SEGMENTAL PAVING AND THE THIRD WAVE

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SUMMARY

World renowned social historian and futurist Alvin Toffler observed that humankind has gone through three major waves of change. This paper shows that concurrent with these three major changes in history, transportation has gone through three similar waves of change. The paper shows that as part of "third wave" lifestyle option of today, transport systems are developing which provide greater individual choice and there is also a trend for separating slow-speed pedestrian transport from mechanized transportation.

The particular role of segmental block paving is identified as being ideal for pedestrian-friendly pavements because of their human-scale architectural and aesthetic appeal created by the chamfered units and their structurally functional joints. In addition segmental paving requires only minimal maintenance and also accommodates misuse or wrong design more readily than other paving methods. Segmental paving also provides the potential for stimulating street-activities, which is important for encouraging the development of urban community and their social enhancement. Segmental paving thus helps restore the traditional role of streets as a place for social exchanges.

The paper discusses the method developed in Southern California by Systems Paving Inc for introducing human-scale segmental paving to designers and others who are only familiar with pavements primarily designed for use by vehicles.

OVERVIEW

World renowned social historian and futurist Alvin Toffler, who coined the oft used expression "future shock", from his book of the same name, observed that humankind has gone through three major waves of change. This paper shows that concurrent with these three major changes in history, transportation has gone through three similar waves of change. Toffler identifies the first wave as lasting from the advent of settled communities until the industrial revolution which began the second great wave of change. However a third great wave of change has been possible since the advent of the personal computer and the information age. The result of this third wave is that humankind will soon no longer need to live in large cities to enjoy culture, the arts, and the quality of choice made possible by industrialized mass marketing.

The paper shows that as part of the third wave lifestyle option of today, transport systems are developing which provide greater individual choice. There is also a trend for separating slow-speed pedestrian transport (analogous to Toffler's first wave), from mechanized transportation (analogous to Toffler's second wave). In the same way as with Toffler's third wave of civilization, the third wave of transportation is being achieved by specifically utilizing and integrating the best of the first two waves.

The specific needs for roads primarily intended for pedestrian and other slow-speed and light in weight transport are compared with the requirements of roads designed for high-speed mechanized transport. These differences in service of the paved road are described and enumerated according to whether they are pedestrian-friendly or vehicle-friendly.

The particular role of segmental block paving is identified as being ideal for pedestrian-friendly pavements because of several reasons. The particular benefit of segmental paving for pedestrian-friendly areas is shown to be the human-scale architectural and aesthetic appeal created by the chamfered units and their structurally functional joints. Segmental paving requires only minimal maintenance and also accommodates misuse or wrong design more readily than other paving methods. Segmental paving is also believed to be ideal for use in areas of known earthquake activity because it ought to maintain service and allow hand-done repairs should power not be available.

Because of all these benefits, pedestrian-friendly segmental paving is shown to be also ideal for use in paving at pedestrian loading points for public transport facilities. Another feature of importance in the third wave of transportation is that areas paved with segmental paving provide the potential for stimulating street-activities. This is becoming increasingly important for encouraging the development of urban community and social enhancement. Segmental paving can therefore help restore the traditional role of streets as a place for social exchanges.

The paper discusses the method which has been developed in Southern California by Systems Paving Inc for introducing human-scale segmental paving to designers and others who are only familiar with pavements primarily designed for use by vehicles. Until made familiar with segmental paving design they have of necessity had to use the principles of design and the materials used for high-speed traffic in pedestrian areas. This has often resulted in bland, featureless paving, lacking in the aesthetic appeal of human-scale features. The paper reviews the experience gained by Systems Paving Inc. in California and explains that the awareness of the potential of segmental paving must be made through showing how common misconceptions, fears, and anticipated problems are unfounded. This experience has also shown that technical educational workshops are ideal for sharing the benefits of segmental paving with a sceptical or uninformed audience.

