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AN OVERVIEW OF SUSTAINABLE REPAIR STRATEGIES FOR POTHOLES IN FLEXIBLE PAVEMENTS DURING REHABILITATION PHASE

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Abstract- The formation of distresses on pavement causes the Pavement Management System to provide an activity of rehabilitation which not only costs money but also has environmental impacts. A pothole is the most occurring flexible pavement distress that not only causes comfort issues but also leads to the degradation of the remaining pavement. It is very significant to address this problem in a sustainable way that would decrease the effect on the environment. This paper aims to study different researches on pothole formation and its repair strategy that would not only increase the capability of the pavement but also be a sustainable solution. A number of research has been done on potholes to find feasible and sustainable solutions. An extensive literature review has been carried out in this paper regarding different materials that are helpful in minimizing the moisture susceptibility of flexible pavement distresses mainly potholes. The analysis indicates that pothole formation is dependent upon many factors including the type of aggregate, binder type, and external factors like moisture infiltration. Moreover, the binder type is a significant factor. The combination of non-woven fabric and ultra-thin asphalt overlay is very susceptible to reducing pothole formation which is also considered to be more environmentally friendly as compared to other strategies like rubber-modified asphalt and hence can be called a sustainable solution.

Keywords- Potholes, Sustainable pavement solution, Pothole repair

1 Introduction

Road network is considered the backbone of any economy and hence road projects are included in major national projects. Road projects have a major impact during the construction and also during the maintenance phase of the project at the same time the appearance of distresses is also a major liability to the project that not only affects the user comfort but also has a very deep impact is the prospect of sustainability. Out of these distresses Potholes is major occurring distress. Hence it is very significant to discuss this distress in view of the maintenance phase of a road project. The composition of the flexible pavement consists of aggregates and bitumen. The structure is provided by the aggregates which provide the skid resistance and resist the load of the vehicles, whereas the bitumen acts as a binder in this mixture. With the advent of time the deterioration process of the pavement takes place this happens mainly due to the bitumen degradation leading to bitumen brittleness, and environmental exposition. Moreover, there are very bright chances of infiltration of moisture into the pavement that later, due to the phenomenon of freeze and thaw causes the initiation of cracks. These cracks can initiate at the bottom or from the top. The continuous loading on the pavement for long periods also causes distress to appear on the surface if rehabilitation and maintenance are not done at specified intervals, these cracks propagate until they form a bowl shape and this bowl-shaped distress is called a pothole. Potholes cause a reduction in the service level of the pavement and it is considered the most infuriating distress in pavements [1]. The properties of the materials that can help in avoiding potholes require being durable to the environment, cohesion and good workability, rutting potential, durability to traffic loading, and free–thaw potential [2]. To repair a pothole there is a variety of methods and materials that have been previously studied. These repair materials contain (i) Cold Mix Asphalt (ii) Hot-mix Asphalt (iii) other additives and polymeric resins and materials. Generally, it is accepted that the hot mix asphalt which is actually the combination of Bitumen and fine and coarse aggregates is the best possible conventional repair methodology, yet its applicability is limited

due to the fact that there are constraints of laying temperature and batch requirement. Contrarily, a low-quality repair is achieved by the Cold mix asphalt which is the combination of the bitumen emulsion and cementitious material and aggregates but higher flexibility of the application exists, for instance, individual potholes can be repaired using a small amount of packages disregard of the weather conditions. Furthermore, modern research has helped in the use of polymeric materials in the pavements as admixtures. These polymeric materials and resins have the potential to repair the potholes with higher efficiency. Polymeric materials like rapid setting urethane resins and DCPD i.e. dicyclopentadiene are good examples. These materials are no doubt expensive and their common use is not possible but with the advancement of technology further materials can be discovered that are sustainable in all three aspects. Shrivastava et al [19] developed a new technique for the identification of potholes using modern machine learning technology. This method would help identify potholes at a very early age hence giving enough time to apply repair strategies. Zhang et al. [20] performed an experimental study in which they used waterborne polyester concrete for cold patching of the potholes. The usage of this modified concrete proved to be very time-saving as the patched surface could be opened for traffic after just 2 hours.

