.

*Table 2 :* Settlement, differential settlement, longitudinal gradient change of embankment

| Case | 1a | 1b | 2a | 2b | 2c | 2d | 2e | 2f | 2g | 3a | 3b | 3c | 3d | 3e | 3f | 3g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Settlement at at crest , cm | 28.8 | 29.0 | 8.8 | 9.1 | 8.9 | 8.8 | 8.8 | 8.8 | 8.9 | 8.6 | 8.6 | 9.1 | 9.95 | 9.0 | 9.1 | 9.2 |
| Settlement at Base, cm | 25.1 | 25.1 | 5.2 | 5.5 | 5.6 | 5.5 | 6.5 | 5.5 | 5.5 | 5.8 | 5.7 | 6.0 | 6.8 | 6.0 | 6.4 | 6.3 |
| Settlement of Fill, cm | 3.7 | 4.1 | 3.6 | 3.6 | 3.3 | 3.3 | 2.3 | 3.3 | 4.4 | 2.8 | 2.9 | 3.1 | 3.2 | 3.0 | 2.7 | 2.9 |
| Differential settlement, % | 0 | 0 | 0.1 | 0.5 | 3.0 | 9.2 | 14.2 | 10 | 12.8 | 0.8 | 1.2 | 5.8 | 13.3 | 8.2 | 8.5 | 8.8 |
| Gradient change $g_e$, % | 1.89 | 1.45 | 0.06 | 0.13 | 0.06 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.11 | 0.12 | 0.16 | 0.12 | 0.13 | 0.14 |

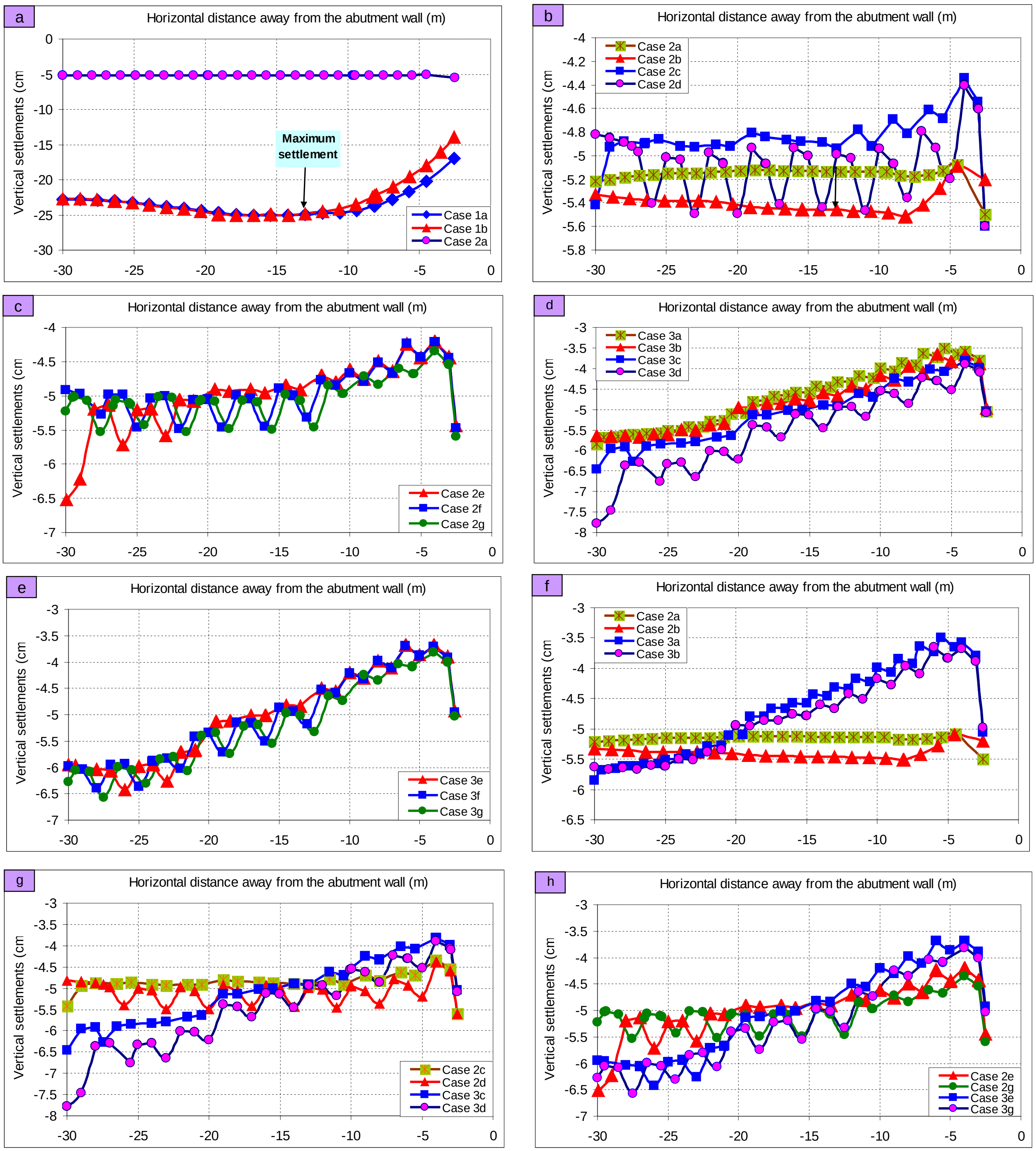
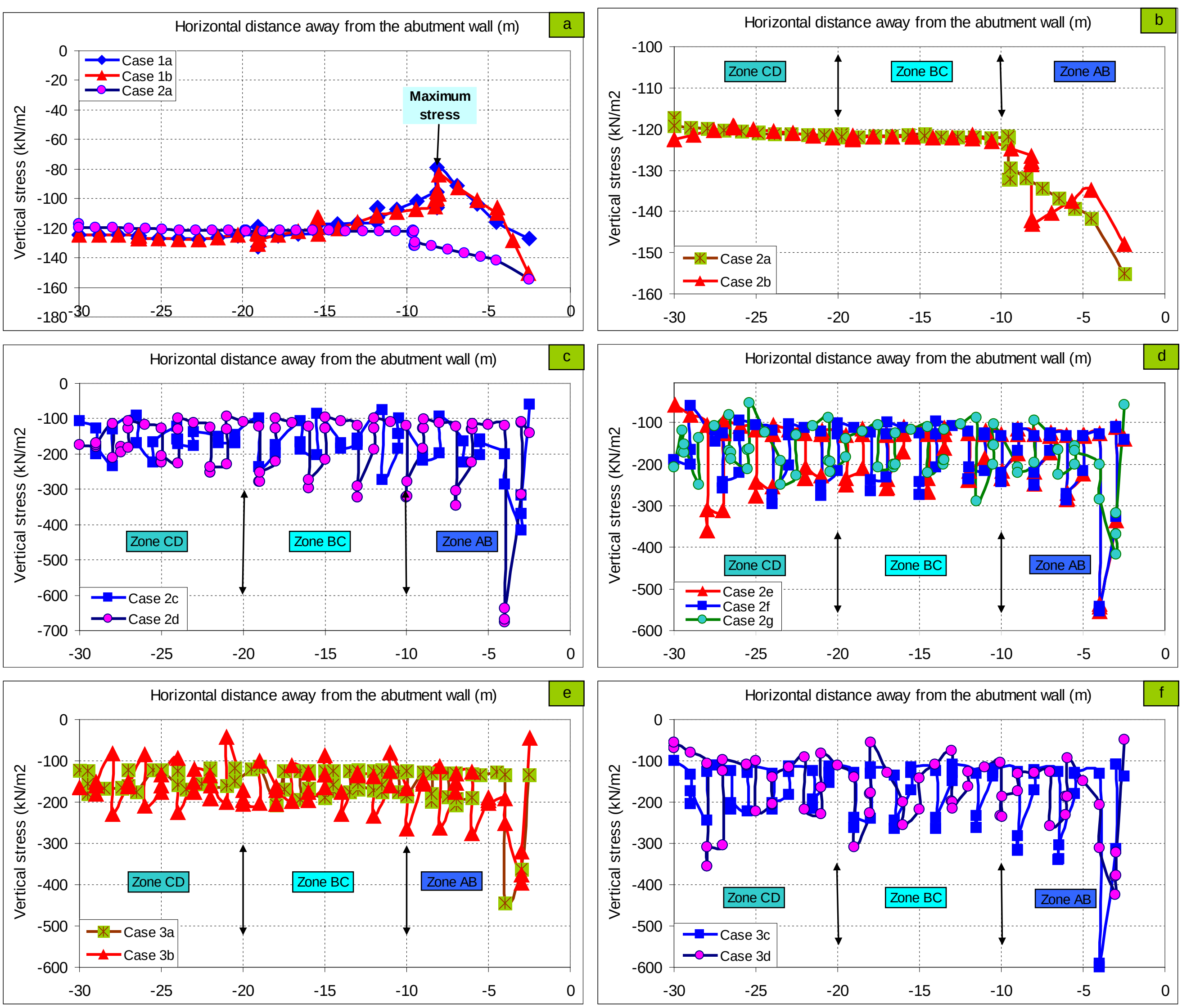



*Figure 14 :* Settlement profile at the base of embankment behind bridge abutment

*e) Vertical stress distribution*

Eight typical cases for distribution of stress at the base of embankment are presented in Fig.15. As compared with case 2a, Fig.15a shows that there are a good agreement about distribution of stress along embankment in cases(1a,1b,2a). But, for zone AB, stress has increasingly steadily in case 2a rather than the reduction in case 1. Fig.15b shows the comparision between case 2a and 2b, and most stress shifted in zone AB with the difference only from 3% to 5%. This had indicated distribution of stress were impacted greatly by arching effects. Simultaneously, the results also shows that the interaction area of embankment and bridge abutment is suitable with value $\sqrt{2}\,h_s$ ($h_s$-the depth of soft clay), nearly only in zone AB.

Fig.15c and Fig.15d shows influence of pile spacing DM to distribution of stress for other cases. The maximum value of stress appeared suddenly at the edge of pile cap (≈550÷700kN/m$^2$) when has the change of pile spacing (2D÷3D). Thus, this position might be destroyed higher significantly than other locations. Fig.15e and Fig.15f show comparision on distribution of stress between cases 3(a,b,c,d). The distribution of stress on DM pile cap in case 3b is higher approximately 17% than case 3a and also quite similarly with case 3c and 3d in zone AB. Fig.15g shows that stress value is not differently much between case 3a and 3g, but much higher (≈32%) compared to case 3a and 3b. Besides, stress concentration ratiowas analysed from all cases has remained about 1 5 and less depend on the change of DM pile length.

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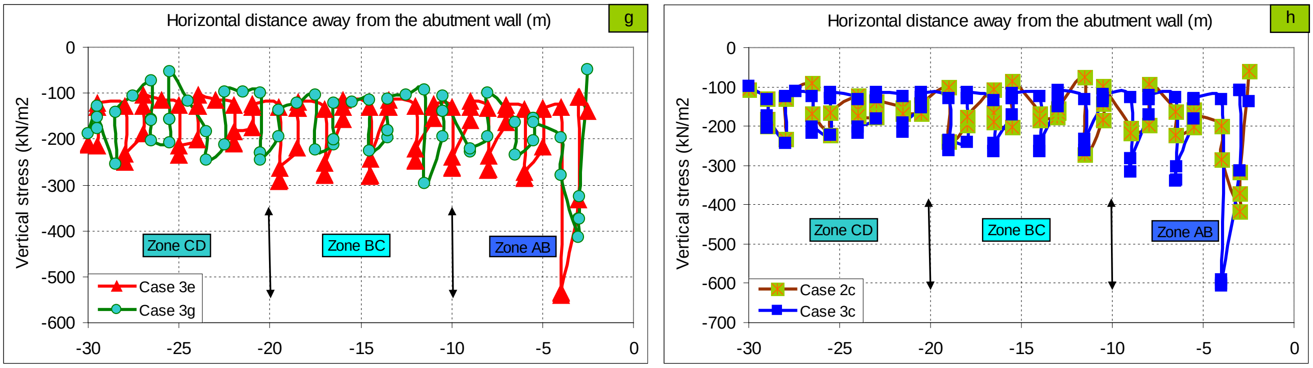


*Figure 15 :* Vertical stress distribution at the base of embankment behind bridge abutment

## IV. Conclusion

A commercially available FE software and soil model were used to compare and discuss the results obtained. The development of strain contour, vertical and horizontal movements of the embankment and soft clayer, the displacement and bending moment of abutment wall, the deformation of embankment, the settlement and stress distribution were analysed, compared and discussed. Additionally, mechanism pertaining to bridge abutment constructed on piled foundation through soft soil have mostly been investigated using numerical analyses presented in this paper. The findings are summerised based on Fe numerical software as follows:

Numerical findings revealed that arching effect and pile group effect have a significant effect on the lateral loading of the abutment wall in long-term.

The arching effect increases the stress on the pile DM concentration leads to lower displacement of soft ground, arching effects will decrease as the pile sapcing is the greater. The pile group effect occurs because phenomena ovelap stress lead to increased displacement of the soft ground, pile group effects also decrease as the distance increases piles. With case 3c, the case of the impact of arching effects tend to be more dominant than the impact of the pile group effect lead to the smallest value of the wall displacement.

The abutment wall is a critical member of the structure system, and FE analysis shown that the displacement of wall was being impacted significant by the stiffness and the thick of soft clayer.

It is necessarily to use GRPS system for support embankment behind abutment. This can reduce settlement, displacement, strain and failure risks of abutment. The best performance might obtain by changing length and spacing of pile DM based on different regions

Deformation zone by interaction between embankment and bridge abutment mainly happen during domain approximately $\sqrt{2}$ $h_s$ away from abutment wall. Depth of clay layer ($h_s$) and variation of $c_u$ with depth are factors that influenced significantly.

The reduction of displacement, differential settlement and deformation can be achieved by installing DM piles. The best performance can be obtained by optimizing the pile spacing under embankment from 2D to 2,5D.

Installing DM piles with a spacing is 2,5D and shift the length of DM piles based on supporting zone might help embankment get the reduction of differential settlement and longitudinal gradient change as well as get a good aggrement with the distribution of stress. longitudinal gradient change should be controlled to be avoid possible failure (≤1,5%).

In the deformation zone behind abutment(AB and BC), stress distributed and focused extremely large at the location of edge of pile cap with cases has treated by GRPS and at the location $\sqrt{2}$ $h_s$ - untreatment cases.

The stress concentration ratio for the GRPS systems ranged from 1 to 5, and nearly less influence to the length of DM piles. But, the shear stress transfer on pile cap depend significant on the length of DM piles.

Foundation piles can provide shear resistance to the shear stress induced by embankment. It is necessarily to install DM piles with larger length in zone $\sqrt{2}$ $h_s$ from abutment to avoid possible failure or dmage of roadways and bridge abutment.

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# A Preliminary Study for Improving the Banana Fibre Fineness using Various Chemical Treatments

By Tholkappiyan. E
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*Abstract-* This work analyses the effect of various alkali and softness treatments on the physical, chemical and mechanical properties of the banana and banana: cotton fibres blended yarns and fabrics. Fibres were scoured, bleached and mercerized by different concentrations of NaOH, $H_2O_2$, $Na_2CO_3$ and softened with Aloe Vera, castor oil, cotton seed oil and soap. The mechanical characterization indicated that the single yarn strength, tensile strength, tear strength and torsion rigidity became decreased by increasing concentration of the NaOH, $H_2O_2$, $Na_2CO_3$. The adequate (spinnability) fineness (5.8 tex) of the banana fibres have been achieved with Na OH, $H_2O_2$ and $Na_2CO_3$ combined treatments. The fastness properties of the banana: cotton blended fabrics show equal to the 100 % cotton fabrics in dry and wet conditions.

