PROCEEDINGS ENGINEERING AND TECHNOLOGY CONFERENCE 2003 (EnTech 2003)

30th July 2003 – 1st August 2003
Crowne Plaza Riverside Kuching, Sarawak, Malaysia

Innovations in Structural Rehabilitation: FRP Systems and External Post-Tensioning

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Abstract
Structural rehabilitation works, either in the form of structural conservation, upgrading or repair, have been on the rise in both developing and developed countries. Besides a proper assessment of existing structures, structural rehabilitation involves the selection and execution of techniques that are not only technically sound, but also economically viable. The emergence of innovative materials and methods such as fibre-reinforced polymer (FRP) systems and external post-tensioning is therefore of significance. FRP composites, comprising high-performance continuous fibres such as carbon, aramid or glass fibres encapsulated in a matrix resin, are available in the form of ropes, bars, grids, sheets, plates and shells. They have excellent properties such as high strength and low unit weight, and are an excellent candidate as a strengthening material. External post-tensioning, on the other hand, refers to the installation and post-tensioning of tendons outside a structural member to strengthen it primarily in flexure. Both innovations offer speed and labour savings in applications, leading to substantial economic benefits. In this paper, the concept and application of FRP composites and external post-tensioning in structural strengthening is highlighted, and basic design principles and issues pertaining to FRP-strengthened concrete structures and externally post-tensioned structures are discussed.

Keywords : External post-tensioning; fibre-reinforced polymer systems; structural rehabilitation.

1. Introduction

Building and civil engineering structures deteriorate due to ageing and environmental elements. The amount of structural rehabilitation works which include conservation of national heritage, and upgrading and repair of infrastructure, repair and retrofit works, is expected to increase as a portion of total construction work in many countries. This has brought about the need for rehabilitation techniques that are effective and economical to execute.

As illustrated in Figure 1, structural rehabilitation could be achieved in four major ways: (a) by addition and/or replacement of structural members; (b) by member or section enlargement; (c) by externally bonded systems; and (c) by external post-tensioning.

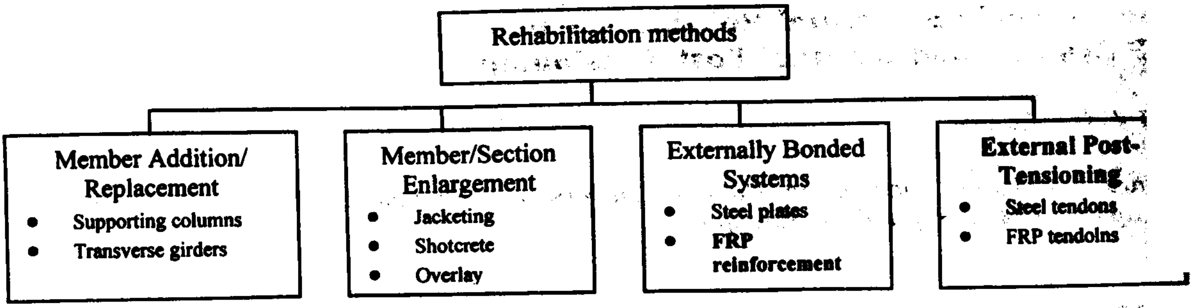


Figure 1. Major Structural Rehabilitation Methods

The selection of a rehabilitation technique depends on many factors such as the load transfer mechanism and serviceability of the retrofitted structure, besides technical viability and cost. The replacement of members would be required for badly damaged structures while members such as columns and transverse girders could be added to support additional loads.

The enlargement of sections or members using concrete jackets and additional reinforcement entails proper surface preparation and supporting formwork, and is labour intensive. However, it usually results in a stiffer and more robust structure. Externally bonded systems using steel plates or fibre-reinforced polymer (FRP) reinforcement provide a less labour intensive method. In particular, FRP reinforcement, with its low unit weight about one-fifth that of steel and high strength and modulus, is becoming a popular method in flexural and shear strengthening.

External post-tensioning is usually applied to beams or girders and sometimes to columns and piers to increase their load carrying capacities. Both steel and FRP tendons may be used, with the latter having the advantage of being a "non-corrosive" material with a lower elastic modulus.

The externally bonded FRP systems and external post-tensioning are emerging as popular methods in structural rehabilitation because of the use of high-performance materials and the speed of application.

2. Fibre-Reinforced Polymer Systems

FRP composites, comprising high-performance continuous fibres such as carbon, aramid or glass fibres encapsulated in a matrix resin, are available in the form of ropes, bars, grids, sheets, plates and shells. They have excellent properties such as high strength and low unit weight, and are an excellent candidate as a strengthening material.

Figure 2 shows the stress-strain relations for FRP reinforcement compared to conventional steel reinforcement. While normal steel reinforcing bars and strands exhibit a elastic-plastic behaviour, FRP reinforcement typically exhibits a linear elastic stress-strain relation up to brittle rupture of the material. Carbon FRP (CFRP) generally has high elastic modulus comparable to that of steel, aramid FRP (AFRP) has lower elastic modulus but comparable tensile strength, and glass FRP (GFRP) in generally has lower elastic modulus and strength but higher strain at rupture. The brittle nature of the material is a concern in its use in concrete structures.

