Use of Cold Mixes for Rural Road Construction

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ABSTRACT

Hot Mix Asphalt (HMA) is used predominantly as a paving mix from many decades in road construction. In India almost 90 percent road network is occupied by bituminous pavements only. Certain limitations associated with HMA use are like emission of green house gases from hot mix plant, shut down of plants during rainy season, problems in maintaining the paving temperature when hauling distances are more, etc.

Due to topographical constraints, rural roads projects in North Eastern States of India like Arunachal Pradesh, Assam, Manipur, Meghalaya and others are beyond time. Indian government is undergoing a massive rural road development plan and is highly concerned for the rural road development projects in North East states. Since many of the rural roads of North Eastern States are in hilly regions having heavy rainfall and many a times they have to meet very strict environmental regulations as many of these projects also lies in forest zone. It sometimes becomes very difficult to go with HMA only for rural road construction. Use of cold mixes should be evaluated in these states. Cold mix asphalt consists of unheated aggregate with emulsion or cutback as binder. Cold mix also offers advantages like; reduction in emissions, low fuel consumption, can be used in rainy seasons etc.

This paper presents the mix design of cold mixes for use in different courses of pavements. The paper provides information on the different additives which are usually used to increase the performance of cold mix. It also gives the results of same earlier studies on cold mixes. It also highlights the scope of using cold mix in rural road construction in North Eastern states of India.

Keywords

Additives in cold mix, cold mix, design of cold mix and emulsified mix.

1. INTRODUCTION

About 740 million people of India live in rural area. Rural connectivity is being focused for the growth of economy, agricultural development and employment generation to rural people. India is having about 2.65 million km of road under rural road category out of total road network of 3.3 million km according to a statistic of Indian road network of National Highways Authority of India. Efforts are going on by central government and state government through different program like Pradhan Mantri Gram Sadak Yojana (PMGSY) to improve road access to rural people. Still about 40 percent of village people of the country are not connected by all weather roads. Either bituminous mix or concrete is required to make these earthen roads into all weather roads. Concrete is not economical one as a paving mix compared to bituminous mix for rural road construction works.

In India majority of road network is occupied by bituminous pavement only in which Hot Mix Asphalt (HMA) is used predominantly as a paving mix from many decades. However this bituminous mix is associated with some limitations. These include excessive emission of greenhouse gases (e.g. sulfur dioxide, nitrogen oxides, carbon monoxides and volatile organic compounds) from HMA plant, shut down of hot mix plant during rainy season and the laying of HMA is difficult in hilly areas and rural areas having long hauling distances, cost of putting up HMA plant is high and comparative budgets of small sections of rural road is very less, etc.

As, Indian rural road network is developing continuously, paving mix like cold mix asphalt or Warm Mix Asphalt (WMA) should be tried. This mix is started to lay on pavement to reduce the problems associated with HMA. Warm mix asphalt is a very new technology compared to cold mix asphalt. Cold mix asphalt should be tried in India for construction of rural roads in hilly areas having high rainfall and difficult terrain.

2. COLD MIX AND ITS ADVANTAGES

Cold mix is a mixture of unheated aggregate and emulsion or cutback and filler. The main difference between cold mix and HMA is that aggregates and emulsion or cutbacks are mixed at ambient temperature (10°C-30°C) in case of cold mix and aggregates and binder are mixed at high temperature (138°C-160°C) in case of HMA. Dense graded cold mixtures have far lower permeability and good resistance to deformation. Open graded mixtures are storable and semi dense mixtures have good adhesion and lower permeability.

Cold mix when used as paving mix can offer following advantages.

- It eliminates heating of aggregate and binder.
- It is environmental friendly and conserves energy. Cold mix pavement can provide energy savings of over 50% compared with hot mix [5]. So it can be considered as green bituminous mix for rural road construction.
- It can be easily prepared using small set up on site. It can be produced manually for small scale job. Laying of HMA for rural road construction sometimes is not economical because setting up of a hot mix plant for small scale job increases the project cost.
- This paving mix is particularly suited for construction of roads in remote and isolated areas of a country where plant produced hot mix may have set before reaching site.
- Cold mix can be laid during wet or humid condition also.
- It is versatile also as a large number of grades of emulsion and cutbacks are available.
- It is economical and high production is possible with low investment.