Typically, the selection of the material for the repair of potholes is dependent on the resources available, distress level, and administrative and political conditions. In this article, to assess the significance of a pothole repair during the maintenance and rehabilitation phase, pothole distress along with the characteristics of flexible pavement and the selection of sustainable remedy has been reviewed based on the available literature. Different researches on pothole formation and its repair strategy in the last few years have been studied to find techniques that would not only increase the capability of the pavement but also be a sustainable solution. A number of research has been done on potholes to find feasible and sustainable solutions. An extensive literature review has been carried out in this paper regarding different materials that are helpful in minimizing the moisture susceptibility of flexible pavement distresses mainly potholes.

2 Flexible pavement characteristics and Pothole formation

The structure of a flexible pavement consists of a subgrade, which is actually the foundation layer, upon this layer, there is a sub-base composed of granular material, on top of the sub-base, a base course is laid which is a combination of fine and coarse aggregate and on top of this layer is the asphaltic wearing course. Using the linearized theory of elasticity, the stresses and the strains on the pavements are evaluated. During the design phase of the flexible pavements, the thickness of the layers is considered based upon allowable values of the stresses and the strains in the flexible pavement. The characteristics of the surface of the pavement include frictional resistance, ride quality, the potential for hydroplaning, sound absorption properties, texture, and wholesome performance of the pavement. The focus on pavement research is due to the growing interest in pavement surface concerns and characteristics about performance, traffic noise, and safety. Flexible pavements are considered different in terms of behavior under loading along with the aging process of the roads. Further research into this topic of flexible pavement can lead to the knowledge of the changes and overall effect on the pavements which can help in optimizing the design and hence come forward as a sustainable solution to different flexible pavement-related problems.

A bowl-shaped depression on the surface of the flexible pavement is called a pothole. The size of the pothole ranges from six inches to almost three feet. During the service period of a road, it is subjected to heavy traffic loads along with environmental conditions. These moving loads displace the small fragments of the surface which deteriorate further and cause different distresses like crocodile cracking which advances to become potholes [14]. These potholes first appear only on the uppermost layer of the structure but with time water pounds and infiltrate the bottom layers, inducing stress, and hence this pothole spreads, depth-wise, further and the stability of the areas decreases further [3]. Potholes are the distresses that are localized and are interrupted in the pavement surface and on that region of the pavement the part of the pavement has split away, causing a depression of shallow depth [4]. Potholes can be categorized as distress that is a depression on the surface of the road in an irregular fashion and the main reason for the formation of this distress is the logging water on the roads [5].

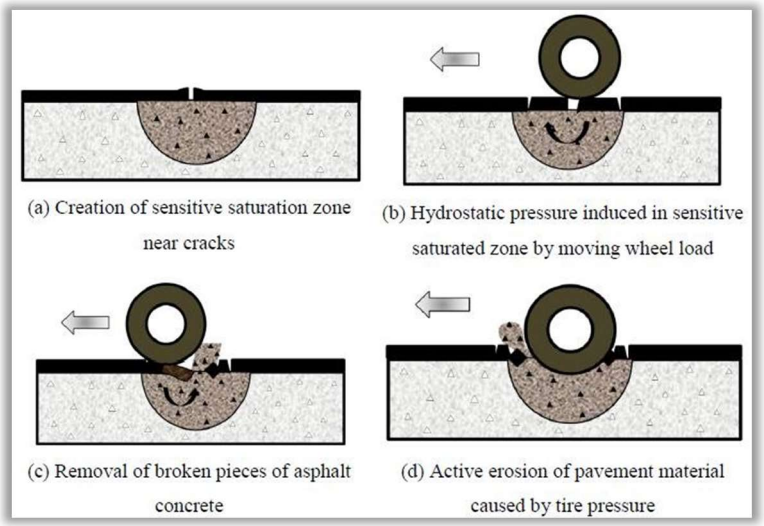

Figure 1: Pothole formation sketch [14].

3 Different Repair Methods

Due to the need to be constructed from time to time the maintenance and repairing of potholes remains to be a severe problem. In suburban and rural areas, pothole maintenance is very rarely done because of the availability and cost of the maintenance. With the intense growth in the construction industry along with the population, the management of waste material has become a major problem for most of the world where a large amount of plastic waste is generated and disposed of in the environment due to the non-degradation property of plastic it would remain as a part of the environment forever causing pollution. Therefore, it is the current need of the country to utilize the waste plastic in road projects. At the same time, the upgradation of roads that takes place due to the spreading of the road network causes the insufficiency of the original materials, simultaneously the waste produced from the demolition of the old structure is also disposed of in the countryside contributes to the increment of land pollution along with traffic congestion. On the bright side, this waste can be used in pavements as the replacement of fillers and aggregates with better performance.