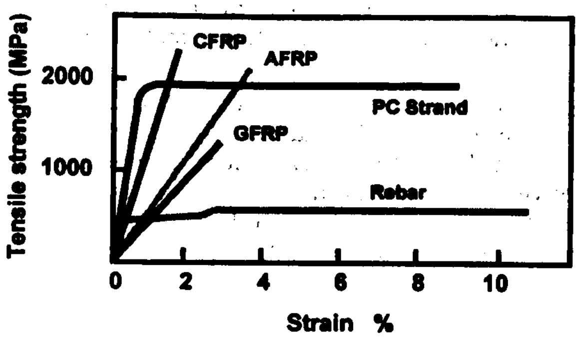


Figure 2. Stress-strain relations for FRP reinforcement

FRP sheets or fabrics are usually bonded to concrete members using a so-called "wet lay-on" procedure. Typically, the surface of the concrete member is first prepared by blasting or grinding. A primer is then applied to improve the bond characteristics of the adhesive resin. The FRP sheets are then impregnated with the resin and then bonded on to the concrete surface usually using the same resin. In other cases, the FRP composite is available in precured sheets or shells. It is then bonded to concrete members using an epoxy mortar.

2.1. Concept of Strengthening with FRP

FRP systems could be used to strengthen concrete members in flexure and shear, or to provide ductility. The concepts for flexural and shear strengthening are illustrated in Figure 3.

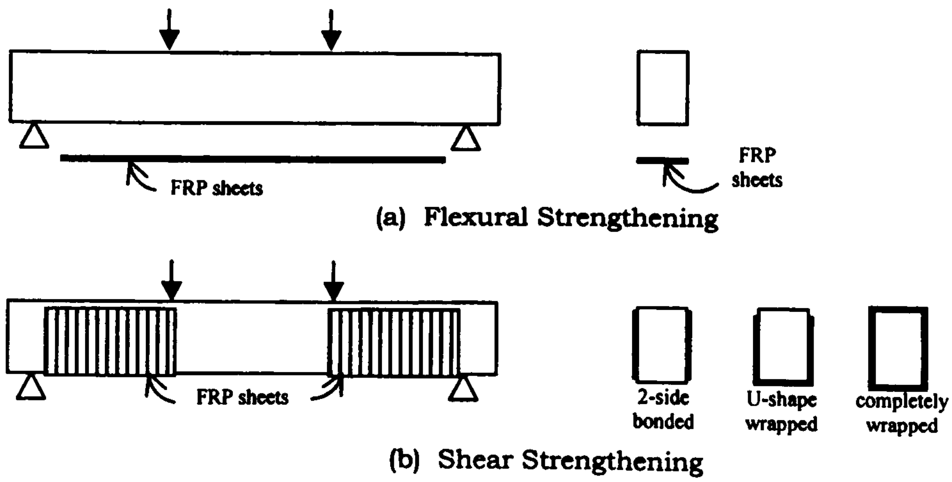


Figure 3. Structural Strengthening using FRP Systems

To strengthen a member in flexure, typically FRP sheets or plates are bonded onto the tensile face, as shown in Fig. 3(a). Attention is required of the end anchorage of the FRP composites so as to prevent premature failure due to debonding of the composites. This could be facilitated by providing an development length beyond the point of contraflexure, by anchoring with transverse sheets, or by anchoring with fibre bolts. The ultimate moment of resistance could be evaluated by the principle of strain compatibility and force equilibrium (JSCE 2001, *fib* 2001, ACI 2002). Usually, safety factors are applied to account for the durability of the material, the lack of ductility and uncertainty associated with the member behaviour. Some codes further limit the stress or strain in the FRP composites to prevent debonding of the composites at cracked sections. The degree of flexural strengthening is limited to the reserve capacity of the concrete compression zone, serviceability requirements, and the requirement for fire resistance.

For shear strengthening, typically FRP reinforcement are bonded transversely on the web of beams, or wrapped around the web in a U-shape, or completely around the member in the case of isolated columns (see Fig. 3(b)). The shear strengthening effect is basically accounted for using the conventional truss analogy, that is, the contribution of FRP reinforcement to shear capacity is quantified by a term similar to that contributed by conventional stirrups, with the stirrup stress replaced by an effective stress in FRP reinforcement.

FRP systems are also used to enhance the ductility of members, in particular that of axially loaded members, to withstand seismic actions. This is facilitated by wrapping FRP sheets or fabrics around the members as shown in Fig. 4, which confines the concrete section when the member is under load. The confinement effect leads to an increase in axial load capacity as well. It is more effective in circular or near square sections than in rectangular sections. For the later cases, the corners of the sections are usually chamfered off to relieve stress concentration in the FRP reinforcement.

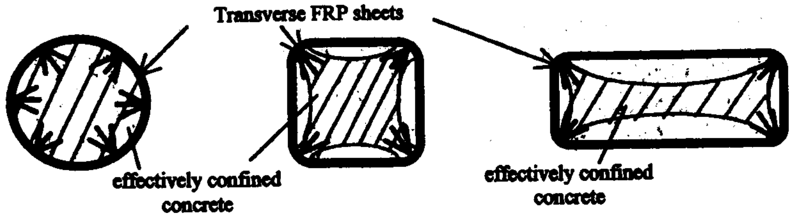


Figure 4. Confinement effect in circular and non-circular sections

2.2. Special Applications

FRP systems may also be used to strengthen special members such as dapped beams or half joints, and beams or slabs with openings. In such cases, the strut-and-tie method and strip method may be used to design the required reinforcement. Figure 5 shows the case of a half joint strengthened with CFRP sheets (Tan 2001). The sheet configuration is determined by considering a strut-and-tie model which transfers the applied loads to the supports. The sheets are placed in amounts that provide the required tensile forces in the tie members. They are anchored to the concrete beam at the free top end using fibre bolts. A U-shape horizontal sheet may be bonded to provide additional anchorage for the system.