*Keywords: banana fibre, fineness, OE spinning, single yarn strength, torsion rigidity, weaving.*

GJRE-J Classification : *FOR Code: 091599*

APRELIMINARYSTUDYFORIMPROVINGTHEBANANAFIBREFINENESSUSINGVARIOUSCHEMICALTREATMENTS

*Strictly as per the compliance and regulations of :*

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Tholkappiyan. E

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## I. Introduction

Natural fibres are becoming an attractive alternative over synthetic fibres due to their advantages such as recyclability, biodegradability, renewability, low cost, high specific mechanical properties and low density [1- 4]. Banana is one of the rhizomatous plants and currently cultivating in 129 countries around the world. It is the fourth most important global food crop. In India, about 7.1 lakhs hectares area is under banana crop with the total fruit production of 26.2 million contributing 14.7 percentage of global [1]. In banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stems and leaves are thrown away annually. Such waste provides obtainable sources of fibers, which leads to the reduction of other natural and synthetic fibers' production that requires extra energy, fertilizer and chemical. The banana fibers are good moisture absorbent, highly breathable, quickly dry with high tensile strength.

The semi-cellulose in banana fibre is arranged in the form of a helix at an angle of 11° to 12° with the fibres diameter of 100 to 200 $\mu$m contrasts to coir fibre, where the spiral angle was found to vary from 40° to 47° for a diameter 100 to 500 $\mu$m [2]. The strand length varies greatly depending on the precise source and treatment of the fiber during fiber extraction. If the fiber is removed from the full length of the sheaths, as in hand or machine stripping, fiber strands from the middle sheaths may run as long as 15 feet or more; average length ranges from 3 to 15 ft. The moisture regain percentage of banana fibre is high compared to cotton fibre about 11-15% [5-7]. Compared to other fibers like cotton, jute and flax, banana fibers have higher water absorbency and water release properties owing to a higher content of non-cellulosic material and lower crystallinity (19-24%) in the fiber structure [7].

The mechanical properties of plant fibre mainly depend on factors like the source, age, the species, processing parameters and the internal structure [2]. The mechanical properties of the banana fibres with the various diameters have been studied. There is no appreciable change in the mechanical properties of the fibres with an increase in the diameter of the fibre in the range investigated 50 to 250 $\mu$m. A gradual decreases in the initial modulus with an increase in diameter of the fibres in the range of 100 to 450 $\mu$m. While ultimate tensile strength and breaking strain increased up to 200 $\mu$m diameter after which they remained constant [2 & 4].

In the recent past, banana fiber had a very limited application and was primarily used for making items like ropes, mats, and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has also been recognized for all its good qualities and now its application is increasing in other fields too such as apparel garments and home furnishings. However, in Japan, it is being used for making traditional dresses like kimono, and kamishimo since the Edo period (1600-1868). Due to its being lightweight and comfortable to wear, it is still preferred by people there as summer wear. Banana fiber is also used to make fine cushion covers, Neckties, bags, table cloths, curtains etc. Rugs made from banana silk yarn fibers are also very popular world over.

The fibre portion of the pseudostem left over after extraction of starch was utilized for the preparation of paper pulp by Subrahmanyam et al., (1963). Banana fibres are reported to have been spun on the jute spinning machinery [9 &10] and used in making ropes and sacks. However, Kulkarni et al., (1983) were the first to report on the fibre yield, structure and properties of banana fibres. Subsequently, Bhama Iyer et al., (1995) evaluated yield, structure and properties of banana

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fibres gathered from a few commercially cultivated varieties and observed that variations exist in both structure and properties of fibres from different regions along the length and across the thickness of the pseudostem. They also reported differences in tensile and structural properties among fibres belonging to different varieties and showed that the matrix in which the cells are embedded in the fibre had a role in deciding the tensile strength of the fibre.

Enzyme application increases tensile energy, extensibility and improves the surface characteristics of the cotton-banana union fabric. Detailed study was undertaken to explore the sewability of cotton-banana blended fabrics and it is concluded that they give higher/better seam pucker but higher bending rigidity than 100% cotton [12 & 13].

This study also aims at such an achievement by increasing the fineness of banana stem fibres. However, an alternative solution is found to make effective use of the banana stem in which the banana stem can be extracted of their fibre and converted as a yarn into fabric through simple techniques.

## II. Experimental

*a) Materials*

The banana fibers were collected from representative village (Gobichittipalayam-Erode, India). The collected raw banana fibers were very coarse (140 Denier) and have more lignin content in nature. Subsequently the removal of lignin content from the fibre surface has done by retting process for 2-3 weeks. After retting treatment the banana fibres have been subjected into chemical treatment to reduce the fineness (rigidity) as shown in Table 1.

*Table 1 :* Fineness of Alkali Treated Banana Fibres

| SI.NO | Concentration of NaOH | Bundle fibre Fineness (Tex) |
|---|---|---|
| 1 | Raw banana fibre | 31.2 |
| 2 | Treated with 2.5% | 8.2 |
| 3 | Treated with 5% NaOH | 5.46 |
| 4 | Treated with 10% NaOH | 4.8 |
| 5 | Treated with 15% NaOH | 3.7 |
| 6 | Treated with 4% $H_2O_2$ & 2% NaOH | 5.5 |
| 7 | Treated with 4% $H_2O_2$, 2% $Na_2CO_3$ and 4% NaOH | 5.8 |

*b) Methods*

i. *Chemical treatments on raw banana fibres*

Alkalization treatment was done by different chemicals like NaOH and $H_2O_2$ with different percentages for hemicelluloses analysis. The chemical treatment of fibre was done by two steps. At first the fibre was bleached with $H_2O_2$ (4% on weight fibres), NaOH (2% on weight fibres), material liquid ratio (MLR) 1:20, few droplets of wetting agent, Temperature of 100°C and Time for 1 hour. After that the fibre was treated with NaOH at different percentages like 1%, 2%, 4% and 8%, with M L R 1:20, Time for 30 min, Temperature of 95°C to reduce the fibre rigidity level (fineness). The softener was prepared by the combination of castor oil (4-6%), Aloe Vera (4-6%), cotton seed oil (4-6%) and emulsifier (2.5%) treated for 1 hour.

## III. Calculate Weight Loss for Chemically Treated Banana Fibres

This is a reduction of the total mass of the banana fibres due to a mean loss of fluid, bark, hemicelluloses, lignin etc, by treated the fibers with NaOH (concentration of 2.5%, 5%, 10% & 15%). The fibre weight loss can be calculated by using the given below formula [2].

$$\text{Weight loss \%} = [(IW - AW)/IW] \times 100 \qquad (1)$$

Where, IW- Mass of before chemical treatments (g), AW- Mass of after chemical treatments (g).

When banana fibres were treated with different chemicals like alkali and peroxide, during the removable of bark and other impurities, considerable weight loss was observed. Treatment leads to the irreversible alkalization effect which increases the amount of amorphous cellulose at the expense of crystalline cellulose. Crystalline reduction is achieved by removal of lignin, hemicelluloses and other residues from the surface of the fibers. As the results shown in Table.2 the weight of the banana fiber was decreased with increases concentration of the alkali.

## IV. Evaluation of Banana Fiber Fineness

The fineness of representative raw banana fibers was determined by using a microscope (single fiber fineness tester) and torsion balance. Microscope works on the theory of vibrating strings to measure the fineness of individual fibers. The result showed that the average fineness of chemically treated banana fiber is 5.57 Tex (As in table.1, Sl.No. 2-7). The fineness has been improved by treated the banana fibers with alkali, so as to manufacture fine yarn. The fineness of the fiber is related to the hardness and rigidity of the fibers.

*Table 2 :* Weight Losses of Alkali Treated Banana Fibres

| Sl. No | NaOH concentration | Weight before alkalization(g) | Weight after alkalization(g) | Weight loss (%) | Conditions |
|---|---|---|---|---|---|
| 1 | 2.5% | 338.16 | 324.22 | 4.122 | MLR=1:20<br>Temp=95°c<br>Time=30min |
| 2 | 5% | 338.16 | 306.42 | 9.386 | |
| 3 | 10% | 126.08 | 111.99 | 11.172 | |
| 4 | 15% | 126.08 | 106.13 | 15.823 | |

## V. Raw Material Preparation for Open End (OE) Spinning

The filament form of chemically treated and softened banana fibre was taken up to 40-50 mm length to avoid the fibre loss and rupturing during carding process. Then the banana fibre was blended with cotton in two different blend proportions like 50:50 and 70: 30 (Banana: Cotton).

### a) *Open end spinning*

The well blend two different fibres were made into web by the help of miniature carding in TIFAC CORE Coimbatore, India. After that the banana and cotton fibres yarn was spun using OE spinning technique. The given below spinning particulars have been followed during the yarn manufacturing process.

### b) *Spinning Particulars*

Sliver Hank - 0.165, Twist per Inch TPI – 36, Opening Roller Speed – 8000 rpm, Rotor speed 30000 rpm, Twist Direction – Z and Yarn count- 10Ne. After spinning the spun the banana yarn, it has been subjected into single yarn strength testing.

## VI. Scoured and Dyed of Banana Fibre based Fabrics

The grey banana fabrics have been scoured using following recipe, NaOH 2%, wetting agent 0.5%, temperature 90°C, MLR of 1:30 and time for 1 hour. The scoured banana fabric is dyed using following recipe, Reactive dye 2%, NaCl-20 gpl, $Na_2$ $CO_3$-10 gpl, temperature- 60°C, Material Liquid Ratio (MLR)-1:30 and time for 1 hour. After dyed the banana fibre based fabrics were subjected into various rubbing and wash fastness evaluation.

## VII. Development of Innovative Banana Fibre Based Fabrics

The two different spun yarns (50:50 and 70:30 banana: cotton) were used as weft yarn to produce the fabrics using conventional shuttle loom with production rate of 160 PPM. After manufacturing the fabrics were subjected into various tests' to analyze the physical and mechanical properties of the fabrics. The fabrics constructional parameters are shown Table 3.

## VIII. Results and Discussions

### a) *Chemical Treatments Influencing on the Banana Fibre Fineness*

The retting and alkalization treatments improve the fiber surface adhesive characteristics by removing natural and artificial impurities, there by producing a rough surface topography. After chemical treatment the size of crystallites, longitudinal shape and their orientation have been modified from cylindrical in to convoluted shape. The fineness of banana fibre is also reduced from 140 Denier to 90 Denier as shown in Table 4. The vegetable oils softening process reduces the fibre roughness and enhances the spinability of the fibers because of that; the fibers can easily pass through different rollers without slippage.

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*Table 3 :* Different Fabric Constructions and Parameters

| Fabric | Warp count, 100% cotton (Ne) | Weft count (Ne) | EPI | PPI | Fabric width (inches) | Cloth Cover Factor | GSM | Thickness (mm) |
|---|---|---|---|---|---|---|---|---|
| 100% cotton | 40 | 10 | 80 | 32 | 41 | 18.2 | 135 | 0.59 |
| 70:30, Banana: Cotton | 40 | 10 | 78 | 30 | 41 | 17.9 | 196 | 0.82 |
| 50:50, Banana: Cotton | 40 | 10 | 79 | 31 | 41 | 17.7 | 125 | 0.63 |

*Table 4 :* Banana Fibres Treated With Different Concentration of NaOH

| Chemical Treatment (NaOH) | Single Banana fibre fineness in (Denier) | Single fibre Strength in (g) |
|---|---|---|
| Raw banana fibres | 140 | 314.8 |
| 0.5% | 120 | 242.7 |
| 1% | 120 | 182.5 |
| 4% | 100 | 101.6 |
| 8% | 90 | 95.6 |

b) *Chemical treatments influencing on the mechanical properties*

The cotton and banana fibre blend proportion made greater influences in yarns' and fabrics' mechanical properties. The single yarn strength of the banana fibre blended yarns have decreased compared to 100% cotton yarn (as shown in Table 5) because of poor cohesion between cotton and banana fibres.

The single yarn strength reduction can be affected both physical and mechanical properties of the banana fibre based fabrics. As shown in Table 5, tensile strength of the 50:50 banana: cotton fabric shows higher than the 70:30 banana: cotton fabrics due to lack of single yarn strength of the higher banana fibre content in the yarn. In the fabric tear testing, 70:30 banana: cotton fabric shows more strength because of higher banana fibre content in the yarn (Table 5). The fastness property of the banana fibre based fabric is equal to the 100% cotton fabrics expect rubbing fastness of 50:50 banana: cotton blended fabric in wet condition (Table 6).

*Table 5 :* Mechanical Properties for the Cotton and Banana/Cotton Blended Yarns and Fabrics

| Materials | Yarn Count, Ne | Single yarn strength (Kgf) | Fabric tensile strength (Kgf) | Fabric tear strength (Kgf) |
|---|---|---|---|---|
| 100% Cotton | 10 | 11.50 | 36.97 | 3.64 |
| 50:50, Banana/Cotton fibres | 10 | 8.10 | 20.34 | 2.26 |
| 70:30, Banana/Cotton fibres | 10 | 6.35 | 18.14 | 2.95 |

c) *The flexural rigidity of chemically treated banana fibres*

The flexural rigidity is a characteristic for estimating the degree of softness of the banana fibres. The experimental results show the changes in the basic mechanical properties of the banana fibers after peroxide, alkalization and softening processes. The flexural rigidity and percentage improvements in softness obtained with banana fibres after the above said chemical treatments. Fibers treated with different softeners are shown in the Table 7.

*Table 6 :* Fastness Properties of the Various Fabrics

| FABRIC | Wash Fastness Rating* | RUBBING FASTNESS Rating* | |
|---|---|---|---|
| | | DRY | WET |
| 100% Cotton | 3 | 4 | 3 |
| 70:30, Banana/Cotton fibres | 3 | 4 | 3 |
| 50:50, Banana/Cotton fibres | 3 | 4 | 2 |

** Fastness Rating: 5-Excellent, 4-Very good, 3-Good, Average-2 and 1-poor*

*Table 7 :* Percentage Improvement in Softness after Various Chemical Treatments

| SI.NO | SAMPLES | FLEXURAL RIGIDITY($Ncm^2$) | IMPROVED SOFTENING (%) |
|---|---|---|---|
| 1 | Raw banana fibres | 1.2438 | Taken as reference |
| 2 | Treated with silicon (4%) and NaOH (2%) | 0.7768 | 37.54 |
| 3 | Treated with silicon (4%) and NaOH (2%) then softened with castor oil (4%), cotton seed oil (4%) and emulsifier (2.5%) | 0.6900 | 44.52 |
| 4 | Treated with $H_2O_2$ (4%) and softened with Aloe Vera (4%), castor oil (4%), cotton seed oil (4%) and emulsifier (2.5%) | 0.3326 | 74.06 |

After the chemical treatments (NaOH and Silicone), the flexural rigidity of banana fiber reduced approximately by 37.54%. In addition, the banana fibers were treated with NaOH and silicone, softened with castor oil, cotton seed oil and soap, the flexural rigidity of banana fibers have been reduced approximately by 44.52%. Finally the raw banana fibers were treated with hydrogen peroxide softened with castor oil, cotton seed oil, soap. Now, the banana fibres have been improved their flexibility by approximately 74.06 %.

## IX. Analysis of Variance (ANOVA) for Mechanical Properties of the Banana Based Yarns and Fabrics

The results of analysis of variance (ANOVA) for cotton and banana: cotton blended yarns and fabrics are listed in Table 8. It shows that the effects of cotton: banana fibres blended ratios have significant effects on various mechanical properties. The critical value is the number that the test statistic must exceed to reject the test. In this $F_{critical\ values}$ (3, 8) = 4.07 at $\alpha = 0.05$. Since F= 21.282 > 4.07, the results are significant at the 5% significance level. The p-value for this test is P =<0.001.

*Table 8 :* The ANOVA Table for Mechanical Properties of the Cotton and Banana: Cotton Fibres Blended Yarns and Fabrics

| Source of Variation | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Between Groups | 3 | 124.656 | 41.552 | 21.282 | <0.001 |
| Residual | 8 | 15.619 | 1.952 | | |
| Total | 11 | 140.275 | | | |

## X. Conclusions

From the experimental results the banana fibre fineness influences the greater in yarn and fabric mechanical properties. The 50:50 banana: cotton fibres blended single yarn strength is more than that the 70:30 banana: cotton fibres blended. The tensile strength, tear strength, torsion rigidity and fastness properties of the banana fibre based fabrics depend on the banana fibre based single yarn strength and banana fibre content in the yarns. Once the banana fibre gets better fineness it meets required strength and the applications of banana fibre based fabrics will become high in the future.