A conclusion is presented that segmental paving has an important role to play in urban renewal, especially for paving areas where fun-related transportation activities such as jogging, skating, and bicycling are encouraged. In addition, if segmental paving is used in areas surrounded by buildings the architectural features of segmental paving could add value to the adjacent buildings. All these benefits are shown to be complementary to the proven structural capability of segmental paving which can be designed to carry every range of loading conditions from the lightest to the heaviest application.

TOFFLER'S THIRD WAVE

World renowned social historian and futurist Alvin Toffler observed that humankind has gone through three major waves of change. [1] [2] He considered that the first major wave of change took place when tribes domesticated animals which allowed them to live in settled communities rather than wander after herds of animals. The second wave of change occurred with the industrial revolution some two hundred years ago. The significant feature of this second wave of change was that it concentrated large numbers of people into urban communities. Alvin Toffler observed that a third and potentially the most exciting wave of change ever, began with the advent of computers. Interaction between individuals irrespective of their physical location became possible through computer networks. Initially the networks were business based but more recently they have linked individuals. Since then it is no longer necessary for people to be located in adjacent offices as was necessary in the second wave. Through computer networks individuals can remain

members of work teams but choose their place and time of work.

TRANSPORTATION'S THIRD WAVE

The transportation needs of societies have similarly followed these three waves of change. During the time of the first wave, transportation used muscle- or wind-power. People walked or were carried by animals or they rode in vehicles pulled by animals. Goods had to be transported by the same means. Transport over water was either in human- or wind-powered boats. In the second wave, resulting from the industrial revolution, transport became mechanized and moved at greater speeds. Because of the numbers of people living in urban communities, shared transport was initially the most logical option. Public transport thus became the norm for most people who lived in urban communities. Light-rail tramways, buses, and inter-city trains were among the public transport systems serving urban communities.

People however walked from their homes to bus stops and train stations. The street surfacings over which people walked and traffic moved was often made with stone setts or clay bricks. These surfaces tended to mirror the materials used for vertical walls and together they provided the fine architectural detail of a more human-scale than that achieved later with asphalt and concrete surfaced streets. Because many people walked in the streets near their homes, vendors and others peddled their trade in the streets creating vibrant street actively. Urban streets served an important function for the social life of the community.

As urban communities became more affluent, families moved from the centres of cities to suburbs. Their places of employment however remained in the city centres which necessitated commuting. In time, rising affluence gave the majority of people the option of owning a private means of transport. Whilst there were many benefits in private ownership of vehicles, the motor age with its complex networks of roads took away the human-scale from much of the built environment. With it, the loss to the street-centred traditions of the community and their important social factors were lost.

As the distance of commuting and the time required for commuting increased, a growing number of people recognized that commuting on congested freeways diminishes the quality of life. This realization created the demand for residences located close to the city centres. Since this provided a more satisfying lifestyle the residences were of high price. To some extent the redevelopment of the city centres caused by this trend slowed down the outward spread of urban areas. The centres of cities contain the architectural heritage and places of historic interest to the community. The preservation of heritage and the recognition that the environment must be restored are important in urban renewal schemes. Transportation needs must also be satisfied within these parameters.

Urban renewal schemes usually seek to replicate the best of the past. Segmental paving is considered by many to be an ideal paving system for roads and pedestrian areas in urban redevelopment areas because it combines the aesthetics of human-scale with proven structural capacity in a system which required minimal maintenance. Segmental paving therefore represents an ideal blend of the traditional street scene with its desirable social implications, with all the benefits of modern technology.

The third wave of change in transportation has benefit to society in two particular ways. Firstly, through urban renewal, the close proximity of residence to place of employment enables an individual to choose between a variety of transport options. It may be possible to walk, cycle, jog, or use public or private mechanized transport for making a journey there. Alvin Toffler's third wave describes the scenario that an increasing number of people will not need to commute because they can do most of their work on a home-based computer linked by modem and networks to global communications systems. For those people able to do so, transportation becomes more of a

pleasure than a necessity. Within both these categories there is a growing demand to restore lost values in the urban community such as a restoration of the architectural human-scale and to the need to recreate "people places" where the social interaction of all previous ages again becomes possible. People places particularly need the human-scale made possible in part by the fine architectural detail of a segmental paved surface.