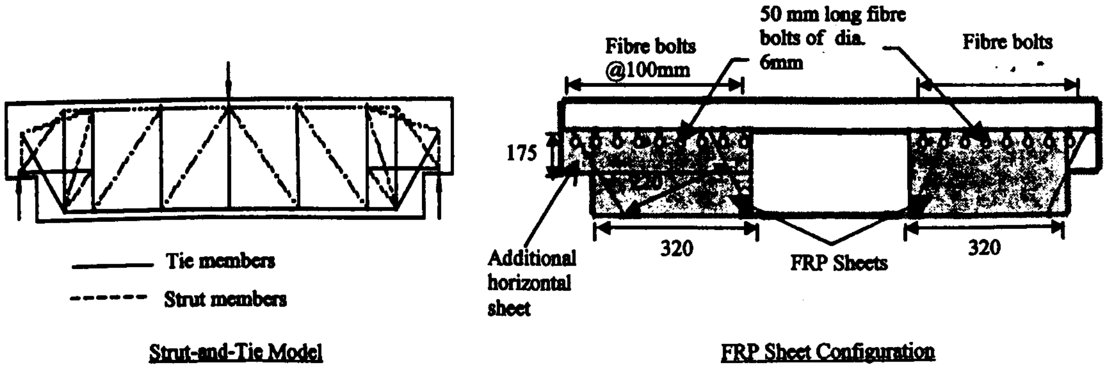


Figure 5. Strengthening of dapped beam using strut-and-tie Method

The strengthening of slabs with openings could be designed following the strip method, as illustrated in Figure 6 for a one-way slab (Tan and Zhao 2003). Strong bands or strips are considered to border the opening, and FRP reinforcement could be provided along these bands to transfer the applied load to the supports.

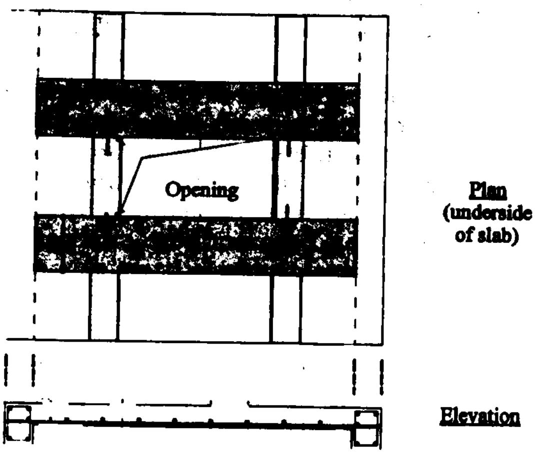


Figure 6. Strengthening of one-way slab with opening using strip method

2.3. Future Development and Challenges
To capitalize on the high tensile strength, the FRP reinforcement may be prestressed prior to bonding in strengthening works. For this purpose, several prestressing and anchorage systems have been developed for site applications (Stoecklin and Meier 2003, Basker et al. 2003). Also, the fire resistance of FRP-strengthened members is of particular interests, although this could be taken care of by protective coating or layer, and by adopting proper design strategy. The durability of FRP systems under ultra-violet radiation and rain and shine (Liew and Tan, 2003), also warrants attention as some FRP systems are known to be susceptible to deterioration under such environmental effects.

3. External Post-Tensioning
External post-tensioning refers to the installation and post-tensioning of tendons outside a structural member, as shown in Figure 7, to strengthen it primarily in flexure. The tendons could be placed in appropriate configurations using deviators to maximize the strengthening effect. The method offers advantages such as speed and labour savings in installation. As the tendons are placed outside the concrete section, it is possible to monitor the condition of the tendons, and re-tension or replace the tendons during the service life of the structure.

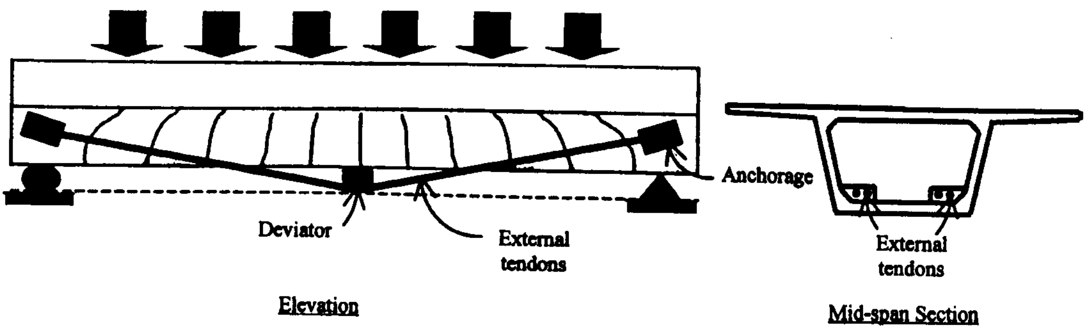


Figure 7. Concept of external post-tensioning

3.1. Design Concept
Under applied loads, the stress in the external tendons is the same at any location between the deviators and the anchorages. A member analysis with the total elongation of the tendons equal to that of concrete at the level of the tendons is generally required to assess the tendon stress, from which the resisting moment could be evaluated. Empirical or semi-empirical equations for the tendon stress at ultimate flexural limit state of beams are available; however, as a simplified method, it is possible to evaluate the tendon stress using

the principle of strain compatibility and force equilibrium by accounting for the unbonded nature of the tendons using bond reduction coefficients (Naaman and Alkhairi 1991).