3. DESIGN OF COLD MIX

Properties of cold mixes are varied by many parameters like; source of aggregate, curing condition and curing time, etc.

Hence there is no universally accepted mix design method for cold mixes. But Marshall Method is popularly used to design emulsified mixes. Marshall Method for emulsified asphalt aggregate design is based on the research conducted at the University of Illinois. This method is applicable to base course mixture for low volume traffic load. Cold mix is used in surface course also for low to medium traffic volume road. The cold mix design is carried out to optimize water and emulsion content for aggregate in the mix. The parameters involved in mix design of cold mix asphalt are;

3.1 Aggregates Selection

In India aggregates should conform the physical requirement laid by MoRTH specification (2001). Testing of aggregate like sieve analysis, specific gravity, aggregate impact value and soundness is necessary.

3.2 Emulsion Selection

Selection of emulsion depends on aggregate type and aggregate gradation and ability of emulsion to coat the aggregate. According IS 8887:2004 specifications, five grade of emulsion; RS-1, RS-2, MS, SS-1 and SS-2 are used to prepare cold mix. Quality tests should be carried out on the selected emulsion according to IS 8887:2004.

3.3 Determination of Initial Emulsion Content

Centrifuge Kerosene Equivalent test (C.K.E) is used to estimate initial residual bitumen content. If C.K.E equipment is not available, emulsified asphalt content designated as P can be estimated using the Asphalt Institute empirical formula given below (Asphalt Institute, 1989).

$$P = (0.05A + 0.1B + 0.5C) \times 0.7$$

Where
P = % Initial residual bitumen content by mass of total mixture,
A = % of aggregate retained on sieve 2.36 mm,
B = % of aggregate passing sieve 2.36 mm and retained on 0.075 mm,
C = % of aggregate passing 0.075 mm.
The initial emulsion content value can be obtained by dividing P by the percentage of bitumen content in the emulsion.

3.4 Coating Test

Using trial emulsion content coating test [12] is to be carried out by using all of the batches of aggregates and filler, pre-wetted with water. Coating test will be carried out at a range of water content. For example, coating test will be started using slow setting emulsion at about 3 percent added water. Sixty seconds of mixing time is sufficient when aggregate is mixed with water. The bitumen emulsion is added afterwards and then mixed for about 1 minute until even coating is obtained. New batch will be prepared with an additional increment of 1 percent water by weight of dry aggregate. Aggregate coating in excess of 50 percent shall be considered acceptable. The optimum pre-wetting water contentment gives the best bitumen coating on the mineral aggregate. This optimum water content will be mixed in all subsequent mixing.

3.5 Determination of Optimum Moisture Content at Compaction

It optimizes the water content at compaction to maximize the desired mixture properties. Specimen will be prepared at different water contents. Generally three increments of water content with a difference of one percent are sufficient to define the stability or density/water content in compaction curve [12]. If the desired water content at compaction differs from the optimum mixing water content, aeration is required. A plot is made of dry density versus fluids content at compaction. Fluids content resulting highest density is considered as optimum for compaction. If the coating of aggregate is not sensitive to the water content at mixing as determined in the coating test, the aggregate may be mixed at the desired water content at compaction, emulsion added and the mixture is compacted immediately [12].

3.6 Variation of Residual Asphalt Content

A set of test specimens are prepared over a range of residual asphalt content. Test mixtures are prepared in increments of residual asphalt contents; using the previously determined optimum water content for mixing and compaction. Specimen can be prepared using the guidelines given for emulsion content in MoRTH specification (2001). Specimens are cured in mold for 1 day at room temperature and 1 day out of the mold in oven at 38°C. Specimens are soaked with water using vacuum apparatus and then tested for soaked stability. Bulk specific gravity, Marshall Stability and flow of dry specimen and soaked stability and flow of wet specimen are determined from the test specimen using Marshall Test apparatus. Optimum residual asphalt content is determined from the plot of dry stability and soaked stability versus residual asphalt content. The optimum residual asphalt content is chosen that provides maximum soaked stability.

3.7 Marshall Mix design criteria for Emulsified Mix

Marshall mix design criteria [MoRTH specification (2001)] for emulsified mixes is given in Table 1. If one or more criteria cannot be met, the mix should be considered inadequate.