The addition of recycled mixture in bitumen for the maintenance activities like repair of potholes reveals a greater efficiency in Improving the mixtures and saving cost. It was established after the study of the recycled materials that the recycled asphalt mixtures are preferable due to their reasonable performance and affordability as compared to the mixtures that are composed of conventional asphalt [6]. Commonly, the use of recycled materials in Hot Mix Asphalt is preferred due to the benefits in regard to environmental sustainability. In alternative to the in aggregate, pavements, made of recycled aggregate, is also cost-effective [7]. In the SBDP pothole interface, the use of ultra-thin asphalt overlay UTAO along with NWF, that is the non-woven fabric, can help in the mitigation of the stresses that are in a horizontal state [8]. In a research study done on the poly ethylene plastics that were used as 10%, 8%, 6% and 4% admixtures in bitumen, and it was found out that the optimum results were achieved at 8% for mix. Similarly, the demolished waste was used in replacement for the original aggregate. During the aggregate tests it was found that the demolished aggregate has the capacity to be used in the village roads and district roads [9]. In another study that was performed to compare the properties of cold mix asphalt with a mixture of waterborne epoxy and Styrene-Butadiene rubber asphalt, it was found that the later gave bright results in terms of forming strength, excellent in initial strength, low temperature construction workability, high temperature stability, low temperature crack resistance, and water stability [10].

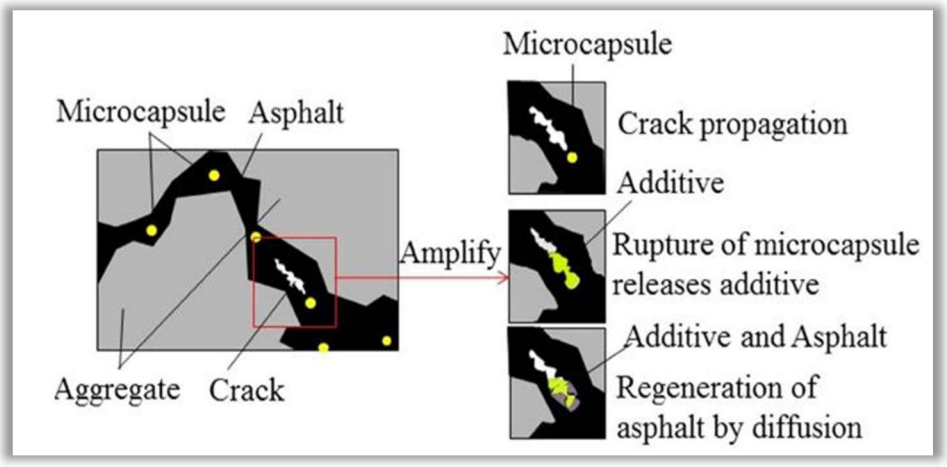

Figure 2: Microcapsule-based self-healing technique [11].

An advanced technique for the prevention of crack propagation that leads to the formation of potholes is the use of microcapsules as shown in figure 1. The healing capsule moves under siphoning action towards the micro-cracks then the catalyst in the asphalt mixture polymerizes this capsule hence filling the crack and making a micro crack bond [11]. When the cracks propagate, they initiate the ignition of microcapsule by rupturing it hence releasing the additive which diffuses with the concrete to seal the crack. When used from 0-0.9% by weight of bitumen at different ratios of air voids it showed good results by decreasing the moisture susceptibility and enhancing the properties of bitumen of asphalt mixtures. Using the Nano silica at every content of air void improved the resistance to moisture [12]. Nanocomposite along with granite and limestone aggregates to test its resistance to stripping. It was seen that the resistance to pothole formation was greatly improved along with the increase of resistance of hot mix asphalt using these admixtures combined [13].

4 Selection of sustainable method

The pavement system uses a substantial amount of resources, which results in the degradation of the environment. To reduce the consumption of pavement construction materials it is very significant to understand the environmental impacts, for proper and effective decision making and for designing sustainable pavements. Hence it is very important to select materials that are environmentally friendly and have better durability and reliability as compared to conventional materials [15]. An overview of the different pothole materials has been provided in table 1 which shows that synthetic binder has more functionality towards damage as compared to conventional repair methods. In this table each type of applied binder has been divided on the basis of application and composition i.e. hot applied, cold applied, and synthetic binder. These binders have been further divided on the basis of durability, equipment used for laying, the limitation for application, environment required for application, their possibility of recycling, and distress type that is mostly experienced in that type of binder.