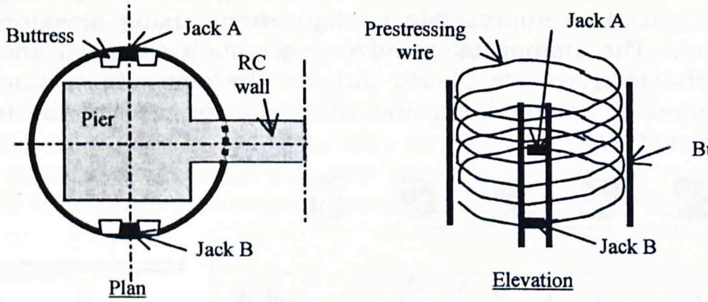
Two aspects have to be further accounted for in beams or girders strengthened by external tendons. First, as the portion of the tendons between the deviators and anchorages is free to move relative to the concrete section, there would be a loss of tendon eccentricity, termed second-order effects, under the action of applied loads. Second, as the strengthening effect in flexure may not be accompanied by an equivalent increase in shear strength, the strengthened beam may become more susceptible to shear failure (Tan and Tjandra 2003a).

3.2. Special Applications

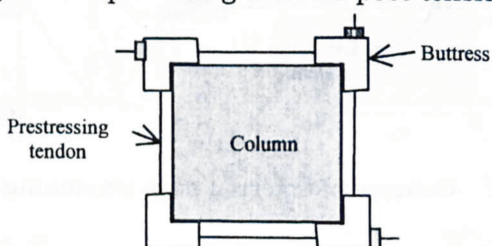
In a way, external tendons have been used in circular concrete structures commonly used for liquid or bulk storage (ACI 1997). In such structures, circumferential prestressing is achieved by wire or strand wrapping. The wire or strand is wrapped round the core wall and fully tensioned before they are covered by shotcrete for protection purpose.

Similarly, external tendons could be applied to strengthen piers and columns, as shown in Figure 9. In Figure 9(a), a twin-pier connected by a reinforced concrete (RC) wall is strengthened by first transforming the square concrete section of the pier into a circular section with built-in vertical buttress. Prestressing wires are threaded through the buttresses and the RC wall continuously in a spiral direction, prestressed using jacks and anchored against the buttresses. As a result of the confinement effect induced by the the cirumferential prestress, the axial load capacity of the pier is increased.

Figure 9(b) shows the case of a square column being strengthened using straight tendons or wires that are placed parallel to the sides of the column at regular spacing along the height of the column (Li et al. 2003). Again, the prestressing forces in the tendons result in the confinement of the concrete section, resulting in higher load carrying capacity.



(a) Strengthening of twin-pier using external post-tensioned spiral reinforcement



(b) Strengthening of square column using external straight tendons

Figure 9. Application of external post-tensioning to axially loaded members

3.3. Future Trends

It is possible to strengthen a reinforced concrete girder by installing external tendons over portions of the member, such as over the negative moment regions of a continuous beams

(Tan et al. 2001). In addition, it is also possible to strengthen precast girders by providing moment continuity using external tendons over the interior supports (Tan and Tjandra, 2003b). In terms of materials, FRP tendons have also been used successfully. Such tendons have the added advantage of a lower elastic modulus compared to steel tendons, leading to smaller loss in prestress due to elastic shortening; however, the possibility of creep rupture, that is rupture of FRP tendons under a sustained static load, has to be carefully evaluated.

4. Conclusions

Structural rehabilitation works are on the increase in many countries due to heritage conservation, and deterioration or change of usage of structures. Externally bonded FRP systems and external post-tensioning works are two economically viable innovations. With a good understanding of their advantages and limitations, these methods could provide versatility and many challenges in application.

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Educating Engineering Educators - Challenges?

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Abstract
Engineering education is currently undergoing a lot of changes due to the global economy and ever changing technology. Academicians have to cope up with this change to ensure that their engineering programmes are relevant and meet the demands of society. As such, they cannot lay back and depend on their own educational experience but rather to pick up the pace and set new trends and targets. Professionalism is another issue that must be handled properly so as not to mar the image of engineering educators. Engineering graduates are the benchmark of the success of any engineering programmes. The challenges faced by academics are highlighted in this paper with possible suggestions for improvement.

Keywords : engineering education, curriculum development, professionalism

1. Introduction

Question:
"Do engineering educators really need to be educated when they have obtained qualifications far beyond the first degree?"