Table1. Mix Design Criteria for Emulsified Mix [14]

Properties	Value
Marshall stability	2.2 kN
Minimum flow (in 0.25mm units)	2
Air voids (VA in %)	3-5
Percent maximum stability loss on soaking	50

4. USE OF ADDITIVES IN COLD MIX

Cold mix is not used as structural layer due to slow curing rate and susceptibility of early life damage due to rainfall. Additives are used to accelerate curing rate imparting initial strength to mix in early life. Portland cement and lime are the common additives used in emulsion mixes. These additives are typically used by 1 to 3 percent of total weight of dry aggregate. Additive imparts some charges to emulsion which help emulsion to break quickly and bitumen droplets come out from emulsion and stick to aggregate giving binding properties. The breaking mechanism of emulsion and the effect of properties of emulsified mix due to presence of additives are studied by many researchers.

Brown and Needham (2000) studied the cement modified emulsion mixture. The main objective of their study was to evaluate the beneficial effect of adding Ordinary Portland Cement (OPC) in emulsified mixes. The mixture composition of their study is given in Table 2. The effect of OPC on stiffness modulus is shown in Fig.1. The study concluded that addition of OPC improved mechanical properties (stiffness modulus, permanent deformation resistance and fatigue strength) of emulsified mixes to levels.

Table 2 Mix composition for cold mix [2]

Mix component	Percentage on aggregate				
Granite aggregate 20mm	26				
14 mm	15				
10 mm	9				
6 mm	15				
Dust	35				
OPC	0	1	2	3	4
Pre-wet water	2.5	2.5	3	3.5	4
Bitumen Emulsion	8.06				

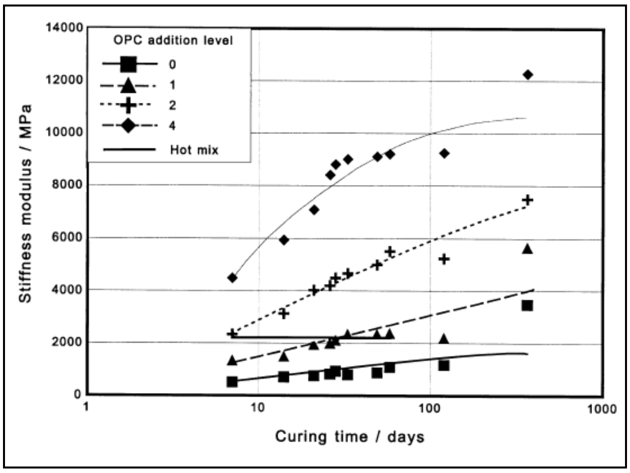

Fig.1 Effect of OPC on stiffness Modulus [2]

Seref Oruc et al. (2006) carried out research on the effect of cement on emulsified asphalt mixture. Portland cement was substituted for mineral filler in an increased percent from 0 to 6 percent in their study. Crushed limestone and cationic slow setting emulsion (CSS-1) were used to prepare cold mix. The used aggregate gradation is shown in Table 3.

Table 3. Gradation of aggregate [6]

Sieve size (mm)	19	12.5	9.5	4.75	2	0.42	0.177	0.075
Passing %	100	86	74	56	38	18	9	6

The study concluded that mechanical properties, resilient modulus, temperature susceptibility, resistance to water damage, creep, permanent deformation resistance were all improved by addition of OPC. The result indicated in a significant increase in the resilient modulus (shown in Fig.2) and decrease of the temperature susceptibility when the level of addition of cement was increased from 1 to 6 percent. The study suggested that emulsified mixture with OPC can be used in structural layer.

Chavez Valencia et al. (2007) used polyvinyl acetate to improve compressive strength of cold mix asphalt. In their study polyvinyl acetate emulsion was added to a quick set emulsified asphalt to obtain a modified asphalt emulsion. The compressive strength was improved in 31% relative to unmodified cold mix asphalt [3].

Pundhir et al. (2010) used OPC by 2 percent in cold mix design of semi dense bituminous concrete. Delhi quartzite aggregate and slow set types [SS-2] were used to prepare the mixes. One comparison between SDBC samples containing 2 percent cement vs. neat samples without cement was drawn at different curing condition in this study. The cold mix with 2 percent cement showed higher stability value (966Kgf) at $25^{\circ}C$ than the stability (688Kgf) of cold mix without cement at same temperature.