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# The Feasibility of a "Hydrogen Society"

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And also, a remarkable development of Fuel-Cell Vehicles (FCVs) has been achieved; for instance, Toyota's FCV, "Mirai," which launched in 2014 after two decades of tireless research, recently rolled out in the US and Europe.

This situation may give many people an impression that a "hydrogen society" will come true in the near future. But is this really true? In fact, there are so many difficulties to overcome before a "hydrogen society" is realized.

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# The Feasibility of a "Hydrogen Society"

Satoshi Matsuda [α] & Hiroshio Kubota [σ]

*Abstract-* The Japanese government has expressed that Japan intends to become a "hydrogen society" where homes and fuel-cell cars are powered by hydrogen, which is regarded as the $CO_2$ emissions-free energy source, and has laid out plans for a "hydrogen highway" peppered with fueling stations, all in time for the Tokyo 2020 Olympics [1].

And also, a remarkable development of Fuel-Cell Vehicles (FCVs) has been achieved; for instance, Toyota's FCV, "Mirai," which launched in 2014 after two decades of tireless research, recently rolled out in the US and Europe.

This situation may give many people an impression that a "hydrogen society" will come true in the near future. But is this really true? In fact, there are so many difficulties to overcome before a "hydrogen society" is realized. This study intends to examine the feasibility of a "hydrogen society" from the stand points of the energy sources (primary energies), energy balance, efficiency, and cost.

## I. Introduction

The Japanese government decided in June 2015 to construct a "hydrogen society," in which everything from buses to cars to homes will be powered by hydrogen, which is regarded as an environmentally-friendly zero-emission fuel. At first, it is planned that hydrogen-fueled buses will ferry athletes and fans around the 2020 Tokyo Olympic event sites. And in March 2016, the "Fukushima new energy initiative" was announced, in which a hydrogen producing plant using wind power with a capacity of 10 thousand kW will be constructed and will supply hydrogen for the 2020 Tokyo Olympics. Toyota has already developed the hydrogen-fueled car "Mirai" ("Future" in English), which went on sale in Japan in late 2014. Honda and Nissan also have similar Fuel-Cell Vehicles (FCVs) in the works [1]. Many people believe that hydrogen is "environmentally-friendly energy" because "it does not emit any carbon dioxide" just as Japanese Prime Minister Shinzo Abe said. But this is only one side of the story behind hydrogen. It is very important to distinguish clearly between an energy source and an energy carrier; fossil fuels (i.e. oil, coal, natural gas), solar, wind, or nuclear fits into the category of energy source ("primary energy"), whereas hydrogen and electricity are energy carriers ("secondary energy") which are produced by consuming the primary energies and are used for energy transportation or storage. Thus, whether or not a "hydrogen society" can be realized in the future depends on the following points: Where will the hydrogen for the "hydrogen society" come from? How is the energy efficient as a whole system? What is the cost of hydrogen? In fact, there are other problems such as security effort and infrastructure improvement due to the characteristics of hydrogen as a chemical substance. In this study, the feasibility of a "hydrogen society" is examined from the viewpoint of science, technology, and economics.

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## II. The History of the Development of Hydrogen use and Fuel Cell

The first research on "hydrogen energy" in Japan started in 1974, the year following the first "oil shock" in 1973, by Japanese government as a part of a new energy-development program called the "Sunshine Project". There were four major research themes in the project, i.e. solar, geothermal, coal, and hydrogen, which were regarded as alternative energies to oil at that time [2]. Thus, hydrogen energy development has a history of more than 40 years. In 1993, a revised version of the new energy development program called the "New Sunshine Project" was launched, in which six research themes were adopted, i.e. solar, geothermal, wind, coal, power generation by fuel cell, and ceramic gas turbine [3]. In that year, the downsizing of the polymer electrolyte fuel cell (PEFC) was achieved successfully in Canada, which accelerated the development of fuel cells. In the same year, several Japanese auto makers, such as Toyota and Nissan, started the development of fuel-cell vehicles (FCV). In the 2000s, hydrogen received remarkable attention around the world due to the oil price increase and global warming. Several big budgets were spent for hydrogen energy development in Japan, and also in 2000 the transit authorities of several European cities (Amsterdam, Barcelona, Hamburg, London, etc.) decided to participate in a joint fuel-cell bus and hydrogen fleet test to significantly enhance the development of Clean Urban Transport for Europe. They joined with leading infrastructure companies such as BP and Norsk Hydro, and with Daimler Chrysler and its bus subsidiary "Evobus". In order to strengthen the development of the new technology and to support the efforts of the transport companies, in 2001 the European Commission decided to support this project with one of largest budgets ever for a single research and demonstration project [4]. In addition, the Multi-Annual Work Program(MAWP) for the second phase of the Fuel Cells and Hydrogen Joint Undertaking (FCH2 JU) under the EU's new funding program for research and innovation, Horizon 2020, is now ongoing. The total investment for this seven-year program is expected to be about 1,330 million Euro [5]. On the other hand, the DOE (Department of Energy) has played a major role in developing hydrogen and fuel-cell technologies in the US. In the 2015 Fiscal Year (FY), congress appropriated approximately $117 million for the DOE Hydrogen and Fuel Cells Program in addition to $30 million for solid oxide fuel cell related activities [6]; although, the budget was reduced to nearly half of about $300 million during the FYs of 2007 to 2009 when the "Hydrogen Fuel Initiative" was driven forward under President Bush [7].

However, the infrastructure construction for a "hydrogen society" is still quite preliminary around the world, e.g. in Japan, in 2015, there were only 15 hydrogen stations, most of which were not commercial facilities but demonstration ones, because the cost for construction as well as operation is very high. The trials of hydrogen use in European and US cities have not been successful so far. This fact would imply that something is wrong with the concept of a "hydrogen society".

## III. The Whole Picture of the Hydrogen Energy System

Since there is no adequate amount of hydrogen gas as an energy source in nature, hydrogen is not a primary energy but a secondary (or even tertiary) one produced from the primary energies, as is stated above. There are two major hydrogen sources; the first one is fossil fuels or biomass resources containing carbon, the other is water.

In the former case, it is usual that the carbon contained in the resources is converted into $CO_2$ in the process of hydrogen production: e.g. At present the most inexpensive way to produce hydrogen is steam reforming of methane, which is the major component of natural gas, described by the chemical reaction formulae, as the following:

$$CH_4 + H_2O = 3H_2 + CO \quad + 206.2 \ \text{kJ/mol} \tag{1}$$

$$+)\ CO + H_2O = H_2 + CO_2 \quad - 41.1 \ \text{kJ/mol} \tag{2}$$

$$CH_4 + 2H_2O = 4H_2 + CO_2 \quad + 165.1 \ \text{kJ/mol} \tag{3}$$

The same amount of $CO_2$ is produced as $CH_4$ burns ($CH_4 + 2O_2 = 2H_2O + CO_2$) in this process, and this is not an exceptional case but a general phenomenon, meaning that hydrogen from fossil fuels or biomass is by no means a "zero-emission fuel." If CCS (Carbon dioxide Capture and Storage) is adopted, in order for the hydrogen produced from these kinds of raw materials containing carbon to be a "zero-emission fuel," the limiting condition for the feasibility of hydrogen use would be naturally stricter than that of a usual situation without CCS. In this case, the total energy efficiency, as well as cost, should be compared between direct use of fossil fuels or biomass resources and their utilization via hydrogen.

The second major source of hydrogen is water, and the "hydrogen from water" system is regarded as the "genuine" zero-emission energy system. So far, there have been many methods to produce hydrogen from water: e.g. electrolysis, photolysis, thermal decomposition, microbial process, and so on. At present, only the electrolysis of water is practically feasible as the hydrogen producing process from the stand point of reaction rate and energy efficiency. That is why the electrolysis of water using wind power was adopted in the "Fukushima new energy initiative" stated above. There is, however, a crucial problem in this process: i.e. electricity as the secondary energy is consumed for hydrogen production, thus the hydrogen produced inevitably becomes "tertiary" energy which is more expensive and inefficient than the secondary one. In addition, the final use of hydrogen is generally a "fuel cell," which is a kind of electricity generator using the chemical reaction of hydrogen and oxygen, because the energy efficiency of the fuel cell is much better than direct combustion use of hydrogen. Then, a peculiar process appears as a result: electricity → hydrogen → fuel cell → electricity. This cycle is nothing but for the wasteful expenditure of electricity. The only one advantage of hydrogen for electricity is that hydrogen can be stored more easily than electricity. In this case, the energy efficiency of hydrogen use must be discussed as an electricity storage system, not a as zero-emission energy system.

The hydrogen production from water without electricity is possible, at least in principle, e.g. photolysis of water using sunlight. It was reported that the solid solution of GaN: ZnO can act as a photocatalyst of complete decomposition of water using visible light [8]. But, the energy conversion efficiency of solar energy to hydrogen is about 0.2%, and the highest value achieved so far is 1.1% [9]. The simplest way to generate electricity form sunlight is beyond doubt solar cell, of which energy efficiency is usually more than 15% (most practical items). Since the hydrogen from sunlight is converted to electricity via fuel cell, of which energy efficiency is about 60%, the energy conversion efficiency of solar to hydrogen must be more than 25% (=15/0.6), meaning that the situation would be far from a feasible condition. In addition, solar cell has more than 200 times higher energy production than thermal power generation with a woody biomass as a means for obtaining electricity from solar energy [10]. The essential reason for this fact is that biomass production is strictly limited by the efficiency of photosynthesis (solar energy accumulated in biomass / total quantity of solar radiation), which is generally about 1% or less on the basis of the annual average. There is a similar situation of the electricity generation from sunlight via hydrogen. Thus, it is very difficult to find a rational reason for adopting hydrogen production via photolysis of water using sunlight as a means of electricity generation from solar energy.

In short, the hydrogen energy system has four phases: 1) The primary energy: fossil fuels, biomass resources, renewable energies such as solar and wind, or nuclear. 2) Hydrogen production: the source of hydrogen and the method of production, e.g. steam reforming of fossil fuels, or electrolysis of water. 3) Transportation and storage: Since it is very easy for hydrogen to leak and explode, the transportation and storage of hydrogen must be done with extreme caution, which will naturally be the factors for increasing in cost. In addition, since it is difficult to liquefy hydrogen, very high pressure would be necessary, e.g. a 700 atm tank is adopted as a hydrogen storage system of Toyota's "Mirai," of which compression work for this system is naturally very large. 4) Utilization: Generally, fuel cell is used because it is the most energy effective way to use hydrogen, but the final product is electricity, which leads to another aporia if hydrogen is produced by the electrolysis of water (electricity to electricity via hydrogen). These four points must be considered when the whole picture of the hydrogen energy system is discussed.

## IV. The Energy Efficiency of the Whole Hydrogen System

In this section, the energy efficiency of the hydrogen system as a whole is discussed in two cases.

*Case 1:* Hydrogen is produced by electrolysis of water.

In this case, the energy efficiency of the hydrogen use should be estimated as an electricity storage system, because the utilization of the hydrogen system as an effective way to store electricity is considered as the sole condition for the hydrogen system to be feasible according to the discussion in the previous section.

The energy efficiency of the electrolysis of water (= the energy efficiency of electricity to hydrogen) is usually 60 to 75%, whereas those of recently developed processes with high temperature and pressure would be 83 to 90%, but there will not be a large difference as a net efficiency between them if the energy required for rising temperature or pressure is taken into account. On the other hand, the theoretical maximum energy efficiency of fuel cell is 82%, whereas it is about 52% in practice. Thus, the overall energy efficiency of this hydrogen system would be $0.8 \times 0.8 = 0.64$ in the best-case scenario, under a more realistic assumption, the value would be $0.6 \times 0.6 = 0.36$, which is lower than that of the pumped-storage power generation, about 0.7 in actual use. In addition, since there are so many electricity storage systems with high energy efficiency being proposed and developed, the hydrogen system using electrolysis of water has little superiority as an electricity storage system. And also, a very huge electricity storage system might not be necessary if a "smart-grid strategy" is established in the future. In short, the hydrogen use as an electricity storage system will be very limited except for a special case, such as isolated island.

There is a concept proposed that hydrogen is generated by the electrolysis of water in remote areas and is transported to Japan. In this case, hydrogen is first converted to other chemical compounds such as methylcyclohexane because liquefied hydrogen is too dangerous to transport using a tanker. In this case, since four steps are required (electricity → hydrogen → another compound → hydrogen → electricity), the overall energy efficiency would be $0.8^4 = 0.41$, even if the energy efficiency of each step is ideally 80%; and, if these values are as practical as 60%, the overall value would be $0.6^4 = 0.13$ without energy required for transportation or compression, indicating that there is little feasibility in the system in which hydrogen is produced by the electrolysis of water.

If hydrogen is first liquefied, compression work is necessary; the practical energy consumption for hydrogen liquefaction is about 1 kWh/Nm$^3$-$H_2$ with the energy efficiency of 30% since the theoretical minimum work is 0.35 kWh/Nm$^3$-$H_2$. Since the standard combustion heat of hydrogen is - 285.83 kJ/mol, the total energy contained in 1 Nm$^3$-$H_2$ is 12,769 (=1,000/22.4 × 285.83) kJ. If the power generation efficiency is 40%, 1 kWh is corresponding to 9,000 (=3,600 kJ/kWh/0.4) kJ. In this case, about 70% (=9,000/12,769) of energy contained in hydrogen will be consumed in the liquefaction process.

As stated above, a 700 atm (70 MPa) tank is adopted as a hydrogen storage system of Toyota's "Mirai" for instance, then the required pressure at a "hydrogen station" is about 80 MPa, and the tank must be cooled to - 40℃ to maintain the temperature in the tank during the compression work under 85℃. Therefore, the total energy required at a "hydrogen station" would be at least 60 to 70% of the energy contained in hydrogen, which is almost the same as the energy required for liquefaction, indicating that the concept of hydrogen production by the electrolysis of water at remote areas has very little feasibility as a whole system because the total energy efficiency is too low (or even minus). The low energy efficiency inevitably leads to a high cost of energy.

*Case 2:* Hydrogen is produced by the steam reforming of methane.

The overall reaction (3) is endothermic, and in addition, heat energy is required to raise the temperature up to around 900 ℃, thus the total amount of $CO_2$ emissions at a practical plant of steam reforming of methane is usually 0.9 kg-$CO_2$/$Nm^3$-$H_2$. 0.9 kg-$CO_2$ is 20.45 (=900 g/44.0 g/mol) mol-$CO_2$, and 1 $Nm^3$-$H_2$ is 44.64 (= 1,000 L/22.4 L/mol) mol-$H_2$, thus 0.458 (= 20.45/44.64) mol-$CO_2$/mol-$H_2$ is emitted, and the more the amount of $CO_2$ would be produced if the heavier hydrocarbon is used as raw material for hydrogen. The standard enthalpy change of formation of $CO_2$ is - 393.5 kJ/mol, and the standard combustion of $H_2$ is - 285.83 kJ/mol, thus, in the case of methane, 63.0 % (= (-393.5)(0.458)/(-285.83)) of hydrogen energy is consumed in the process of steam reforming of methane. It should be noted that the current purpose of hydrogen production by steam reforming of methane is not to obtain an energy carrier, but to produce raw material for chemicals such as ammonia. If the purpose of hydrogen is for energy carrier, the hydrogen production process using carbon containing materials such as hydrocarbon or biomass must be much more energy-efficient than steam reforming. But, so far, there is no other methods found out, probably because the chemical bond energy of C-H is relatively large (412 kJ/mol) compared with other major chemical bonds such as C-O (360 kJ/mol), C-C (347 kJ/mol), and C-N (280 kJ/mol), meaning that severe conditions (high temperature, etc.) would be necessary for the cleavage of C-H chemical bond, which inevitably leads to large energy input.

If CCS (Carbon dioxide Capture and Storage) is adopted in order for the hydrogen produced from these kinds of raw material to contain carbon to be "zero-emission fuel," the energy balance would be much worse, whereas the cost would be much higher. At present, CCS process is not put into practical use, even in the case that fossil fuels or biomass are used directly due to high cost and low energy efficiency. It is obvious that the hydrogen production with CCS would have almost no feasibility, at least in the near future.

## V. Comparison of the Running Cost of Vehicles

In this section, the running cost (in Japanese yen/km) of several kinds of vehicles will be compared.