This paper does not pretend to know the answer to the above question. The author will shed some light on the issues at hand and provide some insights and suggestions. Academicians, engineers in particular, have long been debating on the techniques and methodology in the creation of graduates who can fulfil the requirements of their professions. The question of how best to educate and train has been the drive behind the organization of numerous national and international conferences. Even the United Nations under the umbrella of UNESCO's International Centre for Engineering Education (UICEE) has organized an annually convened conference on Engineering Education around the world.

Countless papers have been presented and debated in the pursuit of improving or innovating methods in engineering education. Leading engineering journals would publish from time to time special issues on this topic. Internationally renowned IEEE has the Education Society with the sole task of disseminating trends in engineering education through its quarterly Transactions. Yet, with all this fervor towards engineering education, one still finds the diabolical question, "why are engineering graduates not qualified?" not gratifying.

The fate of engineering in the country lies in the hands of the educators. The late Y.A.B. Tun Abdul Razak, second Prime Minister of Malaysia clearly sums up the objective of engineering when he said "...the future of engineers is not only to built bridges for troops and traffic to cross over; one of your main tasks is also to bridge the gaps of our economic imbalances between the 'haves' and 'have not'."

This paper focuses on the creation of the engineering educators themselves, sort of looking in the mirror, to see if the above question can be answered. It may raise more questions than answers.

2. Revitalizing Engineering Education

In general, there is a need to revitalize education to keep up with the times. This is more so for the engineering curriculum because it is coupled with the industrialization of the Nation. Failure on the part of the engineering programme would be dramatic and can cause failure in manufacturing (Valkenburg, 1990). To overcome this, Valkenburg argued that a course on design should be taught early in the programme as it requires minimum use of physics and mathematics.

The Malaysian accrediting agency for engineering education, the Engineering Accreditation Council of the Board of Engineers Malaysia, requires that one-third of the required minimum of 120 credits be spent on non-engineering courses (BEM, 2002). The main motivation here is to produce engineers who are balanced and "well-rounded". Educators on the other hand feel that students do not receive enough material depth. Some would like to reduce the humanities aspect, while others would just go for more credits in the engineering content. Where is the dividing line?

3. Who educates who

Unlike the primary and secondary education system where teachers need to have a certificate or diploma in education before they can teach, engineering educators do not generally have formal training in education. Most would have postgraduate degrees in their field of interests. Others top that up with a practicing license as professional engineers. Is this considered a drawback or the converse? Academics is one of the only vocation where one is not trained to carry out the job. For instance, a policeman is trained as a policeman and a physician is trained to practice medicine. As a matter of fact, an engineer is trained to practise his or her engineering skills. I have not heard of an academician earning a degree in lecturing.

That is the predicament. To my belief, engineering educators are not teachers per say. They are masters in their discipline and students are artisans looking for a good coach. This was the practice when blacksmiths would have apprentices. Knights in golden armours would have wards who long to serve their masters and gain entry into knighthood. How they go about coaching and educating the students are left to their own skills. Where does that place engineering educators?

3.1 Education vs. Training

The main purpose of education is to develop character or mental power. It does not matter what the discipline is. Training on the other hand brings a person, an animal, etc., to a desired state or standard of efficiency by instruction and practice. Circuses train tigers, bears, and monkeys to perform circus acts. They, the animals, normally carry out their job well. However, the animals are not educated.

The role of university is for the advancement of knowledge. This is achieved through research and accumulation of knowledge. On top of this, universities produce the next generation of citizens to take on the responsibility left by their predecessors. This is done through education. Last but not least is for universities to contribute to society in whatever form.

Thus, one can say that education is the process to produce functionally literate citizens. In this world, the ability to read and write with a vocabulary of a few hundred or so words may render one technically literate, but does not equip one to participate productively in a dynamic technologically society. This means that the ability to understand, interprete, analyse, create, and communicate information, not just read it or look at it on a television. A nation must have a functionally literate population to be successful in today's world (Abbott, 1990).

- Connected to the needs and issues of the broader community through integrated activities with other parts of the educational system, industry, and government.

6. Conclusion

It is an onerous task for engineering educators to ensure that their profession generates citizens who are experts in their field, but at the same time humane and professional. The ability of the nation to develop into an industrialized country rests on the next generation of engineers who understands and practice "green" engineering albeit pressures from outside. This honourable duty has no immediate rewards and cannot be measured in Ringgit and Sens. Self-satisfaction on the part of the professors alike would be the only key to the running of a successful engineering programme.

Acknowledgment
The author would like to acknowledge the funding for travel provided by Universiti Sarawak Malaysia to present this keynote paper.

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Contents

Keynotes:

Papers

THE EFFECT OF RUBBER COATING ON THE STRENGTH OF ASPHALT CONCRETE

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Abstract
The purpose of this paper is to study the use of rubber as a coating layer at the asphalt-concrete interface. The effect of the thickness of coating layer on the tensile strength of asphalt-concrete is studied by the finite element method (FEM) and the TALA (Thin Adhesive Layer Analysis) method, when the models are subjected to static loading. The 2-D spring elements are used to simulate the tensile properties of rubber. It is found that the coating layer reduces the maximum tensile stress in asphalt-concrete. Comparing the model with and without a coating layer, the maximum tensile stress increased as the thickness of rubber is increased. At a 20-mm thickness of rubber, the maximum tensile stress is approximately equal to the peak tensile stress of case of no rubber coating.