IDENTIFYING AND USING THE BEST OF THE PAST

To achieve the third wave in transportation, it is necessary to incorporate the best of the previous two waves into paving projects. The best of transportation's slow speed first wave is recognized to have been the provision of architectural variety through the attention to detail made possible by human-scale construction and materials. People making journeys were able to enjoy the infinitely variable street scenery. They also had much opportunity for social interaction with others using the same facility. In a relatively slow paced society there was always time to "smell the roses", or "stop and stare". Modern pedestrian areas, described by some as being "roads for people", and residential streets should therefore include the best of the first wave by providing street architecture which incorporates human-scale and provides places for social activity.

The best of the second wave was the high-speed transport routes which were provided for both private and public transport modules. Freeways, containerization, train lines, and air services provided dedicated, high-speed, and non-stop transportation links. There is no need for human-scale architectural detail in the second wave transportation systems. In fact, in the interests of safety, opportunities for social interaction had to be limited to that which might happen within public transport vehicles and at loading stations. Indeed passenger loading and disembarkation places such as train stations, airport, and passenger dock facilities, often incorporated splendid architectural detail because those facilities served the pedestrian community which needed to sit and wait at times and could appreciate architectural features. Paved surfaces and the geometry of second wave transport systems are in complete contrast with those of the first wave for they concern the macro-scale related to high-speed vehicles rather than the micro-scale related to pedestrians.

Until the third wave in transportation was recognized, transport designers attempted to integrate first and second wave transportation needs in a single facility. For example, roads were used unsuccessfully to serve both bicycles and motor vehicles. Inevitably, with this undesirable practice accidents occur and pedestrians and those using human-powered vehicles are at a greatest risk.

Third wave systems of transportation have recognized the need to separate the two distinct aspects of transportation. Specific and safe routes for first wave transport systems need to be provided, and whilst these may follow similar routes to those designed for mechanized transportation, they must be physically separated from each other. As with the best of the second wave, loading and disembarkation stations for public transport services need architectural detail and human-scale features. They therefore are obvious locations for the use of human-scale segmental paving systems.

HUMAN-SCALE FOR THE THIRD WAVE

Segmental paving is increasingly providing the preferred surfacing for first wave transport routes, and second wave public loading and disembarkation facilities. Its many benefits include aesthetic appeal, variety of finishes such as colour and shape, ability to follow deformations in sublayers caused by poor construction with little compromising of service, ease of repair, and its aesthetic human-scale appearance. Pedestrian traffic is however more demanding of the surface than vehicular traffic. The impact force of high-healed shoes for example cause a surprising degree of abrasion. An additional requirement of paving for pedestrian use is for good slip resistance. Concrete segmental paving is typically specified of greater compressive strength to the concrete

used for rigid concrete slabs, thereby giving greater durability and greater resistance to absorption. The chamfered joints between individual paver elements of a segmental paving system add to the slip resistance in a way not possible with other paving procedures. [3]

Concrete is considered by many to be a superior material to asphalt for pedestrian surfaces. (e.g. [4]) Their belief is based partly upon the fact that asphalt is a petroleum-based material which to some extent breaks down chemically with time. During this process, toxins can be released into the immediate environment. Asphalt also requires vehicular trafficking for re-compaction to keep the large aggregate from being exposed on the surface.

Segmental concrete pavers are superior to rigid concrete because they are typically specified to develop in excess of twice the compressive strength of rigid concrete. Denser concrete better resists absorption of greases and oils and retains a cleaner look for longer than rigid paving. Cleaning of a segmental paving surface is also easier and is not required as often as with the less-dense concrete used in rigid paving.

Concrete segmental pavers are often specified because they appear to have a historic appearance. Unlike the brick paving, stone setts or stone cobbles used in urban street paving during the last century, modern small-scale segmental concrete pavers are ideal for use by pedestrians, skaters, wheel-chair users, baby carriages, and the elderly who walk with a cane.