1) Fuel-efficient gasoline vehicles: If the fuel consumption is 25 km/L-gasoline, and the price of gasoline is 140 yen/L (100 yen≒1 US dollars), the running cost would be **5.6** (=140/25) yen/km.
2) Electrical vehicles (EV): The energy consumption of a practical EV (by Nissan) is 6 km/kWh. Suppose that the average cost of domestic electricity is 24 yen/kWh, and 10 % of the battery charge cost is added, then the running cost would be **4.4** (=(24 ×1.1)/6) yen/km.
3) Fuel-cell vehicles (FCV) : Toyota's "Mirai" can travel 650 km on 4.6 kg-$H_2$, and the price of $H_2$ was 1,080 yen/kg-$H_2$ (hearing result at a hydrogen station by the authors), then the running cost would be **7.64** (= 1080/(650/4.6)) yen/km. It should be noted that this current price is the most inexpensive one of hydrogen that is made from natural gas, and the price would be several times higher if hydrogen were made by electrolysis of water. In addition, the major part of the hydrogen cost is occupied by that of the compression process, which cannot be reduced from whatever hydrogen is made.

This comparison of the running cost indicated that FCV is the most expensive vehicle, not only in the manufacturing cost, but in the running one as well. Even though the results of the cost estimation would be varied according to preconditions, the general tendency would not change, because the energy efficiency of EV is the best among these vehicles. The only advantage of FCV at present, is that it has a longer cruising distance than EV; but, this problem would be irrelevant after cartridge type of batteries are developed, which are very quick-release and can be exchanged at gas stations, which exist everywhere, not at hydrogen stations, which are sparsely distributed due to high cost. And the social-infrastructure development for battery charge is much easier than that of hydrogen, which is realized at a rapid rate mainly in European cities. In addition, the superiority of EV would be unchallenged if wireless power transmission technology is put to practical use.

The authors anticipate that fuel-efficient vehicles using fossil fuels (mainly gasoline and natural gas), their hybrid cars, and EV will compete against each other as long as the prices of fossil fuels are relatively low; but, EV will become predominant when the major part of primary energy is electricity from renewable energies such as wind and solar, after fossil fuels are exhausted. Even then, the superiority of EV over FCV will be unchanged, because the direct use of electricity is beyond all doubt much more preferable in energy efficiency and cost than the multistep use via hydrogen. In other words, FCV will have no chance to show off in any period for practical purposes, indicating that hydrogen will be never used, at least as an energy carrier, for vehicles.

## VI. Conclusion

It should be emphasized that hydrogen is never an energy "source" of $CO_2$ emissions-free, but only an energy "carrier" that is produced from primary energies. Thus, the feasibility of a "hydrogen society" must be examined from the stand point of whether or not hydrogen is really a good energy carrier compared with other secondary energies, such as electricity, in terms of energy efficiency, cost, manageability, and security: 1) Hydrogen from carbon containing materials such as fossil fuels and biomass has no meaning as a means of $CO_2$ emissions reduction, because $CO_2$is certain to be released from the hydrogen production processes, and the feasibility will be much worse if CCS is adopted in order to avoid the $CO_2$ emissions. If fossil fuels or biomass are used as a primary energy, the energy efficiency, as well as the cost, should be compared between the direct use of them, e.g. combustion for thermal energy, and the multistep use via hydrogen. 2) If water is the source of hydrogen, the problem is how to obtain hydrogen from water: In the case that hydrogen is produced by electrolysis of water, the purpose of the hydrogen use must be limited to a means of electricity storage, because the final product of hydrogen use is electricity using fuel cell in almost all cases; and thus, the direct use of electricity is naturally much better than the multistep use via hydrogen. In this case, therefore, the efficiency as an electricity storage system must be examined among many other methods and systems. But, the overall energy efficiency of hydrogen use as an electricity storage system is rather low because of multistep, as shown above. The only possible option is that hydrogen is produced from water without electrolysis, e.g. photolysis, thermal decomposition, and microbial process using solar energy. However, the energy efficiency of hydrogen production in this option must be much higher than that of solar cells in practical use, because the final product of the hydrogen system is usually electricity using fuel cells. So far, it is likely that the technological difficulty in producing hydrogen using sunlight other than electrolysis of water is difficult to overcome.

All data and discussions stated above indicate that the possibility of a "hydrogen society" to be feasible is just about nil. An appropriate energy carrier should be selected, not by illusion or myth, but by solid evidence grounded in science, technology, and the economy.

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# Heuristic Scales to Strayed Proneness (HSSP): Assessing the Strayed Proneness of Cross-Over OHE on Railway Tracks

By Ch Srihari Varma, T Rama Subba Reddy & Ch Sai Babu

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*Keywords: overhead equipment (OHE), panto (pantograph), t/out (turn out), X-over (cross-over), ATD (automatic tensioning device), RE (regulated equipment), RDSO (research, designs and standards organization), SMI (standard maintenance instructions), TI (technical instructions), MI (maintenance instructions).*

*GJRE-J Classification : FOR Code: 091599*

# Heuristic Scales to Strayed Proneness (HSSP): Assessing the Strayed Proneness of Cross-Over OHE on Railway Tracks

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## I. Introduction

The 25KV, 1Φ, 50 Hz (Industrial Frequency) A.C. System was adopted for Indian Railways for high density traffic routes since 1957 collaboration with SNCF(French national Railways), since it was superior to other types of Electric Traction systems[1to 7].

The Traction system is divided into three major areas .i.e.

i) Power Supply Installations (PSI).
ii) Over Head Equipment (OHE) and
iii) Remote Control (RC).

All the above three are inter linked with one another and failure on any one of them may cause disruption in traffic (train movements) and causing loss of punctuality of trains.

The major important area of Railway Electric Traction is Over Head equipment (OHE).

The OHE consists of electrical conductors, huge number of insulators, various fittings, and numerous attachments to hold and maintain it in its place. A failure occurring in any one of the numerous parts of OHE could result in a breakdown causing heavy disruptions in railway traffic and causing indefinite delay of train services. So, there is a need of reliable and failure free OHE for smooth passage of Pantograph.

A scheduled maintenance of the OHE with meticulous inspection of every OHE installed parts is necessary to avoid any types of failure. The adjustments at the crossovers or near the overlaps spans have to be checked for any deviations from the specified standards leading to the pantograph getting entangled with the OHE. Also a periodic examination of the OHE parameters as per the design, healthiness of various components and its geometry is necessary to attain zero defects and to achieve high reliability. All OHE breakdowns .i.e. whether it is major or minor must be handled with equal urgency for preventing unduly disruptions and for renewal of the services.

*Fig. 1 :* Electric Locomotive with panto raised condition.

The figure.1 shows the electric locomotive with pantograph in raised condition. The Pantograph is provided on loco roof to receive the required power from overhead contact wire to the electric locomotive. If the pantograph has free movement over the contact wire without any obstacles will ensures the locomotive works efficiently. However if broken fragment of the pantograph arise in the path of overhead wires or else broken overhead wires come in the path of the pantograph it will result in panto entanglement as shown in figure 4 and 5.

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*Fig. 2 :* Testing of turn out OHE with Tower Wagon

*Fig. 3 :* OHE Profile at Turn out Location


*Fig. 4 :* Panto entanglement at Turn out OHE.

*Fig. 5 :* Electric Locomotive with Broken Pantograph

The design of overhead equipment and pantograph ensures constant contact is maintained with contact wire by the pantograph with adequate pressure to obtain current.

Improper adjustment of stagger and heights of contact wire at turnout or cross - over results in pantograph entanglement with overhead wires while moving on the main line [4 & 5]. To avoid this, turnouts are to be adjusted such that the contact wire of secondary line remains 5 cm above the main line, OHE at obligatory structure and also the contact wires shall not be less than 30 cm up to 10m from obligatory structure. The emergency crossovers in between Up and Dn. main lines are also equipped with similar to turnouts. In case of panto entanglement the pantograph and OHE are both damaged and electric traction traffic is dislocated.

In this paper, one of the OHE defects[2] that can cause 43% among the OHE failures is presented. i.e. due to improper adjustment of 309 Nos Cross over and 1190 Nos. turn out OHEs of Secundrabad division of South Central Railway (Indian Railway).

## II. Related Work

Cross Over and Turn-out :

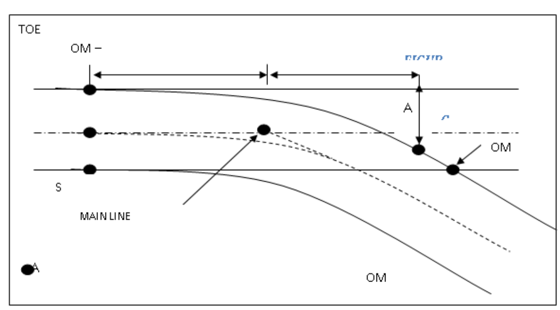


*Fig. 6 :* Cross-over & Turn out layout of Track

A cross over is a track which diverges from one track and converges to another track (Figure.6). This means a crossover will have two turnouts, which are connected by a cross over may be parallel or not, may be curved or may be having gradient in one track, or may be at different levels.

In the case of electrified tracks, at turnouts and crossings additional design parameters are obligatory to be considered for smooth take of pantograph from one OHE to another OHE (figure.3).

Since one cross over is constituted of two turnouts, each turnout parameters are to be designed as per the convergent or divergent point. The OHEs of the two mainline tracks are designed as per the normal principles of design irrespective of type of crossover. But the cross - over OHEs are to be designed in correlation with main line OHE[1& 7].

Another important parameter of turn out/ Cross-over OHE is that, the gradient of contact wires. Every cross over will have two elementary sections of the two tracks, separation of which is achieved by erection of section insulator. The erection of section insulator has got certain technical parameters to be followed during erection [5] which should not be infringed in any case by simply following the turnout heights of contact wire, otherwise results in panto entanglement.

The cross over OHE should be designed keeping the technical parameters for consideration

1) The heights of both mainline tracks OHE are to be adjusted such that there should be minimum allowed gradient of the crossover OHE.
2) Adjustment of crossover OHE should be done at a time in accordance with the as erected drawings supplied by the construction organization during erection and commissioning of OHE.

Any incorrect adjustments of stagger and height at turn out or cross over OHE causes entanglement of the pantograph with overhead wire during its movement on main line or else entanglement with main line during its movement on overhead line.

This problem may be overcome by making sure that height of the contact wire at turn-out or cross-over near obligatory locations is maintained 50 mm above the mainline contact wire and nearly 9m additional distance while pantograph moves on main line to make sure no contact is made with contact wire at turn out and cross over where the track separation is nearly 150 to 700mm.

*Procedure for Adjustment of Turn Out and Cross Over:*
A pre check that is necessary prior to the adjustment of Turn-out and Cross-over (figure.2) near any location is inspection of ATDs of main and loop lines for their free movement. The other steps in the procedure are,

1. Measure fitting of the obligatory mast from L/L & M/L tracks, track separation and perform turn-out adjustments at obligatory point according to SED.
2. Arrange 'G' Jumpers at a distance of 5.6m from obligatory mast at the points of cross-over and turn-out in the parallel run side direction.
3. Fix the contact wire at turn-out at a height 50mm above the M/L contact wire near obligatory mast located at the Cantilever.
4. Perform according to schedule, adjustments of the A&B droppers and tune distances of the A&B droppers from the obligatory mast for M/L and for turn out OHE.
5. Remove hogging on the M/L contact wire with adjustments of the length of 'B' and adjacent droppers to 10 m from the obligatory mast on M/L OHE contact wire in the direction of turn outside.
6. Perform height adjustments of L/L contact wire one mast previous to the obligatory mast considering M/L & L/L track level diff.
7. Execute in the direction of turn out side near 10 mts. distance adjustment of the height of loop line contact wire to min +30mm (with related adjustments of loop line B and the adjacent droppers) according to the height of main line contact wire.
8. Maintain at least 50mm diff. in the contact wire height at M/L & L/L OHE at obligatory mast.
9. Ensure panto does not come in contact with the contact wire of L/L cross over during operations of the tower wagon on M/L.
10. Running tower wagon at turn out track so that M/L contact wire achieves take in/take off panto pan of 650mm + /- 20cm from the center of panto of the tower wagon.
11. Maintain for a cross type turn out near obligatory a height diff. of +1.5 cms, at 5 mtrs and 10 mts distance from mast. In running the tower car on M/L ensure panto does not come into contact with contact wire at turn out and if necessary prevent contact by adjustments of A&B dropper.

## III. Heuristic Scale to Strayed Proneness (HSSP) of Cross-Over OHE

*a) Dataset Preprocessing*

The OHE cross-over preventive maintenance log record contains 25 attributes with the values of type categorical. The 25th attribute is remark, which is descriptive, which is replaced by a Boolean value to represent the state of the respective record log. The dataset that used here in this experimental model is formed from the real time logs collected from the South Central Railway, Secundrabad division. The data set is the combination of records labeled as true and false. In order to balance the computational overhead, we aimed to select optimal attributes from the records labeled as true and also from the records labeled as false. Hence forth, initially we convert all alphanumeric values to numeric values and continuous values to be converted to categorical as follows.

*Table 1:* Description of dataset attributes:

| ID | Description | Values |
|---|---|---|
| F1 | Main line contact wire height on one side | in **H** meters (decimal fraction). |
| F2 | Main line contact wire height on another side | in **H** meters (decimal fraction). |
| F3 | T/Out Contact wire height on one side | in **H+50**meters (decimal fraction) |
| F4 | T/Out Contact wire height on another side | in **H+50**meters (decimal fraction) |
| F5 | Stagger of main line wire stagger on one side | in **200**millimeters (decimal fraction) |
| F6 | Stagger of main line wire stagger on another side | In**200** millimeters (decimal fraction) |
| F7 | Stagger of T/out wire stagger on one side | In**300** millimeters (decimal fraction). |
| F8 | Stagger of T/out wire stagger on another side | In**300** millimeters (decimal fraction). |
| F9 | sag of section insulator | in **Zero** mm |
| F10 | Take-off from one side | In **650 to 720**mm |
| F11 | Take-off from other side | In**650 to 720** mm |
| F12 | Point take-off from one side | in **4**meters (decimal fraction) |
| F13 | Point take-off from other side | in **4**meters (decimal fraction) |
| F14 | stagger of section insulator | ±100 mm |
| F15 | Runner towards the centre of T/out. | In mm (1.65 minimum) |
| F16 | runner away from the centre of T/out | In mm (1.45 minimum) |
| F17 | condition of ATD of T/out & main Line | Free to move |
| F18 | Hex tie rod of limiting device**[6]** | |
| F19 | Setting distance of obligatory mast from one side. | In Metres (mi 3.0Mtrs) |
| F20 | Setting distance of obligatory mast from other side side. | Same as above |
| F21 | Track separation of obligatory mast from one side. | In mm ( 150 to 700mm) |
| F22 | Track separation of obligatory mast from other side. | Same as above |
| F23 | Distance of 'G'Jumper | In **5.6**meters (decimal fraction). |
| F24 | Length of 'G' jumper | In**4** meters (decimal fraction). |
| F25 | Label | true/false |

- Let consider each attribute with alphanumeric values, then list all possible unique values and list them with an incremental index that begins at 1.
- Replace the values with their appropriate index.
- Let consider each attribute with continuous values, and then partition them into set of ranges with min and max values, such that the records distributed evenly through all these ranges.

*b) Optimal Attribute Selection*

- Partition the given network transactions as intruded ( $I$ ) and normal ( $N$ )
- Find the hamming distance (see sec 3.3.1) between unique values of each attribute of $I$ with the counter part of $N$
- Select the attributes having the hamming distance more than the given threshold $hdt$ as set of optimal attributes $I_a$ of size $n$, $N_a$ of size $m$ from $I$ and $N$ respectively

i. *Hamming Distance*

The value of Hamming Distance obtained here is to denote the difference between unique values of same attribute from records labeled true and false. This is one of the significant strategy to assess the difference between to elements in coding theory. This strategy is applied to identify the distance between the unique values observed for an attribute in record set labeled as true and labeled as false.