Keyword: FEA, TALA, asphalt-concrete, rubber

1. Introduction
After roads have been used for a while, cracks may appear on the asphalt-concrete layer surface [1]. There are some reasons that can explain why the cracks occurred. The first explanation is thermal fatigue. Throughout the day, temperature can change about 15-20 degree Celsius. This may cause thermal fatigue to the asphalt-concrete layer [2,3]. Because there is water present underground, corrosion may occur at the bottom surface of the asphalt concrete layer [4,5]. Finally, the most significant reason is vehicle load. The roads are subjected to the weight of the vehicles that pass over it. This applied load is not static in nature but it is cyclical, and this causes the fatigue cracking on the asphalt concrete layer. Vehicle load is the major factor that influences the service life of an asphalt concrete road. Cracking usually starts from the bottom of the asphalt concrete layer and propagates up to the surface [3,6,7,8]. From the record in 1978, the Department of Highway (Thailand) had to pay 600 million baht to maintain the highways [9,10]. From Kim's work [11], they showed that when they coated the bottom surface of asphalt concrete with 270 microns of polyester, the maximum stress was reduced and the crack growth rate was also reduced. From that work, we can see that the thickness of polyester was very thin. This is difficult to do in the real work. Therefore, the purpose of this work is to study the use of rubber instead of polyester as coating layer at the asphalt-concrete interface, and to study the effects of the layer thickness.

The first objective of this study is to understand the effect of rubber coating on the tensile strength of the asphalt concrete layer by using the FEM. The maximum stress and maximum strain that occurred in the asphalt concrete layer for the case of with and without rubber coating were compared. The second objective is to understand the effect of rubber coating thickness on the tensile strength of the asphalt-concrete layer. To do this, the thickness of the rubber coating was varied. Because the rubber layer is very thin, when compared with the asphalt-concrete layer, and in order to avoid creating a huge model, the TALA method was used to simulate the rubber layer to the road model [12,13].

2. TALA method
The general idea of TALA (as shown in Figure 1) is that each pair of coincident nodes between two contacting surfaces in the finite element models is connected by spring elements. The normal stress (σ_z) and shear stresses (τ_{zx}, τ_{zy}) are changed into normal force, and shear force, respectively. The normal and shear strains (ε_z, γ_{zy}, γ_{zx}) are changed into normal and shear relative displacements in spring *i*. The equations used for converting the stresses and strains in the solid element to forces and displacements to define the properties of the spring element are presented below.

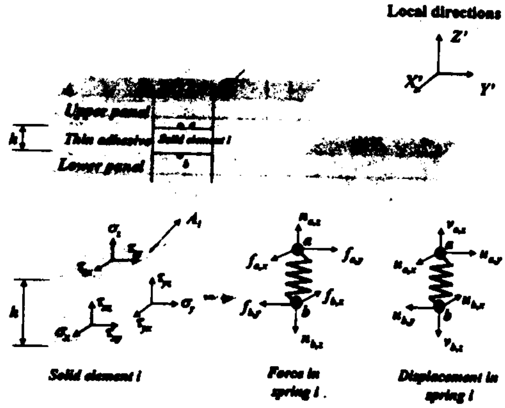

Figure 1. Schematic of a spring representation of a solid adhesive element.

In the normal direction: (Tension and Compression Springs) : $F_{n,i} = K_{n,i} \bullet v_{n,i}$, and $K_{n,i}=E^*(A_i/h)$

In the shear direction: (Shear Springs): $F_{f,I} = K_{f,I}{}^*u_{f,I}$ and $K_{f,i}=G^*(A_i/h)$

where:

- $F_{n,i}$ is the normal force transmitted in spring element i, $v_{n,i}$ is the relative displacement of spring element i in the normal direction,
- $K_{n,I}$ is the local stiffness of spring element i in the local normal direction, and E is the secant elastic modulus of the adhesive.
- $F_{f,i}$ is the shear force transmitted in spring element i, $u_{f,i}$ is the relative displacement of spring element i in the shear direction,
- $K_{f,i}$ is the local stiffness of spring element i in the shear direction, and G is the secant shear modulus of the adhesive.

3. FEM model

The FEM model of the road without rubber coating consisted of 4 layers: asphalt concrete, crushed stone, aggregate subbase and subbase, as showed in Figure 2. For the case with rubber coating, the rubber layer is added between the asphalt-concrete layer and crushed stone layer by using TALA method. Table 1 and Table 2 show the mechanical properties of materials for each layer and the properties of rubber, respectively. The left side edge of model was constrained against motion in the x-direction (to represent an axisymetric model). The bottom edge was constrained against motion in x- and y-direction (to represent the rigid ground).