Table 1 Pot hole repair materials overview on material type basis [15]

	Hot applied asphalt	Cold applied asphalt	Cement	Synthetic binder
Est. durability	Cat I, Cat II, Cat III	Cat I, Cat II	Cat I, Cat II	Cat I, Cat II, Cat III
Equipment	Comprehensive	Limited	Limited	Limited
Application limitation	None	None	Pothole<1/2m dia	Temp >10 deg celsius
Working environment	Special education	None	None	Special education
Possibility of recycling	Yes	Yes	No	No
Type of distresses	Adhesion failure cracks in repair, immersed chipping	Fretting, Loss of material	Adhesion failure, Cracks in repair	Loss of material, loss of chippings, pavement cracks, Cracks in repair

The selection of most sustainable option and the best available option is required for the maximum welfare. Using the state of the art techniques for sustainability the service life of the flexible pavements can be extended using maintenance strategies [16]. If the maintenance budget is increased 2% to account for sustainable maintenance decisions like full-depth repair, cold in-situ recycling, whose emission of greenhouse gasses is lower than other options. It has also been observed that micro surfacing and functional asphalt overlay are more feasible options when there are low financial restrictions [17]. Flexible pavements require periodic maintenance ultimately causing the cost of life cycle to increase [18]. Hence, considering all these aspects three materials can be short listed, the use of waterborne epoxy would be a suitable selection in this case as it gives very fine results in terms of performance but due to its excess cost this admixture cannot be recommended, using synthetic binders have also better results and comparatively are low cost. The use of ultra-thin asphalt overlay UTAO along with NWF, that is the non-woven fabric, can be considered the best option for pothole repair.

5 Practical Implementation

With the increasing rates of materials and the maintenance cost it is the need of the hour to identify techniques that can result in more durable pavements requiring low maintenance. The national highway authorities need to be educated in this regard. Moreover, the wastage of material is of great concern that needs to be looked into. With this study being done the modern methods and materials that have been discussed in this article can be implemented practically. To ensure efficient performance, guidelines provided by the authors should be taken into consideration by the development authority and the techniques should be first applied to small sections of roads and continuous monitoring of that section will be required to confirm the real time performance of the applied technique. Moreover, developing societies should use these modern methods for local streets mainly as the traffic load on these streets is not much. As already mentioned that the cost of the waterborne epoxy is more and it is not economically viable solution for pothole, as compared to this technique the use of UTAO used with non-woven fabric is a sustainable method for repairing portholes. The thin overlay reduces the cost, and also helps sealing cracks that have very minimum width hence stopping cracks to propagate any further. Due to their property of penetration, higher softening point, good ductility this material can be considered fit for pothole repair.

6 Conclusion

The environmental sustainability of the pavement systems can be enhanced by the use of environmentally friendly and recycled materials. The findings of this review article provide valuable information that can be helpful in the selection as well as the design of pavement structures that are sustainable, mainly in regions which are highly urbanized and has scarce resources. Following are the conclusions drawn from the literature study.

1. Pavement deterioration and other pavement distresses are mainly the cause of potholes.
2. Pothole is affected by many factors this includes aggregate type, mix design, asphalt binder type, variation in temperature, method of construction, traffic loads, sensitive saturation zone, and accumulation of water.
3. The cheapest and most sustainable type of repair solution is the use of hot mix asphalt with the addition of waste material.
4. The current trend regarding Pothole formation is bent towards sustainability and specifically, the use of waste materials as additives.
5. The film thickness of the asphalt binder is one of the significant factors that affects the resistance to crack formation. Hence, increasing the film thickness of asphalt around the aggregate surface along with some filler material can enhance the life of pavements.
6. Use of microcapsule self-healing technology is also an effective way of avoiding pothole formation.

On the basis of the conclusion drawn from the literature, it can be said that the main cause of pothole formation is actually other distresses that include alligator cracking, raveling, longitudinal and transverse cracking and, mainly water infiltration that expands and contracts with the variation of temperature. Once a particle from the surface is displaced all other particles in the vicinity become vulnerable hence leading to pothole formation. Hence using strategies that reduce the chances of crack formation will actually reduce the probability of pothole formation.

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