The hamming distance between given vectors $CX = \{cx_1, cx_2, .........., cx_n\}$ and $CY = \{cy_1, cy_2, ........., cy_m\}$ of size $n$ and $m$ respectively will be measured as follows:

Let $CZ \leftarrow \phi$ // is a vector of size 0

$foreach\ \{i \exists i = 1, 2, 3, .....\max(n.m)\}$ Begin

$if\ (\{cx_i \exists cx_i \in CX\} - \{cy_i \exists cy_i \in CY\}) \equiv 0\ then$

$CZ \leftarrow \{cx_i \exists cx_i \in CX\} - \{cy_i \exists cy_i \in CY\}$

Else

$CZ \leftarrow 1$

End

$$hd_{CX \leftrightarrow CY} = \sum_{j=1}^{|CZ|} CZ\{i\}$$

$// hd_{CX \leftrightarrow CY}$ is the hamming distance between $CX$ and $CY$ , $CZ\{i\}$ is the $i^{th}$ element of the vector $CZ$ and $|CZ|$ is the size of the vector $CZ$

*c) Heuristic Scales to Strayed Proneness*

Initially, we apply the Hamming Distance Analysis (see section 3.2) on processed dataset (see section 3.1). Then the records labeled true with selected optimal attribute values of are used for further process of finding Heuristic scale from strayed prone training records (records those labeled true) $hs_{sr}$ (heuristic scale from strayed records) . Similarly the records labeled false with optimal attribute values are used to devise heuristic scale from normal records $hs_{nr}$ of dataset.

Let set of strayed records $SR = \{sr_1, sr_2, sr_3, .......sr_n\}$ and set of normal records $NR = \{nr_1, nr_2, nr_3, .......nr_n\}$ formed by the values of optimal attributes selected (see section 3.2) from records labeled as true and records labeled as false respectively.

Prepare a sets $FS(SR) = \{a_1v_1, a_1v_2, .......a_1v_{m1}, a_2v_1, a_2v_2, ......a_2v_{m2}, ........., a_nv_1, a_nv_2, .....a_nv_{mn}\}$

and $FS(NR) = \{b_1v_1, b_1v_2, .......b_1v_{q1}, b_2v_1, b_2v_2, ......b_2v_{q2}, ........., b_pv_1, b_pv_2, .....b_pv_{qp}\}$, those contains all the unique values of all attributes of $SR$ and $NR$ respectively.

Here $\{a_1v_1, a_1v_2, ........, a_1v_{m1} \exists 0 < m1 <= |SR|\}, .........,$ $\{a_nv_1, a_nv_2, ........, a_nv_{mn} \exists 0 < mn <= |SR|\}$ presents the all possible unique values of optimal attributes $\{a_1 \in SR\}, ....., \{a_n \in SR\}$ respectively.

Similarly $\{b_1v_1, b_1v_2, ........, b_1v_{q1} \exists 0 < q1 <= |NR|\}, .........,$ $\{b_pv_1, a_pv_2, ........, a_pv_{qp} \exists 0 < q_p <= |NR|\}$ represents the all possible unique values of the optimal attributes $\{b_1 \in NR\}, ......\{b_p \in NR\}$ respectively. Further the values of the set $FS(SR)$ and $FS(NR)$ are referred as respective features of $SR$ and $NR$.

Further we build a weighted graph $WG$ such that values of $FS(SR)$ as vertices and edges between these vertices under the constraints such as:

a) No edge is between two vertices, if those two are values of same attribute
b) An edge between two vertices that justifies the above condition is possible if those two vertices are appeared together in at least one given record.

Each edge weighted by the ratio of the given records contains the two vertices of the edge.

Further the closeness of the features $FS(SR)$ and records $SR$ is assessed by using bipartite graph (see fig 7) build between those records and features.

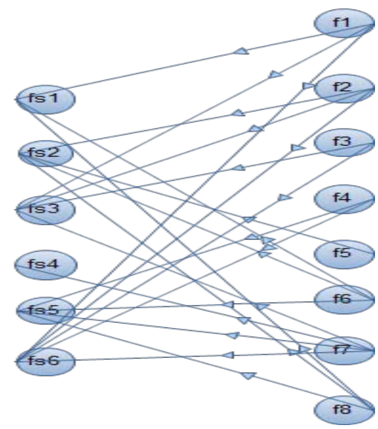


*Fig. 7 :* An example bipartite graph between features and records.

The edge between a feature $\{f_i \exists f_i \in FS(SR)\}$ and record $\{r_j \exists SR\}$ is the average of the edge weights between $f_i$ and all other features in $r_j$ found in weighted graph $WG$ (see Eq1)

$$ew_{(r_i \leftrightarrow f_j)} = \frac{\sum_{k=1}^{k<|r_i|} \{ew_{f_k \leftrightarrow f_j}\ \forall f_k \in r_i \wedge k \neq j\}}{|r_i|} \ .... \quad \text{(Eq1)}$$

Then the feature weights from the bipartite graph are assessed as follows:

Initially a matrix that contains the edge weights of bipartite graph will be formed, such that each feature weight towards each record.

Further the link based ranking model [23] will be applied on bipartite graph (see fig 7) to evaluate the connected set. The confidence of each record $r$ is proportionate to degree of all feature weights. Hence the influence of record $r$ will be derived from these weights. Intuitively, a record with high confidence should contain many of the features. This approach is as follows.

Let matrix representation of records and features of set $FS(SR)$ as a matrix '$M$'. The value represents the edge weight between record and features that calculated by using Eq1.

Find Feature support as matrix $FC$ by summing up the columns of each row of matrix $M'$ (which is transpose of matrix $M$) that represents edge weights between a feature of $FS(SR)$ and all records of $SR$.

The matrix multiplication between $M$ and $FC$ to obtain the record support.

$$RC = M \times FC$$

Then the confidence of each feature $\{f \exists f \in FS(SR)\}$ can be measured as follows

$$c(f) = \frac{\sum_{i=1}^{|SR|} \{RC(r_i) \exists f \subset r_i\}}{\sum_{i=1}^{|SR|} RC(r_i)}$$

$$hssp_{SR}(r_i) = 1 - \frac{\sum_{j=1}^{|FS(SR)|} \{c(f_j) \exists f_j \subset r_i\}}{ec(r_i)}$$

$ec(r_i)$ in above equation represents the edge count connected to record $r_i$

Then the heuristic scale of strayed proneness by strayed records $hssp_{SR}$ can be found as follows:

$$hssp_{SR} = \frac{\sum_{i=1}^{|SR|} \{hssp(r_i) \exists r_i \in SR\}}{|SR|}$$

Here, $|SR|$ indicates the records count

Further find the probable deviation of the " $hssp_{SR}$ " of records from $SR$ as follows:

$$pd(hssp_{SR}) = \sqrt{\frac{\left(\sum_{i=1}^{|SR|} (\{hssp(r_i) \exists r_i \in SR\} - hssp_{SR})^2\right)}{(|SR| - 1)}}$$

Here in the above equation $pd(hssp_{SR})$ represents the probable deviation of the strayed proneness of records of $SR$

The procedure that followed to assess the $hssp_{SR}$ (heuristic scale to strayed proneness) and $pd(hssp_{SR})$ (probable deviation) from records of the $SR$ will be adopted to assess the heuristic scale to strayed proneness $hssp_{NR}$ and probable deviation $pd(hssp_{NR})$ of the records of $NR$.

Further these scales can be used to diagnose the scope of a given recordis Strayed Prone or normal, which is as follows:

i) Record $r$ is said to be as Strayed Prone if
$hssp_{SR}(r) > hssp_{SR} \,||$
$hssp_{NR}(r) < (hssp_{NR} - pd(hssp_{NR}))$

ii) Record $r$ is said to benormal if and only if
$hssp_{NR}(r) > hssp_{NR} \,||$
$hssp_{SR}(r) < (hssp_{SR} - pd(hssp_{SR}))$

## IV. Experimental Study

The real time data (see sec 3.1) was used in experimental study. The overall data collected is the size of 303labeled records and each record contains 24 fields. Among these 213 records were used as training set to define the scale proposed. The remaining 90 records were used to test the scale defined in training phase. The empirical study delivered promising results. The statistics explored in table 2

*Table 2 :* Statistics of the experiment results

| | |
|---|---|
| $hssp_{SR}$ | 7.11324 |
| $pd(hssp_{SR})$ | 1.538036 |
| $hssp_{NR}$ | 2.982372 |
| $pd(hssp_{NR})$ | 0.623142 |

The attributes of the records selected as optimal under different hamming distances thresholds are defined in tables 5, 6 and 7 and the same is visualized in fig 8.

*Table 3 :* Hamming Distance Ratio of all 24 features of strayed records under normal records

| Attribute ID | HD |
|---|---|
| 1 | 0.082736 |
| 2 | 0.052226 |
| 3 | 0.075507 |
| 4 | 0.035821 |
| 5 | 0.027238 |

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| | |
|---|---|
| 6 | 0.093627 |
| 7 | 0.07556 |
| 8 | 0.048156 |
| 9 | 0.057556 |
| 10 | 0.081826 |
| 11 | 0.068945 |
| 12 | 0.073293 |
| 13 | 0.039087 |
| 14 | 0.084389 |
| 15 | 0.089146 |
| 16 | 0.06504 |
| 17 | 0.048562 |
| 18 | 0.049054 |
| 19 | 0.020102 |
| 20 | 0.047748 |
| 21 | 0.071742 |
| 22 | 0.089284 |
| 23 | 0.056242 |
| 24 | 0.027358 |

*Table 4 :* Selected features of the strayed records with canonical correlation threshold >0.054 (mean of the hamming distance of all features)

| Attribute ID | Hamming Distance Ratio |
|---|---|
| 1 | 0.082736 |
| 3 | 0.075507 |
| 6 | 0.093627 |
| 7 | 0.07556 |
| 9 | 0.057556 |
| 10 | 0.081826 |
| 11 | 0.068945 |
| 12 | 0.073293 |
| 14 | 0.084389 |
| 15 | 0.089146 |
| 16 | 0.06504 |
| 21 | 0.071742 |
| 22 | 0.089284 |
| 23 | 0.056242 |

*Table 5 :* Selected features of the strayed records with Hamming Distance Threshold>0.025

| Attribute ID | Hamming Distance Ratio |
|---|---|
| 1 | 0.082736 |
| 2 | 0.052226 |
| 3 | 0.075507 |
| 4 | 0.035821 |

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| | |
|---|---|
| 5 | 0.027238 |
| 6 | 0.093627 |
| 7 | 0.07556 |
| 8 | 0.048156 |
| 9 | 0.057556 |
| 10 | 0.081826 |
| 11 | 0.068945 |
| 12 | 0.073293 |
| 13 | 0.039087 |
| 14 | 0.084389 |
| 15 | 0.089146 |
| 16 | 0.06504 |
| 17 | 0.048562 |
| 18 | 0.049054 |
| 20 | 0.047748 |
| 21 | 0.071742 |
| 22 | 0.089284 |
| 23 | 0.056242 |
| 24 | 0.027358 |

*Table 6 :* Selected features of the strayed records with canonical correlation threshold >0.082

| Attribute ID | Hamming Distance Ratio |
|---|---|
| 1 | 0.082736 |
| 6 | 0.093627 |
| 14 | 0.084389 |
| 15 | 0.089146 |
| 22 | 0.089284 |

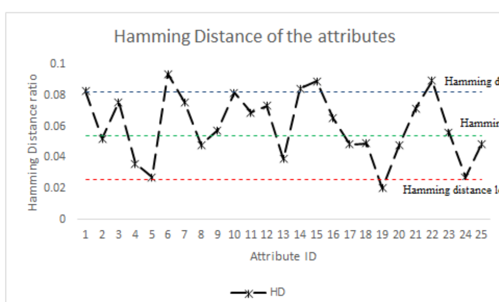


*Fig. 8 :* A line chart that representing the attributes scope under different hamming Distance thresholds

a) *Performance Analysis*

The results obtained for hamming distance threshold is greater than 0.082 are (i) false negatives:4 (strayed record claimed as normal),(ii) true negative are 17 (claimed records normal that are actually normal), true positives: 66,(iii) false positives: 3, and the prediction accuracy is 92.3%.

The experiments also conducted on the same data set under hamming distance ratio >0.052 and >0.025, the results are as follows:

Total records Tested 30% (90 records)(70 strayed records and 20 normal records) hamming distance ratio is greater than 0.052

Total number of records found false negative are 2(strayed record claimed as normal) and found to be true negative are 19 (claimed records normal that are actually normal)

Total number of records found to be true positives are 68 and false positives are1

As per these results, the accuracy of the proposed heuristic scale under hamming distance ratio of 0.052 is 96.5%.

The accuracy observed from the attributes selected under hamming distance ratio >0.25 also reflected the same performance accuracy, but delivered magnitude computational overhead that compared to the computational overhead observed under hamming distance ratio greater than 0.052

The observed time complexity is scalable since the completion time is incrementing with the same ratio against the increase in features count due to lower hamming distance ratio (see fig 9).

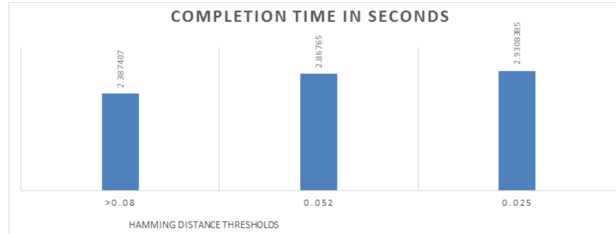


*Fig. 9 :* The completion time of defining HSSP under divergent hamming distance ratios

Hence it is obvious to conclude that hamming distance based optimized attribute selectionis significant to minimize the computational overhead of the proposal, which is done without loss of accuracy.

*Table 6 :* Results observed for statistical metrics under divergent hamming distance thresholds.

| Hamming Distance Ratio | Precision | Recall | f-measure |
|---|---|---|---|
| >0.08 | 0.9565217 | 0.9850746 | 0.9705882 |
| >0.052 | 0.9714285 | 0.9714285 | 0.9714285 |
| >0.025 | 0.9715507 | 0.9714286 | 0.9714896 |

The statistical metrics [8], such as precision, recall, and F-measure were used along with prediction accuracy. The result obtained for these metrics under divergent hamming distance thresholds are explored in table 13 and visualized in fig 10

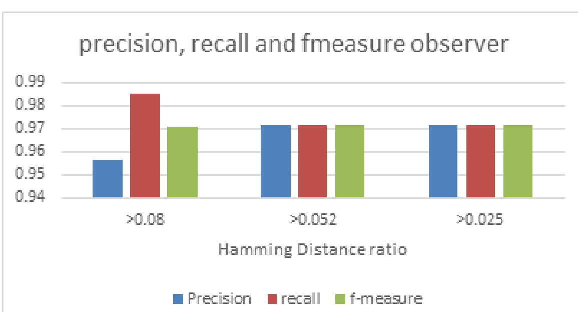


*Fig. 10 :* performance analysis of the prediction accuracy under divergent hamming distance thresholds given.

## V. Conclusion

Heuristic scales to assess strayed proneness of the OHE provided on railway cross- over tracks has been proposed in this paper. The Hamming Distance Analysis of the recorded attributes is devised to obtain the optimal attributes, which is promising to simplify the process of defining Heuristic Scale to Strayed Proneness of the line cross-over's. The reinforcement relation between records and attribute values is analyzed to define the proposed heuristic scale. In order to this the proposed model is using a weighted graph that built by using optimal attribute values as vertices and their associativity scope as edge weight. The other significance of the proposed heuristic scale is that a given report of a line cross over is assessed by couple of heuristic scales called $hssp_{SR}$ and $hssp_{NR}$ , which are built from the respective records of type strayed and normal. The experiments were done using real time data collected from Secundrabad division of South Central Railway zone. The exploration of the results concluding that the Hamming Distance Analysis is promising and significant to select optimal attributes of the records dataset. The heuristic scales proposed are observed to be robust and is with minimal process complexity and retains the maximal prediction accuracy. In future the evolutionary computational approach like GA, CUCKOO search can be devised.

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# Factors influencing the choice of Travel Mode in Inclement Weather Conditions in Indian cities

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*Abstract-* Indian roads in medium size cities have witnessed large number of two wheeler users in the recent years. It is observed that their volume varies according to the prevailing weather conditions. Although efficient mode selection in inclement weather conditions is an important issue for the convenience of commuters, their socioeconomic condition is a major governing factor for modal shift. The study aims to understand the relationship of socioeconomic status with mode change in inclement weather conditions with respect to work trips of two wheeler users. It also tries to understand the importance of affordability, comfort, trip duration, reliability and maneuverability across different socioeconomic classes.