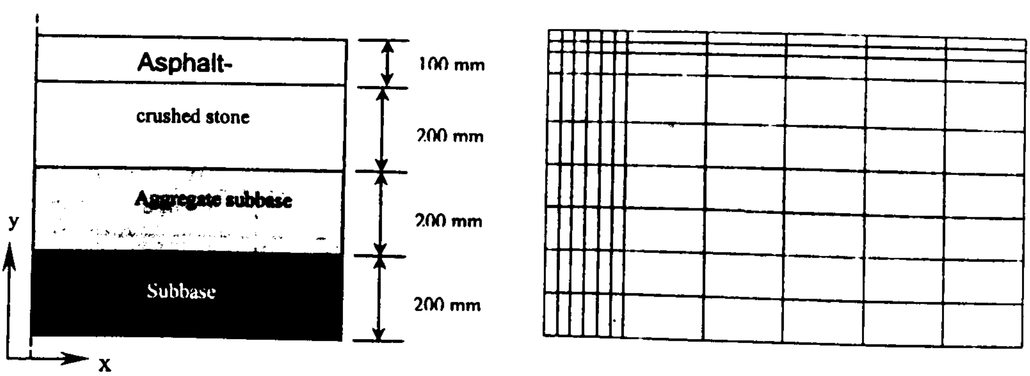

Figure 2 The FEM road model

Table 1 Thickness and Modulus of each layer

Layer	Thickness (mm)	Modulus (MPa)	Poisson ratio
Asphalt-concrete	100	3447.5	0.30

Crushed stone	200	167.0	0.35
Aggregate subbase	200	106.8	0.35
Subbase	200	34.4	0.45

(Ref: Yang H Huang, "Pavement analysis and Design [4])

Table 2 Properties of Rubber

Properties	
Tensile strength (MPa)	17.23
Elongation (%)	750

(Ref: Harper, "Handbook of plastics and Elastomers [14])

4. Results

Table 3 shows the results of the finite element calculations. The maximum tensile stress, maximum tensile strain, and maximum deflection that occurred in the asphalt-concrete at several thicknesses of rubber coating were compared to show the effect of the rubber coating on the maximum stress and strain that occurred in the asphalt-concrete layer. Figure 3 and figure 4 illustrate the stress distribution in the asphalt concrete layer without rubber coating and with rubber coating, respectively. Figure 5 and Figure 6 showed the strain distribution in the asphalt concrete layer without rubber coating and with rubber coating, respectively. Figure 7 and Figure 8 compare the maximum tensile stress and maximum tensile strain that occurred in the asphalt-concrete layer between the case of road with rubber coating and without rubber coating.

Table 3 The FEM results

Rubber thickness	Max. Tensile Stress (MPa)	Max. Tensile Strain ($x10^{-4}$)	Deflection (mm)
No rubber	1.097	2.9622	0.4504
0.5 mm	0.825	2.2680	0.4188
1 mm	0.837	2.2945	0.4214
2 mm	0.858	2.3445	0.4264
4 mm	0.895	2.4352	0.4362
6 mm	0.928	2.5165	0.4457
10 mm	0.986	2.6586	0.4638
15 mm	1.046	2.8092	0.4854
20 mm	1.098	2.9394	0.5062

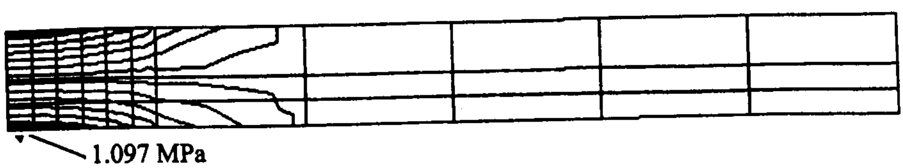

Figure 3 Stress distribution in asphalt-concrete layer in case of without rubber coating

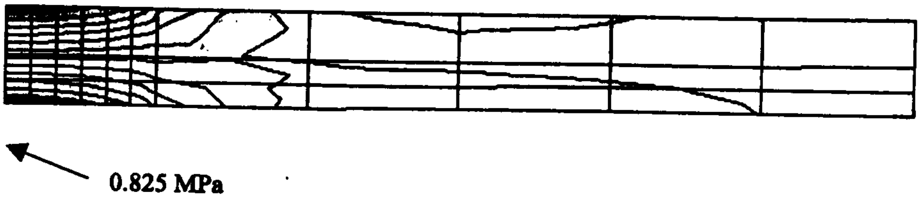

Figure 4 Stress distribution in asphalt-concrete layer in case of with rubber coating

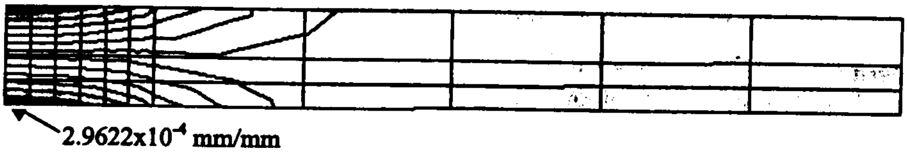

Figure 5 Strain distribution in asphalt-concrete layer in case of without rubber coating

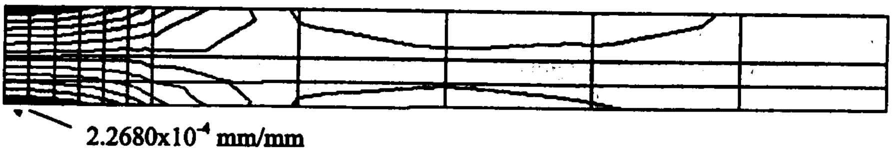

Figure 6 Strain distribution in asphalt-concrete layer in case of with rubber coating