INTRODUCING HUMAN-SCALE PAVING TO COMMUNITIES DESIGNED PRIMARILY FOR VEHICLES

Many communities which developed in the twentieth century did so without the benefit of the heritage of the pedestrian-based first wave. The comparatively recent and growing popularity of walking, jogging, and other first-wave activities by many people in such communities requires the provision of roads primarily designed for people rather than roads primarily designed for vehicles. Unfortunately those who design and specify purpose-made roads for people are unaware of the benefits of segmental paving and of necessity, use the same principles with which they are familiar, namely vehicular paving design. The vehicle-design paradigm in many cases does not allow for the use of paving systems with human-scale aesthetics. An additional factor is that designers must of necessity remain conservative because they fear possible litigation should a seemingly new and apparently unproven system not prove adequate. The vehicle-scale, (rather than human-scale), of asphalt and rigid concrete surfaces has unfortunately been used for pedestrian areas without recognizing the numerous benefits, especially of human-scale, provided by segmental paving.

The introduction of fully-flexible segmental paving as a viable option for pedestrian roads to those not familiar with the technology can be a long process. It invariably involves reminding specifiers of the foundational principles of pavement engineering. It also requires the presentation of evidence of successful use in similar applications elsewhere. There is much experience from around the world to show the use of fully flexible segmental paving in every conceivable paving application. Such information gives considerable encouragement to the would-be specifier.

Most pedestrian areas are not exclusively pedestrian because they are also used by emergency vehicles such as those operated by police, fire, refuse removal, and ambulance services. Roads for people must therefore be designed to standards suitable for their occasional use by vehicles. The normal design methods with which designers are familiar, can readily be used. Design parameters for the segmental blocks together with bedding and jointing sand have been established for all conditions from both empirical experience and from sophisticated theoretical studies made by researchers. (e.g. [3]; [5]; [6]; [7]; [8]; [9]) Thus the specification and design of segmental paving systems can be done with confidence even by those not yet familiar with fully flexible paving systems.

MISCONCEPTIONS, PROBLEMS, AND FEARS.

For those introduced to the concept of fully flexible segmental paving for the first time, a few misconceptions, apprehensions, and fears are sometimes voiced. Since these tend to relate to the application for which the segmental paving is intended, it is necessary to categorize the different users of segmental paving. There are four principle users of concrete segmental paving; the industrial, the domestic, the pedestrian, and the non-load associated. Industrial paving includes its use for civic, commercial, and industrial applications. Domestic paving includes its use for private driveways and swimming pool decks in residential properties. Pedestrian paving includes roads for people and sidewalks. Whilst the term pedestrian paving implies non-vehicular use as discussed above, most pedestrian pavements must be designed for vehicular use by emergency vehicles. Non-load associated use includes the use of segmental paving for soil protection on non-trafficked slopes under freeway bridges for example. This latter use is usually made for aesthetic reasons and it has been our experience that in this connection there are few fears or misconceptions.

Some potential specifiers of segmental paving for industrial and domestic purposes fear the system will not protect the structural support layers from the ingress of moisture. They consider that the sand-filled joints could be highly pervious, allowing significant quantities of water to saturate sub-layers. Research has shown that immediately following construction a minimal amount of water can find its way through the jointing sand. (e.g. [3]) However, within a short period of time moisture causes the small amount of cohesive material in the jointing material to swell, thus pressurizing the joining material against the adjacent segmental units. In addition a sealing cap over the joints forms from surface detritus which further significantly reduces moisture ingress. Water ingress through a properly constructed segmental paving system is not considered by those experienced in design and specification to be an aspect of concern. (e.g. [8])

Potential specifiers of concrete segmental paving systems tend to compare the thickness of the segmental paving units with the thickness of concrete required for a rigid slab to carry the same loads. They are surprised that the seemingly thin concrete units can carry the same loads as a much thicker rigid slab. What is not appreciated is that the segmental elements are but one part of a paving system which utilizes structural support layers. The thickness of structural materials in a segmental paving system is in fact greater than that of an equivalent rigid pavement.