Benedito et al. (2003) conducted research on engineering properties of fiber reinforced cold asphalt mixes to find the effect on mechanical properties due to addition of fibers as additive to cold densely graded emulsified asphalt mixes. The asphalt mixture was treated with 0.10%, 0.25%, and 0.50% staple polypropylene fibers 10 mm, 20 mm, and 40 mm long. The result of the study has shown that the addition of fibers to cold mixtures reduces the dry density and Marshall stability. The study also concludes that the addition of fibers can also lead to reduction of fiber reinforced mixture resilent moduli.

From all those research, it is concluded that ordinary portland cement (at least 2 percent) as additive increase stiffness, resistance to permanent deformation, resistance to fatigue cracking and resistance to water damage of emulsified mixture.

5. PERFORMANCE OF COLD MIX

Cold mixes have been used over the years in various countries like United States of America, Australia and United Kingdom etc. It is used in surface treatment, patching material, pothole filling and paving maintenance applications. It can be used as surface course or base course also. Properties of cold mixes were studied by many researchers because performance of cold mix depends of its improved properties.

Thanaya (2002) studied the performance of cold bituminous emulsion mixtures incorporating waste material. The main objective of the study was to investigate ways of improving cold bitumen emulsion mixture's volumetric and mechanical properties. The binder used was a cationic bitumen emulsion which is having 62 percent residual bitumen of 100 pen grade base bitumen. The aggregate was limestone, red porphyry sand a byproduct of stone crusher (waste material) and limestone filler. The Aggregate gradation for this study was wearing course aggregate gradation. The gradation was determined using fuller's gradation curve. Using compaction effort medium to heavy total voids can be reduced to meet the target viscosity. Cement was used by 2 percent to total weight of aggregate to increase strength to meet stiffness. It was suggested from this study that application of cold mixes to be carried out during dry season or summer.

Serfass et al. (2004) evaluated the influence of curing on cold mix mechanical performance. Two types of cold mixes were produced - (a) 0/10 mm dense graded asphalt concrete made of crushed gneiss with 5 percent of 70/100 residual bitumen and (b) 0/14 mm grave emulsion, made of semi crushed alluvial aggregate and 4 percent of 70/100 residual bitumen. Diverse curing sequences had been applied to the mixes. The effect of different curing condition and compaction on compressive strength of grave emulsified mix is shown in Fig. 3. The study proposed that cold mix should be cure for 14 days at $35^{\circ}C$ and 20 percent Relative Humidity (RH) to obtain this mix in mature state.

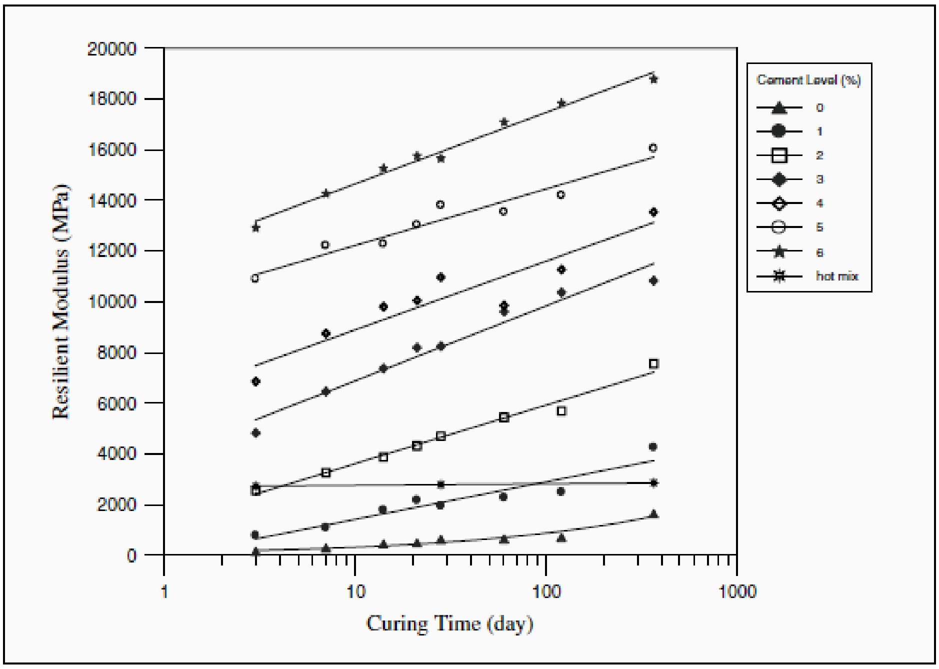

Fig.2 Effect of cement on resilient modulus [6]