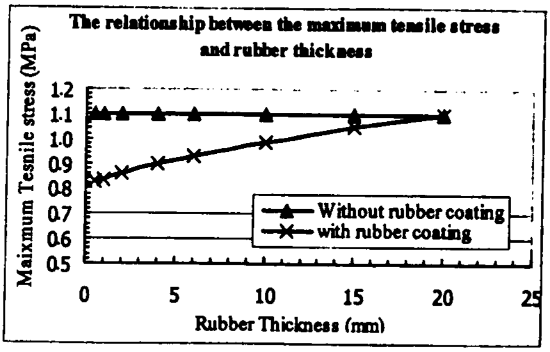

Figure 7 Compared maximum stress results

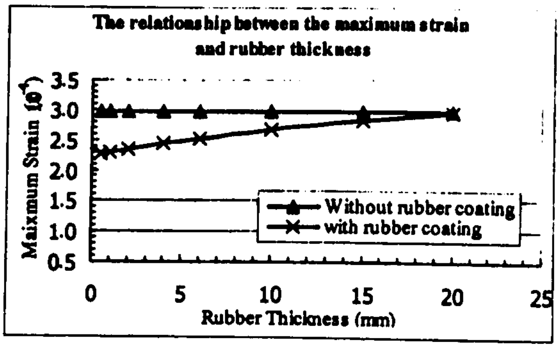

Figure 8 Compared maximum strain results

5. Discussion

From the results of Figure 5 and 6, we can see that the maximum tensile stresses occurred at the center of the applied load region and at the bottom of the asphalt concrete layer. That causes the cracks to propagate at that region. This agrees with the previous work that concluded the crack usually started at the bottom of asphalt-concrete layer. The results also showed that with the 1.00-mm rubber coating, the maximum tensile stress was decreased from 1.097 MPa to 0.837 MPa. It reduced the maximum stress by approximately 23.7 percent. The stresses were reduced because the rubber layer may help the asphalt-concrete layer to dissipate the tensile stress. We can see from the deflection distance of the asphalt-concrete layer that it decreased also. The deflection distance is proportional with the applied bending stress. When the deflection is decreased, it means the bending stress in the asphalt concrete decreases too. From Table 3, it is also shown that with 1.00-mm rubber coating, the deflection of asphalt-concrete layer was decreased from 0.4504 mm (when there is no rubber coating) to 0.4214 mm. Another parameter studied was the rubber coating thickness. From Figure 7, it is seen that when the thickness of the rubber coating is increased, the maximum tensile stress increased correspondingly. The maximum stress varied between 0.837 and 1.100, when the rubber coating thicknesses were change from 1.00 mm to 20 mm. It was determined that with a rubber coating of 20-mm, the maximum tensile stress was equal to the maximum stress for the case with no rubber coating. With a thick rubber layer, the ability to help the asphalt-concrete to receive the tensile stress of the rubber layer was reduced, because the rubber can deform easier. That causes the deflection distances to increase. Therefore the bending stress also increased.

6. Conclusion

1. Coating the bottom surface of the asphalt-concrete layer with rubber helps to reduce the maximum tensile stress and maximum tensile strain that occurred in the asphalt-concrete layer.
2. When the thickness of rubber layer increases the maximum tensile stress and maximum tensile strain increases. At 20-mm rubber thickness, the maximum stress and strain were higher than the case without rubber coating.
3. This work studied only the finite element analysis method. If we would like to understand the effect of rubber coating more, the experimental aspect has to be investigated.

7. Acknowledgement

The author would like to thank Faculty of Engineering, Chiang Mai University and Chiang Mai University who supported to do this research. And the author would like to thank Mr. George Jarque for his help to improve English for this paper.

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An Energy Efficiency Survey in Air-Conditioned Office Buildings in Kuching

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Abstract

Malaysian office buildings tend to be poorly designed from the perspective of energy efficiency and as the result Malaysian office buildings tend to have some of the highest energy consumption in the world - around 269 kWh/m²/year (Lawrence Berkeley Laboratory, 1992).

To have energy efficiency in buildings is important for long term lower running cost and for minimal pollution contribution to the environment. The most important is to the problem of limitation of natural resources fundamental to the generation of electricity in the future.

This is a preliminary study on energy consumption in office buildings in Kuching, Sarawak. The main objective of the project is to investigate the energy efficiency in office buildings around Kuching areas and to identify the significant criteria of their inefficiency.

The surveys were carried out on six fully air conditioned office buildings to find the energy indexes in each of them for comparisons. The indexes gained also are compared with the index targeted by Malaysian Department of Energy - around 135 kWh/m²/year. The analysis is also justified through the characteristics of façade design, applied technologies inside and the age of the buildings.

1.0 Introduction

In Malaysia context, one of the main objectives in building construction is to build cheaper and spectacular, but try to sell or rent out at higher price in order to gain maximum returns. For the tenants or potential owners of a building, the aesthetic values and attractive prices are top of their list in making decision despite of the awareness of the energy inefficiency and associated daily running costs. Consequently, they often end up purchasing or renting buildings with high-energy consumption and expensive energy bills.

The power or energy in Sarawak is generated through four major power stations. The generation of power mix for the year 2001 comprised of 1,174.6 GWh (33.0%) from gas, 503.3 GWh (14.2%) from hydro, 425.1 GWh (12%) from fuel oil and 1,451.0 GWh (40.8%) from the independent power producers. One of the largest method used by the independent power producers is through burning of coal which is also one type of fossil fuels and it is located at Sejingkat Power Station in Kuching *(SESCo Annual Report 2001)*. The whole most power generation in the Sarawak is reliant on the burning of natural resources such as fuel, coal and gas *(Kong, 2003)*.