A common misconception about segmental paving is that the jointing sand will wash out of the joints allowing moisture to penetrate structural support layers and thereby destroy the structural intimacy of the system. Research has shown that the jointing sand should be specified from a narrow range of materials with specific properties. (e.g [3]) A minimum amount of very fine material with cohesive properties forms a part of the requirement. The vibratory plate compactor used to set the segmental units into their matrix also causes the joints to fill with jointing sand. Environmental and load-associated stresses rapidly establish the joints as an important working part of the paving system. The joints are thus substantially sealed from the ingress of moisture which in turn maintain the jointing material within the joints. Typically a segmental paving project is pressure hosed with water as part of the cleaning process upon completion, offering sceptics proof of the intimacy of the jointing sand within the system.

It is sometimes thought that weeds can grow from seeds remaining in soils under the pavers. In time it is thought that plant growth would cause severe distress to the aesthetics and carrying capacity of the pavement. Experience and research has shown that any weed growth that might occur happens in the jointing material and not in the sub-layers. [3] Grass and weeds die when covered by a paving block thus stopping their growth from sub-layers. However, tree roots if not removed from sub-layers could continue to grow under segmental paving and in time they could cause movements of surface levels. If proper sub-base preparation is done it is unlikely that tree roots, which are known to be opportunistic and take the line of least resistance, would force their way through a segmental paving system. [10]; [11]; [12])

Apprehensions are sometimes expressed concerning the stability of segmental paving systems laid

on a steep slope. Considerable experience has been accrued to show that if a herringbone pattern laid at 45 degrees to the direction of the slope is used and that appropriate attention to the provision of lateral restraint is made then segmental paving is stable on a steep slope. [7]; [8]

Colour fade is considered to be a factor for consideration by some architects and home owners. The colouring of concrete is done by pigments and oxides and some degradation of colour due to the ultraviolet light is inevitable. Whilst colour degradation is a factor in all concrete products, the higher density of segmental units by comparison with rigid concrete is believed to retard colour loss.

LIFE-CYCLE COSTS OFTEN NOT CONSIDERED

The life-cycle costs concept is a recognized means of incorporating the total cost of a paving project throughout its design life. It provides a means of comparing the costs incurred throughout the life of various paving options as one of the means of making a decision concerning which paving technique to use. It is a common misconception that initial construction cost is the only cost involved in providing a serviceable pavement for a desired length of time. As with all types of construction there are also on-going costs incurred for periodic maintenance and repair. Another consideration is the value of the materials used at the end of the design life. Another aspect affecting the value of the investment and expenditure needed to maintain that value involve the cost of upgrading an existing paved facility to serve a changed use or to improve its aesthetic enhancement. The latter is becoming a much more important factor as existing paved facilities are often upgraded or enhanced especially in terms of environmental considerations.

The life-cycle costs for any paving therefore include the initial construction costs, periodic maintenance costs, and the value of future expenditure in terms of the monetary value at any specific time during the life of the pavement. However often the initial or construction cost is the only cost considered in comparing costs of several proposals or paving options. Segmental block paving may not be the cheapest solution if only the initial construction costs are considered, but if the costs to be incurred during the design life are considered, segmental paving usually represents the best investment. With asphalt pavements, ongoing maintenance could involve time-consuming and expensive sealing of cracks to protect the support layers from the ingress of excessive amounts of moisture. The provision of overlays at predetermined and specified intervals must also be financed. Where inflation is to be considered, the costs of subsequent maintenance and repairs could easily be numerically greater than the initial construction costs.

The life-cycle costs of segmental paving are usually found to be considerably less than for other paving options. Maintenance other than sweeping and possibly items of a minor cosmetic nature should not to be expected. In addition, any costs for repairing damaged sections due to overloading or other non-planned use is minimal. By comparison, repairs to rigid concrete slabs cannot be predicted and can be very expensive and inconvenient. Similarly, the planned maintenance and unexpected repair costs of asphalt pavements can be expense. However, their costs must be included in the life-cycle costs of the pavement.