*Keywords: socioeconomic status, inclement weather conditions, affordability, comfort, trip duration, reliability, maneuverability.*

*GJRE-J Classification : FOR Code: 291899*

# Factors influencing the choice of Travel Mode in Inclement Weather Conditions in Indian cities

Parampreet Kaur [α], Uttam Kumar Banerjee [σ] & Abraham George [ρ]

*Abstract-* Indian roads in medium size cities have witnessed large number of two wheeler users in the recent years. It is observed that their volume varies according to the prevailing weather conditions. Although efficient mode selection in inclement weather conditions is an important issue for the convenience of commuters, their socioeconomic condition is a major governing factor for modal shift. The study aims to understand the relationship of socioeconomic status with mode change in inclement weather conditions with respect to work trips of two wheeler users. It also tries to understand the importance of affordability, comfort, trip duration, reliability and maneuverability across different socioeconomic classes.

*Keywords: socioeconomic status, inclement weather conditions, affordability, comfort, trip duration, reliability, maneuverability.*

## I. Introduction

Commuting in inclement weather conditions like rain, fog and extremely hot or cold temperature, is difficult for the two wheeler users. It is observed that people switch their mode or their departure time to avoid any potential inconvenience on their way to work. Inclement weather conditions demand better, convenient and economically affordable traveling modes to different socioeconomic classes.

There have been studies done on inclement weather travel behavior but they mainly focus on car, bus and rail transit system and were conducted in western countries (Khattak & Palma, 1997) (Khattak A. , 1991) (Sumalee, Uchida, & William, 2011). India has a large population of two-wheeler users and in some cities it accounts for more than fifty percentage of modal split. In Indian medium size cities, due to poor public transportation and shorter trip length, commuters naturally depend on personal mode; mainly two-wheelers for their daily commute.

It has been observed that the commuter's behavior changes in adverse weather conditions in search of convenient options. A thorough understanding of their character and behavior is essential for the efficient planning and management of transportation systems under such situations. Studies have shown that socioeconomic conditions are dominant factors for mode selection under normal conditions (Williams, 1978). Mode shifts in inclement weather conditions are more profound across different socioeconomic status. In medium size cities like Raipur and Jamshedpur: two wheelers and pedestrians are mostly affected in adverse situations and have large share of the modal split (Authority, 2008) (JJNURM). The prevalent modal shift takes a toll on traffic and transportation networks and they get heavily affected during inclement weather conditions.

Socio-economic status; (SES) which is a combined score of income, occupation and education, is generally considered in medical, marketing and social science studies. It has been observed that higher SES is associated with higher rates of automobile ownership and greater fuel affordability, especially when income is higher (Giles-Corti & Donovan, 2002). A study done in Adelaide, Australia, indicates that higher level of education is related to higher frequency of transport (Cerin, Leslie, & Owen, 2009). Though the use of SES is new to transport related studies, its components i.e. income, education and occupation have established significance in mode selection. Education governs knowledge, attitude and value system of individual and their socioeconomic growth potential. Occupation determines the income generation capacity and social standing of an individual. Income helps to understand their purchase power and socioeconomic status (Parashar, 2009). In this respect, SES holds great potential to understand mode selection patterns across different socio economic classes. For this study kupuswamy's SES scale is taken and correction were made to the base year 2013. This scale divides the population in five major classes, namely; Upper, Upper middle, Lower middle, Upper lower and Lower.

Fourteen variables are found important in mode selection, which are combined to form five factors, namely, Affordability, Comfort, and Trip duration, Reliability and Maneuverability. Criteria for mode selection are given in table 1.

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*Table 1:* Criteria for Mode Change

| Sl. No | Criteria | Variables |
|---|---|---|
| 1 | Affordability | Fare /cost of travel, (Savage, 2010) |
| | | Time value in terms of money (Horowitz) |
| 2 | Comfort (W.Recker & Golob, 1976) | Thermal comfort, |
| | | Convenience , |
| | | Physical comfort, |
| | | Weather proofing |
| 3. | Trip duration | Walking time, (Khattak & Palma, 1997) (Sumalee, Uchida, & William, 2011) |
| | | Waiting time, (Khattak & Palma, 1997) (Sumalee, Uchida, & William, 2011) |
| | | Transfer time, (Khattak & Palma, 1997) (Sumalee, Uchida, & William, 2011) |
| | | In vehicle time (Khattak & Palma, 1997) (Sumalee, Uchida, & William, 2011) |
| 4 | Reliability | Availability of mode, (Lam, Shao, & Sumalee, 2008) |
| | | Regularity, (Sumalee, Uchida, & William, 2011) |
| 5. | Maneuverability | Hindrance to travel, (Rodrıguez & Joo, 2004) |
| | | Terrain impact (Rodrıguez & Joo, 2004) |

Inclement weather conditions are classified for this study based on classification given by Indian Meteorological Department, which are further combined to form nine inclement weather conditions for moist sub humid climate in this study. Table 2 indicates the nine inclement weather conditions.

*Table 2 :* Categorization of Inclement Weather Conditions for Survey Design

| Sl. No | Weather description in Study | Scientific description |
|---|---|---|
| Summer | | |
| 1. | Hot day | Whenever, the maximum temperature remains 40$^{o}$C or more and minimum temperature is 5$^{o}$ C or more above normal, it may be defined as Hot Day, provided it doesn't satisfy the heat wave criteria given below. (Indian metrological department Pune) |
| 2. | Hot-humid | Relative humidity of 60% or greater. |
| 3. | Heat Wave | Heat wave need not be considered till maximum temperature of a |
| | | station reaches at least 40$^{o}$ C for Plains and at least 30$^{o}$ C for Hilly regions. a) When normal maximum temperature of a station is less than or equal to 40$^{o}$ C. Heat Wave Departure from normal is 5$^{o}$ C to 6$^{o}$ station reaches at least 40$^{o}$ C for |

| | | |
|---|---|---|
| | | Plains and at least 30$^{o}$ C for Hilly regions.<br>a) When normal maximum temperature of a station is less than or equal to 40$^{o}$ C. Heat Wave Departure from normal is 5$^{o}$ C to 6$^{o}$ C Severe Heat Wave Departure from normal is 7$^{o}$ C or more<br>b) When normal maximum temperature of a station is more than 40$^{o}$ C, Heat Wave Departure from normal is 4$^{o}$ C to 5$^{o}$ C, Severe Heat Wave Departure from normal is 6$^{o}$ C or more<br>c) When actual maximum temperature remains 45$^{o}$C or more irrespective of normal maximum temperature, heat wave should be declared. (Indian metrological department Pune) |
| Monsoon | | |
| 4. | Light Rain | include light rain, moderate rain i.e. when rainfall is between (2.5 to 35.5 mm per day) (Indian metrological department Pune) |
| 5. | Heavy rain | Heavy rain. i.e. rainfall between 35.6-124.4mm (Indian metrological department Pune) |
| 6. | Very heavy rain | will includes very heavy, extremely heavy and exceptionally heavy rain with precipitation ≥124.5mm or thunderstorm (Indian metrological department Pune) |
| Winter | | |
| 7. | Cold | In the plains of north India, foggy conditions prevail during winter for several days or weeks. The minimum temperature on these days remains above normal, while maximum temperatures remain much below normal. This creates cold conditions for prolonged period. When maximum temperature is less than or equal to 16°C in Plains (Indian metrological department Pune) |
| 8. | Cold wave | Wind chill factor (WCTn) is taken into account while declaring the cold wave situation.Departure of WCTn from normal minimum temperature is from–5°C to–6 C where normal minimum temperature > 10°C and from –4°C to –5°C elsewhere, Cold Wave is declared. For declaring cold wave etc. WCTn only is used and when it is< 10°C only, cold wave is considered. (Indian |

| | | |
|---|---|---|
| | | metrological department Pune) |
| 9. | Cold with precipitation | When cold is accompanied by any type of precipitation which further reduces the temperature. |
| 10. Normal Weather Conditions (Prevailing climate of the region) | | |

This study aims to understand the relationship between SES and use of two-wheelers in various adverse weather conditions. It also tries to verify the impact of five different criteria namely affordability, comfort, trip duration, maneuverability and reliability on mode selection.

## II. The Study

*a) Obejectives of the study*

The main objective of this study is to find relationship between SES and use of two-wheelers; both motorized and non-motorized, in inclement weather condition. Further the study attempts to find the importance of five factors affordability, comfort, trip duration, maneuverability and reliability in mode selection in normal and inclement weather conditions.

*b) Case Study Areas*

Two medium size cities; Raipur and Jamshedpur with comparable demographic and climate where chosen for the study. Table 3 summarizes the details of both the cities.

*Table 3 :* Description of Raipur and Jamshedpur (Authority, 2008) (Jjnurm)

| | Raipur AU | Jamshedpur AU |
|---|---|---|
| Population | 1,122,555 | 1,337,131 |
| Percentage of work force (%) in urban area, state wise | 31.11 | 25.68 |
| Climate | Tropical Wet and Dry Climate | Tropical Wet and Dry Climate |
| Elevation (m) | 298.15 | 159 |
| Max temperature ( o C) | 48 | 49 |
| Min Temperature( o C) | 5 | 1 |
| Precipitation( mm) annually | 1300 | 1200 |
| Percentage of two-wheeler | 66 | 75 |

*c) Main Survey questionaire*

A close end Questionnaire was prepared for data collection. Respondent's demographic profile, general transportation information, their perspective in ten different weather situations on five factors namely: affordability, comfort, trip duration, reliability and maneuverability were obtained in five point Likert scale. Rating of all the weather conditions were also done with respect to its importance in decision making. Subjective explanation of each weather condition and variable were explained to the respondent in order to obtain reliable data.

*d) Data Collection*

In this study, data were collected through primary survey on 1060 people from Raipur and Jamshedpur. Raipur and Jamshedpur cities have population of 1.12 million and 1.33 million respectively (Authority, 2008) (JJNURM). For the population above 1 million, for 95% confidence interval with 5% margin of error, a sample size of 384 is suggested in sample table. With 80 % response rate 480 responses were collected from each city, in three seasons' winter (February, 2013), summer (May,2013) and monsoon (July, 2013). Out of the 480 responses in each city, 430 in Raipur and 444 in Jamshedpur was found valid for analysis.

After conducting surveys at Raipur and Jamshedpur in three different seasons, data were coded and entered in SPSS19 for analysis. Data on income, occupation and education were collected on SES scale at the time of survey and then SES score was computed to distribute the sample in different socioeconomic classes and analyses were performed.

## III. Results

*a) Kuppuswamy's SES and mode of travel for work trips*

After collation of data it was observed that upper lower has highest number of cyclist for work trips. Apart from motorcycle / automated two wheeler, Raipur's Upper middle and lower middle class uses auto rickshaw and bus for commuting whereas, in Jamshedpur auto rickshaw users were from lower middle and upper lower class. Use of motorcycle/ automated two-wheeler were recorded in every class except lower in both the cities, whereas car usage was observed in upper, upper middle and lower middle class. Lower class people who own a bicycle in both the cities depended on it for daily commute.

*Table 4 :* Kuppuswamy's Ses and Mode of Travel for Work Trips ,Raipur

| Mode | Upper | Upper Middle | Lower middle | Upper lower | Lower (Unit) |
|---|---|---|---|---|---|
| Cycle | 0 | 5 | 54 | 76 | 8 |
| Automated two Wheeler | 37 | 145 | 100 | 23 | 0 |
| Car | 23 | 36 | 1 | 0 | 0 |
| Auto rickshaw | 3 | 9 | 9 | 5 | 0 |
| Bus | 4 | 13 | 15 | 3 | 0 |
| Cycle Rickshaw | 0 | 0 | 0 | 0 | 0 |
| Walk | 0 | 0 | 1 | 0 | 0 |

*Table 5 :* Kuppuswamy's Ses and Mode of Travel for Work Trips, Jamshedpur

| Mode | Upper | Upper Middle | Lower middle | Upper lower | Lower |
|---|---|---|---|---|---|
| Cycle | 0 | 3 | 53 | 97 | 10 |
| Automated two Wheeler | 15 | 139 | 126 | 22 | 0 |
| Car | 8 | 43 | 1 | 0 | 0 |
| Auto rickshaw | 0 | 1 | 6 | 6 | 0 |
| Bus | 0 | 1 | 1 | 2 | 0 |
| Cycle Rickshaw | 0 | 0 | 0 | 0 | 0 |
| Walk | 0 | 0 | 0 | 0 | 0 |

*b) Kuppuswamy's SES and Mode Change in Different Weather Conditions*

When survey was conducted it was observed that people change their mode in inclement weather conditions but after the SES categorization and graph plotting it became evident that mode change varies among different SES classes for same inclement weather conditions. From the Table 7 we can observe that upper class people in Raipur are more inclined to change their mode in adverse weather than Jamshedpur. Upper middle class showed similar modal shift pattern in both the cities where as lower middle and upper lower class of Raipur shift modes more frequently than Jamshedpur. In order to find the association of mode change and SES, Chi - Square test of independence was performed on Kuppuswamy's SES and Mode change in nine given inclement weather situations. For this the null hypothesis and research hypothesis were as follows:

*H0* = No relationship exists between Kuppuswamy SES and mode change in the given nine different inclement weather conditions from the normal condition.

*H1* = Relationship exists between Kuppuswamy SES and mode change in the given Nine different inclement weather conditions from the normal condition.

*Table 6 :* Relationship Between Kuppuswamy's Ses and Mode Change in Different Inclement Weather Conditions

| Inclement weather conditions | Raipur | | | Jamshedpur | | |
|---|---|---|---|---|---|---|
| | Pearson Chi square value | Phi and Cramer's V value | Relationship | Pearson Chi square value | Phi and Cramer's V value | Relationship |
| Hot | X2 (4,N=430) =2.87, p=.58 | .082 | No | X2 (4,N=444) =1.71, p=.789 | .062 | No relation |
| Hot humid | X2 (4,N=430) =36.57, p<.001 | .292 | Fair | X2 (4,N=444) =14.69, p=.005 | .182 | Little |
| Heat wave | X2 (4,N=430) =51.99, p<.001 | .348 | Moderate | X2 (4,N=444) =29.52, p<.001 | .258 | Fair |
| Light rain | X2 (4,N=430) =52.592, p<.001 | .350 | Moderate | X2 (4,N=444) =12.14, p=.016 | .165 | Little |
| Heavy rain | X2 (4,N=430) =65.364, p<.001 | .390 | Moderate | X2 (4,N=444) =34.105, p<.001 | .277 | Fair |
| Very heavy rain | X2 (4,N=430) =56.294, p<.001 | .362 | Moderate | X2 (4,N=444) =36.451, p<.001 | .287 | Fair |
| Cold | X2 (4,N=430) =2.096,p=.718 | .070 | No relation | X2 (4,N=444) =.93, p=.92 | .046 | No relation |
| Cold wave | X2 (4,N=430) =18.89, p<.001 | .210 | Little | X2 (4,N=444) =9.259, p=.055 | .144 | No relation |
| Cold with precipitation | X2 (4,N=430) =46.059, p<.001 | .327 | Moderate | X2 (4,N=444) =37.918, p<.001 | .292 | Fair |

Table 6 list the Chi-square value and outcome of the test performed. In some Socio economic studies correlation of 0.26 to 0.50 are considered high when they occur in multiple regression models where one variable is calculated by the use of more than one variable. Cramer's V value indicates the correlation and p value in Pearson Chi square represent the level of significance. It indicates that in all the cases except hot, cold and cold wave in Jamshedpur, there is significant relation of mode change with SES. Considering other external factors like, availability of other options, willingness to change, and combined effect of all the socioeconomic classes in analysis the small value of association is significant. Raipur has higher value of correlation in every weather conditions as compared to Jamshedpur. It has been observed that maximum positive correlation was found in heavy rain situation in Raipur followed by very heavy rain. Further Table 7 Indicates, SES class wise percentage of modal shift in all inclement weather condition. This indicates that modal shift in any weather condition is maximum in upper class followed by upper middle; lower middle and upper lower. It also indicates that people tend to shift their modes more in very heavy and heavy rain situations. Further, they are more likely to shift their mode in Heat wave condition in Raipur and Cold with precipitation condition in Jamshedpur. Mode shift in hot and cold weather is found to be marginal. From the analysis it is evident that Raipur's modal shift is more sensitive to inclement weather as compared to Jamshedpur. From both the tables it can be concluded that Hot and cold weather does not impact the mode choice decision, whereas hot - humid, light rain and cold wave have moderate impact in both the cities. Heat wave, heavy rain, very heavy rain and cold with precipitation have significant impact on the choice of travel mode.