Thanaya et al. (2009) studied the cold lay emulsion mixtures [11]. The main objective of the experiment was to evaluate and improve the properties of cold mixtures. The volumetric properties, indirect tensile stiffness modulus, repeated load axial creep and fatigue properties were evaluated. The three types of cold mixtures were produced in this study. The study concludes that cold mix emulsion mixtures, when properly designed and at full curing even without the addition of cement were comparable in stiffness to HMA of equivalent grade of bitumen.

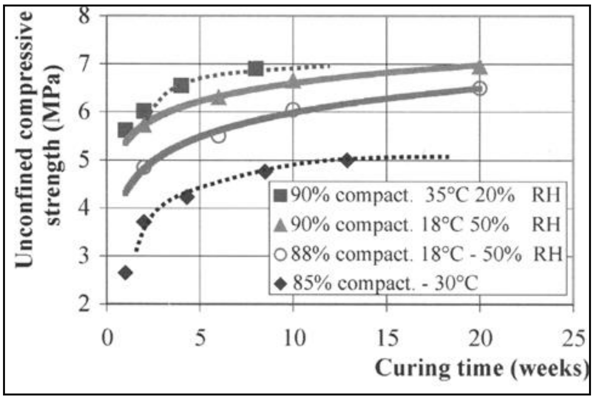

Fig.3 Effect of different curing condition and compaction on compressive strength of grave emulsified mix [9]

In a study [1] emulsified mixture was evaluated for low volume roads and road bases. Crusher fines sand was used with CSS-1h emulsion and local aggregate to prepare the mix. Crusher fines percentages were varied 0 percent to 50 percent of total aggregate weight and Portland cement was varied from 0 percent to 3 percent. The stability, resilient modulus, fatigue and rutting characteristic of such mixes were improved significantly due inclusion of crusher fines and additives. In one research [7] in India, it is found that stability and flow value of cold mix were improved with increased of curing days. Seref Oruc et al. (2006) showed that resilient modulus of a cold mix with cement increased with curing time.

As shown in literature, cold mixes develop its strength over a period of time; it may be several weeks or several months depending upon mixture type and curing condition. Stability and stiffness of this mix are lower during this curing period. The rate of degradation of cold mix depends on the opening traffic after paving. For low volume roads, research on cold mix suggest to keep traffic off for few weeks after laying during this tender period of mix. If this mix is to be used in major roads then this tender period will create a problem.

6. USE OF COLD MIXES IN RURAL ROAD CONSTRUCTION

Construction of rural road using conventional paving mix is sometimes not feasible in high rainfall area because it is difficult to produce and lay HMA. In case of high altitude or snow bound area, lower temperature of environment makes difficult to heat aggregate and binder at high temperature. In case of hilly roads, HMA is supplied from remote HMA plant; it is difficult to maintain mix temperature for long hauling distance. Cold mix can be produced on site. Simple concrete mixture, motor pavers or specialized mixing plant can be used to produce cold mix on site. Cold mix can be lay down by hand for small scale job and compaction is carried out by vibrating roller.

North Eastern States of India belong to hilly area and sometimes roads go through forest zone. Due to its topographical constraints and environmental rule and regulation, use of cold mix may be a promising mix under different site conditions. Field trials have been carried out by CRRI at some location in North Eastern States of India. Cold mix is gaining considerable popularity in rural road construction.

7. CONCLUSION

This review paper has focused on the use of cold mixes in rural road construction. The following overall conclusion can be justified.

- Cold mix can be laid on low to medium volume road as a green paving mix. Mixture can be produced by using conventional plant or by hand. So it can be laid as surface course or bituminous base course for rural road construction.
- Additive can be used in cold mix to make its properties comparable to the properties of HMA.
- Curing rate and mechanical properties of cold mix can be improved.
- Cold mix can be tried for paving mix in north east region of India.
- Large scale laboratory and field trials studies should be carried out to develop better understanding on the performance of cold mixes in rural road construction for different traffic, climate and terrain conditions.

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