It is interesting to note in this connection that whilst no guarantees can be given respecting rigid concrete paving, life-time guarantees for the segmental elements themselves, and a two to five year guarantee on all aspects of the segmental paving system is given by some contractors in areas with an earthquake potential. An example of this is the guarantee given by Systems Paving Inc. of Newport Beach, California, who advertise that they "pave for life". [4]; [13] No guarantee for asphalt or rigid concrete paving is given by contractors working in the same areas. The reason why no guarantees can be given for paving systems other than segmental paving in areas with an earthquake potential is because of the undeniable fact that concrete and asphalt will inevitably crack in such areas. Segmental paving systems are "pre-cracked" and either restore themselves after movement or allow simple maintenance measures to be undertaken to restore the more

damaged areas.

An often forgotten aspect of life-cycle costs is the "present worth" of the pavement. Cracked and faded concrete and asphalt adds little value to the surrounding property whereas segmental paving can add considerably to the value of the surrounding property throughout and beyond its design life. An additional factor is that since the segmental units themselves can be taken up and reused there is an ongoing residual cost of the pavers, not found with any other paving system.

CONCLUSIONS

Alvin Toffler's third wave of change in society has already begun. The third wave in transportation is rapidly following. The provision of roads for people and areas where the once familiar social activity took place on paved streets, is being restored. Areas for social activity and pedestrian use are now often separated from areas dedicated as roads for vehicles. Concrete segmental paving is increasingly the preferred paving for roads for people. It is also becoming an important material for the restoration of the heritage of a community. Restored ancient buildings require the same human-scale in the surrounding paving, for which segmental paving is ideal. It is also now commonly recognized to be the ideal material for the provision of pedestrian-friendly surfaces.

In the urban improvement schemes being carried out in many city centres around the world, concrete segmental paving systems are used because of their many advantages, but specifically because of their proven structural adequacy and their aesthetic appeal. Traditional small-element paving units such as stone setts and cobbles used in urban areas have their modern equivalent in segmental block paving. However, of necessity, municipal engineers and others responsible for urban renewal need to be conservative and often have to specify asphalt and rigid concrete for pedestrian pavements because they lack the confidence to specify a paving system with which they are not yet familiar.

For the introduction of segmental paving in communities which have not enjoyed the principles of the first wave as part of their heritage, education is necessary. Systems Paving Inc. has found that design principles must be discussed together with the provision of ample evidence of the use of concrete segmental paving in similar communities where they have recognized the benefits of modern small-element paving. The technical education necessary for the acceptance of segmental paving is in fact a reminder of the basic principles of pavement engineering, which are often overlooked or forgotten by municipal engineers.

A valuable additional factor in favour of segmental block paving is that in California movements of the earth are a significant factor in the choice of paving systems. Much damage is caused in paving through movements of the earth. Thermal movements, time-related distortions, and seasonal movements due to frost-heave or expansive soils, are among the more usual causes of poor pavement performance. Such movements cause irregular and unsightly cracks to form. Repairs in rigid concrete pavements or flexible asphalt paving systems create a patchwork effect which is also unsightly. In domestic paving, patchwork repairs reduce the investment potential of the property. Concrete segmental paving is however forgiving of such earth movements because the combined effects of each joint ensures considerable flexibility in the paving system which maintains service and aesthetic appeal even through movements of the earth.

The effective introduction of fully flexible segmental paving systems for industrial applications into communities which developed without the heritage of pedestrian paving systems, requires giving would-be users an awareness of its potential. This can be done through review workshops at which participants are led to recall basic pavement engineering principles. This approach can also be supplemented with a brief overview of segmental paving practices from around the world. This serves to expand the appreciation of the potential of fully flexible segmental paving systems to delegates. The review sessions should include basic design principles and explain the significance

of each element in the segmental paving system. The possible fears, misunderstandings, and apprehensions of those being introduced to the potential of segmental block paving must also be addressed. This methodology, currently adopted by Systems Paving Inc. of Newport Beach, California, has proven to be the most effective in its program to share their years of experience of the design and installation of segmental paving.

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