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*Table 7 :* Percentage of Mode Change in Different Inclement Weather Conditions

| Inclement weather conditions | Raipur SES Class | | | | | Jamshedpur SES Class | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Upper | Upper middle | Lower middle | Upper lower | Lower | Upper | Upper middle | Lower middle | Upper lower | lower |
| Hot | 2.7 | 0.7 | 0.7 | 0 | 0 | 0 | 0 | 0.6 | 0.3 | 0 |
| Hot humid | 37.8 | 10.8 | 8.5 | 3.2 | 0 | 20 | 12.1 | 4.9 | 2.6 | 0 |
| Heat wave | 64.9 | 24.3 | 18.3 | 9.5 | 0 | 33.3 | 26.2 | 11.6 | 5.3 | 0 |
| Light rain | 43.2 | 10.1 | 7.7 | 2.1 | 0 | 26.7 | 15.6 | 8.5 | 6.1 | 0 |
| Heavy rain | 67.6 | 27.0 | 14.1 | 8.4 | 0 | 53.3 | 30.5 | 12.8 | 11.4 | 0 |
| Very heavy rain | 73.0 | 35.8 | 24.6 | 11.6 | 0 | 53.3 | 32.6 | 12.8 | 12.3 | 0 |
| Cold | 2.7 | 1.4 | 1.4 | 0 | 0 | 0 | 0.7 | 0.6 | 0 | 0 |
| Cold wave | 18.9 | 3.5 | 1.1 | 5.5 | 0 | 6.7 | 5.0 | 0.6 | 0.9 | 0 |
| Cold with precipitation | 56.8 | 27.7 | 18.3 | 6.3 | 0 | 46.7 | 27.0 | 10.4 | 6.1 | 0 |

c) *Importance of five factors in mode change across nine inclement weather conditions.*

Table 8 Indicates the Spearman rho correlation between mode change and five factors namely Affordability, Comfort, Trip duration, Reliability, and Maneuverability in nine different inclement weather conditions. Further the graphs from 1 to 10 indicate the weighted value of all the five factors across Kuppuswamy's Socioeconomic Classes.

*Table 8 :* Spearman Rho Correlation Between Mode Change and Five Factors in Different Inclement Weather Conditions

| Inclement weather conditions | Raipur | | | | | Jamshedpur | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Affordability | Comfort | Trip duration | Reliability | Maneuverability | Affordability | Comfort | Trip duration | Reliability | Maneuverability |
| Hot | -.103 | .101 | .071 | .002 | -.047 | .038 | .087 | .008 | -.031 | -.023 |
| Hot Humid | -.555 | .332 | .110 | .104 | -.002 | -.268 | .164 | .034 | -.042 | -.107 |
| Heat Wave | -.626 | .315 | .174 | .136 | .039 | -.365 | .095 | -.004 | .080 | -.052 |
| Light Rain | -.557 | .389 | .259 | -.059 | .094 | -.469 | .303 | .007 | -.001 | -.013 |
| Heavy Rain | -.625 | .445 | .102 | -.020 | .027 | -. 429 | .218 | .003 | .042 | -.052 |
| Very Heavy Rain | -.588 | .430 | .155 | .140 | .025 | -.359 | .274 | -.015 | .069 | -.024 |
| Cold | -.164 | .186 | .110 | .032 | .001 | -.130 | .096 | -.045 | -.042 | .004 |
| Cold Wave | -.424 | .282 | .098 | -.067 | -.047 | -.188 | .131 | -.006 | -.002 | .012 |
| Cold with Precipitation | -.644 | .376 | .214 | .151 | .118 | -.376 | .189 | -.039 | .116 | .063 |

Affordability is found to be correlated with a significance level of 0.05 to mode change in all the nine inclement weather conditions in Raipur and eight in Jamshedpur excluding hot days. The negative sign in the values indicates the negative correlation which states that as the importance of affordability decreases, the number of mode change increases. In Raipur affordability has maximum impact in cold with precipitation whereas, in Jamshedpur it's in light rain conditions. Across the different weather conditions affordability is observed showing significant influence on the choice of mode change in heat waves, heavy rain, very heavy rain, hot humid and cold wave in Raipur whereas in Jamshedpur it has significant impact in light rain ,heavy rain, cold with precipitation and heat wave conditions.

After affordability, Comfort was found to be the second important factor in mode change in both the cities. It has positive correlation which indicates the increase in the value of comfort factor increases the chances of mode change across nine inclement weather conditions. In Raipur correlation was observed at the significance level of 0.05 in all the inclement weather conditions highest in heavy rain condition. Whereas in Jamshedpur, hot and hot humid conditions were excluded from the impact of comfort on choice of mode change, highest been in very heavy rain condition.

Trip duration is the third important factor in mode change in Raipur except in hot day condition, but it was not relevant in Jamshedpur. In Raipur the highest correlation was observed in light rain and cold with precipitation.

Reliability also seemed to be a deciding factor in Raipur and Jamshedpur but it has very less correlation and only statistically significant at 0.05 level of significance in cold with precipitation, very heavy rain, heat wave and hot humid conditions in Raipur and cold with precipitation in Jamshedpur. An increase in importance of reliability increases the chances of mode change.

Maneuverability was not an important factor in both the cities. It only had small significant correlation in cold with precipitation in Raipur and hot humid in Jamshedpur.

*d) Importance of five Factors Across Different Socio-Economic Classes in Normal and Nine Inclement Weather Conditions.*

To assess the importance of five factors across socio-economic groups, weighted average method of Likert scale was adopted. In this, the five choices within each factor was given weight from 1 to 5, assuming 1 being 'not at all important' to 5 being 'very much important' with equal interval. Then the weighted value for all the factors were calculated by multiplying the frequencies of responses to their assigned weights and then summing all the value in a factor to get a total score. These scores were then compared to get the importance of different factors according to user in different inclement weather conditions. Though the importance solely doesn't lead to mode change, but provides a perspective towards importance of five factors in respective weather condition according to different socioeconomic classes.

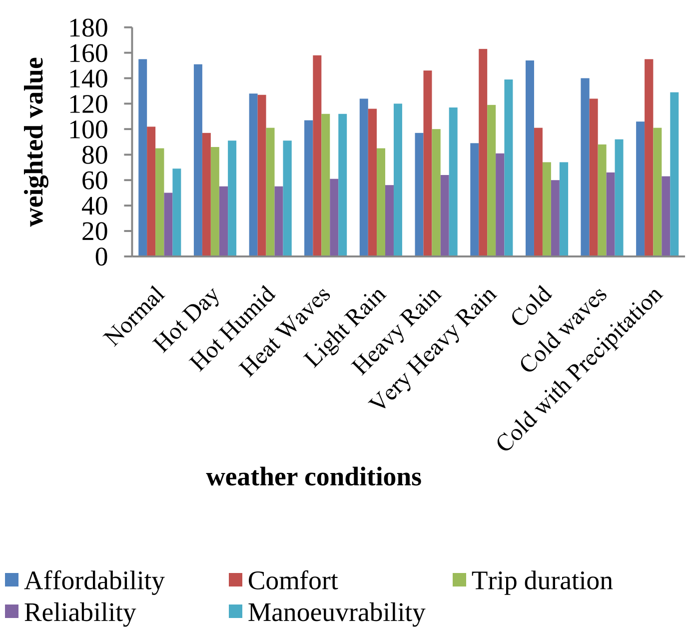


*Fig. 1 :* Raipur's Upper Class Likert Scale Values of Five Factors in Ten Weather Conditions

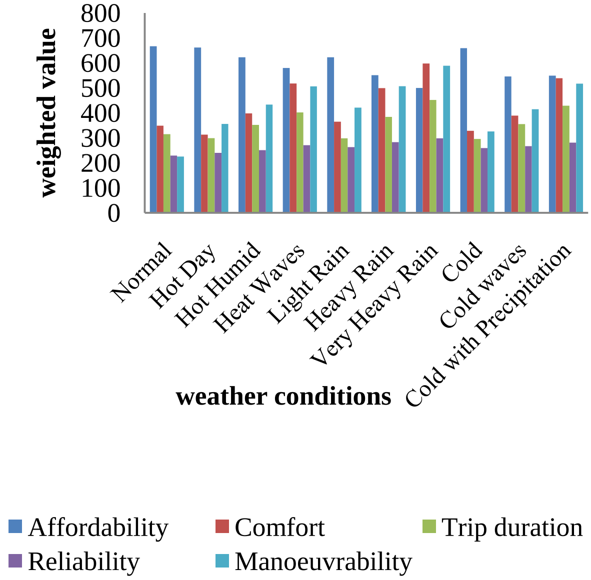


*Fig. 2 :* Raipur's Upper Middle Class Likert Scale Values of Five Factors in Ten Weather Conditions

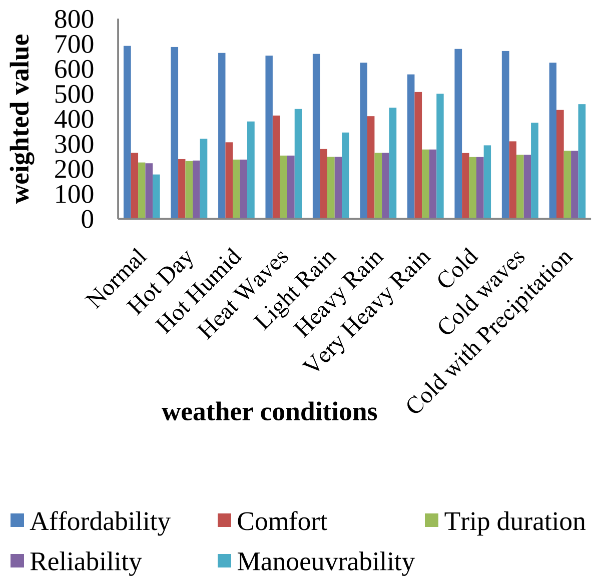


*Fig. 3 :* Raipur's Lower Middle Class Likert Scale Values of Five Factors in Ten Weather Conditions

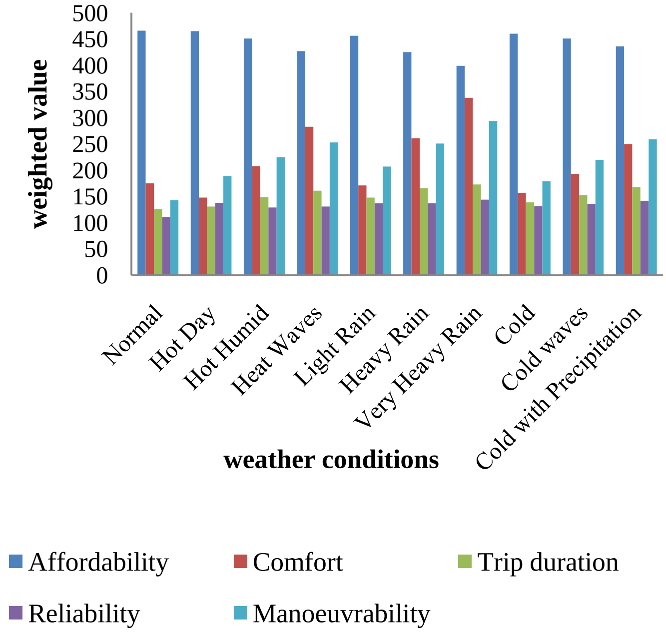


*Fig. 4 :* Raipur's Upper Lower Class Likert Scale Values of Five Factors in Ten Weather Conditions

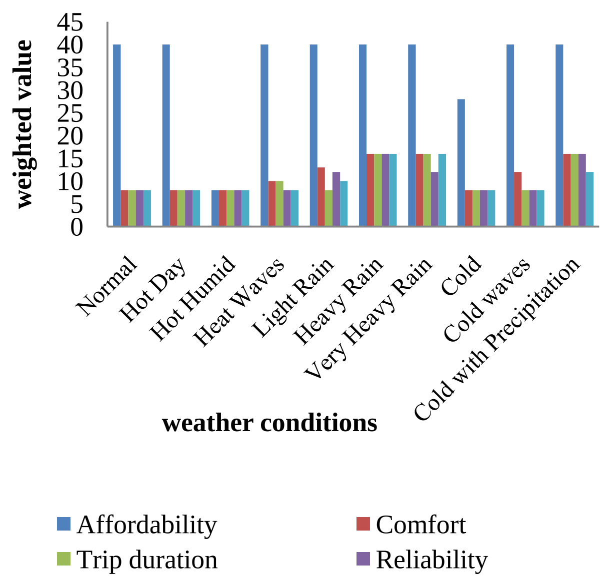


*Fig. 5 :* Raipur's Lower Class Likert Scale Values of Five Factors in Ten Weather Conditions

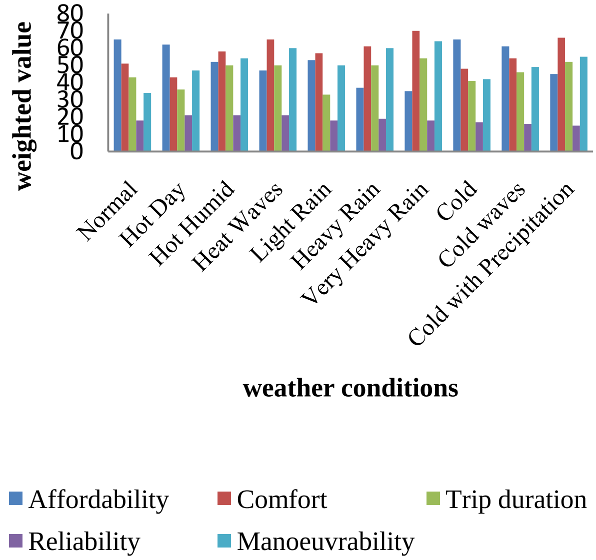


*Fig. 6 :* Jamshedpur's Upper Class Likert Scale Values of Five Factors in Ten Weather Conditions

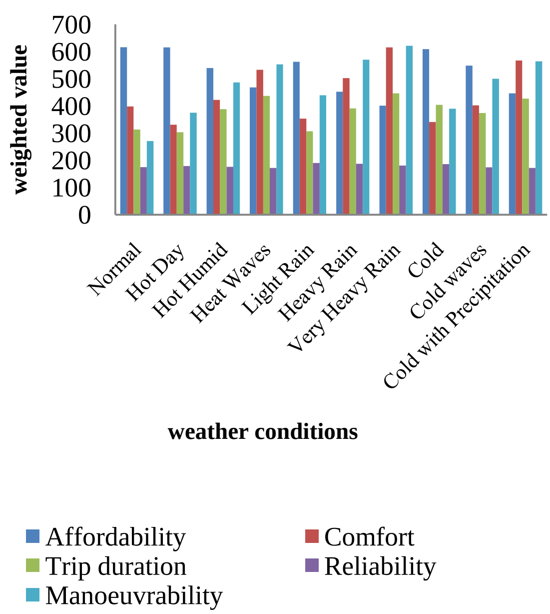


*Fig. 7 :* Jamshedpur's Upper Middle Class Likert Scale Values of Five Factors in Ten Weather Conditions

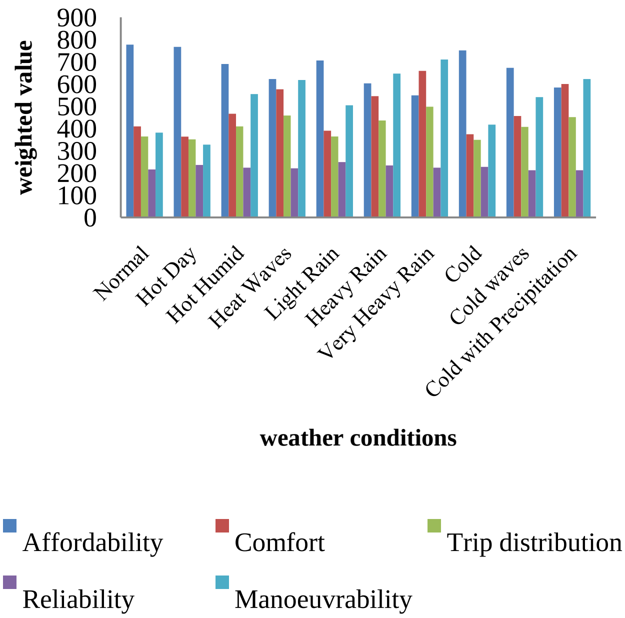


*Fig. 8 :* Jamshedpur's Lower Middle Class Likert Scale Values of Five Factors in Ten Weather Conditions

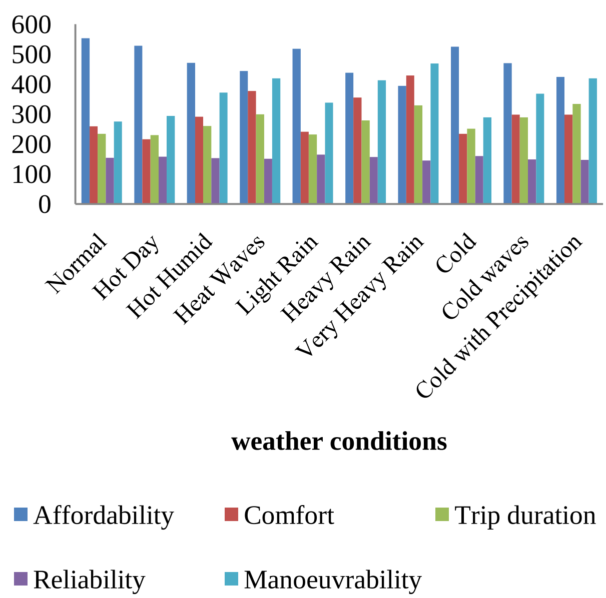


*Fig. 9 :* Jamshedpur's Upper Lower Class Likert Scale Values of Five Factors in Ten Weather Conditions

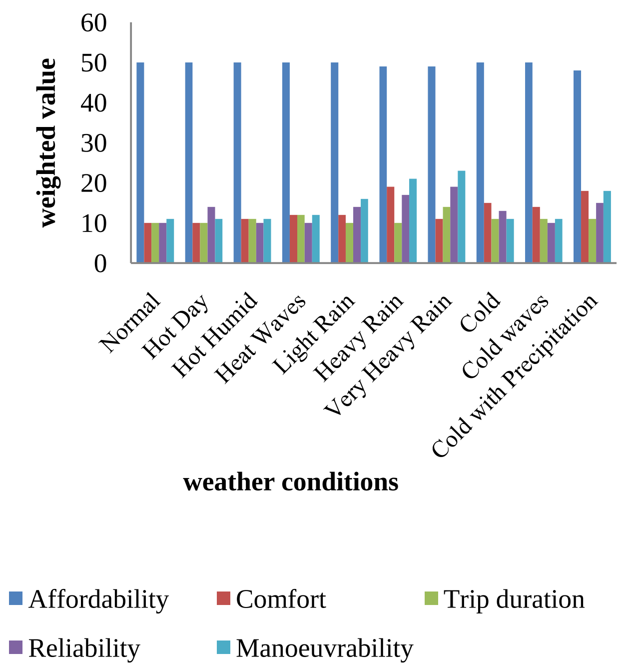


*Fig. 10 :* Jamshedpur's Lower Class Likert Scale Values of Five Factors in Ten Weather Conditions

It was observed that in normal condition affordability is the most important factor across the socioeconomic classes in both the cities. Comfort stood second in Raipur in all the cases where as maneuverability was seen to be second important concern in Upper lower and Lower classes of Jamshedpur. This may be because, after affordability, it was the second most important concern for these groups as they travel mostly by cycles. Maneuverability was the third important issue of Raipur commuters in Upper, Upper lower, and lower class. Trip duration and then Reliability scored fourth and fifth positions respectively on the scale of importance in Raipur and Jamshedpur in normal weather conditions. In lower class only affordability was most important factor and rest factors were found equally important.

In hot day inclement weather condition, similar trends were observed regarding affordability in both the cities. Comfort was second important factor in Raipur in Upper class, Lower middle and lower class. In Jamshedpur maneuverability was mostly in second position of importance except in lower middle class and lower class where comfort and reliability were second important factor, respectively. Trip duration and reliability stood fourth and fifth, respectively. Lower class in Raipur showed similar preferences like normal conditions, whereas in Jamshedpur affordability was followed by reliability and maneuverability then comfort and trip duration were least important.

In hot humid inclement condition, affordability was again most important factor except in upper class in Jamshedpur where it stood third in the line of importance. Maneuverability was second most important factor except in upper class in Raipur, where it was replaced by comfort which was third important factor in this climate across all the classes. Trip duration and reliability came fourth and fifth, respectively in all classes. Raipur lower class preferred comfort after affordability and then they gave equal importance to trip duration, reliability and maneuverability. In Jamshedpur after affordability comfort, trip duration and maneuverability were found to be equally important and reliability stood last.

In heat wave condition, affordability was perceived to be the most important factor except in upper class in both the cities, where comfort took its place and affordability stood third and fourth in Raipur and Jamshedpur, respectively. In Jamshedpur's upper middle class, maneuverability was most important factor for the commuters, though it was second important factor, across all the classes except in upper middle and lower class in Raipur, where it stood third. Trip duration and reliability came fourth and fifth, respectively.

In light rain conditions, affordability was again the most important factor in all the classes except in upper class in Jamshedpur where it preceded comfort. Maneuverability was second important factor across all the remaining classes in both the cities. In general comfort came third, trip duration fourth and reliability fifth. In lower class comfort was the second most important factor in Raipur followed by reliability, then maneuverability and finally trip duration. Whereas maneuverability is the second important factor after

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affordability, and then came reliability, comfort and lastly trip duration.

In heavy rain conditions affordability was still the most important factor in consideration except in upper classes in both the cities. It was also replaced by maneuverability in upper middle and lower middle class in Jamshedpur. Comfort which was the first important factor in upper classes was considered as second important factor in upper lower and lower class in Raipur and upper middle in Jamshedpur, in rest of the classes, maneuverability was voted second important factor. Trip duration was third important factor in upper classes where affordability was fourth important factor. But in rest of the classes, trip duration stood fourth and reliability fifth.

In very heavy rain inclement weather condition again comfort was most important factor across upper class commuters in both the cities, and upper middle class in Raipur in rest of the cases it stood second and affordability was prime factor except in Jamshedpur's upper middle, lower middle and upper lower classes in rest of the cases. Maneuverability stood third, trip duration fourth and reliability fifth.

In cold weather conditions, affordability was the most important factor in user's perspective, followed by comfort in upper class and maneuverability in rest. Trip duration was seen to be the second important factor in case of Jamshedpur's upper middle class. In rest of the classes, trip duration was fourth and reliability stood fifth in importance. In Raipur lower class commuters' perspective only affordability was important and the rest was rated same in the second position. In Jamshedpur, lower class commuter rated comfort as the second important factor after affordability, then reliability, and finally trip duration and maneuverability shared the least importance.

In cold wave condition across all the socioeconomic classes in both the cities, affordability was considered the most important factor followed by comfort in upper class and lower class in both the cities. Maneuverability was the second most important factor in rest of the classes. Trip duration came fourth and reliability, fifth on the importance scale.

In cold with precipitation inclement weather conditions, comfort was the priority factor in upper class in both the cities and in upper middle class of Jamshedpur in rest of cases affordability was still the major factor for consideration, except in lower middle class were maneuverability was a pressing issue. Trip duration came fourth and reliability, fifth on the importance scale.

## IV. Conclusion and Inferences

After a thorough analysis it is found that affordability is the most important factor in both the cities except in few conditions like heat wave, rain and cold with precipitation, comfort is the most important factor for upper class. Decrease in the importance of affordability resulted in increase in choice of mode change. It is the key factor in lower class, which prevented any mode change.

Comfort is the second important factor perceived by the commuters, it is found to be slightly more important in Raipur than Jamshedpur. Importance of comfort in choice of mode however decreased down the socio economic groups.

While trip duration seems statistically significant, its impact on mode change is less. This can be contributed to the fact that both the cities are medium size cities with average work trip length in terms of time; 19 minutes and 30 seconds in Raipur and 19 minutes in Jamshedpur. Short delay has considerably less important than other factors.

For this study, private two wheelers are considered, Reliability is statistically significant in some case but not of much importance in users' perspective, because private two wheelers are the prime mode and its predictability and regularity are not issues in most of the cases.

Maneuverability though seemed important in users' perspective is not statistically significant in inclement weather except cold and precipitation in Raipur and hot humid climate in Jamshedpur. This may be due to the fact that two wheelers are easy to manure in heavy traffic and the case study areas are plain sites, with respect to terrain. Though the above criteria are important for good trip, these do not impact choice of mode of travel in these cities.

It is also noted that hot day is treated as normal day in both the cities with minimal changes. Even cold day in Jamshedpur had similar impact as hot day and normal day. Heavy rain has seen to exercise highest influence on the choice of mode change followed by very heavy rain, may be because of the reason that people tend to change other travel decisions like time of travel in extreme weather condition rather than mode. Light rain and cold with precipitation were also important in Raipur. Highest correlation of SES with mode change was observed cold with precipitation conditions in Jamshedpur, followed by very heavy rain, heavy rain and heat waves.

This research consolidates the understanding regarding the factors influencing the choice of mode in transport across different socio-economic groups in inclement weather conditions in medium sized Indian cities. These results after further research can be utilized for forecasting two-wheeler transportation in inclement weather conditions for proper management of traffic.

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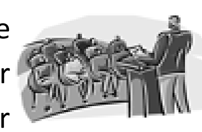

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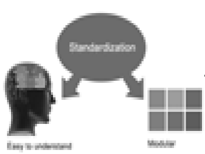


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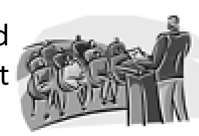

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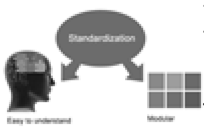


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The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

**(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.**

**(II) Choose corresponding Journal.**

**(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.**

**(B) If you are using Internet Explorer, then Direct Submission through Homepage is also available.**

**(C) If these two are not conveninet , and then email the paper directly to dean@globaljournals.org.**

Offline Submission: Author can send the typed form of paper by Post. However, online submission should be preferred.

# Preferred Author Guidelines

**MANUSCRIPT STYLE INSTRUCTION** **(Must be strictly followed)**

Page Size: 8.27" X 11'"

- Left Margin: 0.65
- Right Margin: 0.65
- Top Margin: 0.75
- Bottom Margin: 0.75
- Font type of all text should be Swis 721 Lt BT.
- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, “Abstract” word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

**You can use your own standard format also.**
**Author Guidelines:**

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

**1. GENERAL**

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

**Scope**

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

Journals Inc. (US) are being abstracted and indexed (in process) by most of the reputed organizations. Topics of only narrow interest will not be accepted unless they have wider potential or consequences.

**2. ETHICAL GUIDELINES**

Authors should follow the ethical guidelines as mentioned below for publication of research paper and research activities.

Papers are accepted on strict understanding that the material in whole or in part has not been, nor is being, considered for publication elsewhere. If the paper once accepted by Global Journals Inc. (US) and Editorial Board, will become the copyright of the Global Journals Inc. (US).

**Authorship: The authors and coauthors should have active contribution to conception design, analysis and interpretation of findings. They should critically review the contents and drafting of the paper. All should approve the final version of the paper before submission**

The Global Journals Inc. (US) follows the definition of authorship set up by the Global Academy of Research and Development. According to the Global Academy of R&D authorship, criteria must be based on:

1) Substantial contributions to conception and acquisition of data, analysis and interpretation of the findings.

2) Drafting the paper and revising it critically regarding important academic content.

3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

**Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.**

**Permissions: It is the author's responsibility to have prior permission if all or parts of earlier published illustrations are used in this paper.**

Please mention proper reference and appropriate acknowledgements wherever expected.

If all or parts of previously published illustrations are used, permission must be taken from the copyright holder concerned. It is the author's responsibility to take these in writing.

Approval for reproduction/modification of any information (including figures and tables) published elsewhere must be obtained by the authors/copyright holders before submission of the manuscript. Contributors (Authors) are responsible for any copyright fee involved.

**3. SUBMISSION OF MANUSCRIPTS**

Manuscripts should be uploaded via this online submission page. The online submission is most efficient method for submission of papers, as it enables rapid distribution of manuscripts and consequently speeds up the review procedure. It also enables authors to know the status of their own manuscripts by emailing us. Complete instructions for submitting a paper is available below.

Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

**4. MANUSCRIPT'S CATEGORY**

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

**5.STRUCTURE AND FORMAT OF MANUSCRIPT**

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

**Papers**: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(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, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

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

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

**Format**

*Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.*

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

**Structure**

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive 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) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

*Abstract, used in Original Papers and Reviews:*

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

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

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin 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 research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

*Acknowledgements: Please make these as concise as possible.*

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

*Tables: Tables should be few in number, 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. Vertical lines should not be used.*

*Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.*

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. 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.

*Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.*

**6. AFTER ACCEPTANCE**

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

**6.1 Proof Corrections**

The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

As changes to proofs are costly, we inquire that you only correct typesetting errors. All illustrations are retained by the publisher. Please note that the authors are responsible for all statements made in their work, including changes made by the copy editor.

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The Global Journals Inc. (US) are enclosed by our publishing's Early View service. Early View articles are complete full-text articles sent in advance of their publication. Early View articles are absolute and final. They have been completely reviewed, revised and edited for publication, and the authors' final corrections have been incorporated. Because they are in final form, no changes can be made after sending them. The nature of Early View articles means that they do not yet have volume, issue or page numbers, so Early View articles cannot be cited in the conventional way.

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**6.4 Author Material Archive Policy**

Please note that if not specifically requested, publisher will dispose off hardcopy & electronic information submitted, after the two months of publication. If you require the return of any information submitted, please inform the Editorial Board or dean as soon as possible.

**6.5 Offprint and Extra Copies**

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You must strictly follow above Author Guidelines before submitting your paper or else we will not at all be responsible for any corrections in future in any of the way.

Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

## TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

**1. Choosing the topic:** In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

**2. Evaluators are human:** First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

**3. Think Like Evaluators:** If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

**4. 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.

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

**6. Use of computer is recommended:** As you are doing research in the field of Computer Science, then this point is quite obvious.

**7. Use right software:** Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

**8. Use the Internet for help:** An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

**9. Use and get big pictures:** Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

**10. Bookmarks are useful:** When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

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

**12. Make all efforts:** Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

**13. Have backups:** When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

**14. Produce good diagrams of your own:** Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

**15. Use of direct quotes:** When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

**16. Use proper verb tense:** Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

**17. Never use online paper:** If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

**18. Pick a good study spot:** To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

**19. Know what you know:** Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

**20. Use good quality grammar:** Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

**21. 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 to your topic. You may also maintain your arguments with records.

**22. Never start in last minute:** Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

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

**24. Never copy others' work:** Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

**25. Take proper rest and food:** No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

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

**27. Refresh your mind after intervals:** Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

**28. Make colleagues:** Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

**29. Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

**30. Think and then print:** When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

**31. Adding unnecessary information:** Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

**32. Never oversimplify everything:** To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

**33. Report concluded results:** Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

**34. After 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 to 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 in 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 criterion for grading the final paper by peer-reviewers.

**Final Points:**

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of 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 the 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 evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

**Title Page:**

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

**Abstract:**

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing 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 approach 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. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than 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 maintain the initial two items to no more than one ruling each.

- Reason of the study - 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 quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness 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 to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled 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 with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose 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 sound written Procedures segment allows a capable scientist to replacement 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 for the least amount of information that would permit another capable scientist to spare 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 object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text 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:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not 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 - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in 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 a 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. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise 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 in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to 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 part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

**Discussion:**

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a 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 implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly 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 with prospect, and let it drop at that.

- Make a decision if each premise is supported, 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 the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One 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 available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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| ***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 |

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